Stability of Cereal Crop Yields' Performance:
An Econometric Analysis For India & Andhra Pradesh

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CHAPTER 1 - INTRODUCTION

"All our knowledge brings us nearer to our ignorance!"
T.S. Elliot.

Agriculture is an important sector of the economy in many developing countries. Of late, in many countries, this sector is believed to be suffering from *unstable performance, especially* where the modern (Green Revolution) technology has been widely adopted. The issue of stability of agricultural performance is one of international concern. This thesis is about the **stability of the performance of cereal crop yields** in India.

Importance of Agriculture in the Indian Economy.

Agriculture is an important sector of the Indian economy. Accounting for more than 30% of the country's national income in 1988-89, the performance of agriculture, both as a source of raw materials for industrial production and as a source of final consumption demand, determines to a large extent the overall performance of the Indian economy. Moreover, despite the rapid growth achieved by the non-agricultural sectors (industries and services) agriculture continues to remain the main, if not the only, source of livelihood for a vast majority of the country's population. In 1991, nearly 65% of the population were dependent on agriculture (Bansil (1991)). Above all these, is the food requirement of the World's second largest population of 870 millions (in 1991) growing at the rate of 2.1% *per annum*. Thus, it is obvious that agricultural development free of undesired instabilities is essential (a) for employment and income generation, and (b) to meet the food requirements of a growing population.

Indeed, during the era of planned development beginning from 1950-51, Indian agriculture has witnessed a transformation from a state of all round backwardness and stagnation to one of technological progress and growth. This can be observed from the agricultural gross domestic product presented in table 1.1. Agricultural gross domestic product at 1980-81 prices (New Series), grew from Rs.23741 crores in 1950-51 to Rs.61789 crores in 1988-89. This amounts to an annual compound growth rate of about 2.48%.

In terms of physical output, (see table 1.1) foodgrains production grew from about 50.8 million tonnes (m.t.) (of which cereals production was 42.4 m.t.) in 1950-51 to about 169.9 m.t. (156.1 m.t. cereals production) in 1988-89. The annual compound growth rate of foodgrains production over this period is 3.14%, while that of cereals production is 3.40%. The simultaneous rapid growth in population over this period has, however, meant that the per capita daily availability of foodgrains (cereals) has risen only marginally, from 394.9 grams (334.2 grams) in 1950-51 to about 494.4 grams (452.4 grams) in 1988-89. Corresponding figures of per capita agricultural GDP are Rs.654 (1950-51) and Rs.757.4 (1988-89).

As a result of the progress achieved in foodgrains production, imports of foodgrains fell to a large extent and in fact in a few years the country even exported small quantities of foodgrains. This transformation has prompted many to claim that India is now "self sufficient in foodgrains".

How has the growth in Indian agriculture come about?

An important characteristic of Indian agriculture is that it is largely private controlled, in the hands of millions of farmers. Thus, the growth achieved would not have been possible without the efforts and cooperation of the millions of Indian farmers. Nevertheless, as we shall see later, the government has played no small part in promoting agricultural growth.

Crop output being acreage (hectares) under the crop times its yields (kilo grammes per hectare), growth in output can come about as a result of growth in acreage and/or yields. It is generally

Table 1.1 – Agricultural Gross Domestic Product; Production, Per Capita Daily Availability & Net Imports of Foodgrains & Cereals.

ear	Population (million)	Agriculture GDP (Rs.Crores)	Agriculture GDP Per Capita (Rs.)	Foodgrains: Production (million tonnes)	Foodgrains: Availability Per Capita Per Day (grams)	Foodgrains: Net Imports (million tonnes)	Cereals: Production (million tonnes)	Cereals: Availability Per Capita Per Day (grams)	Cereals: Net Imports (million tonnes)
950-51	363.2	23741 (55.4)	653.7	50.8	394.9	4.8	42.4	334.2	4.1
951-52	369.2	24095 (54.9)	652.6	52.0	394.5	3.9	48.6	325.4	3.9
952-53	375.6	24855 (55.1)	661.7	59.2	412.6	2.0	50.0	349.9	2.0
953-54	382.4	26769 (55.9)	700.0	69.8	457.8	0.8	59.2	388.1	0.8
954-55	389.7	27556 (55.2)	707.1	68.0	444.0	0.5	57.1	372.9	0.6
955-56	397.3	27318 (53.4)	687.6	68.9	430.7	1.4	55.8	360.4	1.4
956-57	405.5	28803 (53.3)	710.3	69.9	447.1	3.6	58.3	375.3	3.6
957-58	414.0	27509 (51.5)	664.5	64.3	408.8	3.2	54.7	350.3	3.2
958-59	423.1	30281 (52.7)	715.7	77.1	468.3	3.9	64.0	393.4	3.9
959-60	432.5	29976 (51.0)	693.1	76.7	449.6	5.1	64.9	384.1	5.1
960-61	442.4	31995 (50.9)	722.3	82.0	468.7	3.5	69.3	399.7	3.5
961-62	452.2	32022 (49.4)	708.1	82.7	460.9	3.6	71.0	398.9	3.6
962-63	462.0	31395 (47.4)	679.3	80.2	443.8	4.5	68.6	384.0	4.5
963-64	472.1	32119 (46.2)	680.3	80.6	452.0	6.2	70.6	401.0	6.3
964-65	482.5	35082 (46.9)	727.1	89.4	480.1	7.4	76.9	418.5	7.4
965-66	493.2	31208 (43.3)	632.8	72.3	408.1	10.3	62.4	359.9	10.3
966-67	504.2	30764 (42.2)	610.2	74.2	401.4	8.7	65.9	361.8	8.7
967-68	515.4	35339 (44.9)	685.7	95.1	460.2	5.7	83.0	404.1	5.7
968-69	527.0	35283 (43.6)	669.5	93.0	445.1	3.8	83.6	397.8	3.8
969-70	538.9	37551 (43.6)	696.8	99.5	455.0	3.6	87.8	403.1	3.6
970-71	551.3	40214 (44.5)	729.4	108.4	468.8	2.0	96.6	417.6	2.0
971-72	563.9	39459 (43.2)	699.8	105.2	456.1	-0.5	94.1	419.1	-0.5
972-73	576.8	37479 (41.2)	649.8	97.0	421.6	3.6	87.1	380.5	3.6
973-74	590.0	40178 (42.2)	681.0	104.7	451.2	5.2	94.7	410.4	5.2
974-75	603.5	39566 (41.1)	655.6	99.8	405.5	7.5	89.8	365.8	7.5
975-76	617.2	44666 (42.6)	723.7	121.0	424.3	0.7	108.0	373.8	0.7
976-77	631.3	42085 (39.6)	666.6	111.2	429.6	0.1	99.8	386.3	0.1
977-78	645.7	46309 (40.5)	717.2	126.4	468.0	-0.6	114.4	422.5	-0.8
978-79	660.3	47375 (39.3)	717.5	131.9	476.5	-0.2	119.7	431.8	-0.3
979-80	675.2	41323 (36.2)	612.0	109.7	410.4	-0.3	101.1	379.5	-0.5
980-81	688.5	46649 (38.1)	677.5	129.6	454.4	0.7	119.0	417.0	0.5
981-82	703.8	49406 (38.0)	702.0	133.3	455.0	1.6	121.8	415.7	1.6
982-83	718.9	48803 (36.4)	678.9	129.5	437.5	4.1	117.7	397.9	4.1
983-84	734.5	54080 (37.3)	736.3	152.4	480.0	2.4	139.5	437.9	2.4
984-85	750.4	54097 (36.0)	720.9	145.5	454.2	-0.4	133.6	415.9	-0.3
985-86	766.5	54252 (34.6)	707.8	150.4	478.3	-0.5	137.1	434.3	-0.1
986-87	782.7	53335 (32.8)	681.4	143.4	471.8	-0.2	131.7	435.4	-0.4
987-88	799.2	53543 (31.5)	670.0	138.4	449.4	3.8	127.4	411.7	2.3
988-89	815.8	61789 (32.9)	757.4	169.9	474.4	1.2	156.1	452.4	0.6

otes: Agricultural gross domestic product (GDP) is at 1980-81 prices. Figures in brackets are percentages of the total GDP.

ource: National Accounts Statistics.

Economic Survey.

believed that agricultural growth in India in the initial years after the country's independence in 1947, came about largely due to growth in cultivated area than growth in yields. By mid 1960s, however, almost the entire cultivable land in India was already being utilised for crop cultivation and there was very little scope left for further growth in the cultivated area[1]. For example, the total net sown area grew from 119.4 million hectares (m.ha) in 1951-52 to 138.1 m.ha in 1964-65 but had grown to only 140.1 m.ha in 1986-87. Under such a situation, further growth in agricultural output after mid 1960s could mainly come only through growth in crop yields.

Modern Technology and the Government's Role.

The traditional variety seeds that were being cultivated in the country in the 1950s and early 1960s could not give the desired high levels of yields. On the other hand, modern hybrid variety seeds were capable of giving substantially higher yield levels. These high yielding variety (HYV henceforth) seeds give best results when chemical fertilizers are used and the crop is assured timely availability of water. Thus it is possible to achieve high yields by the combined use of HYV seeds, chemical fertilizers and irrigation as a package. This modern technology came to be popularly known as the "Green Revolution" technology. The modern technology was introduced in India in the mid-1960s by the government as a strategy to bring about rapid growth in crop yields necessary for agricultural growth. Through various policies the government sought to promote the modern technology amongst the farmers of India.

On the inputs supply side, the government invested large sums on irrigation projects to make available irrigation facilities necessary for the modern technology to be successful. As a result of these investments gross irrigated area over all crops increased

1 Although this may be true of the total net sown area, gross cropped area over all crops can still grow as a result of multiple cropping.

from 23.2 million hectares (m.ha) in 1951-52 to 55.6 m.ha in 1986-87. However, public investment in agriculture has been found to have somewhat slackened during the 1980s. We shall discuss this issue in more detail in the penultimate chapter of this thesis.

Simultaneously, the government took an active role in making fertilizer available both by encouraging domestic production as well as importing them to meet domestic shortages. Total fertilizer production increased from 150 thousand tonnes (t.t henceforth) of nutrients in 1960-61 to 9044 t.t in 1990-91. Imports of fertilizers increased from 419 t.t to 2758 t.t. over the same period. It may also be noted that imports of fertilizers has been fluctuating between 984 t.t. to 3399 t.t. in the 1980s. As a result of the increase in domestic production supplemented with imports, consumption of fertilizers increased from 292 t.t in 1960-61 to 12567 t.t in 1990-91.

Supplementing these policies, the government has also been providing subsidies aimed at making available at a cheap rate to the farmers inputs like chemical fertilizers, diesel for tractors and pump sets, electricity for pump sets, etc. Further, credit facilities for farmers are made easily available through agricultural development banks, farmers cooperatives, etc. According to Gulati (1989) the total of all input subsidies and credit facilities extended to agricultural sector come to as high as Rs.117930 millions in 1987-87 of which irrigation alone forms 72%.

On the outputs side, the government has been maintaining a price support scheme aimed at providing remunerative prices to the farmers, so that price and revenue uncertainties do not act as a disincentive for farm production. This scheme is in fact a part of a larger system consisting of procurement of grains from farmers at prices preset, maintenance of buffer stocks and public distribution of foodgrains to essentially urban consumers. This system has been under operation since long now. The goal here is to offer price protection to consumers at times of shortages in production while in the years of bumper production it is to ensure that the interests of the farmers are not affected so that production incentives are maintained.

Apart from these, the government also established various agricultural research centres to develop hybrid seeds, organized extension programmes to spread the knowledge about the new technology, etc.

As a result of these direct and indirect measures aimed at promoting the modern technology Indian agriculture witnessed a transformation in the sense that the new technology was generally accepted by millions of farmers across the country. Use of HYV seeds, fertilizers and irrigation grew rapidly as can be seen from the following table at all India level.

Crop	HYV adoption (%)		Irrigation Intensity		Fertilizer Use	
	1966-67	1985-86	1966-67	1985-86	1966-67	1985-86
Rice	2.5	57.1	0.378	0.420		
Wheat	4.2	82.9	0.478	0.753		
Jowar	1.1	37.8	0.041	0.046		
Bajra	0.5	46.9	0.032	0.054		
Maize	4.1	31.0	0.157	0.176		
Total					6.99	47.39

Notes:

$$\text{HYV adoption} = \frac{\text{Acreage of crop under HYV seeds}}{\text{crop acreage}} \times 100$$

$$\text{Irrigation intensity} = \frac{\text{Irrigated acreage of crop}}{\text{crop acreage}}$$

$$\text{Fertilizer use} = \frac{\text{Total fertilizer consumption}}{\text{Total gross cropped area}}\left(\frac{kg}{ha}\right);$$

Cropwisedetailsarenotavailable.

The spread of HYV seeds is highest in the case of wheat followed by rice and other cereal crops. Similarly, with respect to irrigation, wheat and rice have the highest proportion of their respective acreages under irrigation. Fertilizer application, too has registered rapid growth over the 20 years since introduction of the modern technology. Although time series data on cropwise fertilizer applications are not available, the survey by the National Sample Survey Organisation (NSSO) conducted in 1972-73 suggests that rice and wheat account for about 60% of total fertilizer consumption over all the crops in the country.

Impact of Modern Technology.

As a result of promoting the modern technology, outputs of cereals and foodgrains grew as reported earlier (see table 1.1). Looking cropwise, wheat yield levels (in kg/ha) grew from 913 in 1964-65 to 2244 in 1988-89 and that of rice from 1078 in 1964-65 to 1689 in 1988-89. Corresponding figures for jowar (sorghum), bajra (pearl millet) and maize are 536, 382, 1010 in 1964-65 and 697, 646, 1395 in 1988-89, respectively. The growth witnessed in cereals' outputs is mainly due to growth in yields and outputs of wheat and rice. As seen in table 1.2 yields and outputs of wheat recorded spectacular gains followed to a lesser extent by those of rice and maize. In the case of other crops the benefits, if any, from the modern technology seem to be rather limited.

Two points are to be noted now.

First, despite such impressive growth performance in yield levels since the adoption of modern technology in mid 1960s, India seems to be still far behind several other countries in the World in terms of comparative achievements. Yield levels achieved for a few countries in 1987-88 are presented in the following table for a few crops:

International Yield Levels (Kg/Ha) of Selected Crops in 1987-88.

Country	Paddy	Wheat	Maize	Cereals
India	2550	2002	1029	1769
World	3320	2314	3202	2483
China	5304	3017	@	3922
Egypt	5758	4747	4542	4715
France	@	6151	@	6051
Japan	5825	@	@	5429
Romania	@	3600	6094	4760
U.K	@	6137	@	5351
U.S.A	6178	2291	5311	3715

Notes: @ data not available;

Source: Estimates of Area & Production of Principal Crops in India, 1988-89.

Table 1.2 - Outputs & Yields of Cereal Crops.

Year	Rice		Wheat		Jowar		Barley	
	Output	Yield	Output	Yield	Output	Yield	Output	Yield
1949-50	23542.0	771.300	6391.00	654.850	5870.00	378.382	2251.00	707.839
1950-51	20576.0	667.835	6462.00	663.041	5495.00	352.900	2370.00	703.893
1951-52	21300.0	714.046	6183.00	652.835	6077.00	381.147	2387.00	749.280
1952-53	22890.0	764.090	7501.00	763.228	7359.00	419.579	2920.00	902.033
1953-54	28214.0	901.723	8017.00	750.585	8002.00	455.119	2951.00	838.214
1954-55	25219.0	819.757	9043.00	803.100	9201.00	528.855	2980.00	872.876
1955-56	27557.0	874.243	8760.00	708.337	6726.00	387.398	2816.00	823.874
1956-57	29037.0	899.819	9403.00	895.282	7327.00	451.253	2803.00	813.815
1957-58	25525.0	790.297	7998.00	681.841	8635.00	498.816	2292.00	746.823
1958-59	30847.0	929.911	9958.00	789.253	9033.00	502.951	2694.00	813.406
1959-60	31676.0	936.806	10324.0	771.599	8579.00	484.498	2717.00	804.322
1960-61	34574.0	1013.068	10997.0	850.700	9814.00	533.022	2819.00	879.583
1961-62	35663.0	1027.980	12072.0	889.609	8029.00	439.989	3150.00	851.007
1962-63	33217.0	930.578	10776.0	792.936	9748.00	529.380	2420.00	801.590
1963-64	36998.0	1033.204	9853.00	729.906	9198.00	500.544	2038.00	734.079
1964-65	39308.0	1078.054	12257.0	913.202	9603.00	538.276	2521.00	939.970
1965-66	30589.0	862.391	10394.0	828.758	7581.00	428.814	2302.00	902.273
1966-67	30438.0	863.465	11393.0	887.444	9224.00	510.912	2348.00	831.150
1967-68	37612.0	1032.247	16540.0	1102.814	10048.0	545.405	3504.00	1030.222
1968-69	39761.0	1075.501	18651.0	1168.755	9804.00	523.410	2424.00	878.898
1969-70	40430.0	1072.903	20093.0	1208.528	9721.00	522.404	2718.00	982.279
1970-71	42225.2	1123.259	23832.5	1306.671	8104.90	466.499	2784.40	1009.955
1971-72	43068.0	1140.838	26409.9	1379.907	7721.90	460.287	2577.00	1049.586
1972-73	39245.3	1069.710	24734.6	1270.813	6987.60	449.152	2379.10	971.497
1973-74	44051.0	1150.595	21777.5	1171.865	9096.70	544.101	2371.30	894.729
1974-75	39578.9	1044.618	24104.4	1338.387	10414.2	643.281	3134.70	1088.589
1975-76	48739.8	1234.888	28846.3	1410.315	9504.30	590.612	3181.90	1139.232
1976-77	41916.8	1088.434	29009.9	1386.807	10524.1	607.286	2343.80	1045.886
1977-78	52670.4	1307.522	31749.2	1479.758	12064.3	739.325	2311.20	1154.792
1978-79	53773.4	1328.322	35507.8	1568.283	11436.1	708.297	2141.20	1171.463
1979-80	42330.3	1073.983	31830.0	1435.614	11647.7	698.571	1623.70	916.723
1980-81	53631.4	1335.726	36312.6	1629.917	10430.8	659.785	2293.10	1289.010
1981-82	53248.0	1308.019	37451.8	1691.254	12061.9	726.664	1992.60	1153.459
1982-83	47115.8	1231.399	42793.9	1815.009	10753.4	656.640	1866.80	1258.969
1983-84	60097.3	1457.109	45476.3	1843.273	11919.0	725.349	1833.50	1322.776
1984-85	58336.6	1417.354	44068.6	1870.103	11402.3	715.353	1555.00	1241.641
1985-86	63825.0	1551.516	47051.6	2045.962	10197.0	633.460	1862.30	1433.591
1986-87	60556.8	1471.014	44322.9	1916.152	9185.40	575.963	1669.40	1363.109
1987-88	56862.0	1465.289	46169.0	2001.864	12196.0	762.298	1577.00	1379.703
1988-89	70488.0	1606.902	54110.0	2244.390	10170.0	696.623	1722.00	1592.969

Notes: Outputs are in thousand tonnes;

Yields are in kilogrammes per hectare;

Table 1.2 Contnd.

Year	Bajra		Ragi		Maize	
	Output	Yield	Output	Yield	Output	Yield
1949-50	2835.00	308.189	1544.00	699.909	2046.00	627.223
1950-51	2595.00	287.598	1429.00	648.661	1729.00	547.325
1951-52	2348.00	246.454	1312.00	599.360	2078.00	627.190
1952-53	3192.00	298.406	1337.00	596.077	2870.00	796.117
1953-54	4547.00	372.735	1876.00	803.770	3039.00	765.474
1954-55	3519.00	309.608	1653.00	719.321	2975.00	783.545
1955-56	3428.00	302.348	1848.00	800.173	2602.00	704.004
1956-57	2873.00	255.355	1793.00	788.749	3078.00	819.053
1957-58	3820.00	324.111	1798.00	743.378	3150.00	772.248
1958-59	3860.00	330.467	1950.00	787.717	3463.00	811.958
1959-60	3493.00	320.801	1866.00	708.721	4073.00	937.815
1960-61	3283.00	286.250	1838.00	730.815	4080.00	925.800
1961-62	3645.00	323.198	2030.00	808.443	4312.00	958.734
1962-63	3959.00	361.157	2041.00	821.659	4607.00	992.248
1963-64	3878.00	349.275	2021.00	817.888	4561.00	995.417
1964-65	4519.00	382.092	2023.00	774.582	4664.00	1009.961
1965-66	3752.00	313.581	1327.00	492.211	4823.00	1005.001
1966-67	4468.00	385.063	1631.00	704.231	4894.00	984.525
1967-68	5185.00	404.825	1884.00	822.340	6270.00	1123.052
1968-69	3802.00	315.488	1840.00	730.372	5701.00	997.370
1969-70	5327.00	428.399	2117.00	768.890	5674.00	987.929
1970-71	8028.80	621.742	2155.00	871.623	7485.60	1279.087
1971-72	5319.10	451.793	2208.50	910.722	5100.50	899.840
1972-73	3928.40	332.527	1822.00	825.527	6380.50	1094.333
1973-74	7518.20	539.653	2071.80	877.961	5803.50	984.774
1974-75	3271.80	289.831	2135.60	866.882	5558.90	948.118
1975-76	5735.80	495.692	2796.70	1063.506	7255.80	1203.144
1976-77	5853.20	544.443	2044.70	819.092	6361.20	1060.147
1977-78	4730.20	425.998	2066.00	1102.392	5973.30	1051.138
1978-79	5566.40	488.505	3200.40	1183.099	6199.40	1076.228
1979-80	3947.80	373.172	2721.60	1040.044	5602.90	979.425
1980-81	5342.90	458.339	2419.90	958.378	6958.90	1158.557
1981-82	5537.30	469.904	2960.50	1134.117	6897.10	1162.165
1982-83	5131.20	468.937	2223.10	821.798	6540.50	1144.783
1983-84	7725.80	652.944	2831.00	1106.637	7922.20	1352.234
1984-85	6046.40	569.304	2530.10	1059.994	8441.00	1455.608
1985-86	3663.80	343.961	2518.10	1048.946	6643.70	1148.018
1986-87	4513.50	400.830	2708.30	1128.253	7592.80	1201.898
1987-88	3298.00	378.518	2319.00	1025.199	5721.00	1028.772
1988-89	7708.00	645.858	2410.00	1040.138	8229.00	1395.455

Notes: Outputs are in thousand tonnes;

Yields are in kilogrammes per hectare;

Yield levels achieved in India for these crops are far lower than those in other countries even as late as in 1987-88. Thus, there is indeed still an enormous potential for further growth of crop yields in India.

The second point is the one that this thesis is mainly concerned with. Not only the modern technology influenced the growth performance of different crops differently but it is also felt that wherever the growth has been significant it has not been smooth over time, but marked by year to year fluctuations. The yields and outputs of all the crops for which the data are presented in table 1.2 show fluctuations over the entire period 1949-50 to 1988-89. The fluctuations in outputs and yields of the 7 cereal crops at the all India level are shown graphically also in figure 1.1.

At the outset on visual observation, we find from this figure that wheat output has been increasing steadily with very little fluctuations. In the case of rice output which was also growing, the fluctuations over time seem to be small throughout, though towards the later years these seem somewhat more than in the earlier years. The remaining 5 crops (jowar, bajra, ragi, maize and barley), however, seem to show large fluctuations in their outputs. Outputs of jowar, ragi and barley show large but fairly uniform fluctuations over time. Bajra output shows smaller fluctuations initially, which seem to have increased dramatically during later period. Same is true with respect to maize output which showed almost no fluctuations initially but large fluctuations from around mid 1960s.

Similar fluctuations are seen in acreages and yields also. The acreages of rice, wheat and maize show smaller fluctuations which have been fairly uniform throughout. Jowar, bajra and ragi show large fluctuations in the acreage throughout the full period, while barley acreage shows smaller fluctuation which seem to have reduced towards the later years.

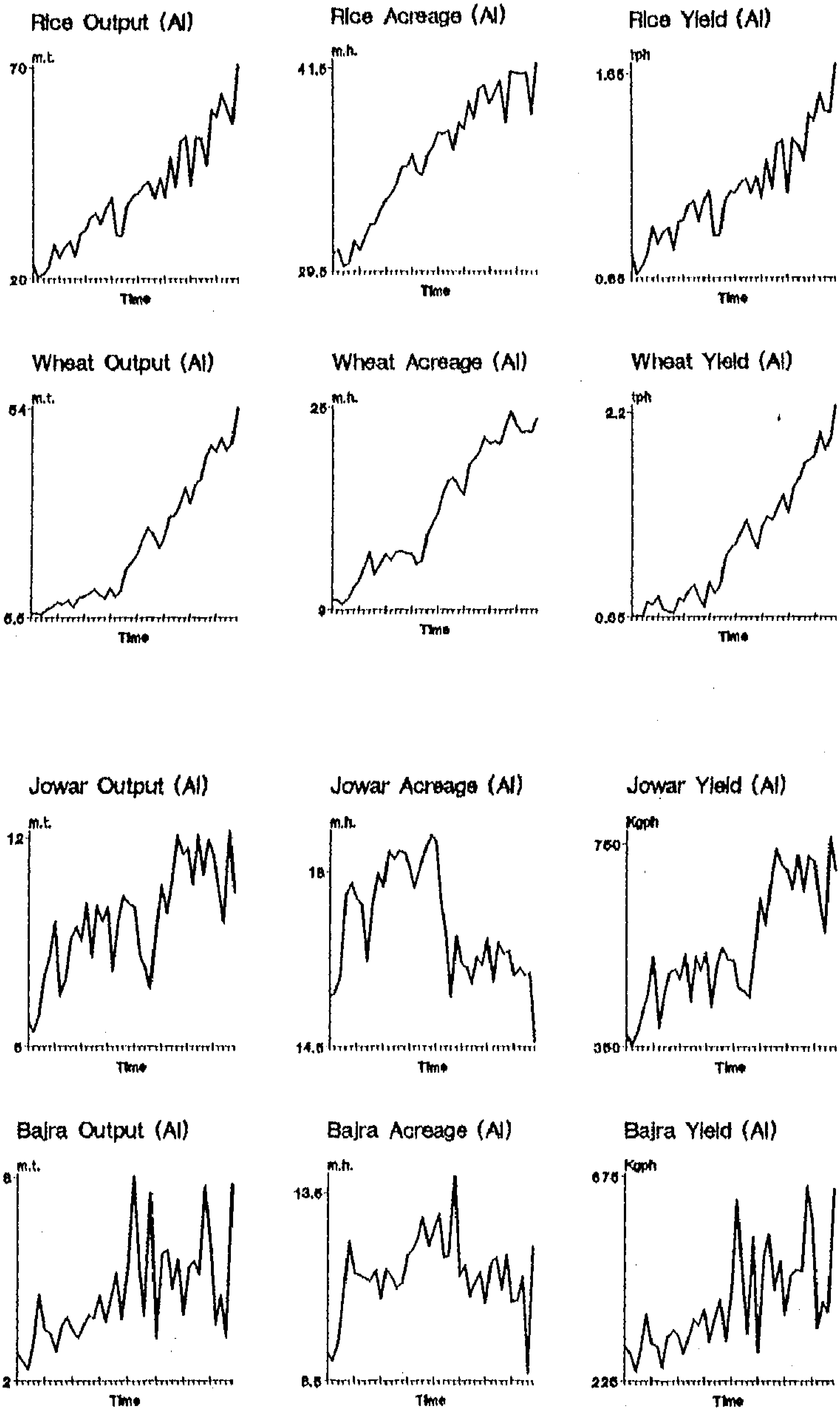

Figure 1.1 - All India

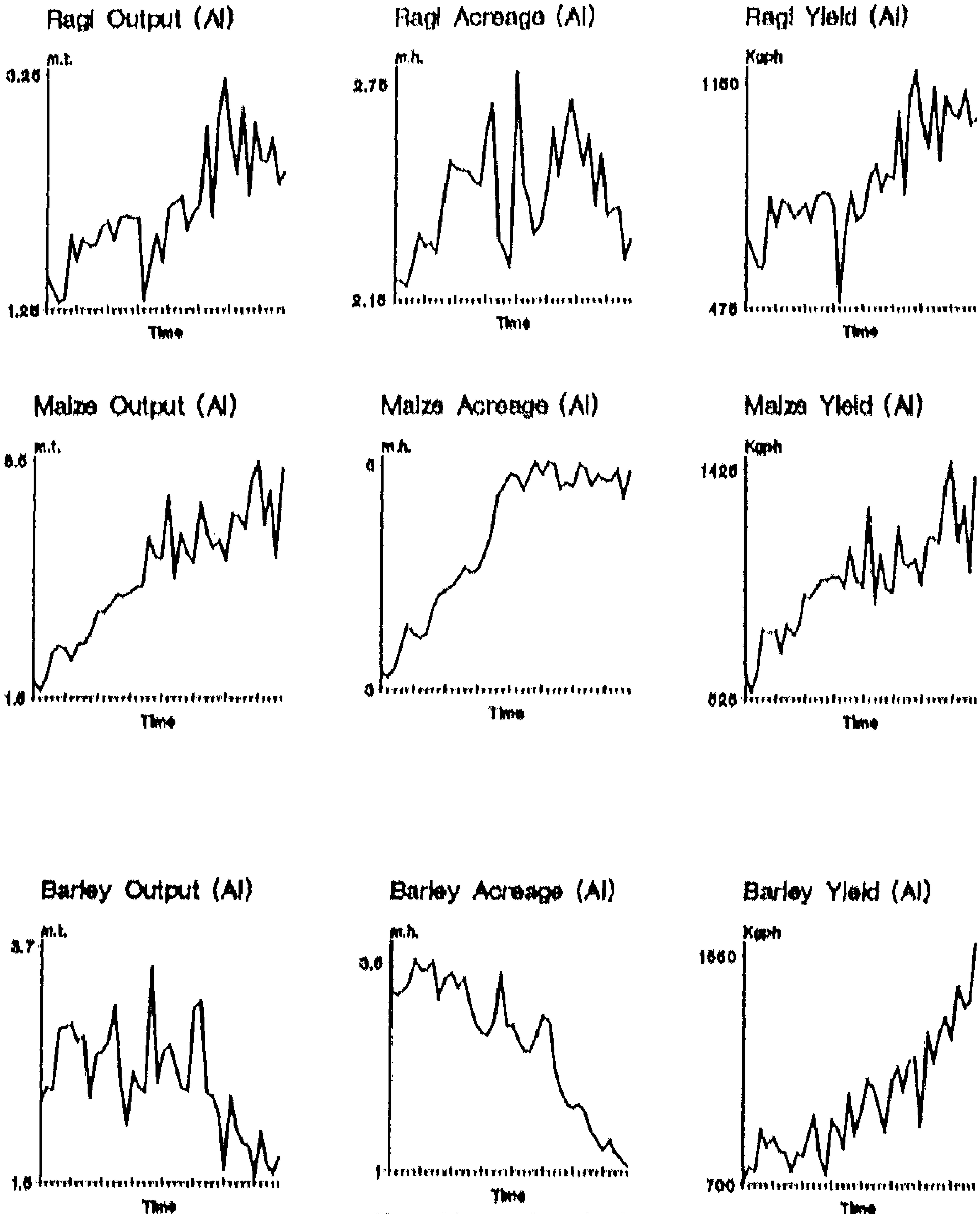

Figure 1.1 Contnd. - All India

Notes: Time axis runs from 1949-50 to 1988-89;
m.t. : million tonnes;
m.h. : million hectares;
tph : tonnes per hectare;
kgph : kilo grammes per hectare;

The fluctuations in the yields of bajra and maize seem to have increased towards the later years. The yields of other crops, especially rice and wheat, seem to show fairly uniform fluctuations over the full period.

Such fluctuations can also be observed in the outputs of cereals and foodgrains presented earlier in table 1.1.

Is the size of the fluctuations increasing over time? If the answer is yes, this raises the question of instability in the performance of yields and outputs. What are the consequences of an increase in the fluctuations of yields and outputs? The issue has some serious implications both in the short run and long run.

Consequences of Fluctuations in Yields and Outputs.

Fluctuations in yields and outputs could cause fluctuations in prices. Price fluctuations in the short run affect both consumers and producers. During troughs (peaks) in production (prices), consumers, especially the poor, would witness an erosion of their purchasing power because of higher prices, which would affect their consumption levels. Of course, the shortfalls in domestic production levels may be compensated by importing grains from abroad and thus prices may be maintained stable. But as Anderson and Hazell (1989) point out, even when aggregate food consumption is relatively stable, the consumption of some of the poorer households can still be at risk particularly when their incomes are tied to agricultural production. Besides, this strategy anyway depends on the extent of foreign exchange availability which is quite scarce for India. Then given that this option is limited, a rise in food prices generally causes an overall increase in non-agricultural prices also thus causing inflationary pressures in the economy. Even the bumper productions beyond expectations, though welcome by all means, seem to be wrought with problems of management! For example, during peaks in production, farmers would witness an erosion in their revenues and profits due to lower prices. In India, while farmers generally do not have adequate storage facilities, most of them in view of their immediate need for cash incomes, are not in a position to indulge in speculative activity of postponing their sales by storing their grain production and waiting for remunerative prices. Here of course, the government's price support scheme (mentioned above) can in principle come to the rescue of farmers. But that depends on how vigorous is the government's agricultural price policy. Often the government sets not only the levels of support prices (determined by taking into account costs of cultivation plus some allowance of profits to farmers) but also targets for quantities (tonnes) to be bought (procured) from the farmers at the support prices it sets. While a deep discussion on the governmental policy is avoided here, it may however be noted that the quantity targets usually depend on not only the public distribution requirements but also the storage facilities that it has. These facilities are generally known to be inadequate and of poor quality. Besides maintaining and operating buffer stocks involve costs in terms of procurement, transport, storage, distribution, and administration. Such a costly operation to be successful requires accurate prediction of the ups and downs in yields and outputs which in turn would need an understanding of the nature and causes of their fluctuations.

Thus as Mellor (1988) says, "security of food consumption cannot be separated from production stability problems". Further, Mellor (1989), explaining that "a given reduction in food supplies will result in a decrease in consumption by the bottom 20 percent of the income distribution in developing countries that is more than 10 times greater than that of the top 5 percent", convincingly argues that the biggest losers from the instability in food supplies and prices are the poor. Braun et.al (1992) also argue the same. In their own words:

> "Seasonal variations in production and seasonally high food prices are often important contributors to transitory food insecurity of poor households, which can escalate over time into chronic food insecurity and nutritional deterioration

(Sahn (1989), Chambers, Longhurst and Pacey (1981)). Sudden changes in incomes and prices affect the ability of households, not always in the same way, to obtain food that is available. (For example, a decrease in food prices may reduce the incomes of food producers while benefiting non-food producing consumers. Surplus farmers who often meet most of their foodgrain needs from home production can choose to maintain adequate levels of food consumption even if real earnings fluctuate, whereas landless agricultural wage laborers whose real earnings are determined by market wages, hours worked and retail prices are highly susceptible to increased variations in production and prices and therefore are adversely affected as consumers). An important source of fluctuation in seasonal food prices lies in the costs of storage and failure to manage public food stocks adequately. Further, the ability of households to effectively demand adequate food is governed by exogenous events (for example, price shocks, war, deteriorating terms of trade), domestic policy changes and stochastic weather-induced events such as droughts, interacting with existing technology and a given resource endowment".

From the above, it may also be noted that short run problems, if persist, can lead to long run problems as well.

In the long run, as the fluctuations in yields and outputs increase over time resulting in increased uncertainty in prices, revenues and profits for the farmers, they can act as a disincentive against agricultural production. This may lead to a fall in agricultural investments, which in turn would affect the long term growth of agricultural output. In India, where the population is still rapidly growing a fall in the growth of domestic agricultural output would have serious consequences for the long term food security. India, due to its population levels of elephantine proportions as well as due to its current low per capita levels of industrial production, cannot yet hope to mainly depend on large scale imports to feed its millions of people. Thus, a consistent investment activity in agriculture sector is essential for a very long to come yet. And, such investment, particularly private investment, flows in consistently in a stable environment void of uncertainties.

Thus, it is obvious that the problem of stability/instability of crop yields and outputs is an important problem. This thesis does not, however, attempt to analyse empirically the short run consequences of yields/output fluctuations, though it attempts in chapter 11 to analyse the long run economic consequences, particularly of a fall in agricultural investment in India. However, the major part of the thesis is primarily devoted to quantitatively assessing the changing order of fluctuations in cereal crop yields.

Statement of the Problem.

The issue of stability of agricultural performance is also one of international concern. Several scholars who have studied this problem for countries like Bangladesh, Indonesia, Mexico, Philippines, Sri Lanka, U.K., U.S.A., etc., have raised doubts over the stability of agricultural growth in various countries under the modern technology. The concern of most of these studies centered around the following questions:

1) Have the fluctuations in yields and outputs been increasing over time particularly under the era of modern technology?
2) If so, which are the crops affected and in which regions?
3) Are growth and instability related?
4) What is the role of different inputs in increasing/decreasing the variability of yields and outputs?
5) Implicit behind the above questions is the measurement of variability/instability. How to measure it?
6) If instability exists at all, what are the policy measures to adopt to stabilize agricultural performance?

This Thesis.

These questions form the subject matter of this thesis, which will focus on the yields of major cereal crops (rice, wheat, jowar (sorghum), bajra (pearl millet), ragi, maize and barley) in India. The study will be done at the all India level and for one State, Andhra Pradesh, at the State and districts levels. The analysis at the all India level covers the period 1949-50 to 1988-89. Though at the Andhra Pradesh State level the yields data are available from 1949-50 to 1988-89, data at the districts levels are available only for the period 1955-56 to 1984-85. Hence for the sake of comparability, the period of analysis at the State level for Andhra Pradesh is restricted to be same as that at the districts level; i.e., 1955-56 to 1984-85.

The thesis starts with a brief assessment of the performance of agriculture at the all India level in chapter 2. The purpose here is mainly to provide such details on agricultural performance relevant for the analysis in the later chapters. The focus will be on the movement over time of some overall indicators like the gross domestic product, investment, irrigation development, costs, the acreage, yields, outputs and inputs usage of different cereal crops.

A similar assessment of the performance of agriculture in Andhra Pradesh State and in its districts is done in chapter 3.

To the extent that chapters 2 and 3 are intended to be mainly informative, they are somewhat descriptive. In chapter 2, we come to note that the output growth rates of cereals after the mid 1960s have been lower in India and some reasons are explored. In chapter 3, while providing information on Andhra Pradesh, the impact on crop intensity of irrigation development will be explored. Further, attention is drawn to some difficulties in making comparative assessment of crop performance before and after mid 1960s, through an illustration. Most importantly, this illustration provides reasons why (i) no drought (poor rainfall) years have been dropped and (ii) any sub-periodization of the sample is avoided, in the econometric analysis that follows in later chapters.

The subject matter of the thesis begins in chapter 4. We start with a brief review of the past studies on the problem of growth, stability and variability of crop outputs and yields. The various issues covered by the past studies on this problem, the methodology adopted by them and their conclusions will be discussed. This chapter ends with a discussion of the shortcomings of the past studies and draws attention to the salient features of our research work that follows from chapter 5 onwards.

According to Anderson and Hazell (1989), statistical analysis shows that "baseline production variability is due primarily to yield variability. The increase in the variability of world cereal production since the 1960s (contrasting the periods before and after 1971) is also predominantly due to increases in year-to-year variations in yields of individual cereals along with the increasingly correlated patterns of yield variation among different cereals". For this as well as some more reasons to be elaborated in later chapters, this thesis analyses the stability issue only for cereal crop yields; not for their acreages or for their outputs.

Chapter 5 conceptualizes the stability issue with regard to various aspects of crop yields and then attempts to provide an unified view for the analysis of growth and instability of crop yields. Four aspects of yield performance are distinguished:
1) stability of yield levels - which relates to the yield levels themselves;
2) stability of growth rates - which relates to the growth performance over time;
3) stability of yield variance around the mean (we call this as **"variability analysis"**). This aspect, forming a major part of the thesis, relates to the changing order (amplitude) of fluctuations in yields around their trends/expected values; and

4) stability of growth path (we call this as "structural change analysis") - which relates to structural change in the growth path.

Our method of analysis is essentially econometric. Discussing the various conceptual and econometric issues involved we come to note that

a) the conceptual issues and econometric procedures are deeply interrelated;

b) for a complete analysis of the problem, a distinction between two analytical frameworks, viz. time trend framework and yield response function framework, is necessary to be made. While in the former framework the analysis is essentially based on the estimated time trends, in the latter framework it is based on the yield responses estimated as a function of various inputs;

c) the estimation results can have a tremendous bearing on the functional form specification, the error specification (additive/ multiplicative) and the estimation procedure; and

d) different error specifications have different meanings particularly in the context of variability.

This discussion culminates in describing a methodology covering the stability of all the above mentioned aspects of yields. The salient features of our methodology are,

1) a procedure to select an appropriate functional form for the time trend / response function to be estimated;

2) test procedures that detect the unknown structural and variability change points.

While the former is based on the non-linear measures developed by Beale (1961) and Bates and Watts (1980), the latter is based on certain tests developed by Hsu (1977).

A distinction between variability within a district and variability across districts (spatial) of yields is also made in this chapter.

A discussion of the data base used, definitions, sources, etc., is also provided in this chapter. Each of the above issues is taken up for analysis in the subsequent chapters.

Chapter 6 analyses crop yields at the all India and Andhra Pradesh State levels in the time trend framework. Growth, changes in variability and structural change in the growth path of yields of 7 cereal crops (rice, wheat, jowar, bajra, ragi, maize, & barley) at the all India level and of 5 cereal crops (rice, jowar, bajra, ragi & maize) at the Andhra Pradesh State level are then analysed.

In chapter 7 similar analyses in the time trend framework is done for the yields of 5 cereal crops (rice, jowar, bajra, ragi & maize) at the districts levels in the State, Andhra Pradesh (AP).

For the analysis in the response function framework, yield response functions are to be estimated first. Chapter 8 is devoted to the estimation of the yield response functions. For various theoretical and empirical considerations (discussed in detail in that chapter), response functions are estimated only for yields at the districts level of AP.

In chapter 9, using test procedures described in chapter 5, the variability of yields over time and with respect to fertilizers and irrigation are analysed based on the yield response functions estimated in chapter 8. Conclusions on the role of modern technology and the role of fertilizers and irrigation in increasing/decreasing yield variability are drawn in this chapter. The analysis in the response function framework was restricted only to yields at the districts level in AP, since response functions were estimated only for them (chapter 8).

Chapter 10 is devoted to the analysis of spatial variability (or the disparities) of yields across the districts of Andhra Pradesh. First, trends in the spatial variability of yields, inputs and infrastructure are analysed. Then, the spatial variability of yields is sought to be explained through the spatial variability in rainfall, fertilizers, and other infrastructural factors like different sources of irrigation.

The analyses in chapters 6 through 10 bring out the importance of irrigation in

1) raising yield levels,
2) explaining the spatial variability of yields.
3) It will also be noted that irrigation unlike fertilizers does not lead to any instability in yields.

Earlier it was mentioned that investment in agriculture in the 1980s has slackened. In chapter 11 the consequences of the fall in agricultural investment on the agricultural sector as well as the rest of the economy are analysed. This analysis is done using a computable general equilibrium model already available in the literature.

The main conclusions of this thesis as well as its limitations are discussed in chapter 12.

CHAPTER 2 - PERFORMANCE OF AGRICULTURE: ALL INDIA

"Ignorance gives one a large range of probabilities!"
- George Elliot.

2.1 Introduction.

In order to place the stability issue of yields performance (mentioned in previous chapter) in a proper perspective, we need to familiarize ourselves with various developments that took place in the agricultural sector in India. This and the next chapter are devoted for this purpose. This chapter concerns with agricultural performance at the all India (AI) level. Only a modest attempt is made here to assess the overall agricultural performance with emphasis on the production of the important cereal crops. The stress here is only on the quantitative aspects rather than qualitative factors. Notably, institutional factors are not covered here. Agricultural performance in Andhra Pradesh - an important State in India will be taken up for discussion in the next chapter.

The performance of agriculture in overall terms as given by some overall indicators are analysed first in section 2.2. The income, investment, infrastructure and the cost of production in the agricultural sector as a whole are covered here. While this would give an overall picture of Indian agriculture the main focus of our study is on 7 important cereals, viz., rice, wheat, jowar, bajra, ragi, maize and barley. The production environment of these 7 cereals crops is studied in detail in section 2.3. For each of the 7 cereals crops the performance of output, acreage, yields, gross irrigation intensity, proportion of crop acreage under high yielding variety seeds and fertilizer intensity are studied.

The entire time period 1949-50 to 1988-89 is split into two sub-periods - 1949-50 to 1965-66 (referred to as Period I) corresponding to the pre-Green Revolution period and 1965-66 to 1988-89 (Period II) corresponding to the post-Green Revolution period. It is attempted to evaluate the performance of the outputs and inputs in terms of the semilog time trend results obtained for the 2 sub-periods separately as well as for the full period. Occasionally annual compound (a.c) growth rates are also used.

All tables referred to are at the end of the chapter.

2.2 Overall agricultural performance.

At the time of independence in 1947, agriculture was characterised by stagnant low levels of production and income and which formed the source of livelihood for a vast majority of the population. Crop cultivation was largely dependent on the monsoon, with little irrigation available that too only in a few regions. The country witnessed frequent famines and even during bountiful years food availability per capita was very low.

Agricultural incomes: With the beginning of the plan process in 1950-51 Indian agriculture began to grow. The annual compound rate of growth in agricultural gross domestic product (GDPA) at 1980-81 prices (New Series) over the period 1950-51 to 1988-89 is about 2.55% (see table 2.1). This overall growth rate is somewhat less than that observed in the 2 sub-periods. The compound rates of growth observed between 1950-51 to 1965-66 is 1.84% while it is 3.01% between 1965-66 to 1988-89.

In spite of this growth in GDPA the share of agriculture in total gross domestic product (GDPT) fell substantially over this period, from about 49% in 1950-51 to about 31% in 1988-89. This has come about because of the rapid growth in the non-agricultural sectors (industries and services). The progress achieved in those sectors, however, did not result in any significant reduction in the proportion of population depending on agriculture. In 1991, as much as 65% of the total work force in the country were employed in agriculture and its allied activities. Per capita agricultural income, at 1980-81 prices, has registered only a modest increase from Rs.795 per annum (p.a.) in 1950-51 to about Rs.1087 p.a. in

1988-89, implying an a.c. *growth rate of only about* 0.83%. Indian agriculture is almost totally private controlled, in the hands of millions of farmers. This is borne out by the fact that nearly 99% of GDPA originates from the private sector.

Agricultural investment: The growth in agriculture witnessed since 1950-51 has been possible because of an increase in agricultural investment. Total agricultural investment (TAI), at 1980-81 prices (New series), grew (see table 2.1) from Rs.1310 crores in 1950-51 to about Rs.4625 crores in 1988-89, having reached a peak of about Rs.5447 crores in 1978-79. In terms of share in the total investment, agricultural investment has ranged between a maximum of 30% in 1952-53 to a low of 10% in 1988-89. Starting from the VI 5-Year Plan (from 1980-81) agricultural investment has been falling, both in absolute terms as also in terms of its share in total investment. The fall in agricultural investment in the 1980s is discussed in greater detail in chapter 11. Though agriculture is mainly in private hands, government has contributed significantly to the growth in agricultural investment since 1950-51. Share of public investment in total agriculture investment has ranged between 30% and 39% over the years (see table 2.1).

Irrigation development: It is expected that major portion of agricultural investment goes into developing various types of irrigation facilities. Table 2.2 presents details of irrigation potential created and their utilisation. Out of an ultimate potential of 113.5 million hectares (m.ha.) of total irrigation, only about 22.6 m.ha. (19.9%) was developed in 1951. By 1988-89, as much as 77.5 m.ha. (68.3% of the ultimate potential) had been developed. Note that even by 1989 as much as 36 m.ha. of irrigation still remains to be developed. The utilisation rate, though not 100%, is very high.

Sourcewise net irrigated area (NIA): Table 2.3 presents for a few years NIA by sources and also total gross irrigated area (TGIA). NIA by surface water sources (canals + tanks) has shown only a modest increase over time; from 14973 thousand hectares (t.ha.) in 1960-61 to 19303 t.ha. in 1986-87. In general while NIA by canals has been increasing over time, NIA by tanks has, however, been decreasing at the same time. Turning to ground water (GWTR) based irrigations, tubewells and other (shallow/dug) wells, GWTR has grown rapidly from 7282 t.ha. in 1960-61 to 21046 t.ha. in 1986-87; i.e., at an annual compound growth rate of 4.17%. Minor irrigations have grown rapidly while major & medium irrigation have shown only moderate growth.

Gross irrigated area (GIA): Gross irrigated area is defined as net irrigated area times the number of irrigations. Total gross irrigated area (TGIA) over all crops in a few years is presented in table 2.3. The increase in TGIA has been highest during the 1970s when 11681 t.ha. was added. The 1980s, however, has witnessed a slow down in the growth in TGIA which could be the result of the fall in agricultural investment observed in the 1980s.

Acreage expansion and cropping intensity: Developing irrigation facilities is likely to affect crop acreages atleast in 3 ways:

1) Extensively: The area under cultivation increases. When irrigation facilities are made available in what were earlier dry/rain dependent waste land regions, it is likely to result in an expansion of cultivated area when fallow or waste lands are brought under cultivation. This can be observed as an increase in the net sown area (NSA) over all crops.

2) Intensively: When irrigation makes water available for crop cultivation even during off-monsoon seasons, it enables raising more than one crop in a year on a plot of land (referred to as multiple cropping). That is, irrigation keeps land under cultivation for a greater part of the year instead of keeping it idle. A part of the increase in the total gross cultivated area (GCA) is due to this cropping intensity. Aggregate cropping intensity (ACI) is generally measured as a ratio between GCA and NSA. Table 2.4 presents for a few years details of NSA, GCA and ACI.

3) Changes in Cropping Pattern: When irrigation facilities are made available, farmers may shift their cultivation to more profitable crops that are water intensive. Such a tendency has been observed in many parts of India, where farmers shift towards cultivation of rice, sugarcane, etc. Thus changes in cropping pattern

can also result in an increase in the crop acreage of some crops.

It is generally believed that irrigation led to expansion of the net sown area only up to the mid 1960s. NSA increased from 119.4 m.ha. in 1951-52 to about 138.1 m.ha. in 1964-65 and fell to 136.2 m.ha. in 1965-66. However, since 1965-66 it has been more or less stagnant. With little arable land left to be brought under cultivation, the scope for further expansion of NSA is very limited. But then the intensity impact of irrigation played an important role since mid 1960s in the expansion of GCA. GCA grew from 133.2 m.ha. in 1951-52 to about 159.2 m.ha. in 1964-65, down to 155.3 m.ha in 1965-66 but rose to 176.9 m.ha. in 1986-87. The lower levels of GCA and NSA in 1965-66 than their levels in 1964-65 are essentially the drought effect. Thus, while NSA has been nearly stagnant since 1964-65, GCA continued to grow though its growth rate fell from 1.1% (1951-52 to 1965-66) to 0.6% (1965-66 to 1986-87). This growth in GCA was brought through mainly by increase in multiple cropping due to irrigation development. ACI has registered a steady increase over time (see table 2.4) since the mid-1960s. ACI was 1.12 in 1951-52, 1.14 in 1965-66 and 1.26 in 1986-87 with the implied annual compound growth rates being 0.15% (1951-52 to 1965-66) and 0.49% (1965-66 to 1986-87).

Green Revolution and cost of cultivation: It became obvious by the mid 1960s that due to little scope for NSA expansion, further growth in agricultural production, to meet the growing food requirement, would have to come about through either growth in yields or in multiple cropping. Such desired growth in yields was, however, not possible given the traditional varieties of seeds that were used till then. This realization led the government to promote adoption of new hybrid seed varieties. These high yield variety (HYV) seeds require the use of chemical fertilizers and irrigation as complementary inputs. The new HYV-fertilizer-irrigation based technology was introduced in the mid 1960s. With the introduction of the modern technology agricultural practices changed in the sense that use of modern farm inputs like fertilizer, pesticides, farm equipments, etc., began to grow rapidly. That is, the amount of purchased inputs began to grow with which cost of production also increased over time. The data on HYV expansion and associated input levels over time have already been looked into in the previous chapter. More details follow later.

One can obtain a picture of the overall cost structure of Indian agriculture from the data on value of agricultural output and the values of various inputs used (see the "National Accounts Statistics" (NAS) published by the Central Statistical Organisation (CSO), Government of India, New Delhi). These data, in both current and at constant (1970-71) prices, available for the period 1960-61 to 1984-85, are presented in table 2.5 for a few years. Overall value of inputs as proportion of value of agricultural output has risen steadily over time. At constant prices, the growth rate in the value of inputs has been higher at 3.45% p.a. than that of the value of output (2.28%) over the period 1960-61 to 1984-85. As a result, profitability of agriculture seems to have fallen over the years.

Turning to the cost structure in terms of the values of various inputs used, we find that, use of all the major inputs has increased over time. While seeds accounted for more than 20% of the value of inputs in 1960-61, by 1984-85 seeds accounted for only about 12.25% of the value of inputs used in agriculture. On the other hand the 3 purchased inputs, chemical fertilizers, electricity and diesel oil, which together accounted for less than 5% of the value of inputs used in 1960-61, account for more than 37% (22 + 4 + 11, respectively) of the value of inputs in 1984-85.

2.3 Cereal Crops.

Dominance of cereal crops in Indian agriculture:

Only 7 major cereal crops (rice, wheat, jowar, bajra, ragi, maize and barley) that the thesis is concerned with are studied in detail here. We first look at their relative importance in terms of their shares in the value of total agricultural output as well as in the total gross cropped area (GCA) under all crops.

Foodgrains (cereals & pulses) production dominates in Indian agriculture both in output and acreage. They account for nearly 55% of the value of output (72% of GCA) of the entire agriculture sector in 1984-85 (see tables 2.6 & 2.7). Within the foodgrains, cereal crops dominate in both value terms as well as crop acreage. In 1984-85, cereals account for more than 91% of value of foodgrains output and about 50% of value of output of entire agriculture. In terms of crop acreages, in 1984-85, cereal crops account for 82% of acreage under foodgrains and 59% of GCA.

Amongst cereals crops, 7 crops (rice, wheat, jowar, bajra, ragi, maize and barley) are the most important cereal crops. In 1984-85, these 7 cereal crops together account for more than 99% of value of output of cereals. Also, these 7 crops together account for 97% of acreage under total cereals and about 57% of GCA under all crops. In this study, the stability issue will be analysed only for the yields of these 7 cereal crops.

Production Performance of the 7 Cereal Crops.

The production performance of the 7 crops are assessed separately by studying the movement over time in the value of output, prices, quantity produced, acreage, yields, crop specific inputs (irrigation, HYV seeds & fertilizers). Performance of each of these variables over the period 1949-50 to 1988-89 and in the 2 sub-periods 1949-50 to 1964-65 (pre-Green Revolution period) and 1965-66 to 1988-89 (post-Green Revolution period) are assessed through separate semilog time trends.

Output of 7 cereal crops in Value Terms: Rice accounts for more than half of the value of cereals followed by wheat (see table 2.6). The value of output of all cereal crops except rice & wheat have fluctuations in growth. Between 1960-61 and 1984-85 wheat output grew 4 times; highest growth among all cereal crops. Outputs of all other cereals including rice grew less than twice during these 25 years. Barley output, particularly, witnessed a fall in the value of its output between 1960-61 and 1984-85.

In terms of ranking of shares, rice accounting for more than 50% of total cereals stood first all over the time. Next come wheat and jowar followed by maize, bajra, ragi and barley in that order. Rice, wheat and jowar account nearly 75% of all the cereals output in India.

Prices of 7 cereal crops: How far the growth in crop outputs could help in containing the prices at reasonable levels? Table 2.8 presents for a few years the wholesale price index (WPI) for the 7 crops. WPI has increased by more than 6 times between 1950-51 and 1988-89 for all the crops except wheat and jowar which registered an increase of only 5.5 times and 4 times, respectively. The increase is highest in the case of rice (7.5 times) followed by maize (7.27 times). WPI of bajra, ragi and barley increased by 6.5 times, 6.1 times and 6.8 times, respectively. Further, the increase in Period I (1950-51 to 1964-65 in the case of rice, wheat, jowar and bajra; 1952-53 to 1964-65 in the case of ragi, maize and barley) has been smaller compared to the increase witnessed since 1964-65. This is borne out by the semi-log time trend results reported in table 2.8.

Thus the growth in cereals outputs over time could not be adequate enough to counter the effects of population growth and overall incomes rise on price levels.

Growth Performance of 7 Cereal Crops: In this light, let us then look at the growth performance of cereal crops more in detail from the time before the beginning of the First Five year Plan in 1951 to 1988-89. Also, not to ignore the effect of year to year fluctuations let us look at the annual growth rates as estimated by semilog time trends instead of a.c. rates based on end point values. In particular, we shall look at the 7 cereal crops' performance over time with regard to their outputs in tonnage, acreage, yield levels and the pattern of inputs usage.

Output of 7 cereal crops: The annual output of the 7 crops and also the seasonwise breakup in the case of rice and jowar in a few years are presented in table 2.9. In the case of rice and jowar alone seasonwise (kharif (June to October) and rabi (October to February)) breakup of the output is available from 1962-63 onwards. Results of semi-log time trends for the full period and for the 2 sub-periods (Period I: 1949-50 to 1965-66; Period II: 1965-66 to 1988-89) separately are also presented in this table.

These trends show that

i) Outputs of rice, wheat, and ragi have shown growth in both sub-periods as well as over the full period.

ii) Jowar, bajra and maize have shown significant positive growth rates only in Period I.

iii) Barley showed no growth at all in Period I, while its growth rate is negative during Period II.

iv) The growth rates over the full period for wheat is 5.84% p.a. which is more than twice the growth rate observed for any other crop. Further its output growth rate at 4.55% p.a. in Period II is highest among all crops. In fact, this growth is double the growth rate of rice output in Period II while jowar and ragi outputs show far lower growth rates in the same period.

v) Wheat is the only crop to grow at a higher rate in Period II than in Period I while rice and ragi outputs grew at a lower rate in Period II than in Period I; the growth rates of other crops in Period II are either insignificant (jowar & maize), or zero (bajra) or even negative (barley).

What could be the reasons for the general pattern of lower growth rates in Period II corresponding to the modern technology compared to those in Period I corresponding to the traditional technology? Of course, wheat is an exception to this pattern!

Such pattern is possible atleast under 3 possible alternative situations. The first of these is regarding the potential of the new technology itself. The other two are based on year to year fluctuations[1] (ups & downs).

a) How significantly the new technology can push the output levels upwards beyond the levels that were already achieved under the old

[1] It is the analysis of these fluctuations that we will be concerned with over a major part of this thesis.

technology? If, for example, the output levels under the old technology itself were already high, further large scale push up may be difficult even under the new technology. In our context, it is very much possible that the new technology could only push wheat output upwards but not as much the other crops' output.

b) Potentialwise, the new technology may be able to push up the output levels significantly; but still the associated risk and uncertainty components may also be very high. In such a situation, there is no guarantee that year after year the crops' performance under the new technology would always be up to expected levels. For example, some crops under the new technology are known to be too sensitive to pest attacks. There could be other factors also such as timely availability of water in particular and precise dosages of nutrient fertilizers, etc. How much control a farmer has on all such related factors which vary across crops? He certainly has no control on weather. His control on pest attacks, etc. is also only limited. Availability of fertilizers and irrigation water at right time on which depends the modern technology is also uncertain most of the time. Thus, the crop performance may be beyond expectations in some years and far below expectations in some other years. That is, the crop may end up having wider fluctuations in its output levels during the new technology regime than in the old technology regime. Consequently the estimated growth rates would accordingly be lower under the new technology. This issue in fact leads to the question of sustainability of agricultural growth in the long run.

c) Thirdly, the ups & downs, if any, in the output levels could purely be in response to the ups & downs in the input levels. Since output is acreage times yield which in turn depends on various inputs such as fertilizers, etc., the changes in output could be due to changes in acreage and/or changes in input levels. It is possible that farmers on their own accord, based on their expectations on prices, weather, revenues and ultimate profits, varied the input levels & acreage in such a fashion during Period II that ultimately the outputs of several cereal crops could grow only at a lower rate under modern technology. Besides, it is also reported frequently that many farmers in India still do not know the intricacies of usage of fertilizers: neither regarding the right mixture of nitrogenous, phosphorus & potassium nutrients nor regarding its optimal dosage per hectare for a given crop in a given region. In this case farmers, rather unknowingly, apply wrong levels of inputs and end up with sub-optimal output levels.

While the lower growth rates in Period II can be explained in the above terms, the issue of fluctuations over time assumes certain importance which has attracted research by many scholars. While a review of these studies is taken up in a different chapter, let us recall that these fluctuations over time have already been noted graphically in the previous chapter.

Since output is acreage (hectares) times yield per hectare, changes in output must be due to changes in both acreage and yields. Let us consider the acreage part first.

Acreages of 7 cereal crops: Table 2.10 presents for a few years data on acreages for the 7 crops along with the periodwise semilog growth rates. Only wheat and to a lesser extent rice recorded an increase in their acreages over the 39 years. While the acreages of jowar and barley fell, those of bajra, ragi and maize remained stagnant over the 39 years. In the case of rice and wheat the growth in acreage witnessed in Period I is much more than that in Period II. Recall from the previous section, wheat output is the only one among cereals which grew at a higher rate in Period II. Its acreage however, as we note here now, did not show a higher growth rate in Period II. Obviously wheat yield must have gone up significantly in Period II; this may be seen later.

Amongst the other crops, the acreages of jowar, ragi and maize showed significant growth rates in Period I while acreage of bajra and barley did not show any significant trend in Period I. In Period II, however, jowar, bajra and barley acreages fell significantly while those of ragi and maize remained stagnant.

A deeper analysis of movements in crop acreages is, however, not the subject of this study. As mentioned earlier, changes/ fluctuations in acreage could only partly be responsible for changes/fluctuations in output of a crop. The extent of crop acreage is directly determined by farmers themselves depending on their expectations on prices, revenues and ultimate profits. Thus changes in acreage reflect only changes in farmers' expectations. To the extent farmers' decisions can be influenced by government policy, any undesired fluctuations in acreage are also controllable. Yields, on the other hand, are under partial control of the farmers in the sense farmers only apply various input levels and hope for the best. That is, they have full control only on input levels just as in the case of acreage. Ultimate yield levels, however, depend on various factors some of which such as material inputs are under farmers' control while others such as weather, soil erosion, pest attack, etc. are beyond the control of farmers. Thus yields, unlike acreage, are not completely under farmers' control. For this reason based on the difference in the nature of movements in acreage and yield, we shall only concentrate on the analysis of yields in later chapters. Let us now look at the movements over time in crop yields.

Yields of 7 cereal crops: Growth performance in the yields of the 7 crops are presented in table 2.11. Yields of all crops except bajra have grown over the full period. Growth rate over the full period was the highest for wheat yields at 3.33% p.a. followed by rice at 1.80% p.a. Other crops show slower growth in their yields. It can also be seen that growth rate has been higher in Period II than in Period I in the case of wheat and ragi yields while it has been lower in Period II than in Period I in the case of rice and jowar. While maize yields grew rapidly in Period I there has been no growth worth mentioning in Period II. Reverse is the case with barely which grew only in Period II. Recall that barley's acreage (table 2.10) fell down drastically during Period II. The rise in yield levels during the same period could not, however, compensate for the acreage fall. Thus its output also registered a fall in Period II (table 2.9). Bajra yields kept on fluctuating over time between levels as low as 286 kg/ha and 646 kg/ha but did not show any consistent growth in both sub-periods or over the full period.

With regard to the seasonwise yields of rice and jowar: in the case of rice, rabi yields are far higher than kharif yields while it is the reverse in the case of jowar (see table 2.11). In the case of jowar, the difference between kharif and rabi yields has increased over time. Kharif yields were only 1.25 times higher than rabi yields in 1965-66, but were 1.45 times higher in 1988-89. Note that rice witnessed growth in its yields in both seasons while jowar yields grew only in kharif season.

Yields depend upon, apart from labour input, the use of various material inputs like seed variety, fertilizers, irrigation, mechanization, and other agro-climatic factors like rainfall, soil fertility, etc. As noted earlier, only a few of these factors, (material inputs and labour used) are under farmers' control.

Input use pattern: Amongst the various material inputs, continuous time series data only on irrigation, seed variety and fertilizer are available from 1955-56 onwards. While the data on irrigation and seed varieties are crop specific, the data on fertilizer consumption over all crops put together alone are available. No continuous time series data exist on mechanization or crop specific labour use. Time series data on input use in the 2 seasons (kharif and rabi) are not available for any of these inputs.

Cropwise irrigation intensity: Data exist only on gross but not net irrigated area under each crop, that too aggregated over both the kharif and rabi seasons. In a very aggregate sense, we define:

$$\text{Irrigation intensity of crop } i = \frac{\text{Gross irrigated area under crop } i}{\text{Gross cropped area under crop } i}$$

Irrigation intensity, as defined above, indicates how much of the total cropped area is under irrigation but not how many times a given piece of land is irrigated.

Table 2.12 shows that gross irrigated area under wheat increased more than 4 times followed by maize by about 2.75 times and rice and bajra by about 1.6 times each over the period 1955-56 to 1986-87. Jowar showed only a marginal increase while ragi and barley witnessed a fall in their gross irrigated areas.

By the end of 1980s more than 3/4ths of total area of wheat was under irrigation, whereas not even a half of rice area was under irrigation. Among other crops, except barley, all the others are grown mostly on unirrigated land. The irrigation intensity of wheat has more than doubled over the period 1955-56 to 1986-87. Other crops including rice have witnessed only marginal growth in their irrigation intensities with growth rates less than even 1.% (see table 2.12) except in the case of maize over the full period. The growth pattern in the irrigation intensities within the 2 sub-periods has not been uniform either. Wheat's irrigation intensity grew at a higher rate (2.64% p.a.) in Period II than in Period I (1.56% p.a.). On the other hand, rice and jowar witnessed a fall in their growth rates in Period II compared to Period I. In the case of bajra, irrigation intensity actually declined in Period I but grew in Period II resulting in a positive growth over the full period. Barley witnessed a positive growth in Period I but no growth at all in Period II. The case of maize is somewhat strange in the sense that although the irrigation intensity shows positive growth over the full period, it does not show any significant growth in the 2 sub-periods considered separately.

Seed variety used under the 7 cereal crops: High yielding variety (HYV) hybrid seeds were introduced in India during the mid-1960s. There are no HYV seeds for ragi and barley. These crops, thus, continue to be grown with traditional variety seeds only. The supposed potential difference between the traditional and HYV seeds as given below further confirms that Indian agriculture has not yet realized the full benefits of the modern technology.

Potential Yields of Seed Varieties (Kg/Ha).

Crop	Traditional	HYV	HYV/Traditional
Rice	1030	6500	6.3
Wheat	800	6100	7.6
Jowar	490	4000	8.2
Bajra	400	2200	5.5
Maize	1120	6100	5.4

Source: Compendium.

Various hybrid varieties are available for each of the 5 crops. For example, some of the hybrid variety seeds available for rice are IR36, CSR-3, PUSA-4, Baku, or 401-7, Iet 7861, etc. Strictly speaking, an attempt at assessing the adoption of HYV should be hybrid specific. However, data exist only on area under HYV as a whole (i.e. over all the hybrid varieties for a crop) but not separately for different hybrid varieties. Let us define the spread of the HYV adoption as follows:

$$\text{HYV proportion of crop i} = \frac{\text{Acreage of crop i under HYV}}{\text{Gross cropped acreage under crop i}}$$

Table 2.13 shows that by 1988-89 (i.e. 23 years since the introduction of HYV seeds) HYV adoption is highest in the case of wheat at 84% followed by rice at 61%. In the remaining 3 crops the HYV adoption is less than 50%.

Over time HYV area proportions became higher than the irrigated area proportions for all the 5 crops: by 1980-81 in the case of rice, 1973-74 for wheat, 1975-76 for maize, 1972-73 for jowar, and by 1968-69 itself for bajra (compare tables 2.12 & 2.13). Jowar and bajra are mostly unirrigated crops anyway. That is, adoption of HYV seeds prevails under unirrigated conditions too.

As noted in the previous chapter the yields of bajra and maize which are lowly irrigated crops, seem to show higher fluctuations since the beginning of Green Revolution. Could it be due to the cultivation of HYV under unirrigated conditions? Then what about jowar which is also unirrigated with as much HYV proportion as bajra and maize? Such questions for all crops, including rice and wheat which are highly irrigated crops with high HYV adoption rates, will be taken up in later chapters.

Fertilizer use: Though chemical fertilizers were being used even since 1951-52 (perhaps even earlier!) the increase in total fertilizer consumption has been rapid since mid 1960s (see table 2.14). The total consumption grew from 65.6 thousand tons (t.t.) in 1951-52 to 784.6 t.t. by 1965-66 (12 times). But the same grew to 11036 t.t. by 1988-89 (14 times since 1965-66). The nitrogen component has been substantially higher than the other two components in the total nutrients consumption. Amongst seasons, fertilizer use is highest during rabi season: about 53% to 65% of the total.

According Vaidyanathan (1993), the latest NCAER survey in 1991 shows that while 89% of the total irrigated area in the country was treated with fertilizer application, the corresponding figure for unirrigated area was only 54% in 1988-89. Besides, the difference in fertilizer intensity (kg/ha) between the irrigated and unirrigated area was found to be widening over time.

The fertilizer data reported in table 2.14 are over all crops. There are no continuous time series data on cropwise fertilizer use although some cross-section studies for a few years provide us with an idea of the pattern of fertilizer use across crops. For example, according to Sarvekshana (1978), rice & wheat put together claim more than 60% of the total. All cereals put together account for about 71% of the total. Only the rest is shared by all other crops, of which sugarcane, groundnut, etc. are important. According to Vaidyanathan (1993), the above shares of rice & wheat did not change between 1975-77 and 1988-89.

In the absence of cropwise fertilizer use time series data and given that cereals take away 71% of total fertilizers, fertilizer consumption rate for the 7 cereals (FRT) is worked out as

$$\text{FRT (kg/ha)} = \frac{\text{Total fertilizer consumption}}{\text{Area under 7 cereals}} \times 0.71$$

This rate grew from less than one kg/ha in 1951-52 to 6 kg/ha in 1965-66 and to 60 kg/ha in 1985-86.

Thus we find that of the 3 major inputs, viz. HYV, irrigation and fertilizer behind the Green Revolution technology, HYV adoption and fertilizer use have been growing rapidly while the irrigation component of the package is growing but only modestly.

With this background, we analyse the stability of different aspects of the yield performance of cereal crops at all India level in chapter 6. Since this analysis would be done for Andhra Pradesh (agriculturally an important State) also, we turn to the agricultural scene there, in the next chapter.

Table 2.1 - Overall Indicators of Agricultural Performance.

Year	GDPA*	GDPA % in GDPT	TAI*	TAI % in TI	PBAI % in TAI	PRAI % in TAI
1950-51	23741	55.4	1310	22.799	n.a	n.a
1951-52	24095	54.9	1486	23.442	n.a	n.a
1952-53	24855	55.1	1379	29.497	n.a	n.a
1953-54	26769	55.9	1404	27.299	n.a	n.a
1954-55	27556	55.2	1409	22.119	n.a	n.a
1955-56	27318	53.4	1670	21.012	n.a	n.a
1956-57	28803	53.3	1659	17.432	n.a	n.a
1957-58	27509	51.5	1700	17.061	n.a	n.a
1958-59	30281	52.7	1618	19.285	n.a	n.a
1959-60	29976	51.0	1373	14.448	n.a	n.a
1960-61	31995	50.9	1777	15.091	33.146	66.854
1961-62	32022	49.4	1773	16.397	33.841	66.159
1962-63	31385	47.4	1928	15.191	35.996	64.004
1963-64	32119	46.2	2094	15.471	34.623	65.337
1964-65	35082	46.9	2262	15.904	33.820	66.180
1965-66	31208	43.3	2478	16.808	32.203	67.796
1966-67	30764	42.2	2486	16.085	27.997	72.003
1967-68	35339	44.9	2714	18.226	25.350	74.650
1968-69	35283	43.6	2838	21.421	27.308	72.692
1969-70	37551	43.6	3016	19.971	25.696	74.304
1970-71	40214	44.5	2884	17.426	27.358	72.642
1971-72	39459	43.2	3059	17.050	27.819	72.181
1972-73	37479	41.2	3317	18.808	31.625	68.375
1973-74	40178	42.2	3352	16.754	29.624	70.376
1974-75	39566	41.1	3123	15.066	29.427	70.573
1975-76	44666	42.6	3556	15.523	29.275	70.725
1976-77	42085	39.6	4457	19.811	30.918	69.082
1977-78	46309	40.5	4281	19.099	35.833	64.167
1978-79	47375	39.3	5447	19.354	31.155	68.845
1979-80	41323	36.2	5414	19.807	32.730	67.270
1980-81	46649	38.1	4864	18.857	36.924	63.076
1981-82	49406	38.0	4741	13.856	37.524	62.476
1982-83	48803	36.4	4865	14.613	35.457	64.543
1983-84	54080	37.3	4406	14.070	38.743	61.257
1984-85	54097	36.0	4888	14.801	34.227	65.773
1985-86	54252	34.6	4641	12.131	32.665	67.335
1986-87	53335	32.8	4360	11.344	32.752	67.248
1987-88	53549	31.5	4486	11.754	32.457	67.543
1988-89	61789	32.9	4625	10.492	29.103	70.897

Annual Compound Growth Rates (%):

	GDPA	TAI
1950-51 to 1965-66	1.84	4.34
1965-66 to 1988-89	3.01	2.75
1950-51 to 1988-89	2.55	3.38

Notes: * : Rs.Crores at 1980-81 prices;
GDPA : Agricultural gross domestic product;
GDPT : Total (agricultural + non-agricultural) gross domestic product;
TAI : Total agricultural investment;
TI : Total (agricultural + non-agricultural) investment;
PBAI : Public agricultural investment;
PRAI : Private agricultural investment;
n.a. : not available;

Source: National Accounts Statistics, CSO, New Delhi.

	1951	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
<u>Potential Developed</u>													
Major & Medium (58.5)*	9.7 (16.6)+	24.8	25.9	26.6	27.3	28.2	29.1	30.0	30.0	30.5	31.0	31.7	32.3 (55.2)+
Minor (55.0)*	12.9 (23.5)+	27.3	28.6	30.0	31.4	32.8	34.2	35.8	37.5	39.0	40.7	42.3	45.2 (82.2)+
Total (113.5)*	22.6 (19.9)+	52.1	54.5	56.6	58.7	61.0	63.3	65.8	67.5	69.5	71.7	74.0	77.5 (68.3)+
<u>Utilisation</u>													
Major & Medium	9.7	21.2	22.1	22.6	22.7	23.2	24.0	24.6	25.3	25.8	26.5	26.8	27.2
Minor	12.9	27.3	28.6	30.0	31.4	32.8	34.2	34.0	35.2	36.5	37.9	39.3	41.0
Total	22.6	48.5	50.7	52.6	54.1	56.0	58.1	58.8	60.5	62.3	64.4	66.1	68.2
Utilisation / Potential (%)													
Major & Medium	100.0	85.5	85.3	85.0	83.2	82.3	82.5	82.0	84.3	84.6	85.5	84.5	84.2
Minor	100.0	100.0	100.0	100.0	100.0	100.0	100.0	95.5	93.9	93.6	93.1	92.9	90.7
Total	100.0	93.1	93.0	92.9	92.2	91.8	91.8	89.3	89.6	89.6	89.8	89.3	88.0

Notes: 1951 refers to 1950-51 and so on.

* : Ultimate potentials are reported in brackets;

+ : As percentage of the respective ultimate potentials;

Source: Economic Survey various issues.

Table 2.3 - Net Irrigated Area by Source & Total Gross Irrigated Area (000 Hectares

Year	Net Irrigated Area: Canals	Tanks	Surface Water	Tubewell	Other Wells	Ground Water	Other Sources	Total	Gross Irrigated Area
1960-61	10483	4490	14973	7282#	n.a	7282	2421	24676	27980
1965-66	10960	4441	15401	8445#	n.a	8445	2595	26441	30901
1970-71	12517	4537	17054	11834#	n.a	11834	2404	31292	38194
1975-76	13775	3986	17761	6769	7577	14346	2384	34491	43363
1980-81	15292	3198	18490	9527	8207	17734	2581	38805	49875
1986-87	16320	2983	19303	12211	8835	21046	2700	43049	55838

Notes: Surface water = Canals + Tanks; Ground water = Tubewells + Other wells;

\# : Pertains to all wells (tubewells + other wells); n.a : not available;

Source: Fertilizer Statistics, Fertilizer Association of India, New Delhi.

Year	GCA	NSA	ACI
1951-52	133234	119400	1.116
1955-56	147311	129156	1.141
1960-61	152772	133199	1.147
1964-65	159229	138120	1.153
1965-66	155276	136198	1.140
1970-71	165791	140784	1.178
1975-76	170984	142224	1.202
1980-81	173096	140299	1.234
1986-87	176920	140149	1.262
Annual Compound Growth Rates (%):			
1951-52 to 1965-66	1.10	0.94	0.15
1965-66 to 1986-87	0.62	0.14	0.49
1951-52 to 1986-87	0.81	0.46	0.35

Notes: GCA : Gross cropped area over all crops in thousand hectares;

NSA : Net sown area over all crops in thousand hectares;

ACI : Aggregate cropping intensity (= GCA/NSA);

Source: Estimates of Area & Production in India, Ministry of Agriculture, New Delhi.

Table 2.5 - Values of Some Major Material Inputs & Output (Rs.Crores at 1970-71 prices).

Year	Value of Inputs					Value of Output	Val.of Inputs / Val.of Output
	Seeds	Fertilizers	Electricity	Diesel Oil	Total		
1960-61	632.33	66.70	9.62	19.22	3054.18	13517.47	0.2259
	(20.70)	(2.18)	(0.31)	(0.63)	(100.0)		
1965-66	663.68	185.53	22.54	30.58	3250.75	12980.42	0.2543
	(20.42)	(5.71)	(0.69)	(0.94)	(100.0)		
1970-71	694.76	343.69	59.09	225.99	4088.58	17530.95	0.2332
	(16.99)	(8.41)	(1.45)	(5.53)	(100.0)		
1975-76	724.12	514.50	118.37	390.25	4824.24	19372.55	0.2490
	(15.01)	(10.66)	(2.45)	(8.09)	(100.0)		
1980-81	789.25	1039.68	195.09	607.60	5906.19	20752.08	0.2846
	(13.36)	(17.60)	(3.30)	(10.29)	(100.0)		
1984-85	843.76	1518.17	271.21	811.07	6890.07	23238.59	0.2965
	(12.25)	(22.03)	(3.94)	(11.77)	(100.0)		
Annual Compound Growth Rates (%):							
1960-61 to 1984-85	1.21	13.91	14.93	16.87	3.45	2.28	

Notes: Figures in brackets are the shares in the total.

Source: National Accounts Statistics, CSO, New Delhi.

Table 2.8 – Values of Outputs of Some Cereal Crops (Rs.Crores at 1970-71 prices).

Year	Value of Outputs									
	All Crops	Foodgrains	Total Cereals	Rice	Wheat	Jowar	Bajra	Ragi	Maize	Barley
1960-61	13517.47	7087.58	6045.57	3793.19	859.85	657.02	197.84	119.34	228.10	136.17
	(100.0)	(52.43)	(44.72)	(28.06)	(6.36)	(4.86)	(1.46)	(0.88)	(1.69)	(1.01)
1965-66	12980.42	6265.17	5438.02	3378.19	811.39	504.25	226.88	80.74	267.29	115.20
	(100.0)	(48.27)	(41.89)	(26.03)	(6.25)	(3.88)	(1.75)	(0.62)	(2.06)	(0.89)
1970-71	17530.95	9276.53	8281.90	4597.02	1872.16	509.03	486.08	133.02	428.09	135.76
	(100.0)	(52.92)	(47.24)	(26.22)	(10.68)	(2.90)	(2.77)	(0.76)	(2.44)	(0.77)
1975-76	19372.55	10507.72	9400.08	5319.26	2276.02	603.28	332.73	181.50	412.53	155.36
	(100.0)	(54.24)	(48.52)	(27.46)	(11.75)	(3.11)	(1.72)	(0.94)	(2.13)	(0.80)
1980-81	20752.08	11444.50	10481.13	5905.23	2830.36	678.81	321.80	147.75	401.09	111.90
	(100.0)	(55.15)	(50.51)	(28.46)	(13.64)	(3.27)	(1.55)	(0.71)	(1.93)	(0.54)
1984-85	23238.59	12667.59	11618.90	6328.48	3435.98	714.99	358.23	157.20	479.84	75.96
	(100.0)	(54.51)	(50.00)	(27.23)	(14.79)	(3.08)	(1.54)	(0.68)	(2.06)	(0.33)

Notes: Figures in brackets are the shares in the total.

Source: National Accounts Statistics, CSO, New Delhi.

Table 2.7 – Crop Acreages: Shares of Some Major Crops.

Year	All Crops (000 Ha.)	Foodgrains	Total Cereals	Rice	Wheat	Jowar	Bajra	Ragi	Maize	Barley
		Percentages								
1960-61	152772	75.85	60.23	22.34	8.46	12.05	7.51	1.65	2.88	2.10
1965-66	155276	73.48	59.50	22.84	8.10	11.39	7.71	1.74	3.09	1.70
1970-71	165791	74.98	61.39	22.67	11.00	10.48	7.79	1.49	3.53	1.54
1975-76	170994	74.96	60.66	23.09	11.96	9.41	6.77	1.54	3.53	1.64
1980-81	173096	73.18	60.20	23.20	12.87	9.13	6.73	1.46	3.47	1.04
1984-85	176418	71.80	58.91	23.27	13.07	9.01	6.37	1.36	3.35	0.69

Source: Estimates of Area & Production in India, Ministry of Agriculture, New Delhi.

Table 2.8 - Wholesale Price Index of Cereal Crops (Base: 1970-71 = 100).

Year	Rice	Wheat	Jowar	Bajra	Ragi	Maize	Barley
1950-51	48.40	53.20	77.20	47.40	50.50*	47.90*	55.80*
1955-56	37.00	38.10	31.40	40.00	31.30	36.60	37.30
1960-61	51.20	47.40	56.90	62.20	60.50	52.20	59.50
1964-65	63.20	66.10	87.00	83.00	84.70	78.00	101.90
1970-71	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1975-76	178.80	159.60	175.60	196.90	185.80	173.70	147.40
1980-81	205.60	176.20	194.20	196.10	188.60	206.40	221.30
1984-85	273.30	209.60	241.50	214.10	243.50	220.80	269.70
1988-89	363.70	292.00	311.40	309.60	308.50	348.20	380.80
Semi-Logarithmic Growth Rates (%)							
Period I	3.67	N	N	4.25	6.07	4.31	5.71
Period II	6.32	5.07	5.27	4.91	5.41	5.30	5.30
Full Period	6.84	5.88	5.98	5.68	6.01	6.43	6.13

Notes: * : Pertains to 1952-53.

All the growth rates reported are significant at 5% level.

Period I : 1951-52 to 1965-66 (rice, wheat, jowar & bajra); 1952-53 to 1965-66 (ragi, maize & barley);

Period II : 1965-66 to 1986-87 for all the crops; Full Period: 1951-52 to 1986-87 for all the crops;

Source: National Accounts Statistics, CSO, New Delhi.

Table 2.9 - Output of Cereal Crops (000 Tonnes).

Year	Rice			Jowar			Wheat	Bajra	Ragi	Maize	Barley
	Kharif	Rabi	Total	Kharif	Rabi	Total					
1949-50	n.a	n.a	23542	n.a	n.a	5870	6391	2835	1544	2046	2251
1955-56	n.a	n.a	27557	n.a	n.a	6726	8760	3428	1846	2602	2816
1960-61	n.a	n.a	34574	n.a	n.a	9814	10997	3283	1838	4080	2819
1965-66	29429	1160	30589	5096	2485	7581	10394	3752	1327	4823	2382
1970-71	39559	2666	42225	5820	2285	8105	23833	8029	2155	7486	2784
1975-76	44745	3995	48740	6994	2510	9504	28846	5736	2797	7256	3192
1980-81	50090	3541	53631	7504	2927	10431	36313	5343	2420	6957	2293
1985-86	59392	4433	63825	7272	2925	10197	47052	3664	2518	6644	1862
1988-89	63853	6635	70488	7356	2814	10170	54110	7780	2410	8229	1722
Semi-Logarithmic Growth Rates (%).											
Period I			3.44			2.64	3.82	2.32	N	5.86	N
Period II			2.73			0.88+	4.95	N	1.61	1.28+	-2.48
Full Period	2.63	4.62	2.64	1.38	N	1.14	5.84	1.65	1.54	2.93	-1.34

Notes: * : Pertains to 1962-63; n.a. : Not available; N : Indicates no growh.

\+ : All the growth rates reported are significant at 5% level, except those with a +.

Full Period: 1949-50 to 1988-89; Period I : 1949-50 to 1965-66; Period II : 1965-66 to 1988-89;

Source: Estimates of Area & Production in India, Ministry of Agriculture, New Delhi.

Table 2.10 - Acreage Under Cereal Crops (000 Hectares).

Year	Rice Kharif	Rice Rabi	Rice Total	Jowar Kharif	Jowar Rabi	Jowar Total	Wheat	Bajra	Ragi	Maize	Barley
1949-50	n.a	n.a	30519	n.a	n.a	15513	9758	9259	2208	3202	3181
1955-56	n.a	n.a	31521	n.a	n.a	17362	12367	11338	2307	3696	3418
1960-61	n.a	n.a	34128	n.a	n.a	18412	12927	11469	2515	4407	3205
1965-66	34826	644	35470	10981	6698	17679	12572	11965	2696	4799	2840
1970-71	35950	1642	37592	10925	6449	17374	18241	12913	2472	5852	2555
1975-76	37442	2033	39475	10208	5884	16092	20454	11571	2630	6031	2802
1980-81	38442	1710	40152	10181	5628	15809	22279	11657	2525	6005	1807
1985-86	39234	1903	41137	9550	6547	16097	22097	10652	2401	5797	1369
1988-89	39090	2646	41736	9153	5446	14599	24109	12046	2317	5897	1081
Semi-Logarithmic Growth Rates (%).											
Period I			1.37			0.55	1.62	N	1.28	2.53	-2.21
Period II			0.60			-0.78	1.41	-0.85	N	N	-5.41
Full Period	0.50	2.08	0.83	-0.83	N	-0.56	2.44	N	N	N	-4.19

Notes: * : Pertains to 1962-63; n.a. : Not available; N : Indicates no growth.

All the growth rates reported are significant at 5% level.

Full Period: 1949-50 to 1988-89; Period I : 1949-50 to 1965-66; Period II : 1965-66 to 1988-89;

Source: Estimates of Area & Production in India, Ministry of Agriculture, New Delhi.

Table 2.11 - Yields of Cereal Crops (Kg/Ha.).

Year	Rice Kharif	Rice Rabi	Rice Total	Jowar Kharif	Jowar Rabi	Jowar Total	Wheat	Bajra	Ragi	Maize	Barley
1949-50	n.a	n.a	771.4	n.a	n.a	378.4	655.0	308.2	899.9	627.2	707.6
1955-56	n.a	n.a	874.2	n.a	n.a	387.4	708.3	302.3	800.2	704.0	823.9
1960-61	n.a	n.a	1013.1	n.a	n.a	533.0	850.7	286.3	730.8	925.8	879.6
1965-66	845.0	1801.2	862.4	464.1	371.0	428.8	828.8	313.8	492.2	1005.0	902.3
1970-71	1100.4	1625.0	1123.3	532.7	354.3	466.5	1306.8	621.7	871.6	1279.1	1090.0
1975-76	1195.1	1965.1	1234.7	685.1	426.6	590.6	1410.3	495.7	1083.8	1203.1	1139.2
1980-81	1303.0	2070.8	1335.7	737.0	520.1	659.6	1629.9	458.3	950.4	1158.6	1289.0
1985-86	1513.8	2329.0	1551.5	761.4	446.8	633.5	2046.0	344.0	1048.9	1146.0	1433.6
1988-89	1633.5	2507.6	1688.9	803.7	516.7	696.6	2244.4	645.9	1040.1	1395.5	1593.0
Semi-Logarithmic Growth Rates (%).											
Period I			2.15			1.78	1.50	N	N	3.37	N
Period II			2.24			1.59	3.17	- N	2.18	N	2.12
Full Period	2.13	2.54	1.80	2.21	N	1.52	3.33	N	1.35	1.59	1.62

Notes: * : Pertains to 1962-63; n.a. : Not available; N : Indicates no growth.

All the growth rates reported are significant at 5% leve.

Full Period: 1949-50 to 1988-89; Period I : 1949-50 to 1965-66; Period II : 1965-66 to 1988-89;

Source: Estimates of Area & Production in India, Ministry of Agriculture, New Delhi.

'able 2.12 - Irrigation Intensities of Cereal Crops*.

'ear	Rice	Jowar	Wheat	Bajra	Ragi	Maize	Barley
955-56	0.349	0.036	0.336	0.035	n.a	0.121	0.428
	(10996)	(623)	(4151)	(394)	n.a	(448)	(1464)
960-61	0.365	0.036	0.328	0.028	n.a	0.128	0.416
	(12458)	(655)	(4236)	(320)	n.a	(564)	(1333)
965-66	0.370	0.040	0.417	0.027	0.130	0.160	0.498
	(13114)	(714)	(5238)	(318)	(650)	(767)	(1316)
970-71	0.397	0.036	0.539	0.040	0.135	0.158	0.520
	(14917)	(626)	(9829)	(514)	(334)	(925)	(1328)
975-76	0.381	0.050	0.618	0.056	0.153	0.157	0.543
	(15051)	(805)	(12641)	(647)	(403)	(946)	(1522)
980-81	0.407	0.040	0.696	0.055	0.117	0.199	0.503
	(16339)	(627)	(15516)	(639)	(295)	(1195)	(909)
986-87	0.433	0.048	0.773	0.057	0.103	0.208	0.545
	(17843)	(761)	(17876)	(646)	(247)	(1233)	(668)
emi-Logarithmic Growth Rates (%) of Irrigation Intensities.							
eriod I	0.76	1.38	1.97	-3.20	....	N	1.70
eriod II	0.71	N	2.58	2.10	-2.05	N	N
ull Period	0.68	0.78	3.48	3.03	-1.71	1.78	0.79

otes: * : Gross irrigated area ÷ Total Cropped area:

Area irrigated under each crop (000 hectares) is given in brackets.

n.a. : not available;

All the growth rates reported are significant at 5% level.

Full Period: 1955-56 to 1986-87;

Period I : 1955-56 to 1965-66;

Period II : 1965-66 to 1986-87;

ource: Fertilizer Statistics, Fertilizer Association of India, New Delhi.

Table [illegible] – Proportions of Acreage under High Yielding Varieties (HYV): Cereal Crops.

Year	Rice	Jowar	Wheat	Bajra	Maize
1966-67	0.025	0 011	0.0[illegible]2	0.005	0.041
	(808)	(191)	(5[illegible]1)	(59)	(207)
1970-71	0.149	0.046	0.3[illegible]5	0.159	0.079
	(5588)	(802)	(64[illegible]0)	(2051)	(462)
1975-76	0.315	0.122	0.6[illegible]8	0.250	0.188
	(12443)	(1958)	(134[illegible]8)	(2897)	(1132)
1980-81	0.454	0.221	0.7[illegible]3	0.312	0.267
	(18234)	(3500)	(161[illegible]4)	(3640)	(1601)
1985-86	0.571	0.378	0.8[illegible]9	0.469	0.310
	(23473)	(6082)	(190[illegible]5)	(4992)	(1798)
1988-89	0.609	0.419	0.8[illegible]7	0.487	0.415
	(25407)	(6113)	(201[illegible]5)	(5865)	(2445)
<u>Semi-Logarithmic Growth Rates (%) of HYV Proportions.</u>					
Period II	3.54	13.14	4.[illegible]1	11.46	7.28

Notes: Area under HYV for each crop (000 hectares) is given in brackets. There are no HYV for ragi and barley.

The growth rates reported are significant at 5% level.

Period II : 1966-67 to 1988-89;

Source: Fertilizer Statistics, Fertilizer Association of India, New Delhi.

Table 2.14 – Fertilizer Consumption (000 Tonnes of Nutrients).

Year	Consumption: Total	N % in Total	P % in Total	K % in Total	Kharif % in Total	Rabi % in Total	Fertilizer* Consumption by 7 cereals Kg/Ha.
1951-52	65.6	89.48	10.52	0.00	n.a	n.a	0.634
1955-56	130.8	82.19	9.94	7.87	n.a	n.a	1.132
1960-61	293.8	72.06	18.07	9.87	n.a	n.a	2.396
1965-66	784.6	73.26	16.89	9.85	n.a	n.a	6.343
1970-71	2256.6	65.55	23.97	10.47	41.04	58.94	16.517
1975-76	2893.7	74.25	16.13	9.62	34.79	65.21	20.741
1980-81	5515.6	66.68	22.00	11.31	38.76	61.24	39.089
1985-86	8474.1	66.80	23.66	9.54	47.25	52.75	59.896
1989-90	11571.1	63.92	26.03	10.05	46.42	53.58	n.a

<u>Annual Compound Growth Rates (%):</u>

1951-52 to 1965-66	19.39
1965-66 to 1989-90	11.87
1951-52 to 1989-90	14.58

Notes: N (Nitrogenous), P (Phosphorous), K (Potassic);

* : (Total fertilizer consumption × 0.71)/(7 cereals acreage);

Source: Fertilizer Statistics, Fertilizer Association of India, New Delhi.

CHAPTER 3 – PERFORMANCE OF AGRICULTURE: ANDHRA PRADESH AND ITS DISTRICTS

"All that we know is, nothing can be known"
– Byron.

3.1 Introduction.

Andhra Pradesh (AP henceforth; sometimes also referred to as Andhra) was chosen for detailed analysis in this study as it is an important State as far as Indian agriculture is concerned. In section 3.2 we briefly look at the relative importance of Andhra Pradesh in Indian agriculture where we also discuss the importance of agricultural sector within Andhra Pradesh. In section 3.3 we note the different geo-political regions of Andhra. In section 3.4 the overall agricultural performance is assessed while in section 3.5 the performance of the cereal crops is assessed. All the tables referred to here are at the end of the chapter.

3.2.1 Importance of Andhra Pradesh in Indian Agriculture.

The relative importance of AP in Indian agriculture in terms of its share in agricultural domestic product, net sown and gross cropped area, gross and net irrigations and crop shares can be noted from table 3.1.

The State is a major producer in the country of 5 (rice, jowar, bajra, ragi & maize) of the 7 cereal crops studied here. Wheat & barley are grown little in AP. In the case of rice output in the country AP has ranked 2nd in most years and even 1st in some years. In fact in the cases of jowar, bajra and ragi also the State has been a major producer in the country, though its contribution to India's maize output has all along been fluctuating.

In terms of yield levels also AP stands as one among the foremost States in the country. The yield levels of rice, bajra & maize are higher in AP than at the all India average levels. The yield levels of ragi are roughly the same as at the AI level. Only in the case of jowar, yield levels in AP are lower than the all India (AI) average levels.

3.2.2 Importance of Agriculture Within Andhra Pradesh.

The Net State Domestic Product (NSDP) of AP at 1970-71 prices and the share of agriculture in NSDP are given below:

Year	NSDP (Rs.Crores)		Share of Agricultue
	Total	Agriculture	in Total NSDP
1960-61	1891.81	1159.90	61.31
1964-65	2292.58	1420.17	61.95
1965-66	2070.02	1171.96	56.62
1984-85	4112.36	1704.94	41.46

Notes: NSDP : Net state domestic product of AP at 1970-71 prices.
Source: National Accounts Statistics, (CSO).

Though over time, due to growth in the industries and services sectors, the share of agriculture has come down, from 61% in 1960-61 to 41% in 1984-85, nevertheless agriculture continues to be a major sector within AP.

Year	No.of Workers (Thousands)		% Employed
	Total	Agriculture*	in Agriculture
1971	18006	12624	70.11
1981	22626	16266	71.89
1991	28392	19454	68.52

* Includes cultivators and agricultural labourers.
Source: Census of India.

The above table shows that agriculture accounting for more than 65% of the total work force, is the most important source of employment in AP.

3.3 Geo-Political Regions of Andhra Pradesh.

The State has three geo-political regions consisting of 23 districts as follows:

I) Coastal Andhra Region.

(1) Srikakulam, (2) Vizianagaram, (3) Vishakhapatnam, (4) East Godavari, (5) West Godavari, (6) Krishna, (7) Guntur, (8) Prakasam and (9) Nellore Districts.

II) Rayalaseema Region.

(10) Kurnool, (11) Anantapur, (12) Cuddapah and (13) Chittoor Districts.

III) Telangana Region.

(14) Ranga Reddy, (15) Hyderabad, (16) Nizamabad, (17) Medak, (18) Mehboobnagar, (19) Nalgonda, (20) Warangal, (21) Khammam, (22) Karimnagar and (23) Adilabad Districts.

Coastal districts are more fertile than the districts in Telangana and Rayalaseema regions which are relatively drier.

Reorganization of Districts: The state witnessed a major reorganization of some of its districts once in 1967 and for the second time in 1979. During the reorganizations parts of some large districts were taken to form new districts. In 1967, the 2 districts of Guntur and Nellore were reorganized into 3 districts - Guntur, Prakasam (which was earlier referred to as Ongole) and Nellore. Similarly, in 1979, the 2 districts of Srikakulam and Vishakhapatnam were reorganized into 3 districts - namely, Srikakulam, Vizianagaram and Vishakhapatnam while the old district of Hyderabad (including the State capital and its surrounding areas) was split into 2 districts - Ranga Reddy and Hyderabad.

In this study, the data for such reorganized districts were aggregated so as to maintain uniformity over time. Thus, for example, the 3 districts Srikakulam, Vizianagaram and Vishakhapatnam are considered in this study as one unit (call it SV) and the corresponding data for these districts are aggregated. That is, up to the point of reorganization in 1979, data of original Srikakulam and Vishakhapatnam districts were aggregated and from 1979 the data of the reorganized Srikakulam, Vishakhapatnam and Vizianagaram districts were aggregated. Then the entire time series from beginning to end are treated to correspond to the aggregated district unit SV. Similar aggregation is done for the districts Guntur, Prakasam and Nellore as one unit and for the districts Ranga Reddy and Hyderabad as another. Thus, from the 23 districts we have 18 districts each of which is referred to by a 2 letter code as follows:

Coastal Andhra.

1. SV - Srikakulam + Vizianagaram + Vishakhapatnam.
2. EG - East Godavari.
3. WG - West Godavari.
4. KR - Krishna.
5. GN - Guntur + Prakasam + Nellore.

Rayalaseema.

6. KU - Kurnool.
7. AN - Anantapur.
8. CU - Cuddapah.
9. CH - Chittoor.

Telangana.

10. RH - Ranga Reddy + Hyderabad.
11. NZ - Nizamabad.
12. ME - Medak.
13. MB - Mehboobnagar.
14. NA - Nalgonda.
15. WA - Warangal.
16. KH - Khammam.
17. KM - Karimnagar.
18. AD - Adilabad.

The district level analysis in this study is done for these 18 districts.

3.4 Agriculture in AP: Some Overall Indicators.

Performance of agriculture in AP, in terms of growth in some overall indicators is assessed over the period 1955-56 to 1984-85, (referred to as full period). This is the period over which data on most of the variables of interest here are available at the

State level and for the 18 districts. Further, the annual compound (a.c) growth rates in 2 sub-periods - 1955-56 to 1965-66 (Period I) and 1965-66 to 1984-85 (Period II) - were also reported[1]. Period II corresponds to the era of modern technology[2]. For some variables (indicated when taken up for discussion), however, data are available only from 1960-61 onwards in which case the growth rates are over 1960-61 to 1984-85.

At the State level, data on most of the variables of interest here are available for a few recent years also. However, corresponding data at the districts levels are not available. For the sake of comparison the discussion here is restricted to the period up to 1984-85 at both the State level and for the districts.

3.4.1 Irrigation Development in AP.

The State, usually referred to as the "River State" in India, derives irrigation benefits from some of the major (Godavari, Krishna, etc.) as well as minor river systems and also a large number of tanks & wells. The ultimate irrigation potential from the various sources of irrigation are as follows:

Surface Water Irrigation	:	85.0	lakh ha.
Major	:	64.8	"
Minor	:	20.2	"
Ground Water Irrigation	:	18.2	"
Total	:	103.2	"

Source: Reddi (1991).

1 In this section which deals with only the overall indicators, only annual compound growth rates based on the two terminal years of a period (or a sub-period - as the case may be) are presented. Obviously, such growth rates do not properly convey adequate information about the in-between years. In the next section we move on to assessment of cereal crops performance on which the thesis is mainly concerned. There the growth rates as estimated by semilog time trends will be presented.

2 Some more specific reasons behind this sub-periodization will be given in the next section.

Since the beginning of the planning process in 1951, various major & medium, and also minor irrigation schemes were taken up. The irrigation potential created in AP before the Plan era and by 1984-85 are as follows:

		Before Plan Era	1984-85
a) Major & Medium irrigation (Lakh Ha.)	:	16.76	32.4
b) Minor irrigation "	:	13.71	23.4
Total "	:	30.47	55.8

Thus we find that out of an ultimate potential of 64.8 lakh ha. under major & medium irrigation only 50% has been developed by 1984-85. Among minor irrigation schemes (including ground water based irrigation) 61% of the ultimate potential of 38.4 lakh ha. has been developed by 1984-85. The overall irrigation potential developed is 54% out of an ultimate potential of 103.2 lakh ha. In a later section, we look at the impact in each district of the development of irrigation potential developed over time.

3.4.2 Sourcewise Net Irrigated Area.

Irrigation comes from the following sources: (1) Canals, (2) Tanks, (3) Tubewells, (4) Other wells (shallow/dug wells) and (5) Other Sources. Of these 5 sources canals and tanks are surface water sources of irrigation while tubewells and other wells are ground water sources of irrigation. Canals and well irrigations are generally considered as sources of assured irrigation. Tanks, on the other hand, are to a larger extent dependent on rainfall and hence, may not be considered as sources of assured irrigation. Table 3.2 presents for a few years, districtwise details on sourcewise as well as the total net irrigated area (TNIA).

At the AP State level, we find that increment in TNIA in the span of 25 years between 1960-61 and 1984-85 is only about 613 thousand hectares (t.ha.). By 1984-85, only a third of the total net sown area in AP is irrigated by some source or the other. Looking at the districtwise data, the growth rates in TNIA are in general higher in some of the non-Coastal districts than in Coastal districts. Thus, the Telangana and Rayalaseema districts, relatively drier areas, received priority in irrigation development though not all such areas received uniform treatment. In fact in some of the districts, whether they belong to Coastal or Rayalaseema or Telangana zones, TNIA has largely been stagnant.

In 1984-85, at the State level, a little more than half of TNIA comes from canals and another 22% comes from tanks. Of the remaining portion, ground water sources account for about 24% of which other wells account for the major portion (18.5%) while tubewells account for a mere 5%. Other sources account for only about 3% of TNIA in 1984-85.

Further, among the different sources of irrigation, canals and tubewells and other wells have increased their shares in TNIA, while tanks have witnessed a sharp fall in their share. The share of other sources in TNIA has remained more or less the same over time. The increases in the shares of canals, tubewells and other wells are partly due to increases in the net irrigated area by these sources and partly due to sharp fall in the irrigated area under tanks. Contrary to the growth in the irrigated area by these sources, tank irrigation fell by a third, from 1151.1 t.ha. in 1960-61 to 774.4 t.ha. in 1984-85. It is estimated that AP has in total 60,745 tanks for irrigation purpose of which Telangana and Rayalaseema claim a large share. In India, only West Bengal seems to have more number of irrigation tanks than AP. Besides, drastic reduction in irrigated area under tanks has taken place not only in AP but also in many other States in India with exceptions being only Haryana, Madhya Pradesh, Maharashtra, Punjab and Tripura.

The data presented in table 3.2 imply that in 1984-85, the 5 Coastal districts account for nearly 59% of the State's TNIA while the 4 Rayalaseema districts (KU, AN, CU and CH) account for 13% and the 9 Telangana districts (RH, NZ, ME, MB, NA, WA, KH, KM and AD) account for the remaining 28% of the State's TNIA. The differences in the development of irrigation across districts is reflected in the proportion of TNIA in NSA.

In terms of net irrigated area as a proportion in net sown area in each district, EG, WG and KR in the Coastal Andhra are the most irrigated districts. KU and AN in Rayalaseema and RH, MB and AD in Telangana are mostly still unirrigated districts with only less than 15% of the net sown area under irrigation.

Issues relating to the pattern of irrigation by individual sources in each district, the growth and disparities in sourcewise irrigations across districts will be discussed at greater length in chapters 8 & 10.

3.4.3 Total Gross Irrigated Area Over All Crops.

Total gross irrigated area (TGIA) has grown in the State as a whole as well as in almost all districts except CU (see table 3.3). The growth in gross irrigated area has not been uniform over districts in any regions. Neither there is uniformity over time. For example, GN which registered a growth rate of 0% in Period I, recorded a growth rate of 2.3% in Period II; while KU which registered a growth rate of 7.67% in Period I, slumped down to a growth rate of only 0.33% in Period II!

3.4.4 Net sown area (NSA) and Gross Cropped Area (GCA).

As elaborated earlier in chapter 2, irrigation development can have substantial impacts on both NSA, GCA and cropping intensity. However, it must be noted that the levels of NSA and GCA can be influenced by many other factors, most important of them being rainfall.

At the State level, both GCA and NSA have remained almost stagnant over time. This is because while some districts recorded positive growth, others recorded negative growth. KU, AN, and CU of Rayalaseema and MB and KM of Telangana are striking examples recording negative growth rates in both the periods in both NSA and GCA. SV in Coastal, CH in Rayalaseema and NZ, KH and AD in Telangana recorded positive growth rates in both the periods in both NSA and GCA. All the other districts showed different patterns of growth over time.

3.4.5 Aggregate cropping intensity (ACI).

Aggregate cropping intensity (ACI), defined as GCA/NSA, measures the cropping intensity. It is highest in Coastal districts compared to other regions. Even in these districts the cropping intensity is only about 1.5 while the State level average is only about 1.17 (in 1984-85).

Having seen in the previous sections, the growth in irrigation development, and the near stagnancy in NSA and GCA (only at the State level but not in all districts) one may erroneously conclude that the overall influence of irrigation on crop acreage is only insignificant. As a matter of fact this is not true. Indeed, irrigation development contributed significantly to crop acreage through an increase in cropping intensity[9].

In order to explore the relation between irrigation development and ACI in AP State as a whole a linear regression involving ACI as the dependent variable and the total net irrigated area (TNIA) as a proportion to the net sown area (NSA) over all crops as the explanatory variable is estimated.

$$ACI = f(TNIA/NSA) \qquad (3.1)$$

Estimation of (3.1) over the period 1960-61 to 1984-85 using the ordinary least squares (OLS) gave the following results:

$$ACI_t = \underset{(30.30)}{0.9215} + \underset{(6.91)}{0.7323} \times \left(\frac{TNIA}{NSA}\right)_t + U_t$$

$$R^2 = 0.6306 \qquad \bar{R}^2 = 0.6174 \qquad DW = 1.4721$$

The coefficients are significant at 1% level.

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9 See Dhawan (1988).

The estimated equation suggests that the irrigation proportion has a strong positive impact on the ACI as can be seen from the significant coefficient of NIA/NSA and the high R^2 of 0.6306. That is when irrigation availability increases it would lead to an increase in the cropping intensity. The above equation, however, does not tell anything about the effect of different sources (surface water based or ground water based) of irrigation on the ACI. These 2 types of irrigation need not have the same impact on ACI. In general canals and well water based irrigation are considered to be relatively more assured sources of irrigation than tank water which depends on rainfall. It is generally believed that ACI would increase when assured irrigation is made available.

In order to study the effect of different sources of irrigation on ACI, regressions involving ACI as the dependent variable and the individual sourcewise irrigations as a proportion to NSA as explanatory variables were estimated. Specifically the following relations were estimated:

$$ACI = f(SWTR, GWTR) \quad (3.2)$$

$$ACI = f(TCNL, TANK, TBWL, OTWL, OSRC) \quad (3.3)$$

where,

SWTR = Surface water (Canals + Tanks) proportion in NSA.

GWTR = Ground water (Tubewells + Other wells) proportion in NSA.

TCNL = Canal irrigation proportion in NSA.

TANK = Tank irrigation proportion in NSA.

TBWL = Tubewell irrigation proportion in NSA.

OTWL = Other wells irrigation proportion in NSA.

OSRC = Other sources irrigation proportion in NSA.

Estimation of the relations (3.2) & (3.3) did not give satisfactory results due to multicollinearity among the explanatory variables. Alternatively, a relation involving ACI and the 2 most important & assured sources of irrigation is estimated. A feature observed in AP State as a whole is that while canals and tanks are important sources under surface water, in the ground water segment other wells are the most dominant source of irrigation. Since canals and well irrigation are considered as more assured sources of irrigation the following relation is also estimated:

$$ACI = f(TCNL, OTWL) \qquad (3.4)$$

TCNL & OTWL did not show any strong multicollinearity. The estimation results are as follows:

$$ACI_t = 1.0168 + 0.6698 \times TCNL_t + 0.6626 \times OTWL_t + U_t$$
$$(51.05)^+ \quad (3.46)^+ \qquad (3.12)^+$$
$$R^2 = 0.7858 \qquad \bar{R}^2 = 0.7699 \qquad DW = 1.9460$$

The coefficient are significant at 1% level.

Both canal and other wells irrigation proportion have strong positive relationship with ACI. The fit also improved substantially as shown by the increase in $\bar{R}^2$. This suggests that, at the AP State level, an increase in canal and other wells irrigation could lead to an increase in ACI. We may refer to these results in later chapters.

At the districts level we find that ACI has gone up in many districts. SV alone in Coastal region and ME alone in Telangana showed no increase at all in cropping intensity. Similarly, all districts except KU in Rayalaseema also showed no increase.

3.5 Performance of Cereal Crops in AP.

Crop performance of cereals (rice, jowar, bajra, ragi & maize) in AP over the period 1955-56 to 1984-85 (full period) and in the 2 sub-periods 1955-56 to 1965-66 (Period I) and 1965-66 to 1984-85 (Period II) is assessed here.

3.5.1 Regional Importance.

Amongst the 7 cereal crops studied wheat and barley are hardly grown in AP. Only 5 cereal crops - rice, jowar, bajra, ragi and maize are important in AP and only these 5 cereal crops are considered here. Rice has always been the most important cereal crop in AP followed by jowar (see table 3.6). Each of the remaining 3 crops (bajra, ragi & maize) accounts for only 2 to 6% of the total cereals production in AP. Of these, bajra & ragi have witnessed a fall in their already low shares in the total. The share of maize in the total has been fluctuating between 2% and 6% over time.

Considering a crop as important within a district if its share in the total cereals output of that district is at least 3%, we find that, amongst the individual crops rice is an important crop in all 18 districts, jowar in 15 out of 18 districts, bajra and ragi in 8 districts each, and maize in only 6 districts. Using the above cut-off level, the important crops in descending order of importance in each district are as follows:

1)	SV :	rice, (bajra, ragi)	3
2)	EG :	rice	1
3)	WG :	rice	1
4)	KR :	rice,	1
5)	GN :	rice, jowar, (bajra, ragi)	4
6)	KU :	jowar, rice,	2
7)	AN :	rice, jowar, ragi, bajra	4
8)	CU :	rice, jowar, bajra, ragi	4
9)	CH :	rice, ragi, bajra, jowar	4
10)	RH :	rice, jowar, ragi, maize	4
11)	NZ :	rice, maize, jowar	3
12)	ME :	rice, jowar, maize	3
13)	MB :	jowar, rice, ragi, bajra	4
14)	NA :	rice, jowar, bajra	3
15)	WA :	rice, jowar, maize	3
16)	KH :	rice, jowar,	2
17)	KM :	rice, maize, jowar	3
18)	AD :	jowar, rice, maize	3
19)	AP :	rice, jowar, maize, (bajra, ragi)	5
			57

Notes: Crops enclosed in brackets have roughly same share in the total.

Districtwise shares in the State's total productions are presented in table 3.7 from which we may identify for each crop the most important districts/regions as follows:

Crop	Coastal Andhra	Rayalaseema	Telangana	% in State Total
Rice	SV, EG, WG, KR, GN (65.88%)	...	NA, KM (11.91%)	77.79
Jowar	GN (6.63%)	KU, AN (26.45%)	RH, ME, MB, NA, KH, AD (48.56%)	81.54
Bajra	SV, GN (53.07%)	AN, CU, CH (23.33%)	MB, NA (11.77%)	88.17
Ragi	SV, GN (48.32%)	AN, CU, CH (32.24%)	MB (11.12%)	91.68
Maize	...	...	NZ, ME, WA, KM, AD (92.22%)	92.22

Notes: Percentage as in 1984-85. Districts contributing atleast 5% of the State totals are shown.

3.5.2 Some Problems in Assessing Growth Performance: Cereal Outputs.

Table 3.8 presents the output of the 5 cereal crops in a few years at the AP State level and in the 18 districts of AP. However, while estimating the growth rates by semilog time trends over the sub-periods some peculiarities of the data led us, to estimate two separate growth rates for Period I: (A) 1955-56 to 1964-65 and (B) 1955-56 to 1965-66. Period II is maintained, however, as 1965-66 to 1984-85. The growth rates estimated for various periods are also presented in table 3.8.

An important aspect of the data seriously hampered the estimation of growth rates for any sub-period, sometimes even for the full period. In view of this problem, which we illustrate below with an example, it became quite difficult to make judgments on the growth performance over sub-periods based on the estimation results of semilog trends. The basic difficulties arose essentially due to the following three reasons:

a) Besides the arrival of modern technology, the years 1965 and 1966 are note worthy for several other reasons also. Both, the war between India & Pakistan in 1965 and a substantial devaluation overnight of the Rupee in June 1966 - caused serious shocks to the Indian economy. Besides, two other important factors directly affecting the performance of the agricultural sector in particular are: one, 1965-66 and 1966-67 were exceptionally bad rainfall years causing severe drought and two, India's foodgrain imports under US P.L 480 which were substantial until mid 1960s gradually declined from 1967 onwards. In this background researchers often tempted to assess growth performance of India over the two sub-periods separately, i.e., up to 1965-66 and after 1965-66. However, the drought factor in particular, which exactly coincided with the period break-up at 1965-66 has serious implication on the estimated growth rates as we see below.

b) Quite many of the districtwise data series on crop outputs, acreages and yields are riddled with fluctuations over time. Thus, though the data seem to indicate an overall rising or falling trend in a given series, the estimation results, however, indicated very poor fits and insignificant growth rates when semilog time trends were fitted.

c) Besides, the movements in the given data may not adequately be described by a semilog trend. This relates to the functional form specification.

Let us illustrate the above points now:

Let us look at the following estimation results of the semilog trend in the case of rice output in SV district (as an example):

	Period I		Period II	
	A 1955-56 to 1964-65	B 1955-56 to 1965-66	C 1964-65 to 1984-85	D 1965-66 to 1984-85
Estimated Slope Coefficient	0.0581	0.0173	0.0286	0.0379
T-values	4.61	0.67	2.73	3.73
R^2	0.73	0.05	0.28	0.44

Obviously, the inclusion/exclusion of 1965-66 made tremendous difference to the estimation results particularly for Period I. By inclusion of this single more observation under Period I, the estimate of the growth rate not only slumped down to as low as 1.73% p.a. from a level of 5.81% p.a. when not included, the slope coefficient also turned out to be insignificant. Besides, note the differences in R^2 also! A look into the data[4] reveals the fact that rice output of SV in 1965-66 indeed is substantially low at 2.52 lakh tonnes (l.t) (compared to 5.73 l.t in the previous year) which made all the difference when this observation also is included in the sample. For this reason two separate growth rates for the Period I were estimated & reported in table 3.8 for all the districts for all the crops. (A) 1955-56 to 1964-65 and (B) 1955-56 to 1965-66. However, the year 1965-66 was included in Period II and the corresponding growth rates were estimated.

Some scholars in their studies dropped all together the observation corresponding to 1965-66[5]. We would like to point out that 1965-66 is not the only year in which output level was so low. In fact, the output levels in the above example in the years 1967-68, 1968-69, 1974-75 and 1976-77 were as low as 2.57, 2.61, 2.71 and 2.82 l.t. respectively. Thus, if some observations were to be dropped at all, all such bad years may also have to dropped. Even if one were to go by actual rainfall in deciding whether a particular year to be dropped or not, let us look at the table 3.9 where the actual rainfall in South-West monsoon for a few selected years is presented.

Table 3.9 conveys that 1965-66 is rainfallwise a bad year not for all districts in AP. For some districts (those of Telangana in particular) rainfall in 1963-64 as well as in several years after

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4 Following is the output series of rice output (tonnes) in SV for the period 1955-56 to 1984-85, (running left to right):

354860	389030	339546	399190	495700	398886	537170	606900
469500	572573	252460	311637	257196	261072	392913	499742
620633	429464	394616	270665	560989	281657	367158	448445
501021	579982	559283	518651	779800	511023		

5 Some studies dropped both the observations corresponding to 1965-66 & 1966-67.

1965-66 are even lower than the rainfall in 1965-66. So is the case even in the two Godavari districts. We believe dropping several such years is not appropriate and hence 1965-66 need not be omitted too in the analysis.

As mentioned earlier, a semilog trend may not be the right functional form to describe the data. That is, possibly some other time trend such as quadratic trend, etc., may be appropriate to fit the data. However, basically the problem seems to be that the series has a lot of fluctuations (going up & down) over time caused for some reason or other such as good/bad rainfall, etc. And in the presence of such fluctuations, (arbitrarily) dropping a few select observations may not be justified.

Let us now consider the econometric aspect of fluctuations in a given data series. Consider, for example, the results of jowar outputs in ME, KH and AD (see table 3.8). All these districts seem to indicate reasonable growth over time. In fact, the annual compound growth rates worked out for these outputs between 1955-56 and 1984-85 years come to 3.95%, 1.58% and 2.35% p.a. for ME, KH and AD, respectively. However, when semilog trends were fitted for the data series, the fits turned out to be too poor and growth rates turned insignificant in all these cases for both the periods as well as the full period.

As we shall see in the following chapters, the analysis of fluctuations over time essentially depends on the analysis of the estimated residuals (gaps between the realizations and expectations, i.e., $\hat{U}_t = Y_t - \hat{Y}_t$). The above example of rice output in SV clearly indicates that the set of residuals obtained under situation A would be different from the set obtained under situation B. Now which set of residuals are to be considered seriously?

These are some of the reasons why this study while analysing the fluctuations, without dropping any observations, in crop yields in the coming chapters, not only is concerned with identifying an appropriate functional form to fit the data, but also entirely avoids any sub-periodization of the full sample since such sub-periodization requires pre-specification of some cut-off point (such as 1964-65 or 1965-66 or any other year). Instead, the data are let to speak for themselves if at all there is any such cut-off point.

Given this background on the presence of fluctuations over time and the problems associated with analysing the growth performance over the sub-periods, it may suffice now to note that in general

i) Several districts have achieved impressive growth rates in the outputs of rice and maize over the full period; while

ii) outputs of jowar, bajra and ragi have almost remained either stagnant or fallen down over full period in most of the districts with a very few exceptions such as bajra output in SV district where it recorded a positive growth.

More detailed discussion of the above results follows in the next section where the growth rates in crop outputs are juxtaposed with the growth rates in the corresponding acreages & yields. We continue to use semilog time trends for the rest of this chapter since the purpose here is only to get a general idea of the growth performance. The question of identifying a right functional form will, however, be taken up in the later chapters.

3.5.3 Growth in Crop Output Versus Growth in Acreage & Yields.

It is again found that the growth rates in acreages as well as in crop yields estimated for Period I differ under the two situations A (1965-66 not included in Period I) and B (1965-66 included in Period I) though the differences are somewhat milder than the differences observed in the case of output growth rates (the differences not reported). In any case, since such differences do persist, our discussion below is more confined to the growth rates as observed for the full period (see table 3.10 and 3.11 for growth rates in acreage and yields, respectively). Also, the discussion is based only upon the cases for which the estimation "clearly" indicated growth pattern, if any.

Rice: Except 4 districts (SV, AN, CH & ME) all the other districts show positive growth rates in rice output. Even these 4 districts show growth in rice output though insignificant as per estimation results. No district shows a negative growth rate. So is the situation in the case of yields also. In any case only in SV the crop yield did not grow over time significantly. All the other 17 districts recorded significant positive growth in rice yields. However, only in 5 districts (EG, WG, GN, NA & AD) the acreage under rice clearly showed a significant positive growth rate over time. Even in these 5 districts also the growth rates in acreage were lower than the growth rates in yields. Thus, one may conclude that in AP, the growth in yields were mainly responsible for the growth in rice output.

Jowar: This crop's performance is almost the opposite to that of rice. Except 4 districts (EG, WG, GN & NA), all other districts show no significant growth/fall in jowar output. The 4 districts show a significant negative growth rate in jowar output. The output data in 8 districts (KU, AN, CU, RH, NZ, ME, KH & AD) actually show some increase in their outputs but as per the estimation results their growth rates are not significant. Coming to yields, no district shows a negative growth rate while 3 districts (KU, AN & CU) indeed show significant positive growth rates. Of these 3 districts, in 2 districts (KU & AN) the jowar acreage, however, recorded significant negative growth rates. Thus what was gained in yields rise was lost in acreage keeping the total outputs with insignificant growth in these 2 districts. Actually, 7 other districts (EG, WG, KR, GN, RH, NZ & NA) also recorded significant negative growth rates in jowar acreage; but the yield levels in these districts did not go up to compensate for the fall in the acreage.

Bajra: While bajra output grew significantly in SV (2.15% p.a), it fell down in WG & KM at far higher rates (-10.26% and -14.00% p.a). Substantial increase (fall) in CU (NA) are riddled with high fluctuations also so that neither of them revealed a clear trend over time. Output in all other districts, not all of them free of wide fluctuations, did not reveal clear trend though they appear to be falling in general. Bajra yields significantly increased in 4 (SV, WG, KR & CU) districts. However, its acreage in SV remained almost stationary; whereas in WG & KR the rise in yields are, however, associated with fall in acreage at far higher rates (thus output also fell down) and in CU the rise in yields was associated with a fall in acreage almost at the same rate (thus, output remained stationary). 6 districts (WG, GN, AN, CU, CH & KM) recorded significant acreage fall over time; whereas WA is the lone district where acreage went up significantly but its fluctuating yield levels led to fluctuations in its output levels also.

Ragi: The 3 districts KR, KU and WA, showed a clear significant falling growth rate in ragi output. Though the output seems to be increasing in GN, RH & MB districts, the fluctuations over time could not reveal a clear trend as per the estimation results. In all other districts, the output is almost stagnant with a falling tendency. Yields have gone up significantly in 4 districts (GN, AN, CU & NA) in all of which simultaneously acreage fell down (significantly in CU & AN). In all 8 districts (KR, KU, AN, CU, CH, NZ, ME & WA) showed significantly negative growth rates in ragi acreage. The rates of fall in ragi acreage in WA, KR & KU were as high as 7.15%, 9.56% and 17.68% p.a., respectively, an obvious reason behind the falling rates in their outputs almost at the same rates (7.23%, 9.08%, 16.68%).

Maize: Growth performance of this crop is almost similar to that of rice; i.e., no district in AP showed up a negative growth rate either for its acreage or yield and thus for outputs also. The number of districts showing significantly positive growth rates for yields, acreage and outputs are 15, 11 and 12, respectively. 2 (RH & ME) of the 3 districts which showed no significant positive growth rate in yields, however, showed significant positive growth rates in the crop acreage. Except in 2 (CH & NZ) districts the growth rates in yield are generally higher than the growth rates in the crop acreage. In any case, growth both in acreage and yields contributed to growth in output of this crop in general.

Thus, we conclude from the above discussion that growth/fall/ stagnancy in cereal crops' outputs in AP is caused either by

a) simultaneous growth in acreage and yields in most of the districts (as in the case of maize); or

b) growth only in yields but not in acreage in most of the districts (as in the case of rice); or

c) fall in acreages in a few districts sometimes simultaneously associated with growing yields (as in the case of ragi, bajra & jowar in a few districts); or

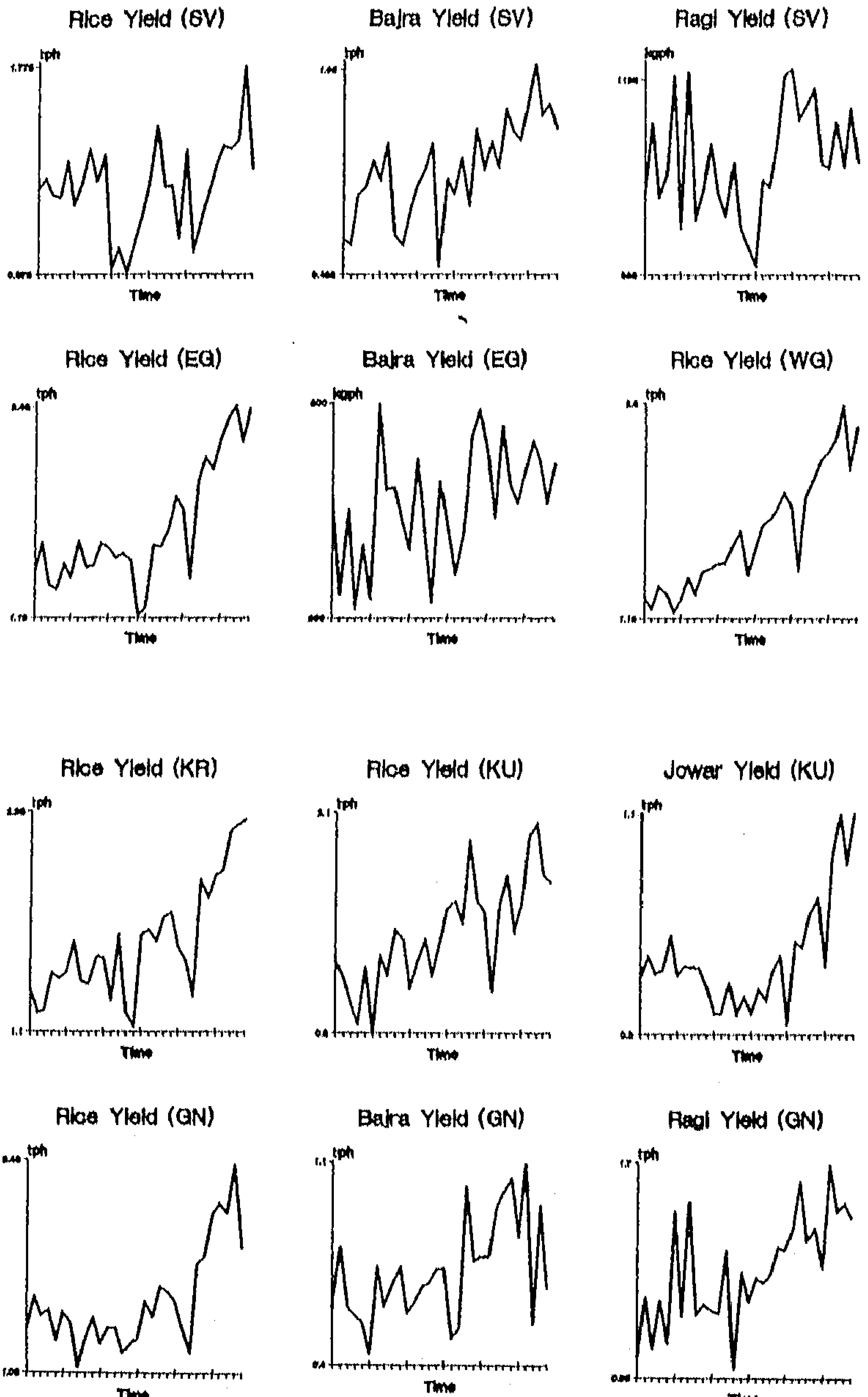
d) near stagnancy in both acreages & yields (as in the case of ragi, bajra & jowar in a few districts).

It was earlier mentioned that presence of wide fluctuations can in principle cause estimation problems making the task of comparative assessment over sub-periods difficult. This was illustrated above in the case of rice output in SV. Figures 3.1 present plots of crop yields for a few of the several important cases showing the extent of fluctuations in them.

How wide are such fluctuations in crop yields over time? How to quantify such fluctuations in some measure or other? Fluctuations (in the sense of outputs/acreages/yields going up & down over time) may always exist; but isn't it a matter of serious concern if they go on widening over time? When did they start widening, if at all they did? These issues will be taken up for the analysis in the later chapters.

3.5.4 Gross Irrigation for Cereal Crops.

Semilog trends were fitted only for rice irrigated area over the full period as well as the two sub-periods. Semilog trends were fitted also for maize irrigated area but only for those districts which do not have zero-valued observations. These trends were not fitted in the case of remaining 3 crops since irrigated


Rice Yield (SV)
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Bajra Yield (EG)
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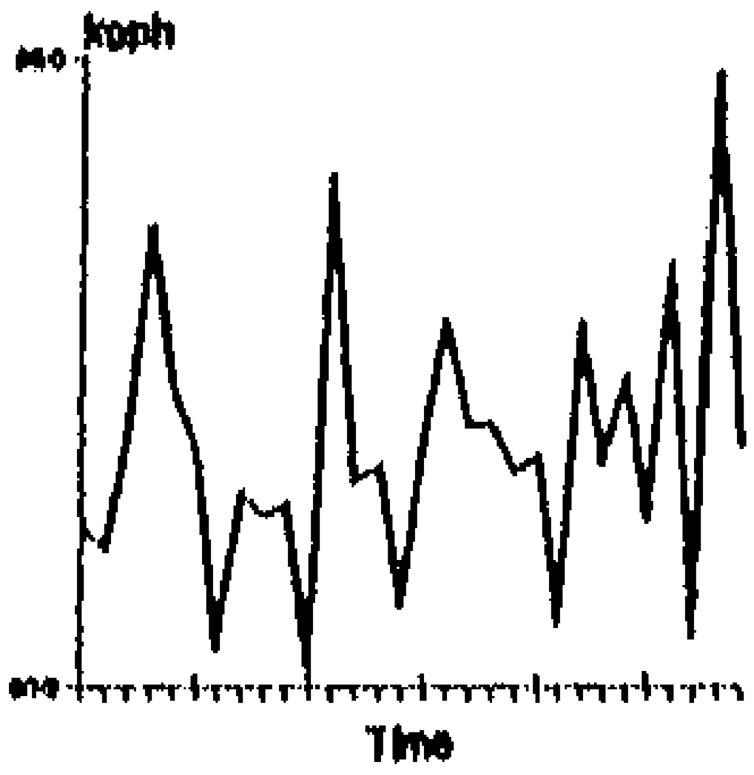
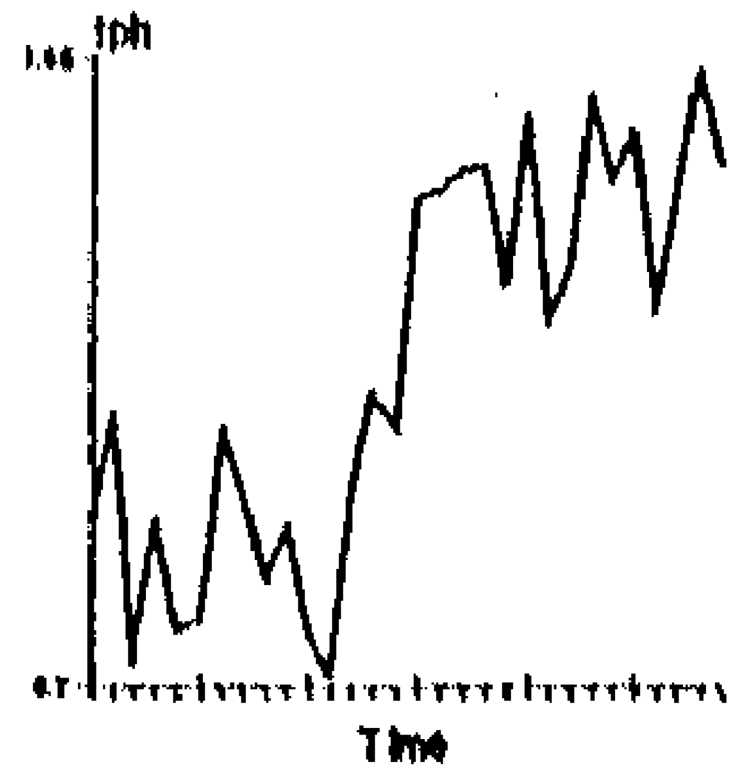
Figure 3.1

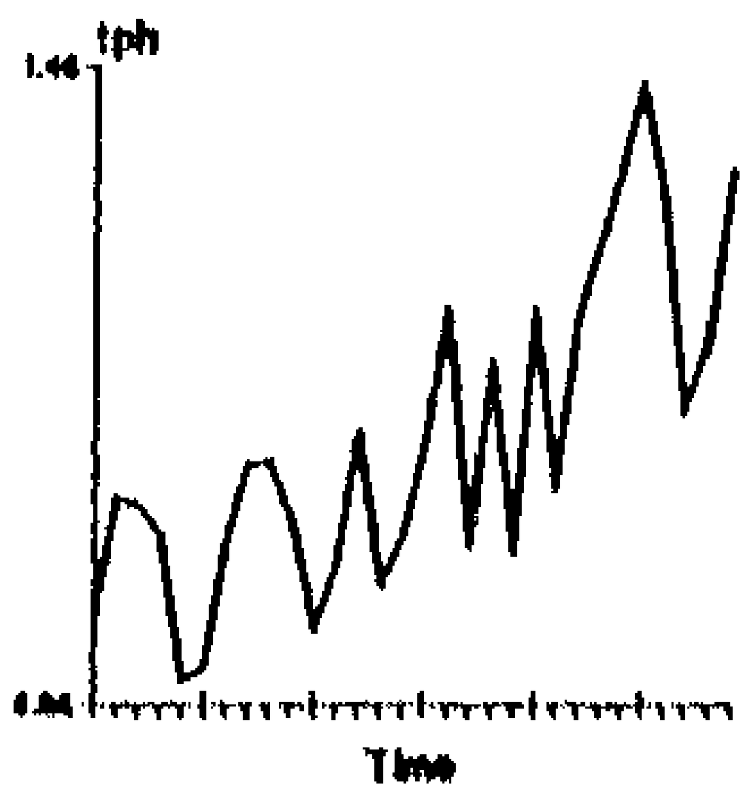
Bajra Yield (AN)



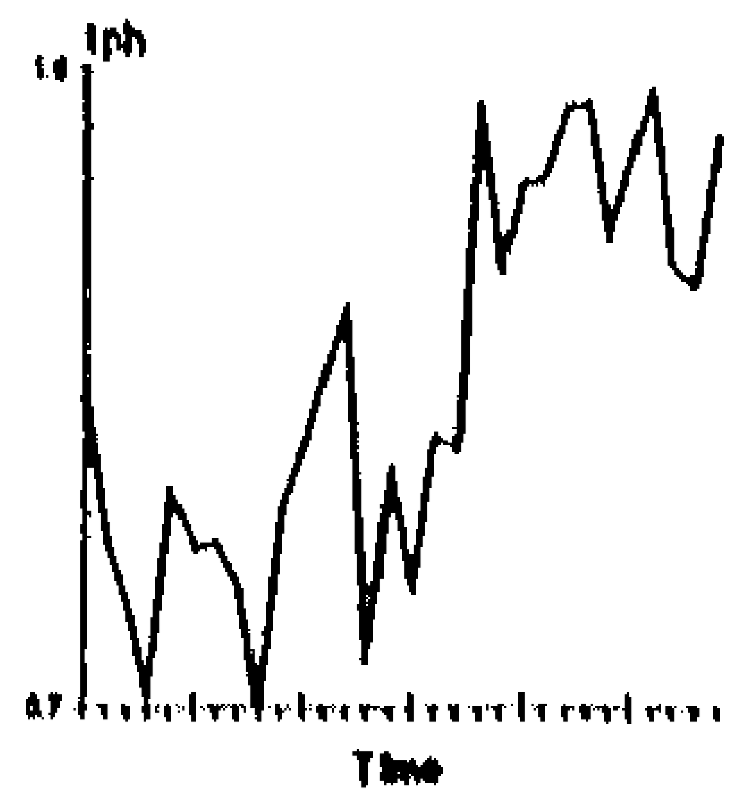
Ragi Yield (AN)



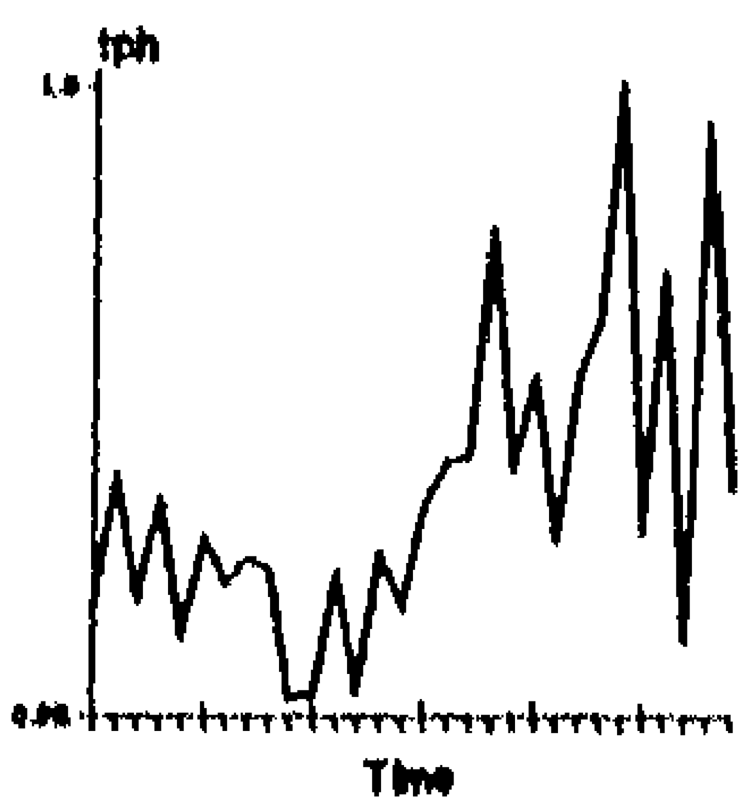
Bajra Yield (CU)



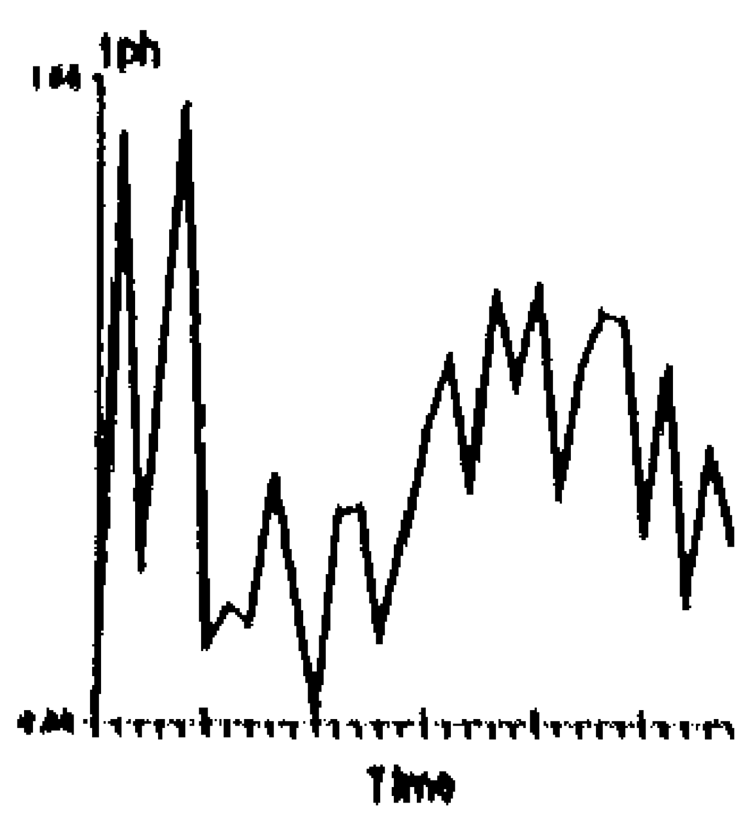
Ragi Yield (CU)



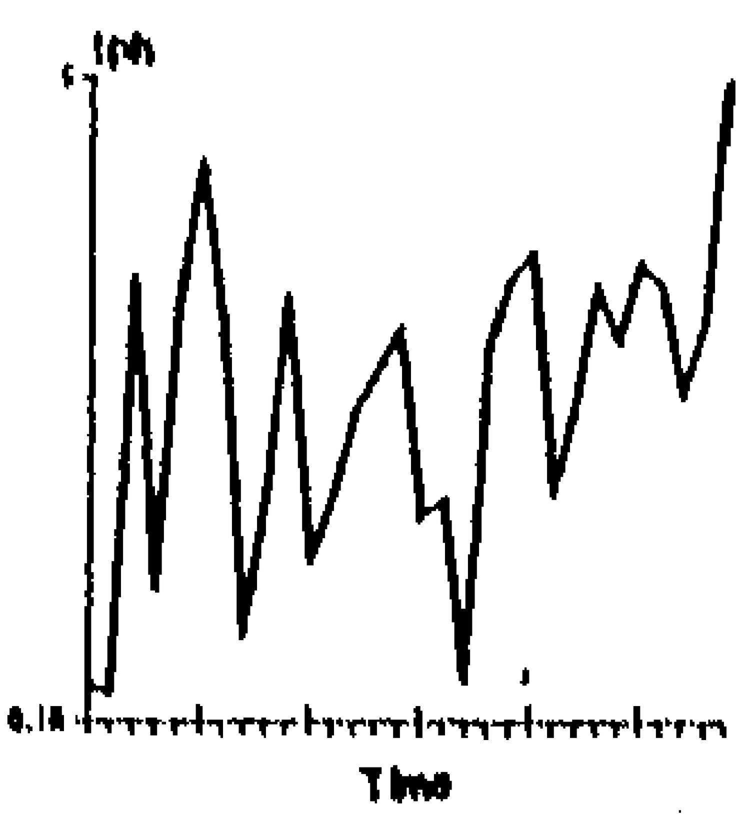
Bajra Yield (CH)



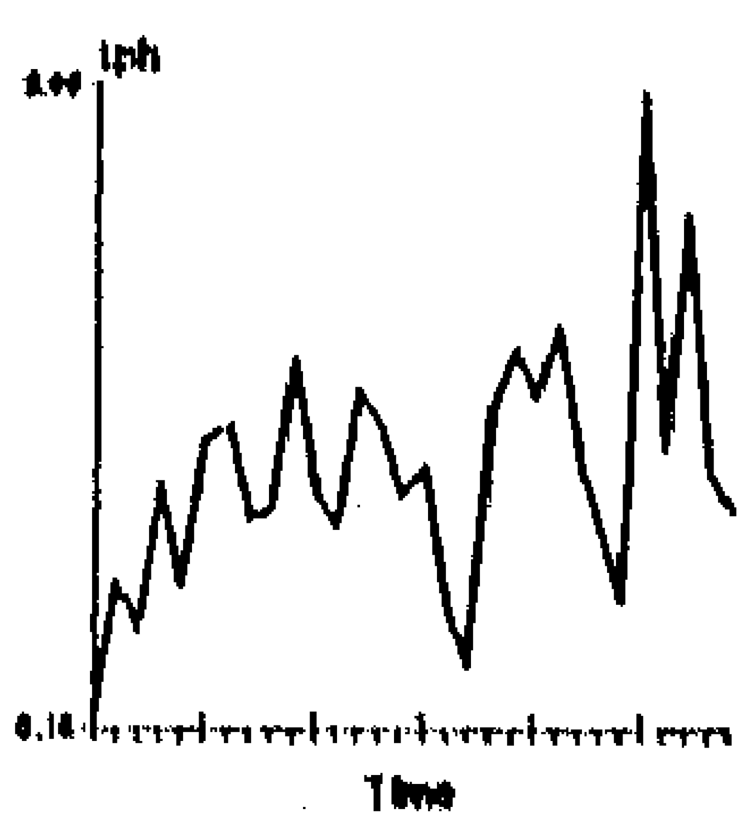
Ragi Yield (CH)



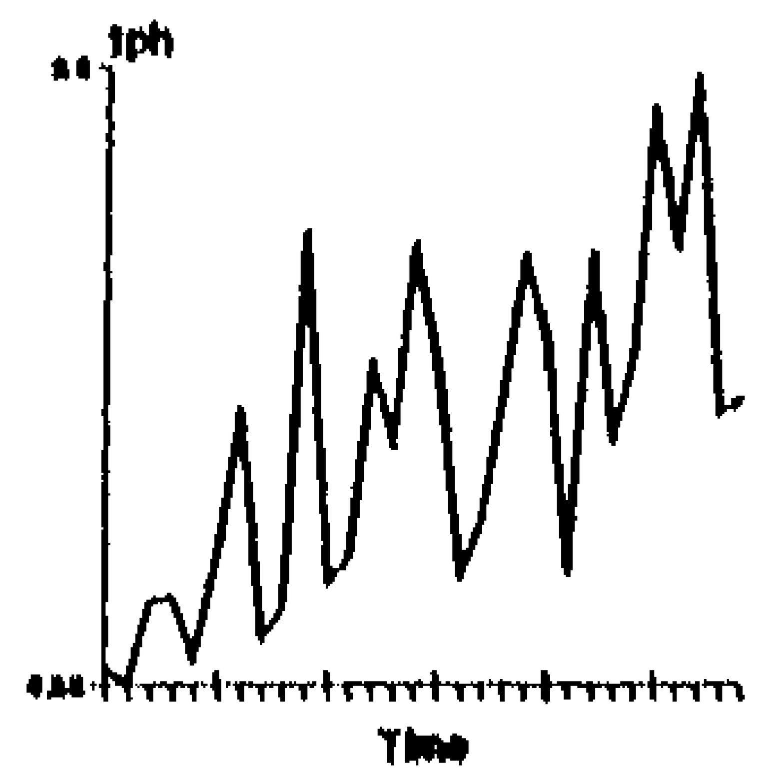
Ragi Yield (RH)



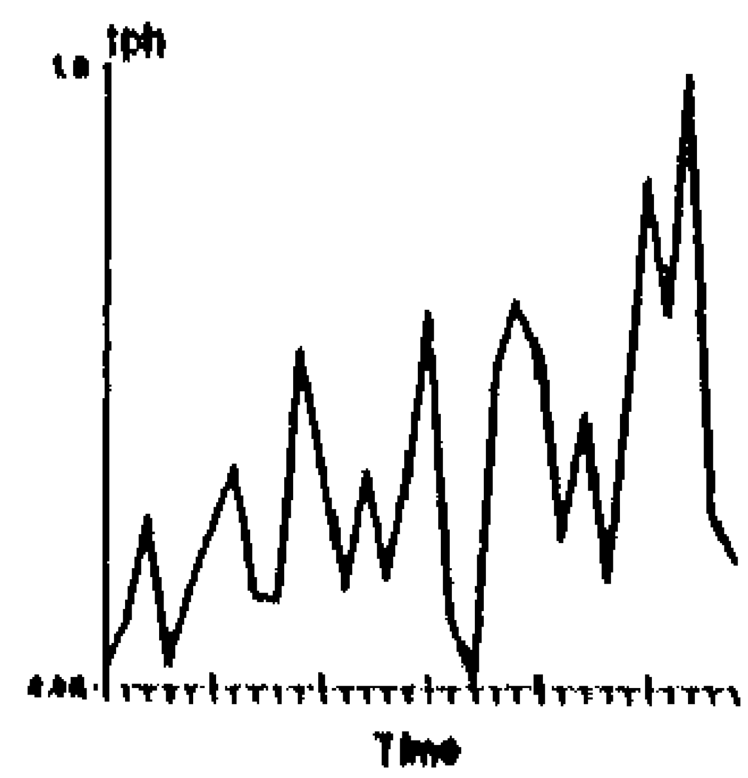
Maize Yield (RH)



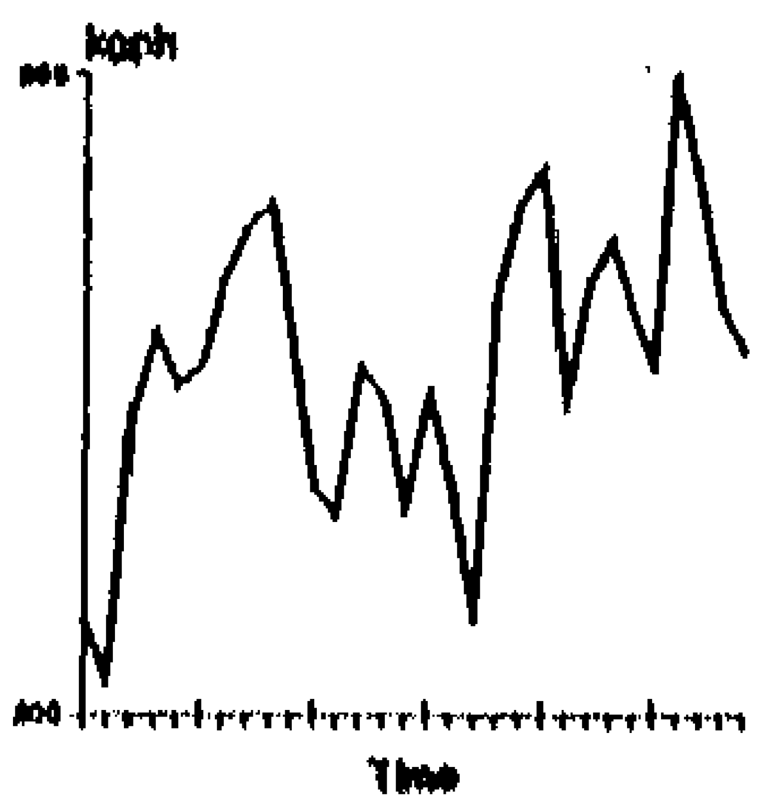
Maize Yield (N[illegible])



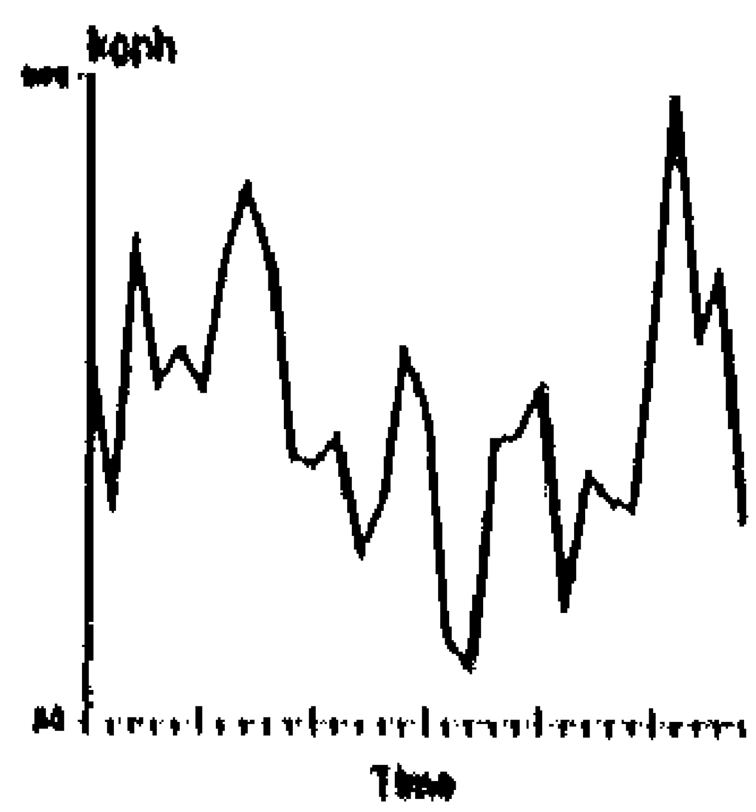
Maize Yield (ME)



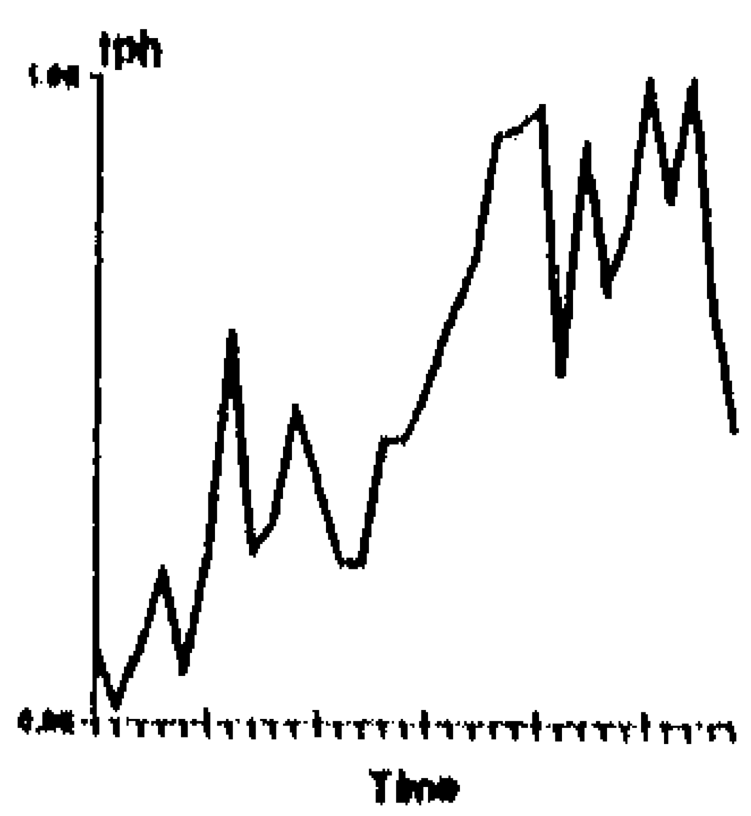
Ragi Yield (MB)



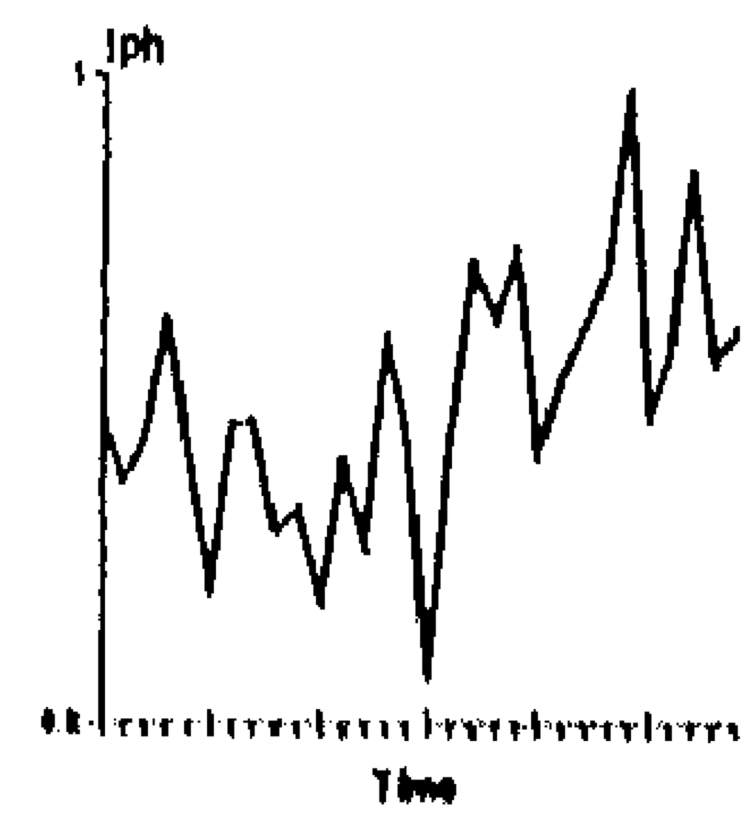
Bajra Yield (NA)



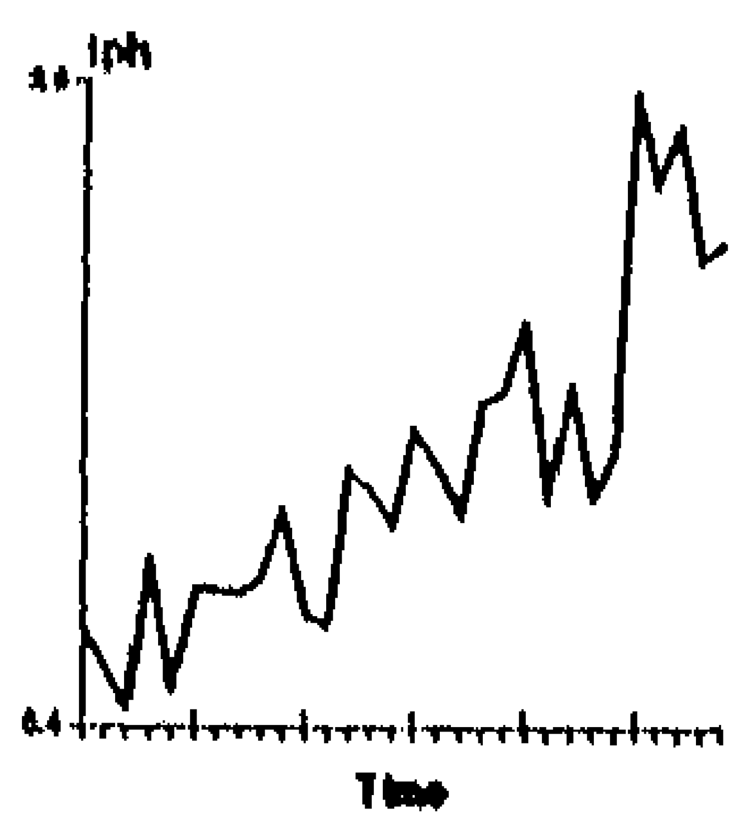
Maize Yield (WA)



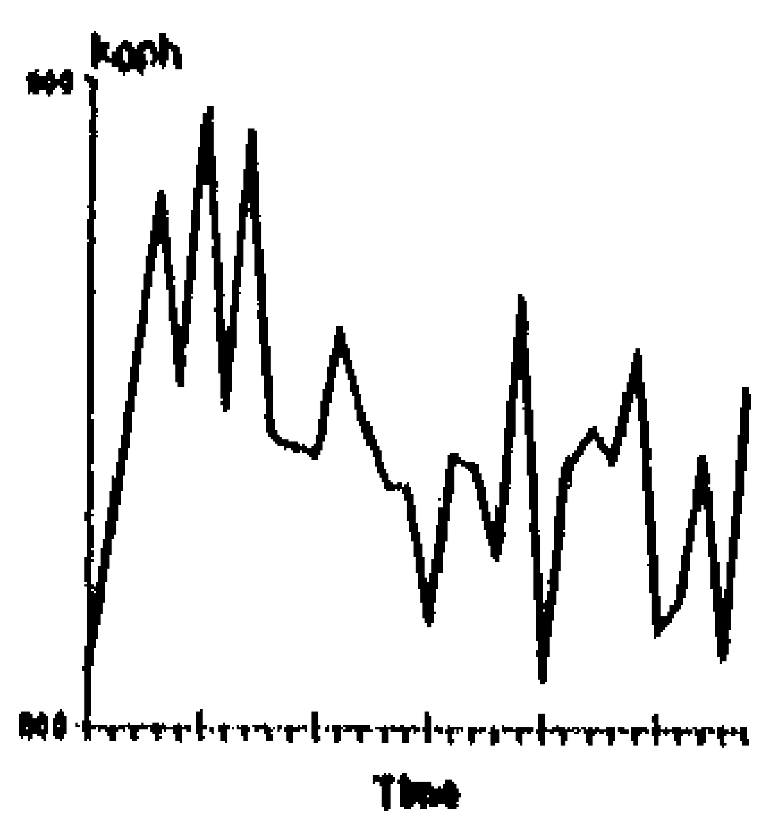
Jowar Yield (KH)



Maize Yield (KM)



Jowar Yield (AD)



Notes: Time axis runs from 1955-56 to 1984-85;

tph : tonnes per hectare;

kgph : kilo grammes per hectare;

See page 41 for District codes;

area in many districts for many years was nil under these crops. Gross irrigation intensity for a crop is defined as the ratio of gross irrigated area under a crop to the total cultivated area under that crop. Details on the gross irrigation acreage and intensities are given in tables 3.12 and 3.13, respectively.

Rice: The irrigated area under rice in the State as a whole has grown over time from about 2549.8 t.ha in 1955-56 to 3306.5 t.ha. in 1984-85. It has grown over the full period only in 5 districts (EG, WG, GN, NA & AD). Amongst these districts growth has been highest in NA at 2.52% p.a. while it has been lowest in EG at 0.90% p.a. In the remaining districts, irrigated area under rice has remained stagnant over the full period. Rice is a highly irrigated crop in the State as a whole, with more than 90% of the area under rice being irrigated (see table 3.13). At the districts level, the intensity is more than 90% in 14 out of the 18 districts of AP (see table 3.13).

Jowar: Jowar is a lowly irrigated crop with its intensity in the State as a whole is less than even 2% (see table 3.13). It is totally unirrigated in some districts, while the highest irrigation intensity for jowar is found in CH even where the proportion of irrigated crop is falling down over time. Though in 4 other districts (GN, KU, AN & CU) irrigated area of jowar is quite substantial, but as proportion in the crop's total cultivated area it is only marginal.

Bajra: Bajra too is an unirrigated crop in the State as a whole. However, there is a sharp difference between bajra and jowar. In a few districts, unlike jowar, bajra is a highly irrigated crop while in some others it is totally unirrigated. In the districts of GN, CU & CH irrigation intensity for bajra is as high as 50%, 57% and 23% in 1984-85. In NZ, though it was totally unirrigated up to 1965-66, the crop became almost totally irrigated by 1984-85. The irrigation intensity is generally low in all other districts. Table 3.12 shows that irrigated area under this crop drastically fell down over time in KU and CH, while it increased in AN.

Ragi: The case of ragi is similar to that of bajra. That is, it is a lowly irrigated crop in many districts of the State whereas in a few districts (SV, GN, KU, AN, CU, CH & NA) it is a highly irrigated crop. At the State level, irrigation intensity for ragi has been around 48% in 1955-56 which has fallen over time to around 33% in 1984-85.

Maize: Though maize too is lowly irrigated in the State as a whole it has the peculiarity that in every district atleast some part of the crop is under irrigation. The irrigation intensity, however, varies widely across the districts. In a few districts (KU, AN, CU, CH, WA & KM) it is a highly/moderately irrigated crop while in many others it is lowly irrigated. Less than 25% of the crop's acreage was under irrigation in 11 out of 18 districts. In general, no district shows a fall in the irrigated area under maize over the full period.

3.5.5 Fertilizer Use.

Continuous time series data on cropwise fertilizer consumption are not available. However, it is known that cereal crops, in particular rice, corner away a large share of the total fertilizer available. For example, as per the NSSO (1978) data, more than 67% of the total fertilizer consumption in AP was for cereals. Rice alone accounted for over 61%. In this situation, the fertilizer consumption for the 5 cereals in AP is worked out districtwise as

$$FRT = \frac{\text{Total Fertilizer Used Over All Crops}}{\text{Area Under 5 Cereals}} \times 0.67$$

Fertilizer intensity as defined above has grown rapidly in the State as a whole (9.88% p.a.) over the 25 years between 1960-61 and 1984-85 (table 3.14). Further, FRT has grown in all districts except in RH. The growth is highest in NA at 16.65% p.a. while it is lowest in WG at 7.22% p.a. In general, we find that, despite the far higher growth rates in fertilizer use in most of the Rayalaseema and Telangana regions, the fertilizer intensity levels in these regions were still far lower than those in the infrastructurally better endowed Coastal districts in 1984-85.

3.5.7 Adoption of High Yielding Variety (HYV) Seeds.

Rice accounts for a major part of the total cereals acreage in most districts. Further, the relative crop shares in cereals acreage have been fairly stable over time in most of the districts (table 3.15). Data on acreage under HYV are available at the State level from 1966-67 onwards for rice, jowar, bajra & maize. Corresponding official data at the districts level, however, are not available[5]. The available data on HYV are aggregated data, over the 2 seasons - kharif and rabi. Seasonwise continuous time series data on HYV acreage are not available. The proportion of a crop's acreage under HYV seeds is used to assess the adoption rates of HYV seeds. There are no HYV seeds for ragi.

By 1984-85, HYV adoption is highest in the case of rice in AP as a whole at 80.7% followed by bajra at 77.9% and maize at 63.1% (table 3.15). HYV adoption in the case of jowar is, however, very low at 28.5% even after nearly two decades since the modern technology arrived.

Recall that at the State level, all these crops except rice have only low levels of irrigation intensity. In the case of rice, irrigation intensity in 1984-85 is still higher than the proportion of the crop's acreage under HYV. The situation is the reverse in the case of jowar, bajra & maize, where the proportion of their crop acreage under HYV is higher than their irrigation intensity. That is some HYV in the case of jowar, bajra & maize is grown under unirrigated conditions in AP State as a whole.

With this background, we analyse the stability of different aspects of crop yield performance at the all India, Andhra Pradesh State and Districts level (chapters 6 to 10) starting with a brief review of the past studies of this issue in the next chapter.

5 Evenson/ICRISAT provide continuous time series data on acreage under HYV seeds at the districts level. These data, however, were found to have some shortcomings which will be discussed in chapter 5, Part C.

Table 3.1 - Share of Andhra Pradesh in Indian Agriculture.

Variable (%)	1955-56	1965-66	1975-76	1984-85
NDPA	8.83*	9.54	8.88	8.04
NSA	8.74	8.07	7.86	7.44
GCA	8.35	7.79	7.58	6.92
NIA	11.79*	11.26	9.96	8.43
GIA	12.48	11.43	10.02	8.26
Output (%)				
Rice	11.07	12.95	13.24	11.84
Jowar	19.49	13.40	10.73	10.66
Bajra	9.04	6.43	6.12	3.40
Ragi	11.92	17.60	13.24	8.55
Maize	4.30	3.79	6.87	5.13
Yields (Kg/Ha)				
Rice	1118.4	1241.8	1656.5	1975.4
	(874.2)	(862.4)	(1234.7)	(1417.4)
Jowar	442.8	407.6	425.7	652.9
	(387.4)	(428.8)	(590.6)	(715.4)
Bajra	473.8	447.6	564.3	521.6
	(302.3)	(313.6)	(495.7)	(569.4)
Ragi	690.2	712.5	1143.1	956.5
	(800.2)	(492.2)	(1063.6)	(1060.0)
Maize	590.9	833.1	1636.5	1383.2
	(704.0)	(1005.0)	(1203.1)	(1455.6)

Notes: * : Pertains to 1960-61.
NDPA : Net domestic product of agricultural sector (Rs. Crores at 1970-71 prices);
NSA : Net sown area over all crops;
GCA : Gross cropped area over all crops;
NIA : Net irrigated area over all crops;
GIA : Gross irrigated area over all crops;
Figures in brackets are average crop yields at the all India level.

[illegible] Districts.

District	Year	Canals	Tanks	Surface Water[1]	Tubewells	Other Wells	Ground Water[2]	Other Sources	Total NIA[3]	Growth[4] in TNIA	TNIA[5] / TNSA
AP	1960-61	45.76101	39.56836	85.32937	0.15540	11.11764	11.27304	3.39759	2909097.0	0.80	0.277
	1970-71	47.65520	33.56973	81.22494	1.98378	13.08774	15.07152	3.39969	3313017.0		0.282
	1984-85	50.92677	21.98520	72.91198	5.25938	18.49929	23.75867	3.32935	3522487.0		0.336
SV	1960-61	32.61827	58.99277	91.61105	0.27539	4.12144	4.39683	3.99409	407066.0	0.18	0.528
	1970-71	26.76181	61.52457	88.28639	0.09712	3.89721	3.99433	7.71928	423200.0		0.444
	1984-85	36.09774	53.86100	89.95875	1.27270	4.76874	6.04144	3.99981	425395.0		0.477
EG	1960-61	80.98030	17.98507	98.96538	0.51922	0.20869	0.72791	0.14760	254401.0	0.00	0.642
	1970-71	76.60670	19.44654	96.05324	2.89715	0.30697	3.20412	0.74264	264191.0		0.633
	1984-85	82.55861	3.36766	85.92626	12.03884	0.17945	12.21829	1.85545	236277.0		0.630
WG	1960-61	72.46458	22.94761	95.41219	0.01319	2.02909	2.04229	2.54549	294116.5	0.38	0.742
	1970-71	65.73697	15.17128	80.90826	11.66154	3.60326	15.26480	3.82410	316519.0		0.752
	1984-85	67.26778	8.86357	76.13135	19.14795	1.58102	20.72897	3.13968	322071.0		0.796
KR	1960-61	76.58694	15.94561	92.53255	0.00731	1.82244	1.82976	5.63772	332350.4	0.00	0.731
	1970-71	77.17744	12.92752	90.10496	3.34204	2.55738	5.89942	3.99562	324981.0		0.656
	1984-85	83.72933	5.13409	88.86342	5.01630	2.71693	7.73323	3.45785	330263.0		0.698
GN	1960-61	57.99597	28.64444	86.64040	0.10180	10.56473	10.66653	2.69307	513652.8	1.60	0.405
	1970-71	68.76176	18.10807	86.86983	1.47505	10.15533	11.63039	1.49977	631028.0		0.399
	1984-85	65.99605	14.32070	80.31675	6.37932	10.77897	17.15829	2.52496	751695.0		0.490
KU	1960-61	47.93056	32.99310	80.92366	0.00000	15.66094	15.66094	3.41528	84578.6	1.35	0.078
	1970-71	74.36118	13.41343	87.77461	0.00000	9.04449	9.04449	3.18090	96545.0		0.094
	1984-85	70.95660	10.43159	81.38819	0.13455	14.52041	14.65497	3.95684	116684.0		0.142
AN	1960-61	21.44571	44.47801	65.92372	0.00287	32.01531	32.01818	2.05821	83582.2	1.27	0.082
	1970-71	33.51081	25.21999	58.73080	0.00000	39.43291	39.43291	1.82020	125801.0		0.128
	1984-85	33.22368	8.41226	41.63594	3.27983	52.31640	55.59623	2.76783	113085.0		0.133
CU	1960-61	33.97036	27.79041	61.76077	0.14501	35.84333	35.98833	2.25090	105789.0	0.00	0.246
	1970-71	31.52624	18.90550	50.43174	0.33498	43.97081	44.30579	5.21040	115231.0		0.265
	1984-85	22.93843	15.51925	38.45769	6.30758	50.25852	56.56610	4.97621	101925.0		0.289
CH	1960-61	0.00000	62.59155	62.59155	0.12980	25.33968	25.46948	10.81294	143761.1	0.00	0.338
	1970-71	0.00000	53.91968	53.91968	0.00000	40.39747	40.39747	5.68284	150752.0		0.318
	1984-85	1.91200	38.90464	40.81663	1.37224	56.13046	57.50270	1.68067	140063.0		0.299
RH	1960-61	12.70469	62.49223	75.19691	1.56220	21.79051	23.35271	1.45068	32639.9	1.05	0.109
	1970-71	7.49548	37.96443	45.45991	0.02029	52.06250	52.08279	2.45729	54208.0		0.141
	1984-85	7.59433	27.10251	34.69685	0.85150	56.25149	57.10299	8.20016	41926.0		0.125

es are given at the end of the table.

rict	Year	Canals	Tanks	Surface Water[1]	Tubewells	Other Wells	Ground Water[2]	Other Sources	Total NAI[3]	Growth[4] in TNIA	TNIA[5] / TNSA
Z	1960-61	52.95342	41.96327	94.91669	0.33001	3.53693	3.86694	1.21637	116510.7	1.08	0.386
	1970-71	45.23029	41.98661	87.21690	0.00000	9.77753	9.77753	3.00557	124735.0		0.404
	1984-85	52.92557	22.64581	75.57139	0.97310	18.54241	19.51550	4.79404	151167.0		0.504
E	1960-61	6.24768	72.63241	78.88009	0.00000	17.66611	17.66611	3.45380	79828.0	1.09	0.178
	1970-71	11.77423	64.57822	76.35246	0.00000	21.23083	21.23083	2.41671	82757.0		0.171
	1984-85	10.21440	49.62978	59.84418	0.03190	37.75761	37.78951	2.36631	103452.0		0.234
3	1960-61	9.75819	60.44346	70.20164	0.00000	25.75492	25.75492	4.04332	85244.3	0.00	0.094
	1970-71	20.62748	52.95946	73.58694	0.00000	23.65912	23.65912	2.75395	108753.0		0.103
	1984-85	15.04554	33.49810	48.54364	0.79089	49.08738	49.87828	1.57808	80921.0		0.106
\	1960-61	21.75775	42.79945	64.55720	0.27174	35.17095	35.44269	0.00000	86810.0	1.27	0.124
	1970-71	53.08585	31.01867	84.10452	0.00000	15.07175	15.07175	0.82373	136089.0		0.197
	1984-85	58.35548	13.84824	72.20371	0.00120	24.34189	24.34309	3.45319	166310.0		0.264
\	1960-61	3.57701	78.65496	82.23197	0.00000	16.86078	16.86078	0.87014	98087.4	1.58	0.244
	1970-71	10.53667	69.43977	79.97643	0.00000	17.84188	17.84188	2.18169	120503.0		0.239
	1984-85	0.86059	42.99087	43.85146	1.44293	52.96416	54.40710	1.74145	143042.0		0.343
\	1960-61	14.64337	78.56947	93.21283	0.00000	1.55898	1.55898	5.22819	62457.6	1.61	0.202
	1970-71	17.82911	63.32813	81.15724	0.14430	10.75472	10.89902	7.94373	85237.0		0.194
	1984-85	46.35963	26.09266	72.45229	8.49874	10.99265	19.49139	8.05632	91543.0		0.212
1	1960-61	15.23852	49.79283	65.03135	0.00000	28.87669	28.87669	6.09196	100209.2	2.36	0.235
	1970-71	13.37645	54.43745	67.81390	0.00000	21.34920	21.34920	2.40548	118604.0		0.236
	1984-85	27.73360	26.84943	54.58304	0.00000	40.68368	40.68368	4.73329	167389.0		0.398
)	1960-61	21.83033	69.31502	91.14535	0.07211	4.28774	4.35986	4.49444	28012.4	1.42	0.060
	1970-71	33.77601	58.88741	92.66342	0.17117	7.00310	7.17427	0.18887	33865.0		0.058
	1984-85	42.00209	37.68171	79.68380	1.64974	12.93821	14.58795	5.72825	39279.0		0.068

:: 1 Surface water = Canals + Tanks.

2 Ground water = Tubewells + Other Wells.

3 Total net irrigated area in hectares.

4 Annual compound growth rates over 1960-61 to 1984-85;

5 Total net irrigated area ÷ Total net sown area;

:: AP : Andhra Pradesh State (all districts);

SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna;

GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor;

RR : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda;

WA : Warangal KH : Khammam; KM : Karimnagar; AD : Adilabad;

Table 3.3 - Gross Irrigated Area Over All Crops: AP State & its Districts.

District	Hectares 1955-56	Hectares 1984-85	Annual Compound Growth Rate % Period I	Period II	Full Period
AP	3199916.0	4469542.0	1.00	1.25	1.18
SV	389906.5	449915.0	0.73	0.37	0.50
EG	287360.7	383496.0	0.90	1.05	1.00
WG	329711.4	506241.0	2.00	1.22	1.49
KR	337980.0	422599.0	0.34	1.00	0.77
GN	552520.3	828233.0	0.00	2.30	1.41
KU	63430.1	141426.0	7.67	0.33	2.80
AN	124996.2	130053.0	0.00	0.52	0.14
CU	118519.6	114217.0	0.87	-0.65	0.00
CH	166677.2	190240.0	0.42	0.48	0.48
RH	49264.0	64163.0	1.44	0.64	0.92
NZ	122239.0	192075.0	0.75	2.00	1.57
ME	97670.2	121645.0	0.87	0.70	0.76
MB	102839.2	130952.0	1.50	0.49	0.84
NA	118908.9	249734.0	1.74	3.04	2.59
WA	122958.6	161676.0	1.27	0.78	0.95
KH	54037.3	105360.0	2.98	1.99	2.33
KM	132250.2	228553.0	1.65	2.04	1.90
AD	28646.5	48964.0	1.51	2.05	1.87

Notes: Period I : 1955-56 to 1965-66;
Period II : 1965-66 to 1984-85;
Full Period : 1955-56 to 1984-85;

Codes: AP - Andhra Pradesh (all districts);
SV - Srikakulam + Vizianagaram + Vishakhapatnam;
EG - East Godavari; KR - Krishna; KU - Kurnool; AN - Anantapur;
WG - West Godavari; CU - Cuddapah; CH - Chittoor; NZ - Nizamabad;
GN - Guntur + Prakasam + Nellore; RH - Ranga Reddy + Hyderabad;
MB - Mehboobnagar; NA - Nalgonda; WA - Warangal; ME - Medak;
KM - Karimnagar; KH - Khammam; AD - Adilabad;

[illegible]

District	Gross Cultivated Area					Net Sown Area				
	Hectares		Annual Compound Growth Rate %			Hectares		Annual Compound Growth Rate %		
	1955-56	1984-85	Period I	Period II	Full Period	1955-56	1984-85	Period I	Period II	Full Period
AP	12301850.0	12212260.0	-0.17	0.05	-0.03	11290140.0	10486310.0	-0.27	-0.25	-0.25
SV	861551.4	1074012.0	1.49	0.30	0.76	691695.0	891075.0	1.77	0.41	0.88
EG	540083.0	557244.0	-0.22	0.28	0.11	451795.1	374833.0	-1.73	-0.06	-0.64
WG	471405.0	593785.0	1.06	0.66	0.80	387138.8	404874.0	0.57	-0.07	0.15
KR	630491.5	706217.0	-0.10	0.65	0.39	529564.4	473469.0	-0.89	-0.12	-0.39
GN	1741227.0	1797291.0	-0.37	0.36	0.11	1524885.0	1532930.0	-0.04	0.05	0.02
KU	1240720.0	898336.0	-0.79	-1.28	-1.11	1184023.0	823995.0	-0.83	-1.48	-1.24
AN	1083064.0	869027.0	-1.99	-0.10	-0.76	1040392.0	851249.0	-1.74	-0.13	-0.69
CU	465143.7	364879.0	-0.70	-0.91	-0.84	435304.8	352388.0	-0.68	-0.75	-0.73
CH	440093.2	520602.0	0.72	0.51	0.58	388356.9	468164.0	1.14	0.39	0.65
RH	355149.2	357005.0	-0.59	0.34	0.58	347274.4	334748.0	-0.72	0.19	-0.13
NZ	303344.1	362005.0	0.35	0.75	0.61	281506.5	299921.0	0.27	0.19	0.22
ME	472607.0	468898.0	0.48	-0.29	-0.03	442014.3	442990.0	0.79	-0.40	0.01
MB	1020386.0	823293.0	-0.97	-0.61	-0.74	1010081.0	761263.0	-1.09	-0.91	-0.97
NA	786850.4	741070.0	-0.90	0.16	-0.21	741885.4	829808.0	-1.35	-0.15	-0.58
WA	482802.8	530119.0	1.39	-0.23	0.32	453371.3	417449.0	1.01	-0.98	-0.28
KH	351288.9	469948.0	1.54	0.73	1.01	349875.4	430804.0	1.46	0.34	0.72
KM	539297.9	483851.0	-0.61	-0.25	-0.37	521183.4	420402.0	-0.66	-0.78	-0.74
AD	516463.1	594884.0	0.46	0.50	0.49	510183.7	578268.0	0.53	0.36	0.42

Notes: Period I : 1955-56 to 1965-66; Period II : 1965-66 to 1984-85; Full Period : 1955-56 to 1984-85;

Codes: AP : Andhra Pradesh State (all districts);
SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna;
GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor;
RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda;
WA : Warangal KH : Khammam; KM : Karimnagar; AD : Adilabad;

Table 3.5 - Aggregate Cropping Intensity: AP State & its Districts.

District	Value		Annual Compound Growth Rate %		
	1955-56	1984-85	Period I	Period II	Full Period
AP	1.090	1.167	0.10	0.31	0.24
SV	1.252	1.214	-0.27	-0.02	-0.11
EG	1.199	1.504	1.63	0.34	0.78
WG	1.222	1.488	0.57	0.74	0.68
KR	1.192	1.503	0.84	0.78	0.80
GN	1.142	1.173	-0.33	0.31	0.09
KU	1.048	1.090	0.05	0.18	0.14
AN	1.041	1.021	-0.25	0.03	-0.07
CU	1.069	1.035	-0.03	-0.16	-0.11
CH	1.136	1.117	-0.41	0.13	-0.06
RH	1.023	1.067	0.14	0.15	0.15
NZ	1.083	1.231	0.10	0.62	0.44
ME	1.070	1.062	-0.30	0.12	-0.03
MB	1.010	1.081	0.12	0.30	0.23
NA	1.061	1.177	0.45	0.31	0.36
WA	1.084	1.270	0.38	0.74	0.61
KH	1.005	1.091	0.08	0.39	0.28
KM	1.035	1.151	0.05	0.54	0.37
AD	1.012	1.032	-0.07	0.14	0.07

Notes: Period I : 1955-56 to 1965-66;
Period II : 1965-66 to 1984-85;
Full Period : 1955-56 to 1984-85;

Codes: AP : Andhra Pradesh (all districts);
SV : Srikakulam + Vizianagaram + Vishakhapatnam;
EG : East Godavari; KR : Krishna; KU : Kurnool; AN : Anantapur;
WG : West Godavari; CU : Cuddapah; CH : Chittoor; NZ : Nizamabad;
GN : Guntur + Prakasam + Nellore; RH : Ranga Reddy + Hyderabad;
MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; ME : Medak;
KM : Karimnagar; KH : Khammam; AD : Adilabad;

Table 3.6 - Cropwise Shares (%) in Total Cereals Output Within Districts: AP.

District	Year	Rice	Jowar	Bajra	Ragi	Maize
AP	1960-61	63.56655	23.55247	5.15898	5.03300	2.68901
	1970-71	72.22218	14.59598	4.51066	3.47975	5.19143
	1984-85	76.93906	13.54042	2.29198	2.40813	4.82041
SV	1960-61	77.37351	1.66779	9.81276	10.74713	0.39881
	1970-71	81.88612	1.47668	7.39895	8.67818	0.56006
	1984-85	78.05262	0.99967	10.07292	9.75751	1.11728
EG	1960-61	95.85299	1.68455	1.03583	1.29790	0.12873
	1970-71	95.44637	0.67582	2.25141	1.27986	0.34653
	1984-85	98.39040	0.29112	0.89725	0.14283	0.27840
WG	1960-61	97.36620	2.11998	0.15772	0.27016	0.08585
	1970-71	99.05064	0.45582	0.13616	0.22994	0.12744
	1984-85	99.62598	0.19694	0.00242	0.00551	0.16916
KR	1960-61	89.65057	9.91676	0.19245	0.08636	0.15386
	1970-71	96.37809	3.04707	0.21890	0.09544	0.26050
	1984-85	97.26915	2.51954	0.03216	0.00511	0.17404
GN	1960-61	68.92801	20.05499	5.15836	5.64237	0.21627
	1970-71	77.84328	10.58729	8.21079	3.01976	0.23888
	1984-85	87.12458	6.23849	3.34859	3.14083	0.14751
KU	1960-61	17.72240	68.52393	10.17586	3.56641	0.01139
	1970-71	54.34511	42.49202	3.03066	0.09630	0.03591
	1984-85	33.09185	64.48780	2.35939	0.03469	0.02628
AN	1960-61	31.98570	30.18797	16.55515	21.16234	0.10884
	1970-71	46.82689	20.59709	14.47272	17.62039	0.48291
	1984-85	41.60146	37.86092	7.94368	12.06009	0.33384
CU	1960-61	52.10989	28.28951	7.21207	12.24856	0.13996
	1970-71	60.18694	21.41512	10.04445	8.31231	0.04118
	1984-85	49.35551	34.77358	9.39431	6.45909	0.01751
CH	1960-61	64.80991	5.63216	14.12901	15.42858	0.00034
	1970-71	72.70798	3.28777	8.62801	15.26952	0.10671
	1984-85	80.28522	3.90381	4.35534	11.37512	0.08050
RH	1960-61	32.27862	53.75041	4.15954	6.25695	3.55448
	1970-71	48.36192	38.13270	2.42476	5.04210	6.03852
	1984-85	45.13256	43.64924	0.77226	6.73042	3.71552

tes are given at the end of the table.

Table 3.8 Contnd.

District	Year	Rice	Jowar	Bajra	Ragi	Maize
NZ	1960-61	68.19679	21.33400	0.00414	0.87264	9.59244
	1970-71	73.01968	3.94265	0.00000	0.45499	22.58267
	1984-85	67.78912	6.88388	0.06008	0.17331	25.09360
ME	1960-61	30.92789	53.41103	0.62622	2.98382	12.05104
	1970-71	48.85407	25.93918	0.62332	2.10090	22.48252
	1984-85	54.28797	28.90309	0.09121	0.73438	15.98334
MB	1960-61	39.99779	44.76959	6.38698	8.84011	0.00552
	1970-71	34.76951	50.59719	7.55285	7.06680	0.01364
	1984-85	48.00291	39.70813	2.55948	9.39806	0.33142
NA	1960-61	57.99566	27.30825	14.20099	0.12210	0.37300
	1970-71	72.92679	15.39493	11.10142	0.04515	0.53171
	1984-85	88.14692	8.23681	3.34538	0.02894	0.24194
WA	1960-61	46.70345	34.97795	2.80474	0.08781	15.42605
	1970-71	57.84526	25.16877	2.37031	0.02964	14.58604
	1984-85	64.00239	19.23779	1.51086	0.00556	15.24341
KH	1960-61	46.66236	46.27229	1.84996	0.32551	4.88988
	1970-71	70.91661	26.41440	0.49416	0.05204	2.12278
	1984-85	41.65392	54.90211	0.33538	0.00358	3.10502
KM	1960-61	41.19070	30.87610	0.01942	0.03218	27.88160
	1970-71	50.01500	13.53661	0.00424	0.02121	36.42294
	1984-85	62.27327	4.54392	0.00035	0.00000	33.18246
AD	1960-61	17.72231	76.65943	0.01638	0.01001	5.59187
	1970-71	31.59979	55.74327	0.04028	0.00000	12.61666
	1984-85	31.12567	60.70222	0.00925	0.00000	8.16286

Codes: AP : Andhra Pradesh (all districts);
SV : Srikakulam + Vizianagaram + Vishakhapatnam;
EG : East Godavari; KR : Krishna; KU : Kurnool; AN : Anantapur;
WG : West Godavari; CU : Cuddapah; CH : Chittoor; NZ : Nizamabad;
GN : Guntur + Prakasam + Nellore; RH : Ranga Reddy + Hyderabad;
MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; ME : Medak;
KM : Karimnagar; KH : Khammam; AD : Adilabad;

Table 3.7 - Districtwise Shares (%) in State Output, Cropwise.

District	Year	Rice	Jowar	Bajra	Ragi	Maize
SV	1960-61	11.07187	0.64411	17.30155	19.42331	1.34906
	1970-71	10.44085	0.93164	15.10519	22.96555	0.99345
	1984-85	7.39641	0.53828	32.04239	29.54201	1.68989
EG	1960-61	11.57389	0.54897	1.54109	1.97932	0.36745
	1970-71	8.55690	0.29980	3.23178	2.38146	0.43220
	1984-85	12.76238	0.21457	3.90685	0.59191	0.57639
WG	1960-61	12.95471	0.76128	0.25856	0.45399	0.27034
	1970-71	13.76978	0.31355	0.30307	0.66344	0.24647
	1984-85	17.28709	0.19417	0.01409	0.03052	0.46850
KR	1960-61	14.11968	4.21535	0.37347	0.17178	0.57283
	1970-71	11.85718	1.85491	0.43119	0.24370	0.44586
	1984-85	12.12590	1.78474	0.13458	0.02035	0.34629
GN	1960-61	17.80764	13.98380	16.42053	18.41087	1.32085
	1970-71	15.53603	10.44199	26.20452	12.49268	0.66240
	1984-85	16.30221	6.63284	21.03315	18.77659	0.44055
KU	1960-61	1.25201	13.06528	8.85769	3.18212	0.01903
	1970-71	2.87685	11.13018	2.58877	0.10580	0.02645
	1984-85	1.82276	20.18375	4.36259	0.06104	0.02310
AN	1960-61	2.21051	5.63071	14.09727	18.47152	0.17782
	1970-71	2.34600	5.10594	11.60947	18.32188	0.33858
	1984-85	1.21786	6.26777	7.76900	11.22800	0.15524
CU	1960-61	2.69726	3.95203	4.59968	8.00736	0.17126
	1970-71	1.92378	3.38697	5.14055	5.51439	0.01831
	1984-85	1.50965	6.04374	9.64590	6.31220	0.00855
CH	1960-61	5.29059	1.24088	14.21150	15.90710	0.00066
	1970-71	4.69747	1.05104	8.92529	20.47525	0.09592
	1984-85	3.24782	0.89735	5.91445	14.70210	0.05198
RH	1960-61	1.16832	5.25074	1.85508	2.86030	3.04130
	1970-71	1.29594	5.05811	1.04035	2.80424	2.25110
	1984-85	1.31280	7.21438	0.75406	6.25488	1.72500
NZ	1960-61	4.57485	3.86258	0.00342	0.73935	15.21174
	1970-71	4.87852	1.30339	0.00001	0.63092	20.98973
	1984-85	4.09875	2.36504	0.12195	0.33480	24.21879

Notes are given at the end of the table.

Table 3.7 Contnd.

District	Year	Rice	Jowar	Bajra	Ragi	Maize
ME	1960-61	1.82463	8.50449	0.45521	2.22331	16.80687
	1970-71	2.73134	7.17577	0.55798	2.43783	17.48650
	1984-85	2.18804	6.61927	0.12341	0.94587	10.28209
MB	1960-61	2.81545	8.50524	5.53952	7.85907	0.00919
	1970-71	2.55565	18.40209	8.88883	10.78074	0.01395
	1984-85	1.77775	8.35598	3.18194	11.12010	0.19590
NA	1960-61	4.07406	5.17748	12.29180	0.10833	0.61941
	1970-71	5.43301	5.67503	13.24226	0.06981	0.55108
	1984-85	6.74446	3.58108	8.59254	0.07075	0.29547
WA	1960-61	1.97821	3.99862	1.46380	0.04698	15.44599
	1970-71	3.67000	7.90127	2.40787	0.03903	12.87414
	1984-85	2.50096	4.27150	1.98185	0.00694	9.50726
KH	1960-61	1.44438	3.86565	0.70556	0.12728	3.57804
	1970-71	2.81838	5.19432	0.31445	0.04293	1.17385
	1984-85	1.51721	11.36301	0.41007	0.00416	1.80517
KM	1960-61	2.08062	4.16883	0.01197	0.02033	32.97268
	1970-71	3.44862	4.61841	0.00468	0.03035	34.93841
	1984-85	5.16546	2.14167	0.00097	0.00001	43.93177
AD	1960-61	1.08133	12.62395	0.01231	0.00771	8.06551
	1970-71	1.16371	10.15760	0.02375	0.00001	6.46381
	1984-85	1.02250	11.33085	0.01020	0.00001	4.28005

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam;
EG : East Godavari; KR : Krishna; KU : Kurnool; AN : Anantapur;
WG : West Godavari; CU : Cuddapah; CH : Chittoor; NZ : Nizamabad;
GN : Guntur + Prakasam + Nellore; RH : Ranga Reddy + Hyderabad;
MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; ME : Medak;
KM : Karimnagar; KH : Khammam; AD : Adilabad;

Table 3.8 - Output of Different Cereal Crops: AP State & its Districts.

District	Rice: Tonnes 1955-56	Rice: Tonnes 1964-65	Rice: Tonnes 1965-66	Rice: Tonnes 1984-85	Rice: Semi-Log Growth Rate % Period I A	Rice: Semi-Log Growth Rate % Period I B	Rice: Semi-Log Growth Rate % Period II	Rice: Semi-Log Growth Rate % Full Period
AP	3049700.0	4927758.0	3898537.0	6909065.0	4.44	3.97	3.98	3.01
SV	354860.0	572573.0	252460.0	511023.0	5.81	0.00	3.79	0.00
EG	422270.0	541394.0	493194.0	881751.0	1.91	1.65	4.28	2.65
WG	430340.0	609744.0	590921.0	1194376.0	3.74	3.65	4.09	3.50
KR	424790.0	571270.0	467344.0	837786.0	3.46	2.79	3.02	2.15
GN	529300.0	716565.0	560162.0	1126330.0	0.00	0.00	4.42	3.22
KU	54120.0	130876.0	100085.0	125936.0	10.08	9.00	0.00	3.87
AN	76910.0	132298.0	83939.0	84143.0	0.00	0.00	0.00	0.00
CU	63910.0	124575.0	74397.0	104303.0	5.65	0.00	0.00	1.73
CH	146880.0	259023.0	131439.0	224394.0	4.73	0.00	0.00	0.00
RH	34320.0	65606.0	51577.0	90702.0	8.45	6.43	0.00	2.76
NZ	102770.0	181614.0	195317.0	283165.0	5.63	5.66	0.00	0.00
ME	70920.0	131570.0	148410.0	151173.0	5.42	6.04	0.00	0.00
MB	69280.0	159784.0	128498.0	122826.0	7.58	6.19	4.17	2.71
NA	73990.0	190812.0	149585.0	465979.0	9.88	2.76	7.42	5.80
WA	59840.0	181165.0	139060.0	172793.0	0.00	6.57	0.00	3.53
KH	38690.0	128875.0	65349.0	104825.0	11.57	9.94	0.00	4.09
KM	67310.0	158849.0	164076.0	356885.0	8.84	8.61	6.98	5.64
AD	29200.0	71145.0	42724.0	70645.0	6.80	5.20	4.23	3.69

District	Jowar: Tonnes 1955-56	Jowar: Tonnes 1964-65	Jowar: Tonnes 1965-66	Jowar: Tonnes 1984-85	Jowar: Semi-Log Growth Rate % Period I A	Jowar: Semi-Log Growth Rate % Period I B	Jowar: Semi-Log Growth Rate % Period II	Jowar: Semi-Log Growth Rate % Full Period
AP	1131440.0	1119636.0	999838.0	1215919.0	0.00	0.00	0.00	0.00
SV	8030.0	10953.0	8125.0	6545.0	0.00	0.00	0.00	0.00
EG	14790.0	4556.0	5583.0	2609.0	-16.48	-14.16	0.00	-3.80
WG	8610.0	5686.0	5160.0	2361.0	-8.18	-10.68	0.00	-4.49
KR	32270.0	21313.0	20552.0	21701.0	0.00	0.00	0.00	0.00
GN	309820.0	201432.0	143911.0	80650.0	-2.39	-2.93	-2.97	-3.34
KU	178920.0	143593.0	110518.0	245418.0	-4.71	-9.91	3.93	0.00
AN	44360.0	30654.0	29252.0	76211.0	0.00	-16.94	0.00	0.00
CU	40210.0	43399.0	42746.0	73487.0	0.00	0.00	0.00	0.00
CH	9740.0	8194.0	7126.0	10911.0	0.00	0.00	0.00	0.00
RH	24030.0	44445.0	49986.0	87721.0	0.00	-6.50	3.65	0.00
NZ	11870.0	26491.0	29631.0	28757.0	0.00	0.00	0.00	0.00
ME	26160.0	69520.0	76954.0	80485.0	0.00	0.00	0.00	0.00
MB	104950.0	87225.0	133279.0	101602.0	0.00	0.00	0.00	0.00
NA	71750.0	71968.0	48163.0	43543.0	0.00	0.00	0.00	-2.87
WA	50660.0	89432.0	68349.0	51938.0	7.94	5.96	0.00	0.00
KH	87740.0	80206.0	58962.0	138165.0	0.00	0.00	0.00	0.00
KM	37300.0	59409.0	43858.0	26041.0	7.39	0.00	0.00	0.00
AD	70230.0	121160.0	117483.0	137774.0	0.00	0.00	0.00	0.00

Notes are given at the end of the table.

Table 3.8 Contnd.

District	Bajra: Tonnes 1955-56	Bajra: Tonnes 1964-65	Bajra: Tonnes 1965-66	Bajra: Tonnes 1984-65	Bajra: Semi-Log Growth Rate % Period I A	Bajra: Semi-Log Growth Rate % Period I B	Bajra: Semi-Log Growth Rate % Period II	Bajra: Semi-Log Growth Rate % Full Period	Ragi: Tonnes 1955-56	Ragi: Tonnes 1964-65	Ragi: Tonnes 1965-66	Ragi: Tonnes 1984-65	Ragi: Semi-Log Growth Rate % Period I A	Ragi: Semi-Log Growth Rate % Period I B	Ragi: Semi-Log Growth Rate % Period II	Ragi: Semi-Log Growth Rate % Full Period
AP	308830.0	282695.0	237402.0	205618.0	0.00	0.00	0.00	0.00	220120.0	286895.0	229078.0	216248.0	0.00	0.00	0.00	0.00
SV	33840.0	46053.0	43305.0	65949.0	0.00	0.00	2.92	2.15	62240.0	93168.0	67437.0	63884.0	4.04	3.06	0.00	0.00
EG	10560.0	10170.0	6915.0	8041.0	0.00	0.00	0.00	0.00	5800.0	8578.0	5981.0	1280.0	20.67	15.39	0.00	0.00
WG	1420.0	1507.0	880.0	29.0	0.00	0.00	-16.58	-10.26	1790.0	2367.0	1368.0	66.0	7.43	0.00	@	@
KR	2690.0	1533.0	1456.0	277.0	0.00	0.00	0.00	0.00	800.0	1298.0	536.0	44.0	0.00	0.00	-16.54	-9.08
GN	66280.0	80800.0	65113.0	43290.0	0.00	0.00	0.00	0.00	24560.0	33412.0	32204.0	40604.0	0.00	0.00	0.00	0.00
KU	37230.0	18048.0	17535.0	8979.0	0.00	0.00	0.00	0.00	7110.0	7964.0	5629.0	132.0	4.48	0.00	-12.61	-16.68
AN	34900.0	31071.0	13369.0	15990.0	0.00	0.00	0.00	0.00	39820.0	35978.0	29541.0	24276.0	0.00	0.00	0.00	0.00
CU	17900.0	18506.0	11392.0	19853.0	0.00	0.00	0.00	0.00	25830.0	19241.0	23324.0	13650.0	0.00	0.00	0.00	0.00
CH	35250.0	13946.0	13705.0	12173.0	-6.84	-9.56	0.00	0.00	36210.0	45406.0	33320.0	31793.0	0.00	-5.08	0.00	0.00
RH	1760.0	2448.0	2573.0	1552.0	0.00	0.00	0.00	0.00	1760.0	7912.0	4436.0	13526.0	0.00	0.00	0.00	0.00
NZ	0.0	19.0	173.0	251.0	‡	‡	‡	‡	690.0	2040.0	819.0	724.0	0.00	0.00	0.00	0.00
ME	1290.0	1451.0	1709.0	254.0	0.00	0.00	0.00	0.00	2380.0	6192.0	5693.0	2045.0	0.00	0.00	0.00	0.00
MB	17270.0	7968.0	18490.0	6549.0	0.00	0.00	0.00	0.00	10910.0	22817.0	18216.0	24047.0	10.47	9.40	0.00	0.00
NA	42340.0	34771.0	27099.0	17685.0	0.00	0.00	0.00	0.00	70.0	125.0	144.0	153.0	0.00	0.00	0.00	0.00
WA	4970.0	13236.0	12150.0	4079.0	8.16	9.36	0.00	0.00	70.0	142.0	173.0	15.0	0.00	0.20	0.00	-7.23
KH	1010.0	1011.0	1345.0	844.0	0.00	-7.15	0.00	0.00	50.0	174.0	195.0	9.0	‡	‡	‡	‡
KM	100.0	70.0	123.0	2.0	0.00	0.00	0.00	-14.00	30.0	69.0	26.0	0.0	‡	‡	‡	‡
AD	20.0	87.0	70.0	21.0	20.59	18.05	0.00	0.00	0.0	12.0	36.0	0.0	‡	‡	‡	‡

Notes are given at the end of the table.

ıle 3.8 Contnd.

trict	Maize							
	Tonnes				Semi-Log Growth Rate %			
	1955-56	1964-65	1965-66	1984-85	Period I A	Period I B	Period II	Full Period
AP	111870.0	253074.0	179846.0	432869.0	8.16	7.63	5.85	6.20
SV	630.0	2975.0	2080.0	7315.0	20.92	15.63	12.14	7.14
EG	1020.0	1338.0	690.0	2495.0	0.00	0.00	7.67	6.84
WG	650.0	571.0	361.0	2028.0	0.00	0.00	11.42	10.40
KR	2380.0	2301.0	1300.0	1499.0	0.00	0.00	6.11	5.40
GN	3120.0	2786.0	2961.0	1907.0	0.00	0.00	5.27	0.00
KU	10.0	271.0	115.0	100.0	0.00	0.00	0.00	0.00
AN	20.0	174.0	74.0	672.0	@	0.00	0.00	9.09
CU	30.0	61.0	351.0	37.0	0.00	0.00	0.00	0.00
CH	30.0	257.0	26.0	225.0	0.00	0.00	0.00	15.25
RH	1230.0	6882.0	5204.0	7467.0	14.55	12.48	0.00	4.70
NZ	11950.0	48688.0	27787.0	104827.0	11.59	10.43	6.78	8.51
ME	15840.0	52164.0	44677.0	44508.0	9.01	9.40	5.53	4.61
MB	10.0	112.0	412.0	848.0	0.00	0.00	20.89	0.00
NA	970.0	1864.0	1760.0	1279.0	0.00	7.45	0.00	0.00
WA	14600.0	36344.0	27602.0	41154.0	3.19	10.35	@	5.76
KH	3590.0	6726.0	5583.0	7814.0	7.61	6.47	0.00	0.00
KM	44500.0	75166.0	48288.0	190167.0	8.01	6.92	6.49	6.67
AD	11290.0	14394.0	10575.0	18527.0	0.00	0.00	3.92	3.74

es: n.a. : not available;
Period I (A) : 1955-56 to 1964-65; Period I (B) : 1955-56 to 1965-66;
Period II : 1965-66 to 1984-85; Full Period : 1955-56 to 1984-85;
@ : The semilog time trend did not give satisfactory results;
# : For these cases time trends were not estimated due to presence of zero valued observations;

es: AP : Andhra Pradesh (all districts);
SV : Srikakulam + Vizianagaram + Vishakhapatnam;
EG : East Godavari; KR : Krishna; KU : Kurnool; AN : Anantapur;
WG : West Godavari; CU : Cuddapah; CH : Chittoor; NZ : Nizamabad;
GN : Guntur + Prakasam + Nellore; RH : Ranga Reddy + Hyderabad;
MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; ME : Medak;
KM : Karimnagar; KH : Khammam; AD : Adilabad;

Table 3.9 - South-West Monsoon Rainfall (Millimetres): AP State & its Distric

District	Average	1955-56	1960-61	1962-63	1963-64	1965-66	1966-67	1972-73	1973-74	1974-75	1979-80	1984-85
AP	590	671	580	616	565	502	584	372	544	495	479	470
SV	670	1524	1267	1442	1091	1070	1370	1192	1107	1079	2102	2123
EG	695	546	768	845	580	598	648	547	539	647	528	507
WG	738	691	884	901	628	634	745	555	561	647	841	543
KR	692	658	802	840	669	502	727	437	534	560	395	481
GN	420	731	1366	809	802	658	1016	672	1102	1387	903	1054
KU	445	597	451	381	293	375	439	319	383	421	377	358
AN	323	356	327	209	273	268	369	208	379	354	384	256
CU	393	396	387	292	360	325	442	294	458	442	295	326
CH	375	384	411	299	308	234	473	290	403	427	408	392
RH	720	947	566	930	802	751	566	342	565	551	1149	1154
NZ	845	1344	842	1040	1121	850	805	532	903	713	704	709
ME	793	1105	534	1045	823	830	707	416	780	639	608	603
MB	602	871	510	599	701	584	451	325	535	474	454	418
NA	563	594	599	651	565	494	488	243	514	307	443	413
WA	828	818	927	1003	778	853	992	407	729	578	612	581
KH	858	828	658	1025	1010	673	956	536	767	653	505	630
KM	778	1016	573	636	594	738	846	559	748	487	686	591
AD	907	1280	694	854	1202	726	917	522	845	547	748	598

Codes: AP : Andhra Pradesh State (all districts);
SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna;
GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor;
RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mahboobnagar; NA : Nalgonda;
WA : Warangal KH : Khammam; KM : Karimnagar; AD : Adilabad;

Table 3.10 - Area Under Different Cereal Crops: AP State & its Districts.

District	Rice					Jowar					Maize				
	Hectares		Semi-Log Growth Rate %			Hectares		Semi-Log Growth Rate %			Hectares		Semi-Log Growth Rate %		
	1955-56	1984-85	Period I	Period II.	Full Period	1955-56	1984-85	Period I	Period II	Full Period	1955-56	1984-85	Period I	Period II	Full Period
AP	2726918.0	3497542.0	2.06	1.07	0.91	2555325.0	1862280.0	0.00	-1.97	-1.21	189319.0	312950.0	1.16	1.78	2.32
SV	333192.6	430130.0	1.90	0.00	0.00	18990.7	12608.0	0.00	-3.24	0.00	665.3	6138.0	0.00	7.19	3.00
EG	291507.9	362642.0	0.00	1.19	0.70	30360.4	4763.0	-12.18	-5.34	-4.21	1186.1	1504.0	0.00	0.00	2.64
WG	324172.1	439509.0	1.44	1.25	0.80	20111.7	4420.0	-6.05	-5.52	-4.52	653.2	951.0	0.00	5.24	5.36
KR	320203.8	378652.0	1.28	0.00	0.00	103061.8	33283.0	-4.13	-5.56	-3.66	2155.8	1173.0	0.00	0.00	0.00
GN	392028.2	596384.0	0.42	1.37	1.59	382569.1	143790.0	0.00	-4.20	-3.73	2831.1	1510.0	0.00	0.00	2.08
KU	43724.3	73910.0	7.39	0.00	@	351641.4	223315.0	-2.11	-1.91	-1.26	7.7	76.0	0.00	0.00	0.00
AN	66702.0	44039.0	0.00	0.00	0.00	144601.6	67734.0	0.00	-4.06	-2.73	19.0	467.0	0.00	0.00	0.00
CU	55370.8	50754.0	1.79	0.00	0.00	103713.7	64617.0	0.00	0.00	0.00	30.8	32.0	0.00	0.00	0.00
CH	111071.7	109067.0	2.28	0.00	0.00	17907.8	15184.0	0.00	0.00	0.00	35.2	174.0	0.00	0.00	9.79
RH	45729.5	45970.0	0.00	0.00	0.00	92600.7	124419.0	0.00	0.00	-1.07	6257.3	9310.0	0.00	2.02	2.52
NZ	104173.9	144470.0	0.00	0.00	0.00	59131.5	42905.0	0.00	-2.77	-1.65	19538.2	66327.0	3.03	3.32	4.70
ME	96019.9	98490.0	0.00	0.00	0.00	115456.5	146856.0	0.00	0.00	0.00	39985.8	68611.0	2.73	3.06	2.31
MB	107102.6	93238.0	0.00	0.00	0.00	256015.9	255014.0	0.00	0.00	0.00	14.6	609.0	0.00	18.15	0.00
NA	115353.3	220919.0	2.82	2.10	2.51	214364.6	122040.0	0.00	-3.44	-2.51	1705.8	1083.0	0.00	0.00	0.00
WA	107034.6	108229.0	0.00	0.00	0.00	137361.8	122281.0	3.58	-2.05	0.00	33089.6	40046.0	0.00	0.00	1.55
KH	52756.9	76394.0	6.25	0.00	0.00	152877.0	203275.0	3.10	0.00	0.00	6278.7	5439.0	0.00	0.00	0.00
KM	118549.5	160779.0	0.00	0.00	0.00	124835.1	50378.0	0.00	-12.41	@	57665.3	87053.0	0.00	1.09	2.03
AD	42224.5	63966.0	2.76	1.77	1.43	199721.8	225198.0	0.00	0.00	0.00	17199.6	22447.0	0.00	1.49	1.60

Notes are given at the end of the table.

Table 3.10 Contnd.

District	Bajra					Ragi				
	Hectares		Semi-Log Growth Rate %			Hectares		Semi-Log Growth Rate %		
	1955-56	1984-85	Period I	Period II	Full Period	1955-56	1984-85	Period I	Period II	Full Period
AP	651602.9	394595.0	0.00	-1.57	-1.00	318929.0	226080.0	0.00	-1.79	-1.49
SV	63460.8	75606.0	0.00	0.00	0.00	74503.0	69698.0	3.00	0.00	0.00
EG	17698.1	11422.0	0.00	0.00	0.00	7105.0	1130.0	4.82	@	@
WG	2852.7	37.0	0.00	-19.79	-13.67	2220.0	69.0	0.00	@	@
KR	5035.1	357.0	-8.26	-15.09	0.00	994.0	49.0	0.00	-15.19	-9.58
GN	109618.9	64060.0	0.00	-1.85	-1.06	37490.0	20806.0	0.00	-1.77	0.00
KU	43304.8	30751.0	0.00	0.00	0.00	8820.0	138.0	0.00	-13.60	-17.68
AN	88786.9	32766.0	-2.37	-3.12	-2.69	41777.0	16282.0	0.00	0.00	-2.60
CU	43204.7	15870.0	0.00	0.00	-2.42	20092.0	7738.0	0.00	-4.84	-3.40
CH	63655.5	15846.0	-5.48	-4.11	-4.11	64152.0	37836.0	-1.54	-1.75	-2.18
RH	9659.5	7355.0	-3.22	0.00	0.00	8952.0	13659.0	1.67	0.00	0.00
NZ	5.3	1191.0	#	#	#	2990.0	1185.0	-1.68	-3.67	-2.41
ME	4023.8	1202.0	4.59	0.00	0.00	11264.0	5036.0	-1.90	-3.90	-2.94
MB	50230.1	31701.0	-2.76	-4.56	0.00	37619.0	44312.0	0.00	0.00	0.00
NA	127393.1	84619.0	0.00	-2.23	0.00	227.0	107.0	0.00	0.00	0.00
WA	17533.8	17013.0	0.00	0.00	1.17	252.0	24.0	5.40	0.00	-7.15
KH	5235.8	4002.0	-3.24	0.00	0.00	194.0	15.0	#	#	#
KM	203.3	8.0	0.00	0.00	-12.73	136.0	0.0	#	#	#
AD	74.9	99.0	14.63	0.00	0.00	2.0	0.0	#	#	#

Notes: Period I : 1955-56 to 1965-66; Period II : 1965-66 to 1984-85; Full Period : 1955-56 to 1984-85;

@ : The semilog time trend did not give satisfactory results; n.a. : not available;

: For these cases time trends were not estimated due to presence of zero valued observations;

Codes: AP : Andhra Pradesh State (all districts);

SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna;

GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor;

RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda;

WA : Warangal KH : Khammam; KM : Karimnagar; AD : Adilabad;

Table 3.11 - Yields of Cereal Crops: AP State & its Districts.

District	Rice					Jowar					Maize				
	Kg/Ha		Semi-Log Growth Rate %			Kg/Ha		Semi-Log Growth Rate %			Kg/Ha		Semi-Log Growth Rate %		
	1955-56	1984-85	Period I	Period II	Full Period	1955-56	1984-85	Period I	Period II	Full Period	1955-56	1984-85	Period I	Period II	Full Period
AP	1118.369	1975.406	1.64	2.90	2.14	442.777	652.920	0.00	2.39	0.00	590.907	1383.189	6.51	3.62	3.88
SV	1065.030	1188.066	0.00	3.63	0.00	422.839	519.115	0.00	0.00	0.00	946.941	1191.756	0.00	5.66	4.10
EG	1448.571	2431.492	0.00	3.60	2.04	487.148	547.764	0.00	0.00	0.00	859.961	1658.910	2.80	5.95	4.37
WG	1327.505	2717.523	2.21	2.84	2.76	428.109	534.163	-4.21	0.00	0.00	995.101	2132.492	0.00	6.18	4.65
KR	1326.624	2212.549	1.72	2.54	1.98	313.113	652.015	0.00	0.00	0.00	1103.999	1277.920	0.00	5.74	4.51
GN	1350.158	1888.559	0.00	3.09	1.66	809.841	560.887	-2.20	0.00	0.00	1102.045	1262.914	0.00	5.87	4.44
KU	1237.756	1703.310	0.00	2.11	1.98	508.814	098.977	0.00	5.62	2.58	1298.701	1315.789	0.00	5.53	4.17
AN	1153.039	1910.647	2.92	0.00	1.39	306.774	125.151	-8.84	5.46	2.53	1052.632	1438.972	0.00	5.39	4.36
CU	1154.219	2055.070	0.00	2.61	1.88	387.702	133.761	0.00	0.00	2.72	974.026	1156.250	0.00	5.68	4.59
CH	1322.389	2057.396	0.00	1.96	1.49	543.897	718.585	0.00	0.00	0.00	852.273	1293.103	0.00	5.62	5.84
RH	750.500	1973.089	5.17	2.70	3.09	259.501	705.045	0.00	3.18	0.00	196.570	802.041	11.26	0.00	0.00
NZ	986.523	1960.165	4.66	0.00	2.37	200.739	670.248	0.00	0.00	0.00	611.622	1560.457	7.80	0.00	3.71
ME	738.597	1534.907	5.73	0.00	2.91	226.575	548.054	0.00	0.00	0.00	396.141	648.701	6.67	0.00	0.00
MB	646.856	1317.338	4.70	2.23	2.18	366.938	398.417	0.00	0.00	0.00	684.932	1392.447	0.00	3.76	3.31
NA	641.421	2109.275	4.91	4.53	3.54	334.710	356.793	0.00	0.00	0.00	568.648	1180.979	7.33	0.00	3.65
WA	559.072	1596.550	0.00	2.92	2.46	368.807	424.743	0.00	0.00	0.00	441.226	1027.668	10.70	8	4.40
KH	733.364	1372.163	0.00	2.94	2.78	573.925	679.695	0.00	0.00	0.00	571.774	1436.661	0.00	3.38	0.00
KM	567.780	2219.724	7.68	4.09	3.83	298.794	516.912	0.00	2.79	0.00	771.695	2184.497	6.47	4.77	4.54
AD	691.542	1104.415	0.00	2.46	2.27	351.639	611.791	0.00	0.00	0.00	656.411	825.366	0.00	0.00	2.15

Notes are given at the end of the table.

District	Bajra					Ragi				
	Kg/Ha		Semi-Log Growth Rate %			Kg/Ha		Semi-Log Growth Rate %		
	1055-56	1984-85	Period I	Period II	Full Period	1955-56	1984-85	Period I	Period II	Full Period
AP	473.765	521.593	0.00	0.00	0.00	690.105	958.511	0.00	1.08	1.07
SV	533.243	872.272	0.00	2.25	1.89	834.735	918.609	0.00	0.00	0.00
EG	598.742	703.992	0.00	0.00	0.00	807.215	1132.743	5.26	0.00	0.00
WG	535.304	783.784	0.00	2.34	1.73	806.270	956.522	0.00	0.00	0.00
KR	534.250	775.910	0.00	2.45	2.15	804.910	897.959	0.00	0.00	0.00
GN	604.640	875.773	0.00	0.00	0.00	655.113	1409.568	0.00	3.03	1.88
KU	859.724	291.991	0.00	0.00	0.00	806.150	956.522	0.00	2.15	0.00
AN	393.076	488.006	0.00	0.00	0.00	953.167	1490.972	0.00	0.00	2.37
CU	414.307	250.977	0.00	4.76	3.42	285.507	1764.478	0.00	2.89	2.78
CH	553.762	778.028	5.12	0.00	0.00	564.437	840.204	0.00	0.00	0.00
RH	182.204	211.013	0.00	0.00	0.00	198.611	990.263	0.00	0.00	0.00
NZ	0.000	210.747	#	#	#	230.754	610.970	0.00	0.00	0.00
ME	320.592	211.314	0.00	0.00	0.00	211.293	408.078	0.00	0.00	0.00
MB	343.763	208.002	0.00	0.00	0.00	290.011	542.875	0.00	0.00	0.00
NA	332.357	208.998	0.00	0.00	0.00	307.028	1429.908	0.00	7.80	4.15
WA	283.453	228.880	8.22	0.00	0.00	278.108	825.000	0.00	0.00	0.00
KH	192.903	210.895	0.00	0.00	0.00	257.487	800.000	#	#	#
KM	352.903	250.000	0.00	0.00	0.00	219.941	0.000	#	#	#
AD	207.023	212.121	0.00	0.00	0.00	0.000	0.000	#	#	#

Notes: Period I : 1955-58 to 1965-66; Period II : 1965-66 to 1984-85; Full Period : 1955-56 to 1984-85;

@ : The semilog time trend did not give satisfactory results; n.a. : not available;

: For these cases time trends were not estimated due to presence of zero valued observations;

Codes: AP : Andhra Pradesh State (all districts);

SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna;

GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor;

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WA : Warangal KH : Khammam; KM : Karimnagar; AD : Adilabad;

District	Rice					Jowar		Bajra		Ragi		Maize				
	Hectares		Semi-Log Growth Rate %			Hectares		Hectares		Hectares		Hectares		Semi-Log Growth Rate %		
	1955-56	1984-85	Period I	Period II	Full Period	1955-56	1984-85	1955-56	1984-85	1955-56	1984-85	1955-56	1984-85	Period I	Period II	Full Period
AP	2549784.0	3306484.0	1.77	1.14	1.00	38726.0	14090.0	72883.0	47510.0	152260.0	73772.0	24690.0	83953.0	1.39	3.41	4.18
SV	303265.0	371467.0	3.28	0.00	0.00	1345.0	0.0	6912.0	0.0	29495.0	9916.0	114.0	116.0	#	#	#
EG	264623.0	347032.0	0.91	1.26	0.90	59.0	212.0	61.0	0.0	139.0	0.0	0.0	217.0	#	#	#
WG	294359.0	434482.0	1.55	1.45	1.01	10.0	74.0	2.0	1.0	213.0	0.0	1.0	681.0	#	#	#
KR	317904.0	376920.0	0.00	0.00	0.00	0.0	0.0	0.0	0.0	34.0	0.0	26.0	293.0	#	#	#
GN	373848.0	582777.0	1.85	1.58	1.93	22539.0	3121.0	41160.0	32232.0	33903.0	28197.0	3.0	221.0	33.41	0.00	9.46
KU	36250.0	65926.0	8.01	0.00	@	1104.0	3164.0	4379.0	123.0	7312.0	15.0	5.0	56.0	0.00	0.00	8.09
AN	66369.0	44019.0	0.00	0.00	0.00	5916.0	3234.0	64.0	1109.0	35133.0	15517.0	5.0	125.0	0.00	0.00	14.41
CU	54803.0	50681.0	1.74	0.00	0.00	1353.0	772.0	10338.0	9085.0	19426.0	7681.0	1.0	32.0	#	#	#
CH	104115.0	100456.0	0.00	0.00	0.00	5040.0	2229.0	9867.0	3653.0	26171.0	11094.0	7.0	155.0	30.00	6.63	14.20
RR	39497.0	40132.0	0.00	0.00	0.00	198.0	245.0	0.0	21.0	18.0	0.0	53.0	651.0	0.00	14.05	9.61
NZ	100254.0	135428.0	0.00	0.00	0.00	0.0	222.0	0.0	1183.0	0.0	1.0	943.0	9031.0	0.00	7.16	7.40
ME	88895.0	88840.0	0.00	0.00	0.00	291.0	0.0	0.0	0.0	4.0	0.0	493.0	1774.0	0.00	0.00	7.95
MB	98947.0	85661.0	0.00	0.00	0.00	437.0	45.0	70.0	85.0	230.0	1298.0	0.0	119.0	#	#	#
NA	115308.0	220919.0	2.77	2.10	2.52	31.0	5.0	6.0	0.0	180.0	53.0	217.0	1.0	#	#	#
WA	102920.0	102406.0	0.00	0.00	0.00	2.0	0.0	1.0	11.0	2.0	0.0	13275.0	10958.0	-3.30	0.00	0.00
KH	49697.0	60580.0	2.61	0.00	0.00	0.0	0.0	21.0	0.0	0.0	0.0	196.0	1095.0	0.00	0.00	3.86
KM	111992.0	158903.0	0.00	0.00	0.00	0.0	343.0	0.0	1.0	0.0	0.0	8901.0	34939.0	6.14	3.50	5.24
AD	26742.0	39855.0	0.00	0.00	1.89	402.0	424.0	0.0	6.0	0.0	0.0	453.0	3499.0	0.00	6.26	7.82

Notes: Period I : 1955-56 to 1965-66; Period II : 1965-66 to 1984-85; Full Period : 1955-56 to 1984-85;

Semilog time trends were not estimated for jowar, bajra & ragi due to presence of zero valued observations for these crops in all districts (see text).

: For these cases time trends were not estimated due to presence of zero valued observations;

@ : The semilog time trend did not give satisfactory results; n.a. : not available;

Codes: AP : Andhra Pradesh State (all districts);

SV : S[illegible] + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna;

GN : [illegible] + Prakasam [illegible]; [illegible]; [illegible]pur; CU : Cuddapah; CH : Chittoor;

RR : [illegible]ddy + Hyderabad; [illegible]; [illegible]; MB : Mehboobnagar; NA : Nalgonda;

WA : [illegible]

	Rice				Jowar				Bajra				Ragi				Maize			
	1955-56	1964-65	1965-66	1984-85	1955-56	1964-65	1965-66	1984-85	1955-56	1964-65	1965-66	1984-85	1955-56	1964-65	1965-66	1984-85	1955-56	1964-65	1965-66	1984-85
AP	93.50	91.85	92.68	94.54	1.52	0.51	0.94	0.76	11.18	8.45	10.18	12.04	47.74	37.66	39.64	32.63	13.04	13.43	13.86	20.44
SV	91.02	89.26	97.58	86.36	7.08	0.00	0.00	0.00	10.89	0.00	0.00	0.00	39.56	22.15	20.58	14.23	17.14	3.25	0.84	1.39
EG	90.78	90.07	91.88	95.70	0.19	0.02	2.00	4.45	0.34	0.24	0.20	0.00	1.93	0.77	0.66	0.00	0.00	0.09	3.74	14.43
WG	90.80	92.91	94.26	98.86	0.05	0.28	0.06	1.67	0.08	0.00	0.11	2.70	9.59	2.13	5.38	0.00	0.15	7.94	7.61	71.61
KR	99.28	96.16	98.48	99.54	0.00	0.00	0.19	0.00	0.00	0.26	4.09	0.00	3.42	2.54	1.94	0.00	1.21	5.64	9.03	24.98
GN	95.36	91.10	91.56	97.72	5.89	0.91	1.57	2.17	37.55	27.87	30.25	50.32	90.43	91.22	93.03	97.89	0.11	7.12	3.77	14.64
KU	82.91	89.95	87.25	89.20	0.31	0.54	1.05	1.42	10.11	9.47	10.90	0.40	82.90	82.07	85.27	10.87	64.94	9.03	88.66	73.63
AN	99.50	96.42	94.69	99.95	4.09	3.55	6.44	4.77	0.07	0.07	0.13	3.38	84.10	83.13	80.10	95.30	25.32	33.71	27.09	26.77
CU	98.97	96.80	96.98	99.86	1.30	1.79	1.95	1.19	23.93	37.06	37.70	57.25	96.69	96.93	99.07	99.29	3.25	86.35	99.79	100.00
CH	93.74	92.10	87.81	92.10	28.14	5.43	17.53	14.68	15.50	15.83	16.52	23.35	40.80	29.22	35.65	29.32	19.89	73.47	73.72	89.08
RR	96.37	83.32	86.82	87.30	0.21	0.17	0.18	0.20	0.00	0.00	0.00	0.29	0.20	0.49	0.72	0.00	0.65	0.46	0.54	6.99
NZ	96.24	94.53	94.10	93.74	0.00	0.00	0.00	0.52	0.00	0.00	0.00	99.33	0.00	0.00	0.00	0.08	4.63	3.03	5.99	13.62
ME	92.58	93.65	90.53	90.20	0.25	0.05	0.20	0.00	0.00	0.49	0.04	0.00	0.04	0.00	0.13	0.00	1.23	0.49	0.92	2.59
MB	92.39	89.96	92.38	91.87	0.15	0.07	0.11	0.02	0.14	0.00	0.00	0.27	0.61	0.41	0.83	2.93	0.00	2.19	0.00	19.54
NA	99.96	99.65	99.77	100.00	0.01	0.02	0.23	0.00	0.00	0.00	0.00	0.00	79.30	50.46	58.96	49.53	12.72	7.88	4.92	0.09
WA	96.16	94.99	96.19	94.62	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.06	0.79	0.00	17.31	0.00	40.12	31.44	28.74	27.36
KH	94.20	67.46	68.01	79.30	0.00	0.00	0.00	0.00	0.40	0.00	0.08	0.00	0.00	0.00	0.00	0.00	3.12	5.88	5.84	20.13
KM	94.47	100.00	95.25	98.83	0.00	0.00	0.13	0.68	0.00	0.00	0.00	12.50	0.00	7.50	1.61	0.00	15.44	22.78	27.58	40.14
AD	63.33	55.27	56.66	62.31	0.20	0.00	0.00	0.19	0.00	0.00	0.00	6.06	0.00	0.00	0.00	0.00	2.63	4.39	5.68	15.59

Codes: AP : Andhra Pradesh State (all districts);
SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna; GN : Guntur + Prakasam + Nellore;
KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor; RR : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak;
MB : Mehboobnagar; NA : Nalgonda; WA : Warangal KH : Khammam; KM : Karimnagar; AD : Adilabad;

Table 3.14 - Fertilizer Intensity Over Cereal Crops: AP State & its Districts.

District	Kg/Ha. 1965-66	Kg/Ha. 1984-85	Semi-Log Growth Rate % Period II	Semi-Log Growth Rate % Full Period
AP	9.4	104.4	8.80	9.88
SV	8.0	45.2	8.82	9.74
EG	21.4	101.0	6.52	7.57
WG	20.6	184.1	7.19	7.22
KR	18.6	138.3	6.40	7.57
GN	11.1	220.2	10.66	11.19
KU	6.2	81.6	6.88	10.14
AN	1.2	48.0	9.53	14.02
CU	7.0	109.1	9.15	11.34
CH	6.8	95.2	7.94	10.78
RH	6.0	55.4	0.00	0.00
NZ	28.6	169.8	9.56	9.35
ME	6.2	48.7	10.32	11.23
MB	2.4	54.3	12.78	14.54
NA	2.9	76.9	14.33	16.65
WA	5.2	79.1	12.56	15.69
KH	4.8	71.8	13.47	16.00
KM	4.9	85.0	12.64	14.22
AD	2.5	21.8	11.76	13.22

Notes: Period I : No data are available;
Period II : 1965-66 to 1984-85; Full Period : 1960-61 to 1984-85;

Codes: AP - Andhra Pradesh (all districts);
SV - Srikakulam + Vizianagaram + Vishakhapatnam;
EG - East Godavari; KR - Krishna; KU - Kurnool; AN - Anantapur;
WG - West Godavari; CU - Cuddapah; CH - Chittoor; NZ - Nizamabad;
GN - Guntur + Prakasam + Nellore; RH - Ranga Reddy + Hyderabad;
MB - Mehboobnagar; NA - Nalgonda; WA - Warangal; ME - Medak;
KM - Karimnagar; KH - Khammam; AD - Adilabad;

Table 3.15 – Cropping Pattern and High Yielding Varieties (HYV) Adoption Rates.

A) Cropping Pattern: Average percentage in 5 cereals acreage: AP State & its Districts.

	1955-56 to 1964-65					1965-66 to 1974-75					1975-76 to 1984-85					1955-56 to 1984-85				
	Rice	Jowar	Bajra	Ragi	Maize	Rice	Jowar	Bajra	Ragi	Maize	Rice	Jowar	Bajra	Ragi	Maize	Rice	Jowar	Bajra	Ragi	Maize
AP	45.2	38.0	9.1	4.9	2.8	46.6	37.3	8.2	4.3	3.6	53.2	31.0	7.4	3.9	4.5	48.3	35.4	8.2	4.4	3.7
SV	69.2	3.7	12.3	14.3	0.5	69.6	4.1	11.9	14.0	0.4	69.6	3.1	13.1	13.2	1.0	69.4	3.6	12.5	13.8	0.6
EG	87.6	5.1	5.1	2.0	0.3	89.3	3.7	4.5	2.0	0.4	92.5	1.9	4.0	1.1	0.4	89.8	3.6	4.5	1.7	0.4
WG	94.4	4.4	0.6	0.5	0.1	95.6	3.3	0.4	0.5	0.2	97.6	1.8	0.1	0.2	0.3	95.9	3.2	0.4	0.4	0.2
KR	78.1	20.6	0.7	0.2	0.3	81.6	17.2	0.7	0.1	0.4	88.0	11.0	0.6	0.1	0.4	82.6	16.2	0.7	0.1	0.4
GN	46.2	38.9	10.9	3.7	0.3	55.4	30.1	10.4	3.9	0.2	66.5	20.5	9.2	3.6	0.2	56.0	29.8	10.2	3.7	0.2
KU	15.4	74.6	7.8	1.9	0.2	21.8	70.9	6.5	0.7	0.1	24.9	66.8	8.1	0.1	0.1	20.7	70.8	7.5	0.9	0.1
AN	18.6	45.9	23.3	12.0	0.1	21.8	47.2	20.7	10.1	0.2	27.0	40.4	20.3	12.0	0.4	22.5	44.5	21.4	11.4	0.2
CU	28.3	45.8	17.3	8.5	0.1	32.0	47.6	12.0	8.4	0.3	33.4	48.0	12.8	5.8	0.1	31.2	47.1	14.0	7.6	0.1
CH	48.7	7.4	19.9	23.9	0.1	57.8	6.1	14.9	21.1	0.1	61.2	7.5	11.2	20.1	0.1	55.9	7.0	15.3	21.7	0.1
RH	29.9	56.0	4.9	6.1	3.1	23.0	61.7	5.2	6.2	3.9	24.7	59.7	4.2	6.9	4.5	25.9	59.1	4.7	6.4	3.8
NZ	56.7	31.3	0.1	1.5	10.5	50.6	29.8	0.1	1.0	18.6	56.0	20.0	0.4	0.8	22.9	54.4	27.0	0.2	1.1	17.3
ME	35.5	45.9	1.5	3.9	13.3	28.9	50.3	1.6	3.3	15.8	31.4	45.7	1.6	2.3	18.9	32.0	47.3	1.6	3.2	16.0
MB	24.5	58.0	9.2	8.2	0.1	19.3	62.7	10.3	7.6	0.1	25.6	56.9	8.9	8.7	0.1	23.1	59.2	9.5	8.2	0.1
NA	27.8	45.9	25.9	0.1	0.3	34.7	39.8	25.1	0.1	0.3	48.3	28.9	22.5	0.1	0.3	36.9	38.2	24.5	0.1	0.3
WA	37.4	47.4	5.1	0.1	10.1	31.1	51.9	5.3	0.1	11.6	38.4	42.1	6.2	0.0	13.2	35.6	47.1	5.5	0.1	11.6
KH	30.2	65.5	1.6	0.1	2.6	28.3	67.7	1.6	0.1	1.2	36.3	59.5	2.7	0.0	1.2	31.6	64.2	1.8	0.1	2.3
KM	41.2	39.4	0.1	0.2	19.3	36.2	38.6	0.1	0.1	25.2	47.8	25.4	0.0	0.0	26.8	41.7	34.4	0.1	0.0	26.8
AD	18.3	75.6	0.1	0.0	6.0	17.9	75.4	0.8	0.0	6.6	20.5	72.4	0.1	0.0	7.1	18.9	74.5	0.1	0.0	6.6

B) HYV adoption rates: AP State.

Crop	HYV Intensity (%) 1966-67	HYV Intensity (%) 1984-85
Rice	8.30	80.7
Jowar	1.40	28.5
Bajra	0.50	77.9
Maize	4.40	63.1

CHAPTER 4 – REVIEW OF LITERATURE

"Things not understood are admired!"
– Thomas Fuller.

4.1 Introduction.

Several scholars have studied the problem of growth, stability and variability of crop outputs and yields for India as well as for various other countries. Some of the noteworthy studies at the international level include Barker, et.al 1981) for the USA, Mexico, Indonesia, Philippines, Pakistan and Sri Lanka; Hazell (1984) for USA & India; Hazell (1985) for the World; Alauddin & Tisdell (1988) for Bangladesh; etc. Studies for India include the works of Sen (1967), Nadkarni (1971), Minhas and Vaidyanathan (1965), Srinivasan (1979), Mehra (1981), Rudra (1982), Nadkarni and Deshpande (1982), Hazell (1982), Ray (1983), Dev (1987, 1989), Majumdar et.al (1988), Dhawan (1988), Anderson and Hazell (1989), Rao, Ray and Subbarao (1989), and so on to name a few. In this review we concentrate on some of the past studies on India though some of the important international studies will also be referred to.

With the introduction of the modern high yielding variety seeds – fertilizers – irrigation based modern (Green Revolution) technology, the concern for growth led some scholars to study the impact of the new technology on growth of output & yields. The question posed here is: did the modern technology bring about an acceleration in the growth of output and yields?

A few studies are essentially concerned with the problem of fluctuations in crop output and/or yields in an environment of overall growth; that is, the year to year changes around growing mean output/yield levels. The fluctuations are usually referred to in the literature as instability (often also as variability). Thus the relationship between growth and instability is the subject matter of these studies.

Almost simultaneously, some other scholars concerned with stability of crop output/yields studied the role of technology on stability. Specifically, the question of interest is: did the modern technology lead to increased instability in crop outputs/ yields? If so, what is the role of various inputs in increasing/ decreasing instability?

Let us first review some of the studies on agricultural growth.

4.2 Growth.

The growth performance of crop outputs and yields for India have been studied notably by Minhas and Vaidyanathan (1965), Srinivasan (1979) and Rudra (1982), amongst many.

The study by Minhas and Vaidyanathan (1965) is one of the earliest attempts at assessing the growth performance of Indian agriculture. Growth between 1951-54 and 1958-61 was assessed using index numbers of aggregate crop output. The study was done at the all India level and for 14 States and 268 districts of the country. They find that aggregate crop output in India grew at an annual compound rate of 3.57% between 1951-54 and 1958-61. Growth was found to be higher than the national average in 7 States (Punjab, Madras, Gujarat, Mysore, Rajasthan, Kerala & Madhya Pradesh) while it was lower than the national average in 7 other States (Maharashtra, Andhra Pradesh, Bihar, Uttar Pradesh, Assam, Orissa & West Bengal).

Using an additive decomposition scheme, they identify 4 sources of growth of aggregate crop output:

a) changes in area;

b) changes in yields;

c) changes in cropping pattern (over 28 crops); and

d) interaction between yields and cropping pattern.

They find that between 1951-54 and 1958-61, growth of aggregate crop output in India came equally from growth in area and growth in yields, both of which together account for about 90% of the growth in output. In individual States, however, the contribution to growth of output by different components vary. In some States (Punjab, Rajasthan, Assam & West Bengal) area increases, while in other States (Kerala, Madras, Madhya Pradesh, Mysore & Bihar) yields rise were responsible for output growth. Cropping pattern changes were found to be important in Punjab, Madras, Gujarat, Maharashtra, Andhra Pradesh, Bihar, Uttar Pradesh & West Bengal. The interaction term in general had negligible impact on output growth.

Srinivasan (1979) analysed the impact of the modern technology on agricultural growth in India. He estimated trends in area, production and yields of rice, jowar, maize, bajra, wheat, cereals, gram, pulses, foodgrains, ground nut, oil seeds, cotton, jute, fibres, sugarcane, tea, tobacco, non-food crops, and all crops, over the period 1949-50 to 1977-78 and in the sub-periods: 1949-50 to 1964-65, 1965-66 to 1977-78 and 1967-68 to 1977-78. Two trend functions are considered: (1) $\mathrm{Log}(Y_t) = \alpha_0 + \alpha_1 \times t$; and (2) $\mathrm{Log}(Y_t) = \beta_0 + \beta_1 \times t + \beta_2 \times t^2$. Shifts in growth path between sub-periods are then assessed using F-tests, while constant or changing growth is tested by the t-test for significance of β_2. His results show that, the rate of growth of gross sown area declined since 1967-68 for most crops and crop aggregates, the exception being wheat. Output & yields of food crops as a whole showed more or less uniform growth over the full period, without any acceleration/deceleration since 1967-68. Amongst individual crops only wheat witnessed an acceleration in the growth of both output & yield since 1967-68, while the rest of the crops including rice, did not show any marked increase in growth rates of both output & yield. Thus, he says, "there is as yet no green revolution but it is still a wheat revolution".

Rudra (1982) also reaches similar conclusions regarding the impact of modern technology on agricultural growth. He analyses trends in foodgrains and overall agricultural output (as measured by corresponding indices) at the all India level, in two periods, 1947-48 to 1964-65 & 1950-51 to 1973-74 using exponential/semilog, linear & gompertz trends. These trends indicate a fairly continuous but declining growth in both foodgrains and agricultural (all crops) output over the period 1947-48 to 1973-74. Further analysis of rice and wheat outputs and yields at the State level shows that growth rates of wheat output and yield in both Punjab & Uttar Pradesh have registered substantial increase from around 1966-67; while rice output & yields in West Bengal and Andhra Pradesh show fairly continuous but declining growth. From these results he concludes that "there has indeed been breakthroughs in production conditions for some crops and in some regions but no such thing has taken place for all crops and in all regions".

It may be noted here that the above mentioned studies of Srinivasan (1979) and Rudra (1982) are concerned with the effect of modern technology on growth without any reference to the problem of variability/instability in outputs/yields. However, as we shall see later (section 4.4), the problem of instability of output/yields has been of interest even prior to these studies.

4.3 Instability.

The issue of stability of crop outputs and yields has been of concern not only to agricultural economists but also to plant breeders and agronomists in general. However, the agronomists are generally concerned with the stability of yield levels of a specific hybrid variety of seed (IR8, Swarna, etc.) obtained in different environments. Whereas, economists are more concerned with yield performance in general that includes growth over time, variations in yield levels around trends, etc. Obviously this distinction meant that the data used by agronomists and agricultural economists are also different.

Plant breeders, before releasing any particular variety of seed to farmers on commercial basis, conduct repeated experiments growing that seed at different locations in different environments. Thus the interest is in stable yield levels.

Various definitions of stability seem to be in use by agronomists and plant breeders. According to Bhatia (1991) there is a "biological concept of stability" which refers to the characteristics of a genotype that shows a near constant yield under different growing environments. This concept of stability, he points out, implies that yields would not respond to improved growing conditions. Hence, this biological concept of stability is of little use.

An alternative definition of stability is called the "agronomic concept of stability" based on the concept of "ecovalence". Ecovalence refers to the extent of the lack of correspondence between the effects of genetic and non-genetic factors on yields also known as the genotype-environment (GE) interaction. Lesser the ecovalence, more stable is the crop performance. A discussion of the various other measures of stability used by agronomists are provided in Bhatia (1991) and Chetty (1991).

As Vaidyanathan (1992) points out, the agronomists' concern seems to be the "predictability of performance across different environments". Economists are concerned more on crop performance within an environment (as found in a region) as reflected in the year to year fluctuations in crop output/yield around the mean level (which may be growing) over time, in a region.

This thesis is not in agronomic perspective but only of agricultural economics. Hence we review here, only the studies on stability/variability of crop output/yield over time as viewed by economists. Several studies used the terms instability and variability generally interchangeably to refer to the existence of year to year fluctuations in output/yield. In this review too, these two terms are used interchangeably to refer to the same phenomenon, namely, year to year fluctuations in crop output/-yields. However, in the next chapter and in the rest of this thesis a distinction will be made between "instability" and "variability" since we believe that variance, to which "variability" refers to, is just one of many aspects of a crop output/yield performance.

Let us first note some general features of the past studies on this problem before discussing them in detail.

In most of the past studies the problem of instability/ variability is posed for a given region (whatever be its level of geographical aggregation) over a period of time. The analysis is based on time series data for that region, usually covering a few years prior to and after the introduction of the new technology and making a comparative study of stability over time in different regions.

The scope of the past studies on this problem differs widely. Some studies have concentrated on analysing crop outputs over time; for example in Sen (1967), Ray (1983), Hazel (1982, 1984, 1985), etc. On the other hand some have analysed crop yields over time; for example Nadkarni (1971), Mehra (1981), Barker et.al (1981), Majumdar et.al (1988).

Though some studies have analysed the problem for individual crops (examples include Nadkarni (1971), Mehra (1981), Barker et.al (1981), Majumdar et.al (1988), etc.), some have analysed for certain crop groups like cereals, foodgrains, all crops, etc. (like in the case of Sen (1967), Hazell (1982, 1984, 1985), Ray (1983), Dhawan (1988), etc.

Also, the level of geographical aggregation covered in these studies varies a lot. Some are at the national level like in Sen (1967), Mehra (1981), etc., while some are at the level of State/ District or for a region, like in Nadkarni (1971), Barker et.al (1981), Majumdar et.al (1988), etc.

It may be noted here that some studies like Sen (1967), Nadkarni (1971), Parthasarathy (1984), etc., have studied only the relationship between growth and instability without any specific reference to the technology. Here the question is: does growth lead to increased output/yield instability? Other studies like Barker et.al (1981), Mehra (1981), Hazell (1982), etc., have studied the role of technology on instability of output/yield. We first review the studies on the relationship between growth and instability.

4.4 Growth & Instability.

Sen (1967) was the first to raise the problem of growth and instability in Indian agriculture. He studied this problem using two independent data sets, one on foodgrains production in undivided India over the 48 years from 1900-01 to 1947-48 and the other for the Indian Union over the 30 years from 1936-37 to 1965-66. The 2 sample periods were divided into half each. The data for undivided India shows a growth in foodgrains output in the first 24 years 1900-01 to 1923-24 at an average annual rate of 0.3% while in the next 24 years 1924-25 to 1947-48 the foodgrains output remained stagnant. Instability in production is analysed through trends fitted separately to the peaks and troughs of output and also from the extent of fluctuations between peaks and troughs. From this he finds that instability increased during the period of growth (1900-01 to 1923-24) as shown by the divergent trends in peaks and troughs; while during the period of stagnation (1924-25 to 1947-48) instability declined as shown by the convergent trends in peaks and troughs. A similar but striking pattern was observed in the 30 years data for the Indian Union, which shows a fall in both output and its instability in the first 15 years 1936-37 to 1950-51 while in the next 15 years 1951-52 to 1965-66 both output and its instability show increasing trends. From this he concluded that "instability tended to increase with the rate of growth". Observing that output growth during the 2 periods was mainly due to acreage extension and also due to increase in use of inputs like fertilizers, he suggests that instability increases when growth is achieved by bringing under cultivation relatively marginal lands that are prone to the adverse effects of droughts. Also when inputs like fertilizers are used more intensively, the risk of loss tends to increase under drought conditions thereby increasing instability.

Nadkarni (1971), however, presents 2 sets of results on the relation between growth and instability (which he calls as uncertainty), one at the State level for Maharashtra that is contrary to Sen's conclusions, and the other at the districts level for Maharashtra that is supportive of Sen's results. He analysed the yields of 8 crops (sugarcane, rice, wheat, jowar, bajra, ground nut, tur & cotton) at the State level, and of cotton alone at the districts level, over the period 1951-52 to 1968-69. Defining uncertainty as deviations from normal yields, yield uncertainty is measured using the coefficient of variation (CV) around (1) simple arithmetic mean, (2) bulk average that ignores extreme values, (3) linear trend values, and (4) 5-year moving averages. The reasoning here is that, while the procedure based on arithmetic mean is subject to extreme values, the procedure based on bulk average avoids this problem. Both these procedures are, however, not satisfactory in the presence of trends, to account for which the procedures based on the linear trend and 5-year moving averages are adopted. The lowest value of the CV from the above 4 procedures is considered as the appropriate one to measure uncertainty. As Nadkarni himself points out, among the CVs computed by the above 4 procedures the one from the linear trend is likely to be the lowest, in which case computing the CV by the other 3 procedures seem redundant. From these CVs he finds that, at the State level, crops showing high growth (sugarcane, rice, wheat & jowar) show low level of uncertainty whereas the crops with low growth (bajra, ground nut, tur & cotton) show high level of uncertainty. This negative relation between growth and uncertainty of yields is contrary to Sen's conclusion which, however, was for foodgrains output. At the districts level for cotton, however, Nadkarni finds that districts showing high growth also are the ones with a high level of uncertainty, which is supportive of Sen's views.

Unlike the above results for Maharashtra, Nadkarni & Deshpande (1982, 1983) find evidence from the State of Karnataka that is clearly supportive of Sen's conclusions. Their analysis used State & district level data on crop output and yields of various individual crops (rice, jowar, bajra, ragi, maize, wheat, minor millets, gram, tur, ground nut, cotton, safflower & sugarcane) and also for the crop group foodgrains, covering the period 1955-56 to 1975-76. Using CV around linear trends they find that most of the crops considered show an increase in instability between the periods 1955-56 to 1965-66 and 1966-67 to 1975-76. Further, they also find a "positive correlation between growth and instability during the period as a whole", a result supportive of Sen's findings.

Ray (1983) measures instability by standard deviation of the year to year changes in the logarithms of output (which are nothing but annual growth rates). This implies that the instability measured here is in growth rates and not in actual output. Instability is measured for fixed periods: 1951-52 to 1964-65 and 1965-66 to 1974-75. Ray himself suggests that this method may be unsatisfactory since it involves comparison of the instability in production over different periods under the assumption of stationary mean and variance in the year to year changes in the components of production index. Further, as Dhawan (1988) points out, this method is equivalent to measuring instability around a semilog time trend. This method is not computable if any term other than the last one is zero. Moreover, instability measured this way may be exaggerated if there are severe falls in the output. As will be seen later, this method despite its shortcomings has been adopted by Dev (1987, 1989), Rao, Ray & Subbarao (1989). The conclusions of Ray's study will be discussed later.

Parthasarathy (1984) analysed the relation between growth and instability in agricultural production at the districts level for the State of Andhra Pradesh. The study is based on production indices with base 1956-57 = 100, for 2 crop aggregates foodgrains and all crops, covering the period 1955-56 to 1978-79. Growth is measured through semilog trends fitted for the full period and also for the 2 sub-periods 1955-56 to 1966-67 (pre-Green Revolution) and 1967-68 to 1978-79 (post-Green Revolution). Instability is measured in 2 ways: (1) following Schultz's procedure wherein an overall measure of instability is derived by computing the average percentage variations from preceding year and deducting from it the trend growth rate. Note that here too it is the instability in growth rates that is being measured; (2) through fluctuations around a log-linear trend as measured by the coefficient of variation of the estimated residuals. The results on instability obtained from both these procedures are largely consistent. His results show that instability is higher for foodgrains than for all crops. The districts of Srikakulam, Vishakhapatnam and Anantapur face high instability with low growth while Nalgonda is favourably placed with high growth and low instability in foodgrains. Further, the post-Green Revolution period shows higher instability. In general, his results "do not suggest a clear relationship between growth rate and instability" for output of all crops.

Dev (1987, 1989) analysed growth and instability in food-grains production using State level data for 17 major states of India, covering the period 1960-61 to 1984-85. Following Ray (1983) he first computes growth rates, both unadjusted and adjust-ed for rainfall, using log-linear time trends fitted for fixed periods (full period and for three sub-periods covering the decades of 1960s, 1970s, and early 1980s) and for 9-year moving periods. His study shows a decline in the growth rate in most states in the 1970s compared to 1960s, though some states staged a recovery in the early 1980s. Following Ray (1983), instability is measured by the standard deviation of the year-to-year changes in the logarithms of output. Thus here too, like in Ray (1983) and Parthasarathy (1984), the notion of instability is applied to growth rates rather than actual output. Instability is measured for (i) fixed sub-periods covering the decades of 1960s, 1970s and early 1980s, and also for the full period 1960-61 to 1984-85; (ii) 9-year moving periods. Dev argued that the procedure based on fixed periods can lead to inconsistent results depending on whether some drought years' observations are included or dropped, whereas the moving period approach would avoid such inconsistencies. Semilog trends are then fitted to the series of moving period standard deviations to analyse trends, if any, in production instability. By this the assumption of stationary mean and variance of the growth rates made by Ray (1983) is sought to be relaxed here. From these trend results, Dev finds that "there was a progressive but marginal decline in instability of foodgrains production at the all India level, though this was not true in all States. Some States (Bihar, Haryana, Jammu & Kashmir, Kerala, Maharashtra, Rajasthan and Punjab) show a fall in instability while others (Andhra Pradesh, Assam, Gujarat, Himachal Pradesh, Karnataka, Madhya Pradesh, Orissa, Tamil Nadu, Uttar Pradesh and West Bengal) show a rise in instability. The analysis of growth rates and instability does not show any significant association between growth and instability.

Rao, Ray & Subbarao (1989) also arrive at similar results. They analysed growth and instability in output of rice, wheat and some crop groups, like cereals, foodgrains, oil seeds and all crops at the all India level over the period 1949-50 to 1984-85, splitting the period into 2 sub-periods at 1964-65. Further, they also analyse foodgrains output in 17 States over the period 1960-61 to 1984-85, splitting the period into 2 sub-periods at 1969-70. Their methodology is similar to that of Dev (1987, 1989) (which is an improvement over Ray (1983)) discussed earlier except that the moving periods are 10-years long instead of 9-years as in Dev (1987, 1989). Their results show that, at the all India level, instability of output increased for rice and all other crop groups while it declined for wheat alone between the 2 sub-periods (1949-51 to 1964-65 and 1965-66 to 1984-85). At the States level, instability of foodgrains output increased in a few States (Gujarat, Karnataka, Maharashtra, Orissa and Tamil Nadu) while it declined in some (Bihar, Haryana, Himachal Pradesh, Jammu & Kashmir, Kerala and Punjab) and in some other States (Andhra Pradesh, Assam, Madhya Pradesh, Rajasthan, Uttar Pradesh & West Bengal) it remained more or less constant. From an analysis of the growth performance and instability in growth, they conclude that "annual variability or instability in output is not caused by growth or stagnation as such".

Unlike the above studies Majumdar et.al (1988) distinguish between the concepts of variability and instability. They refer to "deviations (positive/negative) over time of the actual observed yields from the expected mean" as yield variability, and point out that change in variability so defined is nothing but heteroskedasticity of errors in econometrics. Stability/ instability of growth process on the other hand, is defined with respect to changes, if any, in the growth path as observed by tests for constancy of the parameters of the growth curve. This is same as structural change in econometrics. Their analysis is done for the yields of rice, jowar, ragi, bajra, maize, pulses, wheat, ground nut, sugarcane, tobacco, cotton and rape & mustard. They analysed the problem of growth and instability at the districts levels for 3 states Andhra Pradesh, Karnataka and Haryana, covering the period 1960-61 to 1981-82 (the terminal year of the sample is 1980-81 for Andhra Pradesh and Haryana) which is split into 2 sub-periods up to & after 1966-67. Note that, unlike in Ray (1983) and Parthasarathy (1984), both variability and stability are analysed for crop yields, not for growth rates of crop yields. Both variability, as measured by the CV around trend, and stability of growth path are assessed based on semilog time trends of yields for the full period and for the 2 sub-periods. Changes between the 2 sub-periods in yield variability is tested using a F-test[1] similar to the Goldfeld-Quandt test for heteroskedasticity of errors; stability of growth path is tested using the F-test for constancy of parameters (usually referred to as Chow test). Their results do not indicate any clear relation between growth, variability and

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1 This test procedure is the same as that developed by Hazell as reported in Mehra (1981).

stability. However, as we will see in the next chapter, stability or instability of the parameters of a growth curve is also just one of several aspects of a crop's output/yield performance.

Note that one of the 3 States analysed by Majumdar et.al (1988) is Karnataka for which, as we saw earlier, Nadkarni & Deshpande (1982, 1983) found a clear positive relation between growth and variability of crop yields. This difference in the conclusions between the 2 studies seems to arise because of the difference in the functional forms of the growth curves used in these 2 studies. Both these studies measure variability by the CV around trend which is linear in Nadkarni & Deshpande study while it is semilog in Majumdar et.al. study. The sensitivity of the results on growth, variability and stability has been pointed out by Ray (1983), Alauddin & Tisdell (1988). More on this issue in the next chapter.

It must be clear by now that under the issue of "growth, stability and variability", some studies have analysed the fluctuations in levels of outputs/yields themselves, whereas some others have analysed the fluctuations in the growth rates (sometimes even the standard deviations in them) of outputs/yields of crops or crop groups. Keeping aside for a while issues relating to the comparability of the results of these studies (output versus yields, differences in time period covered, crops and crop groups covered, regions, etc.), we find from the above discussion that no firm conclusion can be made on the nature of the relationship between growth, variability and instability. While the results of some of the studies are mutually contrary (like for example, the positive relation suggested by Sen (1967) versus the negative relation suggested by Nadkarni (1971)) the conclusions of the rest of the studies point out to, if anything, a total absence of any relation between growth, variability and stability. Moreover, these results also seem to be sensitive to the methodology adopted as well as to the functional forms assumed in the analysis (see for example, Nadkarni & Deshpande (1982) versus Majumdar et.al (1988)).

4.5 Modern Technology and Instability.

Let us now look into some of the studies that analysed the role of technology on variability/instability. With the spread of the yield increasing modern technology as the engine of agricultural growth the concern for growth and instability naturally led scholars to question the role of the modern technology in causing instability. The question of concern here is "has the modern technology led to an increase in instability?". Alternatively, this question has also been posed as increased susceptibility of crop yields to risks due to weather, pest attacks, crop diseases, etc. under modern technology regime. The modern technology being characterised by the use of high yielding variety (HYV) seeds, fertilizers and irrigation as a package, the role of these inputs in causing instability and the possible ways of reducing instability has also been sought to be studied.

Barker et.al (1981) studied the long-term consequences of technological change on the stability of wheat yields in a few regions of the USA & Mexico, and rice yields in Indonesia, Pakistan, Philippines and Sri Lanka. Their analysis covered the period 1954-55 to 1977-78 which was split into 2 periods at 1966-67. They measure variability as the deviation from trend (which was assumed linear) by the standard deviation (SD) of the estimated residuals. The SD is considered as a measure of absolute variability while the coefficient of variation (CV) is used as a relative measure of the variability. Their results suggest that "new technology results in greater yield variability, particularly absolute variability", though their evidence on relative variability is less conclusive. They then examine the effect on instability of various factors of production like irrigation, agronomic practices like fertilizer and pesticides, etc., application in various rice growing countries. They conclude by stating that "although irrigation may reduce moisture stress on crops, it is frequently associated with an intensification of crop production and input use that is destabilizing" especially when the infrastructure for flood control, drainage, etc., are not well developed.

Mehra (1981) studying the cause for production and yield instability also comes to similar conclusion on the variability increasing nature of the new technology. Her analysis is based on data on output, area and yields of 18 individual crops (rice, wheat, jowar, bajra, maize, ragi, barley, gram, tur, ground nut, sesamum, rape seed & mustard, linseed, cotton, jute, potatoes, sugarcane and tobacco) and 3 crop aggregates (foodgrains, non-foodgrains and all crops) for the period 1949-50 to 1977-78. The sample period is split into 2 sub-periods 1949-50 to 1964-65 (pre-Green Revolution) and 1967-68 to 1977-78 (post-Green Revolution), after dropping the 2 drought years (1965-66 and 1966-67). The dropping of these 2 drought years seem arbitrary as some other drought years like 1972-73, 1976-77, etc. are included in the analysis. These inconsistencies have been pointed by Dhawan (1988) also. Instability or variability is measured by the standard deviation (absolute variability) and by the coefficient of variation (relative variability) of the deviations of the observed values from the estimated trend values. The trend is estimated using an exponential/semilog equation for the full period and for the 2 sub-periods. Following Hazell's procedure, as reported in an appendix of her study, F-tests are also conducted to test for significant changes in the CV between the 2 sub-periods. That this F-test procedure is similar to the Goldfeld-Quandt test for heteroskedasticity of errors was pointed out by Majumdar et.al (1988).

Mehra's analysis shows that, at the all India level, production variability increased for most of the crops and crop aggregates, the increase in variability being more due to increase in yield variability than due to area variability. Yield variability increased even as mean yield levels increased. Inter crop and inter State comparisons show that yield variability was higher for crops with HYV seeds than for crops with traditional variety seeds. Thus, she concludes, the new technology seems to result in increased yield variability. Her results also indicate that, crops with a high level of irrigation show low variability which increased only marginally like in the case of rice and wheat or even fell like in sugarcane. Thus she concludes that irrigation may be a stabilizing factor. The stabilizing role of irrigation is also shown through a regional analysis for Punjab, a State with high levels of irrigation. Yield variability for the 6 crops considered for Punjab (rice, wheat, maize, barley, gram & sugarcane) either remained constant or fell over time. Districts level data for Punjab also show that yield variability decreased in districts with a higher percentage of tubewells irrigation (which is a source of assured irrigation) while it increased in districts where tubewells were few. Thus assured irrigation seems to be important in reducing yield variability.

It may be mentioned here that Mehra's conclusions seem to based more on visual observation of the change in the SD and CV between the 2 sub-periods than on the results of the F-tests that she reports in an appendix. The F-tests indicate significant change in the CV of yields of only bajra and maize out of the 18 crops at the all India level. At the State level, out of the 32 cases (of various crops) that show an increase in CV upon visual observation, only 10 show a significant increase as per the F-test. None of the crop cases that show a fall in CV visually have a significant F-value. Thus it seems that Mehra's conclusions on the role of new technology in causing increase in yield variability have to be viewed with caution.

Hazell analysed the problem of instability in total cereal production for all India (Hazell (1982)), and compared it with the instability in the USA (Hazell (1984)) while in Hazell (1985) the increased variability in world cereal production is analysed. The crops considered are rice, wheat, bajra, barley, jowar, maize, ragi, small millets and total cereals for India; maize, winter wheat, sorghum, oats, other spring wheats, barley, rice and durum wheat and total cereals for the USA. The methodology adopted is essentially the same in the 3 studies. Like in most other studies, variability and instability essentially refer to the same phenomenon, namely, year to year fluctuations in output. "Instability is measured as the variance of total cereal production which is equal to the sum of the production variances of individual crops within states and the sum of all inter crop and inter state production covariances". The production variances and covariances are then decomposed using statistical identities provided by Bohrnstedt and Goldberger (1969) by which the sources of their change between 2 periods are identified[2]. Denoting area by A, yield by Y, variance by V, covariance by Cov and Δ to indicate change, the sources of change in production variances and covariances are as follows:

(1) change in mean yield, $\Delta\bar{Y}$; (2) change in mean area, $\Delta\bar{A}$; (3) change in yield variance, $\Delta V(Y)$; (4) change in area variance, $\Delta V(A)$; (5) interaction between changes in mean yield and mean area, $\Delta\bar{Y}\cdot\Delta\bar{A}$; (6) change in area-yield covariance, $\Delta Cov(A,Y)$; (7) interaction between changes in mean area and yield variance, $\Delta\bar{A}\cdot\Delta V(Y)$; (8) interaction between changes in mean yield and area variance, $\Delta\bar{Y}\cdot\Delta V(A)$; (9) interactions between changes in mean area, mean yield and area-yield covariances, $\Delta\bar{Y}\cdot\Delta\bar{A}\cdot\Delta Cov(A,Y)$; (10) change in residual.

The 2 periods considered in Hazell (1982 & 1984) for all India are 1954-55 to 1964-65 and 1967-68 to 1977-78, while for USA it is 1950 to 1966 and 1967 to 1980 in Hazell (1984). The results show that variance of total cereal production for India increased by 342% between the two periods, while for the USA it increased by about 240%. This increase in the variance of cereal production is less due to increase in variance of production of individual crops than due to increase in the production covariances, especially inter state covariances within crops, in both the countries. In both the countries the increase in production variance is due to increases in yield variances and yield covariances, inter crop and inter state, the latter covariance being the dominant one. The increase in inter state yield covariances in the USA are attributed to the common genetic base of most of the crops across states, which makes the yields in these states susceptible to the same kind of pests, diseases and weather conditions. Increased price variability in the USA, leading to similar adjustments by farmers across states can also be a factor behind these increased inter

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2 For details of this decomposition procedure see Hazell (1982).

state covariances. In India too, the progressive narrowing of the genetic base for rice and wheat due to widespread adoption of HYV seeds could be the cause for increased inter state covariances, along with erratic rainfall patterns, increased price variability, fluctuations in supply of farm inputs like fertilizers that are required for the HYV seeds, etc. An important conclusion of these studies is that "aggregate production instability is an inevitable consequence of rapid agricultural growth".

The results of Hazell (1985) for India are somewhat different from Hazell (1982 & 1984). While the 2 earlier studies show an increase in production instability for India, the same fell according to Hazell (1985) over time. The difference, as Alauddin and Tisdell (1988) point out, is because of the inclusion of the 2 drought years 1965-66 and 1966-67 in Hazell (1985) while they were dropped in the earlier studies. Thus inclusion/exclusion of extreme values also affect the results of variability.

The conclusions of Barker et.al, Mehra and Hazell regarding the nature of increasing variability under modern technology is supported by Webster and Williams (1988) who analysed wheat and barley production and yields on farms in South-East England, following Hazell's decomposition procedure. The results of Bogahawatte (1992) following Hazell's procedure, for paddy cultivation in Sri Lanka also are also supportive of this conclusion.

This result, however, is not supported by the study of Alauddin and Tisdell (1988) for Bangladesh. Following Hazell's procedure, they study production and yield variability of food-grain for Bangladesh, at both national and regional levels, covering the period 1947-48 to 1982-83. The sample period is split into 2 sub-periods at 1969-70 to correspond to pre- and post-Green Revolution periods. Their results are not supportive of Mehra's and Hazell's conclusion that the modern technology leads to increased yield variability. For Bangladesh as a whole and for its districts, relative yield variability measured by CV fell with greater use of HYV seeds.

Ray (1983) proposes a generalized production function approach to analyse growth and instability in crop production. He proposed this method as an alternative to the method based on the standard deviation of the year to year changes in output that he first attempts and also as an alternative to the methods of Mehra and Hazell based only on time trends. This procedure, he claims, does not imply instability as an inevitable consequence of rapid agricultural growth, as asserted by Hazell. Essentially, he considers a model of the following type:

$$Y_t = F(X_{it}, W_{lt}) \qquad i=1,2,\ldots,G \quad l=1,2,\ldots,L$$

and

$$X_{it} = F(T_{ht}, P_{kt}, W_{lt}) \qquad h = 1, 2, \ldots, H \quad k = 1, 2, \ldots, K$$

where, Y_t is the level of production,

X_{it} is the set of observable and measurable variables representing the farm practices/techniques employed by the farmers. The X's are thus the control variables subject to farmers decisions.

T_{it} is the set of quantitative and qualitative characteristic variables representing the physical, institutional, cultural, socio-economic and technical-organizational environment for production. Variables T are considered to change monotonically over time; as a result X's are also monotonic functions of time.

P_{it} is the set of controllable man-made factors outside the domain of farmers' control. The P variables may contain a systematic and a stochastic component and may or may not change monotonically over time. P variables do not enter the production process but influence the X variables that affect production.

W_{it} is the set of nature determined variables changing stochastically. W variables may affect P, T and X variables besides affecting production directly.

Given the monotonic relation of T variables with time (t), the production function is then essentially a function of time, P and W variables.

$$Y_t = F(t, P, W)$$

The P variable that Ray considers is the ratio of price index of crop to the inputs price index, while the W variable used is the cropwise rainfall index from Ray (1976). The above function is then estimated with all the variables in logarithmic form, for the periods 1951-52 to 1964-65 and 1965-66 to 1974-75. The crops considered are rice, wheat, coarse cereals, pulses, foodgrains, oil seeds, sugarcane, cotton, jute & mesta and tobacco. Production instability is then assessed from the extent of the deviations of the observed production level to the estimated production level obtained from above estimated function. The general conclusions that emerge are that the pattern of growth and instability were due to (i) an increase in the variabilities of rainfall and prices and (ii) an increase in the sensitivity of production to variations in rainfall and prices.

Two points need to be noted about Ray's study are with regard to:
1) The Model: Although Ray's model starts with a generalized production function, as a result of the assumption of monotonicity of input variables with time, the final estimated equation turns out to be neither a pure production function nor a pure time trend, since in the reduced form estimated 2 other variables (rainfall & prices) also figure in. None of the input variables enter into the estimated equation. However, it may also be noted that in a later joint study by Ray, (Rao, Ray and Subbarao (1989) discussed in the previous section) crop output instability was analysed only through the standard deviations of the year to year changes in output.
2) The Concept of Stability: As seen earlier, instability is assessed from the extent of the deviations of the observed production level to the estimated production level obtained from above estimated function. In the same study, Ray also mentions about "usual statistical tests for comparison of regression lines and for testing stability of the parameters estimated separately from the two periods", which he, however, did not conduct (see Majumdar et.al (1988) for such an analysis). Thus, there are two aspects here: one, the extent of deviations from the estimated levels; and two, the parameter values of a functional form. Do both these refer to the same aspect of stability/instability of a crop's performance?

Dhawan's (1988) study is concerned with the effects of irrigation on output, area and yield instability which are analysed by comparing instability under irrigated farming with that under rainfed farming. Recall that, while time series data on irrigated acreage are available, corresponding time series data on output and yields are not available (see chapters 2 & 3). First he estimates the output and yields of foodgrains (foodgrains are expressed as energy equivalents) under irrigated and rainfed conditions, at the State level for 11 states, covering the period 1970-71 to 1983-84. However, the methodology adopted to estimate the irrigated and rainfed output and yields is not given.

Like with most other studies on this problem, here too instability refers to "fluctuations around a fixed point in the case of stationary (i.e., trend free) series and around a trend line for a secularly rising/falling series". Instability is measured by the CV around a linear trend. The results show that irrigation has a favourable impact on instability in area, yield and output as shown by their CVs which is only 5.4% for irrigated all crops output compared to 11.4% for rainfed farming. For foodgrains output, the corresponding CVs are 6.4% and 11.4%, respectively. Further, his results also show that stability gain (i.e., the difference between the CVs of irrigated and unirrigated crops) in yields is much more than that in crop acreage. The CV of yields (acreage) is only 4.3% (1.9%) under irrigated conditions compared to 9.3% (2.9%) under rainfed conditions. Inter State comparisons of instability shows that stability gains due to irrigation is larger in low & medium rainfall States than in high rainfall States. He attributes this inverse relationship of gains in stability with rainfall to the tendency of natural instability in rainfed farming to rise with the levels of rainfall. Apart from the levels of rainfall, stability gains from irrigation is also conditioned by the quality of irrigation in terms of assuredness, maintenance and management of irrigation, control over timing and quantity, etc. Here private tubewells that are least sensitive to drought conditions in the short run, offer more protection against droughts than canal or tank irrigation. These conclusions on the stabilizing role of irrigation, especially assured irrigation are consistent with those of Mehra discussed earlier. Rao, Ray & Subbarao (1989) using Dhawan's data also come to similar conclusions. More on Dhawan's study in the next chapter.

Unlike the earlier studies which assert either an increase or a decrease in instability due to the new technology, Singh & Byerlee (1990) are of the view that "immediate impact of the widespread adoption of the new technology may be destabilizing, but, as the new technology is more widely diffused, variability in yields may decline". They test this hypothesis by studying wheat yield variability for 57 countries covering the period 1951 to 1986. Yield variability is measured in relative terms using the coefficient of variation around a linear trend. Pointing out that the conventional CV overestimates the level of instability in the presence of long-term trends, they use the following correction proposed by Cuddy-Della Valle (1978):

$$CV^* = CV \cdot (1-\bar{R}^2)^{0.5}$$

where, CV^* is the Cuddy-Della Valle index of variability,

CV is the usual coefficient of variation in percent terms,

$\bar{R}^2$ is the regression $\bar{R}^2$ from a time trend estimation (here linear trend).

CV^* is computed for all the 57 countries of their study for the time periods, 1951 to 1965, 1966 to 1975, 1976 to 1986 and 1966 to 1986. Differences in the CV^* between periods are then tested following Anderson and Hazell (1989) using the normal test statistic, $Z = (CV_2^* - CV_1^*)\{[(1 + 2c^2)/2](1/n_1 - 1/n_2)\}^{0.5}/c$

where, CV_i^* is the CV^* in period i of length n_i years,

c is the CV^* in parent population approximated by CV_1^*.

Their results show that wheat yield variability increased between 1951 to 1965 and 1966 to 1975 in developing countries with a high adoption of the new hybrid seed varieties, but subsequently there is "a general decline in yield variability since 1975 in developing countries". The results of the analysis of wheat yields at the State and districts level for India, for the period 1954 to 1986 are also supportive of their hypothesis. Examining various factors that may affect yield instability they find that it is the country size, moisture regime and temperature rather than technological variables like the adoption of HYV and fertilizer dose that determine yield variability.

4.6 Spatial Variability.

In the past studies, the problem of variability of output/yield is usually posed "over time for a region". Few are the studies which analysed spatial variability of output/yield; i.e., variability across regions at a given point of time as well as over time. The need to study this important issue has been felt by others too in different contexts. For example, Vaidyanathan (1993) while studying fertilizer use in India says, "The impact of differences in infrastructure on the dynamics of fertilizer use however remains to be properly investigated. It would be instructive to see if the rate of growth of fertilizers use differs significantly across districts which are otherwise similar, but differ markedly in the base level of infrastructure and credit supply and/or the rate of their improvement".

Raghavan's (1984) study, concerned with the variations in the levels of overall land productivity (expressed in value terms) across the districts of Andhra Pradesh, is one of the very few studies which analyses spatial variability. Using factor-analytic approach, the inter-district variations in land productivity are explained through inter-districts variations in rainfall, farm labour, animal power, irrigation by different sources, fertilizer, cropping intensity, diesel engines, electric pump sets, tractors, short-term and long-term credit, and urbanization. District level data on these variables averaged over 1969-70 to 1971-72 are used in the analysis. A similar analysis is done separately for data averaged over 1976-77 to 1978-79. From these analyses he finds that public investment in canal irrigation, apart from increasing land productivity directly, has also induced private investment in tubewells, diesel engines, pump sets and tractors, all of which have a favourable impact on land productivity. The availability of long- and short-term credit at concessional rates is another factor that determines private investment in capital equipment and current inputs like fertilizer. He also finds that districts with higher investments are also the ones with higher levels of land productivity. Thus, he concludes, the differences in levels of land productivity across districts are directly related to differences in the levels of capital and current inputs used.

It must be noted that in the above study, land productivity is expressed in value terms. To the extent prices differ across districts, spatial variability of land productivity in value terms is not the same as spatial variability of crop yield in physical quantity. Further, the analysis is done only for two blocks of time, each block covering 3 years. Such averaging would smoothen out changes in the pattern of spatial variability over years, which could be an issue of interest on its own. Then, it may be better to analyse spatial variability in each year over a period of time.

Parikh et.al (1991) analyse the role of technology in agricultural development in India. A part of this study addresses this issue to the districts of Andhra Pradesh based on time series of cross sectional data over 1956-57 to 1983-84. However, their study is not in terms of explaining districtwise disparities. Besides, the study is not cropwise. Their study concludes that not only technology but extension, infrastructure and rainfall, etc., also are important in rising crop output.

4.7 This Thesis.

From the discussion so far based on a review of past studies on the subject, some important points with regard to conceptual and methodological issues may be noted. This thesis distinguishes itself especially with respect to the following issues:

1) Concepts: First and foremost, variability and instability are used interchangeably in most of the studies to refer to fluctuations around some "normal" level, which could be the trend level. On the other hand, Majumdar et.al make a distinction between variability and instability. Further as we saw earlier, some studies are concerned with variance of the actual output/yield around the trend, (examples: Mehra, Hazell, etc.;) while some others are concerned with stability of growth rates of output (examples: Parthasarathy, Ray, Dev, Rao Ray & Subbarao, etc.) while agronomists are concerned with stability of yield levels (example: Bhatia (1991), etc.). To our knowledge, hardly any study exists in the literature that attempted to take an unified view incorporating various facets of the stability issue simultaneously. This may be essentially a consequence of the methodology adopted in these studies. As we saw earlier, generally standard deviation (SD) or the coefficient of variation (CV) is used by most of the studies as a measure of stability/ variability. When SD or CV is computed for deviations of output (or yield) around trend, the object of concern is the stability of the variance of actual output (or yield) itself. On the other hand, when SD or CV is computed on the annual difference in logarithms of output (or yield) the concern shifts to stability of growth rates of output (or yield). Obviously, stability of variance around trend and stability of growth rates do not refer to the same aspect of a crop's performance.

Thus the methodology itself not only limits the scope of these studies but also explains the incomparability of results between them. In the next chapter, the various conceptual and methodological issues involved in the analysis of stability (of yields) are discussed and an attempt is made to develop an unified framework that covers different aspects of output/yield performance of a crop including their growth rates.

2) Analytical Framework: Most of these studies are based on time series analysis of outputs/yields using time trends. Based on changes in coefficient of variation around the trend, conclusions

are then drawn on the role of technology and of various inputs in affecting instability/variability. As will be elaborated in the next chapter, this procedure may not be valid enough to draw inferences on the role of technology.

3) Functional Form: While fitting time trends to the data, usually either a linear or a semilog time trend is assumed straightaway for all the crops and in all regions for which the analysis is being done. As Vaidyanathan (1992) points out this assumption is unsatisfactory and "instead several functions should be tried out and that which best captures the systematic trend over time must be used as the basis of measuring variability". Further, as we saw earlier with respect to Nadkarni (1971) versus Majumdar et.al (1988), the functional form specified can affect the conclusions drawn. The importance of the functional form specification for the time trend will be elaborated in the next chapter, where a procedure to select an "appropriate" functional form for the time trend will also be elaborated. In this study, starting with an initial set consisting of various functional forms, an appropriate form to fit the data will be determined empirically.

4) Specification of Change Point: Another aspect of the methodology of the earlier studies is somewhat the arbitrary manner in which the variability/instability change point is pre-specified to split the sample period into sub-periods. Usually, the very year of introduction of the modern technology (i.e., 1965-66) is specified as the change point for variability. The implicit assumption here is that there is an instantaneous impact on the variability due to the new technology without any relation to the rate of its spread. It seems more likely that it would take a few years before the effect of the new technology on variability, if any, is felt. If so, how much time it took for the effect to be felt? And in such a case how to identify the variability/ instability change point? These issues will also be elaborated in the next chapter, where procedures that detect the unknown change point are explained.

econometric issues involved in an analysis of the problem on "growth and stability". An unified methodological framework for such an analysis (for crop yields) is then developed.

5) Spatial Variability: As mentioned earlier, there exist few studies analysing spatial variability. In view of the importance of such studies, this thesis analyses the disparities in yields across the districts of Andhra Pradesh. Unlike Raghavan (1984) and Parikh et.al (1991) discussed earlier, here we consider time series data (1960-61 to 1984-85) on cropwise yield disparities and analyse their movement over time by relating them to the district-wise disparities in irrigation facilities, fertilizer consumption, rainfall, etc.

6) Outputs Versus Yields: As we saw earlier, the instability/ variability problem has been analysed for crop output and/or yields. Some studies have analysed this problem for crop acreages also. What should be the variable(s) to be studied? Output being acreage times yields, fluctuations in output are due to fluctuations in acreage and/or yields. The fundamental difference in the nature of acreage and yields is that acreage is determined solely by the farmer depending on his expectations on various factors like prices, revenues, etc. Thus fluctuations in output due to acreage fluctuations are mainly man made. On the other hand, yields are technologically determined depending on both factors under farmer's control like inputs levels, and also on other factors beyond his control like weather. That is, yields are not fully under farmer's control. Given this differences in the nature of the 2 component variables of output, we restrict ourselves to a study of the stability and variability of crop yields only. Determination of crop acreages are better studied under the broad framework of acreage response (see Narayana & Parikh (1981), etc.) and is not attempted in this study.

7) Individual Crops Versus Crop Aggregates: Some of the past studies have analysed instability/variability for various crop aggregates like cereals, foodgrains, oil seeds, all crops, etc.

aggregates like cereals, foodgrains, oil seeds, all crops, etc. Only a few studies have analysed for individual crops. Since the technology and in particular various inputs would affect different crops differently, it seems more appropriate, the analysis be done for only individual crops rather than for crop aggregates.

8) Regional Disaggregation: Another feature observed in some of the past studies is the inconsistent nature of results obtained at different levels of regional disaggregation. See for example, the inconsistent results at the State and Districts level in Nadkarni (1971). He finds growth and instability to be negatively related at the State level while at the districts level they are positively related. Similar inconsistencies were observed in Majumdar et.al (1988) also. In this background, it seems more appropriate to do the analysis at the most disaggregated level. The lowest disaggregated level at which the agricultural data are available is the districts. Hence in this study, the growth & stability analyses of cereal crop yields are done not only at the levels of all India and one State, Andhra Pradesh, but also separately at the districts levels in Andhra Pradesh.

9) Agricultural Investment: In the course of our study, the importance of irrigation for agricultural development comes out with the implication that neglect of irrigation development can have disastrous consequences for the Indian economy. It is believed that irrigation development is the major component of total agricultural investment in India. The consequences of falling agricultural investment observed since 1980, on both agricultural sector and on the rest of the economy at the all India level are analysed in chapter 11. This is done using a computable general equilibrium model available in the literature, namely, the "Agriculture, Growth and Redistribution of Incomes" model by Narayana, Parikh & Srinivasan (1990).

CHAPTER 5 – METHODOLOGY*

"Ask a complicated question and you get a complicated answer!"
– Dorfman, Samuelson, Solow (1958).

A methodology for analysing the fluctuations in crop yields will be developed in this chapter. Conceptual issues will be elaborated in Part A, based on which econometric issues will be discussed in Part B. Finally, methodological steps will be listed in the last 4 sections of Part B. The data used in the analysis in the subsequent chapters, their definitions, coverage, sources, etc., will be discussed in Part C.

PART A: CONCEPTUAL ISSUES.

5.1 Stability and Analytical Frameworks.

By "stability", one understands as the nature of something "firmly fixed or established, not fluctuating or changing..."[1]. That is, stability refers to the state of being constant and not easily changeable in position or value.

Given this definition, an attempt is made in this chapter to develop a **unified framework** to analyse the stability of different aspects of crop yields **in a given region**. These aspects, summarily stated as "yield performance", cover absolute levels of yields, growth in yield levels, growth pattern and variations in yields.

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* Basic principles of the methodology to be described in detail in this chapter are based upon an earlier work I jointly did with Professor N.S.S.Narayana. See Narayana and Ganesh Kumar (1992).

1 See 'The Little Oxford Dictionary (Clarendon Press, 1969).

Let us first note that the above aspects of crop yields can be analysed in two different contexts: "Temporal" and "Structural". The temporal analysis refers to stability over time. For example, yield levels that have more or less remained constant (stagnant, stationary) over time may be referred to as "stable levels" of yield over time. Here the reference is purely within the "time domain" without a simultaneous reference to the levels of inputs; i.e., whether the input levels have also been more or less constant over time simultaneously. When changes in yield levels have been analysed with specific reference to the associated changes in input levels such an analysis we call here as "structural". Thus there could be two analytical frameworks: "Temporal" and "Structural". There is no reason to suppose that "stability" results with respect to crop yields would be similar under both the frameworks.

Let us begin with the "temporal" framework:

5.2 Temporal Framework.

Under temporal framework, the concept of stability figures in for crop yields atleast in four ways:

a) Stability of yield levels over time,

b) Stability of growth in yields over time ,

c) Stability of the variance of yields around their expected (trend) values, and

d) Stability of growth path of yields over time.

These concepts are elaborated below:

<u>a) Stability of Crop Yield Levels:</u> Given the above definition of stability as something that is fixed and not altering in value, stability of yield levels would then imply that the yield levels are same year after year except for some random fluctuations of minor order. In this case, the yield levels when plotted against time would be scattered around a line parallel to the time axis as shown in fig.5.1. Obviously, then yield levels can be said to be

Stability of Yield Levels

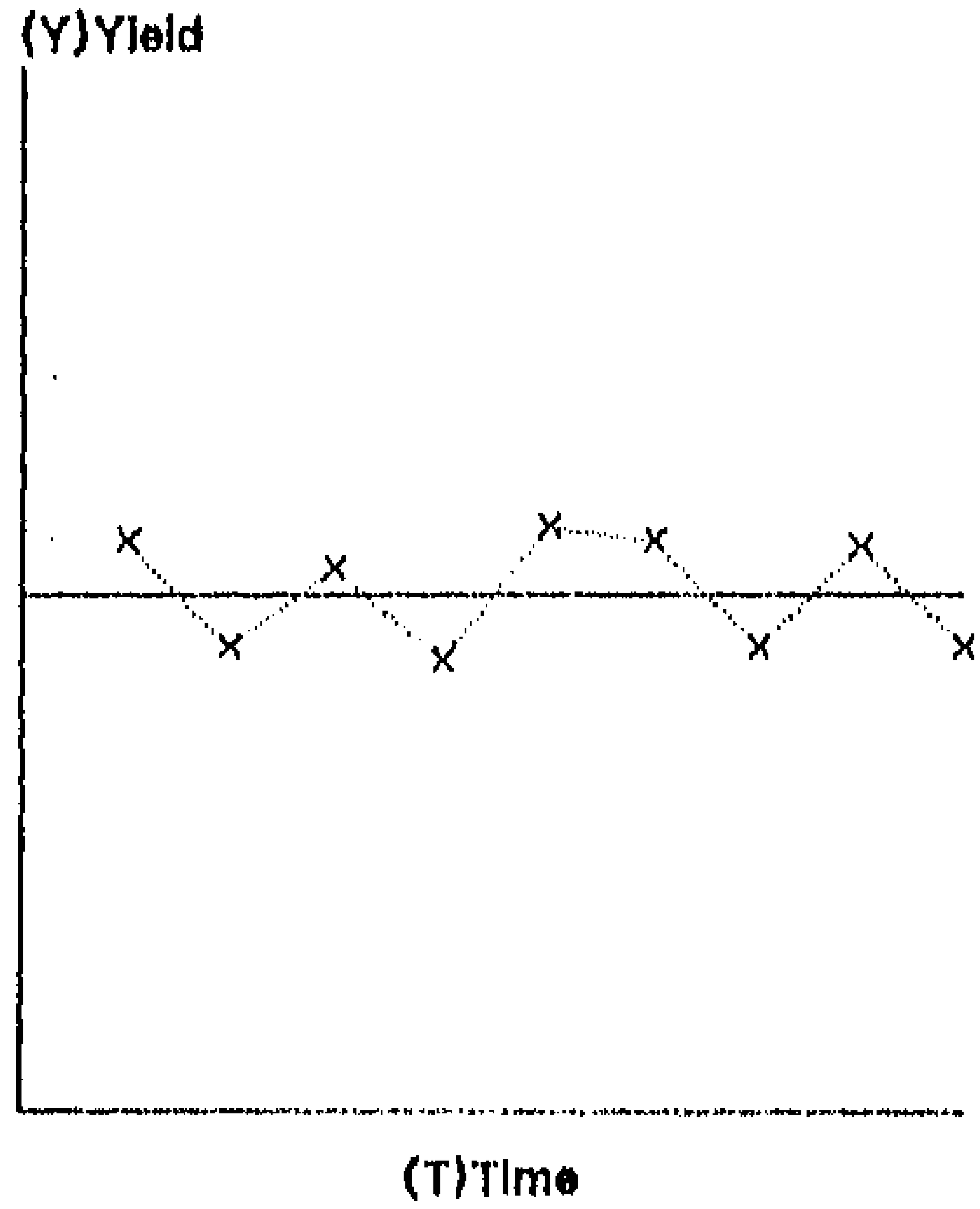

Figure 5.1

Stability of Growth
Semi-Logarithmic Trend

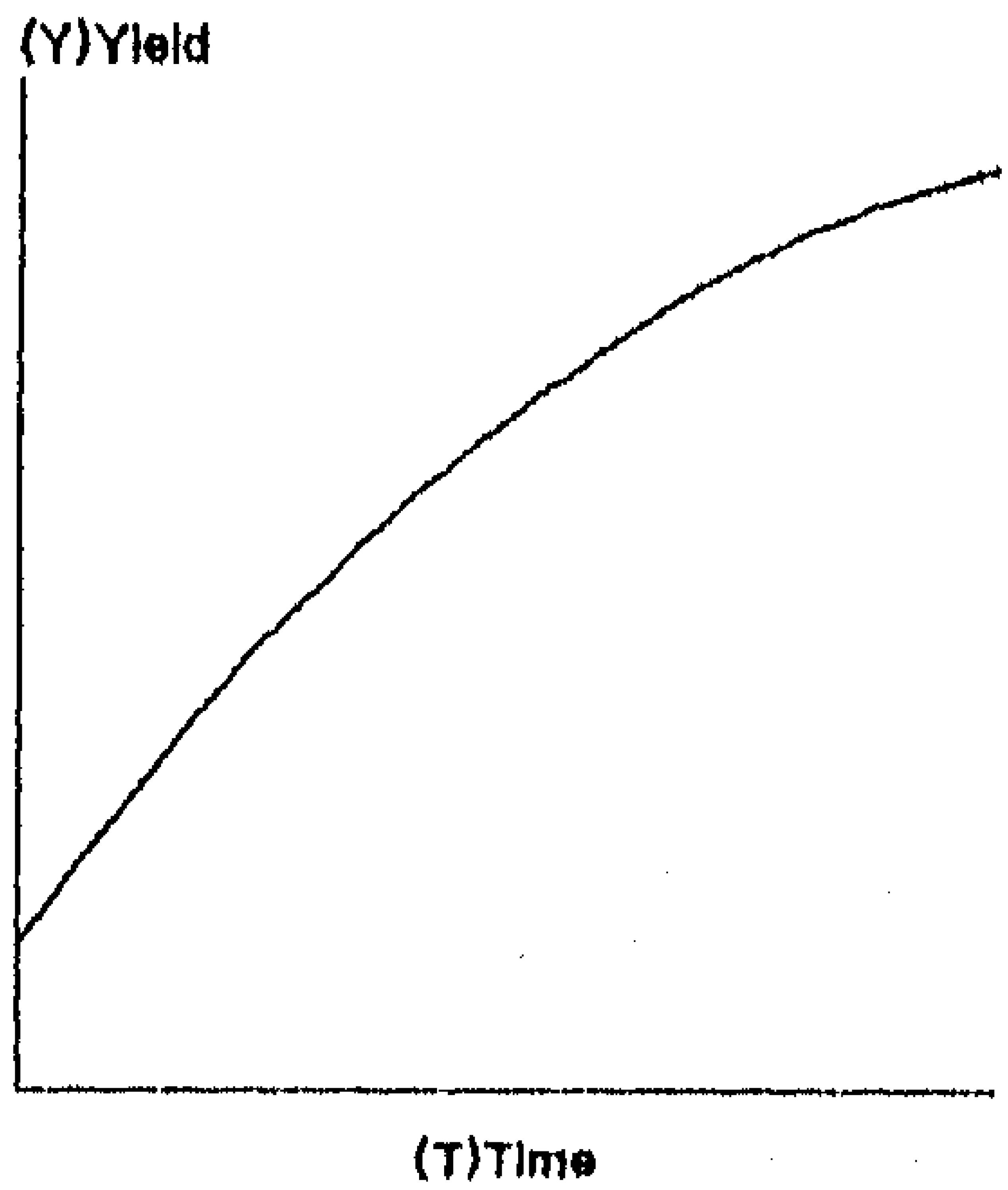

Figure 5.2

stable only under a situation of stagnant yields. When yields show a growth (either rising/falling) in an environment of development, the concept of "stable yield levels" is not applicable. Then a more appropriate question seems to be about the stability of growth.

<u>b) Stability of Growth in Crop Yields:</u> Where yields show growth over time, "stability of growth in crop yields" may refer to the order of growth rates achieved in yields in different years. Given our definition, a "stable growth" would then imply a constant rate of growth of crop yields over time. Growth rate in yields would be constant only when yields follow a growth curve, known as semilog time trend, $Y_t = \alpha\beta^t$, where the constant rate of growth is given as $\log(\beta)$. Figure 5.2 shows a semilog growth curve. But, what if the growth is along some other growth curve? For example, in the case of a linear growth curve, $Y_t = \alpha + \beta t$, the growth rate is β/Y_t. That is, the growth rate depends upon Y_t. Here, as Y changes over time the growth rate also changes. In general when yields follow a growth curve other than semilog time trend, the growth rate in yields would be a variable growth rate implying growth in yields is definitionally, "unstable".

Obviously then, to judge the stability of growth, it is necessary to know first - what are the underlying precise time trends behind the growth in various crop yields? Thus specifying a correct functional form (f.f. henceforth) for the growth curve becomes crucial.

The question of correct specification of the f.f. for the growth curve becomes much more relevant when we analyse yield variability; i.e., the stability/instability of yield variance around the trend. We now turn to this aspect of stability, where the point made with respect to f.f. will be further elaborated.

<u>c) Stability of Variance of Crop Yields Around the Trend:</u> Levels of actual (realized) yields are usually different from the expected (mean) yield levels. Let us denote the actual levels as Y

and the expected levels as $\hat{Y}$.[z] The expected values ($\hat{Y}$), often referred to in the literature as "trend values", may be stationary or growing. The realized yield levels (Y) are in general expected to only randomly fluctuate/vary around the expectations ($\hat{Y}$). The order of deviations (gaps) between the realized (Y) and trend ($\hat{Y}$) levels determines the variance of yields around the trend. This **yield variance around the trend is referred to as "yield variability"** in this study. Yield variability is said to be stable when the variance of yields around the trend is constant all along. That is, the absolute deviations of Y from $\hat{Y}$ are fairly constant over time. Yield variance around the trend is said to be unstable when these deviations change over time systematically (increasing/decreasing); i.e., yield variability is changing over time.

This aspect of the analysis, i.e., stability analysis of variance around the expected values is specifically referred to as "variability analysis" in this thesis.

This concept is indeed referred to as heteroskedasticity of errors in econometrics. Note that the question here is not one of existence of fluctuations (they always exist) in yields around the expectations but one of changing order of these fluctuations over time. That is, yield variability of some extent always exists; but is such variability systematically changing (increasing/decreasing) over time?

The cases of stable and unstable yield variability under growth and stationary conditions of yield are shown in fig.5.3 (a through d). The figures are self explanatory.

Functional Form: The deviations (gaps) of Y from $\hat{Y}$ are none but the residuals ($\hat{U}_t$) estimated from a time trend equation:

$$Y_t = f(t) + U_t = \hat{Y}_t + \hat{U}_t$$

where Y_t are the observed yield levels, $\hat{Y}_t$, the expected yield

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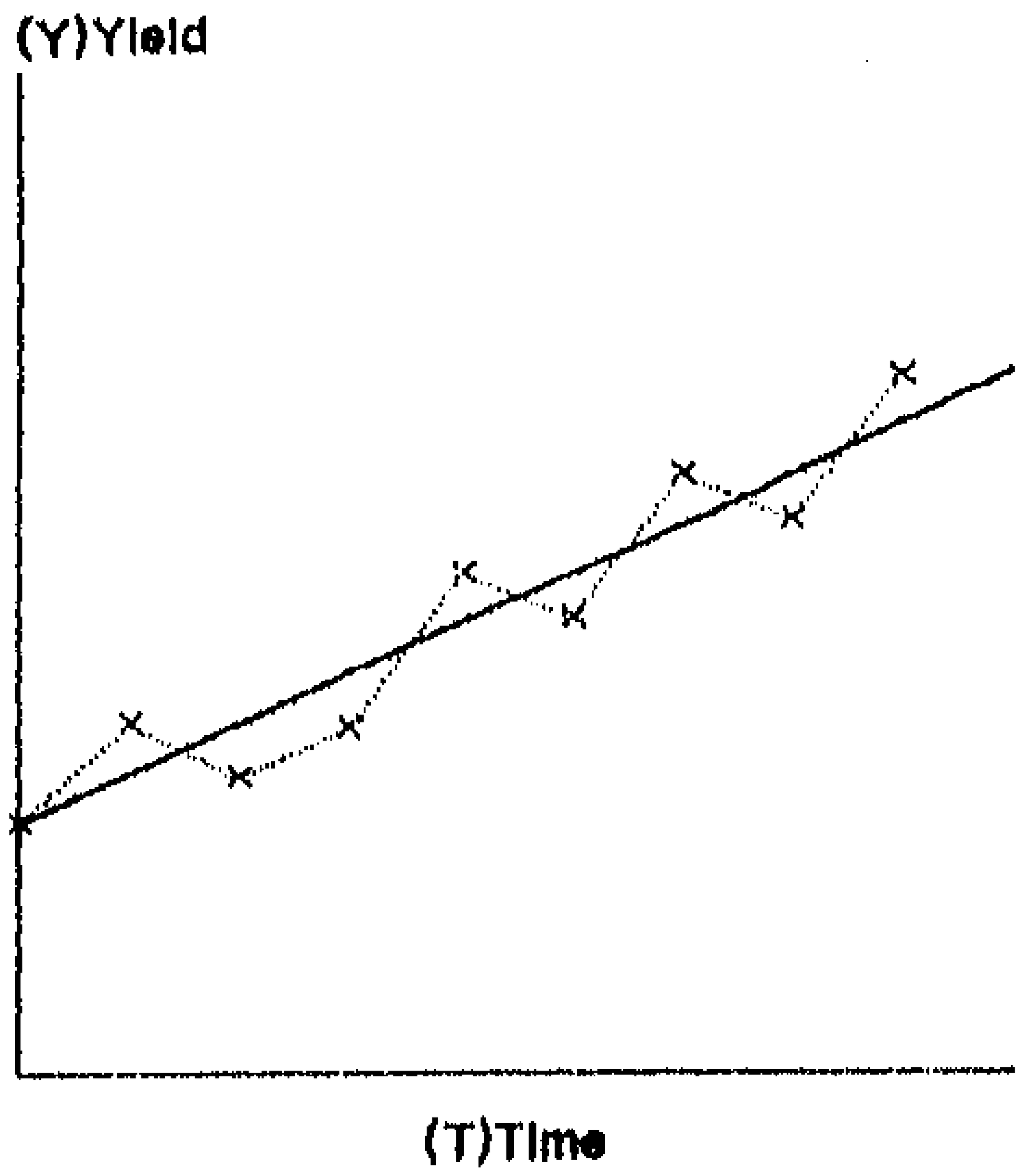
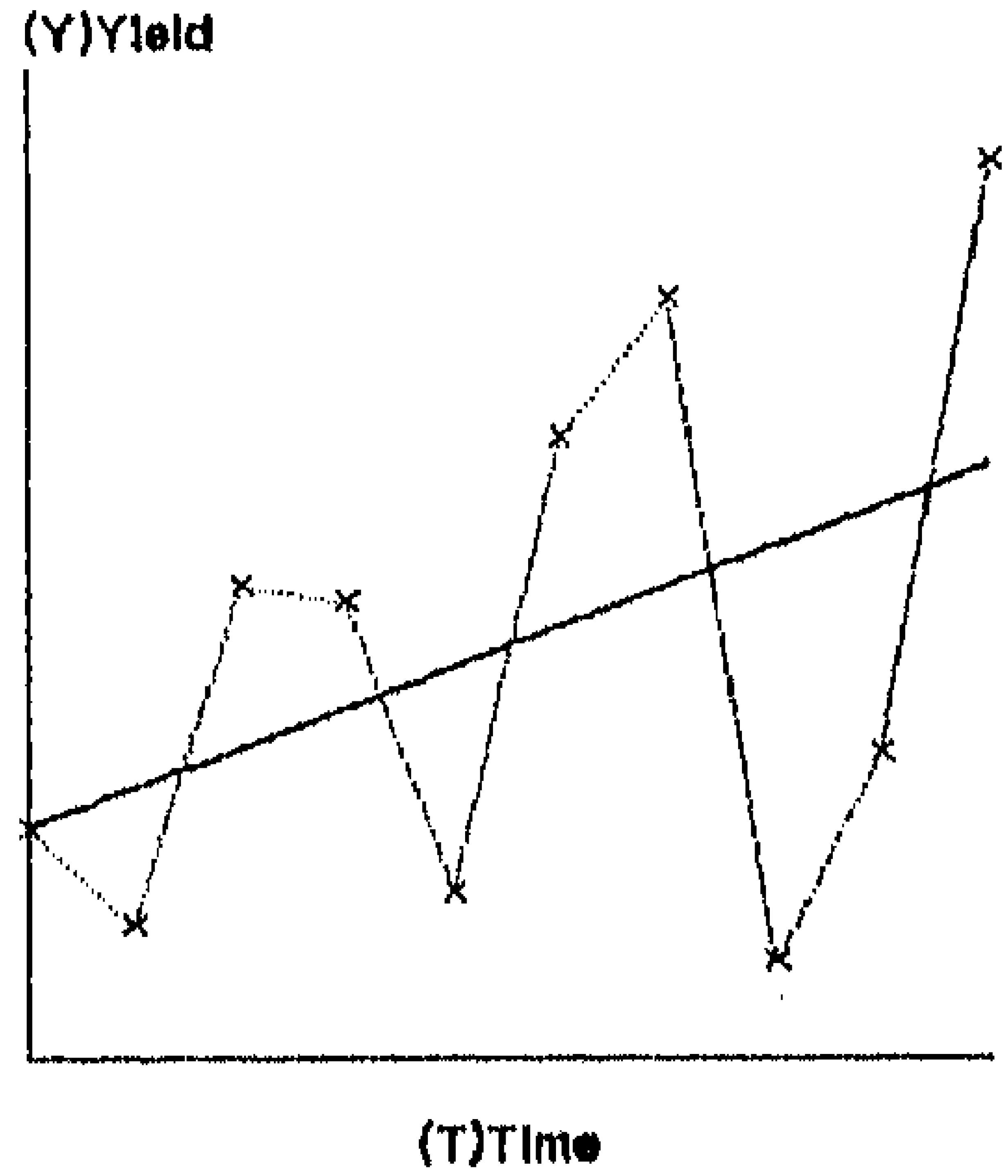
[z] $\hat{Y}$s are actually estimated expected levels.

Stability of Yield Variability



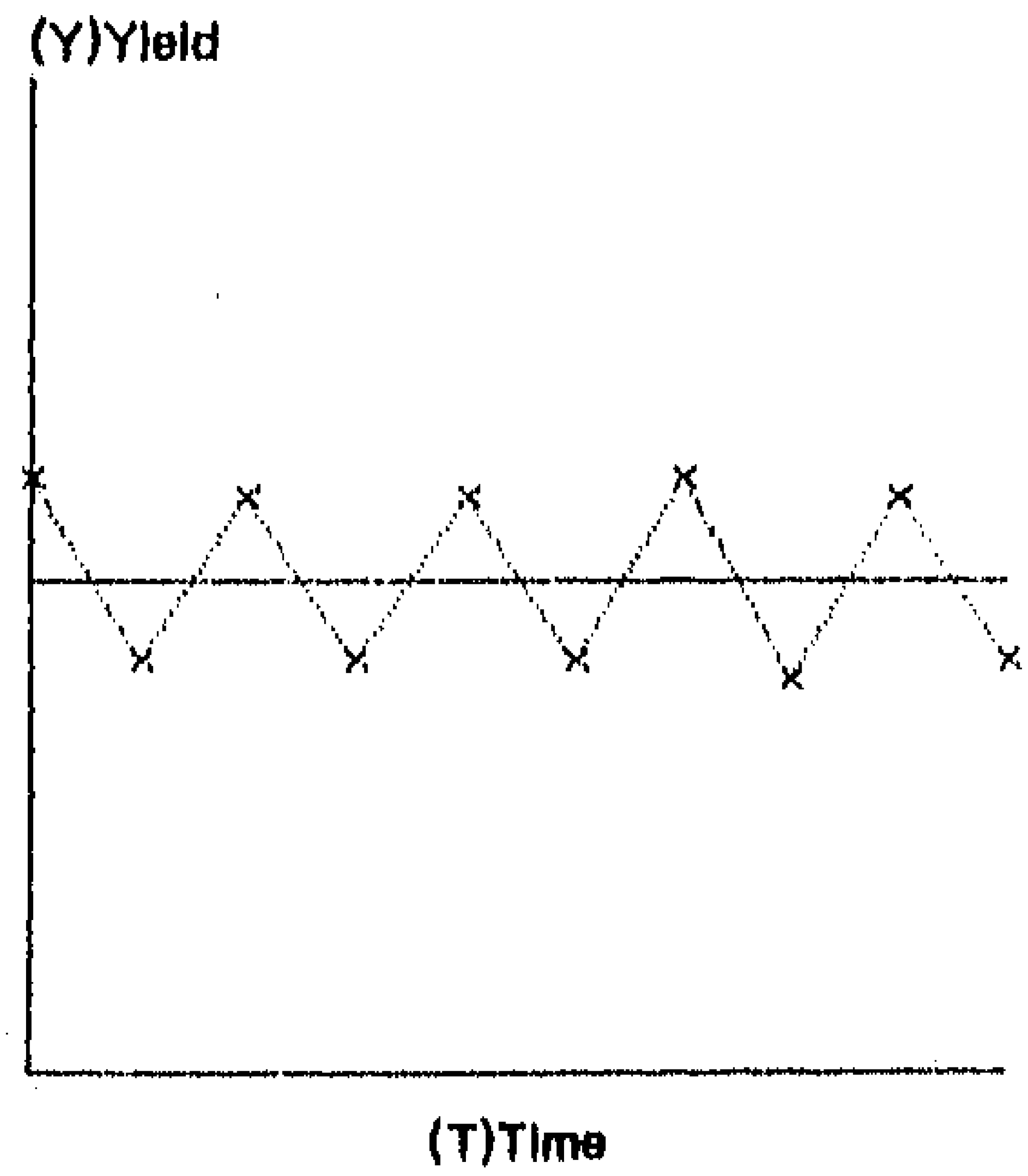
Stable around growing yields

Figure 5.3a



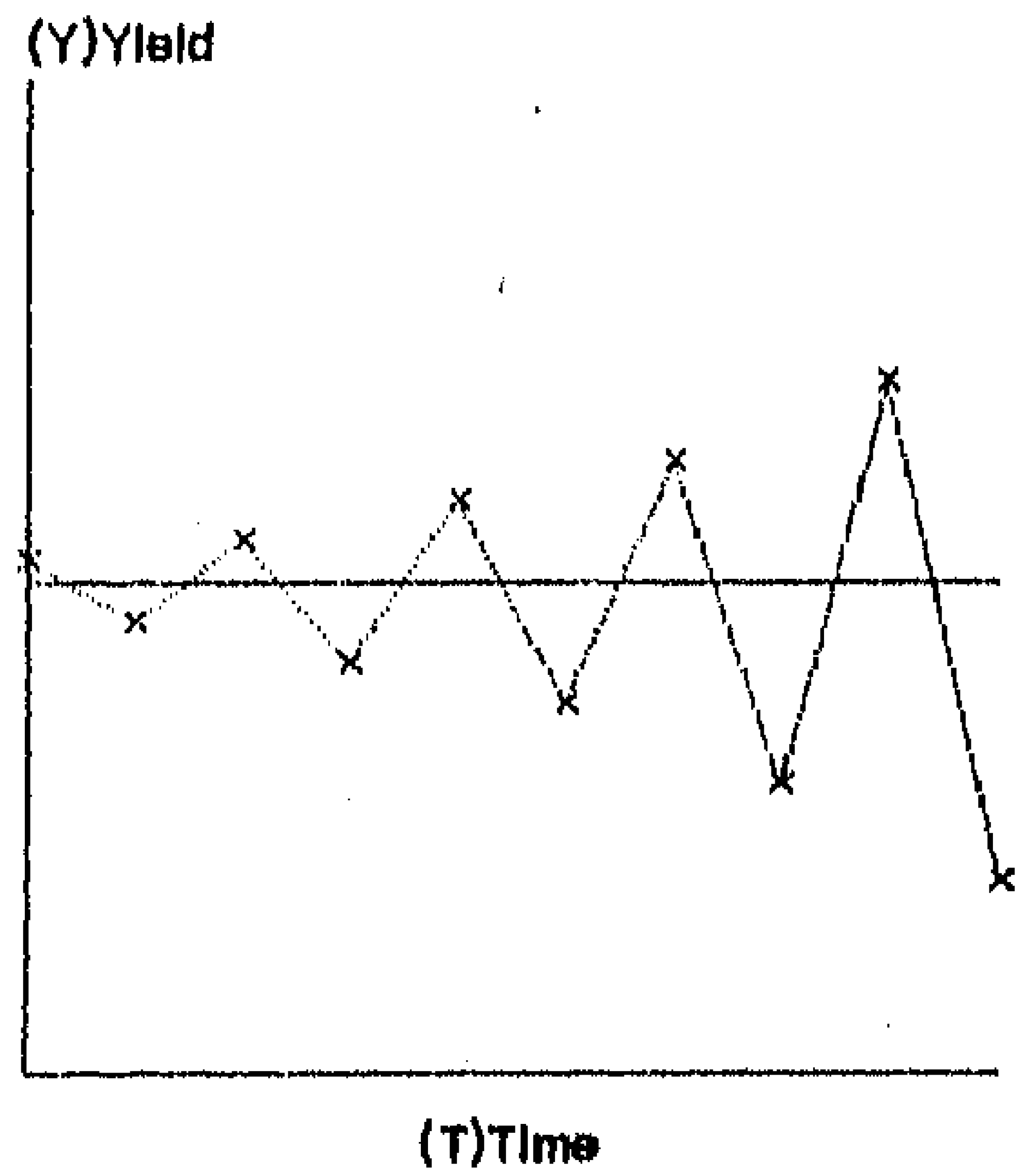
Unstable around growing yields

Figure 5.3b



Stable around stagnant yields

Figure 5.3c



Unstable around stagnant yields

Figure 5.3d

(trend) levels, and $\hat{U}_t$ the residuals (estimated errors). $\hat{U}_t$ generally depend upon the f.f. specified for the expected yields; i.e., the precise form of f(t). $\hat{U}_t$ associated with a wrong f.f. would be inappropriate and econometric tests conducted on a series of such residuals would then lead to biased/incorrect conclusions[3]. This point would be clear from the following illustration where two f.fs for the growth curve for rice yields at the all India level are specified as follows:

<u>Linear:</u> $$Y_t = \hat{Y}_t + \hat{U}_t = \alpha + \beta \cdot t + U_t \qquad (5.1)$$

<u>Semilog:</u> $$Y_t = \tilde{Y}_t \cdot \hat{V}_t = \gamma \cdot \delta^t \cdot V_t \qquad (5.2a)$$

where Y_t is the observed yield at time t;

t is the time variable,

$\hat{U}_t$ & $\hat{V}_t$ are residuals,

α, β, γ and δ are the parameters of the growth curves.

The semilog f.f. (5.2a) is estimated in the logarithmic form as follows:

$$\text{Log}(Y_t) = \text{Log}(\gamma) + \text{Log}(\delta) \cdot t + \text{Log}(V_t) \qquad (5.2b)$$

The time trend equations (5.1) & (5.2b) are estimated using the ordinary least squares (OLS) procedure, for the periods 1949-50 to 1987-88 and for 2 sub-periods - 1949-50 to 1964-65 & 1965-66 to 1987-88. Then, the Goldfeld-Quandt (G-Q) test for heteroskedasticity is conducted on the residuals from both equations (5.1) & (5.2b), i.e., on $\hat{U}_t$ & $\text{Log}(\hat{V}_t)$, respectively. The estimation results and the results of the G-Q test done on $\hat{U}_t$ and $\text{Log}(\hat{V}_t)$ for all India rice yields are as follows[4]:

	Slope Coefficient			G-Q Test for Heteroskedasticity
<u>Period:</u>	<u>1950 to 1965</u>	<u>1966 to 1988</u>	<u>1950 to 1988</u>	
Linear:	24.15 (0.80)	24.89 (0.78)	18.98 (0.86)	Yes
Semilog:	2.62 (0.77)	2.14 (0.79)	1.76 (0.87)	No

Notes: The estimated coefficients are all significant at 1% level. $\bar{R}^2$ is given in brackets.

See Thursby (1982)

While splitting the sample to conduct the G-Q test none of the middle observations were omitted (see Pindyck & Rubinfeld (1981)).

At the outset we find that both the f.fs fit equally well in the 2 sub-periods and also for the full period.

Note that in the case of equation (5.1) testing on var(U) would amount to testing yield variability around a linear trend. The G-Q test conducted on $\hat{U}_t$ shows var(U) changed over time.

In the case of equation (5.2b) testing on var(Log(V)) is equivalent to testing variability of Log(Y) around its linear trend (equation 5.2b). However, since $Log(V_t) \sim N(\mu = 0, s^2)$, it can be proved[5] that

$$var(V) = e^{var(Log(V))}(e^{var(Log(V))} - 1)$$

which implies that var(V) is constant if var(Log(V)) is constant. Hence, the G-Q test result indicating no change in var(Log(V)) implies var(V) is constant. This then implies that yield variability around the semilog trend is constant.

Thus, the G-Q test for heteroskedasticity in errors with 1965-66 as the change point shows change in yield variability in the linear case but not in the semilog case. That is, rice yield variance when considered around a semilog trend is stable but is unstable when considered around a linear trend. Thus we find that 2 f.fs for the growth curve, though fitting equally well, can give different results on yield variability. This only stresses the importance of the correct specification of the f.f. for the growth curve in an analysis on stability (and variability in particular) of crop yields.

Error Specification: At this point another important question arises. This is regarding the nature of variability tested in the above example. Note that U_t in (5.1) enters additively. On the

---

5 $Log(V_t) \sim N(\mu=0, s^2)$
then, by definition,

$$E(V) = m = e^{\mu + s^2/2} = e^{s^2/2}$$

and $$var(V) = \sigma_V^2 = m^2 \cdot (e^{s^2} - 1) = e^{s^2}(e^{s^2} - 1)$$

other hand, in the case of semilog trend, the error term V_t in equation (5.2a) enters multiplicatively. Thus the 2 f.fs differ in their error specifications. Is the concept of variability same across these error specifications?.

$\hat{U}_t$ in (1), being equal to $Y_t - (\hat{\alpha} + \hat{\beta} \cdot t)$, is the estimated absolute[σ] gap between the realized yields (Y_t), and the expected trend levels($\hat{Y}_t = \hat{\alpha} + \hat{\beta} \cdot t$) as given by the linear trend. Thus the G-Q test on $\hat{U}_t$ is a test for change in **absolute yield variability** in crop yields; that is, a test for change in the variance of absolute gaps between realized and expected levels. On the other hand $\hat{V}_t$ in (5.2a), being $Y_t / \tilde{Y}_t$ (where $\tilde{Y}_t = \hat{\gamma} \cdot \hat{\delta}^t$), is the ratio of realized yields (Y_t) to the expected yields ($\tilde{Y}_t$) as given by the semilog trend. Thus $\hat{V}_t$ is the estimated percentage or relative gap between the realized and expected yield levels[7]. Thus the concept of variability involved here is **relative yield variability** - relative to the expected yield levels. Thus the G-Q test on $\text{Log}(\hat{V}_t)$ (which is a test on V_t) is actually a test for change in relative yield variability; that is, for a change in the variance of relative gaps between realized and expected yield levels.

It is important to note that results of variability change of one kind need not imply similar results for the other. Thus we believe that a clear distinction be made while analysing the crop yields with regard to changes in absolute and relative variability.

<u>Spatial Variability:</u> The discussion so far pertains to yield variability over time within a particular District/State, etc. However, variability can be viewed in a different way also, i.e.,

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σ Note that the word "absolute" is used not in the sense of ignoring the sign (+/-) but only in the sense of "additive".

7 The gap between Y_t & $\tilde{Y}_t$ as a proportion of $\tilde{Y}_t$ is given as $(Y_t - \tilde{Y}_t)/\tilde{Y}_t = (Y_t/\tilde{Y}_t) - 1 = \hat{V}_t - 1$. Thus, V_t (ignoring the scalar quantity -1 and multiplication with 100) indicates the percentage/relative error in Y_t.

variability across districts. This is "spatial variability" referring to differences/disparities in yield levels across districts at a point of time. (In)Stability of spatial variability then refers to changes in yield disparities across districts over time. In this study spatial variability of cereal crops yields is also analysed, the methodology of which will be discussed in section 5.13 (Part B).

d) Stability of Growth Path of Crop Yields: Let us now turn to the question of stability of the growth path as described by an appropriate f.f. A change in growth path is deemed to occur when the parameter(s) of the growth curve change over time. Let us consider, as an example, the case of a linear trend (equation (5.1)).

$$Y_t = \alpha + \beta t + U_t.$$

Obviously, a change in this straight line growth path would occur when a change occurs in the intercept (α) and/or the slope (β) from a particular time point, say $t = k$. This can be expressed as follows:

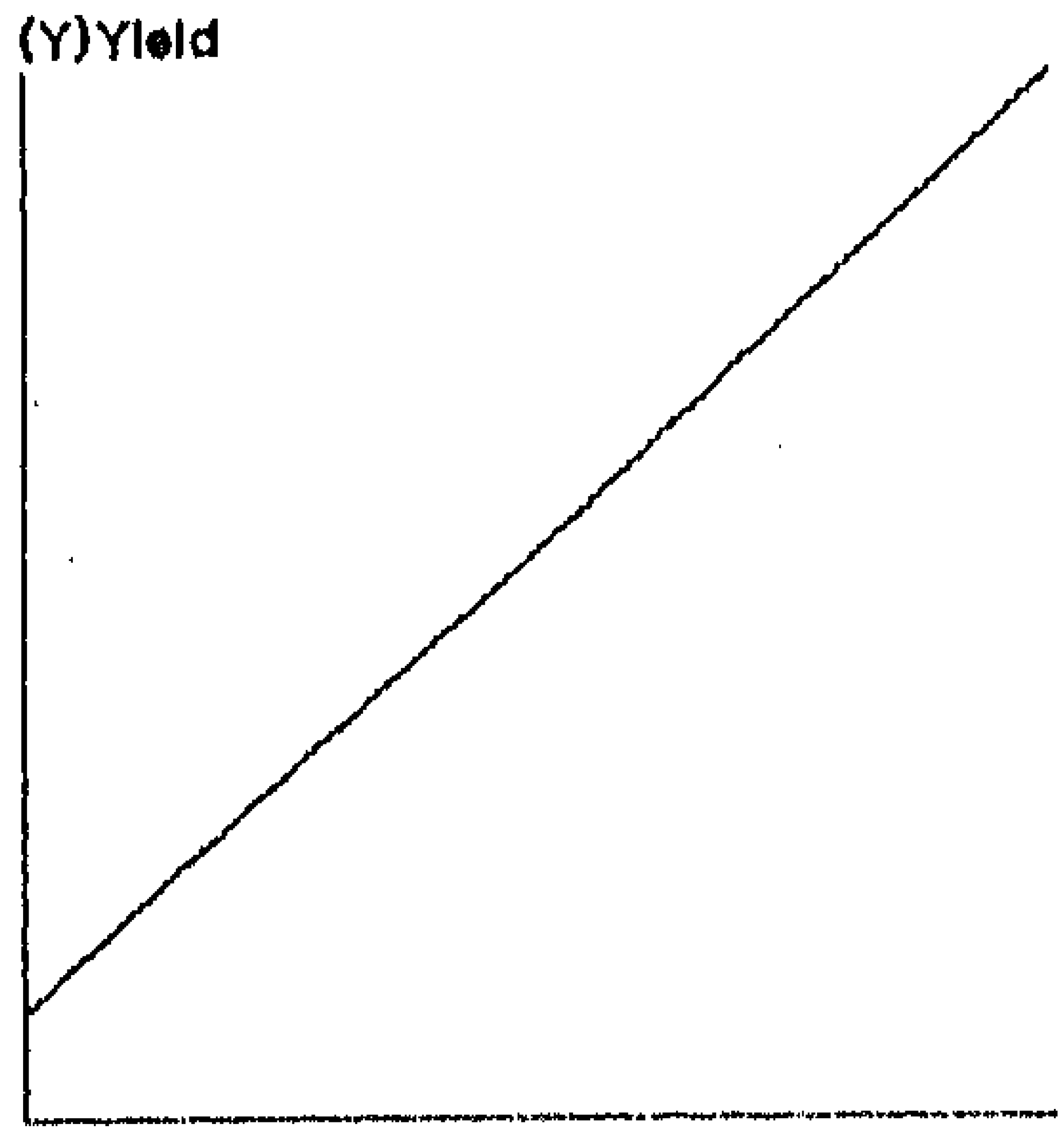
$$\begin{aligned} Y_t &= \alpha + \beta \cdot t & t &= 1, 2, \ldots, k-1. \\ &= (\alpha + \alpha') + (\beta + \beta') \cdot t & t &= k, k+1, \ldots, T. \end{aligned}$$

Such changes in parameters of the growth curve are referred to as "structural change" in the growth path which implies that the growth path has changed. When all the parameters have been stable over time (i.e., no changes in them), there is no structural change and hence the growth path is stable. The cases of stable and unstable growth path in the case of a linear trend are shown in fig.5.4a and fig.5.4b, respectively.

To sum up: The analyses of stability and variability over time of crop yields involve (i) the identification of an appropriate f.f. for the growth curve, (ii) tests for changes in absolute and relative yield variability around the trend, (iii) analysis of structural change in the growth path.

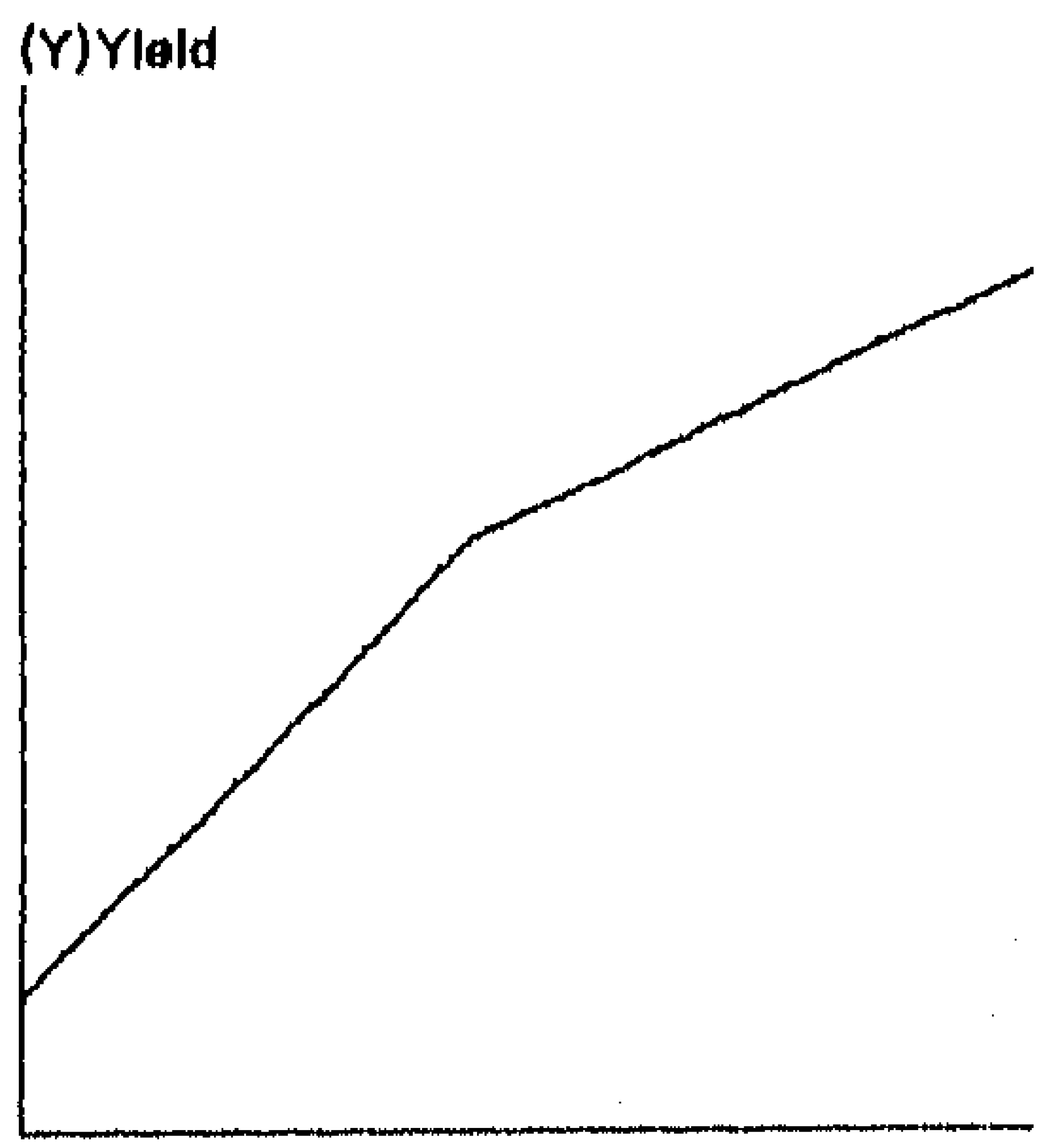
This analytical framework based only on time trends is henceforth referred to as "time trend framework (TTF)".

Stability of Growth Path



Stable growth path

Figure 5.4a



Unstable growth path

Figure 5.4b

5.3 Structural Framework.

So far we considered yields as a function of time alone, i.e, $Y_t = f(t)$ and conceptualized the stability issue of different aspects of yield performance of a crop over time. That is, the analysis is only based on time trend framework, where we have not accounted for changes in the levels of inputs like fertilizer, irrigation, high yielding variety seeds (HYV) and rainfall, etc. These are some important factors amongst many that affect the yield level. In a yield response function (referred to as y.r.f. henceforth) yield levels are related to the levels of these inputs and rainfall:

$$Y_t = f(R_t, F_t, I_t, H_t, Z_t)$$

where Y is yield level,

- R is rainfall,
- F is fertilizer intensity,
- I is irrigation intensity,
- H is rate of HYV adoption,
- Z is other important input variable,
- t is time subscript.

In this framework, the time trend is replaced by a yield response function. Now, what does crop yield stability refer to?

Stability of levels (point (a) in section 5.2) under the structural framework has no meaning since, if yield levels are found to be stagnant irrespective of changes in certain input levels, such inputs would not be used at all. Thus a picture analogous to fig.5.1 (where 't' to be replaced by input levels) does not exist[8]. Secondly, as far as stability of growth (point (b)

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8 However, this concept is perfectly meaningful in agronomy. For example, if the yield levels (Y-axis) of a specific variety of seed are plotted against environmental index (X-axis), then the plot would convey whether the performance of that seed variety is uniformly good or not under different environments. See Bhatia (1991).

in section 5.2) is concerned, growth is generally evaluated in terms of "growth rates" over time which has been already discussed earlier. Under structural framework input elasticities of yield may be treated as analogous to the concept of "growth over time" in the temporal framework. Such elasticities obtained from the estimated y.r.f can be tested for their (near) constancy over all levels of input applications. However, it is known that unless y.r.f is a Cobb-Douglas type production function, input elasticities would not be constant. A Cobb-Douglas specification for y.r.f is, however, rarely appropriate since this specification requires that all input levels without exception must be at positive levels for yields to be positive (see chapter 8 for more elaboration of this point). Hence this specification for y.r.f is theoretically ruled out. Thus, we straight away infer that input elasticities would not in general be constant.

Thus, stability analysis under the structural framework boils down to assessing

(a) stability of yield variability around the y.r.f; i.e., changes, if any, in the variance of gaps between realized (Y) and expected ($\hat{Y}$ as obtained from the y.r.f) yield levels with respect to increasing levels of inputs use, and

(b) stability of parameters of the y.r.f.

Here also the analysis involves (i) specification of an appropriate y.r.f, (ii) testing the corresponding residuals for changes in variability with respect to inputs use, and (iii) tests for changes in the parameters of the y.r.f.

This analytical framework based on estimated yield response functions, is henceforth referred to "response function framework (RFF)".

5.4 Difference in Analytical Scope Between TTF and RFF.

Note that by definition the concepts of stability are the same between the time trend framework (TTF) and the response function framework (RFF).

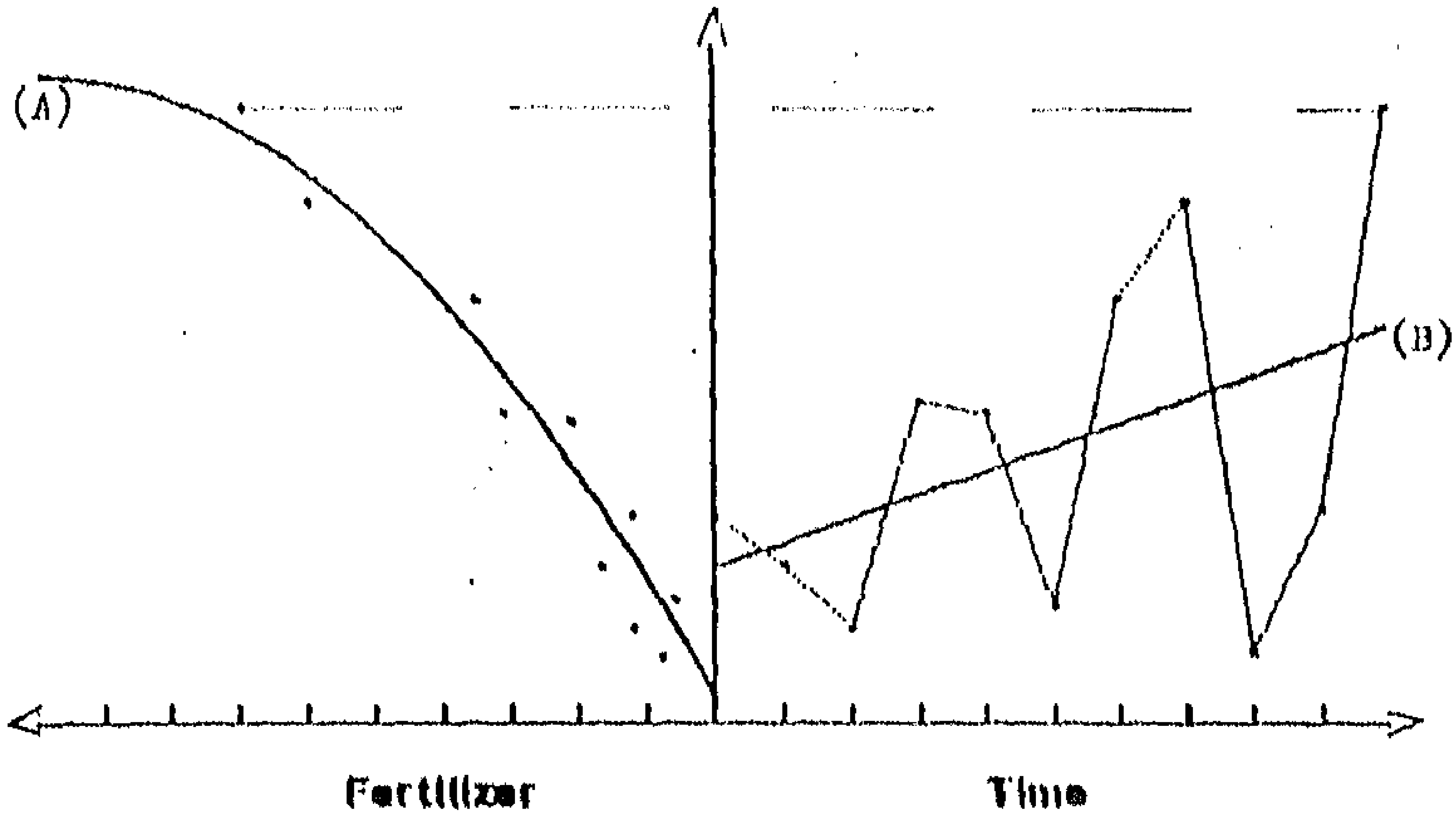
The essential difference between the 2 frameworks is that the expected values are obtained from the estimated time trends in the case of TTF whereas they are obtained from the estimated y.r.f. However, the analytical scope is substantially different between these two frameworks. Let us see this now.

To answer questions on the reliability of the technology, one has to look at the stability of yield variability with respect to inputs use. Now, for example suppose the analysis under TTF showed that yield variability of a crop has changed over time. That is, as time variable increased, the yield variability has also increased (say). From this result, could we have also inferred that yield variability has increased with respect to., say, fertilizer usage (F)? Since, the analysis under TTF does not explicitly account for changes in input variables, there is no a priori possibility of drawing such inferences. However, suppose there is a monotonic relation between time and fertilizer usage such that as time increases, fertilizer use also increases. In this case the "time variable" in TTF can be interpreted as an instrument variable for fertilizer use and then, perhaps, the result of variability change with respect to time could be used to infer a similar result with respect to fertilizer usage also. In the absence of such a monotonicity (in which case time is not a good instrumental variable for F) variability change over time need not imply a variability change with respect to fertilizer use. That is, yields can be heteroskedastic with respect to time in the TTF while they are homoskedastic with respect to F in the RFF.

This situation is shown graphically in figure 5.5 where a set of yields are plotted against time (fig.5.5b) and the same set of yields are plotted against increasing levels of fertilizer use (fig.5.5a). In fig.5.5b, yields show fluctuations of an increasing order around the estimated trend line B. The same levels of yield

(. : Observations; (A),(B) : Estimated Curves)

Fig. 5.5A Yield Fig. 5.5B

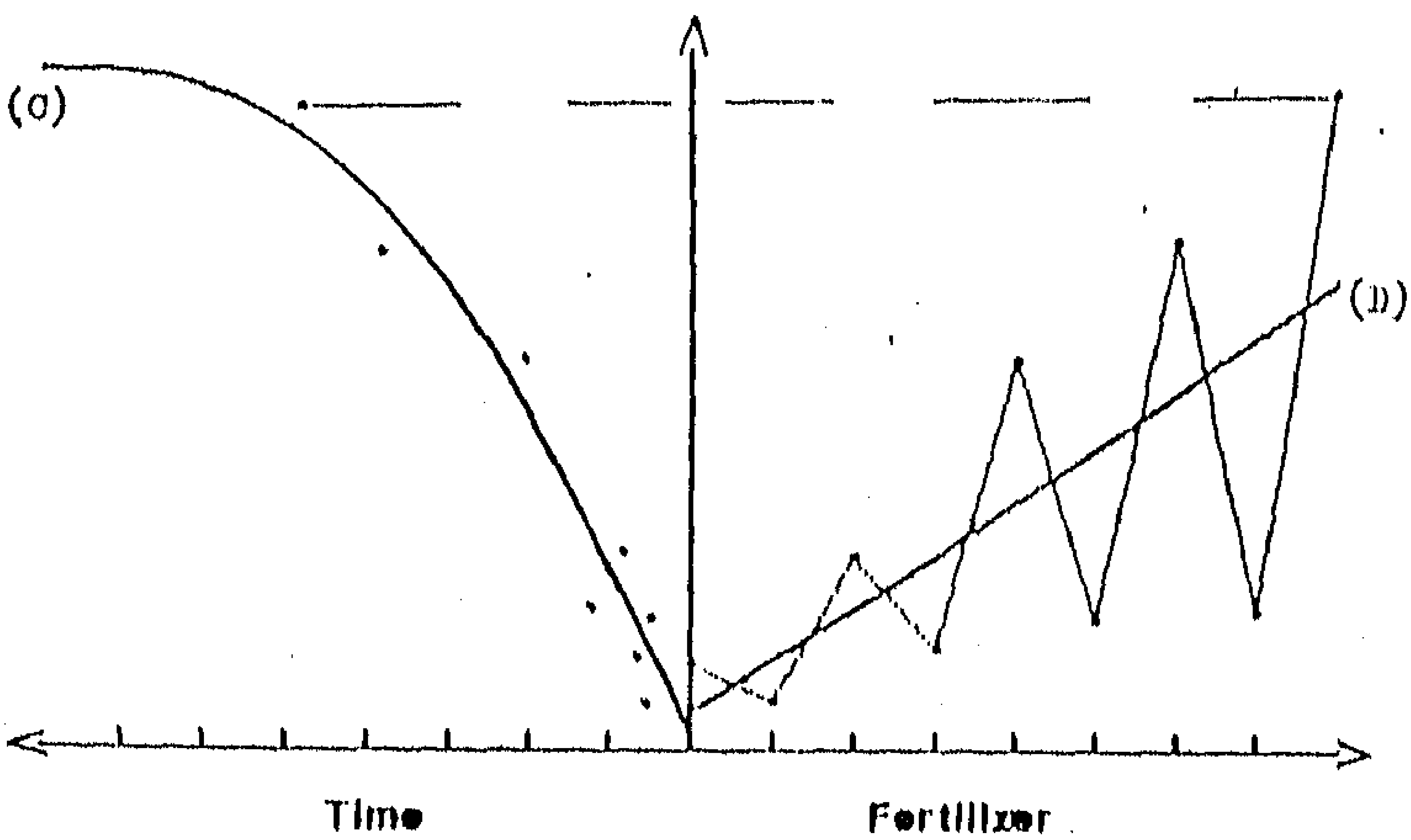


Note: Yield is homoskedastic w.r.t fertilizer (fig A) but heteroskedastic w.r.t time (fig B).

Yield Function

(. : Observations; (C),(D) : Estimated Curves)

Fig. 5.6A Yield Fig. 5.6B



Note: Yield is homoskedastic w.r.t time (fig A) but heteroskedastic w.r.t fertilizer (fig B).

in fig.5.5a show uniform fluctuations around the estimated y.r.f A. Note that high levels of fertilizer use (& hence yield levels) do not always correspond to later time points, nor do low levels of fertilizer (& yields) correspond to earlier time points. Thus the same set of yields are heteroskedastic in the TTF (fig.5.5b) but are homoskedastic in the RFF (fig.5.5a). Thus here time is not a good instrumental variable for fertilizer use.

The reverse situation, i.e., yields being homoskedastic in TTF while they are heteroskedastic in the RFF, is also possible. Figure 5.6 (a & b) shows this situation graphically. Here a set of yields when plotted against increasing levels of fertilizer (fig.5.6b) show fluctuations of an increasing order around the estimated y.r.f D. The same set of yields when plotted against time (fig.5.6a) show uniform fluctuations around the estimated time trend C. In this situation also high (low) levels of fertilizer and yields do not always correspond to later (earlier) time points. Thus, here too, time is not a good instrumental variable for fertilizer use.

In reality, many yield-raising input variables may not actually be correlated with time. A clear example is rainfall. Similarly pesticides application, labour input per hectare, etc. Even fertilizer application and irrigation intensity etc., are found to be highly correlated with time only in the case of certain crops such as rice, wheat (that too only for certain seasons), sugarcane, etc., but not in the case of certain inferior cereals such as jowar, ragi, etc.

The above argument boils down to saying, yields could be varying over time simply because the associated inputs are also varying. Then an analysis based only on time trends (i.e., TTF) cannot, in principle, be adequate enough to throw light on the reliability of a technology. Such an analysis can only analyse yield performance only over time but not with respect to inputs. To assess the variability with respect to inputs use, the analysis must be based on input-output relation (i.e., the response function framework). For some of the cases in this thesis, we analyse yield variability under both TTF and RFF.

Another analytical difference between the two frameworks is with regard to stability of the parameters of the time trends and of the y.r.f. The 2 functions are obviously different. It is possible that the y.r.f might show structural change but the time trend need not. The reverse is generally not expected since usually trends can be changed only by a technological change. It is possible that a shift to modern technology does not bring about substantially higher levels of yield than under traditional technology (as in the case of rice in some parts of India). Then structural change as reflected in the parameter changes of a y.r.f may not lead to parameter changes in the growth function which is only a time trend function. This only means that there has been a change in the technology regime as if only to help maintain a steady growth path.

Various econometric issues become important in the above analyses, concerning specification of f.f. for the growth curve as well as y.r.f, tests for variability change, tests for structural change, pre-specification of the years for variability change and structural change, etc. Often, the conceptual issues described above and econometric issues are interlinked. These econometric issues and their links to the conceptual issues will be discussed in Part B of this chapter.

PART B: ECONOMETRIC ISSUES.

"Irrationally held truths may be more harmful than reasoned errors!"
- T.H. Huxley.

5.5 Functional Form, Error Specification & Estimation Procedure.

Let us first note the consequences of specifying an incorrect functional form to fit the data. Thursby (1982) examined the robustness of the Chow test for structural shift and the Goldfeld-Quandt test for heteroskedasticity to the problem of specification error and showed that the test results can be severely affected by specification error. Based on a set of models, he claimed that for economic data the tests are more likely affected by incorrect functional form than by omitted variables. His main conclusions are that "the sensitivity of the tests to specification error is likely to be greater for cross sectional data than for time series data, greater for incorrect functional form problems than for omitted variables problems and greater in small than in large samples".

In the temporal context of our analysis the problem of omitted variables does not arise since the only variable to be included is time and that anyway figures in the functional forms. Then, the issue is fundamentally on deciding the functional form.

The starting point of the analysis is hence identification of an appropriate f.f. for the growth curve. We start with a set of f.f. consisting of linear as well as nonlinear functions. This set consists of seven most commonly specified time trend f.fs. These include forms such as linear, quadratic, semilog, log-linear, gompertz, etc., the precise forms of which are listed in the next chapter where crop yields at the all India & Andhra Pradesh State level are analysed. All the f.fs are estimated with additive as well as multiplicative error specifications. From amongst these f.fs the most "appropriate" f.f. is then determined for the given data. Subsequent analysis for variability change and structural change are done with this chosen f.f.

It may be mentioned here that the Box-Cox transformation is suggested in the literature as a procedure for determining the "appropriate" specification of the f.f. This procedure, however, has been used only to a limited extent here, the reasons for which will be explained in a later section.

The criteria for choosing or rejecting a particular f.f. as the most appropriate specification for a given data have to be spelt out now.

Typically, in any function estimated by the least squares (LS) procedure, we look for the satisfaction of certain optimal properties as provided by econometric theory. The optimal properties of interest are as follows. The parameter estimators should

1) be unbiased,
2) have minimum variance,
3) follow a normal distribution.

Along with the above 3 properties, the f.f having the highest fit in terms of $R^2/\bar{R}^2$ may be considered as the most appropriate to fit the yields data.

The satisfaction of the above mentioned 3 properties depends largely on the estimation procedure (linear or nonlinear) that one adopts, which in turn depends on both the f.f. (whether it is linear or nonlinear in parameters) as well as the error specification. For example, a nonlinear function such as a semilog function ($Y = \alpha \cdot \beta^t$) can be linearly estimated by resorting to log-transformation[9] in the case of multiplicative error form

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9 An approach based on such transformations is adopted only to a limited extent in our analysis due to some important implications of such transformations on the error term.

(m.e.f) ($Y = \alpha \cdot \beta^t \cdot V_t$) whereas it requires nonlinear estimation in the case of additive error form (a.e.f) ($Y = \alpha \cdot \beta^t + U_t$). However, even a linear function such as $Y = \alpha + \beta \cdot t$, requires nonlinear estimation in the case of m.e.f. ($Y = (\alpha + \beta \cdot t) \cdot V_t$) though it is linearly estimated in the case of a.e.f ($Y = \alpha + \beta \cdot t + U_t$).

Estimators of a model (f.f. with an error specification) which could be obtained by linear estimation (OLS) would satisfy the above 3 optimal properties. Then, generally it is the goodness of fit that decides whether the corresponding function can be selected or not. On the other hand, in the case of nonlinear estimation procedures, though R^2 in a conventional sense as a descriptive statistic to measure the overall fit is still applicable, several other problems arise. For example, the estimate of the true error variance (σ^2) obtained from the regression residuals remains biased; the estimated residuals would neither be normally distributed nor necessarily have a zero mean. This would further imply that the residual sum of squares does not follow a χ^2 distribution. Besides, the parameter estimators not being linear functions of Y (the dependent variable) they would not be normally distributed in which case the conventional t-tests and F-test cannot be applied (see Pindyck & Rubinfeld (1981)). The estimators are in fact neither unbiased nor do they possess minimum variance property.

The upshot of the above discussion is that biased parameter estimators would lead to bias in the expected values (Y) which in turn imply that the estimated residuals would be inappropriate. Hence results on change in yield variability which depends mainly on the estimated residuals would not be reliable in such situations. Thus it is necessary to evaluate the bias in parameter estimators and the skewness in their distributions whenever nonlinear estimations are involved.

According to asymptotic theory, as sample size increases the nonlinear estimators tend to behave more and more like linear estimators provided the error term (U_t or $\text{Log}(V_t)$ as the case may be) are identically and independently distributed normally. That is, the larger the sample size the less is the bias of parameter estimators, their variance closer to minimum levels and their distributions closer to normal. In fact, under these conditions the least squares estimators are also the maximum likelihood estimators which are known to be consistent.

However, how large a sample should be to attain these asymptotic properties? Basically, this seems to be a subjective matter depending on the problem at hand as well as the analyst. According to Ratkowsky (1983), "there are some nonlinear models for which the asymptotic properties are a good approximations even for very small sample sizes, whereas there are other nonlinear models where the asymptotic properties are poorly approximated even for what must be considered to be very large samples in practical terms". This means that all nonlinear models do not suffer from the above discussed problems to the extent of same degree. After all, some models are disastrously nonlinear while others are only moderately nonlinear in terms of degree of curvature. As will be seen later, the properties of the nonlinear estimators are more close to the properties of linear estimators the less the degree of nonlinearity. Then, how to measure the degree of nonlinearity!

3.6 Measures of Nonlinearity[10].

The behaviour of LS estimators of nonlinear models in contrast to those of linear models has been extensively probed in

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Next 12 pages contain a brief review on the theory of nonlinearity measures essentially developed by Beale (1960) and Bates & Watts (1980). The review ultimately culminates in two kinds of nonlinearity measures (IN & PE) due to latter authors followed by a description of Box's bias and Hougaard's skewness measures. Readers not interested in the technical details of these measures may skip these pages and move on to page 125.

rious studies such as Beale (1960), Box (1971), Bates and Watts 980, 1988), Ratkowsky (1983, 1988), Hougaard (1985), etc. to me a few. Noteworthy among these studies is Bates and Watts 988) where a comprehensive treatment of nonlinear regression dels is provided.

Consider the following linear function:

$$\text{(a)} \quad Y_t = \beta X_t + U_t \tag{5.3}$$

here X_t are known fixed numbers. That is, once the data are given act as constants. Our aim is to obtain an estimate of β, say $\hat{\beta}$, uch that the residual sum of squares, $\Sigma(Y - \hat{Y})^2$, where $\hat{Y}_t = \hat{\beta}X_t$, s the minimum.

Suppose for a while the value of β is varied and responses as expectations given by,

$$f_t = \beta X_t \tag{5.4}$$

re observed. Let us call this as expectation function. It is obvious that

$$\frac{\delta ft}{\delta\beta} = X_t \qquad \text{for all } t. \tag{5.5}$$

Same, in the economics' jargon in terms of elasticities, comes to

$$\frac{\%\text{ Change in } f_t}{\%\text{ Change in } \beta} = e_f = \frac{\delta ft}{\delta\beta} \cdot \frac{\beta}{f_t} = \frac{\beta Xt}{f_t} = 1. \tag{5.6}$$

That is, in the case of a linear model, percentage changes in expectations would be in fact equal to percentage changes in parameter values.

ow consider a nonlinear linear function

$$\text{(b)} \quad Y_t = X_t^{\theta} + U_t \tag{5.7}$$

et the corresponding expectation function be

$$g_t = X_t^{\theta} \tag{5.8}$$

t can be shown here that

$$\frac{\%\text{ Change in } g_t}{\%\text{ Change in } \theta} = e_g = \theta \cdot \log(X_t) \qquad \text{(not constant)} \tag{5.9}$$

this case the percentage changes in the parameter (θ) lead to fferent, different, percentage changes in the expectations pending on the current value of θ. For example, when a 10% change in θ is made it makes a tremendous difference to percentage change in the expectations depending on whether θ is changed from 10 to 11 or 100 to 110. Basically, this kind of behaviour in expectations under nonlinear models arises due to the fact that the expectation function has a curvature making the derivatives of expectations with respect to parameters not free of parameters themselves.

However, how expectations change when parameter values change does not solely depend on the curvature aspect alone. To illustrate this point let us now consider another linear function such as

$$(c) \quad Y_t = X_t^{\log\phi} + U_t \qquad (5.10)$$

with the corresponding expectation function is

$$h_t = X_t^{\log\phi} \qquad (5.11)$$

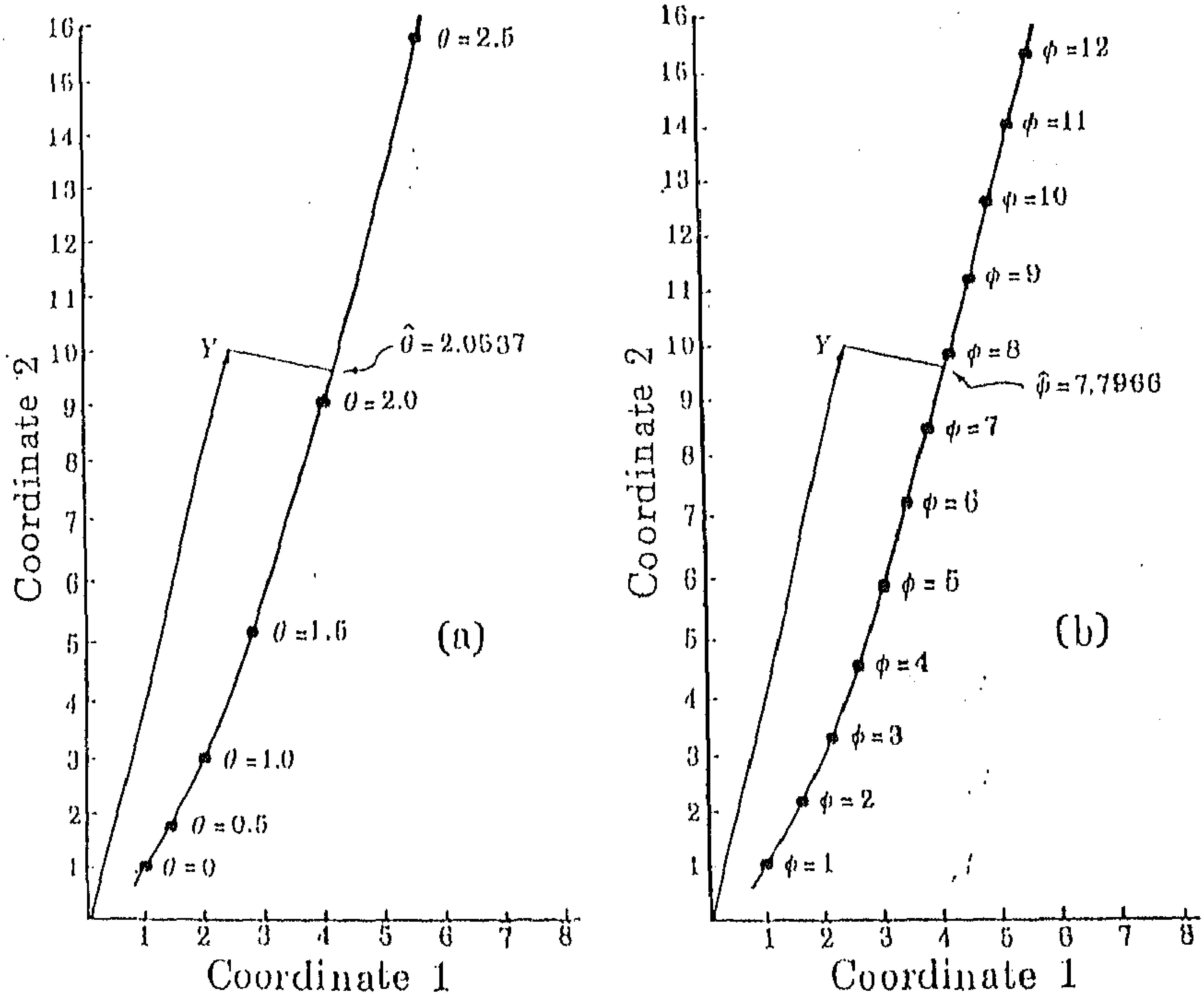
As far as curvature is concerned, this function has same kind of curvature as the function (5.7). However, the parameter enters differently here; θ as $\log\phi$. That is, (5.10) is a reparameterized version of (5.7). It can be shown here that

$$\frac{\%\text{ Change in } h_t}{\%\text{ Change in } \phi} = e_h = \log(X_t) = \begin{matrix}\text{a constant for}\\ \text{given data}\end{matrix} \qquad (5.12)$$

Here there is a kind of uniformity between the changes in parameters and changes in expectations. In this sense, model (5.10) though nonlinear almost behaves as a linear model. Examples (5.7) & (5.10) show that how expectations change with respect to changes in parameter values depends also on how a parameter figures in a model.

The above examples demonstrate two aspects: the curvature aspect which is generally referred to as "intrinsic nonlinearity" and the parameter aspect which is generally referred to as "parameters effects nonlinearity".

The differences in the behaviour of expectations as parameters θ and ϕ change are shown graphically in figure 5.7. The plot



Notes: Sample space representation of data: (a) model $E(Y) = X^{\theta}$; (b) model $E(Y) = X^{\log\phi}$.

Source: Ratkowsky (1983).

Figure 5.7

depicts the changes in expectations with respect to changes in parameter values assuming that the sample size (N) is 2 and the number of parameters (P) to be estimated is 1. Y as a point represents the sample of observations on the dependent variable as a point (Y_1, Y_2) in a coordinate system where the number of coordinates is equal to the sample size. Similarly, the expectation points at different values of parameters can also be located in this sample space and a curve passing through all points can be drawn. Such a curve (PQ in figure 5.7a and RS in figure 5.7b) showing the change in expectations with respect to change in parameter values is called "solution locus" or "expectation surface" (Box and Lucas (1959)). The solution locus in the case of nonlinear (linear) models is a curvilinear (plane) surface when the sample space N>2.

The least squares (LS) problem corresponds to estimating the parameter(s) values which minimizes the distance between Y and the solution locus. $\hat{\theta}$ and $\hat{\phi}$ are such points. The curvature of the solution locus in the neighbourhood of $\hat{\theta}$ (or $\hat{\phi}$) is the "intrinsic nonlinearity" (referred to as IN henceforth) which essentially depends only the model and the data set. Since the basic model is same between plots 5.7a and 5.7b, their intrinsic nonlinearity is also same. That is reparameterization of a model does not affect this nonlinearity. However reparameterization, as we saw above between models (5.7) & (5.10), affects the spacing of the expectations vis a vis spacing of the parameters. This is called "parameter effects" (referred to as PE henceforth) nonlinearity. IN & PE are thus two components of non-linearity in general.

We now turn to another serious problem in the case of nonlinear models; this is with respect to the joint confidence regions (also called inference or likelihood regions). A joint confidence region refers to the set of all values of the parameters associated with that part of the solution locus which is within a specified minimum distance of Y. Generally, a $100(1-\alpha)\%$ confidence region is expressed as

$$S(\theta) - S(\hat{\theta}) \leq P \cdot s^2 \cdot F(P, N-P; \alpha) \qquad (5.13)$$

where $S(\theta)$ and $S(\hat{\theta})$ are the error (true) and residual (estimated) sum of squares, P is the number of parameters, N is the sample size, α is the level of significance and F is the critical value of F distribution at α level with degrees of freedom P and (N-P), and $s^2 = S(\hat{\theta})/(N-P)$.

In the case of linear models ($Y = X\beta + U$), expression (5.13) boils down to

$$(\beta-\hat{\beta})'X'X(\beta-\hat{\beta}) \leq P \cdot s^2 \cdot F(P, N-P; \alpha) \tag{5.14}$$

Since U_t & $\hat{U}_t$, the true errors and estimated residuals, are normally distributed, it is clear that, the distributions of $S(\theta)$, $S(\hat{\theta})$ and s^2 are known to follow χ^2 distribution and hence the confidence region given by (5.13) is exact for linear models.

However, in the case of nonlinear models ($Y = f(\beta;X) + U$), even though U_t follow normal distribution, generally $\hat{U}_t$ being nonlinear function of Y would not be normally distributed. Besides, LS estimators of $\hat{\beta}$ being neither unbiased nor normally distributed, $S(\hat{\theta})$ also is biased. Consequently $s^2 = S(\hat{\theta})/(N-P)$ is not an unbiased estimator of σ^2. In general, there is no variance-covariance matrix of the form $(X'X)^{-1}\sigma^2$. That is, the exact distribution properties are not known.

Beale (1960) suggested a way of approximating the confidence regions in the case of nonlinear models. To put it very briefly, Beale suggested a modified expression, instead of (5.13), for the confidence region as follows:

$$S(\theta) - S(\hat{\theta}) \leq P \cdot s^2 \cdot F(P, N-P; \alpha) \left[1 + N_{\phi}\left(\frac{N(P+2)}{P(N-P)}\right)\right] \tag{5.15}$$

where the quantity N_{ϕ}, is supposed to indicate how nonlinear is the given function. That is, $N_{\phi} \geq 0$ is a measure of nonlinearity. $N_{\phi} = 0$ for linear models. As nonlinearity becomes worse, N_{ϕ} increases resulting in a larger confidence region for a given α.

Beale suggested both theoretical as well as empirical measures of the nonlinearity. One of these measures is in fact an empirical measure of the intrinsic nonlinearity (explained above) as "a sort of generalized curvature of the solution locus in the neighbourhood of" the least squares solution point. Linssen (1975) suggested modifications to Beale's measures while Williams (1962) proposed a different measure. However, Bates & Watts (1980) (BW henceforth) proposed altogether new measures of nonlinearity far improved over Beale's measures. BW measures are based on the geometry of curvature in the solution locus[11] which takes into account both "intrinsic" as well as "parameters effects" components of the nonlinearity that were already explained above.

To appreciate their measures, let us first note that to obtain LS estimators in the case of nonlinear models analytical solutions (such as $\hat{\beta} = (X'X)^{-1}X'Y$ in the case of linear models) rarely exist. Only numerical iterative methods usually involving linear approximations are available. One such method is the Gauss Newton algorithm. According to this algorithm, a nonlinear expectation function $f(X_t, \theta_1, \theta_2, \ldots, \theta_p)$ is expanded and approximated as a first order Taylor series[12] about an initial set of parameters estimates $\theta^o = \theta_1^o, \theta_2^o, \ldots, \theta_p^o$, as follows:

$$f(X_t, \theta_1, \theta_2, \ldots, \theta_p) \simeq f(X_t, \theta^o) + v_{t1}(\theta_1 - \theta_1^o) + v_{t2}(\theta_2 - \theta_2^o) + v_{tp}(\theta_p - \theta_p^o) \qquad (5.16)$$

$$\text{where } v_{tj} = \left.\frac{\delta f(X_t, \theta_1, \theta_2, \ldots, \theta_p)}{\delta\theta_j}\right|_{\theta_1^o, \theta_2^o, \ldots, \theta_p^o} \qquad (5.17)$$

$$j = 1, 2, \ldots, P$$

Putting all the N cases ($t = 1, 2, \ldots, N$) together in a matrix form, we get

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11 For a good exposition on the geometry of least squares see Draper & Smith (1966).

12 According to Taylor's series, expansion of $f(\theta)$ around $\theta = \theta^o$ is $f(\theta) = f(\theta^o) + (\theta-\theta^o)f'(\theta^o) + \frac{1}{2!}(\theta-\theta^o)^2 f''(\theta^o) + \ldots + \frac{1}{p!}(\theta-\theta^o)^p \cdot f^p(\theta^o) + R_{p+1}$

where R_{p+1} is the remainder and $f(\theta)$ is continuous and has a continuous p^{th} derivative. In a first order Taylor series all the terms involving second and higher order derivatives are dropped.

$$f(X,\theta) = f(X,\theta^{\circ}) + V^{\circ}(\theta - \theta^{\circ}) \qquad (5.18)$$

where V° is the NxP derivative matrix with elements $\{v_{tj}\}$. While the true errors are actually

$$Z(\theta) = Y - f(X,\theta) \qquad (5.19)$$

equation (5.18) implies they are approximated as

$$Z(\theta) = Y - f(X,\theta) = Y - f(X,\theta^{\circ}) - V^{\circ}(\theta - \theta^{\circ})$$

$$= Z^{\circ} - V^{\circ}\delta^{\circ} \qquad (5.20)$$

where $Z^{\circ} = Y - f(X,\theta^{\circ})$ and $\delta^{\circ} = (\theta - \theta^{\circ})$ (5.21)

In fact, (5.20) implies

$$Z^{\circ} - V^{\circ}\delta^{\circ} = U \text{ (error vector)}$$

so that $Z^{\circ} = V^{\circ}\delta^{\circ} + U$ (5.22)

Now equation (5.22) can be treated as a linear regression model and $\delta^{\circ} = (\theta - \theta^{\circ})$ = revision in the initial estimates, can be obtained as

$$\hat{\delta}^{\circ} = (V^{\circ\prime}V^{\circ})^{-1}V^{\circ\prime}Z^{\circ} = (V^{\circ\prime}V^{\circ})^{-1}V^{\circ\prime}(Y - f(X,\theta^{\circ}) \qquad (5.23)$$

Using $\hat{\delta}^{\circ}$, the estimates can be revised as

$$\theta^{1} = \theta^{\circ} + \hat{\delta}^{\circ} \qquad (5.24)$$

Now starting from the Taylor series approximation around θ^{1}, the whole process can be repeated several times until there is no significant difference in the residual sum of squares $S(\hat{\theta}) = (Y-f(X,\theta^{l}))^{2}$ between successive iterations l and l-1.

The merit of the procedure lies in step 1 (equations 5.16 to 5.18) which implies that the curvature of the expectation surface (solution locus) at θ° is actually approximated as a plane that is tangent to the surface at θ°. [$f(X,\theta) - f(X,\theta^{\circ}) = V^{\circ}(\theta - \theta^{\circ})$, is precisely the equation for the plane tangent at θ° to the surface $f(X,\theta)$]. This approximation is referred to as the "planar" assumption.

Secondly, assuming the second and higher order derivatives to be zero, terms involving these derivatives are dropped. However, for example, the second order derivatives $\left[\frac{\delta^2 ft}{\delta\theta_j^2}, \frac{\delta^2 ft}{\delta\theta i \cdot \delta\theta j}\right]$ convey information about change in the direction of $\delta f/\delta\theta_j$, as well as, depending on how θ_j enter into the model, the speed with which expectations change with respect to changes in θ_j. Dropping all, but the first, order derivatives as in equation (5.16) & (5.18) implies that uniform changes in θ would lead to uniform changes in $f(X, \theta)$. This approximation, resulting in imposition of linear coordinate system $V(\theta - \theta^o)$, is referred to as "uniform coordinate" assumption.

By now, the connection between the "planar" and "uniform coordinate" assumptions and the previously explained "intrinsic" and "parameter effects" components of nonlinearity must be obvious. Intrinsic nonlinearity is a measure indicating how flat is the expectation surface at the LS solution point. The lower is this measure, the flatter is the surface. Similarly, "parameter effects" nonlinearity is a measure indicating how uniform are the changes in the expectations with respect to uniform changes in parameters. The lower is this measure, the greater is such uniformity.

Thus, the crux of the nonlinearity issue boils down to measuring the higher order derivatives at the solution point. Let us see now how it is achieved.

Following the notation adopted by Bates & Watts, let us write,

a) the (N×P) derivative matrix V, consisting of P velocity or tangent vectors (v_j) as they are called,

$$\{\dot{V}\}_{NP} = \frac{\delta f(Xt,\theta)}{\delta\theta_j} \qquad \begin{matrix} t = 1, \ldots, N \\ j = 1, \ldots, P \end{matrix} \qquad (5.25)$$

b) the N×(P×P) second derivative array $\ddot{V}$ consisting of acceleration vectors as they are called,

$$\{\ddot{V}\}_{N(PP)} = \frac{\delta^2 f(Xt,\theta)}{\delta\theta i . \delta\theta j} \qquad \begin{matrix} t = 1, \ldots, N \\ i = 1, \ldots, P \\ j = 1, \ldots, P \end{matrix} \qquad (5.26)$$

c) Let us also express the expectation surface in a vector form, simply as

$$\eta = f(X, \theta) \tag{5.27}$$

so that $\dot{V} = \delta\eta/\delta\theta$ and $\ddot{V} = \delta^2\eta/\delta\theta\cdot\delta\theta'$

Now suppose, an attempt is made in the P-dimensional parameter space to move from an initial θ^{o} in any arbitrary direction $h = (h_1, h_2, ..., h_P)'$ by a distance of b, so that

$$\theta(b) = \theta^{o} + b\cdot h \tag{5.28}$$

This results in a corresponding movement in the N-dimensional sample space from the initial expectation point η (b=0) so that

$$\eta_h(b) = \eta(\theta^{o} + b\cdot h)$$

The tangent to the curve $\eta_h(b)$ at b = 0 is

$$\dot{\eta}_h = \frac{d\eta_h}{db}\bigg|_{b=o} = \Sigma \frac{\delta\eta}{\delta\theta_i}\bigg|_{\theta^{o}} \cdot \frac{d\theta_i}{db}\bigg|_{o} = \Sigma\, v_j h_j$$

i.e. $\dot{\eta}_h = \dot{V}\cdot h$

Similarly, the acceleration of η_h can be shown as

$$\ddot{\eta}_h = \frac{d^2\eta_h}{db^2}\bigg|_{b=o} = \sum_i \delta\Big(\sum_j v_j h_j\Big) \div \delta\theta_i\bigg|_{\theta^{o}} \cdot \frac{d\theta_i}{db}\bigg|_{o}$$

$$= \sum_j \sum_i v_{ji}\cdot h_j\cdot h_i{}' = h'\ddot{V}h$$

where h' is (1×P), $\ddot{V}$ is (N(P×P)) and h is (P×1) so that, the acceleration vector $\ddot{\eta}_h{}'$ is (N×1).

The acceleration vector $\ddot{\eta}_h$ may not fall in the tangent plane itself. In fact its deviation from the tangent plane indicates the extent of nonlinearity of the expectation surface. $\ddot{\eta}_h$ can then be decomposed essentially into two components[13]: one, the projection of it on the tangent plane say, $\ddot{\eta}_h^N$; the other as a normal to the tangent plane say, $\ddot{\eta}_h^T$. The length of the normal component

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13 In fact, Bates & Watts (1980) decompose $\ddot{\eta}_h$ into three components, one of which indicates the intrinsic nonlinearity and the other two together parameter effects nonlinearity.

obviously depends on how far the acceleration vector deviates away from the tangent plane, thus indicating the intrinsic nonlinearity of the model. This does not depend on θ. Whereas the length of the projection component, however, depends on θ. How precisely? It depends on how θ appear in the $\ddot{\eta}_h$ which in turn depends on the specification of the expectation function (or the model).

Thus, if $\ddot{\eta}_h = \ddot{\eta}_h^N + \ddot{\eta}_h^T$ (5.29)

then, (i) the intrinsic curvature is measured by

$$K_h^N = \| \ddot{\eta}_h^N \| \div \| \eta_h \|^2 \quad (5.30)$$

geometric interpretation of which is "that of the inverse of the radius of the circle" approximating the expectation surface; and

(ii) the parameters effects curvature is measured by

$$K_h^T = \| \ddot{\eta}_h^T \| \div \| \eta_h \|^2 \quad (5.31)$$

which is affected by the parameters of the model. Thus a specification change say, from $f(X,\beta) = X^{\beta}$ to $f(X,\phi) = X^{\log\phi}$ can affect K_h^T.

However, K_h^T and K_h^N are not free of the units problem. To avoid the dependence on scaling of data (yield is in tons/ha or kh/ha), these are converted to dimensionless standardized "relative" measures by multiplying[14] them by $\hat{s}\sqrt{P}$, where $\hat{s}^2$ is the estimated residual sum of squares $[(Y - f(X,\hat{\theta}))^2/(N-P)]$.

i.e., Intrinsic component of nonlinearity (IN):

$$IN = \gamma_h^N = K_h^N \cdot \hat{\rho} \quad (5.32)$$

and Parameter effects component of nonlinearity (PE):

$$PE = \gamma_h^T = K_h^T \cdot \hat{\rho} \quad (5.33)$$

$$\text{where } \hat{\rho} = \hat{s}\sqrt{P} \quad (5.34)$$

Now, using these measures, invariant under changes of scale in the response, "not only different parameterizations for a given problem but also different data sets for the same or different

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14 Dividing the expectation and the model function by a factor will multiply K_h^T and K_h^N by the same factor.

models" can be compared. For more details on purposes served by the scaling by $s\sqrt{\hat{P}}$ especially with respect to joint confidence regions and in general on the theory of nonlinearity measures see Bates & Watts (1988).

It then follows, that for the linear approximation adopted in the nonlinear estimation procedure to be valid, IN & PE should be close enough to zero (which is the case in linear models). Bates & Watts (1980, 1988) show that the smallness (or closeness to zero) of IN & PE can be tested by comparing the computed values of IN & PE against $1/\sqrt{2F}$ where $F = F(P,\ N-P;\ \alpha)$ is the value of the F-distribution corresponding to α level of significance with P & N-P degrees of freedom. Insignificant low values of IN and PE imply that the parameter estimators satisfy the properties of consistency, unbiasedness as well as minimum variance. Also, the distribution of the estimated residuals can now be treated as close enough to normal so that the standard tests such as t- and F- become applicable.

Bias measure: Box (1971) provides a measure of bias in a parameter's estimate based on the first and second derivatives of the expectation function with respect to the parameter. The expression for bias is given as follows:

$$\text{Bias}(\hat{\theta}) = \frac{-\sigma^2}{2}\left[\sum_{u=1}^{N} F_u F_u'\right]^{-1} \cdot \sum_{t=1}^{N} F_t \cdot \text{trace}\left[\left(\sum_{u=1}^{N} F_u F_u'\right)^{-1} H_t\right] \qquad (5.35)$$

where, F_t ($= F_u$) is the Px1 vector of first derivatives of $f(X,\theta)$,
H_t is the PxP matrix of second derivatives with respect to each of the element of θ, evaluated at X_t, $t = 1, 2, \ldots, N$ and at the unknown true parameter values.

This bias measure is expressed as a percentage of the LS estimate itself. Thus, for a model to be accepted, one may require the percentage bias of Box (BB henceforth) to be small, say less than 1%, for each of the parameters in the model. In this study 1% is the cut off used as the maximum permissible bias in the parameter estimates.

Bates & Watts (1980) also prove that Box's (1971) bias measure in parameter estimator is related to their parameter effects component of nonlinearity. Since bias in an estimator is a property of the parameterization, it follows that the bias may be reduced or even eliminated by a suitable reparameterization.

Skewness measure: Hougaard (1985) provides a measure of the skewness in a parameter's distribution based on the first and second derivatives of the expectation function with respect to the parameter. The computation of the skewness is as follows:

Let $J(\hat{\theta})$ be the N×P Jacobian matrix evaluated at $\hat{\theta}$;

$H(\hat{\theta})$ be the N×P×P matrix of second derivatives with respect to parameters evaluated at $\hat{\theta}$;

s^2 be the estimated error variance;

$$L = \left[J'(\hat{\theta})J(\hat{\theta})\right]^{-1}$$

$$W_{jkl} = \sum_{m=1}^{N} J_{mj} H_{mkl} \qquad j, k, l = 1, 2, \ldots, P$$

Then the estimate of the third moment of θ_i is

$$E\left[\left(\theta_i - \hat{\theta}_i\right)\right]^3 = -(s^2) \sum_j \sum_k \sum_l L^{ij}L^{ik}L^{il}(W_{jkl} + W_{kjl} + W_{lkj})$$

$$i, j, k, l = 1, 2, \ldots, P$$

and the skewness of θ_i is given as

$$g_{1i} = E\left[\left(\theta_i - \hat{\theta}_i\right)\right]^3 \div \left(s^2 L^{ii}\right)^{3/2} \qquad (5.36)$$

Smaller the skewness closer is the parameter's distribution to normality. Obviously, for a linear model the skewness would be zero.

To sum up: In order to assess the suitability of a nonlinear model to the given data, we first compute Hougaard's skewness (SK) measure for each of the parameters in the function, Box's percentage bias (BB) in each of the parameters, the 2 overall measures of nonlinearity, IN & PE, of Bates and Watts. These measures have to be small enough such that

(i) SK for each parameter has to be less than 1.0,

(ii) BB for each parameter has to be less than 1%,

(iii) IN & PE, the overall measures of nonlinearity, should each be less than $1/\sqrt{2F}$ where $F = F(P, N-P; \alpha)$ is the value of the F-distribution corresponding to α level of significance with P & N-P degrees of freedom.

Only when all these measures are satisfied, the corresponding nonlinear estimation is considered to be satisfactory enough and the parameter estimates can be relied on. From amongst all such models (linear and nonlinear), possessing desired properties for the parameters

(iv) the best fitting one in terms of highest $R^2/\bar{R}^2$ may then be retained for further analysis.

Based on an iterative method described by Bates & Watts, a FORTRAN program listing has been provided by Ratkowsky (1983, 1989) to estimate a model and compute the nonlinearity (IN & PE), Box's bias (BB) and Hougaard's skewness (SK) measures. These programs have been used by us along with some associated programs developed in house as well as some other programs developed by Dipl.Ing.Guenther Fischer (International Institute of Applied Systems Analysis (IIASA), Laxenburg, Austria).

One may now ask, why has an estimation procedure based on Box-Cox transformation not been adopted for arriving at an "appropriate" functional form specification. Next section will provide an answer to this question.

5.7 Error Specification in Box-Cox Transformations.

Recall that the error specification, additive or multiplicative, has special meaning in the analysis for changes in yield variability. An additive error refers to absolute yield variability while multiplicative error refers to relative yield variability. (See section 5.2).

Consider again the example of a semilog time trend with a multiplicative error ($Y_t = \alpha \cdot \beta^t \cdot V_t$) which is transformably linear. The same semilog trend with an additive error ($Y_t = \alpha \beta^t + U_t$), however, is not transformably linear. Thus, when one estimates a semilog trend by applying OLS on a logarithmically transformed equation (data), the implicit error specification is multiplicative rather than the usually preferred additive form. In principle, this would not pose a serious problem if one were sure that the parameters estimates obtained from the estimation with multiplicative error would be the same as those obtained from the estimation with an additive error. If this were indeed true, then, with the estimated yield levels ($\hat{Y}$ – would be same in both the situations) one can generate both $\hat{U}_t = Y_t - \hat{Y}_t$ (additive error) and $\hat{V}_t = Y_t / \hat{Y}_t$ (multiplicative error).

However, the estimations under the two error specifications need not lead to the same parameter estimates; hence $\hat{Y}$ would be different under the two specifications. Ratkowsky (1983) provides several examples using yields data for Australia where the 2 estimations resulted in parameter estimates that are widely different between the two error specifications.

This point is illustrated below using the data on irrigated and unirrigated outputs (say, Q) of foodgrains and for all crops, for the period 1970-71 to 1983-84, reported in Dhawan (1988). These data are for the States of Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Rajasthan, Tamil Nadu & Uttar Pradesh. Dhawan's aim is to analyse percentage variability as reflected in the series of $(Q_t / \hat{Q}_t)$.

Towards this, he however estimates $Q_t = f(t) + U_t$ which corresponds to an additive error form. Taking f(t) to be a linear trend, he develops a series of $Q_t/\hat{Q}_t$, where $\hat{Q}_t = (\hat{\alpha} + \hat{\beta}t)$ and goes on to compute coefficient of variation in the series. If the interest is in percentage residuals one would normally expect the equation to estimate is $Q_t = (\alpha + \beta t)\cdot V_t = \hat{Q}_t \cdot V_t$; but not $Q_t = (\alpha + \beta t) + U_t$. Dhawan's procedure is, however, valid if (only) the series of $\hat{Q}_t$ would be same whether they are estimated in a multiplicative error form or additive error form. Obviously, the series of $\hat{Q}_t$ would be same between the two error forms if the corresponding parameter estimates are same. Let us see this now. We reestimate his linear trend but with a multiplicative error, $Y_t = (\alpha + \beta t)\cdot V_t$, for the same data. Our estimation results for the multiplicative error form are reported in table 5.1 alongwith the results for the additive error case as reported by Dhawan. These results show quite a difference in the estimated coefficients between the two forms of estimations in the case of irrigated foodgrains output in Punjab & Uttar Pradesh, unirrigated foodgrains output in Gujarat, Madhya Pradesh, & Maharashtra, irrigated all crops output in Haryana, Madhya Pradesh & Uttar Pradesh, unirrigated all crops output in Karnataka (note here the differences in R^2 also) & Maharashtra. The differences are large particularly when R^2 are low. Obviously, differences in parameter estimates would lead to differences in estimated expected values. In the remaining cases, the two error specifications led to approximately the same parameters estimates.

Which set of expected (estimated) yields are to be used to study absolute and relative yield variability if different error specifications imply different expected yields and hence different residuals? Obviously, the expected yields must be same whether one wants to analyse absolute yield variability or relative yield variability!

Therefore, given the conceptual importance of both additive and multiplicative error specifications in our study, each of the various alternative f.fs (mentioned in section 5.5 earlier) is estimated under both additive error form (AEF) and multiplicative

Table 5.1 - Statewise Linear Trend of Output, 1970-71 to 1983-84.

State	Additive Error$			Multiplicative Error#		
	α	β	R^2	α	β	R^2
Andhra Pradesh						
ifg	4155.0	281.2	0.81	4219.7	268.4	0.79
ufg	1728.2	45.8	0.44	1695.0	48.9	0.46
iac	5395.2	338.8	0.82	5462.5	325.7	0.81
uac	3006.2	27.3	0.08	2986.7	27.3	0.09
Bihar						
ifg	2132.0	159.2	0.67	2063.8	164.5	0.68
ufg	4116.4	-15.8	0.01	4111.8	-20.0	0.02
iac	2295.3	155.5	0.66	2224.9	161.0	0.66
uac	4606.7	-24.6	0.03	4599.0	-28.1	0.04
Gujarat						
ifg	637.2	99.6	0.79	689.5	89.3	0.72
ufg	2394.2	-11.9	0.01	2181.1	3.6	0.0005
iac	577.2	192.0	0.87	798.4	154.5	0.77
uac	4183.4	-1.46	0.0002	3588.3	44.8	0.01
Haryana						
ifg	1968.3	267.9	0.91	2132.2	241.4	0.86
ufg	1464.6	-49.7	0.32	1414.7	-49.4	0.27
iac	2617.1	269.2	0.90	2740.6	249.0	0.86
uac	1539.4	-50.2	0.34	1497.9	-50.6	0.28
Karnataka						
ifg	1525.4	48.5	0.29	1550.0	42.0	0.26
ufg	3220.2	26.6	0.04	3149.9	29.9	0.04
iac	2415.2	107.2	0.64	2474.2	96.9	0.62
uac	3874.6	17.6	0.01	3771.7	23.4	0.42
Madhya Pradesh						
ifg	1212.5	137.0	0.71	1343.8	114.4	0.65
ufg	7178.5	125.5	0.17	7296.1	97.9	0.10
iac	1378.1	151.2	0.72	1513.0	128.0	0.67
uac	7692.3	116.3	0.14	7801.6	89.4	0.08

Notes are provided at the end of the table.

Table 5.1 Contnd.

State	Additive Error[$]			Multiplicative Error[#]		
	α	β	R^2	α	β	R^2
Maharashtra						
ifg	805.7	75.8	0.59	733.3	81.9	0.56
ufg	3339.0	364.2	0.70	2775.9	428.9	0.65
iac	2334.7	202.4	0.75	2187.4	218.9	0.76
uac	3935.6	363.1	0.65	3333.2	430.6	0.59
Punjab						
ifg	4611.8	631.0	0.95	4994.7	572.5	0.93
ufg	939.0	-25.8	0.62	934.2	-25.7	0.61
iac	5251.2	633.3	0.95	5577.3	584.0	0.94
uac	1190.3	-41.1	0.75	1192.4	-42.1	0.74
Rajasthan						
ifg	2054.4	136.1	0.86	2090.8	129.7	0.83
ufg	3536.7	3.4	0.0002	3374.6	-0.87	0.00001
iac	2210.4	169.3	0.89	2276.8	158.6	0.86
uac	3830.3	8.0	0.0007	3696.9	-0.96	0.00001
Tamil Nadu						
ifg	5407.6	-45.4	0.06	5395.3	-51.8	0.06
ufg	957.0	-3.0	0.003	947.9	-5.3	0.008
iac	7030.6	14.2	0.004	6997.5	11.0	0.002
uac	1931.0	-25.5	0.10	1939.7	-31.3	0.10
Uttar Pradesh						
ifg	4921.3	795.8	0.88	5535.9	694.1	0.81
ufg	6700.8	42.0	0.02	6691.5	24.1	0.004
iac	8598.0	1025.8	0.89	9201.8	928.5	0.86
uac	7045.3	31.6	0.01	7037.1	13.7	0.001

Notes: $: As reported in Dhawan (1988);
: As estimated by us using data from Dhawan (1988);
ifg : irrigated foodgrains output;
ufg : unirrigated foodgrains output;
iac : irrigated all crops output;
uac : unirrigated all crops output;

error form (MEF). The f.f. in the MEF is estimated after a logarithmic transformation. We then look for the closeness of the parameter estimates from the estimations corresponding to the two error specifications. This is yet another selection criterion used in selecting an appropriate f.f. for the growth curve.

It is for these considerations about the form of error specification that the Box-Cox (B-C) procedure for arriving at an appropriate specification of f.f. has not been straightaway adopted in this study. According to the B-C transformation, yield (Y) and time variable (t) would be transformed respectively as

$$Y_t^{(\lambda y)} = \frac{Y_t^{\lambda y} - 1}{\lambda y} \qquad (5.37)$$

and

$$t^{(\lambda t)} = \frac{t^{\lambda t} - 1}{\lambda t} \qquad (5.38)$$

where λ_y and λ_t are the parameters to be estimated alongwith other parameters of the model. Given these transformations on Y & t we estimate

$$Y_t^{(\lambda y)} = \alpha + \beta \cdot t^{(\lambda t)} + \varepsilon_t \qquad (5.39)$$

If, for example, the estimates of both λy and λt turn out equal to one, then the B-C transformation implies that both Y & t enter in their original form. The functional form (5.39) then reduces to be $Y_t = \alpha + \beta \cdot t + \varepsilon_t$. Note that the error term is additive here.

If, for example, the estimates of $\lambda y = 0$ & $\lambda t = 1$, it implies a logarithmic transformation of Y while t remains untransformed. In this case the equation is $\text{Log}(Y_t) = \alpha + \beta t + \varepsilon_t$. This is nothing but the semilog trend after the logarithmic transformation where the error term ε now corresponds to the logarithm of a multiplicative error in the untransformed semilog trend. The above two examples show that the character of error specification changes depending on the estimated values of λ_y and λ_t, – though such a change is neither intended nor even desired.

The seemingly advantageous aspect of the B-C procedure for choosing a f.f. for the growth curve can thus give misleading results in the presence of heteroskedasticity (see Zarembka (1974) and Seaks and Layson (1983)). In the presence of heteroskedasticity the B-C procedure "is biased in the direction of stabilizing the error variation" (see Zarembka (1974)) by favouring a logarithmic transformation for the dependent variable. The logarithmic transformation is known to stabilize the error variance when heteroskedasticity is present. In our context, where we are indeed testing for the presence of heteroskedasticity, such a favour towards logarithmic transformation perhaps already indicates unstable variance of Y around $\hat{Y}$. However, what it does not indicate at all is the effect of the simultaneous (unintended) changes of the error specification (i.e., from additive to multiplicative as illustrated above) on the values of the parameter estimates. This knowledge is essential for us in view of our illustration above using Dhawan's data.

A further reason for not using the B-C procedure straightaway is that not all the f.fs for the growth curve of interest here are covered by the B-C transformations. For example, the Gompertz growth curve is not covered by the B-C transformations.

However, whenever the f.f. finally chosen by our procedure falls in the class of functions covered by the B-C transformation, we use the B-C procedure only to reconfirm the f.f. already chosen.

5.8 Analysis of Variability and Specification of Change Point.

Most of the statistical tests for heteroskedasticity like the G-Q test, Bartlett's test, etc. require the pre-specification of the variance change point. In the G-Q test, for example, the sample period is split into 2 sub-periods at the pre-specified change point year and separate time trends are estimated for the 2 sub-periods. Using the error sum of squares from the sub-periods estimations a F test for variance change is then conducted. A weakness with such methods is that one would not be able to conduct the test if satisfactory estimation results are not obtained for any of the 2 sub-periods, as in the case of maize yields at all India level, with 1965-66 as the change point, discussed in chapter 2. Recall that maize yields show positive trend in the period 1949-50 to 1964-65 as per the semilog trend, whereas in the period 1965-66 to 1988-89 no significant trend in the yields was observed, for which the semilog trend has a poor fit. Similar problem exists with respect to ragi and barley yields also (see chapter 2 table 2.11). Under such a situation it would not be possible to conduct the G-Q test.

In passing, it may be mentioned here that, Hazell (as reported in Mehra (1981)) developed an elegant methodology of testing for a change in coefficient of variation over two sub-periods. This methodology, applicable in the case of functional form with multiplicative error specification, however, boils down to the G-Q test for heteroskedasticity with no middle level observations omitted. As is known, G-Q test remains valid even if no observations in the middle are omitted. (See Pindyck & Rubinfeld (1976)).

It was mentioned earlier (section 5.5) that since the modern technology in agriculture arrived in India during mid-1960s, most of the past studies split the full sample period of their data into two sub-periods as "up to 1965-66" and "from 1966-67". Later, econometric tests are conducted for equality of the extent of variability between the sub-periods. This implies that variability change, if occurred at all, must be from 1966-67. Two questions arise with regard to the variability change point assumed in the past studies.

1) Did yield variability change in the very year of introduction of the new technology or did it take a few years for the impact of the new technology on yield variability to be felt?"

2) Had a different change point year been specified would the results on variability change (present/not present) be the same? That is, do the results on variability change depend on the variability change point specified?

In view of these questions, we want to let the data suggest the change point of time.

Two test procedures that do not require the pre-specification of the change point have been suggested by Hsu (1977). He dealt with the problem of a gradual change as well as a one step change in the variance at an unknown time point in a sequence of independent normal random variables. The Hsu tests' procedure is described briefly below.

Hsu Tests for Variance Change at an Unknown Time Point: Consider a sequence of M consecutively observed independent normal random variables $Z_1, Z_2, \ldots, Z_M$, with a known constant mean μ. Denoting the variances of these variables as $\sigma_1^2, \sigma_2^2, \ldots, \sigma_M^2$, respectively, the problem is to test

H_o: $\sigma_1^2 = \sigma_2^2 = \ldots = \sigma_M^2 = \sigma_o^2$ (σ_o^2 is unknown)
against
H_1: $\sigma_1^2 = \sigma_2^2 = \ldots = \sigma_k^2 = \sigma_o^2$; $\sigma_{k+1}^2 = \ldots = \sigma_M^2 = \sigma_o^2 + \delta$; $|\delta| > 0$.

where k is unknown (k = 1, 2, ..., M-1);
δ is unknown and $(\sigma_o^2 + \delta) > 0$.

For this series Z, we first define $X_i = (Z_i - \mu)^2$; i = 1, 2,.., M. The X_i's, except for a constant, follow a χ^2 distribution with one degree of freedom, denoted $\chi^2(1)$.

Hsu proposes 2 tests; one called T-test and the other called G-test to test H_o. The T-test is a locally most powerful test for small variance shifts as $\delta/\sigma_o^2 \to 0$. The steps involved in computing the T-test statistic, under H_o, are as follows:

<u>Step 1:</u>

$$T = \frac{\left\{ \sum_{i=1}^{M} (i - 1) \cdot X_i \right\}}{\left\{ (M - 1) \sum_{i=1}^{M} X_i \right\}} \qquad 0 \leq T \leq 1 \qquad (5.40)$$

<u>Step 2:</u> $\quad \mathrm{Var}(T) = (M + 1) / \{6(M - 1)(M + 2)\}$ (5.41)

<u>Step 3:</u> Then the T-test statistic is given as

$$T^* = (T - 0.5) / \sqrt{Var(T)} \qquad (5.42)$$

The T-test statistic is symmetrical about the mean 1/2 and is less peaked than the normal distribution. Further, the distribution of T tends to normal as the sample size M becomes large. Critical values for the T-test are given in appendix 5.A1. T^* greater than critical value implies that H_o may be rejected.

The G-test is based on CUSUMs of χ^2 variables and can be used when a step-change in the variance is suspected and "a convenient estimate of the change point" can be obtained. The steps involved in computing the G-test are as follows:

<u>Step 1:</u> Obtain a series of W_k, a CUSUM of χ^2 variables.

$$W_k = \sum_{i=1}^{k} X_i, \qquad k = 1, 2, \ldots, M. \qquad (5.43)$$

<u>Step 2:</u> Compute the F ratio

$$Q_k = \frac{\left[(W_M - W_k)/(M - K)\right]}{(W_k/k)} \qquad k = 1, 2, \ldots, M-1. \qquad (5.44)$$

<u>Step 3:</u> Compute the integral

$$g_k = \int_o^{Qk} F(t|\ M-k,\ k)\ dt, \qquad (5.45)$$

where $F(t|M-k,\ k)$ represents an F distribution with (M-k) and k degrees of freedom.

<u>Step 4:</u> The G-test statistic is then given as

$$G = \sum_{k=1}^{M-1} g_k / \ (M - 1) \qquad 0 \leq G \leq 1. \qquad (5.46)$$

Under H_o G statistic is symmetrically distributed about the mean 1/2 and tends to a non-normal equilibrium distribution as $M \rightarrow \infty$. The critical values for these tests are given in appendix 5.1 to this chapter.

<u>Step 5:</u> If the null hypothesis H_o of a constant variance is rejected (G > critical value), then the variance change point is given by the value of k at which $|g_k - 0.5|$ is the maximum, k = 1, 2, ..., M-1.

For further details on the T- & G-tests (henceforth referred to as simply Hsu tests) see Hsu (1977). Appendix 5.2 gives the listing of a FORTRAN program written by me to compute the above mentioned T & G statistics under Hsu tests.

The advantages of the Hsu tests are the following:

1) It does not require the pre-specification of the variability change point. Instead it allows the data to suggest the change point.

2) It does not require sub-periodization of the sample and estimating separate time trends for each sub-periods. The estimated residuals from the full period regression can be straightaway tested.

3) Using this procedure it is possible to test for variability change in yields even when the yield levels are stagnant; i.e., the time trend estimation had a poor fit and/or the trend coefficient was insignificant. In such a case the sample mean yield level can be considered as the expected yield level. Yield variability around this constant expected yield level can then be assessed using the Hsu tests.

Considering these advantages, yield variability change (i.e., stability of yield variance around the trend) is assessed in this study by conducting the Hsu tests treating the estimated residuals as the independent, normal, random variables (Z_1, Z_2, ..., Z_M). Note that the Hsu tests are applicable even if the residual mean is not equal to zero (as in the case of nonlinear estimations).

5.9 Autocorrelation.

Recall that Hsu tests can be applied only on independent normal random variables free of autocorrelation. The estimated additive residuals ($\hat{U}_t = Y_t - \hat{Y}_t$) are essentially normal random variables. Similarly, with respect to the multiplicative residuals ($\hat{V}_t = Y_t / \hat{Y}_t$), Log($\hat{V}_t$) satisfies the assumption of normal random. Hence the Hsu tests can be conducted on $\hat{U}_t$ & Log($\hat{V}_t$) provided they both satisfy the other assumption regarding independence of the

... variables. In the context of time-series data independence refers to lack of serial correlation (autocorrelation) amongst the variables. Thus if, $\hat{U}_t$ & Log($\hat{V}_t$) do not show serial correlation, (i.e., they are not autocorrelated) then all the assumptions of the Hsu tests would be satisfied by both these variables. Conducting Hsu tests on $\hat{U}_t$ & Log($\hat{V}_t$) would then be valid.

However, in an analysis based on time-series data as in our case, autocorrelation in the error term is commonly faced. That is, $\hat{U}_t$ may show autocorrelation, which would violate the Hsu test assumptions. Hence, whenever autocorrelation, as indicated by the Durbin-Watson statistic, is found to be present a first order autocorrelation scheme,

$$U_t = \rho \cdot U_{t-1} + \varepsilon_t$$

for the residuals U_t is assumed and the parameters of the function alongwith the ρ parameter are estimated. This re-estimated function should, of course, satisfy all the selection criteria described earlier.

It then follows that, the appropriate procedure in the presence of autocorrelation in $\hat{U}_t$, is to conduct the Hsu tests on $\hat{\varepsilon}_t$ in $U_t = \rho \cdot U_{t-1} + \varepsilon_t$. The reason for using $\hat{\varepsilon}_t$ is as follows: When $\hat{U}_t$ are autocorrelated, the expected yield level has to be computed inclusive of $\hat{\rho} \cdot \hat{U}_{t-1}$ (see Goldberger (1962), Johnston (1972)). In fact, this is done in the calculation of R^2 and $\bar{R}^2$ (see Buse (1973), Kennedy (1979), etc). Under such a situation, $\hat{\varepsilon}_t$ is the appropriate set of residuals to subject to the Hsu tests.

Hence, under the presence of autocorrelation, $\hat{\varepsilon}_t$ are used to test for variability change. When there is no autocorrelation then $\hat{U}_t$ themselves are subjected to the Hsu tests for variance change.

The above analysis on variability change is conducted in this study separately under both the frameworks; i.e., using the estimated residuals obtained in time trend framework (TTF) as well as yield response function framework (RFF).

5.10 Analysis of Structural Change and Specification of Structural Change Point.

At the outset it may be mentioned that none of the past studies except Majumdar et.al (1988) analysed structural change in the growth path. They conduct the Chow test which is a F test for the stability of parameters between 2 periods. But they prespecified 1967-68 as the year of change point in the growth path. Though Ray (1983) refers to "usual statistical tests for comparison of regression lines and for testing stability of the parameters estimated separately from the two periods", he however, did not conduct any such tests for the stability of parameters between the 2 periods.

For reasons due to lack of enough number of observations on the input variables for the pre-Green Revolution period, structural change analysis could not be carried out under the RFF. Since yield data are, however, available, the analysis under TTF could be carried out. Turning to structural change in the growth path, here we look for changes, if any, in the parameter(s) of the growth curve from a particular point of time, say t = k. For this purpose, we adopt a procedure based on dummy variables. In practice, this procedure is done with the f.f. identified earlier as the appropriate specification for the growth curve. This procedure is explained below using linear trend as an example.

Denoting yield by Y, time by X and the dummy variable by D, we estimate

$$Y_t = \alpha_1 + \alpha_2 \cdot X_t + \alpha_3 \cdot D_t + \alpha_4 \cdot D_t \cdot X_t + U_t$$

Suppose the sample of observations is given for a period t = 1, 2, ..., t^*, ..., N. The dummy variable takes the value 0 upto $t^* - 1$ and 1 from t^*. The above equation is estimated several times by varying t^* successively over all the middle years of the sample during which the growth pattern is expected to have changed. The error sum of squares from each estimation is noted. The particular t^* (= k, say) at which the error sum of squares is minimum over all these regressions is then identified. If in this regression (at $t^{*} = k$), α_3 and/or α_4 is significant, it indicates a change in the parameter(s) of the growth curve (intercept and/or slope) from that year $t^{*} = k$; i.e., a structural change has occurred at year k. The year k is the structural change point year.

If both α_3 and α_4 in the regression for $t^{*} = k$, are insignificant, it implies no change in the parameters of the growth curve; i.e. there is no structural change in the growth path of Y.

As Gujarati points out, the above procedure based on dummy variables assumes constant error variance (see Gujarati (1988)). Hence it can be applied only when yields are homoskedastic; i.e., there is no change in yield variability around the trend. This implies that the analysis for change in yield variability has to precede the analysis for structural change in the growth path of yields.

5.11 Summary of the Steps in the Analysis of Crop Yield Stability Under TTF.

1) Starting with an initial set of various functional forms (growth curves), estimate all of them in both additive error form (AEF) and multiplicative error form (MEF). In the case of additive errors var(Y) = var(U) alone, thus independent of $\hat{Y}$. Hence, in the case of absolute variability, no specific relationship between growth and variability is assumed. In the case of multiplicative errors var(Y) = $\hat{Y}^{2} \cdot$var(V), thus not independent of growth in Y. Hence, in the case of relative variability, monotonic relation between growth and variability becomes automatically assumed.

2) Eliminate the f.fs which do not satisfy the 2 measures of non-linearity (intrinsic (IN) and parametric effects (PE) nonlinearity), the skewness measure (SK) of Hougaard, and Box's percentage bias (BB).

3) Of the remaining f.f.s check for similarity of parameter estimates as obtained from AEF and MEF. Eliminate which do not satisfy this requirement.

4) Of the remaining f.f.s select the f.f with highest R^2 and $\bar{R}^2$.

5) Adjust for autocorrelation, if necessary, and re-check for the satisfaction of all the above criteria.

6) If the chosen f.f. falls in the class of functions covered by the Box-Cox transformation, confirm the choice of f.f. by the B-C procedure also.

7) Collect the residuals and conduct Hsu tests for variance change on both additive errors and logarithms of multiplicative errors.

8) Conduct the structural change analysis only for the cases of "variability change not present" (step 7).

9) Reconfirm the result of "variability change not present" for those crop cases that showed structural change. This is to conduct Hsu tests on the residuals obtained from the regressions where the dummy variable are found to be significant.

10) For the no growth cases conduct Hsu tests on the deviations of the yields from the sample mean ($Y_t - \bar{Y}$, where $\bar{Y}$ is the expected yield level) to test for change in absolute variability around the stagnant yield level and on the logarithms of the ratio of the yields to the sample mean ($Y_t/\bar{Y}$) yield to test for change in relative variability around the stagnant yield level.

5.12 Summary of the Steps in the Analysis of Crop Yield Stability Under RFF.

In the case of estimating yield response functions for various crops, some practical considerations (to be explained later) prohibited us from doing an extensive search over various functional forms. In fact as will be seen later, only a quadratic functional form is estimated as y.r.f which could be estimated using OLS. Hence, steps (1) to (6) mentioned in the previous section turn out to be not relevant here. As mentioned in section 5.10 structural change analysis could not be conducted here due to lack of enough number of observations on input variables for the pre-Green Revolution period. Hence, steps (8) and (9) become inapplicable. Finally, step (10) does not arise at all here. Thus, the analysis here boils down to only estimating a quadratic y.r.f and conducting the Hsu tests on the corresponding residuals. This does not amount to that the analysis is far simpler here! As we find later, there are several other econometric problems (particularly multicollinearity among input variables) arise here. These will be discussed when we come to the estimation of the y.r.f in chapter 8.

5.13 Spatial Variability of Crop Yields.

In the beginning of this chapter, we had mentioned about spatial variability of crop yields; that is, the stability of disparities in crop yield levels across districts. Disparity in crop yields at a point of time across districts is measured by the coefficient of variation (CV) in yields at a point of time across the districts. Denoting yields by Y,

$$CV(Y)_t = \sigma_{Yt}/\mu_{Yt}$$

where σ_{Yt} is the standard deviation of Y at time t across the districts,

μ_{Yt} is the mean of Y at time t over the districts.

The stability of the disparity of crop yields over time can be assessed from trends (increasing/decreasing), if any, in $CV(Y)_t$.

Further, in this study, an attempt is made to explain the disparities in crop yield levels across districts in terms of the disparities across districts in various factors such as rainfall, infrastructural factors like irrigation availability from different sources, cropping intensity, and inputs like fertilizer.

$$CV(Y)_t = f(CV(R)_t, CV(I)_t, CV(F)_t, CV(ACI)_t)$$

where R is rainfall, I is irrigation, F is fertilizer, ACI is aggregate cropping intensity. More details follow in chapter 10.

5.14 Policy Analysis Using Computable General Equilibrium Model.

In the penultimate chapter of this study, some policy evaluation in the light of falling agricultural investment observed in the 1980s is made. Specifically, the effects of the fall in agricultural investment on the agricultural sector and on the rest of the economy are analysed. This analysis is done using a computable general equilibrium model (CGEM) for the Indian economy that is already available in the literature. The CGEM used here is the "Agriculture, Growth and Redistribution of Incomes Model (AGRIM)" of Narayana, Parikh and Srinivasan (1990). The salient features of the AGRIM and the methodology adopted for this policy evaluation are discussed in detail in chapter 11.

In the next chapter we start with the analysis of stability & variability of cereal crop yields in the time domain for cereal crop yields at the all India level and at the Andhra Pradesh State level.

PART C: DATA USED – SOURCES AND PERIOD COVERED.

"Get your facts first, and then you can distort 'em as much as you please!"

– Mark Twain.

All details regarding the data used in this study, including their sources and period covered, are discussed here. Table 5.2 provides some of these details in a tabular form.

5.15.1 Data on Acreages and Outputs.

Data on land utilization, covering area cultivated under different crops, area irrigated by different sources and also the area irrigated under different crops are collected by either (1) the village revenue agencies of different States through their village officials, or (2) in States where such agencies do not exist, through sample surveys. Details regarding the source and the period covered by the available area statistics on crop acreages, irrigations, area under different seed varieties, at the AI, AP State and AP Districts levels, are given in table 5.2. Time series (T-S henceforth) data on the gross cropped area over all crops, and under individual crops, aggregated over seasons, are available at the AI, AP State & AP Districts levels. For rice & jowar alone seasonwise gross acreages data are also available, at all levels but for different periods (see table 5.2). T-S data on the net sown area are available only over all crops put together but not for individual crops.

The output of a crop is the product of the area under the crop and its yields (kilograms per hectare). Time series data on annual/aggregate (over the 2 cropping seasons - kharif & rabi and over the 2 water regimes - irrigated and unirrigated) outputs of cereals crops and the seasonwise split of outputs of rice and

Table 5.2 - List of Variables: Data Period Covered & Sources.

a) Variables and Data Period.

Variable	Period Covered*		
	All India	AP State	AP Districts
1) a. Gross Cropped Area			
t-(rce, wht, jwr, bjr, rgi, mze, brl, acr)	1950 to 1989	1950 to 1989	1956 to 1985
k-(rce, jwr), r-(rce, jwr)	1963 to 1989	1963 to 1989	1968 to 1985
b. Net Sown Area			
t-(acr)	1950 to 1989	1950 to 1989	1956 to 1985
2) Output			
t-(rce, wht, jwr, bjr, rgi, mze, brl)	1950 to 1989	1950 to 1989	1956 to 1985
k-(rce, jwr), r-(rce, jwr)	1963 to 1989	1963 to 1989	1968 to 1985
3) a. Net Irrigated Acreage Sourcewise (over all crops)			
t-(cnl, tnk, twl, owl, osr)	1956 to 1987	1956 to 1987	1956 to 1985
b. Gross Irrigated Acreage (total by all sources)			
t-(rce, wht, jwr, bjr, mze, brl, acr)	1956 to 1987	1956 to 1987	1956 to 1985
t-(rgi)	1963 to 1987	1963 to 1987	1956 to 1985
4) Yields			
t-(rce, wht, jwr, bjr, rgi, mze, brl)	1950 to 1989	1950 to 1989	1956 to 1985
k-(rce, jwr), r-(rce, jwr)	1963 to 1989	1963 to 1989	1968 to 1985
i-(rce, bjr, rgi)@, u-(jwr, bjr, rgi, mze)@	n.a.	1956 to 1985	n.a.
5) Gross Crop Acreage Under High Yielding Varieties			
t-(rce, wht, jwr, bjr, mze)	1967 to 1989	1967 to 1989	n.a.
6) Fertilizer Consumption (over all crops)			
t-(Nitrogenous, Phosphatic, Potassic, Total)	1956 to 1989	1956 to 1989	1961 to 1985
k-(Nitrogenous, Phosphatic, Potassic, Total)	1956 to 1989	1956 to 1989	1961 to 1985
r-(Nitrogenous, Phosphatic, Potassic, Total)	1956 to 1989	1956 to 1989	1961 to 1985
7) Rainfall			
monthly, South-West & North-East Monsoons	1950 to 1989	1950 to 1989	1956 to 1985

Notes are provided at the end of the table.

Table 5.2 Contnd.

Variable	Period Covered* All India	AP State	AP Districts
8) Agricultural Investment			
a. New Series: at 1980-81 Prices			
Total	1950 to 1989	n.a.	n.a.
Private, Public	1961 to 1989	n.a.	n.a.
b. Old Series: at 1970-71 Prices			
Total	1950 to 1985	n.a.	n.a.
Private, Public	1961 to 1985	n.a.	n.a.
9) Gross Domestic Product			
a. New Series: at 1980-81 Prices			
Agricultural, Total	1950 to 1989	n.a.	n.a.
b. Old Series: at 1970-71 Prices			
Agricultural, Total	1950 to 1985	n.a.	n.a.

b. Data Sources.

1) 'Estimates of Area & Production of Principal Crops in India', Ministry of Agriculture, Government of India, New Delhi.

2) 'Statistical Abstracts of India', Department of Economics & Statistics, Government of India, New Delhi.

3) 'Fertilizer Statistics', Fertilizer Association of India, New Delhi.

4) 'Season & Crop Report of Andhra Pradesh', Ministry of Agriculture, Government of Andhra Pradesh, Hyderabad.

5) 'National Accounts Statistics', Central Statistical Organization, Government of India, New Delhi.

Notes: AP : Andhra Pradesh;

* : refers to 1949-50, and so on;

t- / k- / r- : refers to annual aggregate- / kharif- / rabi- respectively;

i- / u- : refers to irrigated- / unirrigated- respectively;

@ : The irrigated and unirrigated yields were estimated by us (see section 5.16.4);

n.a. : continuous time series data not available;

Crops: rce : rice; wht : wheat; jwr : jowar; bjr : bajra; rgi : ragi; mze : maize; brl : barley; acr : all crops together;

Irrigation Sources: cnl : canals; tnk : tanks; twl : tubewells; owl : other (dug/shallow) wells; osr : other sources;

jowar, are available at the all India (AI), Andhra Pradesh (AP) State and AP Districts levels (see table 5.2). These output data are aggregated over water regimes (irrigated & rainfed) and over seed varieties (traditional & modern high yielding varieties (HYV)). Disaggregated data according to seed varieties and according to water regimes are not available (n.a).

5.15.2 Data on Irrigation.

Data on the net and gross irrigated area are available. First, the net irrigations data. T-S data on the total net irrigated area (NIA) by different sources of irrigation are available at all levels covering different periods (see table 5.2). The irrigation sources include canals & tanks under surface water irrigation, tubewells & other (dug/shallow) wells under ground water irrigation, and other sources (like small streams, etc.). The sourcewise NIA data are over all crops put together. Cropwise NIA by different sources are not available.

T-S data on the gross irrigated area are available for individual crops and also over all crops, but only by all sources put together. Data on cropwise gross irrigations by different sources of irrigation are not available. It may be noted here that the available data on cropwise gross irrigations are annual data, aggregated over seasons and also over seed varieties. T-S data on cropwise irrigations by seasons and by seed varieties are not available.

5.15.3 Data on Crop Yields.

Yields of cereal crops are the main variable of concern in this study. Yields are defined as the output of a crop (in kilograms) per hectare of land under that crop.

Traditionally, the procedure to estimate yields of a crop were based on what is often called "eye-estimates" since these are based on the personal knowledge of the concerned officials responsible for collecting these data. There was no objective procedure followed, as a result of which the validity of the estimates were in doubt even while the margin of error remained unknown.

With the introduction of crop cutting survey techniques, some of these shortcomings in the data were to a large extent over come. Since mid-1950s, in almost all the States, the estimates of crop yields are obtained by the crop cutting survey procedures. In this method, a plot of land of a given size under the crop is selected by random sampling procedures and the output of the crop in that plot of land is measured. Based on such crop cutting surveys carried out at different geographical locations within a district, estimates of the yield at the district level are obtained. These district level yields are multiplied with the corresponding district level crop acreage figures to obtain the district level output figures. The district level outputs are aggregated to obtain the State level outputs which in turn when aggregated give the national level outputs. Dividing the State and country level output figures by the corresponding acreages figures give the State level and country level yields figures.

T-S data on annual aggregate (over seasons and water regimes) crop yields are available at the all India, State and Districts levels but for different periods (see table 5.2). For rice & jowar alone, seasonwise yields data are also available covering different periods which are also shown in table 5.2. An important point is that these yields data, involve aggregation over seed varieties (traditional/HYV) and over water regimes (irrigated/rainfed). We return to the aspect of aggregation, to be noted in more detail, in chapter 8.

5.15.4 Estimation of Irrigated & Unirrigated Yields at State Level.

There are no continuous T-S data at any level (i.e., at all India, State or Districts) on yields according to seed varieties; nor are there T-S data on irrigated/unirrigated crop yields. Faced with this situation, Dhawan (1988) estimated the overall crop yields according to the source of irrigation, like canals, tanks, etc. He pools 2 years' cross section data on aggregate crop output of a district and regresses them on the corresponding net irrigated area by each source of irrigation as follows. (see Dhawan (1988), pp.115).

$$Y = \beta_0 A_0 + \beta_1 A_1 + \beta_2 A_2 + \ldots + \beta_n A_n$$

where, Y is the aggregate crop output of a district,

A stands for the crop acreage of a district,

β stands for the overall crop yield,

suffix 0 denotes unirrigated and suffixes 1 to n denote 'n' sources of irrigation.

Note that there is no constant term in the above regression equation. Under this situation, the estimates of parameter β_i (i = 0, 1, ..., n) are clearly the yields under different categories of irrigation.

In the context of our study where analysis is to be done cropwise, we neither have cropwise data on A_1, A_2, etc. nor separate analysis of yields under different sources of irrigation falls within the scope of our study. Our primary interest is to analyse the stability issue of crop yields (on which data are available) and if possible separately for the irrigated and unirrigated yields on which data are not available. Hence an attempt is made here first to close this data gap as far as possible by indirect methods.

Using a similar procedure as of Dhawan (1988), we take advantage of the availability of T-S data on cropwise gross irrigated area at the districts level, and estimate the following relation separately for each t(time period) and each crop:

$$Q_{it} = \hat{\alpha}_t IA_{it} + \hat{\beta}_t UA_{it} + \hat{U}_{it} \qquad (5.47)$$

where Q_{it} is the output of the crop in district i at time t,

IA_{it} is the irrigated area under the crop in district i at time t,

UA_{it} is the unirrigated area under the crop in district i at time t,

$\hat{U}_{it}$ is the residual,

i = 1, 2, ..., 18 districts of Andhra Pradesh (sample size)

t runs from 1955-56 to 1984-85.

For a given crop, equation (5.47) was estimated separately for each time period t using the districtwise cross section data on Q, IA and UA. There are 18 districts in AP and hence the sample size for each regression is 18. The parameter estimates $\hat{\alpha}_t$ and $\hat{\beta}_t$ are then the mean levels of irrigated and unirrigated yields of the crop, respectively, in the year t, which can be treated as the State level mean yields. Thus the T-S of estimated State level irrigated and unirrigated yields were built up by running the regression (5.47) for each t(over 1955-56 to 1984-85). Using this procedure T-S estimates of irrigated (i-) and unirrigated (u-) yields at the State level are obtained for the 5 major cereal crops in AP, rice, jowar, bajra, ragi and maize. Satisfactory estimates could be obtained for the following 7 cases: i-rice, u-jowar, i-bajra, u-bajra, i-ragi, u-ragi and u-maize. The T-S of these estimated yields are given in table 5.3. These estimated yields will be used in the analysis in chapter 6.

5.15.5 Crop Acreage Under High Yielding Varieties (HYV).

HYV seeds were introduced in India in the mid-1960s. T-S data on the gross crop acreage under HYV for 5 cereals crops, viz. rice, wheat, jowar, bajra and maize, are available since 1966-67. The available data are aggregated over seasons and over water regimes (irrigated/rain fed); separate disaggregated data are not available. The data are at the AI & State levels including for AP. Corresponding T-S data at the Districts levels are not available.

Table 5.3 - Estimated Irrigated & Unirrigated Crop Yields (Kg/Ha), A.P State Level

Year	i-Rice	u-Jowar	u-Bajra	i-Bajra	u-Ragi	i-Ragi	u-Maize
1955-56	1237.176	393.135	384.268	1030.343	454.651	993.079	608.391
1956-57	1304.651	420.010	278.714	2400.769	631.648	1488.896	634.660
1957-58	1360.523	445.005	468.058	861.188	656.899	869.940	669.939
1958-59	1401.935	559.270	434.959	1283.041	817.820	1057.493	734.818
1959-60	1319.987	546.488	441.518	915.406	1020.986	1163.950	617.921
1960-61	1478.736	458.829	418.180	733.343	422.912	1219.881	863.738
1961-62	1453.208	545.763	446.233	1510.811	994.497	973.346	914.315
1962-63	1293.315	536.640	488.571	916.334	656.415	1182.437	689.415
1963-64	1414.790	524.429	437.761	1374.369	810.609	927.676	656.048
1964-65	1481.141	455.404	353.725	1643.060	805.691	1026.289	1263.427
1965-66	1174.583	424.190	358.337	1048.526	607.598	933.790	845.892
1966-67	1518.729	432.867	527.230	843.543	623.682	1025.473	713.143
1967-68	1736.855	458.780	374.364	1330.503	706.726	1238.435	1220.445
1968-69	1439.983	430.169	308.438	1064.372	631.103	786.923	878.734
1969-70	1258.543	500.848	411.775	1265.263	503.955	1210.000	1359.272
1970-71	1464.399	390.142	393.114	1317.166	559.870	1278.662	1351.340
1971-72	1685.501	426.288	311.431	846.268	781.414	1274.595	641.485
1972-73	1740.761	451.767	207.960	961.462	714.072	1270.694	501.870
1973-74	1802.507	447.859	376.777	1811.311	873.547	1362.595	1303.566
1974-75	1789.614	600.371	378.234	1231.360	810.641	1369.240	1563.385
1975-76	1680.309	361.843	421.568	1377.503	943.280	1486.841	1370.227
1976-77	1525.702	498.835	309.721	1404.756	690.418	1468.079	768.667
1977-78	1560.589	616.180	498.223	1563.317	790.741	1629.260	1449.715
1978-79	2076.200	590.260	441.631	1826.149	871.194	1607.541	937.538
1979-80	2089.558	702.444	484.934	1739.965	789.407	1517.209	1133.793
1980-81	2287.158	537.767	535.108	1382.494	732.675	1378.122	1693.132
1981-82	2351.759	559.728	675.960	1731.842	869.867	1620.937	1415.133
1982-83	2469.997	674.505	487.218	858.910	732.254	1467.857	1966.285
1983-84	2371.111	506.623	597.834	1513.499	809.307	1605.699	842.698
1984-85	2329.529	566.631	466.404	960.678	708.169	1482.289	704.757

Notes: i-Rice - Irrigated rice; u-Jovar - Unirrigated jovar; u-Bajra - Unirrigated bajra; i-Bajra - Irrigated bajra; u-Ragi - Unirrigated ragi; i-Ragi - Irrigated ragi; u-Maize - Unirrigated maize;

Evenson/ICRISAT (E-I henceforth) provide some data on HYV acreage at the districts level for various States in India covering the period 1966-67 to 1983-84. A copy of these data relating to AP has kindly been provided to us by the Indira Gandhi Institute of Development Research (IGIDR), Bombay. These data, however, were found to suffer from certain shortcomings such as the following:

1) For many years, the HYV acreage summed over the districts differ substantially (higher/lower) from the official figures for the AP State as a whole referred to in the previous para.

2) For many districts, for many years, the HYV acreage figures of E-I exceed the official figures of even the total acreage under the crop.

3) Discontinuities in the series.

For these reasons the E-I data on HYV acreage are not used in our analysis for estimation purposes.

5.15.6 Data on Fertilizer Use.

T-S data on total fertilizer consumption over all crops as also the split into nitrogenous (N), phosphatic (P) and potassic (K) fertilizers, are available, both seasonwise and annual (aggregated over seasons) at all the levels covering different periods (see table 5.2). There are no T-S data on cropwise fertilizer use at any level. Nor are there any T-S data on fertilizer use according to water regimes or according to seed varieties. In this study, the data on annual total (N + P + K) fertilizer consumption over all crops are used.

5.15.7 Data on Rainfall.

T-S data on monthly rainfall (in millimetres) and also in the 2 monsoon seasons (South-West: June to September, North-East: October to December) are available at all levels and these are used in the analysis in chapters 8 & 10.

The above mentioned variables, viz., output, acreages, yields, irrigations, HYV, fertilizer & rainfall are used in the analysis in chapters 6 to 10 where stability of yields is analysed. In chapter 11, some policy simulations are carried out at the all India level in which the variables of concern are different. The data on these variables are now discussed.

5.15.8 Data on Agricultural Investment.

T-S data on total agricultural investment and also the split up into private and public agricultural investments, are available at the AI level only (see table 5.2). The investment data from the New Series of the National Accounts Statistics (NAS) at 1980-81 Prices are used in this analysis. The data refer to investment in the entire agricultural sector in the country as a whole. Investment data under different heads are not available. Notably, there are no T-S data on investment in irrigation.

5.15.9 Data on Gross Domestic Product.

T-S data on the agricultural gross domestic product (GDPA) and the total (agricultural + non-agricultural) gross domestic product (GDPT) are available from the New Series of NAS at both current and 1980-81 prices. These data also are used in chapter 11.

Appendix 5.A1 - Critical Values for Hsu's T- & G-Tests.

Critical values for Hsu's T-test in the standardized scale

M	$S_{0.01}$	$S_{0.025}$	$S_{0.05}$	$S_{0.10}$	$S_{0.25}$
2	1.414	1.410	1.397	1.345	1.000
3	1.901	1.771	1.613	1.370	0.803
4	2.083	1.868	1.643	1.343	0.749
5	2.170	1.906	1.650	1.325	0.724
6	2.219	1.925	1.652	1.314	0.710
7	2.251	1.938	1.652	1.306	0.700
8	2.260	1.940	1.651	1.303	0.697
9	2.266	1.942	1.650	1.301	0.695
10	2.272	1.944	1.650	1.299	0.693
15	2.289	1.949	1.648	1.294	0.687
20	2.298	1.952	1.647	1.290	0.684
25	2.304	1.953	1.647	1.289	0.682
30	2.308	1.954	1.646	1.287	0.680
∞	2.326	1.960	1.645	1.282	0.674

Approximate critical values for Hsu's G-test

M	$C_{0.01}$	$C_{0.025}$	$C_{0.05}$	$C_{0.10}$	$C_{0.25}$
2	0.989	0.973	0.947	0.895	0.746
3	0.964	0.935	0.898	0.838	0.698
4	0.948	0.914	0.874	0.813	0.680
5	0.938	0.902	0.860	0.800	0.671
6	0.931	0.894	0.852	0.792	0.665
7	0.927	0.889	0.847	0.787	0.662
8	0.924	0.885	0.843	0.783	0.660
9	0.921	0.883	0.840	0.781	0.658
10	0.920	0.881	0.838	0.779	0.657
15	0.915	0.876	0.833	0.774	0.654
20	0.913	0.873	0.831	0.772	0.652
30	0.911	0.871	0.829	0.770	0.651
100	0.909	0.869	0.826	0.768	0.650
∞	0.908	0.868	0.825	0.767	0.649

Sample size;

[illegible] Hsu, D.A. (1977). [illegible]ts for Variance Shift at an Unknown Time

Appendix 5.A2 - FORTRAN Program to Compute the Hsu Tests.

In this appendix a FORTRAN program, alongwith some associated subroutines, to compute Hsu's (1977) T-test and G-test is given. The cumulative density function (CDF) required in G-test is

$$P = \int_0^{Qk} F(F|n1,\ n2)\ df = 1 - Q$$

where, F is the computed F-ratio and n1, n2 are the degrees of freedom and the expression for Q is as in one of the following 2 cases. (See Abramowitz and Stegun (1972)).

Define $X = n2/(n2 + n1\cdot F)$, and

$\theta = \arctan\sqrt{n1 \cdot F/n2}$

<u>Case 1:</u> Atleast one of n1 and n2 is even;

a) n1 is even;

$$Q = X^{n2/2}\left[1 + \frac{n2}{2}(1-X) + \frac{n2(n2+2)}{2.4}(1-X)^2 + \ldots + \frac{n2(n2+2)\ldots(n2+n1-4)}{2.4\ldots(n1-2)}(1-X)^{(n1-2)/2}\right]$$

b) n2 is even;

$$Q = 1 - (1-X)^{n1/2}\left[1 + \frac{n1}{2}\cdot X + \frac{n1(n1+2)}{2.4}\cdot X^2 + \ldots + \frac{n1(n1+2)\ldots(n2+n1-4)}{2.4\ldots(n2-2)}\cdot X^{(n2-2)/2}\right]$$

<u>Case 2:</u> n1 & n2 are odd;

$Q = 1 - A(t|n2) + \beta(n1,\ n2)$, where

$$A(t|n2) = \begin{cases} \frac{2}{\pi}\left\{\theta + \sin\theta\left[\cos\theta + \frac{2}{3}\cos^3\theta + \ldots + \frac{2.4.\ldots.(n2-3)}{3.5.\ldots.(n2-2)}\cos^{n2-2}\theta\right]\right\} & \text{for } n2 > 1 \\ \frac{2\theta}{\pi} & \text{for } n2 = 1. \end{cases}$$

$$\beta(n1,n2) = \begin{cases} \dfrac{2}{\sqrt{\pi}} \dfrac{\left(\frac{n2-1}{2}\right)!}{\left(\frac{n2-2}{2}\right)!} \sin\theta \cdot \cos^{n2}\theta \left\{ 1 + \dfrac{n2+1}{3}\sin^2\theta + \ldots + \dfrac{(n2+1)(n2+3)\ldots(n1+n2-4)\sin^{n1-3}\theta}{3.5.\ldots.(n1-2)} \right\} & \text{for } n2 > 1 \\ 0 & \text{for } n1 = 1 \end{cases}$$

The CDF is computed in the subroutine FDIST, which on an IBM compatible PC-AT/386 reproduces the table values of F-distribution when both the degrees of freedom, n1 & n2, are less than 57. Machine limitations do not permit using this subroutine when n1 and/or n2 ≥ 57. However, this limitation did not pose any serious problem in our study since the sample size is only 40.

The subroutine FCTRL computes factorial of real numbers of the type (N + 0.5), where N is a positive integer. This subroutine is required in FDIST for the computation of the CDF.

```
c       Program to compute the 'T' and 'G' statistics of D.A.Hsu (1977)
c       'Tests for Variance Shift at an Unknown Time Point',
c       Applied Statistics V26(3), 1977.
c
c       Names of the variables have been kept the same as in Hsu (1977),
c       as far as possible.
c
c       Input  : m                : sample size;
c                z (1,...,m)      : data variable;
c       Output : x (1,...,m)      : the chi-squared variable; x = (z - zmean)**2
c                w (1,...,m)      : CUSUMs of the x variable;
c                q (1,...,m-1)    : F-ratios;
c                g (1,...,m-1)    : Significance level of the F-ratios q;
c                tstat            : computed T-test value;
c                gstat            : computed G-test value;
c                kk               : variance change point;
c                gmax             : maximum value of abs(g(k) - 0.5);
c                sub-samplewise variances of z (A or B below);
c                A) if kk > 4 and (m-kk) > 4;
c                     zvar1  : sub-sample 1 variance (observations 1 to kk);
c                     zvar2  : sub-sample 2 variance (observations kk+1 to m);
c                B) if kk or (m-kk) < 4
c                       zvar   : variance of the larger sub-sample;
c
c       subroutines required    : VAR, FDIST, FCTRL;
c----------------------------------------------------------------------------
```

```
      dimension z(40),x(40),w(40),q(40),g(40)
      open (unit=5,file='data',status='old')
      open (unit=6,file='output',status='unknown')
c
c     data input
c
      read(5,900)m
      read(5,902)(z(i),i=1,m)
c
c     compute the chi-squared variable X = (Z - ZMEAN)**2
c
      zmean=0.0
      do 101 i=1,m
      zmean=zmean+z(i)
101   continue
      zmean=zmean/m
c
      sumx=0.0
      do 102 i=1,m
      x(i)=(z(i)-zmean)**2
      sumx=sumx+x(i)
102   continue
c
c     compute 'T' statistic
c
      s1=0.0
      do 103 i=1,m
      s1=s1+((i-1)*x(i))
103   continue
      s2=(m-1)*sumx
      tstat=s1/s2
c
c     compute Standard Deviation of 'T' statistic
c
      rm=float(m)
      vart=0.0
      vart=(rm+1.0)/(6.0*(rm-1.0)*(rm+2.0))
      tstat=(tstat-0.5)/sqrt(vart)
c
c     compute Wk's (k=1,2,...,m)
c
      do 104 k=1,m
      w(k)=0.0
      do 105 i=1,k
      w(k)=w(k)+x(i)
105   continue
104   continue
c
c     compute 'Qk', 'gk' & 'G' statistic
c
      gstat=0.0
      do 106 k=1,m-1
      s1=(w(m)-w(k))/(m-k)
      s2=w(k)/k
      q(k)=s1/s2
      n1=m-k
```

```
      n2=k
      ff=0.0
      call fdist(n1,n2,q(k),ff)
      g(k)=ff
      gstat=gstat+(g(k)/(m-1))
106   continue
c
c     find Change-Point 'K' - stored in KK
c
      kk=1
      gkmax=0.0
      do 107 k=1,m-1
      s1=g(k)-0.5
      s1=abs(s1)
      if(gkmax.gt.s1)goto 107
      gkmax=s1
      kk=k
107   continue
c
c     compute variances for the 2 sub-periods - stored in XVAR1 & XVAR2
c
      mkk=m-kk
      if(kk.le.3 .or. mkk.le.3)goto 108
      zvar1=0.0
      i1=1
      i2=kk
      call var(z,i1,i2,zvar1)
      zvar2=0.0
      i1=kk+1
      i2=m
      call var(z,i1,i2,zvar2)
      goto 109
c
c     Size of one of the 2 sub-samples is too small. Hence variance is
c     computed only for the larger sub-sample - stored in XVAR
c
108   continue
      if(kk.le.3)then
        i1=kk+1
        i2=m
      endif
      if(mkk.le.3)then
        i1=1
        i2=kk
      endif
      zvar=0.0
      call var(z,i1,i2,zvar)
c
c     print results
c
109   continue
      write(6,901)m
      write(6,902)(z(i),i=1,m)
      write(6,903)
      write(6,902)(x(i),i=1,m)
      write(6,904)
```

```
      write(6,902)(w(i),i=1,m)
      write(6,905)
      write(6,902)(q(i),i=1,m-1)
      write(6,906)
      write(6,902)(g(i),i=1,m-1)
      write(6,907)tstat,gstat
      write(6,908)kk,gkmax
      if(kk.le.2 .or. mkk.le.2)then
        write(6,909)zvar
      else
        write(6,910)zvar1,zvar2
      endif
c
      stop
c
c     format statements
c
900   format(i2)
901   format('Data: Z Variable - Sample size = ',i2)
902   format(6f12.4)
903   format(/,'Chi-Squared Variable: X(i),  i=1,...,m')
904   format(/,'CUSUMs of X variable: W(k),  k=1,...,m')
905   format(/,'F-ratios: Q(k),  k=1,...,m-1')
906   format(/,'F-ratios significance level: G(k),  k=1,...,m-1')
907   format(/,'T - Statistic: ',f8.5,/,'G - Statistic: ',f8.5)
908   format(/,'Variance change occurred at K        = ',i4,/,
     1 'Maximum Value of ABS(G(k)-0.5))     = ',g13.6)
909   format('Variance change in Z is towards the extreme ends of the
     1 'sample;',/,'Variance for the larger Sub-sample = ',g13.6)
910   format('Variance of Z for 1st Sub-sample    = ',g13.6,/,
     1 'Variance of Z for 2nd Sub-sample    = ',g13.6)
      end


      subroutine var(x,i1,i2,xvar)
c     subroutine to compute variance of X between I1 & I2.
c     the variance is stored in XVAR
c
c     Input  : x, i1, i2
c     Output : xvar
c----------------------------------------------------------------------
      dimension x(40)
      n=i2-i1+1
      sum=0.0
      do 1 i=i1,i2
      sum=sum+x(i)
1     continue
      sum=sum/n
      xvar=0.0
      do 2 i=i1,i2
      xvar=xvar+((x(i)-sum)**2.0)
2     continue
      xvar=xvar/(n-1)
      return
      end
```

```
      subroutine fdist(n1,n2,f,pf)
c     subroutine to compute the Cumulative Density Function for F(f/n1,n2)
c     where, f          : is the F-ratio
c            n1 & n2 : are the degrees of freedom
c
c     Input  : n1, n2, f
c     Output : pf   (is the C.D.F);
c
c     Reference:  Handbook of Mathematical Functions  - Ed. by
c     M.Abramowitz and I.A.Stegun, pp 946, Dover Publn., New York, 1972.
c-----------------------------------------------------------------------
      rn1=float(n1)
      rn2=float(n2)
      s1=rn2+rn1*f
      xx=rn2/s1
      xm1=1.0-xx
c
c     determine odd/even n1,n2
c
      ieven=0
      oe=rn1/2.0
      noe=oe
      diff=oe-noe
      if(diff.eq.0.0)ieven=1
      if(ieven.eq.1)goto 101
      oe=rn2/2.0
      noe=oe
      diff=oe-noe
      if(diff.eq.0.0)ieven=2
      if(ieven.eq.2)goto 101
      ieven=3
101   continue
      goto (110,120,130),ieven
c
c     n1 is even
c
110   continue
      nn=(n1-2)/2
      nrn=n2
      xa=xm1
      goto 102
c
c     n2 is even
c
120   continue
      nn=(n2-2)/2
      nrn=n1
      xa=xx
c
102   continue
      sum=1.0
      do 103 i=1,nn
      nnr=nrn
      ndr=2
      s1=1.0
      s2=1.0
```

```
      do 104 j=1,i
      s1=s1*float(nnr)
      s2=s2*float(ndr)
      nnr=nnr+2
      ndr=ndr+2
104   continue
      s3=s1*(xa**i)/s2
      sum=sum+s3
103   continue
c
      if(ieven.eq.1)then
        s1=rn2/2.0
        qf=sum*(xx**s1)
      endif
      if(ieven.eq.2)then
        s1=rn1/2.0
        qf=1.0-(sum*(xm1**s1))
      endif
      goto 105
c
c     n1, n2 are odd
c
130   continue
      pi=3.141592654
      theta=sqrt(rn1*f/rn2)
      theta=atan(theta)
      if(n2.gt.1)goto 131
      aa=2.0*theta/pi
      goto 132
131   continue
      sum=cos(theta)
      nn=(n2-3)/2
      do 133 i=1,nn
      nnr=2
      ndr=3
      s1=1.0
      s2=1.0
      do 134 j=1,i
      s1=s1*float(nnr)
      s2=s2*float(ndr)
      nnr=nnr+2
      ndr=ndr+2
134   continue
      ndr=ndr-2
      s3=s1*(cos(theta)**ndr)/s2
      sum=sum+s3
133   continue
      sum=theta+sin(theta)*sum
      aa=2.0*sum/pi
132   continue
      if(n1.ne.1)goto 135
      bb=0.0
      goto 136
135   continue
      sum=1.0
      nn=(n1-3)/2
```

```
      do 137 i=1,nn
      nnr=n2+1
      ndr=3
      s1=1.0
      s2=1.0
      do 138 j=1,i
      s1=s1*float(nnr)
      s2=s2*float(ndr)
      nnr=nnr+2
      ndr=ndr+2
138   continue
      ndr=ndr-3
      s3=s1*(sin(theta)**ndr)/s2
      sum=sum+s3
137   continue
      f1=(rn2-1.0)/2.0
      fc1=0.0
      call fctrl(f1,fc1)
      f2=(rn2-2.0)/2.0
      fc2=0.0
      call fctrl(f2,fc2)
      bb=(2.0/sqrt(pi))*(fc1/fc2)*sin(theta)*(cos(theta)**n2)*sum
136   continue
      qf=1.0-aa+bb
105   continue
      pf=1.0-qf
      return
      end

      subroutine fctrl(fn,fc)
c     Subroutine to compute factorial of a real number 'fn'
c
c     Input  : fn
c     Output : fc  (factorial of fn);
c
c     Reference:  Handbook of Mathematical Functions  - Ed. by
c     M.Abramowitz and I.A.Stegun, pp 255, Dover Publn., New York, 1972.
c-----------------------------------------------------------------------
      if(fn.ne.0.5)goto 101
      fc=0.8862269254
      goto 110
c
c     determine if FN is integer/real
c
101   continue
      ffn=aint(fn)
      fnf=fn-ffn
      iint=2
      if(fnf.eq.0.0)iint=1
      goto (102,103),iint
c
c     FN is integer
c
102   continue
      fc=1.0
```

```
      nf=fn
      do 104 i=1,nf
      fc=fc*i
104   continue
      goto 110
c
c     FN is real; factorial of FN is a gamma function
c
103   continue
      ghalf=1.7724538509
      zz=fn+1.0
      nf=zz-0.5
      nnf=2*nf-1
      fc=1.0
      do 105 i=1,nnf,2
      fc=fc*i
105   continue
      fc=fc*ghalf/(2.0**nf)
c
110   continue
      return
      end
```

CHAPTER 6 – ANALYSIS IN TIME TREND FRAMEWORK: ALL INDIA AND ANDHRA PRADESH STATE

"The World hates change, yet it is the only thing that has brought progress!"

– *Charles Kettering.*

6.1 Introduction.

In this chapter the results of the analysis for variability change and structural change over time in yields of cereal crops at the all India level and Andhra Pradesh State level are discussed. The analysis here is only within the time domain with time as the only explanatory variable considered in this analysis. Input variables such as irrigation, fertilizer, etc., do not directly figure in here though some references will be made in explaining the results pertaining to "over time". Thus, in this chapter, several time trends (growth curves) are fitted to the crop yields and a specification of the growth curve is selected by the method discussed in chapter 5. The Hsu tests for variance change are then conducted on the estimated residuals from the selected growth curve. Where no such change in the variance is detected the analysis for structural change is done as described in chapter 5. This framework of the analysis based on time-trends will be referred to as "time trend framework".

All India (AI): At the all India (AI) level, in all 11 crop cases are analysed. These include 7 crops: rice, wheat, jowar, bajra, ragi, maize and barley. The crop yield data used in this analysis are from the "Estimates of Area and Production" published by the Ministry of Agriculture, Government of India, New Delhi. The analysis for these 7 crops is for the period 1949-50 to 1988-89 using their aggregate (over kharif and rabi seasons) annual crop yields. These aggregate yields are denoted as t-rice, t-wheat, t-jowar, t-bajra, t-ragi, t-maize and t-barley. Of these 7 crops, for rice and jowar, *seasonwise* analysis is also done for their yields; i.e., separately for the two crop seasons kharif (k) and rabi (r). These data on yields of k-rice, r-rice, k-jowar and r-jowar, are available only from 1962-63 onwards. The period of analysis for these 4 seasonal crop cases is therefore 1962-63 to 1988-89.

Andhra Pradesh (AP): At the Andhra Pradesh (AP) level the analysis was done for 16 crop cases. These include 5 annual crop yields aggregated over seasons, t-rice, t-jowar, t-bajra, t-ragi and t-maize; 4 seasonal crop yields, k-rice, r-rice, k-jowar and r-jowar and 7 crop yields distinguished by their water regimes (irrigated/unirrigated).

The analysis for the 5 annual crop yields is done for the period 1955-56 to 1984-85[1]. Data for the 4 seasonal crop yields are available only from 1962-63 onwards. The analysis for these 4 seasonal crops is done for the period 1962-63 to 1984-85. In chapter 5, time series of irrigated and unirrigated crop yields, as estimated by us, were presented (chapter 5, table 5.3) for seven crop cases. These are i-rice, u-jowar, i-bajra, u-bajra, i-ragi, u-ragi and u-maize. These estimated yields are for the period 1955-56 to 1984-85. See chapter 5 (Part C) for further details regarding these estimated yields. In this chapter, the analysis is carried out for these 7 crop cases also using the corresponding estimated yields. Thus at the AP State level yields of 16 crop cases are analysed.

Notation: In the rest of this chapter, a crop case is indicated by the name of a crop followed by AI or AP in brackets to indicate an all India level crop or Andhra Pradesh State level crop. A t-, k-, r-, i- or u- in front of the crop name is used to denote a annual aggregate (sometimes referred to as "total")-, kharif-, rabi-, irrigated- or unirrigated- crop yield, respectively. Thus, for example, t-rice(AI) would mean annual aggregate yield of rice

---

1 Data at the AP State level are available up to 1988-89 but the data at districts level used here and in the next chapter are available only up to 1984-85. The analysis at the State level is, therefore, restricted up to 1984-85 for comparability of the results at the State level with those at the districts level (see chapter 7).

at the all India level and so on.

Crop cases: To sum up, the total number of crop yields considered for analysis in this chapter are as follows:

All India: 11 crop cases;

i) 7 Annual aggregate yields: t-rice(AI), t-wheat(AI), t-jowar(AI), t-bajra(AI), t-ragi(AI), t-maize(AI) and t-barley(AI).

ii) 4 Seasonwise yields: k-rice(AI), r-rice(AI), k-jowar(AI) and r-jowar(AI).

Andhra Pradesh: 16 *crop cases;*

iii) 5 Annual aggregate yields: t-rice(AP), t-jowar(AP), t-bajra(AP), t-ragi(AP) and t-maize(AP).

iv) 4 Seasonwise yields: k-rice(AP), r-rice(AP), k-jowar(AP) and r-jowar(AP).

v) 7 Water regimewise yields: i-rice, u-jowar, i-bajra, u-bajra, i-ragi, u-ragi and u-maize.

Total crop cases: 27.

These 27 crop cases have been subjected to variability and structural change analyses which involve a series of steps (discussed in more detail in chapter 5) briefly mentioned below:

1) Estimating 7 functional forms for each crop case in both additive error form (AEF) and multiplicative error form (MEF).

2) Check for the 2 measures of nonlinearity, intrinsic (IN) and parametric effects (PE) nonlinearity and also, the skewness measure (SK) of Hougaard, and Box's percentage bias (BB).

3) Check for similarity of parameter estimates as obtained from AEF and MEF.

4) Select the functional form with highest $R^2/\bar{R}^2$.

5) Adjust for autocorrelation if necessary and confirm the choice of functional form through Box-Cox transformation.

6) Collect the residuals and conduct Hsu tests for variance change on both additive errors and logarithms of multiplicative errors.

7) Conduct Hsu tests for the no growth cases using the deviations with respect to sample means.

8) Conduct the structural change analysis for the "variability-change not present" cases as obtained under step 6.

9) Reconfirm the results of 'variability-change not present' for those crop cases that showed structural change.

Detailed discussion of the results obtained at every step of the above methodology for all the 27 crop cases is rather time consuming monotonous task. Hence let us discuss only for any one of these crop cases the results in detail at each step and note how we arrive at the final result. The next section (6.2) is devoted for that. It takes the reader through each and every step of our methodology in the case of crop yields, t-wheat(AI). Section 6.3 presents the final results of all the 27 crop cases.

6.2 Illustration of the Methodology: t-Wheat(AI).

i) The first step in the analysis is the specification of an appropriate functional form (f.f. henceforth) for the growth curve. Various forms for the growth curve can be specified and estimated.

ii) The two measures of nonlinearity, intrinsic (IN) and parametric effects (PE) nonlinearity, should be insignificant. Significance at 5% level is used while conducting the 'F' test (see chapter 5).

iii) A cut off level of 1.0 is used here as the maximum permissible skewness in the parameter's distribution, measured by SK.

iv) A maximum of 1.0% for the Box's measure of percentage bias (BB) is used as the cut off level in deciding about the extent of bias in the parameters.

v) The parameter estimates as obtained from the estimation with an additive error specification should be close to those estimates obtained under a multiplicative error specification.

vi) Of the f.f.s satisfying (ii) to (v) above, the one with the highest fit as measured by $\bar{R}^2$ is selected as the most appropriate f.f. If the $\bar{R}^2$ has a value less than 0.4 the fit is considered poor and the crop case does not show any trend at all over the period of estimation.

vii) If for the finally chosen f.f. the Durbin - Watson (D-W) statistic shows autocorrelation a first order autocorrelation scheme is assumed and the function is reestimated. The reestimated function is then checked for the satisfaction of the statistics in (ii) to (vi) above.

In this analysis seven commonly used f.f. are considered for the growth curve. These f.f., in both additive and multiplicative error forms, are listed in Table 6.1. These include linear trend (f.f.1), quadratic (f.f.2), semi-log (f.f.3), reciprocal (f.f.5), double-logarithmic (f.f.6) and the gompertz (f.f.7). Functional form 4 describes a quadratic trend for log(Y). The table also lists the expression for the growth rate implicit in these f.f.

The linear trend (f.f.1) specifies a straight line for the trend in yield. Depending upon the sign of the slope coefficient (β) the trend is either rising ($\beta > 0$) or falling ($\beta < 0$). No trend if $\beta = 0$; i.e., the line is parallel to the time-axis. The linear trend implies a variable growth rate (see table 6.1).

The quadratic trend (f.f.2) specifies a concave/convex type of curve depending upon the parameters β and γ. These 2 parameters determine both the direction of growth (increasing or decreasing) as well as the rate of change in the Y variable. When these 2 parameters have opposite signs Y has a maximum or minimum at $T = -\beta/2\gamma$. Here too, the growth rate varies over time.

The semi-log (f.f.3) also describes a concave/convex type of curve depending upon the value of β coefficient. Unlike the linear and quadratic trends, the semi-log trend implies a constant rate of growth. In fact this is the only one among the 7 f.f.s considered here that implies a constant rate of growth.

Functional forms 4, 5 and 6 describe concave/convex type of curves of various nature. All of them involve a variable growth rate. For more details on the nature of these curves see Ratkowsky (1989).

The Gompertz curve (f.f.7) is a flexible curve which can describe various types of growth depending upon the values of β

Table 6.1 - Specifications for the Growth Curve.

Function	Additive Error Specification		Multiplicative Error Specification		Growth Rate (%)
1	$Y_t = a + b*TIME_t + u_t$	(@)	$Y_t = (a + b*TIME_t)*v_t$ $Log(Y_t) = Log(a + b*TIME_t) + Log(v_t)$		b/Y_t*100
2	$Y_t = a + b*TIME_t + c*TIME_t^2 + u_t$	(@)	$Y_t = (a + b*TIME_t + c*TIME_t^2)*v_t$ $Log(Y_t) = Log(a + b*TIME_t + c*TIME_t^2) + Log(v_t)$		$(b + 2*c*TIME_t)/Y_t*100$
3	$Y_t = a*b^{TIME_t} + u_t$		$Y_t = (a*b^{TIME_t})*v_t$ $Log(Y_t) = Log(a) + Log(b)*TIME_t + Log(v_t)$	(@)	$b*100$
4	$Y_t = Exp(a + b*TIME_t + c*TIME_t^2) + u_t$		$Y_t = Exp(a + b*TIME_t + c*TIME_t^2)*v_t$ $Log(Y_t) = a + b*TIME_t + c*TIME_t^2 + Log(v_t)$	(@)	$(b + 2*c*TIME_t)*100$
5	$Y_t = \frac{1}{a + b*TIME_t} + u_t$		$Y_t = \frac{1}{a + b*TIME_t}*v_t$ $Log(Y_t) = -Log(a + b*TIME_t) + Log(v_t)$		$-(b*Y_t)*100$
6	$Y_t = a*TIME_t^b + u_t$		$Y_t = (a*TIME_t^b)*v_t$ $Log(Y_t) = Log(a) + b*Log(TIME_t) + Log(v_t)$	(@)	$b/TIME_t*100$
7	$Y_t = a*b^{c^{TIME_t}} + u_t$		$Y_t = (a*b^{c^{TIME_t}})*v_t$ $Log(Y_t) = Log(a) + Log(b)*c^{TIME_t} + Log(v_t)$		$Log(b)*Log(c)*c^{TIME_t}*100$

Notes: Y_t is Yield at time t; $TIME_t$ is the time variable; u_t is the additive error; v_t is the multiplicative error;
(@) : Can be estimated by Ordinary Least Squares (OLS). Others require nonlinear estimation.

and γ parameters. (For more details see Croxton et.al (1988)). This also involves a variable growth rate over time.

These seven growth curves are estimated in both additive error form (AEF) and multiplicative error form (MEF). Thus for each crop case considered 14 estimations (models) are there. Note that 5 out of these 14 estimations are linear in parameters. These are f.f.1(AEF), f.f.2(AEF), f.f.3(MEF), f.f.4(MEF) and f.f.6(MEF). These 5 linear models can be estimated using the ordinary least squares (OLS). For these linear models by definition, IN, PE, SK and BB are all zero and hence our selection criteria (ii) to (iv) above are all automatically satisfied by each of them. The remaining 9 estimations are, however, nonlinear in parameters and have to be estimated using nonlinear least squares (NLS) techniques. For these nonlinear estimations, IN, PE, SK and BB can be all non-zero. It is for these nonlinear estimations, the selection criteria (ii) to (iv) above are applied.

The estimation results for the 14 models for t-wheat(AI) yields, for the period 1949-50 to 1988-89, are given in table 6.2.

The second step in our selection procedure is to check if the IN and PE statistics are within acceptable limits as given by $1/2\sqrt{F}$ (for both IN and PE) where $F(p,n-p;\alpha)$ is the critical value of the F-distribution with p and (n-p) degrees of freedom at α level of significance, p being the number of parameters estimated and n is the number of observations. At 5% level of significance $1/2\sqrt{F(2,37)}$ is 0.5590 (for equations with 2 parameters) and $1/2\sqrt{F(3,36)}$ is 0.5903 (for equations with 3 parameters). The estimates of IN and PE for various f.f. are as follows:

Function Form	Under AEF IN	Under AEF PE	Under MEF IN	Under MEF PE
f.f.1	0.0	0.0	0.0278	0.0512
f.f.2	0.0	0.0	0.0249	0.0507
f.f.3	0.0167	0.1346	0.0	0.0
f.f.4	0.0306	0.0609	0.0	0.0
f.f.5	0.0169	0.0269	0.0211	0.0252
f.f.6	0.0626	1.6379	0.0	0.0
f.f.7	0.0725	21390.8	0.0872	59.896

Table 6.2 – Estimation Results for T-Wheat(AI).

<u>f.f.1</u> <u>(AEF)</u>

$$Y_t = \underset{(10.68)^+}{431.48} + \underset{(21.15)^+}{37.27} * TIME_t + U_t$$

SK: 0.0 0.0

BB: 0.0 0.0

IN = 0.0 PE = 0.0 $\bar{R}^2$ = 0.9215 DW = 0.5727

<u>f.f.1</u> <u>(MEF)</u>

$$LOG(Y_t) = LOG(\underset{(16.86)^+}{519.46} + \underset{(16.83)^+}{31.98} * TIME_t) + V_t$$

SK: 0.0987 0.0125

BB: 0.0876 -0.0084

IN = 0.0278 PE = 0.0512 $\bar{R}^2$ = 0.8898 DW = 0.5024

<u>f.f.2</u> <u>(AEF)</u>

$$Y_t = \underset{(15.24)^+}{647.62} + \underset{(1.14)}{5.59} * TIME_t + \underset{(6.66)^+}{0.7908} * TIME_t^2 + U_t$$

SK: 0.0 0.0 0.0

BB: 0.0 0.0 0.0

IN = 0.0 PE = 0.0 $\bar{R}^2$ = 0.9639 DW = 1.2504

<u>f.f.2</u> <u>(MEF)</u>

$$LOG(Y_t) = LOG(\underset{(21.46)^+}{670.48} + \underset{(0.25)}{1.11} * TIME_t + \underset{(7.12)^+}{0.914} * TIME_t^2) + V_t$$

SK: 0.0778 -0.0263 0.0265

BB: 0.0686 -3.6904 0.1344

IN = 0.0249 PE = 0.0507 $\bar{R}^2$ = 0.9541 DW = 1.1983

<u>f.f.3</u> <u>(AEF)</u>

$$Y_t = \underset{(29.59)^+}{568.07} * \underset{(864.13)^+}{1.034}^{TIME_t} + U_t$$

SK: 0.0460 0.0325

BB: 0.0291 0.0006

IN = 0.0167 PE = 0.1346 $\bar{R}^2$ = 0.9607 DW = 1.1227

<u>f.f.3</u> <u>(MEF)</u>

$$LOG(Y_t) = \underset{(216.4)^+}{6.36} + \underset{(24.92)^+}{0.0319} * TIME_t + V_t$$

SK: 0.0 0.0

BB: 0.0 0.0

IN = 0.0 PE = 0.0 $\bar{R}^2$ = 0.9423 DW = 0.9319

<u>f.f.4</u> <u>(AEF)</u>

$$Y_t = EXP(\underset{(108.5)^+}{6.38} + \underset{(5.29)^+}{0.0284} * TIME_t + \underset{(0.86)}{0.0001} * TIME_t^2) + U_t$$

SK: -0.0970 -0.0535 -0.0342

BB: -0.0164 0.2514 -1.3516

IN = 0.0306 PE = 0.0609 $\bar{R}^2$ = 0.9604 DW = 1.1478

Notes are given at the end of the table.

Table 6.2 Contnd.

<u>f.f.4</u> <u>(MEF)</u> $LOG(Y_t) = 6.44 + 0.0211*TIME_t + 0.0003*TIME_t^2 + V_t$

(148.8)+ (4.22)+ (2.25)++

SK: 0.0 0.0 0.0

BB: 0.0 0.0 0.0

IN = 0.0 PE = 0.0 $\bar{R}^2$ = 0.9480 DW = 1.0612

<u>f.f.5</u> <u>(AEF)</u> $Y_t = \frac{1}{0.0014 - 0.00003*TIME_t} + U_t$

(37.04)+ (-21.66)+

SK: 0.0502 -0.0333

BB: 0.0181 0.0181

IN = 0.0169 PE = 0.0269 $\bar{R}^2$ = 0.9440 DW = 0.8169

<u>f.f.5</u> <u>(MEF)</u> $LOG(Y_t) = -LOG(0.0015 - 0.00003*TIME_t) + V_t$

(43.51)+ (-23.53)+

SK: 0.0450 -0.0099

BB: 0.0105 -0.0048

IN = 0.0211 PE = 0.0252 $\bar{R}^2$ = 0.9379 DW = 0.8763

<u>f.f.6</u> <u>(AEF)</u> $Y_t = 205.66 * TIME_t^{0.5939} + U_t$

(6.04)+ (11.67)+

SK: 0.3369 0.1347

BB: 0.9427 0.1948

IN = 0.0626 PE = 1.6379 $\bar{R}^2$ = 0.8356 DW = 0.2941

<u>f.f.6</u> <u>(MEF)</u> $LOG(Y_t) = 6.004 + 0.3650*LOG(TIME_t) + V_t$

(56.0)+ (9.76)+

SK: 0.0 0.0

BB: 0.0 0.0

IN = 0.0 PE = 0.0 $\bar{R}^2$ = 0.7127 DW = 0.2506

<u>f.f.7</u> <u>(AEF)</u> $Y_t = 2.65 * 223.02^{1.005^{TIME_t}} + U_t$

(0.13) (0.13) (143.89)+

SK: -4060.9 4106.3 -4068.1

BB: 2126.9 4150.9 0.0011

IN = 0.0725 PE = 21390.8 $\bar{R}^2$ = 0.9603 DW = 1.1456

Notes are given at the end of the table.

Table 6.2 Contnd.

f.f.7 (MEF) $LOG(Y_t) = 4.89 + 1.54 * 1.015^{TIME_t} + V_t$

	(4.6)$^+$	(1.49)	(130.4)$^+$
SK:	-3.183	3.279	-0.1427
BB:	-10.91	34.64	0.0062

IN = 0.0872 PE = 59.896 $\bar{R}^2$ = 0.9472 DW = 1.0462

Notes: Y_t : Yield at time t; $TIME_t$: Time variable;
See table 6.1 for the functional form (f.f.). AEF and MEF denote additive error form and multiplicative error form, respectively.
t values are given in brackets;
+/++/+++ indicates significance of t-values at 1%, 5% and 10% level, respectively.
SK : Skewness statistic; (cut off point 1.0).
BB : Box's % bias; (cut off point 1.0%).
IN : Intrinsic nonlinearity;
PE : Parametric effect nonlinearity;
(critical F-values for IN & PE: 0.5590 (0.5903) for 2 (3) parameter f.f
DW : Durbin-Watson statistic;

Comparing the estimated IN and PE for each of the 14 equations with the critical values, we find that f.f.6 (AEF) and f.f.7 (both AEF and MEF) have high parametric effects nonlinearity. Therefore, at this stage the double logarithmic curve (f.f.6) and the gompertz curve (f.f.7) are rejected considering them as inappropriate specifications of the growth curve for t-wheat(AI) yields.

Next, we look, for each parameter, the smallness of skewness measure (SK) and Box's percentage bias (BB) against cut off values of 1.0 and 1.0%, respectively. At this stage only f.f 1, 2, 3, 4 and 5, in both the error forms (10 estimations), are considered since f.f.6 and f.f.7 have already been ruled out earlier. The skewness measure (SK) and Box's percentage bias (BB) of these remaining f.f. can be noted from table 6.2. The skewness measure is well within the cut off limit for all the parameters of these 10 remaining estimations. However, the cut off for Box's percentage bias is exceeded for one parameter each in f.f.2 (MEF) and f.f.4 (AEF). Functional forms 2 and 4 are, therefore, eliminated at this stage leaving only f.f. 1, 3 and 5 (6 estimations) for further consideration.

Next, we look for the closeness of the parameter estimates as obtained from additive error specification and multiplicative error specification. Thus we now pairwise compare the closeness of the parameter estimates between f.f.1 (AEF) & f.f.1 (MEF); f.f.3 (AEF) & f.f.3(MEF); and f.f.5 (AEF) & f.f.5 (MEF). Note that in the case of f.f.3 (AEF) & f.f.3 (MEF) the parameters of f.f.3 (AEF) have to be compared with the exponent of the parameters of f.f.3 (MEF) since that is the way the estimates have been obtained (see table 6.1). In the case of f.f.1 (AEF) & f.f.1 (MEF) and f.f.5 (AEF) & f.f.5 (MEF) the parameters are all comparable straightaway. The comparable parameter estimates from the additive error specification and the multiplicative error specification for these three f.f. are given below:

Function Form	Under AEF $\hat{a}$	$\hat{b}$	Under MEF $\hat{a}$	$\hat{b}$
f.f.1: $Y = a+b*X$	431.48	37.27	519.46	31.98
f.f.3: $Y = a*b^X$	568.07	1.034	578.25	1.032
f.f.5: $Y = \frac{1}{a+b*X}$	0.0014	-0.00003	0.0015	-0.00003

Notes: Y : Yields; X : Time;

By visual comparison, the estimates of f.f.3 (AEF) & f.f.3 (MEF) are close; and similarly the estimates of f.f.5 (AEF) & f.f.5 (MEF). Between f.f.1 (AEF) & f.f.1 (MEF) the constant term is quite different while the slope coefficient is fairly close. Therefore, function f.f.1, namely, linear trend, is eliminated from the analysis leaving the semi-log function (f.f.3) and the reciprocal function (f.f.5) for further analysis.

The next step is to choose from amongst f.f.3 and f.f.5 the one with the highest fit as given by $\bar{R}^2$. The $\bar{R}^2$ for these two f.f. are as follows:

Function Form	Under AEF	Under MEF
f.f.3	0.9607	0.9423
f.f.5	0.9440	0.9379

Here the additive error specifications (f.f.3(AEF) and f.f.5(AEF)) are considered as one set (where Y_t is the dependent variable) and multiplicative error specifications (f.f.3(MEF) and f.f.5(MEF)) as a separate set (where $Log(Y_t)$ is the dependent variable). In principle the $\bar{R}^2$ are not comparable across these sets due to differences in the dependent variables. The semi-log f.f.3 is found to have the highest fit under both AEF and MEF specifications. However, f.f.5 has a fit almost close to that of f.f.3. Further, the PE value of f.f.5(AEF) is less than that of f.f.3(AEF). Therefore, both f.f.3 and f.f.5 are retained as equally appropriate specifications of the growth curve for t-wheat(AI) yields. All further analysis is carried out using both these specifications.

Note that for these two chosen functions the Durbin-Watson (D-W) statistic indicates presence of significant positive autocorrelation, both in AEF and MEF (see table 6.2). To correct this a first order auto correlation is assumed for both additive errors and the logarithm of multiplicative errors and the functions are reestimated. Alongwith the model and autocorrelation parameters, IN, PE, SK and BB are also reestimated and these are required to satisfy their respective tests. Also, the parameter estimates from the AEF after correcting for autocorrelation must be close to those obtained from the MEF after autocorrelation correction. The estimation results after correcting for autocorrelation, shown in table 6.3, satisfy all the above selection criteria.

Thus far, the issue of appropriate functional form as the growth curve for t-wheat(AI) yields from amongst various specifications has been settled (though we still have two alternatives here!). As mentioned already in chapter 5, we have also estimated a Box-Cox (B-C) transformation curve whenever the finally chosen f.f. falls within the class of B-C transformation curves. Parameter estimates resulting from B-C transformation curve estimation can provide us with a cross check regarding the appropriateness or otherwise of the f.f. chosen by us to the data. Here both the f.f.3 and f.f.5 chosen earlier fall in the class of functions covered by the B-C procedure. The B-C procedure is, therefore, used to confirm the choice of f.f. made. According to the B-C transformation curve $\lambda y = 0$ & $\lambda t = 1$ would indicate f.f.3 whereas $\lambda y = -1$ & $\lambda t = 1$ would (indirectly) indicate f.f.5. The results of the B-C estimation are as follows:

$$\left[\frac{Y_t^{\lambda y} - 1}{\lambda y}\right] = \underset{(75.03)^+}{6.468} + \underset{(1.26)}{0.014}\left[\frac{TIME_t^{\lambda t} - 1}{\lambda t}\right] + \underset{(2.90)^+}{0.451}*U_{t-1} + e_t$$

$$\bar{R}^2 = 0.9639 \qquad D\text{-}W = 1.9628$$

where the estimated $\lambda y = 0$ and $\lambda t = 1.274$ (Std. Error = 0.2616) and t-values of the parameters are given in the brackets.

For the null hypothesis $H_0 : \lambda t = 1$ against $H_1 : \lambda t \neq 1$ the t-value is (1.274-1)/0.2616 = 1.05 which is insignificant at 10% level of significance. Thus the null hypothesis that $\lambda t = 1$ could not be rejected and thus λt may be taken to be 1. $\lambda y = 0$ implies Y_t enters as $Log(Y_t)$ and $\lambda t = 1$ implies $TIME_t$ enters linearly. Thus we have the functional form

Table 6.3 – Final Estimates for All India Wheat Yields.

f.f.3 AEF

$$Y_t = \underset{(18.60)^{+}}{553.1} * \underset{(573.06)^{+}}{1.035}^{TIME_t} + \underset{(2.60)^{+}}{0.402}*U_{t-1} + \varepsilon_t$$

SK: 0.2831   0.0762   0.0001

BB: 0.0249   0.0005   -0.0144

IN = 0.0187   PE = 0.1565 $\bar{R}^2$ = 0.9696

f.f.3 MEF

$$Log(Y_t) = \underset{(110.3)^{+}}{6.332} + \underset{(14.37)^{+}}{0.033}*TIME_t + \underset{(3.68)^{+}}{0.519}*Log(V_{t-1}) + Log(\delta_t)$$

SK: 0.0   0.0   0.0

BB: 0.0   0.0   0.0

IN = 0.0   PE = 0.0 $\bar{R}^2$ = 0.9602

f.f.5 AEF

$$Y_t = \frac{1}{\underset{(18.99)^{+}}{0.0015} - \underset{(-13.34)^{+}}{0.00003}*TIME_t} + \underset{(4.30)^{+}}{0.611}*U_{t-1} + \varepsilon_t$$

SK: 0.8763   -0.7249   0.0366

BB: 0.0131   0.0138   0.0498

IN = 0.0163   PE = 0.0277 $\bar{R}^2$ = 0.9654

f.f.5 (MEF)

$$LOG(Y_t) = -LOG(\underset{(43.51)^{+}}{0.0015} - \underset{(-23.53)^{+}}{0.00003}*TIME_t) + \underset{(4.09)^{+}}{0.567}*Log(V_{t-1}) + Log($$

SK: 0.5915   -0.3246   0.0009

BB: 0.0069   -0.0033   0.0531

IN = 0.0203   PE = 0.0254 $\bar{R}^2$ = 0.9585

Notes: Y_t : Yield at time t; $TIME_t$: Time variable;

See table 6.1 for the functional form (f.f.). AEF and MEF denote additive error form and multiplicative error form, respectively.

t values are given in brackets;

+/++/+++ indicates significance of t-values at 1%, 5% and 10% level, respectively.

SK : Skewness statistic; (cut off point 1.0).

BB : Box's % bias; (cut off point 1.0%).

IN : Intrinsic nonlinearity;

PE : Parametric effect nonlinearity;

(critical F-values for IN & PE: 0.5590 (0.5903) for 2 (3) parameter f.f)

$$Log(Y_t) = \beta_0 + \beta_1 \times TIME_t + \rho \times U_{t-1} + \varepsilon_t$$

which is the f.f.3 in the multiplicative error form that was chosen earlier. Thus the B-C procedure confirms the choice of the f.f.3 made earlier.

Having chosen f.f.3 (confirmed by B-C procedure) and also f.f.5 (in view of its less nonlinear behaviour than f.f.3) as appropriate specifications for the growth curve of t-wheat(AI) we then proceed to conduct the Hsu tests for variance change. For this purpose, we use the estimated errors obtained from the estimations reported in table 6.3. Note that now the error estimates (residuals) are from a correct specification of the growth curve having all desirable properties for its parameter estimates and with autocorrelation corrected for. The Hsu tests for change in absolute variability are conducted on the estimated additive errors ($\hat{\varepsilon}_t = Y_t - \hat{Y}_t$). To test for change in percentage (relative) variability the percentage errors ($\hat{\delta}_t = Y_t / \hat{Y}_t$) are considered and Hsu tests are conducted on the logarithms of these percentage errors ($\hat{\delta}_t$).[2] It may be noted here that the time series of ε_t and $Log(\delta_t)$, both being normal random variables and free from autocorrelation satisfy the assumptions of Hsu tests. The results of both these tests, the details of which were given in chapter 5, are given below.

Function Form	Absolute Variability T-Test	Absolute Variability G-Test	Relative Variability T-Test	Relative Variability G-Test
3	0.59118	0.65788	-1.71105	0.17980
5	1.29022	0.82046	-1.05716	0.29642

Critical values: T-test - 2.308 (1%); 1.954 (5%);
G-test - 0.999 (1%); 0.888 (5%);
(see chapter 5, appendix 5.A1).

2 Imagine the model in MEF with autocorrelation as
$Y_t = f(X_t)\cdot V_t = f(X_t)\cdot V^{\rho}_{t-1}\cdot\delta_t$;
where $Log(Y_t) = Log[f(X_t)] + \rho\cdot Log(V_{t-1}) + Log(\delta_t)$.
Note that δ_t ~ Log-Normal$(1,\sigma^2)$ and $Log(\delta_t)$ ~ $N(0,s^2)$. It then follows from the relationship between σ^2 and s^2 that a test on s^2 is indeed a test on σ^2. Hence the variability results on $Log(\delta_t)$ hold for δ_t. See chapter 5 for further discussion.

The above results show clearly that, at 5% level of significance, there has been no significant change in the variance, both in absolute errors and in percentage errors, of t-wheat(AI) yields which ever of the above two f.f. is considered. This implies that the fluctuations in the realized annual aggregate yields of wheat have been fairly uniform around the corresponding trend values all through the time period 1949-50 to 1988-89. Thus aggregate wheat yield at all India level could not be said to exhibit any change in variability over time.

Depending upon the results of the tests for variability change, we either proceed with the analysis for structural change (for the cases of no change in variability) or stop the analysis at this stage (for the cases of variability change present)[8]. As the Hsu tests indicate the absence of variability change in t-wheat(AI), we, therefore, proceed with the analysis for structural change as described in chapter 5.

For this purpose we use the linearised form of the chosen function(s) and incorporate dummy variables for both intercept and trend (Time) variable to capture structural change, if any, in the growth path over time. The linearised form of the chosen function is used since in this form IN, PE, skewness and Box's bias would each be zero and the parameter estimates would be free of all the problems associated with nonlinear equations. Besides, incorporation of dummy variables is easier in linear equations.

In our example of t-wheat(AI), the linearised form of the chosen functions with the dummy variable is as follows:

<u>f.f.3</u> $\quad \mathrm{Log}(Y_t) = \beta_0 + \beta_1 * TIME_t + \beta_2 * D_t + \beta_3 * D_t * TIME_t + \mathrm{Log}(V_t)$

<u>f.f.5</u> $\quad 1/(Y_t) = \beta_0 + \beta_1 * TIME_t + \beta_2 * D_t + \beta_3 * D_t * TIME_t + U_t$

where the dummy variable $D_t = 0$ for $t < k$ and $D_t = 1$ for $t \geq k$, and k is the change point year to be scanned for between 1963-64 and 1976-77. That is, the above two equations are estimated several times, varying k over the period 1963-64 to 1976-77 successively.

8 The procedure used here for the analysis of structural change is valid only under the assumption of homoskedastic errors.

The new technology which was supposed to have significantly improved yield levels was introduced in the country in mid-1960s. However, it is possible that it took some years before the impact of the new technology began to be felt. Thus, structural change in yields, if any, could be expected to have occurred some time after mid 1960s, and hence the change point is searched for between the years 1963-64 and as far as 1976-77 by scanning.

Over the scan period, the year-value of k at which the corresponding estimate of the error sum of squares is the least is taken as the appropriate change point year (= k^*). If at k^* atleast one of the dummy coefficients β_2 and β_8 turns out significant structural change is deemed to have occurred at the change point k^*. Otherwise, no structural change occurred. Where a crop case is found to show autocorrelation a first order auto regressive scheme is imposed separately for the period before and after the change point.

Note that the above procedure assumes that once a f.f. is chosen at the full sample level (t = 1, ..., n), the f.f. still remains appropriate for sub-samples (t = 1, ..., k^* & t = k^*+1, ..., n) also. However, the estimated parameters would be different not only between the full and sub-sample regressions but also between the sub-sample regressions. These differences are supposed to be indicated by the significance of the dummy variable coefficients. Therefore, the estimated growth rates (whether constant or variable) would not be same between the full sample and sub-sample regressions.

The estimation results for structural change for t-wheat(AI) yields are given in table 6.4. The results show that there has been a structural change in 1966-67 in t-wheat(AI) yields. The nature of the structural change has been such that the growth rate has increased in the period after 1966-67, the structural change point year. In the case of f.f.3 the slope dummy is significant and positive indicating an increase in the growth rate. Thus, it is clear that, since the introduction of the Green Revolution technology the country has witnessed an acceleration in the growth

Table 6.4 – Estimation Results of Structural Change Analysis: All India Wheat

f.f.3 (MEF)

$$LOG(Y_t) = 6.503 + 0.0143*TIME_t - 0.0330*D_t + 0.0149*D_t*TIME_t + 0.0534*U^{\ddagger}_{t-1} + 0.1738*U^{\$}_{t-1} + \epsilon_t$$

$(164.88)^{+}$ $(3.83)^{+}$ (-0.34) $(3.14)^{+}$ (0.24) (0.79)

CHANGE POINT YEAR = 1967 $\bar{R}^2 = 0.9842$

f.f.5 (AEF)

$$\frac{1}{Y_t} = 0.0015 - 0.00002*TIME_t - 0.00026*D_t - 0.0000005*D_t*TIME_t + 0.0875*U^{\ddagger}_{t-1} + 0.1661*U^{\$}_{t-1} + \epsilon_t$$

$(32.80)^{+}$ $(-4.36)^{+}$ $(-2.36)^{++}$ (-0.09) (0.46) (0.61)

CHANGE POINT YEAR = 1967 $\bar{R}^2 = 0.9564$

Notes: See table 6.1 for the functional form (f.f.). AEF and MEF denote additive error form and multiplicative error form, respectively.

t values are given in brackets; +/++/+++ indicates significant at 1%, 5% and 10% level respectively.

Y_t - yield at time t; $TIME_t$ - time variable; D_t - dummy variable = 0 (= 1) for period before (after) change point year;

$U^{\ddagger}$ & $U^{\$}$ are the residuals for the period before and after the change point year respectively;

DW - Durbin-Watson statistic;

of wheat yields. Note that the change point year estimate not only turned out to be same under both the f.fs but also is quite close to the year of introduction of the HYV technology in the country (1965-66).

This in detail is the methodology used to analyse variability change and structural change (instability of the coefficients of growth curve) which has been illustrated above for one crop case, namely, yields of t-wheat(AI). The same procedure is used for the analysis of yields of all other crop cases too. The final results of all the crop cases are discussed in the next section.

6.3 The Results.

In this section the results from the analysis of variability and structural change of cereal crop yields are discussed. The methodological procedure for each of these 27 crop cases, 11 at the AI level and 16 at the AP State level, was exactly in the same manner as was illustrated earlier for t-wheat(AI). Only the final results are discussed below, avoiding the intermediate details.

6.3.1 Functional Form.

First, the 7 f.f. for the growth curve, both in the additive and multiplicative error forms, were estimated for all the 27 crop cases. At the AI level the estimation was carried out for the period 1949-50 to 1988-89 (40 years) for the 7 aggregate crop yields and from 1962-63 to 1988-89 (27 years) for the 4 seasonal crop yields. At the AP State level the estimation was carried out for the period 1955-56 to 1984-85 (30 years) for the 5 aggregate crop yields as well as the 7 estimated (irrigated- and unirrigated-) crop yields, and from 1962-63 to 1984-85 (23 years) for the 4 seasonal crop yields. Thus in all 27 (7 + 4 + 5 + 7 + 4) crop cases at the AI and AP levels put together are analysed here.

For 11 out of the total 27 crop cases none of the 14 estimations had a good fit; i.e. $\bar{R}^2$ for all the 14 estimations (7 f.f × 2 error forms) for these 11 cases was less than 0.4. The remaining 16 crop cases had a good fit in terms of $\bar{R}^2$. In other words, while 11 crop cases showed no trend at all, 16 crop cases (9 at AI level and 7 at AP level) showed growth (positive or negative). The number of crop cases with good and poor fits are as follows:

	Good Fit		Poor Fit		
AI level:					
7 Annual aggregate crop yields	6		1		
4 Seasonal crop yields	3		1		
		9		2	
AP level:					
5 Annual aggregate crop yields	3		2		
4 Seasonal crop yields	2		2		
7 Water regime crop yields	2		5		
		7		9	
Total		16		11	= 27

Table 6.5[4] gives more details of the good and poor fit cases. The 11 poor fit cases that do not show any trend in their yields are 2 AI level crops (t-bajra and r-jowar) and 9 AP level crops (t-bajra, t-ragi, k-jowar, r-jowar, u-jowar, u-bajra, i-bajra, u-ragi and u-maize). Note that 5 out of the 7 estimated irrigated- and unirrigated- yields at AP levels also do not show any growth. These 11 cases of no trend will henceforth be referred to as "no growth cases".

The remaining 16 crop cases (6 AI aggregate crop yields, 3 AI seasonal crop yields, 3 AP total crop yields, 2 AP seasonal crop yields and 2 AP estimated irrigated-, unirrigated- crop yields) had good fits ($\bar{R}^2 \geq 0.4$). These 16 crop cases show a trend (positive or negative growth) in their yields and they will henceforth be referred to as "growth cases". For each of these 16 crop cases an appropriate f.f. satisfying all the selection criteria

4 For the sake of completeness the results for t-wheat(AI) discussed earlier are also reported in all the tables referred to in this section.

Table 6.5 - Total Number of Regressions.*

Good Fit Cases (16)					Poor Fit Cases (11)		
With 1 f.f. Selected		With 2 f.f. Selected					
k-rce(AI)(3)	r-rce(AI)(1)	t-rce(AI)(3,5)	t-wht(AI)(3,5)	t-jwr(AI)(3,5)	t-bjr(AI)	r-jwr(AI)	t-bjr(AP)
k-jwr(AI)(1)	t-jwr(AP)(2)	t-rgi(AI)(3,5)	t-mze(AI)(2,6)	t-brl(AI)(3,5)	t-rgi(AP)	k-jwr(AP)	r-jwr(AP)
t-mze(AP)(1)	k-rce(AP)(5)	t-rce(AP)(3,5)	r-rce(AP)(3,5)	i-rce(AP)(3,5)	u-jwr(AP)	u-bjr(AP)	i-bjr(AP)
i-rgi(AP)(3)					u-rgi(AP)	u-mze(AP)	
Total (25) 7 * 1 = 7		9 * 2 = 18					

Notes: * For each case several functional forms have been estimated and the best one or the best two models have been selected. Thus the total 25 regressions correspond to the 16 good fit cases. For details on these models see table 6.6.

Figures in brackets refer to the serial number of f.f. selected.

t- / k- / r- / i- / u- before a crop name indicates the yields correspond to the aggregate annual- / kharif- / rabi- / irrigated- / un-irrigated- crop, respectively.

AI or AP in brackets after the crop name indicates an all India level or Andhra Pradesh State level crop, respectively.

Crops: rce - rice; wht - wheat; jwr - jowar; bjr - bajra; rgi - ragi; mze - maize; brl - barley;

described earlier was chosen from among the 7 f.f. In 9 out of the 16 cases an unique choice of the f.f. could not be made since two functional forms performed equally well (just as in the case of t-wheat(AI) described in the previous section) in the sense, both f.f.. have almost same level $\bar{R}^2$s simultaneously satisfying all the other econometric tests such as IN, PE, etc. Hence, for these 9 crop cases both such f.f. have been retained for further analysis. These 9 consist of 6 AI aggregate annual crop yields (t-rice(AI), t-wheat(AI), t-jowar(AI), t-ragi(AI), t-maize(AI) and t-barley(AI)) and 3 AP level rice yields (t-rice(AP), r-rice(AP) and i-rice(AP)) (see table 6.5). Table 6.5 provides the details of the number of f.f. chosen for each of the growth crop cases. For the 7 remaining crop cases showing growth a clear single f.f. satisfied all the criteria and had the highest fit. These 7 consist of 3 AI level crop yields (k-rice(AI), r-rice(AI) and k-jowar(AI)) and 4 AP level crop yields (t-jowar(AP), t-maize(AP), k-rice(AP) and i-ragi(AP)). Thus in all, for the 16 crop cases showing growth, 25 specifications (9×2 + 7×1 = 25) were finally chosen.

The details of the f.f. chosen for each of the 16 crop cases are given in table 6.6. Note that of the seven f.f. tried, the gompertz curve (f.f.7) could not be chosen for any of the crop cases. This specification was found to have a high parametric effects nonlinearity and was hence rejected for all the crop cases. Semi-log curve (f.f.3) and reciprocal curve (f.f.5) were found to be appropriate specifications for most of the crop cases. These two f.f. cover 11 out of the total 16 crop cases showing growth. The remaining 5 cases are covered by the f.f.1 (linear), f.f.2 (quadratic) and f.f.6 (double logarithmic).

6.3.2 Growth.

Recall that there are total 27 crop cases of which 16 showed growth and 11 showed no growth (see page 167). Table 6.7 presents the estimation results of all the 25 regression equations (corresponding to the finally chosen f.f) for the 16 crop cases (9 at AI 7 at AP level) showing trend. The results show that all the 9

Table 6.6 - Cropwise Estimated and Chosen Functional Form for All India & Andhra Pradesh.*

Functional Form	All India	Andhra Pradesh
1) $Y_t = a + b*TIME_t$	r-rce k-jwr$	t-mze
2) $Y_t = a + b*TIME_t + c*TIME_t^2$	t-mze	t-jwr
3) $Y_t = a*b^{TIME_t}$	t-rce k-rce t-rgi t-brl t-wht$ t-jwr$	t-rce$ r-rce i-rce$ i-rgi
4) $Y_t = Exp\{ a + b*TIME_t + c*TIME_t^2 \}$		
5) $Y_t = \dfrac{1}{a + b*TIME_t}$	t-rce t-rgi t-brl t-wht$ t-jwr$	t-rce$ k-rce i-rce$ r-rce
6) $Y_t = a*TIME_t^b$	t-mze	
7) $Y_t = a*b^{c^{TIME_t}}$		
Total (25)	15	10

Notes: * See table 6.7 for estimation results. $: These cases required correction for autocorrelation.

t- / k- / r- / i- / u- before a crop name indicates the yields correspond to the aggregate annual- / kharif- / rabi- / irrigated- / un-irrigated- crop, respectively.

Crops: rce - rice; wht - wheat; jwr - jowar; bjr - bajra; rgi - ragi; mze - maize; brl - barley;

Table 6.7 - Estimation Results of the Finally Chosen Growth Functions for Crop Yields.

Crop	Function Y =	Parameters a	b	c	Rho	t values a	b	c	Rho	Skewness Coefficients (SK) a	b	c	Rho	Box's % Bias (BB) a	b	c	Rho	IN	PE	$\bar{R}^2$	D-W
All India (AI)																					
t-rice	$a \cdot b^X$	729.89	1.019	...	...	32.85^{+}	903.55^{+}	...	...	0.04	0.02	...	...	0.02	0.01	...	...	0.02	0.10	0.8801	2.01
	$1/(a + bX)$	0.0013	-0.00002	...	...	43.10^{+}	-16.98^{+}	...	...	0.04	-0.02	...	...	0.01	0.01	...	...	0.01	0.02	0.8875	2.11
k-rice	$a \cdot b^X$	882.57	1.019	...	...	26.97^{+}	484.32^{+}	...	...	0.05	0.02	...	...	0.03	0.01	...	...	0.02	0.11	0.7650	2.25
r-rice	$a + bX$	1251.27	47.62	...	...	30.28^{+}	18.47^{+}	...	...	0.00	0.00	...	...	0.00	0.00	...	...	0.00	0.00	0.9289	2.06
t-wheat	$a \cdot b^X$	553.11	1.035	...	0.402	18.60^{+}	573.06^{+}	...	2.60^{++}	0.28	0.08	...	0.01	0.02	0.01	...	-0.01	0.02	0.16	0.9696	...
	$1/(a + bX)$	0.0015	-0.00003	...	0.611	18.99^{+}	-13.34^{+}	...	4.30^{+}	0.88	-0.72	...	0.04	0.01	0.01	...	0.05	0.02	0.03	0.9654	...
t-jowar	$a \cdot b^X$	398.05	1.015	...	0.356	15.75^{+}	433.32^{+}	...	2.28^{++}	0.24	0.07	...	0.01	0.04	0.01	...	-0.01	0.03	0.14	0.7545	...
	$1/(a + bX)$	0.0024	-0.00003	...	0.373	18.52^{+}	- 6.18^{+}	...	2.41^{++}	0.29	-0.15	...	-0.01	0.03	0.03	...	0.04	0.02	0.04	0.7513	...
k-jowar	$a + bX$	447.04	15.40	...	0.298	10.35^{+}	5.98^{+}	...	1.54	0.00	0.00	...	0.00	0.00	0.00	...	0.00	0.00	0.00	0.7525	...
t-ragi	$a \cdot b^X$	641.04	1.014	...	...	24.33^{+}	646.25^{+}	...	...	0.05	0.02	...	...	0.04	0.01	...	...	0.02	0.12	0.6701	1.69
	$1/(a + bX)$	0.0015	-0.00002	...	...	28.76^{+}	- 9.01^{+}	...	...	0.07	-0.03	...	...	0.03	0.03	...	...	0.02	0.03	0.6693	1.69
t-maize	$a + bX + cX^2$	623.55	24.07	-0.218	...	11.67^{+}	4.00^{+}	-1.53	...	0.00	0.00	0.00	...	0.00	0.00	0.00	...	0.00	0.00	0.7321	2.14
	$a \cdot X^b$	508.48	0.237	...	...	12.89^{+}	9.46^{+}	...	...	0.12	0.08	...	...	0.17	0.15	...	...	0.04	0.50	0.7425	2.20
t-barley	$a \cdot b^X$	690.59	1.018	...	...	28.89^{+}	788.80^{+}	...	...	0.04	0.02	...	...	0.03	0.01	...	...	0.02	0.11	0.8291	1.85
	$1/(a + bX)$	0.0014	-0.00002	...	...	38.71^{+}	-14.18^{+}	...	...	0.05	-0.02	...	...	0.02	0.02	...	...	0.02	0.03	0.8512	2.11
Andhra Pradesh (AP)																					
t-rice	$a \cdot b^X$	1021.00	1.023	...	0.420	18.30^{+}	348.34^{+}	...	2.36^{++}	0.34	0.06	...	0.01	0.03	0.01	...	-0.12	0.02	0.13	0.8753	...
	$1/(a + bX)$	0.0009	-0.00001	...	0.455	16.90^{+}	- 5.55^{+}	...	2.23^{++}	0.54	-0.36	...	-0.05	0.02	0.03	...	-0.09	0.02	0.04	0.8727	...
k-rice	$1/(a + bX)$	0.0008	-0.00001	...	...	27.08^{+}	- 7.94^{+}	...	...	0.07	-0.36	...	...	0.03	0.03	...	...	0.02	0.04	0.7400	1.87
r-rice	$a \cdot b^X$	1322.30	1.024	...	...	13.35^{+}	206.76^{+}	...	...	0.10	0.05	...	...	0.14	0.01	...	...	0.04	0.23	0.5236	1.95
	$1/(a + bX)$	0.0007	-0.00001	...	...	16.15^{+}	- 4.79^{+}	...	...	0.12	-0.05	...	...	0.10	0.10	...	...	0.04	0.06	0.5320	1.98
i-rice	$a \cdot b^X$	1107.47	1.025	...	0.520	10.25^{+}	224.33^{+}	...	3.12^{+}	0.89	0.04	...	-0.01	0.05	0.01	...	-0.10	0.03	0.17	0.8293	...
	$1/(a + bX)$	0.0008	-0.00001	...	0.488	13.89^{+}	- 5.15^{+}	...	2.68^{++}	0.69	-0.46	...	-0.02	0.03	0.03	...	-0.08	0.03	0.04	0.8327	...
t-jowar	$a + bX + cX^2$	520.08	- 10.61	0.520	...	13.81^{+}	- 1.89	2.95^{+}	...	0.00	0.00	0.00	...	0.00	0.00	0.00	...	0.00	0.00	0.4374	1.85
i-ragi	$a \cdot b^X$	962.27	1.017	...	...	17.88^{+}	355.15^{+}	...	...	0.07	0.03	...	...	0.08	0.01	...	...	0.03	0.16	0.5465	1.93
t-maize	$a + bX$	503.65	43.42	...	...	5.11^{+}	7.82^{+}	...	...	0.00	0.00	...	...	0.00	0.00	...	...	0.00	0.00	0.6745	1.87

Notes: Significance at 1% and 5% are indicated by + and ++ respectively. Y is the yield. X is the time variable.

Rho(ρ) is the autocorrelation parameter. IN : intrinsic nonlinearity; PE : parametric effects nonlinearity; D-W : Durbin-Watson statistic.

crop cases at the AI level show a continuous rising trend in their yields. Among the 7 AP crop cases all except t-jowar(AP) show a continuous rising trend. t-jowar(AP) shows a fall in yields initially, reached a minimum in 1964-65 and started showing a rising trend later on.

Trend growth rates estimated for the 16 crop cases are given in table 6.8 where the 11 crop cases that showed no growth rate at all are also pointed out. This table reports the constant growth rates for those crop cases for which the semi-log function (f.f.3) was chosen. For the rest, variable growth rates estimated at the last year of the sample period is reported. The growth rates at the sample mean was not computed as the sample mean is changing over time. The algebraic expressions for growth rates for the underlying f.f. for each of the crop cases have been reported earlier in table 6.1.

All India (AI):

Total cases (11): (6 growth + 1 no growth =) 7 annual aggregates
+ (3 growth + 1 no growth =) 4 seasonals.

Annual Aggregate crop yields: At the AI level, of the 7 aggregate crop yields, t-bajra(AI) does not show any trend while the remaining 6 aggregate crop yields (t-rice(AI), t-wheat(AI), t-jowar(AI), t-ragi(AI), t-maize(AI) and t-barley(AI)) show a continuous rising trend over the period 1949-50 to 1988-89. The constant rate of growth obtained from the estimates of f.f.3 show that t-wheat(AI) yields grew fastest at 3.34% followed by t-rice(AI) at 1.77%. The other crops showed a slower growth in yield; t-jowar(AI): 1.59%, t-ragi(AI): 1.39% and t-barley(AI): 1.69%. In the case of t-maize(AI) only a variable growth rate could be estimated. Growth rate in 1988-89 estimated by f.f.6 is 0.58% (see table 6.8).

These results point out that yields of the two superior cereals rice and wheat experienced higher growth rates over time than the inferior cereals' yields. Thus, a real breakthrough in the growth rates is yet to take place in the case of the latter crops which are supposed to be dry crops. The case of bajra which has not shown any growth despite the spread of HYV seeds up to 50%

Table 6.8 - Estimated Growth Rates (%).

Crop	All India	Andhra Pradesh
t-Rice	1.77	2.27
k-Rice	1.91	3.49*5
r-Rice	1.85*1	2.43
i-Rice	----	2.47
t-Wheat	3.34	----
t-Jowar	1.59	3.15*2
k-Jowar	1.92*1	0.00N
r-Jowar	0.00N	0.00N
u-Jowar	----	0.00N
t-Bajra	0.00N	0.00N
i-Bajra	----	0.00N
u-Bajra	----	0.00N
t-Ragi	1.39	0.00N
i-Ragi	----	1.69
u-Ragi	----	0.00N
t-Maize	0.58*6	3.14*1
u-Maize	----	0.00N
t-Barley	1.69	----

Notes: Constant growth rates from f.f.3 are reported whenever the undelying f.f. is a semi-log time trend.
Variable growth rates are indicated by a * followed by a number corresponding to the f.f.; For eg., *1 indicates estimated from function form 1 and so on. The variable growth rates correspond to the last year of the sample period, 1988-89 for All India and 1984-85 for Andhra Pradesh.
N : indicates no growth (poor fit cases).
---- : These cases not analysed due to lack of data.

(see chapter 2, table 2.13) is particularly disappointing. The results also point out that wheat yields grew almost at twice the rate of growth in rice yields.

Seasonal crop yields: Of the 4 seasonal crops at the AI level, r-jowar(AI) does not show any trend as mentioned earlier. The remaining 3 seasonal crops, k-rice(AI), r-rice(AI) and k-jowar(AI), show a continuous trend over the period 1962-63 to 1988-89. Thus the growth observed earlier in the yields of t-rice(AI) comes from both the kharif and rabi crops, whereas in the case of jowar, the growth observed in the yields of t-jowar(AI) comes mainly from the kharif crop, which in 1988-89 accounted for about 70% of the aggregate jowar output. For k-rice(AI) the constant rate of growth computed from f.f.3 was 1.91%. For r-rice(AI) and k-jowar(AI) the variable growth rates computed from f.f.1 (linear trend - same for both of them, see table 6.6) in the last year of the sample period, 1988-89, are 1.85% and 1.92%, respectively.

Note that most of the rainfall in India takes place in the kharif season covering June to October. Thus, it implies that irrigation becomes essential in the rabi season to meet the water requirement necessary for crop growth. According to table 2.11 in chapter 2, rabi yields are in general higher than kharif yields in the case of rice whereas reverse is true in the case of jowar. This further points out the necessity for developing yet a satisfactory dry crop technology particularly suitable for the rabi season.

Andhra Pradesh (AP):

Total cases (16): (3 growth + 2 no growth =) 5 annual aggregates
+ (2 growth + 2 no growth =) 4 seasonals
+ (2 growth + 5 no growth =) 7 water regimes.

At the AP State level, rice (total-, kharif-, rabi- & irrigated-) yields show a continuous rising trend over the period of estimation. Thus, it can be said that rice yields in AP is witnessing an all round growth. The constant (f.f.3) growth rates for t-rice(AP), r-rice(AP) and i-rice(AP) are 2.27%, 2.43% and 2.47% over the whole period, respectively. In the case of k-rice(AP) the variable growth rate, in 1984-85, obtained from f.f.5 was 3.49%. The i-rice(AP) yields shows a slightly higher growth than the yields of the total crop. Rice in AP is mainly an irrigated crop with about 95% of the crop acreage under irrigation. The total crop includes both irrigated and unirrigated rice and to that extent the higher growth rate obtained for i-rice(AP) vis a vis that for t-rice(AP) seems tenable.

Yields of t-jowar(AP) also show a trend. In this case, yields fell initially, reached a minimum in 1964-65 and started showing a rising trend later on. The variable growth rate from f.f.2 in 1984-85 is 3.15%. This result for the total crop is, however, not supported by the results for k-jowar(AP) and r-jowar(AP) both of which do not show any trend. Nor does u-jowar(AP) yields show any trend. Jowar in AP being mainly an unirrigated crop, yields of which do not show any trend, the observed growth in the yields of the total crop must have come from the irrigated component, (less than 1% of the total area) whatever little it may be. Note also that the spread of the HYV is also less than 30% for this crop. In any case, the fit observed in the time trend of t-jowar(AP) yields is only 0.43 (see table 6.7).

Bajra yields in AP (total-, irrigated- and unirrigated-) do not show any trend at all. Thus bajra in AP is an extremely bad case with yields stagnant in both irrigated (12% of the total acreage) and unirrigated conditions despite the fact that the spread of HYV is nearly 80% of the total acreage under this crop.

In the case of ragi, yields of the total crop as also the estimated unirrigated yields do not show any trend. Yields of i-ragi(AP), however, show a continuous rising trend. The constant rate of growth for i-ragi(AP) is 1.69%. Ragi being a moderately irrigated crop in AP (in 1984-85, about 33% of ragi is grown under irrigation) the low growth rate observed in the irrigated yields has not had any effect on the yields of the total crop. There is no HYV adoption here.

Yields of t-maize(AP) have shown a continuous rising trend over the period of estimation. The variable growth rate from f.f.1 (linear trend) in 1984-85 was 3.14%. Maize in AP is a low to moderately irrigated crop. In 1984-85, only a fifth of maize cultivation was irrigated while about 4/5th of maize was grown under unirrigated condition. Yields of u-maize(AP) do not show any trend and thus it seems that the growth observed in the case of the total crop must be due to growth in the irrigated crop. Nearly 65% of the crop acreage is under HYV. If one were to assume that all irrigated maize is under HYV then the results indicate the combination of HYV and irrigation is more growth promoting in the case of maize yields than in the case of bajra yields.

6.3.3 Variability.

Proceeding further with the analysis for the growth cases, (cases with a trend) additive and multiplicative errors as obtained from the estimations corresponding to the chosen f.f. reported in table 6.7 were taken into account separately. For the no growth cases, variability is assessed against the sample mean as already explained in section 6.2. The results of the Hsu tests are presented in table 6.9. The significance of these test statistics are judged at 5% level. A summary of the results on variability change are given in table 6.10.

All India (AI): From table 6.10 it can be seen that, out of the eleven crop cases at the AI level, only one crop case, t-maize(AI) (growth case), shows increased absolute variability in its yields; i.e., the absolute fluctuations of the realized yield around the expected trend levels have increased over time. The estimated variance change point in the fluctuations is 1969-70. Note that the variance change occurred a few years after the introduction of the new HYV - fertilizer based technology. t-maize(AI) yields being a growth case, the implication of the variability result is that fluctuations have increased over time around a rising mean level. From the figure for t-maize(AI) yields in chapter 1 it can be seen that from around 1969-70 t-maize(AI) yields indeed began

Table 6.9 - Results of Hsu Tests for Variability Change Over Time.

Crop	Function Form	Absolute Variability T-test	Absolute Variability G-test	Relative Variability T-test	Relative Variability G-test
t-Rice(AI)	3	0.9422	0.6902	-0.5465	0.3384
	5	0.4762	0.5916	-1.1164	0.2257
k-Rice(AI)	3	0.5064	0.6242	-0.5194	0.3982
r-Rice(AI)	1	-1.5112	0.3132	-2.7887	0.1650
t-Wheat(AI)	3	0.5912	0.5879	-1.7111	0.1798
	5	1.2902	0.8205	-1.0572	0.2964
t-Jowar(AI)	3	1.2560	0.7899	-0.1876	0.4685
	5	1.3008	0.7844	-0.1997	0.4607
k-Jowar(AI)	1	1.1539	0.7240	-0.3835	0.4247
r-Jowar(AI)#	-	-0.5653	0.4197	-0.8018	0.3958
t-Bajra(AI)#	-	1.0910	0.6719	0.4059	0.5418
t-Ragi(AI)	3	0.6383	0.6217	-0.5120	0.3915
	5	0.8259	0.6699	-0.4001	0.4158
t-Maize(AI)	2	2.7099^{+}	0.9298^{+} ↑(1970)	1.0919	0.7254
	6	2.7181^{+}	0.9087^{++} ↑(1970)	0.8186	0.6526
t-Barley(AI)	3	0.9323	0.7142	-0.2628	0.4357
	5	0.8820	0.6764	-0.1693	0.4395
t-Rice(AP)	3	1.4529	0.8002	0.5953	0.6296
	5	1.8594	0.8696	1.1817	0.7644
k-Rice(AP)	5	1.0032	0.7251	0.3279	0.5724
r-Rice(AP)	3	-3.5070^{+}	0.1258^{++} ↓(1971)	-3.4285^{+}	0.1167^{++} ↓(1971)
	5	-3.4310^{+}	0.1102^{++} ↓(1971)	-3.5227^{+}	0.1160^{++} ↓(1971)
i-Rice(AP)	3	0.5361	0.6034	-0.0001	0.4804
	5	0.9727	0.7065	0.0606	0.5087
t-Jowar(AP)	2	0.8177	0.6510	0.1530	0.4983
k-Jowar(AP)#	-	-0.8519	0.2866	-0.8623	0.2797
r-Jowar(AP)#	-	-0.2784	0.4443	-0.7389	0.3514
u-Jowar(AP)#	-	1.6559	0.7708	1.3387	0.7317
t-Bajra(AP)#	-	2.9641^{+}	0.9156^{+} ↑(1971)	2.5906^{+}	0.9026^{++} ↑(1968)
u-Bajra(AP)#	-	2.0558^{++}	0.8499 ↑(1971)	1.4311	0.7743
i-Bajra(AP)#	-	-1.0973	0.3190	-0.2915	0.4458
t-Ragi(AP)#	-	0.0077	0.4641	-0.2524	0.4060
u-Ragi(AP)#	-	-2.2770	0.0646 ↓(1962)	-2.4833^{+}	0.0484^{+} ↓(1962)
i-Ragi(AP)	3	-2.2349^{+}	0.1160^{++} ↓(1969)	-2.4719^{+}	0.0854^{+} ↓(1969)
t-Maize(AP)	1	3.1654^{+}	0.9754^{+} ↑(1974)	0.9896	0.7480
u-Maize(AP)#	-	1.5399	0.7707	0.8459	0.6670

Notes: +/++ : indicates significance at 1% and 5% level, respectively. See chapter 5, appendix 5A.1 for critical values;
↑(↓) indicates an increase (decrease) in variance. # No growth cases. Figures in brackets are the variability change point.

Table 6.10 - Hsu Tests Results for Variability Change Over Time.

	Changes in Absolute Variability		Changes in Relative Variability	
	Present	Not Present	Present	Not Present
All India	t-mze↑(1970)	t-rce k-rce r-rce t-jwr k-jwr r-jwr# t-wht t-bjr# t-rgi t-brl	---	t-rce k-rce r-rce t-jwr k-jwr r-jwr# t-wht t-bjr# t-rgi t-mze t-brl
Andhra Pradesh	r-rce↓(1971) t-bjr↑(1971)# u-bjr↑(1971)# u-rgi↓(1962)# i-rgi↓(1968) t-mze↑(1974)	t-rce k-rce i-rce t-jwr k-jwr# r-jwr# u-jwr# i-bjr# t-rgi# u-mze#	r-rce↓(1971) t-bjr↑(1968)# u-rgi↓(1962) i-rgi↓(1968)	t-rce k-rce i-rce t-jwr k-jwr# r-jwr# u-jwr# u-bjr# i-bjr# t-rgi# t-mze u-mze#
Total (27)	7	20	4	23

Notes: Variability change point year is shown in brackets.

↑(↓) Indicates an increase (decrease) in variance. # No growth cases.

t- / k- / r- / i- / u- before a crop name indicates the yields correspond to the aggregate annual- / kharif- / rabi- / irrigated- / un-irrigated- crop, respectively.

AI or AP in brackets after the crop indicates an all India level or Andhra Pradesh State level crop, respectively.

Crops: rce - rice; wht - wheat; jwr - jowar; bjr - bajra; rgi - ragi; mze - maize; brl - barley;

to show larger fluctuations compared to the earlier period where these fluctuations were almost negligible. However, if one were to consider not absolute but relative variability (i.e., realized yields as a percentage of the rising mean (expected) yield level), the results show that there has been no change in the relative variability of t-maize(AI) yields.

The remaining 10 crop cases (6 total crops and 4 seasonal crops of rice, wheat, jowar, bajra, ragi and barley) do not show any change in variability, both absolute and relative. Notably, t-rice(AI) and t-wheat(AI), which benefited most from the new technology do not show any variability change. Further, the seasonal crops too did not show any change. This result implies that the observed fluctuations in the yields of these crops have been uniform around their trend values over time. In the case of yields of rice(AI) (total-, kharif- and rabi-), t-wheat(AI), jowar(AI) (total- and kharif-), t-ragi(AI) and t-barley(AI), - all of which showed significant growth over time - these fluctuations have been uniform around a growing mean level as can be seen from the figures of crop yields in chapter 1. In the case of yields of r-jowar(AI) and t-bajra(AI), - which showed no growth over time - the fluctuations have been uniform around a stagnant mean level. Thus it may be summed up that except in the case of maize, variability changes, if any, over time in cereal crop yields are not significant enough to be deemed as a serious problem at the AI level.

An important point has to be noted here. As stated in chapter 5, the above results on variability refer only to significant or insignificant <u>changes</u> in the order (amplitude/size) of fluctuations over time but not to the order itself. For example, despite that t-maize(AI) yields show variability change over time, it is still possible that the order of its fluctuations is lower than the order of fluctuations in the case of yields t-ragi(AI), t-barley(AI), etc., which do not show any variability change over time.

Andhra Pradesh (AP): At the AP State level, from table 6.10 it can be seen that, among the 5 aggregate crop yields only t-bajra(AP) (no growth case) and t-maize(AP) (growth case) show increased absolute variability over time. Yield variability has increased from 1970-71 onwards in the case of t-bajra(AP) and from 1973-74 in the case of t-maize(AP). Of these 2 crop cases only t-bajra(AP) showed increased relative variability and the increase is from 1967-68. It may be noted here that, both these crops are mainly HYV seeds based and are grown under unirrigated conditions. In 1984-85, 78% of bajra cultivation and 63% of maize cultivation were under HYV, whereas only 12% and 20% of the respective crop acreages were under irrigation.

The remaining 3 total crops, t-rice(AP), t-jowar(AP) (both of them growth cases) and t-ragi(AP) (no growth case) show neither absolute nor relative variability change. Of these 3 crops, rice is mainly HYV based with irrigation, while both jowar and ragi are traditional seeds based with very little to moderate irrigation. In 1984-85, the percentage of crop acreage under HYV was 80%, 28% and 0% in the case of rice, jowar and ragi, respectively; whereas irrigation proportion was 95%, 1% and 33%, respectively. As far as variability over time is concerned the AP results on aggregate crop yields suggest a pattern as follows:

Crops	Growth	Seeds	Irrigation	Variability over time Absolute	Relative
Rice	Yes	HYV	Yes	No	No
Jowar	Yes	Traditional	No	No	No
Bajra	No	HYV	No	Yes	Yes
Ragi	No	Traditional	Partly	No	No
Maize	Yes	HYV	No	Yes	No

The above pattern implies

(a) Growth has no effect on variability change;

(b) Crop yields under traditional technology with or without irrigation and under modern technology with irrigation do not show changing variability; and

(c) Only crop yields under modern technology not supported by irrigation may show variability change over time.

Such a pattern was not easily discernible at the AI level earlier perhaps due to too much aggregation over different States. In any case, even the State level results obtained here can be different from the results (to be obtained in the next chapter) at the districts level. Thus these results may need further confirmation.

Turning to the 4 AP seasonal crops, from table 6.10 it can be seen that the result of no variability change (noted above) for t-jowar(AP) is supported by both k-jowar(AP) and r-jowar(AP) both of which are no growth cases and do not show any changing variability, absolute or relative. In the case of rice only k-rice(AP) (growth case) is free of changing variability of both types. R-rice(AP) (growth case) shows, however, a decrease both in absolute and relative variability from 1970-71 onwards. This would imply that year to year fluctuations around the growing mean yield levels of r-rice(AP) are in fact narrowing down. It may be pointed out here that in Andhra Pradesh also rabi rice yield levels are in general higher than kharif rice yield levels though the difference is not as wide as at the all India level. Secondly, the fact that 95% of total rice acreage is under irrigation indicates that irrigation is used in both the seasons. Thirdly, as stated already, most of rainfall in Andhra occurs in kharif season, which means that the interaction between rainfall and irrigation is more in kharif season than rabi season. The greater control over the water input during rabi season led not only to higher yield levels but also to a reduction in yields' variance around the trend in the case of rice in Andhra Pradesh.

Turning to the 7 estimated irrigated- and unirrigated- crops at the AP State level only 3 show a changing variability. These are u-bajra(AP) (no growth) with respect to only absolute variability, and u-ragi(AP) (no growth) & i-ragi(AP) (growth case) with respect to both absolute and relative variability (see table 6.10). While in the case of u-bajra(AP) absolute variability increased from 1970-71 onwards, in the case of u-ragi(AP) (from 1961-62) and i-ragi(AP) (from 1967-68) both absolute and relative variability decreased. Note that yields of ragi, grown under both irrigated and unirrigated conditions with only traditional seeds, shows a fall in variability. Assuming that all irrigated bajra is grown with HYV seeds, the unirrigated bajra yields grown with HYV seeds accounting for more than 65% (78% (total HYV) - 12% (under irrigation)) of its total acreage shows an increase in absolute variability. The remaining 4 estimated yields, i-rice(AP) (growth case), u-jowar(AP), i-bajra(AP) and u-maize(AP) (all 3 of them no growth cases), do not show any change in variability, both absolute and relative.

It may be noted that for the 4 crop cases of AP which showed changes in both absolute and relative variabilities, for 3 cases the estimated change points under absolute as well as relative variabilities turned out to be same; 1971 for r-rice(AP), 1962 for u-ragi(AP) and 1968 for i-ragi(AP). Note that the variability change point for u-ragi(AP) was well before the modern technology arrived in India. In the case of t-bajra(AP), however, the change points were 1971 and 1968 for absolute and relative variabilities, respectively.

Finally it may be noted that all the cases which showed a change in relative variability did show a change in absolute variability also; but the reverse is not true. This applies to both AI and AP crop cases.

6.3.4 Structural Change.

The structural change analysis in the sense of assessing changes if any in the parametric values of the growth path was carried out exactly in a similar way (scanning procedure with dummy variables incorporated into the chosen f.f., as described earlier in section 6.2 for the yields of t-wheat(AI)). This methodology, as mentioned in section 6.2, is valid only under the assumption of constant error variance (homoskedasticity); i.e., no changing variability. The structural change analysis is, therefore, carried out only for those crop cases showing trend but not changing variability (both absolute and relative). This analysis was thus confined to only 8 crop cases. These consist of 7 aggregate crop yields t-rice(AI), t-wheat(AI), t-jowar(AI), t-ragi(AI) t-barley(AI), t-rice(AP), and t-jowar(AP), and one water regime crop yield, i-rice(AP), all of which are growth cases not showing any changing variability. The question of structural change for the crop yields that do not show any trend anyway does not arise.

This analysis was not done for the seasonal crops as data for these crops at both AI and AP levels, are available only from 1962-63 implying too few observations pertaining to the pre-green revolution period (i.e., prior to 1965-66). Assessing structural change in yields, which is expected to have occurred due to Green Revolution is, therefore, not possible for the seasonal crops.

Table 6.11 shows the estimation results only for those crop cases showing structural change; i.e., at least one of the dummy variables incorporated turned out significant. A summary of the results from the structural change analysis is given in table 6.12.

The results show that, at the AI level, all the 5 total crops viz. t-rice(AI), t-wheat(AI), t-jowar(AI), t-ragi(AI) and t-barley(AI), for which this analysis was done, show structural change. At the AP State level, only t-jowar(AP) shows a structural change. Notably, t-rice(AP) and i-rice(AP) do no show any structural change. This result for rice in AP is particularly interesting. Over time most of the rice cultivation shifted to modern technology. Thus indeed a structural change occurred technologically. However, the yield increases achieved under new technology are not sufficiently higher to show up as a significant upward break in the trend but only helped in maintaining the pre-vailing trends (for more on this point see Srinivasan (1979)). Hence, the time trend does not reveal any structural change.

There is an interesting point to note here. Recall that we have chosen two f.f. for each of the crop yields of t-wheat(AI), t-ragi(AI), t-rice(AP) and i-rice(AP). While both the f.f.s of t-rice(AP) and i-rice(AP) showed no structural change, both the f.f.s of t-wheat(AI) and t-ragi(AI) showed structural change. Besides, for t-ragi(AI) both the f.f.s showed that a change occur-red in the intercept term only. But, for t-wheat(AI) f.f.3 shows a

Table 6.11 – Estimation Results of Structural Change Analysis*

Crop	Functional Form	Parameters a	b	c	Dummy Variable d	e	f	Rho1	Rho2	Change Point Year	$\bar{R}^2$	D-W
t-rice(AI)	5	0.0014	-0.00003	...	-0.00005	0.00001	...	...	...	1966	0.8776	2.09
		(36.35)$^{+}$	(-7.58)$^{+}$		(-0.60)	(2.61)$^{++}$						
t-wheat(AI)	3	6.503	0.0143	...	-0.0330	0.0149	...	0.0534	0.1738	1967	0.9842	...
		(162.9)$^{+}$	(3.83)$^{+}$		(-0.34)	(3.14)$^{+}$		(0.24)	(0.79)			
	5	0.0015	-0.00002	...	-0.00026	-0.0000005	...	0.0875	0.1661	1967	0.9564	...
		(32.80)$^{+}$	(-4.36)$^{+}$		(-2.36)$^{++}$	(-0.09)		(0.48)	(0.61)			
t-jowar(AI)	3	6.018	0.0114	...	0.8127	-0.0203	...	0.2298	-0.499	1977	0.9329	...
		(108.2)$^{+}$	(3.40)$^{+}$		(3.68)$^{+}$	(-2.83)$^{+}$		(1.24)	(-1.0)			
t-ragi(AI)	3	6.477	0.0153	...	-0.3090	0.0080	...	...	...	1966	0.6846	1.77
		(111.3)$^{+}$	(2.55)$^{++}$		(-2.66)$^{++}$	(1.15)						
	5	0.0015	-0.00002	...	0.00037	-0.0000068	...	...	...	1966	0.8165	1.64
		(19.04)$^{+}$	(-2.57)$^{++}$		(2.28)$^{++}$	(-0.70)						
t-barley(AI)	3	6.662	0.0045	...	-0.1687	0.0145	...	...	...	1965	0.8213	2.22
		(146.7)$^{+}$	(0.91)		(-2.26)$^{++}$	(2.59)						
t-jowar(AP)	2	446.80	15.73	-1.061	-997.30	64.73	-0.3046	...	...	1971	0.5502	2.42
		(8.73)$^{+}$	(1.07)	(-1.19)	(-2.14)$^{++}$	(1.48)	(-0.24)					

Notes: * See table 6.1 for functional form. F.f. 2 was estimated as $Y = a + bX + cX^2 + dD + eXD + fX^2D^2$;
F.f. 3 was estimated as $\text{Log}(Y) = a + bX + dD + eXD$; and f.f. 5 was estimated as $1/Y = a + bX + dD + eXD$;
where Y is yield, X is Time and D is the dummy; a, b and c are the intercept, slope and quadratic coefficients in the regression; d, e and f are the corresponding dummy variable coefficients.
t values are given in brackets. Significance at 1% and 5% are indicated by + and ++ respectively.
Rho1 & Rho2 are the autocorrelation coefficients for the periods before and after the change point year respectively.

Table 6.12 – Analysis of Structural Change and the Change Point.

	Structural Change Occurred		No Structural Change Occurred	
	t-rce(AI 1966)	t-wht(AI 1967)	t-rce(AP)	i-rce(AP)
	t-jwr(AI 1977)	t-rgi(AI 1966)		
	t-brl(AI 1965)	t-jwr(AP 1971)		
Total(8)	6		2	

Notes: 1 The estimated structural change point is shown in brackets.
t- / i- before a crop name indicates the yield correspond to the total- / irrigated- crop, respectively.
AI or AP in brackets after the crop indicates an all India level or Andhra Pradesh State level crop, respectively.

Crops: rce - rice; wht - wheat; jwr - jowar; rgi - ragi; brl - barley;

significant change in the slope coefficient, f.f.5 shows a significant change in the intercept term. It is also interesting to note that both the f.f.s chosen for t-wheat(AI) [t-ragi(AI)], indicate same structural change point year viz., 1966-67 [1965-66]. In fact two f.fs were chosen earlier even for t-rice(AI), t-jowar(AI) & t-barley(AI). However, only one of the chosen f.fs showed structural change in these cases.

The change point years for those cases showing a structural change are given in tables 6.11 and 6.12. The change point year differs from crop to crop. The structural change point in the case of t-rice(AI) was 1965-66; 1966-67 for t-wheat(AI), 1976-77 for t-jowar(AI), 1965-66 for t-ragi(AI), 1964-65 for t-barley(AI) and 1970-71 for t-jowar(AP). Apart from differences in the change point year the nature of the structural change - intercept change or change in the slope or change in both - also varies from crop to crop. The nature of the structural change in these 6 crops are given below:

	Increase in growth rate	Decrease in growth rate	No change in growth rate
Increase in intercept	---	t-jowar(AI)	---
Decrease in intercept	t-barley(AI)	---	t-ragi(AI) t-jowar(AP)
No change in intercept	t-wheat(AI)	t-rice(AI)	t-rice(AP) i-rice(AP)

Of the 6 cases showing a structural change, 2 crops, t-wheat(AI) and t-barley(AI), show an increase in the growth rate in the period after the structural change point year; i.e., the upward/ downward (depending upon the f.f. of the growth curve) change in the slope coefficient represented by the corresponding dummy variable is significant. 2 crops, t-rice(AI) and t-jowar(AI), show a decrease in the growth rate in the period after the structural change point year. 2 crops, t-ragi(AI) and t-jowar(AP), show only a vertical shift downwards in the growth path simultaneously associated with an insignificant increase in the growth rates. That is there is a significant change in their intercepts but not in the growth coefficients.

Though t-ragi(AI) is a non-HYV crop, it still shows structural change in the year 1966 perhaps brought due to either cross impacts between crops or changes in input variables (irrigation, fertilizer, etc.) other than seeds. In the case of t-jowar(AP) though the crop continues to be largely unirrigated the HYV adoption increased from 1.4% in 1966-67 to nearly 30% by 1984-85. The HYV adoption led only to an insignificant increase in the growth rate as the results show for this crop in AP. In contrast, in the case of t-jowar(AI) the yield curve is pushed up but growth rates have fallen down.

For each of the crop cases showing structural change the earlier result (before incorporating dummy variables) of no change in variability is to be reconfirmed (see step 9 under section 6.1). For this purpose, estimated residuals from the regressions involving the dummy variables (reported in table 6.11) were collected and Hsu tests were conducted on these residuals to check for changing variability, if any. The results of these tests are given below:

Crop Case	Functional Form	T-Test	G-Test
t-rice(AI)	5	-1.7872	0.2075
t-wheat(AI)	3	-1.2872	0.2406
	5	-1.7082	0.2868
t-jowar(AI)	3	-1.1273	0.2622
t-ragi(AI)	3	0.3907	0.5840
	5	-0.5589	0.3893
t-barley(AI)	3	0.1628	0.4980
t-jowar(AP)	2	1.7368	0.8322

None of these 6 crop cases show significant change in the variability. Thus, these tests reconfirm the earlier result of no change in variability. That is, the above crop cases, even after accounting for the structural change in their yields, do not show any variability change over time.

A summary of all the results from the analysis in TTF of crop yields at the AI and AP levels is given in table 6.13.

Crop Yield	All India (AI)	Andhra Pradesh (AP)
t-Rice	VNP SCO(1966)	VNP NSC
k-Rice	VNP SCN	VNP SCN
r-Rice	VNP SCN	VP(1971) SCN
i-Rice	---	VNP NSC
t-Wheat	VNP SCO(1967)	---
t-Jowar	VNP SCO(1977)	VNP SCO(1971)
k-Jowar	VNP SCN	NGR VNP
r-Jowar	NGR VNP	NGR VNP
u-Jowar	---	NGR VNP
t-Bajra	NGR VNP	NGR VP(1971)
i-Bajra	---	NGR VNP
u-Bajra	---	NGR VP(1971)
t-Ragi	VNP SCO(1966)	NGR VNP
i-Ragi	---	VP(1962) SCN
u-Ragi	---	NGR VP(1962)
t-Maize	VP(1970) SCA	VP(1974) SCA
u-Maize	---	NGR VNP
t-Barley	VNP SCO(1965)	---

Notes: NGR: No growth (poor fit $\bar{R}^2 < 0.4$) cases;
VNP: Variability change not present;
VP : Variability change present (variability change point in bracket)
NSC: No structural change occurred;
SCO: Structural change occurred (structural change point in bracket);
SCA: Structural change ambiguous (these are the cases that show variability and hence structural change analysis was not done);
SCN: For these cases the structural change analysis was not done due to inadequate number of observations pertaining to the pre-Green Revolution period.

6.4 Conclusions.

In this chapter the nature of growth, variability change, if any, around the trend and structural change in the growth path for cereal crop yields at the all India level and Andhra Pradesh State level were studied.

At the all India level: (1) 6 (rice, wheat, jowar, ragi, maize and barley) of the 7 aggregate crop yields and 3 (kharif-rice, rabi-rice and kharif-jowar) of the 4 seasonal crop yields show growth over time; (2) only for one crop yield - aggregate maize - growth is accompanied by an increase in absolute, but not relative, variability; (3) 5 aggregate crop yields (rice, wheat, jowar, ragi and barley) showing growth also show structural changes in their growth paths. (4) 2 crop yields - aggregate bajra and rabi-jowar - show neither any growth (positive/negative) over time nor any variability change around their stagnant yield levels.

The results indicate that amongst superior cereals wheat yields grew at almost twice the rate of growth in rice yields. The growth rates of yields of the rain dependent inferior cereals are far lower than those of the superior cereals. The necessity of developing yet a satisfactory dry crop technology is further confirmed by the analysis of seasonal crop yields also.

At the Andhra Pradesh State level: (1) 7 (t-rice(AP), k-rice(AP), r-rice(AP), i-rice(AP), t-jowar(AP), t-maize(AP) and u-ragi(AP)) of the 16 crop yields studied show trend over time; (2) in the case of t-maize(AP) yields growth was accompanied by an increase in absolute but not relative variability, and (3) in the case of r-rice(AP) and i-ragi(AP) the growth over time was accompanied by a fall in both absolute and relative variability. (4) The yields of only t-jowar(AP) shows structural change in the growth path. (5) 9 crop yields (t-bajra(AP), u-bajra(AP), i-bajra(AP), t-ragi(AP), u-ragi(AP), k-jowar(AP), r-jowar(AP), u-jowar(AP) and u-maize(AP)) do not show any growth over time; (6) in 2 of these cases, (yields of t-bajra(AP) and u-bajra(AP)) there was a rise in absolute variability (and relative variability also in the case of t-bajra(AP)) around the stagnant yields, and (7) in the case of yield of u-ragi(AP) there is a fall in both absolute and relative variability around the stagnant yields.

As far as growth and variability are concerned, the results for AP show the following pattern:

(a) Growth has no effect on variability change;

(b) Crop yields under traditional technology with or without irrigation and under modern technology with irrigation do not show variability change as shown by ragi(AP) yields; and

(c) Only crop yields under modern technology not supported by irrigation show variability change over time as shown by bajra and maize yields.

Such a pattern is not easily discernible at AI level perhaps due to too much aggregation over different States.

The comparison of the rice yield performance between kharif and rabi seasons suggests that greater control over the water input during rabi season led not only to higher yield levels but also to a reduction in yields' variance around the trend.

As mentioned earlier, in this chapter, the growth characteristics of cereal crop yields were studied in the time domain at the all India and Andhra Pradesh State levels. In the next chapter the similar analysis is carried out for the cereal crop yields at the districts level for the 18 districts of Andhra Pradesh.

CHAPTER 7 – ANALYSIS IN TIME TREND FRAMEWORK: DISTRICTS OF ANDHRA PRADESH

"There is nothing permanent except change!"
– Heraclitus.

7.1 Introduction.

Agro-climatic and economic conditions which affect crop yields usually vary considerably across large geographical areas, such as India as a whole or even for a large State like Andhra Pradesh. On the other hand, districts being much smaller geographical units, the cropping and economic environment may not vary considerably *within* a district (though they vary considerably across districts). Thus, problems arising due to aggregation within the districts may not be serious. Besides, districts are the smallest levels at which data are available. Hence in this chapter the analysis for growth, structural change and variability of crop yields over time at the districts level is conducted. The steps involved in the analysis here are the same as that followed in the analysis of crop yields at the all India and Andhra Pradesh State level in the previous chapter.

All 5 cereal crops (rice, jowar, bajra, ragi and maize) in each of the 18 districts of Andhra Pradesh (AP), i.e., total 90 crop cases, are to be considered for analysis here. These 90 crop cases pertain to annual aggregate (over kharif and rabi seasons as well as irrigated & unirrigated[1]) crop yields. Districtwise data on the aggregate crop yields for these cases were taken from the Season and Crop Reports for A.P, published by the Ministry of Agriculture, Government of A.P. The data covers the period 1955-56 to 1984-85 (30 years). Kharif and rabi seasonal crop yields are

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1 However later on, separate analysis for irrigated and unirrigated yields will be attempted to the extent possible. More details on this follow at a later stage.

not studied here as these data are not available for all these 30 years. They are available only for 18 years from 1967-68 onwards.

Notation: In the rest of this chapter the districts are referred to by 2 letter codes, as follows:

Coastal Andhra

1) SV : Srikakulam + Vizianagaram + Vishakhapatnam.
2) EG : East Godavari.
3) WG : West Godavari.
4) KR : Krishna.
5) GN : Guntur + Prakasam + Nellore.

Rayalaseema

6) KU : Kurnool.
7) AN : Anantapur.
8) CU : Cuddapah.
9) CH : Chittoor.

Telangana

10) RH : Ranga Reddy + Hyderabad.
11) NZ : Nizamabad.
12) ME : Medak.
13) MB : Mehboobnagar.
14) NA : Nalgonda.
15) WA : Warangal.
16) KH : Khammam.
17) KM : Karimnagar.
18) AD : Adilabad.

A crop case is denoted by the name of the crop followed by the 2 letter code for the district in bracket. For example, rice(KR) denotes aggregate annual yields of rice in Krishna, and so on.

Crop-cases studied: Out of the 90 crop cases 38 crop cases were dropped from the analysis as these crops were found to be relatively less important within the respective districts. The share of a crop in the total-cereals production in the district was used to determine whether or not that crop is an important crop within that district. If the share of the crop is less than 3% of the total-cereals production in a district (see chapter 3, table 3.6) the crop was deemed unimportant in that district and was dropped from the analysis. Thus out of the total 90 crop cases only 52 crop cases are analysed here. *Table 7.1 gives the details of the* crop cases included/ dropped in this analysis.

Amongst the crops, rice is an important crop in all the 18 districts. Hence it was included for all the 18 districts. Thus the entire rice production in Andhra Pradesh is covered here. Jowar is found to be unimportant in 4 districts - SV, EG, WG and KR. In the remaining 14 districts jowar is an important crop. In 1984-85, these 14 districts account for about 95% of the State's jowar production. Bajra is found to be important only in 7 districts, namely, SV, GN, AN, CU, CH, MB and NA. These 7 districts together account for 90% of the State's bajra production in 1984-85. Ragi is an important crop in only 7 districts, namely, SV, GN, AN, CU, CH, RH and MB. These 7 districts account for about 97% of the State's ragi production in 1984-85. Maize too, like bajra and ragi, is an important crop only in a few districts. 6 districts - RH, NZ, ME, WA, KM and AD - account for about 95% of the State's maize production in 1984-85. Only these important crop cases (total 52) are included in the analysis.

Thus, the 52 crop cases *included in* this analysis cover a major portion of the State's production of the 5 crops being studied. The results of the analysis for growth, variability and structural change of the yields of these 52 crop cases are discussed below.

Methodology: As mentioned earlier, the analysis is carried out exactly in the same way as it was done at the all India and AP State level discussed in the previous chapter. The estimation results of only the finally chosen f.f will be presented here.

7.2 Functional Forms.

First, the 7 specifications for the growth curve (see table 6.1 of chapter 6), both in the additive error form (AEF) and

Table 7.1 - List of Crop Cases Included / Dropped from the Analysis.

District	Crop Cases Included in the Analysis	Crop Cases Dropped from the Analysis[$]
SV	rice(SV) bajra(SV) ragi(SV)	jowar(SV) maize(SV)
EG	rice(EG)	jowar(EG) bajra(EG) ragi (EG) maize(EG)
WG	rice(WG)	jowar(WG) bajra(WG) ragi (WG) maize(WG)
KR	rice(KR)	jowar(KR) bajra(KR) ragi (KR) maize(KR)
GN	rice(GN) jowar(GN) bajra(GN) ragi (GN)	maize(GN)
KU	rice(KU) jowar(KU)	bajra(KU) ragi (KU) maize(KU)
AN	rice(AN) jowar(AN) bajra(AN) ragi (AN)	maize(AN)
CU	rice(CU) jowar(CU) bajra(CU) ragi (CU)	maize(CU)
CH	rice(CH) jowar(CH) bajra(CH) ragi (CH)	maize(CH)
RH	rice(RH) jowar(RH) ragi (RH) maize(RH)	bajra(RH)
NZ	rice(NZ) jowar(NZ) maize(NZ)	bajra(NZ) ragi (NZ)
ME	rice(ME) jowar(ME) maize(ME)	bajra(ME) ragi (ME)
MB	rice(MB) jowar(MB) bajra(MB) ragi (MB)	maize(MB)
NA	rice(NA) jowar(NA) bajra(NA)	ragi (NA) maize(NA)
WA	rice(WA) jowar(WA) maize(WA)	bajra(WA) ragi (WA)
KH	rice(KH) jowar(KH)	bajra(KH) ragi (KH) maize(KH)
KM	rice(KM) jowar(KM) maize(KM)	bajra(KM) ragi (KM)
AD	rice(AD) jowar(AD) maize(AD)	bajra(AD) ragi (AD)
Total(90)	52	38

Notes: $: A Crop is dropped from the analysis if its share is less than 3% of total cereal production in that district.

Codes: *SV : Srikakulam + Vizianagaram + Vishakhapatnam;* EG : East Godavari; WG : West Godavari; KR : Krishna; GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

multiplicative error forms (MEF) (total 14 regressions) were estimated for each of the 52 crop cases. The estimation was carried out for the period 1955-56 to 1984-85. For 23 crop cases, none of the 14 estimations had a good fit thus indicating no trend in their yield. The list of these poor fit crop cases is given in table 7.2. The remaining 29 out of the 52 crop cases show a trend revealing some growth over time in their yields, as indicated by reasonably good fits in terms of $R^2/\bar{R}^2$.

For these 29 growth cases, from among the 7 f.f.s (14 estimations), an appropriate f.f. satisfying all the selection criteria described in chapter 5 was chosen. However, in many cases (20 out of the 29 growth cases) an unique choice of f.f. could not be made as two f.f.s performed equally well, in the sense, both the f.f.s have almost same levels of $\bar{R}^2$ and simultaneously satisfy all other econometric tests like IN, PE, etc. That is, for both these best fitting f.f.s the nonlinearity measures, IN and PE, are insignificant, the skewness measure of Hougaard (SK) for each of the parameters is less than the cut off value of 1.0, the percentage bias measure of Box (BB) for each of the parameters is less than the cut off value of 1.0%, and the parameter estimates obtained under the AEF are close to the estimates obtained under the MEF. Hence both such f.f.s are chosen as appropriate for each of these 20 growth crop cases. Only for the remaining 9 out of the 29 growth cases a clear single specification satisfied all the criteria and had the highest fit. Hence for these 9 crop cases only a single f.f. was chosen as appropriate. The details of the number of specifications chosen for each of the 29 growth cases are also given in table 7.2. Thus in all, for the 29 growth cases 49 specifications ($20 \times 2 + 9 \times 1 = 49$) were finally chosen. Details of the f.f. finally chosen are given in table 7.3.

Amongst the 7 f.f.s for the growth curve, f.f. 3 (semi-log) and f.f. 5 (reciprocal) were chosen 15 times each. The two f.f. amongst themselves cover 21 out of the 29 growth cases. The f.f. 1 (linear), f.f. 2 (quadratic) and f.f. 4 were chosen 13 times, 4 times and 2 times, respectively. These cover the remaining 8 out of the 29 growth cases. The double logarithmic curve (f.f. 6) and

Table 7.2 - Total Number of Chosen Functional Forms (f.f.) for Crop Yields: Districts of Andhra Pradesh.

Good Fit Cases* (29)					Poor Fit Cases* (23)		
With 1 f.f Selected		With 2 f.f.s Selected					
rice (EG)	rice (KR)	bajra(SV)	rice (WG)	rice (GN)	rice (SV)	ragi (SV)	jowar(GN)
jowar(AN)	jowar(CU)	ragi (GN)	rice (KU)	jowar(KU)	bajra(GN)	bajra(AN)	jowar(CH)
bajra(CU)	rice (RH)	rice (AN)	ragi (AN)	rice (CU)	bajra(CH)	ragi (CH)	jowar(RH)
maize(NZ)	rice (WA)	ragi (CU)	rice (CH)	rice (NZ)	ragi (RH)	maize(RH)	jowar(NZ)
maize(WA)		rice (ME)	rice (MB)	rice (NA)	jowar(ME)	maize(ME)	jowar(MB)
		rice (KH)	rice (KM)	maize(KM)	bajra(MB)	ragi (MB)	jowar(NA)
		rice (AD)	maize(AD)		bajra(NA)	jowar(WA)	jowar(KH)
Total (49) 9 * 1 = 9			20 * 2 = 40				

Notes: * : Poor fit cases are those for which none of the f.f. showed $R^2 \geq 0.4$.

For each good fit ($R^2 \geq 0.4$) case several f.f.s have been estimated and the best one or the best two models have been selected. Thus the total 49 regressions correspond to the 29 good fit cases. For details on these models see table 7.3.

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna; GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

Table 7.3 – Cropwise Estimated and Chosen Functional Form for Crop Yields: Districts of Andhra Pradesh.

Functional Form (f.f.)	SV	EG	WG	KR	GN	KU	AN	CU	CH	RH	NZ	ME	MB	NA	WA	KH	KM	AD
1) $Y_t = a + b*TIME_t$							RCE RGI$			RCE	RCE MZE	RCE	RCE$		RCE$ MZE$	RCE	RCE$ MZE	MZE
2) $Y_t = a + b*TIME_t + c*TIME_t^2$		RCE$			RCE	JWR	JWR											
3) $Y_t = a*b^{TIME_t}$	BJR		RCE	RCE$	RGI$	RCE	RCE RGI$	RCE RGI$	RCE		RCE		RCE$	RCE$			RCE$	RCE$
4) $Y_t = Exp(a + b*TIME_t + c*TIME_t^2)$					RCE	JWR												
5) $Y_t = \frac{1}{a + b*TIME_t}$	BJR		RCE		RGI$	RCE		RCE JWR BJR RGI$	RCE			RCE		RCE$		RCE	MZE	RCE$ MZE
6) $Y_t = a*TIME_t^b$																		
7) $Y_t = a*b^{c^{TIME_t}}$																		
Total (49)	2	1	2	1	4	4	5	6	2	1	3	2	2	2	2	2	4	4

Notes: $: For these crop cases a first-order auto regressive scheme is imposed to correct for autocorrelation.

Crops RCE : Rice; JWR : Jowar; BJR : Bajra; RGI : Ragi; MZE : Maize;

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari;
KR : Krishna; GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah;
CH : Chittoor; RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar;
NA : Nalgonda; WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

the Gompertz curve (f.f. 7) could not be chosen for any of the crop cases. The double logarithmic trend was generally found to have a lower fit than the other curves, and in some cases with a high parametric effects nonlinearity (PE). The Gompertz curve, though usually fitted the data quite well, it however, was found to have a high PE. These 2 f.f. could hence not be chosen for any of the crop cases.

7.3 Growth.

The estimation results for the 49 regressions corresponding to the finally chosen f.fs for the 29 good fit crop cases are given in table 7.4. The fits have been some what low (R^2 falling between 40% and 50%) only in the cases of ragi(GN), rice(NZ), maize(NZ), rice(KH) and maize(AD). The other statistics such as IN, PE (nonlinearity measures), skewness coefficients, Box's percentage bias, etc. are all satisfactory as may be seen from table 7.4. The T-values of all the coefficients are significant too.

The results show that 25 out of the 29 crop cases (see table 7.2) with growth show a continuous rising trend in the yield. The remaining four crop cases, namely, rice(EG) and rice(GN), jowar(KU) and jowar(AN) show a falling trend initially, reach a minimum and then show a rising trend later on. The estimated turning point towards rising trend was 1956-57 in the case of rice(EG), 1964-65 in the case of rice(GN), 1967-68 in the case of jowar(KU) and 1966-67 in the case of jowar(AN).

Growth rates estimated for these 29 crop cases are given in table 7.5. This table reports the constant growth rates for those crop cases for which the semi-log function (f.f.3) was (one of) the chosen f.f.(s). For the rest, variable growth rates estimated for the last year of the sample period, 1984-85, is reported. For details on the expression for the growth rates for the 7 f.f.s used see chapter 6 table 6.1. At the districts level, it can be seen from table 7.5 that the growth performance has been different across crops and across districts.

Table 7.4 - Estimation Results of the Finally [illegible]

Crop	Function Y =	Parameters a	Parameters b	Parameters c	Parameters Rho	t values a	t values b	t values c	t values Rho	Skewness Coefficients a	Skewness Coefficients b	Skewness Coefficients c	Skewness Coefficients Rho	Box's % Bias a	Box's % Bias b	Box's % Bias c	Box's % Bias Rho	IN	PE	$\bar{R}^2$	D-W
Srikakulam + Vizianagaram + Vishakhapatnam (SV)																					
bajra	$a \cdot b^X$	571.93	1.017	...	...	17.39^{+}	345.08^{+}	...	...	0.07	0.03	...	...	0.08	0.01	...	...	0.03	0.17	0.5270	1.92
	$1/(a + bX)$	0.0017	-0.00002	...	...	20.31^{+}	- 5.78^{+}	...	...	0.09	-0.03	...	...	0.06	0.06	...	...	0.03	0.05	0.5356	1.98
East Godavari (EG)																					
rice	$a + bX + cX^2$	1840.00	-44.87	2.461	0.211	10.71^{+}	- 2.09^{++}	3.84^{+}	1.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.7939	...
West Godavari (WG)																					
rice	$a \cdot b^X$	1168.09	1.028	...	...	23.69^{+}	500.13^{+}	...	...	0.05	0.03	...	...	0.04	0.01	...	...	0.02	0.14	0.8782	1.91
	$1/(a + bX)$	0.0008	-0.00001	...	...	30.66^{+}	-13.43^{+}	...	...	0.06	-0.03	...	...	0.03	0.03	...	...	0.02	0.03	0.8771	1.93
Krishna (KR)																					
rice	$a \cdot b^X$	1145.00	1.020	...	0.327	12.68^{+}	282.54^{+}	...	1.73^{+++}	0.30	0.06	...	-0.01	0.06	0.01	...	-0.18	0.03	0.18	0.8660	...
Guntur + Prakasam + Nellore (GN)																					
rice	$a + bX + cX^2$	1568.43	-54.10	2.550	...	15.17^{+}	- 3.52^{+}	5.30^{+}	...	0.00	0.00	0.00	...	0.00	0.00	0.00	...	0.00	0.00	0.7097	1.67
	$Exp(a + bX + cX^2)$	7.33	-0.0303	0.0015	...	102.7^{+}	- 2.98^{+}	4.81^{+}	...	-0.12	0.04	0.02	...	-0.02	-0.46	-0.26	...	0.04	0.08	0.7039	1.67
ragi	$a \cdot b^X$	833.90	1.019	...	-0.312	16.18^{+}	325.31^{+}	...	-1.69	0.05	0.03	...	-0.01	0.14	0.01	...	0.16	0.05	0.28	0.4641	...
	$1/(a + bX)$	0.0012	-0.00002	...	-0.332	20.11^{+}	- 6.90^{+}	...	-1.81^{+++}	0.06	-0.02	...	-0.01	0.10	0.10	...	0.07	0.05	0.08	0.4770	...
Kurnool (KU)																					
rice	$a \cdot b^X$	1009.54	1.020	...	...	15.66^{+}	316.69^{+}	...	...	0.08	0.04	...	...	0.10	0.01	...	...	0.03	0.19	0.5829	1.85
	$1/(a + bX)$	0.0010	-0.00001	...	...	18.24^{+}	- 6.06^{+}	...	...	0.10	-0.04	...	...	0.07	0.07	...	...	0.03	0.07	0.5767	1.82
jowar	$a + bX + cX^2$	708.28	-48.14	1.990	...	12.04^{+}	- 5.50^{+}	7.25^{+}	...	0.00	0.00	0.00	...	0.00	0.00	0.00	...	0.00	0.00	0.7581	2.07
	$Exp(a + bX + cX^2)$	6.51	-0.0704	0.0029	...	66.68^{+}	- 4.96^{+}	6.95^{+}	...	-0.18	0.04	-0.01	...	-0.05	-0.32	-0.19	...	0.05	0.11	0.7717	2.19
Anantapur (AN)																					
rice	$a + bX$	1216.76	22.80	...	...	21.18^{+}	7.05^{+}	...	...	0.00	0.00	...	...	0.00	0.00	...	...	0.00	0.00	0.6264	1.80
	$a \cdot b^X$	1247.48	1.014	...	...	24.28^{+}	475.05^{+}	...	...	0.05	0.02	...	...	0.04	0.01	...	...	0.02	0.12	0.6165	1.77
jowar	$a + bX + cX^2$	583.11	-39.09	1.700	...	8.69^{+}	- 3.92^{+}	5.43^{+}	...	0.00	0.00	0.00	...	0.00	0.00	0.00	...	0.00	0.00	0.6695	1.95
ragi	$a + bX$	729.70	28.77	...	0.348	7.04^{+}	5.16^{+}	...	1.92^{+++}	0.00	0.00	...	0.00	0.00	0.00	...	0.00	0.00	0.00	0.6993	...
	$a \cdot b^X$	805.50	1.024	...	0.362	9.59^{+}	203.95^{+}	...	1.97^{+++}	0.46	0.10	...	0.01	0.10	0.01	...	0.04	0.04	0.24	0.6924	...
Cuddapah (CU)																					
rice	$a \cdot b^X$	1202.73	1.019	...	...	19.30^{+}	387.39^{+}	...	...	0.06	0.03	...	...	0.07	0.01	...	...	0.03	0.16	0.6373	1.86
	$1/(a + bX)$	0.0008	-0.00001	...	...	23.40^{+}	- 7.46^{+}	...	...	0.08	-0.03	...	...	0.04	0.04	...	...	0.03	0.04	0.6571	1.99
jowar	$1/(a + bX)$	0.0031	-0.00007	...	...	10.92^{+}	- 6.37^{+}	...	...	0.17	-0.11	...	...	0.21	0.21	...	...	0.06	0.09	0.5888	1.85
bajra	$1/(a + bX)$	0.0021	-0.00004	...	...	11.14^{+}	- 5.76^{+}	...	...	0.17	-0.10	...	...	0.20	0.20	...	...	0.06	0.09	0.5852	1.72
ragi	$a \cdot b^X$	818.10	1.028	...	0.259	9.04^{+}	195.27^{+}	...	1.45	0.35	0.11	...	-0.01	0.15	0.01	...	0.06	0.05	0.32	0.6703	...
	$1/(a + bX)$	0.0011	-0.00002	...	0.299	11.13^{+}	- 4.80^{+}	...	1.67	0.41	-0.25	...	0.01	0.09	0.10	...	0.23	0.04	0.07	0.6517	...
Chittoor (CH)																					
rice	$a \cdot b^X$	1298.31	1.015	...	...	21.68^{+}	426.40^{+}	...	...	0.06	0.03	...	...	0.05	0.01	...	...	0.03	0.13	0.5918	2.24
	$1/(a + bX)$	0.0008	-0.00001	...	...	24.59^{+}	- 6.30^{+}	...	...	0.07	-0.02	...	...	0.04	0.04	...	...	0.03	0.04	0.5868	2.22

Notes are given at the end of the table.

Table 7.4 Contnd.

Crop	Function Y =	Parameters a	b	c	Rho	t values a	b	c	Rho	Skewness Coefficients a	b	c	Rho	Box's % Bias a	b	c	Rho	IN	PE	$\bar{R}^2$	D-W
Ranga reddy + Hyderabad (RH)																					
rice	a + bX	762.86	39.29	...	...	9.78^{+}	8.94^{+}	...	...	0.00	0.00	...	...	0.00	0.00	...	...	0.00	0.00	0.7315	1.86
Nizamabad (NZ)																					
rice	a + bX	1037.13	39.74	...	...	7.53^{+}	5.12^{+}	...	...	0.00	0.00	...	...	0.00	0.00	...	...	0.00	0.00	0.4655	1.84
	a·b^{X}	1125.21	1.024	...	...	9.95^{+}	205.29^{+}	...	...	0.13	0.07	...	...	0.25	0.01	...	...	0.05	0.32	0.4548	1.81
maize	a + bX	703.32	47.52	...	...	4.11^{+}	4.92^{+}	...	...	0.00	0.00	...	...	0.00	0.00	...	...	0.00	0.00	0.4449	2.18
Medak (ME)																					
rice	a + bX	690.17	36.48	...	...	6.65^{+}	6.24^{+}	...	...	0.00	0.00	...	...	0.00	0.00	...	...	0.00	0.00	0.5669	1.76
	1/(a + bX)	0.0012	-0.00001	...	...	12.49^{+}	- 5.55^{+}	...	...	0.15	-0.08	...	...	0.18	0.16	...	...	0.05	0.08	0.5560	1.73
Mehboobnagar (MB)																					
rice	a + bX	770.00	28.29	...	0.344	7.56^{+}	5.08^{+}	...	1.69	0.00	0.00	...	0.00	0.00	0.00	...	0.00	0.00	0.00	0.7313	...
	a·b^{X}	843.20	1.022	...	0.367	9.75^{+}	201.97^{+}	...	1.78^{+++}	0.43	0.11	...	-0.01	0.09	0.01	...	0.05	0.04	0.23	0.7259	...
Nalgonda (NA)																					
rice	a·b^{X}	792.10	1.036	...	0.286	13.59^{+}	301.68^{+}	...	1.49	0.25	0.09	...	-0.01	0.06	0.01	...	-0.15	0.03	0.22	0.9012	...
	1/(a + bX)	0.0012	-0.00003	...	0.385	14.85^{+}	- 9.49^{+}	...	1.70^{+++}	0.46	-0.37	...	0.03	0.05	0.05	...	0.08	0.03	0.05	0.8849	...
Warangal (WA)																					
rice	a + bX	711.80	39.30	...	-0.384	12.57^{+}	12.34^{+}	...	-2.04^{+++}	0.00	0.00	...	0.00	0.00	0.00	...	0.00	0.00	0.00	0.7425	...
Maize	a + bX	462.90	42.73	...	0.356	2.38^{++}	3.98^{+}	...	1.63	0.00	0.00	...	0.00	0.00	0.00	...	0.00	0.00	0.00	0.6392	...
Khammam (KH)																					
rice	a + bX	742.19	30.12	...	...	7.42^{+}	5.35^{+}	...	...	0.00	0.00	...	...	0.00	0.00	...	...	0.00	0.00	0.4876	2.11
	1/(a + bX)	0.0012	-0.00002	...	...	12.59^{+}	- 5.07^{+}	...	...	0.15	-0.07	...	...	0.15	0.16	...	...	0.05	0.08	0.4926	2.15
Karimnagar (KM)																					
rice	a + bX	528.40	58.63	...	0.305	5.42^{+}	11.10^{+}	...	1.63	0.00	0.00	...	0.00	0.00	0.00	...	0.00	0.00	0.00	0.9035	...
	a·b^{X}	752.10	1.039	...	0.349	10.52^{+}	238.10^{+}	...	1.86^{+++}	0.41	0.12	...	-0.01	0.09	0.01	...	0.14	0.03	0.27	0.8996	...
maize	a + bX	434.13	59.16	...	...	3.76^{+}	9.10^{+}	...	...	0.00	0.00	...	...	0.00	0.00	...	...	0.00	0.00	0.7383	1.74
	1/(a + bX)	0.0013	-0.00003	...	...	12.95^{+}	- 7.84^{+}	...	...	0.14	-0.10	...	...	0.15	0.15	...	...	0.05	0.08	0.7472	1.83
Adilabad (AD)																					
rice	a·b^{X}	738.60	1.023	...	-0.233	15.21^{+}	310.43^{+}	...	-1.13	0.06	0.03	...	-0.01	0.15	0.01	...	0.22	0.05	0.30	0.5366	...
	1/(a + bX)	0.0012	-0.00002	...	-0.201	17.81^{+}	- 5.90^{+}	...	-0.95	0.08	-0.03	...	-0.01	0.10	0.10	...	0.08	0.05	0.08	0.5227	...
maize	a + bX	637.58	19.96	...	...	8.55^{+}	4.75^{+}	...	...	0.00	0.00	...	...	0.00	0.00	...	...	0.00	0.00	0.4269	1.89
	1/(a + bX)	0.0013	-0.00002	...	...	12.64^{+}	- 4.04^{+}	...	...	0.15	-0.05	...	...	0.15	0.15	...	...	0.05	0.08	0.4107	1.79

Notes: Significance at 1%, 5% and 10% are indicated by +/++/+++ respectively. Y is the yield. X is the time variable.

Rho(ρ) is the autocorrelation parameter. IN : intrinsic nonlinearity; PE : parametric effects nonlinearity; D-W : Durbin-Watson statistic.

Table 7.5 - Estimated Growth Rates (%). Sample Period: 1955-56 to 1984-85.

District	Rice	Jowar	Bajra	Ragi	Maize
SV	N	D	1.69	N	D
EG	4.23*2	D	D	D	D
WG	2.76	D	D	D	D
KR	1.98	D	D	D	D
GN	5.24*2	N	N	1.88	D
KU	1.98	10.36*4	D	D	D
AN	1.39	5.59*2	N	2.37	D
CU	1.88	7.94*5	5.00*5	2.76	D
CH	1.49	N	N	N	D
RH	1.99*1	N	D	N	N
NZ	2.37	N	D	D	3.01*1
ME	2.38*1	N	D	D	N
MB	2.18	N	N	N	D
NA	3.54	N	N	D	D
WA	2.46	N	D	D	4.16*1
KH	2.74	N	D	D	D
KM	3.83	N	D	D	6.55*5
AD	2.27	N	D	D	2.42*1

Notes: Unstarred figures are constant growth rates estimated by semilog trends

* : Variable growth rates are indicated by a * followed by a number corresponding to the functional form; for eample, *1 indicates estimated from function form 1 and so on. The variable growth rates correspond to the last year of the sample period, 1984-85. See chapter 6, table 6.1 for the functional forms.

N : indicates no trend (poor fit cases).

D : indicates the crop case was dropped from the analysis.

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam;
EG : East Godavari; WG : West Godavari; KR : Krishna;
GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur;
CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad;
NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda;
WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

Rice: Rice yields show a trend in all the districts except SV. Observing only the districts with a constant rate of growth (estimated from f.f. 3) it varies from a high of 3.83% in KM to a low of 1.39% in AN. The pattern of growth has been that most of the districts of Coastal Andhra (EG, WG and GN) and Telangana (N2, ME, MB, NA, WA, KH, KM and AD) show growth rates more than 2% while the districts of Rayalaseema (KU, AN, CU and CH) only show growth rates less than 2%. It may be recalled here that rice is an irrigated crop in all the districts of AP (see chapter 3 for details).

These results are consistent with the result in the previous chapter for rice yield at the AP State level, where too the aggregate annual rice yields showed growth.

Jowar: Of all the other crops which show a trend only in a few districts unlike rice, jowar stands out clearly. 11 out of the 14 districts where jowar is an important crop do not show a trend in the yields. Only 3 districts, KU, AN and CU, all from Rayalaseema region show growth in jowar yields. These 3 districts account for about 1/3rd of the state's jowar production in 1984-85. None of the Telangana districts show any growth in jowar yields. Jowar is an unimportant crop in all the districts of Coastal Andhra except GN, where too jowar yields are stagnant. Note that jowar is largely an unirrigated crop in all the districts of AP.

Recall from the previous chapter that aggregate annual jowar yields at the State level show growth. Thus it is the rising yield levels in the 3 districts of Rayalaseema that is reflected in the State level result.

Bajra: The picture in the case of bajra is similar to that of jowar. 5 out of 7 districts where bajra is an important crop face stagnant yield levels. Only SV and CU show growth in bajra yields. In SV the crop is totally unirrigated and in CU partly irrigated. The 5 districts (GN, AN, CH, MB and NA) where bajra is an important crop did not show any trend in its yields, account for about 44% of the state's production in 1984-85. That is a major portion of bajra cultivation faces stagnant yields and this aspect is reflected in the State level result obtained in the previous chapter that showed aggregate annual bajra yields to be stagnant. Bajra is partly irrigated in GN and CH and is mostly unirrigated in AN, MB and NA.

Ragi: In the case of ragi 4 out of 7 districts where the crop is important do not show trend. These are SV, CH, RH and MB where the crop is mainly unirrigated. These 4 districts account for about 62% of the state's production in 1984-85. Thus a major portion of ragi cultivation in AP faces stagnant yield levels. This result is consistent with the State level result where too aggregate annual ragi yields did not show any growth (see previous chapter). The district level trend results for ragi show clearly the importance of irrigation in rising yield levels. The 3 districts (GN, AN and CU) that show growth in ragi yields are also the ones where ragi is almost fully irrigated. These districts, however, make only 39% contribution to State total production.

Maize: In the case of maize 4 out of 6 districts where the crop is important show a trend in yields. These are NZ, WA, KM and AD, which together account for 82% of the state's production in 1984-85. That is most of maize cultivation in AP enjoys growing yield levels and it is this feature that is reflected in the State level result that shows aggregate annual maize yields to be growing. Of the 6 districts where maize is an important crop, it is partly irrigated in WA and KM but unirrigated in the remaining 4 districts (RH, NZ, ME & AD).

Thus, we find that there are large differences across districts in growth performance of crop yields. In a later chapter we attempt to explore the disparities in districtwise yield levels in terms of disparities in some possible explanatory variables such as irrigation, etc. Right now we note that rice yields in almost all the districts and maize yields in most of the districts where the crop is important show growth. Though both these crops are grown mostly with HYV seeds yet there is a tremendous difference in their irrigation intensities. Ragi yields, though grown only with traditional seeds, recorded positive growth under irrigated but not under unirrigated conditions. This result of ragi may be contrasted with that of bajra yields which, though grown with HYV seeds, mostly remained stagnant perhaps due to its unirrigated conditions. Jowar is grown almost unirrigated mostly with traditional seeds and hence its yields also have remained stagnant in most of the districts. These results in general point out the growth promoting effect of irrigation vis a vis HYV seeds, particularly in the case of inferior cereals. Recall that, even at the State level (previous chapter) the irrigated segment of traditional ragi but not the HYV segment of unirrigated bajra showed growth.

7.4 Variability.

Proceeding further with the analysis,

for the growth cases, additive residuals $(Y_t - \hat{Y}_t)$ and multiplicative residuals $(Y_t/\hat{Y}_t)$ are collected from the estimations of AEF & MEF corresponding to the chosen functional form(s);

for the no growth cases, the sample mean itself was taken to be the expected (mean) yield level. The deviations from the sample mean $(Y_t - \bar{Y})$ and the ratio of the observed yield to the sample mean $(Y_t/\bar{Y})$ were treated as equivalents to additive and multiplicative errors.

Table 7.6 presents the estimated values of different statistics under the Hsu tests based on the above residuals. The results of these tests for variability are summarised in table 7.7.

These results suggest that in as many as 45 out of the 52 (29 growth + 23 no growth) crop cases there is no change in both absolute and relative yield variability over time. That is, whatever level of variability existed to start with continues to exist over time without any appreciable change in these 45 crop cases. These 45 crop cases with no variability change include rice in 15 districts, jowar in 13 districts, bajra in 6 districts, ragi in 6 districts and maize in 5 districts (see table 7.7). The remaining 7 crop cases showed change in absolute variability over time.

Table 7.6 - Hsu Tests for Variability Change Over Time in Crop Yields: Districts of Andhra Pradesh.

Crop	Crop	Function Form (f.f)	Absolute Variability T-test	Absolute Variability G-test	Relative Variability T-test	Relative Variability G-test
SV	Rice#	-	1.8144	0.8813++	1.0354	0.7532
	Bajra	3	-0.9137	0.3216	-1.5228	0.2256
		5	-0.8921	0.3263	-1.5358	0.2199
	Ragi#	-	-0.4457	0.3766	-0.4098	0.3908
EG	Rice	2	0.7704	0.6423	0.1250	0.4919
WG	Rice	3	2.3377+	0.8443	1.0266	0.6386
		5	2.4790+	0.9052++	1.2297	0.7263
KR	Rice	3	0.6936	0.6623	0.1697	0.5423
GN	Rice	2	2.5840+	0.9035++	1.5907	0.7957
		4	2.7417+	0.9210+	1.6572	0.8195
	Jowar#	-	-1.4104	0.2026	-0.7940	0.2973
	Bajra#	-	1.5895	0.7830	1.0513	0.7073
	Ragi	3	-1.4012	0.2337	-1.7773	0.1782
		5	-1.4023	0.2558	-1.8526	0.1810
KU	Rice	3	0.7741	0.6432	-0.5458	0.3399
		5	0.7786	0.6578	-0.5271	0.3545
	Jowar	2	1.2294	0.6870	0.4146	0.5430
		4	1.5775	0.7594	0.6337	0.5996
AN	Rice	1	0.9848	0.6296	0.5837	0.5598
		3	0.7966	0.5958	0.3492	0.5105
	Jowar	2	0.2492	0.5443	-1.5276	0.1966
	Bajra#	-	1.2422	0.7260	0.7091	0.6663
	Ragi	1	-0.5316	0.3550	-1.8430	0.2019
		3	-0.3661	0.3951	-1.7795	0.2197
CU	Rice	3	1.0582	0.7316	0.1738	0.5207
		5	0.9547	0.7133	0.0913	0.5010
	Jowar	5	2.1229+	0.8648	1.4886	0.7193
	Bajra	5	1.7388	0.8331	-0.7298	0.3236
	Ragi	3	0.4641	0.6222	-0.8224	0.3377
		5	0.4725	0.6224	-0.7996	0.3373
CH	Rice	3	1.1112	0.7661	0.3644	0.6092
		5	1.1580	0.7702	0.4243	0.6174
	Jowar#	-	0.4390	0.5907	0.1906	0.5462
	Bajra#	-	2.3127+	0.8888++	1.4257	0.8068
	Ragi#	-	-2.5261+	0.0697+	-2.3803+	0.0695+
RH	Rice	1	0.6450	0.6461	-0.7314	0.3099
	Jowar#	-	-1.5924	0.1674	-1.7519	0.1607

Notes are given at the end of the table.

Table 7.6 Contnd.

Crop	Crop	Function Form (f.f)	Absolute Variability T-test	G-test	Relative Variability T-test	G-test
RH	Ragi#	-	-1.0792	0.3078	-2.1207	0.1695
	Maize#	-	1.2541	0.6521	-1.3103	0.2805
NZ	Rice	1	0.6688	0.6144	0.5347	0.5721
		3	0.6025	0.6029	0.4330	0.5545
	Jowar#	-	0.5013	0.5917	-0.4934	0.4053
	Maize	1	1.2472	0.8197	-0.1483	0.4889
ME	Rice	1	1.1579	0.6853	0.8795	0.5992
		5	1.1170	0.7107	0.7781	0.5948
	Jowar#	-	-1.7318	0.1644	-1.3770	0.2029
	Maize#	-	1.7451	0.7599	0.5088	0.5773
MB	Rice	1	1.7986	0.8657	0.0404	0.5284
		3	1.8654	0.8623	0.0214	0.5199
	Jowar#	-	-0.2103	0.4210	-0.8193	0.2970
	Bajra#	-	-0.1474	0.4750	0.2853	0.5662
	Ragi#	-	-0.7539	0.3233	-1.8282	0.1633
NA	Rice	3	-0.1405	0.5018	-1.6803	0.1922
		5	1.2317	0.7661	-1.0258	0.3163
	Jowar#	-	-0.3128	0.4565	0.0787	0.5392
	Bajra#	-	0.9269	0.7220	0.8268	0.6755
WA	Rice	1	-1.0872	0.2961	-1.8155	0.2817
	Jowar#	-	0.3217	0.5460	-0.3803	0.3910
	Maize	1	1.6991	0.8358	-1.4548	0.2480
KH	Rice	1	1.8345	0.8841	0.7171	0.6818
		5	1.7671	0.8683	0.5968	0.6408
	Jowar#	-	1.1655	0.7793	0.5787	0.6625
KM	Rice	1	1.2969	0.8091	-0.9350	0.3001
		3	1.4692	0.8163	-1.0533	0.2509
	Jowar#	-	0.4401	0.5447	-0.6350	0.3676
	Maize	1	2.5953+	0.8283	-1.0251	0.2641
		5	2.5580+	0.8968++	-1.0439	0.3051
AD	Rice	3	0.4235	0.6293	-0.4888	0.4087
		5	0.4270	0.6215	-0.5178	0.3871
	Jowar#	-	-1.3524	0.2491	-0.7672	0.3479
	Maize	1	1.7280	0.8986	0.6357	0.6994
		5	1.8180	0.8938	0.7616	0.7152

Notes: +/++ : indicates significance at 1% And 5% level, respectively. Critical values are given in chapter 5, appendix 5.A1.

: No growth cases. See notes to table 7.5 for district codes.

[illegible]

[illegible]

District	Absolute Variability Change: Present	Absolute Variability Change: Not Present	Relative Variability Change: Present	Relative Variability Change: Not Present
SV	rice ↑(1962)#	bajra ragi#	---	rice# bajra ragi #
EG	---	rice	---	rice
WG	rice ↑(1976)	---	---	rice
KR	---	rice	---	rice
GN	rice ↑(1976)	ragi jowar# bajra#	---	rice jowar# ragi bajra#
KU	---	rice jowar	---	rice jowar
AN	---	rice jowar ragi bajra#	---	rice jowar ragi bajra#
CU	jowar↑(1966)	rice bajra ragi	---	rice jowar ragi bajra
CH	bajra↑(1978)# ragi ↓(1966)#	rice jowar#	ragi↓(1966)#	rice jowar# bajra#
RH	---	rice jowar# ragi# maize#	---	rice jowar# ragi# maize#
NZ	---	rice jowar# maize	---	rice jowar# maize
ME	---	rice jowar# maize#	---	rice jowar# maize#
MB	---	rice jowar# ragi# bajra#	---	rice jowar# ragi# bajra#
NA	---	rice jowar# bajra#	---	rice jowar# bajra#
WA	---	rice jowar# maize	---	rice jowar# maize
KH	---	rice jowar#	---	rice jowar#
KM	maize↑(1975)	rice jowar#	---	rice jowar# maize
[illegible]	---	rice jowar# maize	---	rice jowar# maize
(52)	7	45	1	51

Variability change point year is shown in brackets.

↑(↓) : Indicates an increase (decrease) in variance.

: No growth cases. See notes to table 7.5 for district codes.

These are:

rice in SV, WG & GN
jowar in CU
bajra in CH
ragi in CH, and
maize in KM.

Of these 7, all cases showed an increase in absolute but no change in relative variability except ragi(CH) where both absolute and relative variability decreased over time. Thus again we find that the presence of change in relative variability is also accompanied with change in absolute variability but not the other way.

For the crop cases which showed change in variability over time, the change-point years are also shown in table 7.7.

The above results for rice, jowar and ragi are more or less consistent with the State level results which showed the aggregate annual yields of these 3 crops to be free from any variability problem; i.e., the variance of the gaps between the realizations and expectations has remained stable over time. Bajra yields at the State level show change in variability. Among the districts, *however, only* CH, contributing 6% to the state's bajra production in 1984-85, shows variability change. To a large extent the State level result for bajra is thus not supported by the district level results. In the case of maize, KM is the only district showing variability change over time. KM being a major district for maize contributing 44% to the state's production in 1984-85, it seems that the State level result of variability change in the case of maize yields reflects mainly the situation in KM.

The 7 crop cases showing change in absolute variability consist of 4 growth cases and 3 no growth cases. The growth cases are rice(WG) and rice(GN), jowar(CU) and maize(KM). The no growth cases showing change in absolute variability are rice(SV), bajra(CH) and ragi(CH). Of them all only ragi(CH) (no growth case) shows a fall in absolute variability while the remaining 6 cases show an increase in absolute variability in the period after the change point year. The increase over time in the variance has been of the order of 5 to 6 times in the case of rice(WG), rice(GN), maize(KM), rice(SV) and bajra(CH). In the case of jowar(CU) the increase in variance was of the order of 8.75 times in the latter period. In the case of ragi(CH), a no growth case, the fluctuations around a stagnant mean yield levels have reduced over time the decrease being of the order of 3.97 times. Note that, the variability change point has not been the same in these 7 crop cases. The variability change point is 1961-62 in the case of rice(SV) (surprisingly, even before the modern technology arrived in India!), 1965-66 in the case of jowar(CU) and ragi(CH), 1974-75 in the case of maize(KM), 1975-76 in the case of rice(WG) and rice(GN), and 1977-78 in the case of bajra(CH).

From table 7.7 it can also be seen that out of the 52 crop cases only one, ragi(CH) (no growth case), shows relative variability. Both the direction of change as well as the change point year is same in the case of both absolute and relative variability of ragi(CH). Ragi(CH) yields (partly irrigated) have witnessed a fall in both absolute and relative variability since 1965-66.

Cropwise, the cases that show (absolute) variability change over time account in the State total production in 1984-85 for

rice :	rice (WG), rice (GN), rice (SV)	total 42%
jowar:	jowar(CU)	total 6%
bajra:	bajra(CH)	total 6%
ragi :	ragi (CH)	total 15%
maize:	maize(KM)	total 44%

Let us now look for some pattern in the results obtained so far with respect to growth, a crop being irrigated/unirrigated as also a crop being grown with traditional/HYV seeds. Fairly reliable data exist on irrigation intensity (irrigated area ÷ crop acreage) levels of the crops. Recall that, rice is an irrigated crop in all the districts; jowar is unirrigated in all the districts; bajra and maize are mostly unirrigated crops though in some districts a moderate part of the crop is under irrigation; while ragi is fully irrigated in some districts and almost totally unirrigated in other districts. Amongst the seven crops showing change in variability, the 3 rice crop cases rice(SV), rice(WG) and rice(GN) are irrigated; some parts of bajra(CH), ragi(CH) and maize(KM) are irrigated while jowar(CU) is an unirrigated crop. However, we do not have continuous time series data at the districts level on the extent of cultivation under HYV seeds. The districtwise data provided by Evenson/ICRISAT can, however, provide some idea regarding the usage of these seeds in different districts, though these data suffer from certain shortcomings as discussed in chapter 5, Part C. Thus using the official data on irrigation levels and Evenson/ICRISAT data as only indicative of the seed adoption rates, we may be able to draw some broad patterns in our results with respect to irrigation and HYV adoption. The results of yield variability over time at the AP districts level vis a vis irrigation and seed variety used are summarised in table 7.8.

Growth versus variability: From table 7.8 we find that out of the 52 crop cases analysed 29 cases show growth while 23 do not. Of the 29 cases with growth 4 crop cases (rice(WG), rice(GN), jowar(CU) & maize(KM)) show change in variability also. The remaining 25 crop cases that show growth do not show any change in variability. Of the 23 cases of no growth, 3 cases (rice(SV), bajra(CH) & ragi(CH)) however, show change in variability. Thus, the results suggest that growth and variability are not related.

Traditional variety seeds and yield variability: Among the 52 crop cases analysed, 30 correspond to yields grown with traditional seeds of which 6 are grown under highly/partly irrigated conditions while 24 are grown under unirrigated conditions. Amongst the 6 cases (rice(SV), bajra(GN), ragi(GN, AN, CU), maize(WA)) of traditional varieties grown under some irrigation 5 did not show any variability change the lone exception being rice(SV). Amongst the 24 crop cases growing traditional varieties under unirrigated conditions 22 did not show any variability change; only 2 (jowar(CU) & ragi(CH)) showed variability change. In other words, of the 30 crop cases grown with traditional varieties, except in 3 cases (the irrigated yields of rice(SV) and the unirrigated yields of jowar(CU) & ragi(CH)), the remaining 27

Crop	Districts Analysed	Growth	Seeds	Irrigation	Change in Absolute Variability	No. of Districts
Rice	18	Yes	HYV	Yes	No	15
		Yes	HYV	Yes	Yes	2 (WG, GN)
		No	T	Yes	Yes	1 (SV)
Jowar	14	Yes	T	No	No	2 (KU, AN)
		Yes	T	No	Yes	1 (CU)
		No	T	No	No	11
Bajra	7	Yes	HYV	Partly	No	1 (CU)
		Yes	T	No	No	1 (SV)
		No	HYV	No	No	1 (AN)
		No	HYV	No	Yes	1 (CH)
		No	T	No	No	2 (MB, NA)
		No	T	Partly	No	1 (GN)
Ragi	7	Yes	T	Yes	No	3 (GN, AN, CU)
		No	T	No	No	3 (SV, RH, MB)
		No	T	No	Yes	1 (CH)
Maize	6	Yes	HYV	Partly	Yes	1 (KM)
		Yes	T	No	No	2 (NZ, AD)
		Yes	T	Partly	No	1 (WA)
		No	HYV	No	No	1 (RH)
		No	T	No	No	1 (ME)

Notes: T : Traditional variety seeds; HYV : High yielding variety seeds;

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam;
EG : East Godavari; WG : West Godavari; KR : Krishna;
GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur;
CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad;
NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda;
WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

crop cases did not show any change in variability in their yields irrespective of the level of irrigation.

High yielding variety seeds and yield variability: Among the 52 crop cases analysed 22 are grown with HYV seeds of which 19 are grown under highly/partly irrigated conditions while 3 (bajra(AN, CH) and maize(RH)) are grown under unirrigated conditions. Of the 19 crop cases grown with HYV seeds and some irrigation 16 did not show any change in variability. Only 3 of these 19 crop cases showed variability change; these are rice(WG), rice(GN) and maize(KM). Amongst the 3 crop cases grown with HYV seeds under unirrigated conditions only bajra(CH) showed change in variability. Thus, in all out of the total 22 crop cases grown with HYV seeds only 4 showed variability change of which 3 correspond to irrigated and 1 corresponds to unirrigated yields. Thus irrigated HYV yields generally did not show any variability change though we are unable to make such judgment with respect to unirrigated HYV yields since the number of such cases analysed turned out to be too few (only 3).

Thus these results suggest that
(1) Growth has no relationship with variability changes,
(2) Traditional seeds grown with or without irrigation in general do not show change in yield variability; the exceptions are rice(SV), jowar(CU) and ragi(CH),
(3) High yielding variety seeds (HYV) grown with irrigation in general do not show yield variability change; the exceptions are rice(WG), rice(GN) and maize(KM).

The above pattern at the districts level is broadly consistent with the pattern observed at the State level in the previous chapter though a firm conclusion with respect to unirrigated HYV yields could not be obtained here.

It may be stressed once again that the above mentioned conclusions on yield variability, irrigation and seed variety used are subject to the limitations of the data on HYV provided by Evenson/ICRISAT.

7.5 Structural Change.

The issue of structural change does not arise for the crop cases (23 out of 52) that showed no growth at all. The analysis is relevant only for the 29 crop cases which showed growth over time. Recall that 4 out of these 29 growth cases showed variability change over time, while the remaining 25 did not show variability change in their yields. So only these 25 cases are analysed for structural change.

The analysis for structural change was carried out as described in the previous chapter (and also chapter 5) incorporating dummy variables into the chosen f.fs and scanning over the period 1964-65 to 1976-77 to identify the structural change point. The estimation results for those crop cases showing structural change are given in table 7.9. The results of this analysis are summarised in table 7.10.

The results show that 8 out of the 25 crop cases which show a structural change in the growth pattern of yield. That is, at least one of the coefficients (intercept, slope or quadratic) of the dummy variables in the estimations reported in table 7.9 is significant. The crop cases showing structural change are, rice(AN), rice(RH), jowar(KU), jowar(AN), ragi(GN), ragi(AN), ragi(CU), and maize(WA). Note that bajra yields did not show any structural change in both (SV & CU) districts analysed here despite differences in HYV adoption.

We find from table 7.10 that the year of the structural change point, has not been the same in the 8 crop cases. While ragi(GN) shows a structural break in 1964-65, jowar(KU) shows structural break in 1967-68, rice(AN) in 1969-70, ragi(CU) in 1972-73, rice(RH) in 1973-74, jowar(AN) in 1974-75, rice(AN) in 1975-76, and maize(WA) in 1976-77. Thus, among these 8 crop cases the structural break in the growth path over time has occurred in some cases well after the introduction of the Green Revolution technology.

Table 7.9 – Estimation Results of Analysis of Structural Change in Crop Yields Districts of Andhra Pradesh.

Crop	Functional Form	Parameters a	b	c	Dummy Variable d	e	f	Rho1	Rho2	Change Point Year	$\bar{R}^2$	D-W
rice(AN)#	1	1166.00	29.97	...	-849.00	26.13	...	...	...	1978	0.6974	2.11
		(10.19)+	(5.60)+		(-2.15)++	(1.62)						
rice(RH)	1	812.20	29.47	...	1233.00	-39.82	...	...	...	1974	0.8265	1.98
		(9.87)+	(3.87)+		(3.46)+	(-2.50)++						
jowar(KU)#	2	447.50	41.47	-4.254	598.50	-129.70	7.233	...	...	1968	0.8074	2.77
		(5.16)+	(1.27)	(1.74)+++	(1.48)	(-2.59)++	(2.78)+					
jowar(AN)	2	534.50	-23.78	0.659	5177.0	-427.80	9.013	...	...	1975	0.7024	2.22
		(6.41)+	(-1.24)	(0.92)	(2.25)++	(-2.29)++	(2.36)++					
ragi(GN)#	3	6.554	0.0629	...	-0.0783	-0.0334	...	-0.999	-0.447	1966	0.9298	...
		(111.5)+	(5.89)+		(-0.80)	(-2.95)+			(-2.20)++			
ragi(AN)#	1	889.40	2.879	...	420.80	2.949	...	-0.033	-0.203	1970	0.8040	...
		(10.14)+	(0.28)		(2.30)++	(0.24)						
ragi(CU)#	3	6.772	0.0153	...	0.7081	-0.0174	...	-0.001	-0.191	1973	0.9156	...
		(70.22)+	(1.68)		(2.27)++	(-1.18)		(-0.01)	(-2.20)++			
maize(WA)	1	148.52	73.32	...	3138.66	-137.66	...	0.414	0.094	1977	0.7509	...
		(0.65)	(4.28)+		(1.90)+++	(-2.27)++		(1.66)	(0.27)			

Notes: * : See chapter 6, table 6.1 for functional form. F.f. 1 was estimated as $Y = a + bX + dD + eXD$; F.f. 2 was estimated as $Y = a + bX + cX^2 + dD + eXD + fX^2D^2$; F.f. 3 was estimated as $Log(Y) = a + bX + dD + eXD$; where Y is yield, X is Time and D is the dummy; a, b and c are the intercept, slope and quadratic coefficients in the regression; d, e and f are the corresponding dummy variable coefficients.

: For each of these crop cases two functional forms were chosen (see table 7.4). Though the analysis was done using both these functional forms results of only of these estimations are reported in this table.

t : values are given in brackets. Significance at 1%, 5% and 10% are indicated by +/++/+++ respectively.

Rho1 & Rho2 are the autocorrelation coefficients for the periods before and after the change point year respectively.

Table 7.10 – Summary Results of the Analysis of Structural Change in Crop Yields and the Change Point Year: Districts of Andhra Pradesh.

	Structural Change Occurred		No Structural Change Occurred		
	ragi(GN 1965)	jowar(KU 1968)	bajra(SV)	rice (EG)	rice (KR)
	rice(AN 1976)	jowar(AN 1975)	rice (KU)	rice (CU)	bajra(CU)
	ragi(AN 1970)	ragi (CU 1973)	rice (CH)	rice (NZ)	maize(NZ)
	rice(RH 1974)	maize(WA 1977)	rice (ME)	rice (MB)	rice (NA)
			rice (WA)	rice (KH)	rice (KM)
			rice (AD)	maize(AD)	
Total(25)	8		17		

Notes: The estimated structural change point is shown in brackets.

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam;
EG : East Godavari; WG : West Godavari; KR : Krishna;
GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur;
CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad;
NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda;
WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

The signs (+/-) of the significant dummy variables corresponding to the intercept and/or trend variable can indicate the nature of the structural change in these 8 crop cases in terms of increase in growth/fall in growth/mere shift (vertically up or down) of the growth curve of the yield. For example, if only the intercept dummy is significant but not the dummies of the trend variable, then it implies that the yield curve has merely been shifted vertically up/down. The nature of the structural change, i.e., intercept change or slope change or both, in the 8 crop cases is given below:

	Increase in growth rate	Decrease in growth rate	No change in growth rate	
Increase in intercept	jowar(AN)	rice (RH) maize(WA)	ragi (AN)	ragi (CU)
Decrease in intercept	---	---	rice (AN)	
No change in intercept	jowar(KU)	ragi (GN)	bajra(SV) rice (KR) rice (CU) rice (CH) maize(NZ) rice (MB) rice (WA) rice (KM) maize(AD)	rice (EG) rice (KU) bajra(CU) rice (NZ) rice (ME) rice (NA) rice (KH) rice (AD)

A notable result of this analysis is that rice yield in most of the districts of AP does not show any structural change in the sense parameters of the growth curve (trend equation) did not change significantly at all over time. The only exceptions are rice(RH) and rice(AN). There is a difference between the natures of structural change occurred in these two cases. For rice(RH), though the growth rate fell down significantly the yield curve got, however, pushed far up significantly. For rice(AN), though the yield curve shifted downwards significantly, it is however associated with an insignificant increase in the growth rate. The overall results are consistent with the result obtained for rice at the AP State level which also did not show any structural change in the growth path. Implications of such a result with respect to rice has already been discussed in the previous chapter. This essentially points out that the introduction of modern technology could not push up the growth rates in rice yields to significantly higher levels in most of the districts in AP.

Of the 8 crop cases showing a structural change, only 2 show significant increase in the growth rate in the period following the structural change point year. Both these are jowar yields (jowar(AN) and jowar(KU)). While jowar(AN) shows a significant change in the intercept also, jowar(KU) does not show any significant change in the intercept. 3 crop cases show a decrease in the growth rate in the period after the structural change point year. These are rice(RH), maize(WA) and ragi(GN). Of these only the latter does not show any significant change in the intercept. The remaining 3 crop cases show only an intercept change with no significant change in the trend variable coefficient but the growth curve is either pushed up (ragi(AN) and ragi(CU)) or is pulled down (rice(AN)).

For these 8 crop cases showing structural change Hsu tests were conducted on the estimated residuals after accounting for the dummy variables. These tests (not reported here) reconfirmed the earlier result of no variability change in the yields of these crop cases.

A summary of all the results from the analysis of crop yields in time domain at the districts level is presented in table 7.11.

7.6 Conclusions.

In this chapter the nature of growth, change in variability around the trend levels and structural change in the growth path of cereal crops' yields at AP district level were studied. The results on growth suggest that the growth promoting effect on yields of irrigation is generally higher than that of HYV seeds in the case of inferior cereals.

I. 1) While 29 out of total 52 crop cases showed growth in yields,

Table 7.11 - Summary Results of Dynamic Analysis of Crop Yields: Districts of Andhra Pradesh.

Dist.	Rice	Jowar	Bajra	Ragi	Maize
SV	NGR VP(1962)	D	VNP NSC	NGR VNP	D
EG	VNP NSC	D	D	D	D
WG	VP(1976) SCA	D	D	D	D
KR	VNP NSC	D	D	D	D
GN	VP(1976) SCA	NGR VNP	NGR VNP	VNP SCO(1965)	D
KU	VNP NSC	VNP SCO(1968)	D	D	D
AN	VNP SCO(1976)	VNP SCO(1975)	NGR VNP	VNP SCO(1970)	D
CU	VNP NSC	VP(1966) SCA	VNP NSC	VNP SCO(1973)	D
CH	VNP NSC	NGR VNP	NGR VP(1978)	NGR VP(1966)	D
RH	VNP SCO(1974)	NGR VNP	D	NGR VNP	NGR VNP
NZ	VNP NSC	NGR VNP	D	D	VNP NSC
ME	VNP NSC	NGR VNP	D	D	NGR VNP
MB	VNP NSC	NGR VNP	NGR VNP	NGR VNP	D
NA	VNP NSC	NGR VNP	NGR VNP	D	D
WA	VNP NSC	NGR VNP	D	D	VNP SCO(1977)
KH	VNP NSC	NGR VNP	D	D	D
KM	VNP NSC	NGR VNP	D	D	VP(1975) SCA
AD	VNP NSC	NGR VNP	D	D	VNP NSC

Notes: NGR : No growth (poor fit $\bar{R}^2 < 0.4$) cases;

D : These crop cases were dropped from the analysis;

VP : Variability change present (variability change point in bracket);

VNP : Variability change not present;

SCO : Structural change occurred (structural change point in bracket);

NSC : No structural change occurred;

SCA : Structural change ambiguous (these cases show variability change and hence structural change analysis was not carried out);

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam;

EG : East Godavari; WG : West Godavari; KR : Krishna;

GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur;

CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad;

NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda;

WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

2) only in 4 of them the growth was accompanied by an increase in (absolute) variability.

3) Of the 25 growth cases that did not show any change in variability 8 show a structural change in the growth path.

II. 4) 23 out of 52 crop cases do not show any growth in yield.

5) While 2 of them face an increase in absolute variability around a stagnant yield level,

6) 1 shows a reduction in variability (both absolute and relative) around a stagnant yield level.

The variability analysis results suggest that

1) Growth has no relationship with changes in variability,

2) Traditional seeds grown with or without irrigation in general did not show changes in yield variability though rice(SV), jowar(CU) and ragi(CH) remained as exceptions.

3) High yielding variety seeds (HYV) grown with irrigation in general did not show changes in yield variability though rice(WG), rice(GN) and maize(KM), remained as exceptions.

The above pattern at the districts level is broadly consistent with the pattern observed at the State level in the previous chapter.

The structural change analysis shows that except in 2 districts, the trends in rice yields in Andhra Pradesh could not be substantially pushed upwards during the era of modern technology.

As mentioned earlier, in this chapter yield characteristics were studied in the time domain alone; i.e., time was the only explanatory variable considered in this analysis. This framework permits us to draw conclusions about the growth, variability changes and stability of the growth path only with reference to "over time" but not "over input levels". As argued in chapter 5, variability change can be validly related to changes in input variables only by means of input-output relationships. Thus we require estimation of input-output relationships. In the next chapter, the technological characteristics of yields at the districts level are studied by relating yield levels to levels of inputs like fertilizer, irrigation, and rainfall.

Chapter 8 – Estimation of Yield Response Functions: Districts of Andhra Pradesh

Hoare's law of large problems:

"Inside every large problem is a small problem struggling to get out!"

8.1 Introduction.

We argued earlier in chapter 5 that the nature of variability and changes in it can be different as observed along a time trend versus as observed along an input-output relation (here, yield response function). The framework of the analysis based on the yield response functions will henceforth be referred to as "response function framework" to distinguish it from the "time trend framework". Analysis in the response function framework has obvious advantages. For example, variations in yield levels could be specifically related to variations in rainfall as well as farm inputs - which is not possible in the case of analysis with time trends alone. It is very much possible that farmers on their own will could be varying the input levels subject, of course, to their expectations on prices, revenues and ultimate profits[1]. In such a case, given the underlying yield response function, variations in yield due to variations in farm inputs must be accounted for before changes in variability around the expected values are analysed. It is then obvious that production functions which explain yield responses in terms of levels of various inputs have to be estimated first. This chapter is devoted for this purpose.

For some theoretical as well as empirical considerations

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1 The input and output prices do not explicitly enter into our analysis. Since they, however, ultimately reflect on the input levels on which farmers have reasonable control, only the latter enter directly into our analysis.

elaborated in a later section the response functions could not be estimated for crop yields at all India and Andhra Pradesh State levels. The estimation is restricted only to crop cereal yields at the district level for the 18 districts of Andhra Pradesh (AP). The analysis at the district level is done for the period 1960-61 to 1984-85 for which continuous time series data on yields and various inputs are available at the district level.

Structural change analysis in the response function framework (RFF henceforth) is not conducted as there are too few observations available on all the variables at the district level corresponding to the pre-Green Revolution period.

8.2 Estimation of Yield Response Functions.

8.2.1 Functional Form for the Yield Response Functions.

This exercise starts with the specification and estimation of a yield response function. A yield response function relates crop yield levels (Y) to the levels of inputs used like fertilizer intensity (F), irrigation intensity (I), rate of adoption of high yielding variety seeds (HYV), rainfall (R) and other inputs (Z).

$$Y = f(R,\ F,\ I,\ HYV,\ Z)$$

The estimated functional form (f.f.) for the yield response function must satisfy all the econometric criteria specified in chapter 5. These are:

(1) The 2 measures of nonlinearity, intrinsic nonlinearity (IN) and parametric effects (PE) nonlinearity, must be insignificant as per the F test (see chapter 5 for details).

(2) The estimated parameters must be unbiased and consistent. The bias in the parameter estimates as measured by Box's percentage bias (BB) must be close to zero.

(3) The parameters must be normally distributed. The skewness in the parameter's distribution as measured by Hougaard's skewness (SK) measure must be close to zero for normality of the

parameter's distribution.

(4) Autocorrelation among errors, if exists, must be corrected for while estimating the f.f. Where auto correlation is found to be present (as shown by the Durbin-Watson (DW) statistic) a first-order auto regressive scheme is assumed and the f.f. is re-estimated along with the autocorrelation (ρ) parameter.

(5) The chosen f.f. must have the highest fit in terms of $\bar{R}^2$ among all the estimated f.f. that satisfy the above criteria (1) to (4). The estimated coefficients must be significant with correct signs.

Apart from these econometric considerations, the chosen f.f should also satisfy the additional constraint that the expected yield level should be positive even if some (not all) input levels (fertilizer used, irrigation, etc.) are set to zero. For example, the Cobb-Douglas type function $Y = aR^bF^cI^d$, (where Y, R, F, I are as defined earlier) would not satisfy this property since Y becomes zero even if just one of the variables (R, F and I) takes a zero value[2]. But in reality one can obtain some positive level of yield for a crop even if some of the input variables are zero. Thus a crop may still give positive yields when it is grown under unirrigated conditions without applying any fertilizers. The yield response function should be able to account for such a possibility.

Even the specifications such as the Constant Elasticity of Substitution (CES) production function or the Transcendental Logarithmic (Translog) production function are not free of problems. For example, a CES production function represented as

$$Y_t = \gamma\left[\delta I_t^{-\rho} + (1-\delta)F_t^{-\rho}\right]^{-\nu/\rho}$$

$$(\gamma > 0; \quad 1 > \delta > 0; \quad \nu > 0; \quad \rho \geq -1)$$

leads to problems while estimation because δ/I_t^{ρ} becomes infinity if $I_t = 0$ for any year. Similarly, in the case of translog function represented as

$$\log Y_t = \beta_0 + \beta_1 \log I_t + \beta_2 \log F_t + \beta_3 (\log I_t)^2 + \beta_4 (\log F_t)^2 + \beta_5 (\log I_t)(\log F_t)$$

2 For a critical discussion of this issue see Rudra (1982).

$\log I_t$ becomes undefined whenever $I_t = 0$ for any year. For more details on this see Kmenta (1990).

A linear (in parameters) function for the yield response function such as

$$Y_t = \beta_0 + \beta_1 {*} RSW_t + \beta_2 {*} RNE_t + \beta_3 {*} F_t + \beta_4 {*} I_t + \beta_5 {*} F_t^2 + \beta_6 {*} I_t^2 + \beta_7 {*} (F_t {*} I_t) + U_t \quad (8.1)$$

where, Y_t is yields at time t;
RSW_t is rainfall during South-West monsoon at time t;
RNE_t is rainfall during North -East monsoon at time t;
F_t is fertilizer intensity at time t;
I_t is irrigation intensity at time t;
U_t is random error;

would be free of the problems mentioned above. Further, such a linear function can be estimated using the Ordinary Least Squares (OLS) procedure. In this analysis, therefore, only linear functions of the type (8.1) specified above are considered for estimation. Such a specification for the response function would have the following implications:

(1) The marginal product of fertilizer and irrigation are given by $\delta Y/\delta F$ and $\delta Y/\delta I$, respectively.

$$\partial Y/\partial F = \beta_3 + 2\beta_5 F + \beta_7 I \quad (8.1a)$$

$$\partial Y/\partial I = \beta_4 + 2\beta_6 I + \beta_7 F \quad (8.1b)$$

That is, the marginal products of both F & I depend on both these inputs.

(2) The rate of change of the marginal products are given by $\delta^2 Y/\delta F^2$ and $\delta^2 Y/\delta I^2$.

$$\partial^2 Y/\partial F^2 = 2\beta_5 \quad (8.1c)$$

$$\partial^2 Y/\partial I^2 = 2\beta_6 \quad (8.1d)$$

Thus, β_5 and $\beta_6 < 0$ would imply diminishing marginal products.

(3) Assuming β_3, $\beta_4 > 0$ and β_5, $\beta_6 < 0$, the optimum levels of F ($=F^*$) and I ($=I^*$) for achieving maximum yields are given as follows:

$$F^* = \frac{\beta_4\beta_7 + 2\beta_9\beta_6}{4\beta_5\beta_6 - \beta_7^2}$$

$$I^* = \frac{\beta_9\beta_7 + 2\beta_4\beta_5}{4\beta_5\beta_6 - \beta_7^2}$$

For a linear function estimated by OLS procedure, by definition, IN, PE, BB and SK are all zero. That is we would obtain parameter estimators that are unbiased, normally distributed and have minimum variance. Specification (8.1) is estimated only with an additive error. As explained in chapter 5, absolute variability in yields is assessed using additive errors whereas relative variability in yields is assessed using multiplicative errors obtained from estimated yield function (see chapter 5 for details). In chapters 6 and 7 we observed that all the crop cases showing change in relative yield variability showed change in absolute yield variability also. However, the reverse is not true. The above pattern is expected to hold true here also under RFF. That is while all crop cases showing absolute variability change need not show a change in relative variability, it is expected that a crop that showed no change in absolute variability would not show a change in relative variability also. Therefore, in this analysis the yield response functions are estimated only in additive error form. Yield response functions in multiplicative error form are not estimated.

8.2.2 *Some Issues Related to Data Shortcomings.*

Annual aggregate crop yields: Ideally, yield response functions should be estimated separately for different water regimes (irrigated/unirrigated) and for different seed varieties (i.e., separate functions for traditional seed cultivation and HYV seed cultivation), since different seeds under different water regimes could lead to different yield responses with respect to input levels such as fertilizers, etc. Estimating separate yield functions according to the seed variety/water regime is, however, not possible here due to

i) lack of continuous time series data at the all India/State/ District level on seed-variety specific yields;

ii) lack of continuous time series data on application of inputs like irrigation, fertilizer, etc. for seed-variety specific cultivation; and

iii) in fact, with regard to fertilizer usage, let alone for seed-variety specific cultivation, even time series data on fertilizer use for individual crop levels are not available. The available district level fertilizer data relate to only total fertilizer consumption over all crops (cereals and non-cereals) put together but not separately for different crops - be they HYV based or traditional seeds based. More on this later.

For these reasons, estimating seed-variety/water regime specific yield functions could not be possible.

Yield response functions are estimated only using the data on aggregate annual crop yields at the districts level. Some elaboration may be required here. With respect to the available all India/State/District level data on aggregate crop yields, several types of aggregation are involved:

1) Geographical/spatial aggregation: District level data are the aggregates over numerous farms; State level data are aggregates over districts; and finally the all India level data are the aggregates over States.

The spatial dimension of the aggregation has some implications on the corresponding aggregate yield response function. For example, the all India level aggregate crop yields involve aggregation over different States which are vastly different in their agro-climatic environment, soil conditions, the level of development of agricultural infrastructure like irrigation, mechanization, etc. Difference in these factors play a crucial role in determining the different yield responses in different States. Thus, if one aggregate yield response function is estimated for entire India, it is very much likely that regional differences in yield response/performance are not properly accounted for.

The implication of this is that an analysis of yield variability, particularly in the response function framework should be based on yield functions estimated for a region with (near) homogeneous cropping conditions; that is, with similar rainfall pattern, soil conditions and other infrastructural conditions relevant for crop cultivation.

Districts being much smaller geographical units than a State, the cropping and economic environment may not vary considerably within a district (though these vary considerably across districts). An analysis of district level yields would then reasonably be free of any short comings arising due to spatial heterogeneity. Besides, districts are the smallest levels at which data are available. Hence, the variability analysis in the RFF is done only for crop yields at the district levels or (as we see later) for a group of districts with similar agricultural characteristics in AP. It is possible that contiguous districts face similar cropping environment, permitting us to put them together (if such a need arises) into (near) homogeneous groups. Aggregate yield functions separately estimated for such groups may be more appropriate than a single aggregate y.r.f estimated for the entire State.

2) Irrigation regimes: Some farms are completely rainfed while others have irrigation facility. Recall that in chapter 5 Part C, we estimated the irrigated and unirrigated yield levels for some crops using the districtwise data on aggregate output and irrigated and unirrigated acreages. These yield estimates obtained there correspond to the State as a whole but not to the individual districts. Since we do not have separate continuous time series data at the district level on irrigated and unirrigated crop yields, only the aggregate data over these two irrigation regimes are considered here.

However, though separate yield data are not available, such data on acreage do exist. Later, we use these data to identify the districts for each crop where it is irrigated and where it is not[a]

[a] as done in the previous chapter.

and attempt to analyse the yield behaviour in them separately to the extent possible.

3) *Seed regimes:* *Some crops in AP are still predominantly* based on traditional seeds; for example, ragi in all the districts of AP. Likewise, some crops are predominantly based on HYV seeds; for example, rice in almost *all districts of* AP. *However, for some* crops the HYV adoption has been neither zero as in the case of ragi nor near cent percent as in the case of rice. There are no official time series data available at the district level on yields separately for these seed regimes and hence we are constrained to deal with only the data aggregated over traditional and HYV seed regimes.

A yield function estimated for crop yields aggregated over seed varieties has then the limitation that the estimated elasticity of yield to a particular input would represent only the aggregate responsiveness (over all seed varieties) of that crop's yield to the input considered. Then, the results of our analysis using aggregate yields would also be aggregative (over all seed varieties) in nature. This point has to be borne in mind while interpreting our results since it is possible that yields of different seed varieties could have opposite kinds of change in their variability so that aggregate yields may not show any variability change.

4) **Seasons:** There are basically two broad seasons: kharif and rabi. The kharif season covers the months June-October and rabi season covers the months *October-February*. Most of the rainfall (90%) occurs in the South-West monsoon during June-September meeting the water requirements for kharif season. Since the relatively less rainfall during North-East *monsoon*, occurring in October-December, may not be sufficient to meet the water requirement in the corresponding rabi season, irrigation is supposed to provide the required water input. However, since irrigation is not exclusively devoted to only rabi season one should not count that all kharif as unirrigated and rabi as irrigated.

Though for rice and jowar seasonwise yield data at district level are available from 1967-68 onwards, corresponding seasonwise input data are, however, not available. Hence our analysis in this chapter confines to only aggregate yield levels[4]. Aggregation over different cropping seasons also has some implications for an annual aggregate yield response function. A yield function estimated using annual aggregate yields assumes that the yield elasticity to various inputs is the same in both kharif and rabi seasons. This, however, need not be so in reality.

<u>To sum up:</u> The variability analysis in RFF is done at districts level using annual aggregate yields for which time series data are available from 1960-61 onwards. The results at the districts level, being reasonably free of the shortcomings arising out of spatial heterogeneity for the reasons mentioned above, however, are subject to the limitations of aggregation over seed varieties, water regimes and over seasons. These limitations of this analysis are entirely due to the absence of appropriate time-series data on yields and inputs used.

Some estimation problems: At the time of estimation, three problems arise:

One, the lack of time series data on cropwise fertilizer use.
Two, the lack of time series data on acreage under HYV at the district level;
Three, problem of multicollinearity between the input variables (rainfall, irrigation and fertilizer).

While the first of these is discussed below, the other two will be taken up in the next section.

Fertilizers data: Strictly, fertilizer intensity in equation (8.1) should be crop specific, defined as follows:

$$\text{Fertilizer intensity of crop i} = \frac{\text{Fertilizer used for crop i (Kg)}}{\text{Acreage under crop i (Ha)}} = F_i / A_i$$

4 Since input data are not required in the previous chapter, the seasonwise data of rice and jowar could be analysed there.

However, lack of cropwise fertilizer use data is a major problem while estimating yield response functions. The only data on fertilizer available are the total consumption of fertilizer over all crops in each district. In such a situation, a somewhat simple (if not crude) way of accounting for fertilizer use is, therefore, adopted here. In the light of the discussion in section 3.5.6 (chapter 3) recall that rice usually claims a large proportion of the total fertilizer whereas each of the other 4 cereal crops (jowar, bajra, ragi and maize) claims only a minor proportion of the remaining fertilizer available. Further, it was also reported that according to Vaidyanathan (1993) the cropwise shares in total fertilizer consumption have rather been stable over time. It may then be assumed that fertilizer use for a crop (i) is some fixed proportion of the total fertilizer consumption; i.e., $F_i = \gamma_i T_F$, where $T_F = \Sigma F_i$ = total fertilizer consumption over all crops, and γ_i is constant.

Then, a proxy variable for fertilizer intensity for rice (FRCE) can be defined as the ratio of total fertilizer consumption to the total acreage under rice cultivation.

$$FRCE = \frac{\text{Total Fertilizer (nutrients) Consumption in kg}}{\text{Area under rice cultivation in ha}}$$

While using FRCE in equation (8.1) the proportionality constant, γ_i (i = rice), would be subsumed in the regression coefficient for fertilizer intensity variable.

However, for the other cereal crops (jowar, bajra, ragi and maize) the ratio of total fertilizer consumption to the acreage under the 5 cereal crops put together is used as a proxy for fertilizer intensity for these crops (denoted by F).

$$F = \frac{\text{Total Fertilizer (nutrients) Consumption in kg}}{\text{(ARCE + AJWR + ABJR + ARGI + AMZE) in ha}}$$

where ARCE, AJWR, ABJR, ARGI and AMZE are the acreages under rice, jowar, bajra, ragi and maize, respectively.

The fertilizer variable F used in the regression analysis for the inferior cereals may be justified for the following 3 reasons:

a) At the AP State level, according to NSSO (1978), in 1971-72, rice accounts for 60.5%, jowar 1.9%, bajra 0.73%, ragi 0.76% and maize 3.37% of the total fertilizer consumption over all crops. These are the γ_i mentioned above. In the absence of such data at the districts level, can one assume the State level percentages (γ_i) to be applicable to even districts? To verify this, districtwise fertilizer intensities were computed for the year 1971-72 using the districtwise data on total fertilizer and crop acreages using the State level percentages (γ_t) reported above. The following table is the result of these computations.

Fertilizer intensities (Kg/Ha): Cropwise, 1971-72.

	Rice	Jowar	Bajra	Ragi	Maize	Total Cereals
% of total fertilizer	60.56	1.92	0.73	0.76	3.37	67.93
AP	55.42	2.11	38.92	7.76	34.61	28.48
SV	17.34	11.28	1.28	1.09	147.55	13.72
EG	35.09	42.66	8.82	24.55	525.81	35.93
WG	51.13	54.20	216.54	123.60	1372.45	55.14
KR	54.03	7.91	118.34	470.24	890.85	49.39
GN	63.58	4.27	5.25	10.43	1570.24	42.03
KU	122.56	1.31	6.64	400.85	3070.94	32.77
AN	57.56	0.90	0.78	1.58	189.07	14.68
CU	131.91	2.17	4.45	5.00	31579.99	40.94
CH	87.16	26.57	4.65	2.93	3159.45	57.34
RH	123.57	1.24	5.85	7.62	34.28	64.79
NZ	141.39	4.13	5015.89	69.90	12.12	57.44
ME	49.49	0.67	7.67	6.03	3.29	12.69
MB	56.72	0.40	0.94	2.41	15673.24	9.71
NA	19.53	0.61	0.35	174.82	134.03	8.10
WA	102.88	1.36	5.21	3132.53	8.87	26.90
KH	95.23	0.78	16.57	502.81	35.90	20.98
KM	76.83	1.39	2624.84	819.81	3.62	21.59
AD	9.35	0.05	22.05	0.00	0.93	1.44

Looking at the districtwise cropwise intensities rice intensity varies between 9.35 Kg/Ha (AD) and 141.39 Kg/Ha (NZ). Similarly, for jowar the range is between 0.05 Kg/Ha (AD) and 54.2 Kg/Ha

(WG); for bajra 0.35 Kg/Ha (NA) and 5016 Kg/Ha (NZ); for ragi 0 Kg/Ha (AD) and 3132 Kg/Ha (WA); for maize 0.9 Kg/Ha (AD) to 31580 Kg/Ha (CU). Obviously, by no stretch of imagination these fertilizer intensity figures at the district level for the inferior cereals can be realistic. That is, the percentage composition observed at the State level are not valid at the districts level. So, dividing T_F by the individual cropwise acreage (i.e., T_F/A_i) to specify as cropwise fertilizer intensity variable in the regression does not seem to be alright.

However, in the above table, the intensity figures for rice as well as total cereals seem to be not too unrealistic. Hence, for the rice yield regressions the fertilizer variable is specified as FRCE = T_F/ARCE (defined above) whereas for the inferior cereals yield regression it is specified as F = T_F/Acreage under all cereals ($T_{Acereals}$). This way, the variation in the fertilizer intensity variable (F) has atleast been kept in a realistic range.

b) Whatever may be the correct values of γ_i at the district level, as long as they are fairly stable over time they can be treated as constants. In addition, as observed in chapter 3 (table 3.15) the crop shares (δ_i) in total cereals acreage too have been stable over time; in which case in fact one can write

$$\frac{F_i}{A_i} = \left(\frac{\gamma_i}{\delta_i}\right) \times \frac{T_F}{T_{Acereals}} \qquad \text{(i = jowar, bajra, ragi \& maize)}$$

where the bracketed term can be treated as a constant to be subsumed in the estimated regression coefficient of the fertilizer variable.

c) F_i/A_i on which though data are not available are well known in general to be dependent on the fertilizer availability. Thus, F_i/A_i is a function of $T_F/T_{Acereals}$. Hence, $T_F/T_{Acereals}$ in the place of F_i/A_i is justifiable.

In the light of the above discussion, the above defined proxy variables seem to be adequate enough for inclusion in the regression analysis later.

Apart from fertilizer, there are no cropwise continuous time series data at the district level for some other important input variables also affecting crop yield levels like labour, mechanization, pesticides used, etc. These variables could, therefore, not be accounted for in the yield response functions estimated here.

8.2.3 Other Data Issues and Multicollinearity.

1) High yielding varieties acreage and fertilizer application data: Lack of time series data at the district level on cropwise acreage under HYV is another problem encountered while estimating yield response functions at the district level[5]. Therefore, the HYV adoption rates do not directly figure in our estimation. However, they do figure in indirectly in the sense that fertilizers and HYV application are generally considered as a package of technology i.e., they are complementary inputs (Also, see Parikh (1978)). Indeed at the AP State level, proportion of HYV acreage and fertilizer intensity are highly correlated. The simple correlation coefficient between fertilizer intensity (FRCE and F defined above) and cropwise HYV proportions (HYV acreage of a crop as a proportion of the total acreage under the crop) computed over the period 1966-67 to 1984-85 at the AP State level are 0.91 for rice, 0.94 for jowar, 0.96 for bajra and 0.95 for maize. There are no HYV for ragi. Such high correlations indicating multicollinearity between fertilizer use and HYV adoption are expected in the districts too. Given this, the fertilizer variables FRCE and F which figure in the yield response function would indirectly account for the effect of HYV adoption rates also.

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5 ICRISAT and Evenson provide time series data on HYV acreage, at the district level. For many years, the total over districts from these data, however, were found to vary substantially from the State total data given by the Ministry of Agriculture. These data could not hence be used. For further details, see chapter 5, section 5.16.5.

2) **Multicollinearity amongst other input variables:** In fact, the problem of multicollinearity amongst the input variables turned out to be rather serious one. The input variables at the district level are found to be highly correlated in most of the districts, though there are a few exceptions. Let us now briefly report on our experience with the estimations of y.r.f. carried out for the important crop cases at the districts levels separately. In general 2 problems were encountered:

a) Multicollinearity between input variables.

In the case of rice, the correlation between FRCE and irrigation intensity for rice was found to be generally high in most districts. For example, in WG[σ] this is 0.76. Such high correlations were found in many districts for other crops too. The high correlations did not permit estimation of separate y.r.fs for each crop in each district. As mentioned earlier, some crop cases, however, stood as exceptions, the corresponding inputs of which did not show severe multicollinearity.

b) Yield response functions estimated for these exceptional cases often turned out with poor fits in terms of $R^2/\bar{R}^2$.

Only in 4 cases separate y.r.fs at the district level could be estimated. These are: jowar(KU), jowar(KH), bajra(SV) & ragi(SV).

Thus, the problem of multicollinearity made it impossible most of the times to estimate yield response functions for each crop in each district separately. Results of the few exceptional cases mentioned above will be discussed later.

What could be a way out now!

Since multicollinearity is essentially a data problem, we thought of pooling the data of some districts and see whether the

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σ **District codes:** SV - Srikakulam + Vizianagaram + Vishakhapatnam; GN - Guntur + Prakasam + Nellore; RH - Ranga Reddy + Hyderabad; EG - East Godavari; KR - Krishna; KU - Kurnool; AN - Anantapur; WG - West Godavari; CU - Cuddapah; ME - Medak; CH - Chittoor; MB - Mehboobnagar; NA - Nalgonda; KH - Khammam; NZ - Nizamabad; KM - Karimnagar; WA - Warangal; AD - Adilabad;

pooling has effected a reduction in the degree of correlations between the explanatory variables. Districts with similar characteristics are grouped together and their data are pooled. Note that it is only pooling; not aggregating. For the pooled data the correlations among the input variables are found to be low[7]. A common yield function is, then, estimated using the pooled data for all the districts together in the group. Such a common yield function, however, would imply that yield response to the input variables is assumed to be same in all the districts in that group. However, as explained in the previous section, this need not be a serious short coming as the districts are grouped based on their similarity of their agricultural characteristics. Under such a situation one may expect the inter-district differences in the yield response to various inputs to be only marginal. The grouping of the districts is discussed in the next section.

8.3 Grouping of Districts.

The objective here is to group the districts with similar characteristics together so that a common yield function for the group as a whole is valid in the sense yield response is same in all these districts. The question here is - What should be the criterion for grouping the districts?

Districts can differ among themselves with respect to
a) natural endowments in terms of soil fertility, agro-climatic conditions including rainfall pattern, etc.,
b) infrastructural facilities in terms of irrigation facilities available, etc., and
c) farmers' cultivation practices.

Now let us see how far these criteria would help us in classifying the AP districts into homogeneous groups.

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7 A typical example for the correlation observed at the group level will be provided later.

8.3.1 Natural Endowments.

Taking rainfall pattern to be an indicator of natural endowment for agriculture one can classify the districts according to the rainfall.

National Commission on Agriculture (1976), in their study on rainfall and cropping patterns in India, divided Andhra Pradesh mainly into 28 different rainfall zones and identified different parts of various districts falling into these zones. These details are given in the appendix 8.A1 to this chapter. From these details, we find that the rainfall pattern in AP varies from district to district. Besides, there is no one to one correspondence between districts and rainfall patterns. For example, entire Medak district has an uniform rainfall pattern and so has Nalgonda district. But within Guntur district itself 4 kinds of rainfall patterns prevail.

However, as mentioned earlier, districts are the smallest levels at which cropping data are available. Yields data are not available at the rainfall zone level within each district. Thus, rainfall pattern could not be used as the criterion for grouping the districts.

8.3.2 Infrastructural Facilities.

Alternatively, one may group the districts based on their infrastructural characteristics. Under infrastructural variables, one may look at irrigation availability, electricity, road-network, etc. Of them irrigation is an important factor directly affecting crop yields. Besides, we have reliable time series data on irrigation within each district, i.e., the sources of irrigation and their extent within each district. Hence this factor may be used as the criterion for classifying districts into homogeneous groups.

Grouping based on sourcewise irrigation characteristics: In the background on sourcewise irrigations (discussed in detail in the appendix 8.A2 at the end of this chapter), the districts of AP are found to fall into the following groups based on the characteristics of irrigation regimes:

G1) Irrigation is mostly by canals under surface water (SW) (≥ 50% of the total net irrigated area (TNIA)); ground water (GW) sources contribute only a little to TNIA (< 25% of TNIA): EG, WG, KR, GN, KU & NZ districts.

G2) Irrigation is mostly by tanks under SW (≥ 25% of TNIA) with a high percentage of GW (≥ 25% of TNIA): CH, RH, ME & MB districts.

G3) Irrigation is mostly by tanks under SW (≥ 25% of TNIA) with a little GW (< 25% of TNIA): SV & WA districts.

G4) A shift from tanks to canals under SW with high percentage of GW (≥ 25% of TNIA): AN, CU, NA & KM districts.

G5) A shift from tanks to canals under SW with very little GW (< 25% of TNIA): KH & AD districts.

Table 8.1 gives the names of districts under the above groupings. In the rest of this chapter the 5 groups are denoted as G1, G2, G3, G4 and G5, respectively.

Having classified the 18 districts into 5 different groups, the district level time series data on various variables within each group are pooled for estimating the group level yield response functions. In all, there are (5 crops × 5 groups =) 25 group-wise crop cases for estimation at this stage.

Pooled data and multicollinearity at group-level data: Grouping of districts was resorted to as a possible way out of multicollinearity problem faced at the level of individual districts. In order to verify if this step has been effective in overcoming multicollinearity correlations amongst the input variables were computed using the pooled data. These correlations were found to be low suggesting that multicollinearity is not a serious problem with the pooled data. For example, the correlation between

	Characteristic	Districts
oup 1: 1)	Surface water is mostly through canals; very little ground water.	EG, WG, KR, GN, KU, NZ
oup 2: 2)	Surface water is mostly through tanks; a high percentage of ground water.	CH, RH, ME, MB
oup 3: 3)	Surface water is mostly through tanks; very little ground water.	SV, WA
roup 4: 34)	Under surface water, canals gaining importance over tanks A high percentage of ground water.	AN, CU, NA, KM
roup 5: 35)	Under surface water, canals gaining importance over tanks very little ground water.	KH, AD

odes: SV : Srikakulam + Vizianagaram + Vishakhapatnam;

EG : East Godavari;	WG : West Godavari;	KR : Krishna;
GN : Guntur + Prakasam + Nellore;		KU : Kurnool;
AN : Anantapur;	CU : Cuddapah;	CH : Chittoor;
RH : Ranga Reddy + Hyderabad;		NZ : Nizamabad;
ME : Medak;	MB : Mehboobnagar;	NA : Nalgonda;
WA : Warangal;	KH : Khammam;	KM : Karimnagar;
AD : Adilabad;		

fertilizer and irrigation intensity for rice for G1 turned out to be as low as -0.09 though the same for WG (included in G1) is as high as 0.76 as reported earlier. This implies that estimations of yield response functions can be carried out using the pooled data.

But it may be mentioned here that multicollinearity due to correlation between fertilizer and its square term, irrigation and its square term may still be there (see equation 8.1 above). This is unavoidable given the specification involving both the variable and its quadratic term. This point has to be kept in mind in the course of the discussion of the estimation results.

Group level Yield Response Functions: To start with, the linear f.f. 8.1 specified earlier in section 8.2.1 for the yield response function has been estimated for each of the 25 group level crop cases using pooled data and the OLS procedure. Of these 25, in 13 cases the fits obtained were poor ($\bar{R}^2 < 0.4$). Only in 12 cases the fits were satisfactory ($\bar{R}^2 \geq 0.4$). In 9 of these 12 cases, correction for autocorrelation was required. These 12 group level crop cases are as follows:

Crop	Group*	%of Stateproduction in 1984-85 coveredby the estimations
rice	G1, G2, G3, G4, G5	100.0
jowar	G4	18.0
bajra	G2, G4	36.0
ragi	G1, G2	53.0
maize	G2, G3	23.0

* See table 8.1 for the list of the districts in the groups.

The estimation results for these 12 cases will be discussed in section 8.5. Right now, let us note 2 points:

a) Though all the rice cultivation (in terms of percentage of State production) was covered by the above group level estimations, only small parts of other crops' cultivation was covered by them. That is, large parts of jowar, bajra, ragi & maize cultivations still need to be explained.

b) Within any single group the constituent districts may still vary widely according to cultivation practices adopted.

Both these points lead us to estimate y.r.fs at different levels also other than only at the group levels. We now, further classify these groups into sub-groups.

8.3.3 Cultivation Practices.

This is the third criterion that was mentioned in the beginning of the section 8.3. Earlier while discussing the analytical implications of using aggregated data, it was pointed out that acreage data, but not yield data are available at districts level, separately for irrigated and unirrigated regimes of a crop. At the AP State level this problem was surmounted by estimating time series of these yields using districtwise cross section data where a crop's total output was regressed on its irrigated and unirrigated acreages (see chapter 5, Part C).

Without recourse to such indirect estimations it is still possible given the acreage data, to distinguish the crops atleast into mostly irrigated part and mostly unirrigated part. In table 8.2, for each district, cropwise data on the average (over 1978-79 to 1984-85) gross irrigation intensities (defined as gross irrigated area as proportion in the crop's cultivated area) are presented. The table also reports districtwise data on irrigation facility available (net irrigated area/net sown area of all crops).

Looking at the extent of irrigation facility available versus cropwise irrigation intensities, it can be seen from table 8.2 that there are large differences among the districts. First, there are wide differences across districts in the extent of irrigation. In 1984-85, the proportion of total net irrigated area in total net sown area varied from about 80% in West Godavari to only about 7% in Adilabad. Secondly, the cropwise gross irrigation intensities, however, present a different kind of picture. From table 8.2 it can be seen that rice is a highly irrigated crop in all the districts. Even in AD district, which has the lowest overall irrigation proportion and where rice is the second most important ble 8.2 – Cropwise Gross Irrigation Area Proportion in Gross Cultivated Area (Average Over The Period 1978-79 To 1984-85).

District	Rice	Jowar	Bajra	Ragi	Maize	NIA/NSA*
SV	0.877	0.000	0.000	0.156	0.022	0.477
EG	0.951	0.051	0.000	0.003	0.254	0.630
WG	0.983	0.013	0.029	0.048	0.591	0.796
KR	0.993	0.002	0.005	0.051	0.272	0.698
GN	0.971	0.024	0.440	0.975	0.189	0.490
KU	0.888	0.009	0.007	0.144	0.585	0.142
AN	0.991	0.048	0.039	0.887	0.567	0.133
CU	0.991	0.015	0.428	0.990	0.980	0.289
CH	0.909	0.174	0.211	0.296	0.812	0.299
RH	0.882	0.004	0.010	0.002	0.069	0.125
NZ	0.942	0.004	0.983	0.002	0.141	0.504
ME	0.909	0.000	0.002	0.002	0.030	0.234
MB	0.928	0.001	0.003	0.021	0.421	0.106
NA	0.999	0.001	0.000	0.796	0.040	0.264
WA	0.950	0.000	0.010	0.226	0.359	0.343
KH	0.768	0.000	0.030	0.283	0.154	0.212
KM	0.986	0.004	0.600	0.000	0.391	0.398
AD	0.655	0.002	0.085	0.999	0.142	0.068
AP	0.943	0.008	0.113	0.350	0.223	0.336

otes: * : Total net irrigated area/Total net sown area in 1984-85.

odes: SV : Srikakulam + Vizianagaram + Vishakhapatnam;
EG : East Godavari; WG : West Godavari; KR : Krishna;
GN : Guntur + Prakasam + Nellore; KU : Kurnool;
AN : Anantapur; CU : Cuddapah; CH : Chittoor;
RH : Ranga Reddy + Hyderabad; NZ : Nizamabad;
ME : Medak; MB : Mehboobnagar; NA : Nalgonda;
WA : Warangal; KH : Khammam; KM : Karimnagar;
AD : Adilabad; AP : Andhra Pradesh (all districts);

cerea. crop, an average [illegible] tion. In most of the dis[illegible]s, we[illegible] over 90% o[illegible] th[illegible] [illegible] acreage is irrigated. In the cas[illegible] of jowar, the average (over [illegible]78-[illegible] to 1984-85) gross irrigation intensity ranged only between [illegible]0% (SV, ME, WA and KH) to about [illegible]7% in CH. Thus, the districtwise differences as far as rice and jowar irrigation intensities are concerned, are only marginal. The other crops though on average have low irrigation intensities show wider differences across districts. In the case of bajra the gross irrigation intensities are [illegible]ow in most districts, although in NZ its intensity is as high as for rice, and moderate in GN, CU, NZ and KM districts. The average gross irrigation intensity in these latter districts is GN - 44%, CU - 42%, NZ - 98% and KM - 60%. The case of ragi is similar to that of bajra, where again ragi is largely unirrigated in most districts though in a few districts (GN, AN, CU, NA and in particular, AD) it is almost fully irrigated. A notable feature is that atleast some amount of maize is grown under irrigation in every district. Gross irrigation intensity for maize ranged between 2% (SV) and 98% (CU). The districts with a high gross irrigation intensity for maize are WG, KU, AN, CU, CH, MB, WA and KM. The remaining districts have less than a third of maize under irrigation.

Sub-grouping based on cropwise gross irrigation intensities: Given these cropwise and districtwise differences in the gross irrigation intensities which to some extent reflect cultivation practices, the districts within each group are further classified for each crop. Considering an arbitrary cut-off point of 0.35 for the irrigation intensity, the districts in each (total) group (G1, G2, G3, G4 & G5) were separated into two sub-groups as "highly/moderately irrigated" and "lowly irrigated" categories, denoted as A and B respectively. Thus, for example, G1A refers to sub-group of districts "highly/moderately irrigated" under group 1, G1B to subgroup of districts "lowly irrigated" under group 1; and so on[a].

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a A crop with 50% of its cultivated acreage under irrigation in a district may not be considered as "highly" irrigated in that district. Such crop cases may be considered as moderately irrigated.

in all the districts in each group [illegible] sub-grouping within any group was possible for these two crops. This is as the districts fall in the class of highly irrigated in the case of rice and in the class of lowly irrigated in the case of jowar. These group level estimations were already carried out in the previous section.

Coming to bajra, ragi and maize crops, their irrigation intensities widely varied over the districts within each group. Sub-classification of the districts with respect to each of these crops in each total group is made. These details are given in table 8.3. Thus we have 2 sub-groups within each of the 5 groups for these 3 crops, i.e., total 2x5x3 = 30 crop cases at sub-group level.

Of these 30 cases, estimations were, however, carried out only for 13 of them since either there are no districts at all in some sub-groups (see table 8.3) or all the districts together in a sub-group do not contribute significantly to the State total output[9].

Pooled data & multicollinearity at sub-group level data: As with the total group crop cases, for each of the 13 sub-group crop cases the corresponding district level data are pooled. Then presence of multicollinearity amongst the input variables is checked by computing correlations between the input variables using the sub-groupwise pooled data. These correlations (not

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9 In all there are 7 cases out of 30 at the sub-group level without any district. These are bajra in G2A, G3A, G5A; ragi in G2A & G3A; maize in G3A & G5A. Of the remaining 23 cases, 10 were dropped from the analysis as being unimportant since all the districts together in each of these sub-groups together contribute only marginally to the the State's total output. These 10 cases are - bajra in G1B & G5B; ragi in G1B, G4B, G5A & G5B; maize in G1A, G2A, G4B & G5B. Only the remaining 13 sub-group cases are considered as important for analysis here.

Table 8.3 – Sub-grouping Of AP Districts Within Each Total Group Based On Gross Irrigation Intensity,[1] Cropwise.

	Total Group	Highly/Moderately Irrigated[2] Sub-Group A:	Lowly Irrigated[2] Sub-Group B:
Rice	G1	EG WG KR GN KU N2	...
	G2	CH RH ME MB	...
	G3	SV WA	...
	G4	AN CU NA KM	...
	G5	KH AD	...
Jowar	G1	...	EG WG KR GN KU N2
	G2	...	CH RH ME MB
	G3	...	SV WA
	G4	...	AN CU NA KM
	G5	...	KH AD
Bajra	G1	GN N2	EG WG KU KU
	G2	...	CH RH ME MB
	G3	...	SV WA
	G4	CU KM	AN NA
	G5	...	KH AD
Ragi	G1	GN	EG WG KR KU N2
	G2	...	CH RH ME MB
	G3	...	SV WA
	G4	AN CU NA	KM
	G5	AD	KH
Maize	G1	WG KU	EG KR GN N2
	G2	CH MB	RH ME
	G3	...	SV WA
	G4	AN CU KM	NA
	G5	...	KH AD

Notes: 1 Gross irrigated area under crop / gross cultivated area under crop.

2 A crop is considered lowly irrigated if its gross irrigation intensity is ≤ 0.35; otherwise it is highly/moderately irrigated. See table 8.2 for average gross irrigation intensities.

Groups: G1 : EG, WG, KR, GN, KU, N2; G2 : CH, RH, ME, MB; G3 : SV, WA; G4 : AN, CU, NA, KM; G5 : KH, AD;

See notes to table 8.2 for district codes.

reported here showed that the degree of multicollinearity is low here also.

For each of the 13 sub-group crop cases, the linear f.f. 8.1 specified earlier for the yield response function is estimated using the pooled data. Only in 5 of the 13 cases, the estimations resulted in poor fits ($\bar{R}^2 < 0.4$). In the other 8 cases the fits were satisfactory. The sub-group level estimation results will also be discussed in section 8.5. The 8 sub-group crop cases for which we have yield response functions are

Crop	Sub-Groups	% of State production in 1984-85 covered by the estimations
bajra	G1A, G2B, G4A	57.0
ragi	G2B, G4A	51.0
maize	G1B, G3B, G4A	81.0

The 3 underlined cases in the above table are cases for which all the districts of the corresponding total group fall in the same sub-group (just as in the case of rice & jowar crops). Hence for these 3 cases the sub-group estimation is the same as that for the total group as a whole. Now with these sub-group level estimations, though a large part of maize remains explained, the explained part of bajra, ragi and obviously jowar still remains low. This turns us to the district level estimations.

8.4 Some District Level Estimations.

In section 8.2.3 it has been mentioned that only a few district level cropwise estimations could be carried out. These are the following 4 cases: KU & KH for jowar and bajra & ragi in SV. KU and KH accounted for 20% and 11% of jowar output in the State in 1984-85, respectively. SV accounted for 32% of bajra and 30% of ragi output in the State in 1984-85. These are the 4 important crop cases which also do not suffer from the problem of multicollinearity due to correlation between fertilizer and irrigation intensity. Results under the individual y.r.fs for the 4 crop cases will also be discussed in next section 8.5.

8.5 Yield Response Functions: Estimation Results.

In all we have 12 (groupwise) + 5 (sub-groupwise)[10] + 4 (districtwise) = 21, estimated yield response functions for the 5 crops in AP. In this section, these estimation results are discussed. All these 21 different estimated y.r.fs have been reported in table 8.4. The coverage of these 21 estimations with regard to crops' total production in the State is fairly high now except in the case of jowar. These details are as follows:

Crop	Group/Sub-group/ District	%of State Output in1984-85 covered.	Equation No. in Table 8.4
Rice	G1⁺ G2⁺ G3⁺ G4⁺ G5⁺	100.0	1 to 5
Jowar	G4⁺ KU* KH*	50.0	6 to 8
Bajra	G1A@ G2⁺ G4⁺ G4A@ SV*	89.0	9 to 13
Ragi	G1⁺ G2⁺ G4A@ SV*	99.0	14 to 17
Maize	G2⁺ G3⁺ G1B@ G4A@	93.0	18 to 21

Notes: + : Total groups; @ : Sub-groups; * : Districts;

From table 8.4 we find that, for all these 21 yield functions the fits obtained have been fairly high in terms of R^2. The fit is highest in the case of bajra in G3 (equation 11), for which the R^2 is slightly greater than 0.9. For most of the crop cases, R^2 has ranged between 0.5 and 0.7.

Note that in equations 1, 2, 3, 5, 16 and 20, the constant term is negative. However, for all these cases, the expected yield level when computed for the lowest levels of fertilizer intensity and irrigation intensity observed over the sample data is still positive. Hence these estimations were retained as valid for the crop yields in those cases. The estimation results are discussed cropwise.

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10 Of the total 8 sub-group cases for which estimations are available 3 of them are same as the corresponding group level estimations. See last para of section 8.3.3 and also footnote 8.

Table 8.4 - Yield Functions: Andhra Pradesh Regions.

Rice: Equations 1 to 5*.

Equation (1)

Group - 1 [Districts: EG, WG, KR, GN, KU, NZ contributing 64.40% of State output in 1984-85].

$$Y_t = -2956.68 + 0.173*RSW_t - 0.184*RNE_t + 0.9052*FRCE_t + 4672.15*I_t + 0.699*U_{t-1} + \varepsilon_t$$
$$(-4.54)^{+} \quad (2.44)^{++} \quad (-2.98)^{+} \quad (2.80)^{+} \quad (6.75)^{+} \quad (10.57)^{+}$$
$$R^2 = 0.6629 \qquad \bar{R}^2 = 0.6512$$

Equation (2)

Group - 2 [Districts: CH, RH, ME, MB contributing 8.53% of State output in 1984-85].

$$Y_t = -1936.70 + 0.355*RSW_t + 0.762*RNE_t + 3.2496*FRCE_t - 0.0076*FRCE_t^2 + 3146.27*I_t + 0.637*U_{t-1} + \varepsilon_t$$
$$(-2.86)^{+} \quad (3.32)^{+} \quad (3.57)^{+} \quad (4.14)^{+} \quad (-4.36)^{+} \quad (3.96)^{+} \quad (7.46)^{+}$$
$$R^2 = 0.6996 \qquad \bar{R}^2 = 0.6803$$

Equation (3)

Group - 3 [Districts: SV, WA contributing 9.90% of State output in 1984-85].

$$Y_t = -2072.19 + 0.326*RSW_t + 5.2364*FRCE_t - 0.0083*FRCE_t^2 + 2847.48*I_t + 0.219*U_{t-1} + \varepsilon_t$$
$$(-1.4912) \quad (2.94)^{+} \quad (2.92)^{+} \quad (-1.47) \quad (1.96)^{+++} \quad (1.36)$$
$$R^2 = 0.5947 \qquad \bar{R}^2 = 0.5486$$

Equation (4)

Group - 4 [Districts: AN, CU, NA, KH contributing 14.64% of State output in 1984-85].

$$Y_t = 1182.21 + 0.125*RSW_t + 0.477*RNE_t + 3.3691*FRCE_t - 0.0044*FRCE_t^2 + 0.654U_{t-1} + \varepsilon_t$$
$$(10.51)^{+} \quad (1.13) \quad (2.05)^{++} \quad (3.62)^{+} \quad (-2.02)^{++} \quad (7.80)^{+}$$
$$R^2 = 0.6890 \qquad \bar{R}^2 = 0.6725$$

Equation (5)

Group - 5 [Districts: KH, AD contributing 2.54% of State output in 1984-85].

$$Y_t = -202.38 + 0.660*RSW_t + 3.5481*FRCE_t - 0.0072*FRCE_t^2 + 961.03*I_t + U_t$$
$$(-0.66) \quad (4.27)^{+} \quad (3.06)^{+} \quad (-2.18)^{++} \quad (2.00)^{++}$$
$$R^2 = 0.5437 \qquad \bar{R}^2 = 0.5032 \qquad DW = 1.9460$$

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* : See notes at the end of the table.

Table 8.4 Contnd.

Jowar: Equations 6 to 8*.

Equation (6)

Group - 4 [Districts: AN, CU, NA, KH contributing 18.03% of State output in 1984-85].

$$Y_t = \underset{(6.43)^{+}}{420.84} - \underset{(-2.11)^{++}}{0.148*RSW_t} + \underset{(2.71)^{+}}{0.406*RNE_t} + \underset{(2.93)^{+}}{2.1354*F_t} + \underset{(6.75)^{+}}{0.652*U_{t-1}} + \varepsilon_t$$

$R^2 = 0.5342$ $\bar{R}^2 = 0.5146$

Equation (7)

KU alone in Group 1 [Contributing 20.18% of State output in 1984-85].

$$Y_t = \underset{(8.86)^{+}}{407.85} + \underset{(1.01)}{1.1399*F_t} + \underset{(2.97)^{+}}{0.2661*F_t*I_t} + U_t$$

$R^2 = 0.6930$ $\bar{R}^2 = 0.6651$ DW = 1.6546

Equation (8)

KH alone in Group 5 [contribting 11.36% of State output in 1984-85].

$$Y_t = \underset{(4.04)^{+}}{516.64} - \underset{(-1.52)}{0.188*RSW_t} + \underset{(1.96)^{+++}}{0.620*RNE_t} + \underset{(3.49)^{+}}{8.4938*F_t} - \underset{(-2.80)^{+}}{0.0584*F_t^2} + U_t$$

$R^2 = 0.5340$ $\bar{R}^2 = 0.4408$ DW = 1.7191

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* : See notes at the end of the table.

Table 8.4 Contnd.

Bajra: Equations 9 to 13.*

Equation (9)

Group - 2 [Districts: CH, RH, ME, MB contributing 9.96% of State output in 1984-85].

$$Y_t = 162.65 + 0.194*RSV_t + 0.381*RME_t + 2133.30*I_t + 0.112*U_{t-1} + \varepsilon_t$$
$$(2.52)^{++} \quad (2.40)^{++} \quad (1.90)^{+++} \quad (5.85)^{+} \quad (1.07)$$
$$R^2 = 0.5577 \qquad \bar{R}^2 = 0.5390$$

Equation (10)

Group - 4 [Districts: AN, CU, NA, KM contributing 26.01% of State output in 1984-85].

$$Y_t = 260.11 + 0.664*RME_t + 917.52*I_t - 1796.25*I_t^2 + 9.5243*F_t*I_t + 0.351*U_{t-1} + \varepsilon_t$$
$$(5.64)^{+} \quad (3.26)^{+} \quad (3.46)^{+} \quad (-4.48)^{+} \quad (4.48)^{+} \quad (3.35)^{+}$$
$$R^2 = 0.5884 \qquad \bar{R}^2 = 0.5665$$

Equation (11)

Group - 1 Sub-Group A: [Districts: GN and N2 contributing 21.15% of State output in 1984-85].

$$Y_t = 204.11 + 0.137*RSV_t + 10229.7*I_t + U_t$$
$$(2.69)^{+} \quad (1.77)^{+++} \quad (7.74)^{+}$$
$$R^2 = 0.6431 \qquad \bar{R}^2 = 0.6279 \qquad DW = 2.1039$$

Equation (12)

Group - 4 Sub-Group A: [Districts: CU and KM contributing 10.00% of State output in 1984-85].

$$Y_t = 196.62 + 0.290*RME_t + 2.4979*F_t + 7929.99*I_t + 0.436*U_{t-1} + \varepsilon_t$$
$$(2.55)^{+} \quad (1.11) \quad (2.65)^{+} \quad (4.86)^{+} \quad (3.10)^{+}$$
$$R^2 = 0.7530 \qquad \bar{R}^2 = 0.7310$$

Equation (13)

SV alone in Group 3 [contributing 32.04% of State output in 1984-85].

$$Y_t = 416.80 + 0.072*RSV_t - 0.182*RME_t + 20.2083*F_t - 0.2028*F_t^2 + 16786.6*I_t - 98898.9*I_t^2 - 1009.93*F_t*I_t - 0.699*U_{t-1} + \varepsilon_t.$$
$$(7.93)^{+} \quad (2.59)^{++} \quad (-3.70)^{+} \quad (8.00)^{+} \quad (-5.77)^{+} \quad (3.27)^{+} \quad (-1.77)^{+++} \quad (-3.04)^{+} \quad (-3.67)^{+}$$
$$R^2 = 0.9044 \qquad \bar{R}^2 = 0.8566$$

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* : See notes at the end of the table.

Table 8.4 Contnd.

Ragi: Equations 14 to 17*.

Equation (14)

Group - 1 [Districts: EG, WG, KR, GN, KU, N2 contributing 19.81% of State output in 1984-85].

$$Y_t = 761.63 + 0.096*RSW_t + 0.219*RNE_t + 915.15*I_t - 946.67*I_t^2 + 0.9265*F_t*I_t + 0.671*U_{t-1} + \varepsilon_t$$

$$(12.30)^{+} \quad (1.90)^{+++} \quad (4.93)^{+} \quad (2.06)^{++} \quad (-1.99)^{++} \quad (1.19) \quad (10.39)^{+}$$

$R^2 = 0.6380$ $\bar{R}^2 = 0.6228$

Equation (15)

Group - 2 [Districts: CH, RH, ME, MB contributing 33.02% of State output in 1984-85].

$$Y_t = 259.24 + 0.279*RSW_t + 0.441*RNE_t + 2.9289*F_t - 0.03807*F_t^2 + 1865.84*I_t - 3677.81*I_t^2 + 12.3465*F_t*I_t + U_t$$

$$(4.51)^{+} \quad (3.99)^{+} \quad (2.79)^{+} \quad (2.18)^{++} \quad (-2.93)^{+} \quad (2.14)^{++} \quad (-1.65) \quad (3.28)^{+}$$

$R^2 = 0.6448$ $\bar{R}^2 = 0.6178$ $DW = 1.8649$

Equation (16)

Group - 4 Sub-Group A: [Districts: AN, CU and NA contributing 17.80% of State output in 1984-85].

$$Y_t = 411.35 + 0.723*RNE_t + 5.3499*F_t + 514.973*I_t + 0.623*U_{t-1} + \varepsilon_t$$

$$(2.12)^{+} \quad (2.64)^{+} \quad (4.06)^{+} \quad (2.72)^{+} \quad (6.33)^{+}$$

$R^2 = 0.7046$ $\bar{R}^2 = 0.6877$

Equation (17)

SV in Group 3 [contributing 29.54% of State output in 1984-85].

$$Y_t = -381.28 - 0.139*RNE_t + 25.1716*F_t - 0.2691*F_t^2 + 8782.1*I_t - 19426.0*I_t^2 + 0.510*U_{t-1} + \varepsilon_t$$

$$(-0.88) \quad (-1.73) \quad (2.60)^{++} \quad (-2.18)^{++} \quad (2.53)^{++} \quad (-2.62)^{++} \quad (3.88)^{+}$$

$R^2 = 0.5963$ $\bar{R}^2 = 0.4617$

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* : See notes at the end of the table.

Table 8.4 Concld.

Maize: Equations 18 to 21.

Equation (18)

Group - 2 (Districts: CH, RH, ME, MB contributing 12.26% of State output in 1984-85).

$$Y_t = 474.97 + 0.373*RSW_t - 0.570*RNE_t + 14.5048*F_t - 0.1528*F_t^2 + 2143.96*I_t - 2354.85*I_t^2 + 19.2421*F_t*I_t + 0.197*U_{t-1} + \varepsilon_t$$

(2.64)[+] (1.62)[+++] (-1.42) (3.29)[+] (-3.77)[+] (3.35)[+] (-3.33)[+] (3.72)[+] (1.71)[++]

$R^2 = 0.5466$ $\bar{R}^2 = 0.5067$

Equation (19)

Group - 3 (Districts: SV, WA contributing 11.20% of State output in 1984-85).

$$Y_t = -858.75 + 0.852*RSW_t + 0.744*RNE_t + 30.1792*F_t - 0.1997*F_t^2 + 5498.44*I_t - 8745.12*I_t^2 + U_t$$

(-2.58)[++] (4.45)[+] (2.31)[++] (4.50)[+] (-3.56)[+] (2.35)[++] (-1.73)[+++]

$R^2 = 0.6171$ $\bar{R}^2 = 0.5637$ DW = 1.6110

Equation (20)

Group - 1 Sub-Group B: (Districts: EG, KR, GN, NZ contributing 25.59% of State output in 1984-85).

$$Y_t = 258.16 + 0.542*RSW_t - 0.1543*RNE_t + 16.7645*F_t - 0.0492*F_t^2 + 0.413*U_{t-1} + \varepsilon_t$$

(0.97) (2.83)[+] (-1.13) (5.06)[+] (-4.49)[+] (4.01)[+]

$R^2 = 0.5135$ $\bar{R}^2 = 0.4876$

Equation (21)

Group - 4 Sub-Group A: (Districts: AN, CU and KM contributing 44.10% of State output in 1984-85).

$$Y_t = 471.21 + 24.6159*F_t - 0.1955*F_t^2 + 1771.61*I_t - 1777.88*I_t^2 + 13.635*F_t*I_t + 0.5133U_{t-1} + \varepsilon_t$$

(1.66)[+++] (3.56)[+] (-4.12)[+] (1.91)[+++] (-1.99)[++] (1.63) (4.39)[+]

$R^2 = 0.6257$ $\bar{R}^2 = 0.5927$

Notes: t-statistics are given in brackets. +/++/+++ indicates significance at 1%, 5% and 10% levels respectively.

Variables: Y_t : Yields; RSW_t : Rainfall South West Monsoon; RNE_t : Rainfall North East Monsoon;

I_t : Gross Irrigation proportion; $FRCE_t$: Fertilizer intensity for rice (= fertilizer consumption / rice acreage);

F_t : Fertilizer intensity other crops (= fertilizer consumption / 5-Cereals acreage);

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna;

GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor;

RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda;

WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

Rice: In the case of rice all the 18 districts in the 5 groups are covered by the *yield response functions reported* in table 8.4 (equations 1 to 5). We noted earlier that rice is a highly irrigated crop in all the 18 districts. Hence, no sub-grouping was possible in the case of *rice*. These 5 *yield functions* are the only ones for rice and they cover the entire rice output of AP.

The fit is highest for equation 2 corresponding to G2 with R^2 = 0.6996, followed closely by equation 4 for G4 with R^2 = 0.6725, and equation 1 for G1 with R^2 = 0.6629. The remaining 2 equations (3 and 5) corresponding to G3 and G5 have some what lesser fit.

It was mentioned in chapter 2 that kharif season (June to October) is the main growing season for rice in all the districts of AP. At the AP State level around 70% of the total production comes from this season. A major portion of the water requirement for rice cultivation during this season comes from the South-West (RSW) monsoon (June to September) during which most of the rain-fall occurs. The importance of rainfall during the South-West monsoon for rice cultivation comes out clearly in the estimated yield response functions. RSW figures in all the rice equations 1 to 5, and has a positive coefficient which is significant in all the equations except in equation 4. The other season's rainfall, North-East monsoon, (RNE), is also found to be important but only in the districts of G1, G2 and G4. In equations 2 and 4 it has significant positive coefficients, while in equation 1 (for G1 - which includes most of the coastal districts) it has significant negative coefficient. That is in the districts of G1 RNE has an adverse impact on rice yields.

The importance of fertilizer for rice cultivation is also borne out by these estimations. The fertilizer variable FRCE is found to be an important variable for rice yields in all the 5 groups. Both FRCE (with significant positive coefficient) and its quadratic term $FRCE^2$ (with significant negative coefficient except in equation 3 where it is insignificant even at 10% level) enter in the rice yield response functions for 4 groups (G2, G3, G4 and

G5). The positive FRCE with negative $FRCE^2$ term suggests that rice yields in these districts rise along with fertilizer levels, attains a maximum after which they would fall with further rise in the level of fertilizer use. On the other hand, in G1 only FRCE (and not $FRCE^2$) with a significant positive coefficient enters in the regression equation, suggesting only a linear relation between rice yields and fertilizer levels in the 6 districts of G1.

Irrigation is also a major input affecting rice yields in most of the districts. Irrigation intensity (without its square term) enters into the yield response function for all the groups except for G4 (equation 4) which is rather surprising. G4 consists of AN, CU, NA & KM districts and all of them have very high irrigation intensity. This can be explained as follows: irrigation intensities for rice in all these 4 districts are high and roughly equal. That is there is very little variation across these 4 districts. Further, within each of these 4 districts, there is hardly any variation in irrigation intensity over time. Thus, the irrigation variable (with values close to unity) acts more like a constant. Its effect is captured in the constant term and irrigation variable does not figure in equation 4 for G4.

The irrigation intensity has a significant positive coefficient in all the other 4 rice yield response functions where it enters (equations 1, 2, 3 and 5). The absence of quadratic term for irrigation intensity suggests only a linear relation between rice yields and its irrigation intensity.

Note that the interaction variable (FRCExI) did not become significant in any of the equations for rice yields. These 5 yield response function have brought out the importance of rainfall, fertilizer and irrigation in determining rice yields in all the districts of AP.

Jowar: In the case of jowar we have groupwise yield response function for only G4 (equation 6 in table 8.4). Apart from this we have estimations for 2 districts KU in G1 (equation 7) and KH in

G5 (equation 8). Since jowar in general is largely an unirrigated crop in AP, the sub-groups B of jowar are also the corresponding total groups. The above estimations for jowar together account for about 50% of the State's jowar output in 1984-85.

From table 8.4 we find that for equation 7 (KU) the fit is fairly high (R^2 = 0.69) while in the other 2 equations the fit is only moderate (R^2 = 0.53). The characteristic of unirrigated cultivation of this crop is borne out by these 3 yield response functions. Only in equation 7 for KU alone, the irrigation variable that too only as an interaction variable with fertilizer appears and it has a significant positive coefficient. Otherwise, irrigation intensity for jowar does not enter in the equation separately. Jowar being mostly a rainfed crop, RSW and RNE enter into equations 6 for G4 and 8 for KH. In both these equations RSW has a significant negative coefficients, while RNE has significant positive coefficient, implying that the South-West monsoon has an adverse impact on jowar yields in the 4 districts of G4 and in KH. The rainfall terms do not figure in equation 6 for KU where the interaction variable between irrigation and fertilizer appears.

Fertilizer availability is a crucial variable affecting jowar yields in all the 6 districts covered by these 3 equations despite the fact that only minor quantities of fertilizer are applied for this crop (see section 3.5.6, chapter 3) which is grown mostly unirrigated all over AP. In all the 3 equations F has a significant positive coefficient. Only in equation 8 for KH alone, the quadratic term F^2 figures in and it has a significant negative coefficient.

Bajra: In the case of bajra, yield response functions could be estimated for 2 groups - G2 and G4 (equations 9 and 10 in table 8.4, respectively) and at sub-groups level for 3 cases - G1A, G2B (same as G2) and G4A. Note that for CU and KM in G4A we have a yield function for the sub-group as well as for the group as a whole. For SV district a district level a separate yield response function could also be estimated. These 5 estimated yield response functions (equations 9 to 13 in table 8.4), covering 11 districts accounted for about 89% of the State's total output of bajra in 1984-85.

From table 8.4 we find that the fits are high for all these 5 equations, with R^2s ranging from 0.56 to 0.90. From these results we find that, apart from rainfall, irrigation is important in determining bajra yield levels in all the 11 districts covered by these estimations (see table 8.4). Fertilizer is found to affect bajra yields in only SV, AN, CU, NA and KM. Irrigation intensity in all the 5 equations has a significant positive coefficient. Its quadratic term I^2 enters only for G4 and SV district (equations 10 & 13, respectively) with a significant negative coefficient. It may be mentioned here that, according to table 8.2, irrigation intensity for bajra is zero over the years 1979-80 to 1984-85 in both SV and NA but it figures in the yield response functions for both these districts (equation 13 for SV and equation 10 for G4 in which NA falls). This may be explained as follows: in the case of SV, irrigation intensity for bajra was found to be positive (around 9%) in the earlier years though it has fallen over time. That is there has been positive (however small) amounts of irrigation for bajra in SV which affects its yields. In the case of NA of G4, the irrigation intensity of bajra is, though nil in NA, rather high in CU & KM which also fall in the same group (see table 8.2). This is reflected in equation 10 for G4 as a whole. It may also be mentioned here that irrigation intensity for bajra is high in GN and N2 also, which fall in G1A, and this has a direct effect on bajra yields in these 2 districts (equation 11).

Fertilizer availability (F) by itself enters in only equations 12 and 13 of G4A and SV, respectively, with significant positive coefficients; F^2 enters in only equation 13 of SV and has a significant negative coefficient. The interaction term FxI enters in equations 10 and 13 of G4 and SV, respectively, with negative coefficient in equation 13 (SV) and a positive coefficient in equation 10 (G4). Thus atleast in 6 districts (CH, RH, ME, MB, GN & N2), irrespective of the crop's irrigation intensity, fertilizer application does not seem to be an important variable for bajra yields.

Both the rainfall seasons, RSW and RNE, are found to affect bajra yields in the districts of G2 and in SV. In SV bajra yields are, however, adversely affected by rainfall during North-East monsoon. In the 2 districts GN and NZ of G1A only RSW is found to affect bajra yields while in the districts of G4 only RNE influences bajra yields (equations 10 and 12).

Ragi: In the case of ragi we have estimations for G1 and G2 groups as a whole, for the sub-group G4A and for SV alone from G3. These 4 estimations cover 14 districts which together account for nearly all of ragi output in AP (99% in 1984-85). These 4 estimations (equations 14 to 17), have reasonably good fits with R^2s ranging between 0.60 and 0.70.

For the 2 groupwise estimations (equations 14 and 15 of G1 and G2, respectively), both the rainfall terms, RSW and RNE, enter and have significant positive coefficients. For the sub-group estimation (equation 16 of G4A) only RNE figures in with a significant positive coefficient. In the estimation for SV alone in G3 (equation 17), RNE enters but with an insignificant negative coefficient whereas RSW does not enter at all.

For this crop, which is grown all over AP only with traditional seeds, fertilizer application seems to be important in all the districts. In the groupwise estimation for G2 (equation 15) both F and I enter along with their quadratic terms and also their interaction term. The interaction term has a positive coefficient implying that use of fertilizer and irrigation together is beneficial to ragi cultivation. The interaction term enters in for G1 (equation 14) also with a positive coefficient along with the irrigation terms. For sub-group G4A, both F and I enter and both have significant positive coefficients. In equation 17 for SV alone, F and I with positive coefficients enter along with their quadratic terms with significant negative coefficients.

The equations (14, 15, and 17 of G1, G2 and SV, respectively) with positive linear terms and negative quadratic terms suggest that yields response to that input variable rises with the input level upto a point where it, attains a maximum and later yields begin to fall.

Maize: In the case of maize groupwise yield response functions were obtained for G2 and G3 only (equations 18 and 19), while sub-groupwise yield response functions were obtained for G1B and G4A (equations 20 and 21). These 4 equations cover 13 out of 18 districts in AP, which together account for about 93% of the State's maize output in 1984-85.

From table 8.4, we find that fits in terms of R^2 range from about 0.51 to about 0.63. Amongst the rainfall variables, both RSW and RNE enter into all the equations except equation 21 where neither of them enter. RSW, with a significant positive coefficient, is favourable to maize yields. RNE on the other hand, is found favourable only in G3, where it has a significant positive coefficient while in equations 20 (for G1B) and 18 (for G2) it has negative, but insignificant, coefficients.

Amongst the two inputs fertilizer and irrigation, we noted earlier that every district has some maize cultivation under irrigation. Secondly, after rice, maize is the next most important cereal for fertilizer application. Fertilizer enters in all 4 equations with a quadratic term also, while irrigation and its quadratic term enter in all except one equation (equation 20 for G1B). The signs of these variables and their quadratic terms are as expected and are significant; the linear term is positive and quadratic term is negative suggesting that yields rise with a rise in these input levels, attain a maximum after which yields begin to fall. The results show that the marginal returns of yield with respect to fertilizers become negative at much lower levels of fertilizers in Rayalaseema and Telangana districts than in Coastal districts (G1). The interaction term between fertilizer and irrigation intensities enter in equations 18 (for G2) and 21 (for

G4A). In both these equations, the interaction term has a positive coefficient which is significant only in equation 18 but not in equation 21.

All the y.r.fs reported in table 8.4 for the 5 cereal crops corresponding to the districts of AP can be taken to be well behaved. The estimation results are meaningful as explained above and the fits are reasonable too. Hence they may be used for further analysis.

8.6 Conclusions.

In this chapter yield response functions for the 5 cereal crops for the districts of AP were estimated.

First, district level yield response functions were attempted for estimation. However, due to multicollinearity amongst the input variables at the district level, the yield response functions could not be estimated for most of the districts individually. Only for a few crops in a few districts, for which multicollinearity was not a serious problem, yield response functions were estimated individually. Hence, districts exhibiting similar characteristics with regard to the sources of irrigations were put together to form homogeneous groups and group level yield response functions were then estimated using pooled data which did not show serious multicollinearity.

In order to assess the yields according to the irrigation regimes, for each crop the groups were then split into 2 sub-groups: highly/moderately irrigated and lowly irrigated based on cropwise gross irrigation intensities. Yield response functions were then estimated at the sub-group levels too using pooled data for the sub-group. Thus in all 21 yield response functions were estimated.

In the case of rice, the groupwise yield response functions covers all the 18 districts, while in the case of bajra, ragi and maize, all the districts that are major producers for these 3 crops were covered by the yield response functions estimated in this chapter. It is only in the case of jowar that the success has been moderate.

The 21 estimated yield response functions satisfy all the econometric criteria, namely, that the parameters are unbiased, have minimum variance and are normally distributed. The estimated functions have been corrected for autocorrelation wherever required.

With the estimated residuals (if they are autocorrelated, then, only the non-autocorrelated part of them, i.e., $\hat{\varepsilon}_t$ in $\hat{u}_t = \hat{\rho}.\hat{u}_{t-1} + \hat{\varepsilon}_t$) obtained from these 21 estimated yield response functions, we now proceed to analyse variability in response function framework which will be taken up in the next chapter.

G4A). In both these equations, the interaction term has a positive coefficient which is significant only in equation 18 but not in equation 21.

All the y.r.fs reported in table 8.4 for the 5 cereal crops corresponding to the districts of AP can be taken to be well behaved. The estimation results are meaningful as explained above and the fits are reasonable too. Hence they may be used for further analysis.

8.6 Conclusions.

In this chapter yield response functions for the 5 cereal crops for the districts of AP were estimated.

First, district level yield response functions were attempted for estimation. However, due to multicollinearity amongst the input variables at the district level, the yield response functions could not be estimated for most of the districts individually. Only for a few crops in a few districts, for which multicollinearity was not a serious problem, yield response functions were estimated individually. Hence, districts exhibiting similar characteristics with regard to the sources of irrigations were put together to form homogeneous groups and group level yield response functions were then estimated using pooled data which did not show serious multicollinearity.

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Appendix 8.A1 - Rainfall Patterns in Andhra Pradesh

National Commission on Agriculture (1976), in their study on rainfall and cropping patterns in India, divided Andhra Pradesh mainly into 28 rainfall zones and identified different taluks* falling into these zones. To describe a rainfall zone, the following coding scheme was adopted:

A : Greater than 30 mm rainfall in a month;

B : Between 30 and 20 mm rainfall;

C : Between 20 and 10 mm rainfall;

D : Between 10 and 5 mm rainfall;

E : Less than 5 mm rainfall;

Let A_j, B_j, C_j, D_j and E_j represent the corresponding monthly rainfall levels in j number of consecutive months. Each rainfall zone is described by the monthly rainfall levels codes starting from February. For example a code such as

$$D_2\ E_2\ (B_3\ C_1)\ C_1\ D_1\ E_2$$

means that the rainfall pattern in this zone is at level D during February - March, at level E during April and May, at level B during June, July and August, at level C during September and so on to be interpreted till January. The bracketed term refers to the South-West monsoon season June to September. Different rainfall patterns (total 28 of them) occurring in each of the 21 districts in AP are shown below (names of taluks are not given).

District	Yearly Rainfall Pattern	
1. Srikakulam	[$D_2E_2(B_3C_1)C_1D_1E_2$]	[$D_1E_3(C_4)C_1D_1E_2$]
2. Vishakhapatnam	[$D_1E_3(C_4)C_1D_1E_2$]	[$D_2E_2(B_1C_3)C_1D_1E_2$]
3. East Godavari	[$E_4(C_4)B_1C_1E_2$]	[$D_1E_3(C_4)C_1D_1E_2$]
	[$D_2E_2(B_3C_1)C_1D_1E_2$]	
4. West Godavari	[$E_4(C_4)B_1C_1E_2$]	[$E_4(B_1C_3)C_1D_1E_2$]

* Taluk is a sub-region within a district. The system of dividing a district into several taluks was given up in AP a few years ago. The sub-regions of a district are now called Mandals.

District	Yearly Rainfall Pattern	
5. Krishna	[$E_4(C_4)C_1D_1E_2$]	[$E_4(C_4)B_1C_1E_2$]
	[$E_4(B_1C_3)C_1D_1E_2$]	[$E_4(B_2C_2)D_1E_3$]
6. Guntur	[$E_4(C_1D_2E_1)C_2E_2$]	[$E_4(C_3D_1)C_1D_1E_2$]
	[$E_4(C_3D_1)C_2E_2$]	[$E_4(C_1)C_1D_1E_2$]
7. Prakasam	[$E_4(C_1D_2E_1)C_2E_2$]	[$E_4(C_1D_2E_1)B_1C_1E_2$]
	[$E_4(C_3D_1)D_1E_3$]	[$E_4(C_3D_1)C_2E_2$]
8. Nellore	[$E_4(D_3E_1)B_2C_1E_1$]	[$E_4(C_1D_2E_1)B_2E_2$]
	[$E_4(C_1D_3)A_1B_1C_1E_1$]	
9. Kurnool	[$E_4(C_1D_3)D_1E_3$]	[$E_4(C_3D_1)D_1E_3$]
10. Anantapur	[$E_4(C_1D_3)D_1E_3$]	[$D_1E_3(C_1D_1E_2)D_1E_3$]
	[$D_1E_3(C_1D_2E_1)C_1D_1E_2$]	
11. Cuddapah	[$E_4(C_1D_3)D_2E_2$]	[$E_4(C_1D_3)$....]
	[$E_4(C_2D_2)D_2E_2$]	[$E_4(C_2D_2)C_2E_2$]
12. Chittoor	[$E_4(C_1D_3)A_1B_1C_1E_1$]	[$D_1E_3(C_1D_3)C_2E_2$]
	[$D_1E_3(C_2D_2)C_2D_1E_1$]	[$D_1E_3(C_2D_2)C_1D_1E_2$]
13. Hyderabad	[$E_4(C_3D_1)D_1E_3$]	[$E_4(B_1C_3)D_1E_3$]
14. Nizamabad	[$E_4(B_1C_3)D_1E_3$]	[$E_4(B_3C_1)D_1E_3$]
15. Medak	[$E_4(B_1C_3)D_1E_3$]	
16. Mehboobnagar	[$E_4(C_3D_1)D_1E_3$]	
17. Nalgonda	[$E_4(C_3D_1)D_1E_3$]	
18. Warangal	[$E_4(C_3D_1)D_1E_3$]	[$E_4(B_1C_3)D_1E_3$]
	[$E_4(A_1B_1C_2)D_1E_3$]	
19. Khammam	[$E_4(B_1C_3)D_1E_3$]	[$E_4(B_2C_2)D_1E_3$]
20. Karimnagar	[$E_4(B_1C_3)D_1E_3$]	[$E_4(B_2C_2)D_1E_3$]
21. Adilabad	[$E_4(B_1C_3)D_1E_3$]	[$E_4(A_1B_1C_2)D_1E_3$]
	[$E_4(A_2B_1C_1)D_1E_3$]	

For more details see "Rainfall and Cropping Patterns", Volume 1 (Andhra Pradesh), National Commission on Agriculture, 1976; Ministry of Agriculture & Irrigation, Government of India, New Delhi.

Appendix 8.A2 - Characteristics of Irrigation in Andhra Pradesh.

In this appendix, the characteristics of irrigation in AP, based on which the districts are grouped, are discussed. Table 8A2.1 presents the sourcewise net irrigated area as percentage in the total net irrigated area (TNIA) for each district, for three years 1960-61, 1970-71 and 1984-85 of the 25 years (1960-61 to 1984-85) time series data. The sourcewise net irrigated area as a proportion of the total net sown area for each district is presented for the same 3 years in table 8A2.2.

Surface water (SW): From table 8A2.1 it can be seen that the surface water (canals & tanks together) is the most dominant source of irrigation in all the districts. However, in all the districts the percentage of surface water in total irrigation has been falling over time. By 1984-85, only in 12 (SV, EG, WG, KR, GN, KU, NZ, ME, NA, KH, KM and AD) out of 18 districts SW sources account for more than 50% of the TNIA. Even in the remaining 6 (AN, CU, CH, RH, MB and WA) districts the share of surface water was more than 50% in earlier years. The two sources, canals and tanks, can therefore be considered as the most important sources of irrigation in AP.

The relative importance of these two sources, however, differs from district to district. While canals dominated in 7 districts (EG, WG, KR, GN, KU, CU and NZ) all along, in the remaining 11 districts tanks dominated over canals in the beginning.

In the 11 districts where tanks dominate, in 5 districts (AN, NA, KH, KM and AD) canals have replaced tanks as the important source within surface water in recent years. The share of canals in these 5 districts show an increase while that of tanks show a fall in recent years. In 3 districts (RH, MB and WA) both canals and tanks have lost in percentage terms to ground water. In 2 districts (CH and ME) while canals have only a small (and stagnant) share in the total irrigation, tanks have lost in percentage terms to ground water. SV is the only district where

Table 8.A2.1 – Total Net Irrigated Area (TNIA) and Sourcewise Composition (% of TNAI): Andhra Pradesh and its Districts.

District	Year	Canals (%)	Tanks (%)	Surface Water[1] (%)	Tube-Wells (%)	Other Wells (%)	Ground Water[2] (%)	Other Sources (%)	Total NIA[3] (Hectares)
SV	1960-61	32.62	58.99	91.61	0.28	4.12	4.40	3.99	407066.0
	1970-71	26.76	61.52	88.29	0.10	3.90	3.99	7.72	423200.0
	1984-85	36.10	53.86	89.96	1.27	4.77	6.04	3.99	425395.0
EG	1960-61	80.98	17.99	98.97	0.52	0.21	0.73	0.15	254401.0
	1970-71	76.61	19.45	96.05	2.90	0.31	3.20	0.74	264191.0
	1984-85	82.56	3.37	85.93	12.04	0.18	12.22	1.86	236277.0
WG	1960-61	72.46	22.95	95.41	0.01	2.02	2.04	2.55	294116.5
	1970-71	65.74	15.17	80.91	11.66	3.60	15.26	3.02	316519.0
	1984-85	67.27	8.86	76.13	19.15	1.58	20.73	3.14	322071.0
KR	1960-61	76.59	15.95	92.53	0.01	1.82	1.83	5.64	332350.4
	1970-71	77.18	12.93	90.10	3.34	2.56	5.90	3.99	324981.0
	1984-85	83.73	5.13	88.86	5.02	2.72	7.73	3.46	330263.0
GN	1960-61	57.99	28.64	86.64	0.10	10.56	10.67	2.69	513652.6
	1970-71	68.76	18.11	86.87	1.48	10.16	11.63	1.50	631028.0
	1984-85	65.99	14.32	80.32	6.38	10.78	17.16	2.52	751695.0
KU	1960-61	47.93	32.99	80.92	0.00	15.66	15.66	3.42	84578.6
	1970-71	74.36	13.41	87.77	0.00	9.04	9.04	3.18	96545.0
	1984-85	70.96	10.43	81.39	0.13	14.52	14.65	3.96	116684.0
AN	1960-61	21.45	44.48	65.92	0.00	32.02	32.02	2.06	83582.2
	1970-71	33.52	25.22	58.74	0.00	39.43	39.43	1.83	125891.0
	1984-85	33.22	8.41	41.64	3.28	52.32	55.60	2.77	113085.0
CU	1960-61	33.97	27.79	61.76	0.15	35.84	35.99	2.25	105789.0
	1970-71	31.53	18.91	50.43	0.33	43.97	44.31	5.21	115231.0
	1984-85	22.94	15.52	38.46	6.31	50.26	56.57	4.98	101925.0
CH	1960-61	0.00	62.59	62.59	0.13	25.34	25.47	10.81	143761.1
	1970-71	0.00	53.92	53.92	0.00	40.40	40.40	5.68	150752.0
	1984-85	1.91	38.90	40.82	1.37	56.13	57.50	1.68	140063.0
RH	1960-61	12.70	62.49	75.20	1.56	21.79	23.35	1.45	32639.9
	1970-71	7.50	37.96	45.46	0.02	52.06	52.08	2.46	54206.0
	1984-85	7.59	27.10	34.70	0.85	56.25	57.10	8.20	41926.0

Notes are given at the end of the table.

Table 8.A2.1 Contnd.

District	Year	Canals (%)	Tanks (%)	Surface Water[1] (%)	Tube-Wells (%)	Other Wells (%)	Ground Water[2] (%)	Other Sources (%)	Total NIA[3] (Hectares)
NZ	1960-61	52.95	41.96	94.92	0.33	3.54	3.87	1.22	116510.7
	1970-71	45.23	41.99	87.22	0.00	9.78	9.78	3.01	124735.0
	1984-85	52.93	22.65	75.57	0.97	18.54	19.52	4.79	151167.0
ME	1960-61	6.25	72.63	78.88	0.00	17.67	17.67	3.45	79828.0
	1970-71	11.77	64.58	76.35	0.00	21.23	21.23	2.42	82757.0
	1984-85	10.21	49.63	59.84	0.03	37.76	37.79	2.37	103452.0
MB	1960-61	9.76	60.44	70.20	0.00	25.75	25.75	4.04	85244.3
	1970-71	20.63	52.96	73.59	0.00	23.66	23.66	2.75	108753.0
	1984-85	15.05	33.50	48.54	0.79	49.09	49.88	1.58	80921.0
NA	1960-61	21.76	42.80	64.56	0.27	35.17	35.44	0.00	86810.0
	1970-71	53.09	31.02	84.10	0.00	15.07	15.07	0.82	136089.0
	1984-85	58.36	13.83	72.20	0.00	24.34	24.34	3.45	166310.0
WA	1960-61	3.58	78.65	82.23	0.00	16.86	16.86	0.87	98087.4
	1970-71	10.54	69.44	79.98	0.00	17.84	17.84	2.18	120503.0
	1984-85	0.86	42.99	43.85	1.44	52.96	54.41	1.74	143042.0
KH	1960-61	14.64	78.57	93.21	0.00	1.56	1.56	5.23	62457.6
	1970-71	17.83	63.33	81.16	0.14	10.75	10.90	7.94	85237.0
	1984-85	46.36	26.09	72.45	8.50	10.99	19.49	8.06	91543.0
KM	1960-61	15.24	49.79	65.03	0.00	28.88	28.88	6.09	100209.2
	1970-71	13.38	54.44	67.81	0.00	21.35	21.35	2.41	118604.0
	1984-85	27.73	26.85	54.58	0.00	40.68	40.68	4.73	167389.0
AD	1960-61	21.83	69.32	91.15	0.07	4.29	4.36	4.49	28012.4
	1970-71	33.78	58.89	92.66	0.17	7.00	7.17	0.19	33885.0
	1984-85	42.00	37.68	79.68	1.65	12.94	14.59	5.73	39279.0
AP	1960-61	45.76	39.57	85.33	0.16	11.12	11.27	3.40	2909097.0
	1970-71	47.66	33.57	81.22	1.98	13.09	15.07	3.40	3313017.0
	1984-85	50.93	21.99	72.91	5.26	18.50	23.76	3.33	3522487.0

Notes: 1 : Surface water = Canals + Tanks. 2 : Ground water = Tubewells + Other Wells.
3 : Total NIA = Total net irrigated area by all sources put together.

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna;
GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor
RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda
WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad; AP : Andhra Pradesh (all districts);

Table 8.A2.2 - Net Irrigated Area: Sourcewise Proportions in Total Net Sown Area: Andhra Pradesh and its Districts.

District	Year	Canals	Tanks	Surface Water[1]	Tube-Wells	Other Wells	Ground Water[2]	Other Sources	Total NIA[3]
SV	1960-61	0.172	0.310	0.482	0.001	0.022	0.023	0.021	0.526
	1970-71	0.119	0.273	0.392	0.000	0.017	0.018	0.034	0.444
	1984-85	0.172	0.257	0.429	0.006	0.023	0.029	0.019	0.477
EG	1960-61	0.520	0.115	0.635	0.003	0.001	0.005	0.001	0.642
	1970-71	0.485	0.123	0.608	0.018	0.002	0.020	0.005	0.633
	1984-85	0.520	0.021	0.542	0.076	0.001	0.077	0.012	0.630
WG	1960-61	0.538	0.170	0.708	0.000	0.015	0.015	0.019	0.742
	1970-71	0.494	0.114	0.609	0.088	0.027	0.115	0.029	0.752
	1984-85	0.535	0.071	0.606	0.152	0.013	0.165	0.025	0.796
KR	1960-61	0.560	0.117	0.678	0.000	0.013	0.013	0.041	0.731
	1970-71	0.506	0.085	0.591	0.022	0.017	0.039	0.026	0.656
	1984-85	0.584	0.036	0.620	0.035	0.019	0.054	0.024	0.698
GN	1960-61	0.235	0.116	0.351	0.000	0.043	0.043	0.011	0.405
	1970-71	0.274	0.072	0.347	0.006	0.041	0.046	0.006	0.399
	1984-85	0.324	0.070	0.394	0.031	0.053	0.084	0.012	0.490
KU	1960-61	0.037	0.026	0.063	0.000	0.012	0.012	0.003	0.078
	1970-71	0.070	0.013	0.083	0.000	0.009	0.009	0.003	0.094
	1984-85	0.100	0.015	0.115	0.000	0.021	0.021	0.006	0.142
AN	1960-61	0.018	0.036	0.054	0.000	0.026	0.026	0.002	0.082
	1970-71	0.043	0.032	0.075	0.000	0.051	0.051	0.002	0.128
	1984-85	0.044	0.011	0.055	0.004	0.070	0.074	0.004	0.133
CU	1960-61	0.084	0.068	0.152	0.000	0.088	0.089	0.006	0.246
	1970-71	0.083	0.050	0.134	0.001	0.116	0.117	0.014	0.265
	1984-85	0.066	0.045	0.111	0.018	0.145	0.164	0.014	0.289
CH	1960-61	0.000	0.212	0.212	0.000	0.086	0.086	0.037	0.338
	1970-71	0.000	0.172	0.172	0.000	0.129	0.129	0.016	0.318
	1984-85	0.006	0.116	0.122	0.004	0.168	0.172	0.005	0.299
RH	1960-61	0.014	0.068	0.082	0.002	0.024	0.026	0.002	0.109
	1970-71	0.011	0.054	0.064	0.000	0.074	0.074	0.003	0.141
	1984-85	0.010	0.034	0.043	0.001	0.070	0.072	0.010	0.125

Notes are given at the end of the table.

Table 8.A2.2 Contnd.

District	Year	Canals	Tanks	Surface Water[1]	Tube-Wells	Other Wells	Ground Water[2]	Other Sources	Total NIA[3]
NZ	1960-61	0.205	0.162	0.367	0.001	0.014	0.015	0.005	0.386
	1970-71	0.183	0.169	0.352	0.000	0.039	0.039	0.012	0.404
	1984-85	0.207	0.114	0.321	0.005	0.093	0.098	0.024	0.504
ME	1960-61	0.011	0.130	0.141	0.000	0.032	0.032	0.006	0.178
	1970-71	0.020	0.110	0.130	0.000	0.036	0.036	0.004	0.171
	1984-85	0.024	0.116	0.140	0.000	0.088	0.088	0.006	0.234
MB	1960-61	0.009	0.057	0.066	0.000	0.024	0.024	0.004	0.094
	1970-71	0.021	0.055	0.076	0.000	0.024	0.024	0.003	0.103
	1984-85	0.016	0.036	0.052	0.001	0.052	0.053	0.002	0.106
NA	1960-61	0.027	0.053	0.080	0.000	0.044	0.044	0.000	0.124
	1970-71	0.104	0.061	0.165	0.000	0.030	0.030	0.002	0.197
	1984-85	0.154	0.037	0.191	0.000	0.064	0.064	0.009	0.264
WA	1960-61	0.009	0.192	0.201	0.000	0.041	0.041	0.002	0.244
	1970-71	0.025	0.166	0.191	0.000	0.043	0.043	0.005	0.239
	1984-85	0.003	0.147	0.150	0.005	0.181	0.186	0.006	0.343
KH	1960-61	0.030	0.159	0.188	0.000	0.003	0.003	0.011	0.202
	1970-71	0.035	0.123	0.158	0.000	0.021	0.021	0.015	0.194
	1984-85	0.099	0.055	0.154	0.018	0.023	0.041	0.017	0.212
KM	1960-61	0.036	0.117	0.153	0.000	0.068	0.068	0.014	0.235
	1970-71	0.032	0.129	0.160	0.000	0.050	0.050	0.006	0.236
	1984-85	0.110	0.107	0.217	0.000	0.162	0.162	0.019	0.398
AD	1960-61	0.013	0.041	0.054	0.000	0.003	0.003	0.003	0.060
	1970-71	0.020	0.034	0.054	0.000	0.004	0.004	0.000	0.058
	1984-85	0.027	0.026	0.054	0.001	0.009	0.010	0.004	0.068
AP	1960-61	0.127	0.109	0.236	0.000	0.031	0.031	0.009	0.277
	1970-71	0.135	0.095	0.229	0.006	0.037	0.043	0.010	0.282
	1984-85	0.171	0.074	0.245	0.018	0.062	0.080	0.011	0.336

Notes: 1 : *Surface water = Canals + Tanks.* 2 : *Ground water = Tubewells + Other Wells.*

3 : Total NIA = Total net area irrigated by all sources put together.

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna; GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad; AP : Andhra Pradesh (all districts);

the respective shares of canals, tanks and ground water have remained some what stationary.

Within the 7 districts where canals continue to dominate CU is lone exception where both canals and tanks lost significantly in percentage terms to ground water.

Ground water (GW): Ground water irrigation is gaining in several districts of AP over time. It provided more than 25% of the total irrigation in AN, CU, CH, RH, ME, MB, NA, WA and KM districts none of which is a coastal district. Particularly in AN, CU, CH and RH its share in 1984-85 is more than 50%. The GW segment is by tubewells and other (open/dug) wells. Ground water irrigation in the districts of AP is mainly through dug wells. Tubewells as a source of irrigation has not developed in most of the districts except in the two Godavari districts where by 1984-85 tubewells account for more than 10% of the irrigated area. In all other districts, the share of tubewells is less than 2%. except in KR, GN, AN, CU and KH where its share in 1984-85 was between 2% and 9%.

Grouping based on sourcewise irrigation characteristics: In this background on sourcewise irrigations, the districts of AP are found to fall into the following groups based on the characteristics of irrigation regimes:

G1) Irrigation is mostly by canals under SW (≥ 50% of the TNIA); GW sources contribute only a little to TNIA (< 25% of TNIA): EG, WG, KR, GN, KU & N2 districts.

G2) Irrigation is mostly by tanks under SW (≥ 25% of TNIA) with a high percentage of GW (≥ 25% of TNIA): CH, RH, ME & MB districts.

G3) Irrigation is mostly by tanks under SW (≥ 25% of TNIA) with a little GW (< 25% of TNIA): SV & WA districts.

G4) A shift from tanks to canals under SW with high percentage of GW (≥ 25% of TNIA): AN, CU, NA & KM districts.

G5) A shift from tanks to canals under SW with very little GW (< 25% of TNIA): KH & AD districts.

Table 8.1 in the text gives the names of districts under the above groupings. In the rest of this chapter the 5 groups are denoted as G1, G2, G3, G4 and G5, respectively. An important point has to be mentioned with respect to the positions of NA and WA districts in our grouping in contrast to what appears in table 8A2.1. In our sample period 1960-61 to 1984-85, only in 8 out of the 25 years GW in NA district has its share in total irrigation less than 20%. Thus NA is slotted into G4 which has high percentage of GW. Similarly, the GW in WA district has been mostly less than 25% in total irrigation until 1976-77. Thus WA is slotted into G3.

CHAPTER 9 – ANALYSIS OF YIELD VARIABILITY IN RESPONSE FUNCTION FRAMEWORK: DISTRICTS OF ANDHRA PRADESH

"Remember, son, many a good story has been ruined by over verification!"

— *James Bennet.*

9.1 Introduction.

In the previous chapter (8), yield response functions were estimated for the 5 cereal crops (rice, jowar, bajra, ragi & maize) at the districts level (see chapter 8, table 8.4). In this chapter the analysis of yield variability is carried out by conducting Hsu tests on the estimated residuals obtained from the yield response functions reported in the previous chapter.

The yield response functions (y.r.f) reported in table 8.4 were all estimated with an additive error only[1]. Therefore, only absolute variability is assessed in this chapter using the estimated additive errors obtained from the y.r.f reported in table 8.4.

The variability analysis is carried out for each district separately. For the crop cases for which y.r.f could be estimated at individual district level itself, the corresponding districtwise residuals are straight away available. But, note that most of the y.r.fs were estimated using pooled data. In this case, the Hsu tests for detecting the variability change are based on the districtwise residuals obtained from the regressions with pooled data.

An important point must be noted now. The estimated y.r.f, that were reported in table 8.4 (chapter 8) are based on time

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1 Reasons for not estimating the y.r.f in multiplicative error form were given in the previous chapter (see section 8.2).

series data. Then, the residuals ($\hat{U}_t$) corresponding to a crop case in a district are naturally according to the order of time variable. That is, (subscript) 't' runs over the time period 1960-61 to 1984-85 (our data period) as follows:

$$\hat{U}_{1960-61}, \hat{U}_{1961-62}, \ldots, \hat{U}_{1984-85},$$

such that the residuals correspond to successive values of time variable. Results of Hsu tests conducted on this series as such would then only indicate whether there has been a change of variance over time and if so, from which year onwards. The variability change results obtained here would be comparable (subject to some limitations to be elaborated later) with the results on variability change obtained under time trend framework done in chapter 7 since in both situations ($\hat{U}_t$) remain ordered according to successive values of time only. These results and the comparison are discussed in section 9.2.

The above results do not, in principle, answer questions regarding variability change due to input levels. Note that input levels could fluctuate over time with or without monotonicity between time variable and input levels. That is, it is not necessary that fertilizer levels, irrigation intensity, etc., must always go up (or down) as time increases (and it is here that farmers' expectations come into picture). Obviously then, the residuals ($\hat{U}_t$) in the order $\hat{U}_{1960-61}$, $\hat{U}_{1961-62}$, ..., $\hat{U}_{1984-85}$, *need not correspond to successive levels of inputs usage.*

It is, however, still possible to analyse variability change due to input levels using *the same set of residuals* estimated from the y.r.f.s reported in table 8.4. This can be done by re-ordering the districtwise time series of y.r.f. residuals according to increasing values of a specific input, *say fertilizer*, and then conducting Hsu tests on this re-ordered series of residuals. This would tell us if there is any change in variability of yields with respect to increasing levels of fertilizer use. Where a change in variability is indeed detected, the test procedure (G-Test) would then provide us the level of fertilizer from which the variance change occurred. Similarly, yield variability with respect to irrigation intensity can also be analysed by re-ordering the time series of residuals according to increasing values of irrigation intensity and then conducting Hsu tests on these re-ordered series of residuals.

The objective of this study being to assess variability change due to modern technology such analyses of yields with respect to fertilizer and irrigation alone are carried out. These results are discussed in section 9.3. Such analysis could not be done with respect to HYV adoption separately due to lack of reliable data at districts level on acreage under HYV seeds. As argued in chapter 8, fertilizer levels could be considered as an *instrumental* variable for the rate of adoption of HYV seeds, since the two are usually highly correlated. Hence, the results obtained with respect to fertilizer usage may represent those with respect to HYV adoption rate also. Yield variability with respect to rainfall is not assessed.

9.2 - *Yield Variability Over Time in the Response Function Framework.*

As mentioned earlier, the districtwise time series of residuals obtained from the y.r.f reported in chapter 8 table 8.4, are subjected to the Hsu tests for variance change. These residuals correspond to the following 62 crop cases:

Crop	Districts	Total
Rice	SV, EG, WG, KR, GN, KU, AN, CU, CH, RH, NZ, ME, MB, NA, WA, KH, KM, AD	18
Jowar	KU, AN, CU, NA, KM, KH	6
Bajra	SV, GN, AN, CU, CH, RH, NZ, ME, MB, NA, KM	11
Ragi	SV, EG, WG, KR, GN, KU, AN, CU, CH, RH, NZ, ME, MB, NA	14
Maize	SV, EG, KR, GN, AN, CU, CH, RH, NZ, ME, MB, WA, KM	13
		62

The ordering of these residuals being according to time variable, the tests would then be for variance change over time. The results of these tests are reported in table 9.1[2]. A summary of the results of these tests are given in table 9.2.

Did yield variability increase over time? Of 62 crop cases at various district levels for which we have estimated residuals, yields of 11 crop cases show change in variability. Of these 11 cases rice yield in KU stands as an exception. It is the only crop case to witness a fall in variability since 1961-62, a result that is surprising because modern technology arrived in India only during mid-1960s. Yields corresponding to the remaining 10 crop cases have all witnessed an increase in variability from different years (see table 9.2). These are yields of rice in WG (a Coastal district), maize in CH, AN, CU, KM, EG, KR, GN, & SV, and bajra in CH. Thus, maize yields in 8 out of total 18 districts in AP exhibit variability change over time.

First, different crop cases show variability change, if present, in different years. Secondly, most of such changes occurred not immediately with arrival of modern technology. Most of them showed variability change in later half of 1970s. Of the 8 districts showing variability change for maize yields, while 6 of the districts experienced variability change only in late 1970s,

2 Note that, in the case of bajra yields in CU and KM we have 2 y.r.f estimations; one for these 2 districts falling in sub-group A (G4A) (equation 12 of table 8.4), and the other for the group G4 as a whole along with AN and NA (equation 10 of table 8.4). Details of the grouping, sub-grouping and constituent districts are given in tables 8.1 & 8.3 of chapter 8. It turned out that Hsu tests conducted on the estimated residuals for CU and KM as obtained from equation 10 and those conducted on the residuals obtained from equation 12 gave the same result (though the estimated values of the test statistics were marginally different between the 2 sets). Hence, for these 2 districts, the test values computed using the residuals obtained from equation 10 (for the total group) is reported in table 9.1.

Table 9.1 - Results of Hsu Tests for Variance Change Over Time Based on Yield Response Functions.

	Rice		Jowar		Bajra		Ragi		Maize	
	T-Test	G-Test	T-Test	G-Test	T-Test	G-Test	T-Test	G-Test	T-Test	G-Test
Group 1										
EG	-0.549	0.378	‡	‡	‡	‡	-1.214	0.391	3.037†	0.943†
VG	2.296†	0.887††	‡	‡	‡	‡	0.516	0.618	‡	‡
KR	-0.128	0.465	‡	‡	‡	‡	1.084	0.748	3.443†	0.971†
GN	0.095	0.521	▮	▮	0.872	0.645	-0.525	0.367	2.835†	0.860
KU	-2.623†	0.089†	0.939_D	0.684_D	▮	▮	1.338	0.743	‡	‡
NZ	-0.398	0.389	▮	▮	-1.128	0.390	0.254	0.556	-0.416	0.373
Group 2										
CH	0.085	0.463	▮	▮	2.517†	0.904††	0.862	0.715	3.407†	0.983†
RH	-0.238	0.433	▮	▮	-1.684	0.169	-1.608	0.248	1.907	0.860
ME	0.014	0.464	▮	▮	0.949	0.659	1.153	0.700	1.691	0.833
MB	0.432	0.592	▮	▮	-1.159	0.231	0.227	0.545	1.827	0.854
Group 3										
SV	-1.204	0.258	‡	‡	0.002_D	0.734_D	0.346_D	0.618_D	2.904†	0.923†
WA	-0.639	0.351	▮	▮	‡	‡	‡	‡	1.284	0.755
Group 4										
AN	0.065	0.489	1.760	0.882††	1.048	0.797	0.482	0.833	3.632†	0.973†
CU	0.469	0.642	1.624	0.789	0.056	0.719	-1.239	0.278	3.113†	0.942†
NA	-0.392	0.416	0.062	0.517	0.728	0.646	-1.022	0.238	‡	‡
KM	1.121	0.748	1.948	0.849	1.184	0.711	‡	‡	2.696†	0.908†
Group 5										
KH	0.263	0.540	0.419_D	0.561_D	‡	‡	‡	‡	‡	‡
AD	-0.462	0.428	▮	▮	‡	‡	‡	‡	‡	‡

Notes: †/†† Indicates significance at 1%, and 5% levels respectively (Critical values are given in Chapter 5, appendix 5.1).
▮ For these crop cases no model could be fitted. ‡ These unimportant crop cases were dropped from the analysis.
D Results for these crop cases are based on independent district level regression. Results for all other crop cases are based on pooled regressions. See text for explanations.

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna; GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

Table 9.2 - Summary Results of Yield Variability Over Time Based on Yield Response Functions and the Estimated Change Point.

	Change in Variability Present: Highly/Moderately Irrigated A	Change in Variability Present: Lowly Irrigated B	No Change in Variability: Highly/Moderately Irrigated A	No Change in Variability: Lowly Irrigated B	No Results Cases
Group 1					
EG	...	MZE↑(1974)	RCE	RGI	JWR$ BJR$
WG	RCE↑(1976)	...	...	RGI	JWR$ BJR$ MZE$
KR	...	MZE↑(1976)	RCE	RGI	JWR$ BJR$
GN	...	MZE↑(1976)	RCE BJR RGI	...	JWR#
KU	RCE↓(1962)	...	...	JWR RGI	BJR$ MZE$
NZ	...	...	RCE BJR	RGI MZE	JWR#
Group 2					
CH	MZE↑(1971)	BJR↑(1979)	RCE	RGI	JWR#
RH	...	...	RCE	BJR RGI MZE	JWR#
ME	...	...	RCE	BJR RGI MZE	JWR#
MB	...	...	RCE MZE	BJR RGI	JWR#
Group 3					
SV	...	MZE↑(1979)	RCE	BJR RGI	JWR$
WA	...	...	RCE	MZE	JWR# BJR$ RGI$
Group 4					
AN	MZE↑(1978)	...	RCE RGI	JWR BJR	
CU	MZE↑(1978)	...	RCE BJR RGI	JWR	
NA	...	...	RCE RGI	JWR BJR	MZE$
KM	MZE↑(1965)	...	RCE BJR	JWR	RGI$
Group 5					
KH	...	...	RCE	JWR	BJR$ RGI$ MZE$
AD	...	...	RCE	...	JWR# BJR$ RGI$ MZE#
Total (90)	6	5	25	26	28

Notes: ↑ (↓) Indicates increase (decrease) in variability. The variability change point is given in brackets.
For these crop cases no model could be fitted (9 cases).
$ These crop cases were dropped from the analysis (19 cases).

Crops: RCE - Rice; JWR - Jowar; BJR - Bajra; RGI - Ragi; MZE - Maize;

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna; GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

KM an important contributor to the State total production experienced variability change as early as 1964-65. Bajra yield showed variability change in a lone district, that is CH. Yields of ragi and a few cases of jowar that could be analysed did not show variability change in any of the districts. On the whole an overwhelming 51 crop cases at the *district level, do not* show variability change over time.

Irrigated yields versus unirrigated yields: Recall that in the previous chapter a clear distinction could be made regarding which crop is irrigated to what extent in *each district*. Using this information, we find from the results reported in table 9.2 that the 51 crop cases not showing change in yield variability include both crop cases that are highly or moderately irrigated and those that are lowly irrigated[9]. For example, ragi in GR is highly (97.5%) irrigated while ragi in KU (both from group 1) is lowly irrigated crop. Ragi yields in both these districts, however, do not show change in variability. Similar is the case of maize in ME (lowly irrigated) and MB (moderately (42%) irrigated) (both in group 2) both of which do not show any change in variability. On the contrary, maize in CH (group 2) which is also highly (81%) irrigated, however, showed an increase in variability.

Similarly, amongst the 11 crop cases showing variability change there are cases with high as well as low irrigation intensities. These suggest that irrigation and yield variability over time are not related. A striking example to show that is the case of rice yield in WG and KU, both of which are highly irrigated. While rice yield variability in WG increased over time, in KU it decreased over time.

Comparison of variability results between TTF and RFF: As mentioned earlier the results of variability change over time obtained under the response function framework (RFF) are in

9 A crop with below 35% of its acreage under irrigation is considered as lowly irrigated crop. Otherwise, depending on the actual percentage under irrigation it is considered as either highly or moderately irrigated.

principle comparable to the results obtained under the time trend framework (TTF) done in chapter 7. Two major points must, however, be kept in mind while comparing the 2 sets of results. One relating to the estimation procedure and the other relating to the period of analysis. Some elaboration on these two issues follows.

First is, on the estimation procedure adopted. Recall that in chapter 7, time trends of crop yields were estimated for individual districts separately. The estimated residuals from these (individual) time trends were then subjected to the Hsu tests for variance change. On the other hand, the analysis in the RFF was done using *yield response functions* (chapter 8) most of which (with a few *exceptions*) *were estimated* at a group/sub-group levels pooling the data over constituent districts[4]. Hsu tests were then separately conducted for *each of* the districts using the corresponding districtwise *estimated residuals*. Only for 4 crop cases (jowar(KU), jowar(KH), bajra(SV) *and* bajra(SVI) separate y.r.f's could be estimated at the district level, and the variability analysis for these 4 crop cases was *done* using the estimated residuals from the individual yield *response* functions. Bearing this point in mind, it is hoped any *discrepancies* in results arising due to this difference in the *estimation procedures* would only be minimal.

The other major point to be noted while comparing the 2 sets of results pertain to the sample period covered under the 2 sets of analysis. The analysis in the TTF (chapter 7) covered the period 1955-56 to 1984-85. Whereas, the analysis in the RFF was done for the period 1960-61 to 1984-85 only owing to the lack of data on some input variables for the 5 earlier years, 1955-56 to 1959-60. This difference in the periods of analysis, again it is hoped, would not lead to serious discrepancies in the 2 sets of results.

Keeping these 2 points in mind the results of variability obtained under TTF and under the RFF are compared here. Note that

4 Reasons for such grouping/sub-grouping of districts were *discussed* at length in the previous chapter 8.

while in the TTF both absolute and relative yield variability over time were analysed, in the RFF only absolute yield variability was analysed. Hence, only the results corresponding to absolute variability under the two frameworks are compared.

In all there are 5 (crops) x 18 (districts) = 90 crop cases at the district level. The details regarding the number of crop cases analysed under each of the 2 frameworks and the number of crops cases comparable are as follows:

	TTF	RFF
Total number of cases	90	90
Results available	52	62
Incomparable cases	9	19
Comparable cases	43	43

Only for 43 crop cases results are available for comparison. That is, only for these 43 cases estimation results are available under both frameworks. Details of these 43 crop cases are as follows:

Crop	Districts	Total
Rice	SV, EG, WG, KR, GN, KU, AN, CU, CH, RH, NZ, ME, MB, NA, WA, KH, KM, AD	18
Jowar	KU, AN, CU, NA, KH, KM	6
Bajra	SV, GN, AN, CU, CH, MB, NA	7
Ragi	SV, GN, AN, CU, CH, RH, MB	7
Maize	RH, NZ, ME, WA, KM	5
		43

Table 9.3 presents for these 43 crop cases a comparative picture of the results under both the frameworks.

At the outset, we find that the variability change (present/ not present) results as obtained from both the frameworks are the same in 38 out of the 43 crop cases compared here. Thus we find that the estimation procedure adopted for the y.r.f based on pooled data has mostly not affected the results of yield variability over time. Nor has the different sample periods covered under the 2 frameworks affected the variability results for these 38 crop cases.

Table . - Comparative [illegible]

Response Function Framework		Time-Trend Framework: Variability Change Present	Time-Trend Framework: Variability Change Not Present	Total cases
	Variability Change Present	Rice (VG - 1976/76) Bajra(CH - 1979/78) Maize(KM - 1965/75) (Cases = 3)	Rice (KU - 1976) (Cases = 1)	4
	Variability Change Not Present	Rice (SV - 1962) Rice (GN - 1976) Jowar(CU - 1966) Ragi (CH - 1966) (Cases = 4)	Bajra(SV) Ragi (SV) Rice (EG) Rice (KR) Bajra(GN) Ragi (GN) Jowar(KU) Rice (AN) Jowar(AN) Bajra(AN) Ragi (AN) Rice (CU) Bajra(CU) Ragi (CU) Rice (CH) Rice (RH) Ragi (RH) Maize(RH) Rice (NZ) Maize(NZ) Rice (ME) Maize(ME) Rice (MB) Bajra(MB) Ragi (MB) Rice (NA) Jowar(NA) Bajra(NA) Rice (WA) Maize(WA) Rice (KH) Jowar(KH) Rice (KM) Jowar(KM) Rice (AD) (Cases = 35)	39
Total Cases		7	36	43

Notes: Variability change point year is given in brackets; 1976 refers to 1975-76 and so on. Where both TTF and RFF show variability change, the variability change point year as per RFF is given first followed by the variability change point year as per TTF.

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna; GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

From table 9.3 we find that, 3 of the 38 crop cases show change in variability under both frameworks while an overwhelming 35 crop cases do not show any change in variability over time under either framework. The 3 crop cases showing change in variability under both the frameworks are rice(WG), bajra(CH) and maize(KM). They all show increase in variability over time. The variability change point obtained under both the frameworks also turned out to be same in the case of rice(WG) (1975-76) and roughly the same in the case of bajra(CH) (1977-79). Only in the case of maize(KM) the analysis under the 2 frameworks show different variability change points; the variability change point is 1964-65 under the RFF and it is 1974-75 as per the time-trend analysis. The 35 cases that showed no variability change under both frameworks include all the 4 crop cases (jowar(KU), jowar(KH), bajra(SV) and bajra(SV)) with individual district level y.r.f. The remaining 34 crop cases which also show same result under both the frameworks are all based on pooled group/sub-group y.r.fs.

Coming to the 5 crop cases for which the variability results under the 2 frameworks are different, these 5 are rice(SV), rice(GN), rice(KU), jowar(CU) and ragi(CH). Of them, rice(KU) is the only one which shows change in variability over time (variability fell over time) in the RFF. The remaining 4 crop cases, rice(SV), rice(GN), Jowar(CU and ragi(CH), showed change in variability (variability increased over time in all these 4 cases) only in the TTF but not in the RFF.

We may now conclude that as far as assessment of variability change over time is concerned, the results under both the frameworks are likely to be same if one is working with time series data. In view of the similarity of the results with respect to time between the frameworks, for a discussion on the nature of the results chapter 7 may be referred to.

9.3 Yield Variability With Respect To Increasing Input Levels.

The advantage of the analysis under RFF lies in that it is possible to explicitly link up the variability aspect to various input levels also. This is a more appropriate procedure to assess technology, than the procedure under TTF where references to input levels has been only indirect without directly bringing them into the analysis. The analysis under RFF relating variability changes to changes in fertilizer usage and irrigation intensities follows now.

9.3.1 Yield Variability With Respect To Fertilizer Use.

To assess variability changes with respect to changing input levels, we use the same set of districtwise residuals obtained from the y.r.f reported in the previous chapter. These time series of residuals are first re-ordered according to increasing levels of fertilizer (nutrients) use in kilo grammes/hectare (Kg/Ha) and then Hsu tests are conducted on the re-ordered series of residuals to assess change in yield variability with respect to fertilizer use. Note that we had defined in the previous chapter two proxy fertilizer variables for the purpose of estimating the y.r.f's. The two proxy variables are (1) FRCE for rice, and (2) F for the other cereal crops (jowar, bajra, ragi & maize). Denoting the acreage under rice, jowar, bajra, ragi & maize as ARCE, AJWR, ABJR, ARGI & AMZE, respectively, the two proxy variables are as defined below:

For rice,

$$FRCE = \frac{\text{Total Fertilizer Used(in Kg)}}{\text{ARCE} \quad \text{(in Ha)}}$$

For jowar, bajra, ragi & maize,

$$F = \frac{\text{Total Fertilizer Used}}{\text{ARCE + AJWR + ABJR + ARGI + AMZE}} \quad \frac{\text{(in Kg)}}{\text{(in Ha)}}$$

Since, due to lack of time series data on crop specific fertilizer use, FRCE for rice and F for the other 4 crops (jowar, bajra, ragi & maize) were used for the purpose of estimating y.r.f (in chapter 8), the residuals are also re-ordered according to the increasing levels of FRCE (for rice) and F (for other crops).

Variability analysis with respect to fertilizer use is done for all the 62 crop cases at districts level for which we have the estimated residuals from y.r.f. The results of the Hsu tests, conducted on these residuals after re-ordering them according to increasing levels of FRCE (for rice) or F (for jowar, bajra, ragi & maize), are reported in table 9.4[5]. Also a summary of the results is given in table 9.5.

From table 9.5 we find that in all only 9 crop cases show a change in yield variability as fertilizer level increases. These include only one case of bajra yields in CH and 8 maize cases (in the districts EG, KR, GN, CH, SV, AN, CU & KM). Of these 9 crop cases only bajra(CH) (contributing 6% of the State's bajra output in 1984-85) and maize(KM) (contributing 44% of the State's maize output in 1984-85) are important crop cases. The remaining 7 crop cases, each with a share of less than even 2% of the State's output in 1984-85, are only of negligible importance.

Regarding the direction of the change, all these 9 crop cases show an increase in variability with respect to increase in fertilizer use. That is yield variability increases with increase in fertilizer use. Note that all these 9 crop cases showed an increase in variability with respect to time also as reported in table 9.2.

The level of fertilizer use at which the variance change in the residuals has occurred (call it as critical levels) differed among the 9 crop cases as follows:

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5 As in the case of variability over time discussed in the previous section, for bajra yields in CU and KM, the residuals from both equations 10 & 12 of table 8.4 were tested for variability change with respect to fertilizer. Again, for both CU & KM, the variability results obtained from both the sets of residuals turned out to be the same except for some marginal difference in the computed value of the test statistic Hence for bajra yields in CU and KM only the results obtained using the residuals obtained from equation 10 (for the total group) are reported in table 9.4.

Table 9.4 - Results of Hsu Tests for Variance Change With Respect To Fertilizer Use.

	Rice		Jowar		Bajra		Ragi		Maize	
	T-Test	G-Test	T-Test	G-Test	T-Test	G-Test	T-Test	G-Test	T-Test	G-Test
Group 1										
EG	-0.5605	0.3659	$	$	$	$	-0.9031	0.4295	2.6504*	0.9309*
WG	1.8360	0.8790	$	$	$	$	0.6999	0.6337	$	$
KR	-0.0304	0.4786	$	$	$	$	1.6206	0.8546	2.9704*	0.9550*
GN	0.2773	0.5642	#	#	0.9178	0.6526	-0.3762	0.3973	2.6831*	0.8342
KU	-2.2665*	0.1270	0.9773_D	0.6814_D	#	#	1.2487	0.7425	$	$
NZ	-1.1315	0.2836	#	#	1.1287	0.6249	-0.6375	0.3729	-0.3110	0.4159
Group 2										
CH	-0.1279	0.4278	#	#	2.2088*	0.8648	0.9084	0.7298	3.7662*	0.9847*
RR	-0.6879	0.3392	#	#	-1.9105**	0.2510	-0.7792	0.3670	1.5182	0.7975
ME	-0.5552	0.3372	#	#	0.7453	0.6178	0.4690	0.5612	1.3151	0.7621
MB	-0.1260	0.4639	#	#	-0.8337	0.2888	0.1968	0.5279	1.4415	0.7884
Group 3										
SV	-1.2199	0.2705	$	$	0.5716_D	0.6683_D	0.4588_D	0.6460_D	2.7267*	0.9222*
WA	-0.3860	0.3831	#	#	$	$	$	$	0.5950	0.6444
Group 4										
AN	0.3533	0.5625	1.0504	0.6621	1.3098	0.7058	0.1251	0.5649	3.4387*	0.9749*
CU	1.1307	0.7360	0.7982	0.6789	0.7917	0.7058	-0.0470	0.4876	3.4792*	0.9520*
NA	-0.4425	0.3844	0.1103	0.5208	0.3148	0.5686	-1.1373	0.2100	$	$
KM	1.6950	0.8281	1.8658	0.8464	1.2585	0.7151	$	$	2.4272*	0.8995**
Group 5										
KH	0.3089	0.5634	0.5696_D	0.5895_D	$	$	$	$	$	$
AD	-0.6670	0.3446	#	#	$	$	$	$	$	$

Notes: */** Indicates significance at 1%, and 5% levels respectively (Critical values are given in Chapter 5, appendix 5.1).

\# For these crop cases no model could be fitted. $ *These unimportant crop cases were dropped from the analysis.*

D Results for these crop cases are based on independent district level regression. Results for all other crop cases are based on pooled regressions. See text for explanations.

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna; GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor; RR : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

Table 9.5 - Summary Results of Variability With Respect To Fertilizer Use and the Estimated Variability Change Fertilizer Level.

	Change in Variability Present		No Change in Variability		No Results Cases
	Highly/Moderately Irrigated A	Lowly Irrigated B	Highly/Moderately Irrigated A	Lowly Irrigated B	
Group 1					
EG	...	MZE↑(75.0)	RCE	RGI	JWR$ BJR$
WG	...	...	RCE	RGI	JWR$ BJR$ MZE$
KR	...	MZE↑(83.0)	RCE	RGI	JWR$ BJR$
GN	...	MZE↑(62.0)	RCE BJR RGI	...	JWR#
KU	...	...	RCE	JWR RGI	BJR$ MZE$
NZ	...	...	RCE BJR	RGI MZE	JWR#
Group 2					
CH	MZE↑(50.0)	BJR↑(71.0)	RCE	RGI	JWR#
RH	...	...	RCE	BJR RGI MZE	JWR#
ME	...	...	RCE	BJR RGI MZE	JWR#
MB	...	...	RCE MZE	BJR RGI	JWR#
Group 3					
SV	...	MZE↑(44.0)	RCE	BJR RGI	JWR$
WA	...	...	RCE	MZE	JWR# BJR$ RGI$
Group 4					
AN	MZE↑(36.0)	...	RCE RGI	JWR BJR	
CU	MZE↑(60.0)	...	RCE BJR RGI	JWR	
NA	...	...	RCE RGI	JWR BJR	MZE$
KM	MZE↑(32.0)	...	RCE BJR	JWR	RGI$
Group 5					
KH	...	...	RCE	JWR	BJR$ RGI$ MZE$
AD	...	...	RCE	...	JWR# BJR$ RGI$ MZE#
Total (90)	4	5	27	26	28

Notes: ↑ Indicates increase in variability. Fertilizer (Kg/Ha) level at the variability change point is given in brackets.
For these crop cases no model could be fitted (9 cases).
$ These crop cases were dropped from the analysis (19 cases).

Crops: RCE - Rice; JWR - Jowar; BJR - Bajra; RGI - Ragi; MZE - Maize;

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna; GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; KH : Kh[illegible]; KM : Karimnagar; AD : Adilabad;

1) Bajra(CH) - 71 Kg/Ha
2) Maize(EG) - 76 Kg/Ha
3) Maize(KR) - 83 Kg/Ha
4) Maize(GN) - 62 Kg/Ha
5) Maize(CH) - 50 Kg/Ha
6) Maize(SV) - 44 Kg/Ha
7) Maize(AN) - 36 Kg/Ha
8) Maize(CU) - 60 Kg/Ha
9) Maize(KM) - 32 Kg/Ha

The increase in yield variability with respect to increase in F means: As fertilizer application increased beyond the critical levels, the absolute gaps ($\hat{U}_t$) between the expected yield and the actual realized yields widened such that, as indicated by the Hsu tests, the variance of these gaps increased; i.e., yield variability increased.

From table 9.5 we find that in the remaining 53 out of the 62 crop cases analysed here do not show any change in yield variability with respect to fertilizer use. This includes rice yields in all the 18 districts of AP. Recall that in 4 districts, SV, WG, KU and GN rice yields show change in variability over time (rice yield in WG under both the frameworks and rice yield in SV and GN only under TTF and rice yield in KU only under RFF). The result that rice yield even in these 4 districts did not show variability change with respect to fertilizer usage clearly supports the view taken by us in chapter 5 where we argued that yields which show a change in variability over time, need not present a similar picture with respect to input levels. That is, fluctuations in yield levels observed over time are partly/largely due to fluctuations over time in the levels of inputs used (here fertilizer).

Apart from rice yields in all 18 districts, the 53 crop cases not showing any change in yield variability with respect to fertilizer include yields of jowar in 6 districts, ragi in 14 districts, bajra in 10 districts and maize in 5 districts (for which we have y.r.fs). All these crop cases did not show variability change over time either. That is the yields of these crops do not face changing yield variability either over time or with respect to fertilizer use.

Irrigated yields versus unirrigated yields: As can be seen from table 9.5, these 53 cases include crop yields both under high/ moderate irrigation (27 crop cases) and low irrigation (26 crop cases). Of the 9 crop cases showing variability change with respect to fertilizer use, 4 crop cases (maize(CH), maize(AN), maize(CU) & maize(KM)) yields are under highly/moderately irrigated conditions (i.e., at least 35% or more of the crop's acreage is under irrigation). The remaining 5 crop cases (maize(EG), maize(KR), maize(GN), maize(SV) & bajra(CH)) all correspond to yields under lowly irrigated (i.e., with less than 40% of the crop's acreage under irrigation) conditions. Thus, it seems that presence or absence of irrigation does not seem to affect yield variability with respect to fertilizer use.

9.3.2 Yield Variability With Respect To Irrigation Intensity.

As in the case with respect to fertilizer use discussed in the previous section, here too, first the estimated residuals obtained from the y.r.f (reported in the previous chapter) are re-ordered according to increasing values of cropwise irrigation intensities. While re-ordering the residuals, quite many of the total 62 crop cases for which we have estimations, are noted to be lowly irrigated. In fact for several of them the irrigation intensity for many years was actually zero; i.e., the crop cases are totally unirrigated cases which do not permit re-ordering of the residuals according to increasing levels of irrigation intensity. Such cases are 27 in number. Hence, this analysis is restricted only to the remaining 35 crop cases that do not face this problem. The 35 crop cases are as follows:

Crop	Districts Analysed	Total
Rice	SV, EG, WG, KR, GN, KU, AN, CU, CH, RH, NZ, ME, MB, NA, WA, KH, KM, AD	18
Bajra	GN, CU, KM	3
Ragi	GN, AN, CU, NA	4
Maize	KR, GN, AN, CU, CH, RH, NZ, ME, WA, KM	10
		35

In these 35 cases, the level of irrigation intensity has never been zero and hence re-ordering the residuals according to increasing values of irrigation intensity is, therefore, possible. Hsu tests are then conducted on these re-ordered series of residuals. The results of the Hsu tests are reported in table 9.6. A summary of the results of variability change with respect to irrigation intensity is reported in table 9.7.

In the case of rice yields, none of the 18 districts in AP show variability change with respect to irrigation intensity. This result is exactly similar to the result obtained with respect to fertilizer intensity.

The 3 cases of bajra yields (GN, CU & KM) and 4 cases of ragi yields (GN, AN, CU & NA) analysed here do not show any change in yield variability with respect to irrigation intensity. Note that none of these 7 crop cases showed any change in variability with respect to fertilizer use nor over time.

From table 9.7 we find that only two crop cases (maize(RH) and maize(KM)) show increase in yield variability with respect to irrigation intensity. The level of irrigation intensity at which variability changed is about 4.2% in the case of maize(RH) and 22.4% in the case of maize(KM). Maize(KM), as noted earlier, is an important crop case in the sense KM contributed as much as 44% of the State total maize production. Maize(RH) contributing about 2% of the State's maize production, however, is only of minor importance. Recalling our earlier results, of these 2 crop cases only maize(KM) shows variability change with respect to time (under both frameworks) and also with respect to fertilizer use. Thus, variability of maize(KM) yields has been found to be increasing with respect to time, fertilizer use and also irrigation intensity. Thus maize(KM) stands unique showing an all round increase in yield variability. Note that yield levels of maize(KM) have shown significant positive growth over time while maize(RH) shows stagnant yield levels (see chapter 3).

33 crop cases do not show any change in yield variability with respect to irrigation intensity. Thus, an overwhelming

Table 9.6 – Results of Hsu Tests for Variance Change With Respect To Irrigation Intensity.

	Rice		Jowar		Bajra		Ragi		Maize	
	T-Test	G-Test	T-Test	G-Test	T-Test	G-Test	T-Test	G-Test	T-Test	G-Test
Group 1										
EG	-0.2894	0.4033	$	$	$	$	@	@	@	@
VG	1.4742	0.8254	$	$	$	$	@	@	$	$
KR	0.5372	0.6542	$	$	$	$	@	@	1.3839	0.7518
GN	0.2965	0.5437	#	#	1.6900	0.8121	-0.4214	0.3966	1.8315	0.8466
KU	-2.2399^{+}	0.2228	@	@	#	#	@	@	$	$
NZ	-0.0716	0.4640	#	#	@	@	@	@	-0.9683	0.2654
Group 2										
CH	-1.4710	0.2101	#	#	@	@	@	@	-0.5909	0.4057
RH	-0.2116	0.4423	#	#	@	@	@	@	2.2500^{+}	0.8742^{++}
ME	-0.3956	0.4135	#	#	@	@	@	@	0.6490	0.6358
MB	1.3166	0.7527	#	#	@	@	@	@	@	@
Group 3										
SV	-0.3568	0.4266	$	$	@	@	@	@	@	@
VA	-0.5642	0.4362	#	#	$	$	$	$	1.6451	0.8275
Group 4										
AN	-0.6074	0.3241	@	@	@	@	0.1980	0.5624	-0.9395	0.3405
CU	-0.0344	0.5185	@	@	1.1460	0.7793	-0.2580	0.3906	0.6568	0.6643
NA	0.1136	0.5096	@	@	@	@	1.4056	0.7729	$	$
KM	0.4346	0.5903	@	@	0.6154	0.5653	$	$	2.0060^{++}	0.9022^{++}
Group 5										
KH	0.5038	0.6555	@	@	$	$	$	$	$	$
AD	-0.6192	0.3568	#	#	$	$	$	$	$	$

Notes: +/++ Indicates significance at 1%, and 5% levels respectively (Critical values are given in Chapter 5, appendix 5.1).
For these crop cases no model could be fitted. $ These unimportant crop cases were dropped from the analysis.
@ For these cases the analysis could not be done due to zero level of irrigation intensity (see text for explanations).

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna; GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda; WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

and the Estimated Variability Change: Irrigation Intensity Level.

	Change in Variability Present		No Change in Variability		No Results Cases
	Highly/Moderately Irrigated	Lowly Irrigated	Highly/Moderately Irrigated	Lowly Irrigated	
	A	B	A	B	
Group 1					
EG	...	...	RCE	...	RGI[@] MZE[@] JVR[$] BJR[$]
WG	...	...	RCE	...	RGI[@] JVR[$] BJR[$] MZE[$]
KR	...	...	RCE	MZE	RGI[@] JVR[$] BJR[$]
GN	...	...	RCE BJR RGI	MZE	JVR[!]
KU	...	...	RCE	...	JVR[@] RGI[@] BJR[$] MZE[!]
NZ	...	...	RCE	MZE	BJR[@] RGI[@] JVR[!]
Group 2					
CH	...	...	RCE MZE	...	BJR[@] RGI[@] JVR[!]
RH	...	MZE↑(0.042)	RCE	...	BJR[@] RGI[@] JVR[!]
ME	...	...	RCE	MZE	BJR[@] RGI[@] JVR[!]
MB	...	...	RCE		BJR[@] RGI[@] MZE[@] JVR[!]
Group 3					
SV	...	...	RCE	...	BJR[@] MZE[@] RGI[@] JVR[$]
WA	...	...	RCE	MZE	JVR[!] BJR[$] RGI[$]
Group 4					
AN	...	...	RCE RGI MZE	...	JVR[@] BJR[@]
CU	...	...	RCE BJR RGI MZE	...	JVR[@]
NA	...	...	RCE RGI	...	JVR[@] BJR[@] MZE[$]
KM	MZE↑(0.224)	...	RCE BJR	...	JVR[@] RGI[$]
Group 5					
KH	...	...	RCE	...	JVR[@] BJR[$] RGI[$] MZE[$]
AD	...	...	RCE	...	JVR[!] BJR[$] RGI[$] MZE[!]
Total (90)	1	1	28	5	55

Notes: ↑ Indicates increase in variability. Irrigation intensity level at the variability change point is given in brackets.

@ For these cases the analysis could not be done due to zero level of irrigation intensity (see text for explanations).

! For these crop cases no model could be fitted. $ These crop cases were dropped from the analysis.

Crops: RCE - Rice; JVR - Jowar; BJR - Bajra; RGI - Ragi; MZE - Maize;

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; WG : West Godavari; KR : Krishna;
GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor;
RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda;
WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

proportion of crop cases analysed (33 out of 35) indicate that increase in the irrigation intensity does not lead to increase in yield variability. These 33 cases include:

(i) 23 cases with significant positive growth in yields. These are rice in 17 out of districts the exception being SV, bajra in CU, ragi in GN, AN & CU, and maize in NZ & WA;

(ii) 3 cases with stagnant yield levels. These are rice in SV, bajra in GN and maize in ME; and

(iii) 7 cases for which trend analysis was not done. These are bajra in KM, ragi in NA and maize in KR, GN, AN, CU & CH.

Thus, except for the two cases (maize(RN) and maize(KM)), no district shows variability change in any crop yield with respect to irrigation intensity. This result is important as it suggests that increasing levels of irrigation are most unlikely to cause instability in yield variance for any crop.

Also it seems that the relation between growth factor in yield levels and yield variability with respect to irrigation intensity is rather weak.

9.4 Overall Results.

Let us now pull together all the results; i.e., variability over time, fertilizer application and irrigation intensity. Table 9.8 provides this in a summary form.

A notable result we observe from table 9.8 is that rice yields in all 14 districts of AP do not show any change in variability with respect to time nor with respect to irrigation intensity nor with respect to fertilizer use. Rice yields in the other 4 districts (SV, WG, GN & KU) show variability change over time, though they however, do not show variability change with respect to fertilizer & irrigation intensities. This result implies that the fluctuations observed over time in rice yields are consistent to the fluctuations in irrigation and fertilizer intensities. This corresponds to the situation depicted in figure 5.5 in chapter 5.

Table 9.8 - Crop Cases Showing Variability Change Over Time, Fertilizer Application and Irrigation Intensity.

	Variability Change Present		
	Over Time	Fertilizer Application	Irrigation intensity
Total no. of cases	90	90	90
No. of cases analysed	52(TTF)/ 62(RFF)	62	35
No. of cases showing variability change	7(TTF)/ 11(RFF)	9	2
Crop:			
Rice	rice (SV)↑ rice (WG)↑ rice (GN)↑ rice (KU)↓	none	none
Jowar	jowar(CU)↑	none	none
Bajra	bajra(CH)↑	bajra(CH)↑	none
Ragi	ragi (CH)↑	none	none
Maize	maize(SV)↑ maize(EG)↑ maize(KR)↑ maize(GN)↑ maize(AN)↑ maize(CU)↑ maize(CH)↑ maize(KM)↑	maize(SV)↑ maize(EG)↑ maize(KR)↑ maize(GN)↑ maize(AN)↑ maize(CU)↑ maize(CH)↑ maize(KM)↑	maize(RH)↑ maize(KM)↑

Notes: ↑ (↓) Indicates increase (decrease) in variability.

These results put together further confirm that fluctuations over time may largely be only as a consequence of similar fluctuations in the associated input levels. That is, after accounting for the effect due to variations in input levels, the remaining (unexplained) variations in yield levels is purely random.

From table 9.8 we also find that 5 out of the 8 maize cases that showed change in variability over time and also with respect to fertilizer use, do not show any change in variability with respect to irrigation intensity. These 5 cases are maize in the districts KR, GN, AN, CU & CH. Thus in these 5 crop cases higher levels of variability are associated with relatively higher levels of fertilizer application. That is, when fertilizer levels were increased beyond a critical level expecting higher yield levels, the crop performance not being upto expectations, widened the gap ($\hat{U}_t$) between actual realizations and expectations. This then reflects as increasing variability. This feature also showed up as a change in variability over time. The result for these 5 crop cases is in contrast with the case of maize(RH). Maize(RH) shows variability change with respect to irrigation intensity but not with respect to fertilizer nor over time. Amongst all the crop cases analysed this is the only one which showed variability change with respect to to some input levels (here, irrigation intensity) but not variability change over time. This corresponds to the situation depicted in figure 5.6 in chapter 5. Even if one were to think that higher irrigation intensity might lead to higher variability for maize(RH), then obviously the other inputs (could be fertilizers) must be counter acting simultaneously towards variance stabilization, so that the net result is that no variability change over time could be observed. Maize(KM) is the lone exception which showed variability change with respect to time, fertilizer and irrigation intensities.

In the case of maize our results indicate that increasing of fertilizer application could cause instability in yield variance, be they irrigated/unirrigated. However, increasing levels of irrigation intensity are rarely found to cause instability in yield variance for any crop.

9.5 Summary and Conclusions.

In this chapter yield variability in the response function framework was analysed, with respect to time, fertilizer use and irrigation intensity, using the estimated residuals obtained from the yield response functions reported in the previous chapter. 10 out of the 62 crop cases analysed in this chapter showed an increase in variability over time, 1 showed decrease in variability while the remaining 51 crop cases did not show any change in variability over time. In most of the crop cases, these results were found to be the same as those obtained in chapter 7 where yield variability over time was assessed in the time trend framework. Putting together the results obtained under the TTF as well as RFF, we find that only 15 crop cases (4, 1, 1, 1, 8 cases under rice, jowar, bajra, ragi & maize, respectively) showed changes in yield variability over time.

As regards changes in yield variability with regard to inputs use, (fertilizer and irrigation) only 9 out of 62 crop cases show an increase in variability with respect to fertilizer use. Yield variability in these 9 cases (8 of which are maize yields in different districts and 1 is bajra yield) increased at different levels of fertilizer use. It would be instructive to further explore in the case of these crops in these districts, how far the actually applied fertilizers differ from the recommended dosages as well as the mix of the nutrients. In the absence of readily available such data, this could not be done here.

Similar analysis with respect to irrigation intensity was also carried out. This analysis, however, was restricted to only 35 crop cases for which irrigation intensity was never zero in any of the years. The results indicate that only 2 crop cases (maize(RH) & maize(KM) show an increase in yield variability with respect to irrigation intensity. Variability in these 2 crop cases increased at different levels of irrigation intensity. Remaining 33 crop cases did not show any change in variability with respect to irrigation intensity.

Thus, an overwhelming number of crop cases do not show any variability either over time or with respect to use of both fertilizer and irrigation. Notably rice in all 18 districts do not show any change in variability with respect to any of the inputs though in 3 districts (SV, WG & GN), yield variability increased over time while in one district (KU), it decreased.

In the 6 districts analysed for jowar, yield variability did not change over time (except in the district CU) nor with respect to fertilizer use. Jowar being mainly an unirrigated crop variability of jowar yields with respect to irrigation was not analysed.

In the case of bajra, of the 11 districts analysed yields in 10 districts do not show any change over time and also with respect to fertilizer use. Only in CH bajra yield shows change in variability over time and also with respect to fertilizer use. Bajra yield variability with respect to irrigation intensity was analysed for 3 districts only (GN, CU & KM) all of which do not show any change in yield variability.

In the case of ragi, yields in 14 districts were analysed. All districts showed no change in variability over time (except CH), and also with respect to use of fertilizer and irrigation.

In the case of maize yield, 13 districts were analysed, of which 8 districts (SV, EG, KR, GN, AN, CU, CH & KM) show increase in yield variability over time and also with respect to fertilizer use. Variability with respect to irrigation intensity was analysed only for 10 (KR, GN, AN, CU, CH, RH, NZ, ME, WA & KM) of these 13 districts. Of these 9 districts, only in RH and KM maize yields show an increase in yield variability with respect to irrigation. Notably in KM, which is the most important district for maize cultivation in Andhra Pradesh, maize yields show increase in variability over time and also with respect to use of both fertilizer and irrigation.

From our analysis so far (in previous chapters and this chapter), we may now conclude:

a) Most of the crop yields, except those of maize, in various districts of AP do not suffer from the problem of increasing yield variability over time (see section 9.2). The analyses under TTF as well as RFF support this result.

b) Though rice yields in a few districts (SV, WG, & GN) seem to face increasing yield variability over time, their fluctuations over time could be explained in terms of fluctuations in the associated input levels of fertilizer application and irrigation intensity (see section 9.4 and table 9.8).

c) Maize yields in almost all the districts where the crop is important suffer from the problem of increased variability over time as well as with respect to increasing levels of fertilizer. Maize(KM) is the lone case that showed increased variability over time and with respect to increases in fertilizer application and irrigation intensity also.

d) Unirrigated yields of several crops in various districts did not show a change in yield variability over time. Likewise, not all irrigated yields showed unchanging variability over time (see section 9.2). However, in the latter case, there is no evidence to suggest that irrigation intensity led to this variability change. In fact, the relation between irrigation intensity and yield variability over time seems to be generally weak (see section 9.2).

e) An overwhelming proportion of the number of crop cases (33 out of 35) analysed show that increasing the irrigation intensity of a crop does not lead to increase in yield variability (see section 9.3.2 and table 9.7).

f) Excepting in the case of maize yields, yields of other crops do not show increase in variability with respect to increase in fertilizer application.

CHAPTER 10 - ANALYSIS OF SPATIAL VARIABILITY IN CROP YIELDS

"It is better to know some of the questions than all of the answers!"

- James Thurber.

10.1 Introduction.

It was mentioned in chapters 1 and 5 that the problem of variability in crop yields can be viewed in two ways:

i) Variability of crop yields within a District, a State, etc.

ii) Spatial variability - variability in crop yields across Districts or States. Variability within the districts was analysed in the time trend framework in chapters 6 and 7, and in the response function framework in chapters 8 and 9. In this chapter spatial variability in crop yields across various districts of Andhra Pradesh is analysed.

Spatial variability, as defined in chapter 5, refers to variations (differences) in crop yields across districts during a given time period. Large differences across districts are observed in the yield levels of various crops. For example, in 1984-85, rice yields varied from a high level of about 2718 kg/ha in West Godavari to a low level of about 1104 kg/ha in Adilabad. Similarly in the case of jowar, in 1984-85, yields ranged between 1134 kg/ha (Cuddapah) and 357 kg/ha (Nalgonda). In the case of bajra the highest and lowest yield levels in 1984-85 were 1251 kg/ha (Cuddapah) and 206 kg/ha (Mehboobnagar), respectively; in the case of ragi these were 1764 kg/ha (Cuddapah) and 406 kg/ha (Medak), respectively, and in the case of maize these were 2184 kg/ha (Karimnagar) and 649 kg/ha (Medak), respectively. Such large differences across districts in yields for other years may also be observed in chapter 3 table 3.11.

Differences in the crop yields across districts may be expected given that different districts spread over vast geographic areas are unlikely to be homogeneous in terms of their natural endowments like soil fertility, irrigation, weather conditions, etc., besides other institutional factors including farmers' cultivation practices. While some of the factors that cause spatial variability in yields may be under human control, some other factors might not be, and to that extent spatial variability would persist. The question that arises here is "What are the factors that explain the spatial variability in crop yields?". The objective of this chapter is to identify some important factors that may explain the differences in crop yields of rice, jowar, bajra, ragi and maize, across the districts of Andhra Pradesh.

Differences in crop yields across districts can arise due to differences in various factors across districts. These factors are: (1) Agroclimatic factors like rainfall, soil fertility conditions, etc.; (2) Infrastructural factors like sources of irrigation and the extent of irrigation; (3) Differences in agricultural practices across districts - traditional or modern, seed variety used, input applications, mechanization, labour used, etc.; (4) Social and institutional factors like farmers' education level, credit facilities, etc. In chapters 3 and 8 the differences across districts in some of these factors were discussed in detail.

In this analysis only the first three factors, namely, agroclimatic, infrastructural and agricultural practices across districts are considered. In particular, the differences across districts in rainfall, sourcewise net irrigation proportions, aggregate cropping intensity, fertilizer intensity and cropwise gross irrigation proportions are considered. Specifically, the spatial variability in crop yields is related to the spatial variability in these explanatory factors.

Rainfall is a crucial variable that affects crop cultivation. Variations across districts in the amount of rainfall may, hence, be a factor determining the spatial variability of crop yields. Rainfall during the two monsoon seasons - South-West and North-East - are considered in this analysis.

Apart from climatic factors, differences in the infrastructure may also cause differences in yield levels across districts. Specifically irrigation being another crucial factor determining yield levels, the extent of irrigation availability may act as a constraint to crop cultivation in a district. Differences across districts in irrigation availability would naturally be an important factor in explaining spatial variability in crop yields. In this analysis, sourcewise net irrigation as a proportion to the total net sown area over all crops are considered as the measure of availability of irrigation. In chapters 3 and 8 earlier, we have already noted the differences in the order of development across districts in AP regarding surface water (canals and tanks), ground water (tubewells and other wells) and other sources of irrigation. These form the infrastructural variables in this analysis.

Availability of irrigation would not only ensure adequate water to crop growth in a season but also may permit raising more than one crop on a particular plot of land thereby increasing aggregate crop output in a year. Aggregate cropping intensity (ACI) defined as the ratio of gross cropped area over all crops to net sown area over all crops, is a measure of multiple cropping. Inter-district differences in ACI may also explain spatial variability of crop yields. ACI is another variable considered here.

While the effects of the above mentioned factors such as rainfall, net irrigation proportion and ACI may be felt over all cereal and non-cereal crops, some crop specific input variables, like cropwise gross irrigation proportion, fertilizer intensity, seed variety used, cropwise labour used, mechanization, etc., all of which play a direct role in determining the yield level, may also explain spatial variability of yields of specific crops. In this analysis only cropwise gross irrigation proportion and fertilizer availability are considered. Differences across districts in seed variety used, cropwise labour used, and mechanization could not be considered due to absence of continuous reliable time series data (1960-61 to 1984-85) on these variables at the district level.

Spatial variability at the States level, i.e., across the States of the country, is not studied as continuous time series data on sourcewise irrigation and cropwise gross irrigation are not available for all the major States of the country. The problem of spatial variability in crop yields is studied across the districts of Andhra Pradesh only. The analysis at the districts level is conducted for the period 1960-61 to 1984-85. Though data are available for some of the variables (in particular crop yields at the districts level) right from 1955-56, for some other variables such as fertilizers at the districts level data are available only from 1960-61 to 1984-85. This restricts our analysis to confine only to the period 1960-61 to 1984-85, for which continuous time series data on all the variables are available.

Before proceeding to explain the spatial variability in crop yields, the extent of spatial variability in yields and in the explanatory factors is first analysed. In section 10.2 a measure of spatial variability is defined and trends in the spatial variability analysed. In section 10.3 factors causing spatial variability in yields are analysed. Conclusions are provided in the last section.

10.2 Spatial Variability Across Districts of Andhra Pradesh - Its Measurement and Its Trend.

In this section a measure of spatial variability is defined and the degree as well as movement over time in the spatial variability of yields, rainfall, sourcewise net irrigation proportions, aggregate cropping intensity, fertilizer intensity and cropwise gross irrigation proportions, are analysed.

10.2.1 Spatial Variability in Crop Yields.

For any given year, spatial variability in yields is measured by the coefficient of variation (CV) in yields across districts in that year. The CV at time t for a variable Y (crop yields here), denoted as CV(Y), is thus defined as follows:

Let i: be the subscript for district;

t: be the time subscript (1960-61, 1961-62, ..., 1984-85);

Y_{it} = Yield level of a crop in i-th district at time t,

k = number of districts = 18;

$CV(Y)_t$ = Coefficient of variation across districts at time t in variable Y;

and $\bar{Y}_t = \frac{1}{k} \sum_{i=1}^{k} Y_{it}$ is the mean over districts of Y at time t.

and $\sigma_t = \sqrt{\frac{1}{k-1} \sum_{i=1}^{k} \left(Y_{it} - \bar{Y}_t\right)^2}$ is the standard deviation of Y over districts at time t.

The $CV(Y)_t$ is then simply,

$$CV(Y)_t = \sigma_t / \bar{Y}_t$$

$CV(Y)_t$, computed across districts, is a measure of the disparity at time t amongst the districts in variable Y. Time series of CVs across districts are computed for the period 1960-61 to 1984-85 for the yields of rice, jowar, bajra, ragi and maize (denoted by YRCE, YJWR, YBJR, YRGI and YMZE, respectively). Table 10.1 presents the time series of CV of the crop yields for the five crops. From these time series of the CVs the trends in the disparity or spatial variability in crop yields can be studied.

The CV is essentially a measure of dispersion around the sample mean. Low (high) values for the CV indicate close (wide) scatter of observations around the sample mean. Surekha and Griffiths (1984) and Evans and King (1985) consider variations in a series with a CV less than 0.3 (greater than 0.5) to be "mild" ("severe"). Using their cut off limit of 0.3[1] it can be seen from table 10.1 that in general the yields of rice, jowar and maize show mild variation while those of bajra and ragi show a high degree of variation across districts barring a few exceptional years here and there. In the case of rice the CV exceeds 0.3 only in the year 1972-73; i.e., only once in a span of 25 years. The CV exceeds 0.3 in 5 out 25 years in the case of jowar and 3 out of 25

1 In the rest of this chapter, this cut-off of 0.3 is used in deciding whether the disparities are low or high.

Table 10.1 - Coefficient of Variation (CV) Across (AP) Districts: Crop Yields.

Year	CV(YRCE)	CV(YJWR)	CV(YBJR)	CV(YRGI)	CV(YMZE)
1960-61	0.2778	0.3396	0.4012	0.2718	0.2401
1961-62	0.2029	0.2411	0.3052	0.1863	0.1702
1962-63	0.2721	0.2255	0.3365	0.3231	0.1965
1963-64	0.1781	0.1071	0.2578	0.2320	0.1026
1964-65	0.1094	0.2021	0.3977	0.2560	0.2319
1965-66	0.2564	0.2354	0.2970	0.3841	0.0822
1966-67	0.2446	0.2528	0.4472	0.4202	0.1229
1967-68	0.2185	0.2127	0.4572	0.4795	0.2011
1968-69	0.2429	0.2257	0.5324	0.3064	0.1813
1969-70	0.1937	0.2301	0.3312	0.3219	0.2411
1970-71	0.1738	0.2836	0.3528	0.3906	0.1824
1971-72	0.2195	0.2653	0.6963	0.4379	0.2391
1972-73	0.3676	0.3057	0.6978	0.6202	0.2904
1973-74	0.1513	0.2460	0.5066	0.3671	0.1260
1974-75	0.2156	0.2170	0.4555	0.3849	0.1685
1975-76	0.1442	0.3271	0.4642	0.3213	0.1363
1976-77	0.2056	0.2702	0.6721	0.4669	0.1875
1977-78	0.2658	0.1922	0.3816	0.3909	0.1918
1978-79	0.1772	0.2037	0.5236	0.3553	0.2207
1979-80	0.1842	0.2140	0.6146	0.3489	0.2044
1980-81	0.1814	0.2364	0.4459	0.3566	0.2737
1981-82	0.1692	0.2670	0.3660	0.3307	0.3899
1982-83	0.2037	0.2786	0.4561	0.3113	0.2368
1983-84	0.1455	0.3288	0.4422	0.4116	0.4612
1984-85	0.2354	0.3602	0.6769	0.3975	0.3036

Notes: YRCE, YJWR, YBJR, YRGI and YMZE are the yields of rice, jowar, bajra, ragi and maize, respectively.

years in the case of maize. In the case of bajra and ragi, however, the CVs are greater than 0.3 in most of the years: they are less than 0.3 only in 2 out of 25 years in the case of bajra and 4 out of 25 years in the case of ragi. Thus it can be said that the degree of spatial variability (disparity) in crop yields across the districts is generally low in the case of rice, jowar and maize and generally high in the case of bajra and ragi. Note that the CV for each of these crops is not constant over the period under consideration (see table 10.1). More on this later.

Having identified the crops with a high/low degree of spatial variability in yields, let us now identify, for each crop, the relative ranking of each district in the matter of crop yields. Table 10.2 presents for 3 years, viz., 1960-61, 1970-71 and 1984-85, cropwise, the range of yields observed over the districts, the State level yields and the classification of districts into low value districts (LVD) and high value districts (HVD). The LVD (HVD) are the districts with yield levels below (above) the State's average level of yield which is (not $\tilde{Y}$ defined above) the total production divided by the total acreage of a crop in the State as a whole. That is, State level yield $Y_t = Q_t / A_t$ where Q_t and A_t are the output and acreage of a crop in the State as a whole in time t, respectively.

Though table 10.2 provides crop yield details for only 3 years, it is a representative of the general pattern in crop yields across districts. The pattern for other years is largely in conformity with the trends as presented in table 10.2. From table 10.2, HVD(yields)[2] of the 5 crops regionwise in AP are as below:

2 In the rest of this chapter, for a variable X, HVD(X) means high value districts and LVD(X) means low value districts in comparison to the State average value of X.

Table 10.2 - Range and Ranking of Districts: Crop Yields (Kg/Ha).

Crop	Year	Lowest	Highest	State	Low Valued Districts (LVD)!	High Valued Districts (HVD)!
Rice	1960-61	691.983 (KH)	1506.317 (CU)	1216.645	SV KU RH ME MB NA VA KH KM AD (10)	EG VG KR GN AN CU CH NZ (8)
	1970-71	933.217 (AD)	1768.583 (NZ)	1359.305	SV EG GN CU RH ME MB NA VA KH KM AD (12)	VG KR KU AN CH NZ (6)
	1984-85	1104.415 (AD)	2717.523 (VG)	1975.406	SV GN KU AN RH NZ ME MB VA KH AD (11)	EG VG KR CU CH NA KM (7)
Jowar	1960-61	287.975 (NA)	870.891 (AD)	488.926	SV EG AN CU MB NA VA KH KM (9)	VG KR GN KU CH RH NZ ME AD (9)
	1970-71	220.250 (NZ)	694.325 (CH)	376.797	SV EG VG KR GN KU AN CU NZ NA KH KM (12)	CH RH ME MB VA AD (6)
	1984-85	356.793 (NA)	1133.761 (CU)	652.920	SV EG VG KR GN ME MB NA VA KH AD (11)	KU AN CU CH RH NZ KM (7)
Bajra	1960-61	264.479 (EG)	815.717 (KR)	473.263	EG GN CU NZ ME MB NA VA KM AD (10)	SV VG KR KU AN CH RH KH (8)
	1970-71	0.000 (NZ)	744.988 (CH)	516.031	EG KU AN RH NZ ME MB NA VA KH KM AD (12)	SV VG KR GN CU CH (6)
	1984-85	206.002 (MB)	1250.977 (CU)	521.593	KU AN RH NZ ME MB NA VA KH KM AD (11)	SV EG VG KR GN CU CH (7)
Ragi	1960-61	531.642 (MB)	1433.156 (GN)	808.130	SV AN CH ME MB NA VA KH KM AD (10)	EG VG KR GN KU CU RH NZ (8)
	1970-71	0.000 (AD)	1436.005 (AN)	785.208	SV RH NZ ME MB NA VA KH KM AD (10)	EG VG KR GN KU AN CU CH (8)
	1984-85	0.000 (KM)	1764.478 (CU)	956.511	SV KR CH NZ ME MB VA KH KM AD (10)	EG VG GN KU AN CU RH NA (8)
Maize	1960-61	112.360 (CH)	1026.673 (NZ)	838.484	KR GN AN CU CH ME MB VA AD (9)	SV EG VG KU RH NZ NA KH KM (9)
	1970-71	655.200 (KH)	1713.879 (NZ)	1343.541	SV EG VG KR GN CU RH ME MB NA VA KH AD (13)	KU AN CH NZ KM (5)
	1984-85	648.701 (ME)	2184.497 (KM)	1383.189	SV KR GN KU CU CH RH ME NA VA AD (11)	EG VG AN NZ MB KH KM (7)

Notes: ! : Low (High) Valued Districts are districts with yields below (above) State level yields;

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; VG : West Godavari; KR : Krishna; GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor; RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda; VA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

Crop	Coastal Andhra [SV, EG, WG, KR, GN]	Rayalaseema [KU, AN, CU, CH]	Telangana [RH, NZ, ME, MB, NA, WA, KH, KM, AD]	Total
YRCE	EG, WG, KR	AN, CU, CH	NZ	7
YJWR	--	KU, CH	RH, NZ, ME, AD	6
YBJR	SV, WG, KR, GN	CU, CH	--	6
YRGI	EG, WG, KR, GN	KU, AN, CU	RH	8
YMZE	EG, WG	KU, AN	NZ, KH, KM	7

It can be noted that 15 out of the 18 districts are HVD(yields) for one or more crops; 3 districts (MB, NA and WA) are not HVD(yields) for any crop. There is an interesting point to mention here. Some districts that are LVD(yields) for a crop are, however, major contributors to the State's production of that crop. For example, though GN is LVD(YRCE), rice is not only an important crop within GN, but also GN contributes significantly to the State's rice production. Same is true of jowar in MB and KH; bajra in AN and NA; ragi in SV, MB and CH; and maize in ME and WA. (See chapter 3, table 3.8).

It can be seen from table 10.2 that, some districts have, over time, improved their rankings in yield levels from less than State average to greater than State average; i.e., some LVD became HVD over time. The converse can also be observed; i.e., some HVD became LVD over time. In the case of rice 2 districts (NA and KM) became HVD over time and 3 other districts (GN, AN and NZ) turned LVD in the same period. In the case of jowar, 3 districts (AN, CU and KH) became HVD and 5 districts (WG, KR, GN, ME and AD) became LVD by 1984-85. Bajra yields too witnessed changes in the rankings of the districts; 3 districts (EG, GN and CU) became HVD while 4 districts (KU, AN, RH and KH) became LVD by 1984-85. In the case of ragi yields, however, the relative rankings of the districts have been more or less stable with only 2 districts (KR and NZ) turning HVD and 2 other districts (AN and NA) turning LVD by 1984-85. In the case of maize, 3 districts (AN, RH and MB) became HVD while 3 districts (SV, KU and NA) became LVD by 1984-85.

Growth Performance Versus Relative Rankings of Districts: Changes in ranking of a district depend not only on the district's own performance but also on the performance of other districts over time. This point would be clear from the actual growth rates of crop yields in each district as estimated by semilog time trend for the period 1960-61 to 1984-85 presented (along with those for a few other variables) in table 10.3[3]. From tables 10.2 and 10.3 it may be noted that GN which inspite of growth of 2.04% per annum (p.a.) in YRCE moved from HVD to LVD over time; whereas NA and KM with impressive growth rates of 3.4% p.a. and 4.12% p.a., respectively, moved from LVD to HVD. Further, it is possible that a district that showed slow growth can remain a HVD if the yield levels were sufficiently high initially. A case in point here is CH with *only* 1.61% p.a. growth in YRCE, but which has remained a HVD all through. Similar examples may be found in the case of other crops also.

Districtwise Growth Performance and Changes in Inter-Districts Disparity: Now turning specifically to the movement of CVs over time, it was mentioned earlier that CV(*yields*) *for these* 5 crops have not been constant over time. The question here is "are the CVs rising or falling or stationary fluctuating around a constant level?". A rise (fall) in the CV would indicate a *widening* (*narrowing*) of the gap between the districts in their crop yield levels over time. CVs that are stationary (fluctuating around a constant level) would indicate constancy of the gap between the districts in their crop *yield* levels over time.

Initially, we attempted regression analysis (estimating time trends) to answer this question. *Unfortunately*, this analysis gave very poor results in terms of R^2 and $\bar{R}^2$. In view of this, we resorted to non-parametric analysis based essentially on a T-test (and an associated F-test). The theme of the T-test is to split the whole time series of CV(Yields)[4] into two sub-samples (say,

3 Table 10.3 reports growth rates, constant over the period 1960-61 to 1984-85, estimated by semi-log trends whereas *chapter* 7 table 7.5 *reports constant*/variable (period: 1955-56 to 1984-85) growth rates as per the time trend equation chosen.

4 In the rest of this chapter the CV across districts *of* a variable X would be *denoted* as CV(X).

Table 10.3 - Estimated Semi-log Growth Rates for the Period 1960-61 to 1984-85 Districts(AP).

District	YRCE	YJVR	YBJR	YRGI	YMZE	TCNL	TANK	SWTR	OTWL	GWTR
SV[1]	0.00	0.00	1.87	0.00	4.56	1.02	0.00	0.00	-6.24	-3.73
East Godavari	2.25	0.00	0.00	0.00	4.92	0.00	0.00	0.00	0.00	7.63
West Godavari	2.83	0.00	2.19	0.93	5.20	0.00	0.00	0.00	-9.19	9.05
Krishna	1.80	0.00	1.77	1.11	4.72	0.48	0.00	0.00	0.00	5.30
GN[1]	2.04	0.00	0.00	0.00	4.78	3.18	-1.88	1.80	1.74	3.85
Kurnool	2.12	3.16	0.00	0.00	4.69	3.02	-4.25	1.14	0.00	0.00
Anantapur	1.17	4.18	0.00	2.69	5.08	2.38	-4.11	0.00	2.76	2.83
Cuddapah	1.73	0.00	3.96	3.04	4.86	-1.88	0.00	-1.89	1.29	1.56
Chittoor	1.61	0.00	0.00	0.00	6.58	0.00	-2.72	-2.21	3.14	3.21
RH[1]	2.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.99	2.82
Nizamabad	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.37	7.52
Medak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.66	4.67
Mehboobnagar	2.20	0.00	0.00	0.00	3.62	2.70	0.00	0.00	3.97	3.99
Nalgonda	3.40	0.00	0.00	5.02	2.60	7.09	0.00	2.64	0.00	0.00
Warangal	3.24	0.00	0.00	0.00	3.17	-7.07	0.00	0.00	4.85	4.98
Khammam	2.61	0.00	0.00	0.00	0.00	5.08	0.00	0.00	8.04	10.84
Karimnagar	4.12	0.00	0.00	0.00	4.22	3.69	0.00	0.00	5.20	5.20
Adilabad	2.34	0.00	0.00	0.00	0.00	4.71	0.00	0.00	7.73	8.01
AP State	2.31	0.00	0.00	1.25	3.29	1.54	-1.49	0.00	2.75	3.68

Notes: 1 : SV - Srikakulam + Vizianagaram + Vishakhapatnam; GN - Guntur + Prakasam + Nellore; RH - Ranga reddy + Hyderabad;

YRCE, YJVR, YBJR, YRGI and YMZE are the yields of rice, jowar, bajra, ragi and maize, respectively.

TCNL, TANK, SWTR, OTWL and GWTR are the net irrigated area (hectares) by canals, tanks, surface water, other wells and ground water, respectively.

Period I and Period II), compute the means of the series over the sub-samples and test for equality/inequality of these two sub-sample means. The mathematical details and stepwise details to conduct the T-test (and the associated F-test) are given in appendix 10.A1 at the end of this chapter.

The results of the T-tests conducted to see whether the levels of CV(Yields) have significantly changed (increased/decreased) over time between 1960-61 to 1970-71 (Period I) and 1974-75 to 1984-85 (Period II) or not are as follows:

Crop	T-test	T-test Degrees of Freedom
CV(YRCE)	-1.1712	20
CV(YJWR)	0.5470	20
CV(YBJR)	3.0683^{+}	20
CV(YRGI)	1.5406^{+++}	16
CV(YMZE)	2.1983^{++}	17

Notes: +/++/+++ denotes significance at 1%, 5%, and 15%, respectively.

These results suggest that CV(YRCE) and CV(YJWR) (both with low CVs) have remained unchanged (corresponding T-statistics are insignificant) over time while CV(YBJR), CV(YRGI) (both with high CVs) and CV(YMZE) (low CV) have increased over time (corresponding T-statistics are positive and significant). That is, the low disparities across districts in the yield levels of rice and jowar that existed to start with could not be further reduced despite infrastructural development. In the case of bajra, ragi and maize the disparities have actually risen.

Given the definitions of CV= σ/μ where σ and μ are the standard deviation and mean, it is obvious in our context that if the yields of a crop grow exactly at the same rate in all the districts, then CV does not change at all. However, generally all districts do not grow at the same rate. In fact, crop yields in some districts may grow, while in some other districts they may fall and in still some others they may remain stationary.

In a situation where some districts show positive while others show negative growth rates with overall mean μ, however, remaining constant, then movements in CV purely depend on the movements in σ. If, for example, HVD are the ones showing negative growth rates while LVD are the ones showing positive growth rates, then CV obviously comes down. Similarly if HVD are the ones showing positive growth rates while LVD are the ones showing negative growth rates, CV goes up.

In a situation where all districts show positive but unequal growth rates, the mean μ certainly goes up; but whether CV goes up or down depends on the growth pattern. If HVD show higher growth rates than LVD then CV further increases whereas if LVD grow faster than HVD, CV would fall.

In general, when different districts show different growth patterns the movements in CV depend on the relative movements in μ and σ.

From the semi-log trend results presented in table 10.3, first let us note that none of the districts have shown a negative growth rate for any crop yields in Andhra Pradesh.

YRCE has grown in all the districts except in SV, N2 and ME. The rate of growth in YRCE was found to be different across districts. In fact the growth rates recorded by some LVD(YRCE) (NA, WA and KM) are higher than the growth rates recorded by any of the HVD(YRCE) including WG (2.83% p.a.). But the other LVD(YRCE) (SV, GN, KU, RH, ME, MB, KH and AD) did not grow adequately enough to reflect in a significant fall in CV(YRCE). Thus the inter-district disparity in YRCE has remained more or less constant over time (though, visibly, there seems to be a mild downward trend in it).

The stagnant CV(YJWR), unlike that in rice, reflects stagnant jowar yields in almost all districts. Only 2 districts (KU and AN) showed positive growth rates in YJWR, but that has not been enough to bring a change in the overall CV(YJWR).

In the case of bajra, yields grew only in 4 (SV, WG, KR and CU) out of 18 districts in Andhra Pradesh. In rest of the districts it has remained stagnant. From table 10.2 we know that all the 4 districts showing growth in YBJR are HVD(YBJR). This growth pattern, naturally, has led to an increase in the inter-districts disparity in YBJR as shown by the increase in CV(YBJR).

Similar is the case of YRGI which grew only in 5 (WG, KR, AN, CU and NA) districts of which 4 (except NA) districts are HVD(YRGI). YRGI has been stagnant in all the remaining 13 districts. The increase in CV(YRGI), though significant only at 15% level, reflects this growth pattern.

In the case of maize yields, some HVD as well as some LVD have shown growth. Further, YMZE has grown in most of the districts, although maize is an unimportant crop in most of them. 13 of the 18 districts in AP, have shown positive growth in YMZE, which are in general far higher than the growth rates recorded for other crops in any of the districts (except YRGI in NA). Of these 13, 5 (EG, WG, KU, AN and KM) are HVD(YMZE) with growth rates above 4.2% p.a. The remaining 8 districts are all LVD of which 3 (MB, NA and WA) show far lower growth rates. Besides, 3 other LVD (RH, ME and AD) did not show any growth at all. Thus the increase in the standard deviation of YMZE is more than the increase in the overall mean, resulting in significant increase in CV(YMZE).

The overall growth pattern of the crop yields is as follows: The superior cereal rice has experienced growth in almost all districts, particularly the LVD(YRCE) showing faster growth than the HVD(YRCE). Among the inferior cereals, while jowar yields have remained stagnant in almost all districts, bajra and ragi yields grew only in a few districts which are already HVD(YBJR) and HVD(YRGI). The case of maize is opposite to that of rice, where several districts show growth but HVD(YMZE) growing faster than LVD(YMZE). This explains the movement over time in CV(Yields) presented above.

Before proceeding to explain the spatial variability in crop yields in terms of our explanatory variables mentioned earlier, let us first look at the spatial variability in the explanatory variables themselves.

10.2.2 Spatial Variability in Rainfall.

The rainfall variables considered here are rainfall (in m.m.) during South-West monsoon (RSW) and rainfall (in m.m.) during North-East monsoon (RNE). Details on various rainfall zones corresponding to the districts of AP were given in appendix 8.A1 (chapter 8). Like in the case of crop yields, time series of CV(RSW) and CV(RNE) are computed for the period 1960-61 to 1984-85. Table 10.4 presents these CVs.

It can be seen from this table that both CV(RSW) and CV(RNE) are high; the CVs for both RSW and RNE exceed the cut off level of 0.3 for all the years in the period studied here. Further, amongst the 2 rainfalls, RNE has higher CVs, often exceeding 1.0 implying that the standard deviation is greater than the mean level. RSW and RNE being climatic factors, their dispersion across districts are unlikely to show any systematic change over time. Hence the T-test for equality of means of the 2 sub-periods are not conducted on the time series of CV(RSW) and CV(RNE).

10.2.3 Spatial Variability in Infrastructural Variables.

The sources of irrigation considered are (1) canals, (2) tanks, (3) tubewells, (4) other wells, and (5) other sources. Apart from these 5 individual sources of irrigation 3 aggregated variables - surface water component (= canals + tanks), ground water component (= tubewells + other wells) and the total net irrigation by all the 5 sources - are also considered. The infrastructural variables considered in this analysis are the source-wise net irrigation as a proportion to the total net sown area (NSA) over all crops. Further, aggregate cropping intensity (ACI) defined as the ratio of gross cropped area over all crops to the

Table 10.4 - *Coefficient of Variation (CV) Across Districts (AP): Rainfall*

Year	CV(RSW)	CV(RNE)
1960-61	0.4078	1.3189
1961-62	0.3296	0.6431
1962-63	0.4088	1.4432
1963-64	0.4081	0.8599
1964-65	0.3236	0.8421
1965-66	0.3610	1.5158
1966-67	0.3688	1.1190
1967-68	0.4274	1.2996
1968-69	0.3504	0.8751
1969-70	0.4371	1.2747
1970-71	0.3827	1.1288
1971-72	0.5281	0.8950
1972-73	0.4781	1.2982
1973-74	0.3328	0.7182
1974-75	0.4185	0.5815
1975-76	0.3724	0.7900
1976-77	0.3962	1.4477
1977-78	0.3715	1.1113
1978-79	0.3741	1.3310
1979-80	0.6430	1.2123
1980-81	0.6295	1.5151
1981-82	0.5355	1.3842
1982-83	0.5257	1.0252
1983-84	0.4414	0.7912
1984-85	0.6641	1.3437

Notes: RSW, RNE : South-West and North-East rainfalls.

net sown area over all crops, representing the extent of multiple cropping, is another factor, considered in this analysis.

Sourcewise net irrigation proportions:

The extent and the relative importance of the various sources of irrigation districtwise, were discussed in chapters 3 and 8 and appendix 8.A2. The general features observed therein are, (1) wide disparities in the total net irrigated area exist among the districts; (2) The 2 surface water sources, canals and tanks, put together are the most important sources of irrigation in all the districts of AP; (3) Tank irrigation is being neglected in most of the districts as shown by falling net irrigated area by tanks in most of the districts; (4) In some districts canals instead of tanks became the major source of irrigation under surface water component; (5) Regarding the ground water component (tubewells and other wells), while in some districts these are fairly developed in other districts these are negligible; (6) Tubewells as a source of irrigation is of negligible importance in most of the districts (except in EG and WG; see chapters 3 and 8 for further details).

Here, time series of CVs for each of the sources of irrigation as a proportion to the net sown area over all crops are computed for the period 1960-61 to 1984-85. To denote:

TCNL = net irrigated area by canals ÷ total net sown area.

TANK = net irrigated area by tanks ÷ total net sown area.

SWTR = net irrigated area by surface water (= canals + tanks) ÷ total net sown area.

TBWL = net irrigated area by tubewells ÷ total net sown area.

OTWL = net irrigated area by other wells ÷ total net sown area.

GWTR = net irrigated area by ground water (= tubewells + other wells) ÷ total net sown area.

OSRC = net irrigated area by other sources ÷ total net sown area.

TNAS = total net irrigated area ÷ total net sown area.

ACI = aggregate cropping intensity.
= total gross cropped area ÷ total net sown area.

Table 10.5 presents time series of CV(TCNL), CV(TANK), CV(SWTR), CV(TBWL), CV(OTWL), CV(GWTR), CV(OSRC) and CV(TNAS). Time series of CV(ACI) is also presented in this table and these would be discussed separately later. From this table it can be seen that the spatial variability (disparities) across districts is high for each of the 5 sources of irrigation as also for the 3 aggregated variables, SWTR, GWTR and TNAS. The CVs for all these sources are well above the cut off level of 0.3. Amongst the various sources of irrigation tubewells has the highest CVs followed by canals. Note that as mentioned earlier tubewells as a source of irrigation is relatively unimportant in most of the districts of A.P.

Surface water (canals & tanks): Turning to the relative ranking of districts, table 10.6 presents for a few years (1960-61, 1970-71 and 1984-85) sourcewise, the range (highest and lowest values across districts) of net irrigation proportion and the classification of districts into low value districts (LVD) and high value districts (HVD) in comparison to the State level values. The details for ACI is also presented in this table and these would be discussed later. In the case of canals and SWTR as a whole, for all these years, all the 5 coastal districts are HVD while all the districts of Rayalaseema and Telangana with the sole exception of NZ are LVD. The relative rankings of the districts as LVD and HVD has not changed over time in both canals and SWTR. Recall that the coastal districts are HVD with respect to most of the crop yields also (see page 292). The deterioration of the situation with respect to tanks as an important source of irrigation can be seen from table 10.3. While in 14 of the 18 districts, tank irrigation proportion has been stagnant, in fact in 4 districts, particularly in Rayalaseema it fell down significantly. Most of Rayalaseema is actually drought prone.

Ground water (tubewells & other wells): In the case of tubewells, the proportion in NSA in 1960-61 had been negligible in all the districts. By 1984-85, however, the coastal districts (EG, WG, KR and GN), CU and KH had witnessed some development in this source. By 1984-85, though in some of these districts tubewells proportion is as high as about 15%, in the State as a whole it still is a [illegible] across Districts (AP): Infrastructural Variables.

Year	CV(TCNL)	CV(TANK)	CV(SVTR)	CV(TBVL)	CV(OTVL)	CV(GVTR)	CV(OSRC)	CV(TNAS)	CV(ACI)
1960-61	1.4089	0.6151	0.8664	2.1853	0.8540	0.8339	1.1542	0.7502	0.0991
1961-62	1.4036	0.5367	0.7781	2.0926	0.8567	0.7839	0.8139	0.6408	0.1215
1962-63	1.4217	0.5341	0.7662	2.4872	0.8952	0.8278	0.8076	0.6439	0.0950
1963-64	1.4030	0.5658	0.7777	2.2429	0.8879	0.7825	0.9769	0.6698	0.0975
1964-65	1.4229	0.5730	0.7959	2.3044	0.8146	0.7003	0.6942	0.6745	0.1021
1965-66	1.4292	0.6139	0.8214	2.6260	0.9414	0.8280	0.8705	0.6735	0.1043
1966-67	1.4211	0.6070	0.8121	2.8255	0.8872	0.7780	0.6896	0.6834	0.0955
1967-68	1.3708	0.5956	0.7915	2.6377	0.8803	0.7662	0.7927	0.6662	0.1077
1968-69	1.3654	0.7612	0.9164	2.4930	1.0019	0.8331	0.9515	0.7480	0.1086
1969-70	1.2791	0.6449	0.8134	2.7531	0.9158	0.7952	0.8696	0.6838	0.1071
1970-71	1.2617	0.6387	0.7983	2.8148	0.8613	0.7754	0.9883	0.6847	0.0912
1971-72	1.3469	0.8967	0.9772	2.7681	0.9420	0.8079	0.9258	0.7727	0.0998
1972-73	1.3611	0.9074	0.9680	2.5783	0.8794	0.7174	0.8912	0.7513	0.0989
1973-74	1.3260	0.6686	0.8218	2.4034	0.9903	0.8046	0.7976	0.6710	0.1011
1974-75	1.2501	0.6846	0.8266	2.2883	0.9234	0.7100	0.7830	0.6583	0.1088
1975-76	1.2359	0.6030	0.7829	2.2997	0.9567	0.7433	0.7088	0.6413	0.1074
1976-77	1.2620	0.6058	0.7736	2.3556	0.8919	0.6923	0.7216	0.6186	0.0795
1977-78	1.2643	0.6810	0.8530	2.1995	0.8682	0.6693	0.6489	0.6499	0.1214
1978-79	1.2281	0.6357	0.7738	2.3248	0.8784	0.6796	0.6594	0.6039	0.1111
1979-80	1.2503	0.9077	0.8686	2.2264	0.8697	0.6415	0.7824	0.6368	0.1247
1980-81	1.1824	0.7640	0.8558	2.2768	0.8972	0.6833	0.7434	0.6205	0.1209
1981-82	1.1746	0.6461	0.7960	2.3218	0.8510	0.6531	0.6665	0.6070	0.1187
1982-83	1.1685	0.7079	0.8367	2.2081	0.8706	0.6532	0.8371	0.6192	0.1325
1983-84	1.1297	0.6193	0.7486	2.2170	0.8395	0.6249	0.6339	0.5769	0.1284
1984-85	1.1456	0.8449	0.8143	1.9240	0.8426	0.6268	0.6275	0.6235	0.1361

Notes: TCNL : Net area irrigated by canals as a proportion to net sown area over all crops;

TANK : Net area irrigated by tanks as a proportion to net sown area over all crops;

SVTR : Net area irrigated by surface water (= canals + tanks) as a proportion to net sown area over all crops;

TBVL : Net area irrigated by tubewells as a proportion to net sown area over all crops;

OTVL : Net area irrigated by other wells as a proportion to net sown area over all crops;

GVTR : Net area irrigated by ground water (= tubewells + other wells) as a proportion to net sown area over all crops;

OSRC : Net area irrigated by other sources as a proportion to net sown area over all crops;

TNAS : Net area irrigated by all sources as a proportion to net sown area over all crops;

ACI : Aggregate Croping Intensity (= gross cropped area over all crops / net sown area over all crops);

... variables.

Variable	Year	Lowest	Highest	State	Low Valued Districts (LVD)[‡]	High Valued Districts (HVD)[‡]
TCNL	1960-61	0.000 (CH)	0.560 (KR)	0.127	KU AN CU CH RH ME MB NA VA KH KM AD (12)	SV EG VG KR GN NZ (6)
	1970-71	0.000 (CH)	0.506 (KR)	0.135	SV KU AN CU CH RH ME MB NA VA KH KM AD (13)	EG VG KR GN NZ (5)
	1984-85	0.003 (VA)	0.584 (KR)	0.171	KU AN CU CH RH ME MB NA VA KH KM AD (12)	SV EG VG KR GN NZ (6)
TANK	1960-61	0.026 (KU)	0.310 (SV)	0.109	KU AN CU RH MB NA AD (7)	SV EG VG KR GN CH NZ ME VA KH KM (11)
	1970-71	0.013 (KU)	0.273 (SV)	0.095	KR GN KU AN CU RH MB NA AD (9)	SV EG VG CH NZ ME VA KH KM (9)
	1984-85	0.011 (AN)	0.257 (SV)	0.074	EG VG KR GN KU AN CU RH MB NA KH AD (12)	SV CH NZ ME VA KM (6)
SVTR	1960-61	0.054 (AN)	0.708 (VG)	0.236	KU AN CU CH RH ME MB NA VA KH KM AD (12)	SV EG VG KR GN NZ (6)
	1970-71	0.054 (AD)	0.609 (VG)	0.229	KU AN CU CH RH ME MB NA VA KH KM AD (12)	SV EG VG KR GN NZ (6)
	1984-85	0.043 (RH)	0.620 (KR)	0.245	KU AN CU CH RH ME MB NA VA KH KM AD (12)	SV EG VG KR GN NZ (6)
TBVL	1960-61	0.000	0.000	0.000	SV EG VG KR GN KU AN CU CH RH NZ ME MB NA VA KH KM AD	
	1970-71	0.000 (SV)	0.088 (VG)	0.006	SV KU AN CU CH RH NZ ME MB NA VA KH KM AD (14)	EG VG KR GN (4)
	1984-85	0.000 (KU)	0.152 (VG)	0.018	SV KU AN CH RH NZ ME MB NA VA KM AD (12)	EG VG KR GN CU KH (6)
DTVL	1960-61	0.001 (EG)	0.088 (CU)	0.031	SV EG VG KR KU AN RH NZ MB KH AD (11)	GN CU CH ME NA VA KM (7)
	1970-71	0.002 (EG)	0.129 (CH)	0.037	SV EG VG KR KU ME MB NA KH AD (10)	GN AN CU CH RH NZ VA KM (8)
	1984-85	0.001 (EG)	0.181 (VA)	0.062	SV EG VG KR GN KU MB KH AD (9)	AN CU CH RH NZ ME NA VA KM (9)
GWTR	1960-61	0.003 (KH)	0.089 (CU)	0.031	SV EG VG KR KU AN RH NZ MB KH AD (11)	GN CU CH ME NA VA KM (7)
	1970-71	0.004 (AD)	0.129 (CH)	0.043	SV EG KR KU NZ ME MB NA KH AD (10)	VG GN AN CU CH RH VA KM (8)
	1984-85	0.010 (AD)	0.186 (VA)	0.080	SV EG KR KU AN RH MB NA KH AD (10)	VG GN CU CH NZ ME VA KM (8)

‡ Notes are given at the end of the table.

Variable	Year	Lowest	Highest	State	Low Valued Districts (LVD)#		High Valued Districts (HVD)#	
OSRC	1960-61	0.000	0.041	0.009	EG KU AN CU RH NZ ME MB NA		SV VG KR GN CH KH KM	
		(NA)	(KR)		VA AD	(11)		(7)
	1970-71	0.000	0.034	0.010	EG GN KU AN RH ME MB NA VA		SV VG KR CU CH NZ KH	
		(AD)	(SV)		KM AD	(11)		(7)
	1984-85	0.002	0.025	0.011	KU AN CH RH ME MB NA VA AD		SV EG VG KR GN CU NZ KH KM	
		(MB)	(VG)			(9)		(9)
TNAS	1960-61	0.060	0.742	0.277	KU AN CU RH ME MB NA VA KH		SV EG VG KR GN CH NZ	
		(AD)	(VG)		KM AD	(11)		(7)
	1970-71	0.058	0.752	0.282	KU AN CU RH ME MB NA VA KH		SV EG VG KR GN CH NZ	
		(AD)	(VG)		KM AD	(11)		(7)
	1984-85	0.068	0.796	0.336	KU AN CU CH RH ME MB NA KH		SV EG VG KR GN NZ VA KM	
		(AD)	(VG)		AD	(10)		(8)
ACI	1960-61	1.007	1.327	1.124	KU AN CU RH NZ ME MB NA VA		SV EG VG KR GN CH	
		(KH)	(GN)		KH KM AD	(12)		(6)
	1970-71	1.017	1.345	1.139	KU AN CU RH ME MB KH KM AD		SV EG VG KR GN CH NZ NA VA	
		(AN)	(EG)			(9)		(9)
	1984-85	1.021	1.504	1.167	KU AN CU CH RH ME MB KH KM		SV EG VG KR GN NZ NA VA	
		(AN)	(EG)		AD	(10)		(8)

Notes: # : Low (High) Valued Districts are districts whose levels are below (above) State level values;

TCNL : Net area irrigated by canals as a proportion to net sown area over all crops;

TANK : Net area irrigated by tanks as a proportion to net sown area over all crops;

SWTR : Net area irrigated by surface water (= canals + tanks) as a proportion to net sown area over all crops;

TBWL : Net area irrigated by tubewells as a proportion to net sown area over all crops;

OTWL : Net area irrigated by other wells as a proportion to net sown area over all crops;

GWTR : Net area irrigated by ground water (= tubewells + other wells) as a proportion to net sown area over all crops;

OSRC : Net area irrigated by other sources as a proportion to net sown area over all crops;

TNAS : Net area irrigated by all sources as a proportion to net sown area over all crops;

ACI : Aggregate Croping Intensity (= gross cropped area over all crops / net sown area over all crops);

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; VG : West Godavari; KR : Krishna;
GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor;
RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda;
WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

negligible source of irrigation. Other wells is the dominant source under ground water in all districts, though ground water itself is not the dominant source of irrigation in general. Ground water sources contribute little to irrigation in the Coastal districts while in several of the Rayalaseema and Telangana districts, they are important. In all the districts except in SV, KU & NA, GWTR has witnessed high growth rates (see table 10.3). These growth rates are in general higher in the relatively drier districts of Rayalaseema and Telangana than in the Coastal districts. The growth in GWTR came essentially through the development of tubewells component (practically with no development at all in the other wells component) in Coastal districts, whereas it is essentially through other wells component in the non-Coastal districts.

Other sources: The relative rankings of the districts in the case of other sources of irrigation has been more or less stable. The coastal districts are HVD. The Rayalaseema districts are mostly LVD. The Telangana districts except NZ did not witness any change in their relative position with RH, ME, MB, NA, WA and AD remaining LVD and KH and KM remaining HVD. NZ is the only Telangana district that turned HVD over time.

Thus in general, efforts at irrigation development seem to be somewhat non-uniform across various districts in different regions in Andhra. In particular, the districts in Rayalaseema seem to be unfavourably positioned in this context.

Movements over time in the CVs of the sourcewise net irrigation proportions: The sourcewise net irrigations represent the extent of irrigation available for crop cultivation. The total irrigation availability has grown in all the districts of AP. In order to judge the changes in overall disparity across districts, we now turn to movements over time, if any, in the CVs of the sourcewise irrigation proportions. The results of the T-tests for the equality of mean levels of CV between the 2 sub-periods (1960-61 to 1970-71 and 1974-75 to 1984-85) are as follows:

	T-test	T-test Degrees of Freedom
CV(TCNL)	-3.1933+	20
CV(TANK)	2.5812++	18
CV(SWTR)	-0.0163	20
CV(TBWL)	-2.9860+	15
CV(OTWL)	-0.5288	19
CV(GWTR)	-3.1821+	20
CV(OSRC)	-3.5117+	16
CV(TNAS)	-4.8599+	19

Notes: +/++ denotes significance at 1%, and 5%, respectively.

From these results it can be said that the disparities across districts in the overall net irrigation proportion has declined over time as indicated by the fall in CV(TNAS) (with significant negative T-statistic) over time. This, however, is not true in the case of all the individual sources of irrigation. Amongst the 2 surface water sources, canals and tanks, the inter-districts disparity in canal irrigation proportion has fallen as shown by the fall in CV(TCNL) (with significant negative T-statistic); whereas the disparity in tank irrigation proportion has risen over time as shown by the rise in CV(TANK) (with significant positive T-statistic). From the discussion in chapters 3 and 8 we know that TCNL has grown in all the districts, both HVD and LVD, and its growth pattern has been in a manner that led to a reduction in its CV. Tank irrigation, both in absolute (hectares) and as a proportion to the total net sown area, however, has declined in most, but not all, of the districts. As a result, its CV has increased over time. The movement in opposite directions in TCNL and TANK has resulted in SWTR being stagnant in almost all the districts. Thus CV(SWTR) has also remained stagnant over time.

Amongst the ground water sources, tubewells and other wells, the inter-districts disparity in tubewell irrigation proportion has declined over time as shown by the fall in CV(TBWL) (though the magnitude of CV(TBWL) itself is very high as seen in table 10.5). Other wells irrigation proportion has, however, not witnessed any fall in its inter-districts disparity as shown by the stationary levels of CV(OTWL) (which is also high). As mentioned earlier, tubewells irrigation proportion has grown in all the districts, although it remains negligible in all but the 2 Godavari districts. The growth pattern in TBWL across districts has resulted in a fall in its CV. Other wells, which form the major component of GWTR, has also grown in most of the districts, although its growth pattern has not affected its CV. As a result of the growth in both TBWL and OTWL, GWTR grew in most of the districts in such a manner that has resulted in a fall in CV(GWTR).

With respect to OSRC, the results show that its inter-districts has reduced over time as shown by the fall in CV(OSRC)

Aggregate cropping intensity:

Cropping intensity is a measure of the intensity of cultivation on a given plot of land; i.e., the number of harvests of different crops raised on a given plot of land in one year. But, we do not have such data cropwise; i.e., how many times, same crop is raised more than once in a year on a given plot of land. In other words we do not have cropwise data on net cultivated area. However, since we have data on total gross cultivated area, and also the total net cultivated area overall crops put together, we can arrive at the cropping intensity measured overall crops. Thus aggregate cropping intensity (ACI), is defined as the ratio of the sum of gross cultivated area of all crops to the total net cultivated area overall crops.

$$ACI = \frac{\text{Total gross cultivated area of all crops}}{\text{Total net cultivated area over all crops}}$$

Since water is an important input for cultivation, irrigation, especially assured irrigation, can be expected to play an important role in promoting ACI. Canals and well irrigation are generally considered to be sources that offer assured irrigation. In chapter 3 we reported linear regression of ACI on TCNL and OTWL, at the AP State level, which confirmed the expected positive relationship between ACI and these 2 sources of irrigation (see chapter 3 for details). As described above, these 2 sources have shown different growth pattern across the districts which would result in differences across districts in the ACI.

CV(ACI) is also presented in table 10.5. It can be seen that CV(ACI) across districts of AP has been "low" (< 0.3) through out the period under consideration and it is far lower than the CV of the irrigation variables. This would imply that the level of ACI, unlike irrigation, is more or less uniform across the districts. From table 10.6 it can be seen that all the 5 coastal districts have remained HVD(ACI) through out. While NZ, NA and WA from Telangana have improved from LVD to HVD, the remaining Telangana districts (RH, ME, MB, KH, KM and KM) have been LVD through out. Same is true with the Rayalaseema districts KU, AN, CU and CH of which CH was initially HVD though.

If as the above mentioned regression results suggest, irrigation facilities contribute to ACI the differences in the magnitudes of CVs of ACI and irrigation facilities is worth more consideration. CV(ACI) is far lower than CV(TCHL) and CV(DTWL). This only implies that though irrigation facilities do contribute to ACI, the response of ACI with respect to irrigation development is different in different districts. The above relation between ACI and irrigation actually suggests that the elasticity of ACI with respect to irrigation is likely to be higher the higher the irrigation proportion. In fact the growth rates in ACI reported in table 3.5 in chapter 3 are higher in the Coastal districts than in non-Coastal districts. This suggests that CV(ACI) is likely to go up over time.

Although CV(ACI) is low, a visual observation itself of the CV(ACI) (table 10.5) indicates that it has increased over time. In 1984-85 this ranged from 1.021 (AN) to 1.504 (EG) with the State average being 1.167 while in 1960-61 it ranged only from 1.007 (KH) to 1.327 (GN) (see table 10.6). Again, a T-test as described earlier has been conducted to see whether disparity in ACI across districts has increased over time. The results are as follows:

	T-test	T-test Degrees of Freedom
ACI	2.7162++	16

Notes: ++ denotes significance at 5%.

This confirms that the mean level of CV(ACI) is significantly higher in the sub-period 1974-75 to 1984-85 than in the sub-period 1960-61 to 1970-71. That is, disparity in ACI has increased over time. Recall that, ACI has grown over time only in a few districts (EG, WG, KR, NZ, NA, WA and KM) while it has remained stagnant in the rest of the districts (see chapter 3 table 3.5). The increase in CV(ACI) reflects this growth pattern across districts.

10.2.4 *Spatial Variability in Crop Specific Inputs.*

The crop specific inputs considered in this analysis are the cropwise gross irrigation proportions and fertilizer availability.

Gross Irrigation Proportions:

Gross irrigation proportion (sometimes referred to as "irrigation intensity") for a crop is defined as the ratio of gross irrigated area under a crop to the total cultivated area under that crop. The gross irrigation proportions of rice, jowar, bajra, ragi and maize are denoted as IRCE, IJWR, IBJR, IRGI and IMZE, respectively. Time series of the CVs across districts for the gross irrigation proportions for the period 1960-61 to 1984-85 are reported in table 10.7. This table reports the CVs for fertilizer availability also which will be discussed separately later.

From this table it can be seen that CV(IRCE) is low (< 0.3) through out. The corresponding CVs for the remaining 4 crops are, however, high (> 0.3) often exceeding 1.0. Of them, IJWR has the highest CV for several years followed closely by CV(IBJR). CV(IRGI) and CV(IMZE) are generally less than CV(IJWR) and CV(IBJR) with CV(IRGI) being higher than CV(IMZE) for most of the later years in the sample period. These figures suggest that the levels of irrigation intensity for rice cultivation are more or less uniform across the districts whereas it is not so for other crops. Table 10.8 gives the range of values of the gross irrigation proportions as also the classification of districts into HVD and LVD for 3 years, 1960-61, 1970-71 and 1984-85. This table gives these details for FRT also which will be discussed later.

Table 10.7 - Coefficient of Variation (CV) Across Districts (AP): Crop Input Variables.

Year	|-- Cropwise Gross Irrigation Proportions[1] --|					Fertilzer[2] Availability
	CV(IRCE)	CV(IJWR)	CV(IBJR)	CV(IRGI)	CV(IM2E)	CV(FRT)
1960-61	0.1326	1.5783	0.8826	1.1851	0.9581	0.9176
1961-62	0.1217	2.0115	1.1768	1.2252	1.1791	1.0502
1962-63	0.1257	1.7796	1.7066	1.1833	1.3030	1.0516
1963-64	0.1318	2.6775	1.2848	1.0490	1.7487	1.0329
1964-65	0.1356	1.6153	1.2609	1.0854	1.4794	0.8057
1965-66	0.1213	1.9967	1.3918	1.1567	1.3929	0.8541
1966-67	0.1111	1.4826	1.5082	1.1898	0.9551	0.8783
1967-68	0.0938	1.6056	1.9243	1.1106	1.0616	0.6520
1968-69	0.1163	1.8830	1.5910	1.0953	0.8976	0.7556
1969-70	0.1039	1.8347	2.0294	1.0588	1.0936	0.7767
1970-71	0.1061	1.7301	1.6759	1.2799	1.0705	0.6002
1971-72	0.1585	1.7819	1.7437	1.1619	0.9342	0.6103
1972-73	0.1264	1.4409	1.7828	1.1742	0.9482	0.6752
1973-74	0.0870	1.5044	1.6697	1.1852	1.0310	0.5409
1974-75	0.0968	1.6213	1.7809	1.2741	0.8140	0.5202
1975-76	0.2390	1.4808	1.6867	1.3340	0.9714	0.5942
1976-77	0.1059	1.5978	1.7312	1.1865	1.0292	0.5819
1977-78	0.1023	1.6378	1.8418	1.2666	1.0264	0.5991
1978-79	0.0951	1.9479	1.9948	1.2501	0.9829	0.6973
1979-80	0.1010	1.9518	1.5398	1.1732	0.8155	0.6679
1980-81	0.0945	2.4443	1.6008	1.1405	0.8537	0.6221
1981-82	0.0883	2.0435	1.4598	1.2004	0.8737	0.4518
1982-83	0.0983	2.1971	1.4871	1.1528	0.8236	0.5541
1983-84	0.0987	1.7746	1.4666	1.0368	0.8465	0.6012
1984-85	0.1021	1.6238	1.4812	0.9571	0.9890	0.5684

Notes: 1 : IRCE, IJWR, IBJR, IRGI and IM2E are gross irrigated area under crop divided by gross cropped area under crop (rice, jowar, bajra, ragi and maize, respectively);

2 : FRT : Total fertilizer consumption divided by area under 5 cereals;

Table 10.8 - Range and Ranking of Districts: Crop Input Variables.

Variable	Year	Lowest	Highest	State	Low Valued Districts (LVD)[1]	High Valued Districts (HVD)[1]
IRCE	1960-61	0.503 (AD)	0.998 (NA)	0.929	SV KU RH ME MB KH AD (7)	EG VG KR GN AN CU CH NZ NA VA KM (11)
	1970-71	0.624 (AD)	1.000 (NA)	0.943	SV KU RH ME MB KH AD (7)	EG VG KR GN AN CU CH NZ NA VA KM (11)
	1984-85	0.623 (AD)	1.000 (NA)	0.945	SV KU CH RH NZ ME MB KH AD (9)	EG VG KR GN AN CU NA VA KM (9)
IJVR	1960-61	0.000 (EG)	0.148 (CH)	0.019	EG VG KR KU CU NZ ME MB NA VA KH KM AD (13)	SV GN AN CH RH (5)
	1970-71	0.000 (EG)	0.060 (CH)	0.009	EG VG KR KU RH NZ ME MB NA VA KH KM AD (13)	SV GN AN CU CH (5)
	1984-85	0.000 (SV)	0.147 (CH)	0.008	SV KR RH NZ ME MB NA VA KH KM AD (11)	EG VG GN KU AN CU CH (7)
IBJR	1960-61	0.000 (EG)	0.296 (NZ)	0.102	SV EG VG KR AN RH ME MB NA VA KH AD (12)	GN KU CU CH NZ KM (6)
	1970-71	0.000 (EG)	0.464 (CU)	0.102	SV EG VG KR KU AN RH NZ ME MB NA VA KH KM AD (15)	GN CU CH (3)
	1985-85	0.000 (SV)	0.993 (NZ)	0.120	SV EG VG KR KU AN RH ME MB NA VA KH AD (13)	GN CU CH NZ KM (5)
IRGI	1960-61	0.000 (NZ)	0.981 (CU)	0.443	EG VG KR CH RH NZ ME MB VA KH KM AD (12)	SV GN KU AN CU NA (6)
	1970-71	0.000 (EG)	1.000 (NA)	0.337	SV EG VG KR KU RH NZ ME MB VA KH KM AD (13)	GN AN CU CH NA (5)
	1984-85	0.000 (EG)	0.993 (CU)	0.326	SV EG VG KR KU CH RH NZ ME MB VA KH KM AD (14)	GN AN CU NA (4)
IMZE	1960-61	0.000 (VG)	0.498 (SV)	0.169	EG VG KR GN AN RH NZ ME MB NA KH AD (12)	SV KU CU CH VA KM (6)
	1970-71	0.009 (SV)	1.000 (CU)	0.214	SV EG VG KR RH NZ ME NA KH AD (10)	GN KU AN CU CH MB VA KM (8)
	1984-85	0.000 (NA)	1.000 (CU)	0.204	SV EG GN RH NZ ME MB NA KH AD (10)	VG KR KU AN CU CH VA KM (8)

Notes are given at the end of the table.

Table 10.8 (Contnd.)

Variable	Year	Lowest	Highest	State	Low Valued Districts (LVD)*	High Valued Districts (HVD)*
FRT	1960-61	0.000 (NA)	0.018 (NZ)	0.005	SV KU AN CU CH RH ME MB NA VA KH KM AD (13)	EG VG KR GN NZ (5)
	1970-71	0.007 (AD)	0.084 (NZ)	0.035	SV AN ME MB NA VA KH KM AD (9)	EG VG KR GN KU CU CH RH NZ (9)
	1984-85	0.032 (AD)	0.329 (GN)	0.156	SV EG KU AN CH RH ME MB NA VA KH KM AD (13)	VG KR GN CU NZ (5)

Notes: * : Low (High) Valued Districts are districts whose levels are below (above) State level values;

IRCE : Gross irrigation proportion for rice; IJVR : Gross irrigation proportion for jowar;

IBJR : Gross irrigation proportion for bajra; IRGI : Gross irrigation proportion for ragi;

IMZE : Gross irrigation proportion for maize;

FRT : Fertilizer availability (= Total fertilizer consumption divided by area under 5 cereals;

Codes: SV : Srikakulam + Vizianagaram + Vishakhapatnam; EG : East Godavari; VG : West Godavari; KR : Krishna;

GN : Guntur + Prakasam + Nellore; KU : Kurnool; AN : Anantapur; CU : Cuddapah; CH : Chittoor;

RH : Ranga Reddy + Hyderabad; NZ : Nizamabad; ME : Medak; MB : Mehboobnagar; NA : Nalgonda;

WA : Warangal; KH : Khammam; KM : Karimnagar; AD : Adilabad;

Rice is a highly irrigated crop in all the years in all the districts of AP. This explains the low CV(IRCE) in general. In 1984-85, IRCE ranged only from 0.623 (AD) to 1.0 (NA) with the State average being 0.945 (see table 10.8). Further, the relative rankings of the districts with respect to IRCE has been more or less maintained with only CH and NZ slipping from HVD to LVD over the 25 years. It may be noted here that about 76% of the State's rice production in 1984-85 came from the HVD of which 58% came from EG, WG, KR and GN alone[5].

Jowar in AP is grown mainly under unirrigated condition in all the districts. In 1984-85, IJWR ranged from 0.0 (SV, KR, ME, MB, NA, WA and KH) to 0.147 (CH) with only 0.008 being the State average; i.e., less than 1% of the jowar acreage in the State is under irrigation. All HVD(IJWR) put together account for only about 40% of the State production in 1984-85 of which about 20% comes from KU alone. That is, the districts which contribute 60% of the State total production of jowar sparsely use irrigation for its cultivation.

The case of irrigation intensity for bajra cultivation (IBJR) across districts is more interesting than the cases of rice (where almost all districts are irrigated) and jowar (where almost all of them are unirrigated) cultivations. Though the low State average level of IBJR (0.120) indicates that bajra too, like jowar, is mainly an unirrigated crop in most districts of AP, however, in 1984-85, IBJR ranged between as low as 0.0 (SV, EG, KR, ME, NA, WA and KH) to as high as 0.993 (NZ). In 1984-85, 3 districts have a high level of IBJR. These are GN(50.3%), CU(57.2%) and NZ(99.3%). The contribution in 1984-85 of these districts to State production are: GN(21%), CU(10%) and NZ(< 1%). The case of NZ is unique as very little bajra is grown in that district but almost completely under irrigation. This may be contrasted with SV which accounted for 32% of the State total in 1984-85 but where only 9% of bajra

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5 See chapter 3 for cropwise, districtwise details of the gross irrigation proportions, districtwise productions and their shares in the State's total.

is grown under irrigation. This shows, there are wide differences across districts in the growing conditions of bajra. The share of the five HVD(IBJR) in State production of bajra in 1984-85 is about 38% of which 37% comes from GN, CU and CH. Amongst the LVD(IBJR), SV, AN and NA are substantial contributors (32%, 8% and 9% in 1984-85, respectively) to the State's production.

Turning to ragi, in 1984-85 IRGI also ranged between 0.0 (EG, WG, KR, RH, NZ, ME, WA, KH, KM and AD) and 0.993 (CU), the State average being 0.326. While in the State as a whole a third of ragi cultivation is under irrigation, in as many as 10 of the total 18 districts ragi is grown under completely un-irrigated conditions. The share of HVD(IRGI) in State output of ragi in 1984-85 was about 36% almost all of which came from GN, AN and CU. Amongst the LVD(IRGI) the major contributors in 1984-85 were SV(30%), CH(14%), RH(6%) and MB(11%).

In the case of maize also, the crop's irrigation intensity (IMZE) ranged between 0.0 (NA) and 1.0 (CU) and the State average is 0.204. A feature of maize cultivation in AP is that in almost all the districts, atleast some amount of maize is grown under irrigation. While in some districts IMZE is as high as 0.7 or even more, it is less than 0.5 in the 4 districts that are major contributors to State's total maize production (NZ(24%), ME(10%), WA(10%) and KM(44%) together account for about 88% of State production in 1984-85). In 1984-85, IMZE was 0.136, 0.026, 0.274 and 0.401 in NZ, ME, WA and KM, respectively.

Thus, in the case of superior cereal rice the major contributors to the State's output are the districts where the crop is mostly under irrigated conditions, whereas in the case of inferior cereals, the major contributing districts are the ones where these crops are mostly under unirrigated conditions.

Let us now look for changes, if any, over time in the CVs of the cropwise irrigation intensities. Visual observation of the CVs reported in table 10.7 does not indicate any change in CV(IRCE), CV(IJWR), CV(IBJR) and CV(IRGI). CV(IMZE), however, seems to show a fall towards the end of the period. In order to confirm these observations, T-tests are conducted to assess changes, if any, in the disparity levels across districts in cropwise irrigation intensities over time. The result of the T-test with the 2 sub-periods being 1960-61 to 1970-71 (Period I) and 1974-75 to 1984-85 (Period II) are as follows:

	T-test	T-test Degrees of Freedom
CV(IRCE)	-0.5253	13
CV(IJWR)	0.0365	20
CV(IBJR)	1.2918	16
CV(IRGI)	0.8349	19
CV(IMZE)	-3.4022+	13

Notes: + denotes significance at 1% level.

These results indicate that only in the case of maize there is a significant fall in the mean levels of CV(IMZE) in the second sub-period. In the remaining 4 crops, however, there has been no significant change in the CV between the 2 sub-periods. These results confirm the visual observation made earlier.

IRCE, IJWR and IRGI have remained more or less unchanged in all the districts. Thus their CVs across districts also have not changed over time. IBJR has grown in a few districts (GN, CU and NZ) while in the rest of the districts it has remained unchanged. As a result CV(IBJR) shows a mild increase which is significant only at the 25% level (not shown in the above table). IMZE on the other hand has grown in almost all the districts and this seems to have reduced its inter-districts differences as shown by the significant fall in CV(IMZE).

Fertilizer Availability:

With respect to fertilizer availability, as mentioned in earlier chapters, continuous time series data on cropwise fertilizer use are not available[σ]. In the absence of such data, we take

σ Data on cropwise fertilizer applications are, however, available from some cross section studies for a very few years. For example see, Sarvekshana (1978).

into consideration here the total fertilizer available (Kg/Ha of all cereals together) in each district (same as F defined in chapter 8). FRT, defined as the ratio of total fertilizer consumed to the total cultivated acreage under the 5 cereal crops, is a measure of the fertilizer "availability" per acre of the 5 cereals crops. From the districtwise data, CV(FRT) is computed for the period 1960-61 to 1984-85. This time series of the CV(FRT) is reported in table 10.7.

It can be seen that CV(FRT) has been high (> 0.3) through out. In 1984-85, it ranged between 3.2 kg/ha (AD) to about 32.9 kg/ha (GN) with the State average being about 15.6 kg/ha. See table 10.8 for details. WG, KR, GN, CU and NZ are the districts using relatively high levels of fertilizer compared to others. It is somewhat surprising that a very fertile district EG fell to below the State average level over time.

The time series of CV(FRT) (see table 10.7) seem to show a fall over time. Results of the T-test for assessing the changes in CV(FRT) between the 2 sub-periods 1960-61 to 1970-71 (Period I) and 1974-75 to 1984-85 (Period II) are as follows:

	T-test	T-test Degrees of Freedom
CV(FRT)	-5.2378^{+}	19

Notes: + denotes significance at 1%.

The T-test confirms that CV(FRT) has fallen significantly over the 25 years, implying the inter-district disparity in fertilizer use has fallen over time. As a result the inter-districts differences in FRT, though still high, has come down over time.

Summary: In this section, the degree of CV, as also its movement over time, of yields and various explanatory factors were discussed. Table 10.9 presents the summary of these details for each of these variables. To sum up, the analysis indicates that over time:

1) Yield disparities across districts for rice and jowar are low and remained unchanged. Yield disparity for maize is also low but shows an increase. Yield disparity for ragi and bajra are high and have increased.

Table 10.9 - Spatial variability: A Summary.

T-Test for equality of mean level of CVs between the 2 sub-periods (sub-period 1: 1960-61 to 1970-71; sub-period 2: 1974-75 to 1984-85)					F-Test for equality of variance of CVs between the 2 sub-periods		
Null Hypothesis[1] is rejected (mean levels of CVs have changed) at significance levels of				Null Hypothesis[1] not rejected (mean levels of CVs not changed) (T-Statistic is insignificant)	Variances are equal	Variances are unequal	
1%	5%	15%	25%				
CV(YBJR)$^{H}\uparrow$	CV(YMZE)$^{L}\uparrow$	CV(YRGI)$^{H}\uparrow$	CV(IBJR)$^{H}\uparrow$	CV(YRCE)^{L}	CV(YJWR)	CV(YRCE)$\downarrow$	CV(YRGI)$\downarrow$
CV(TCNL)$^{H}\downarrow$	CV(TANK)$^{H}\uparrow$			CV(YJWR)^{L}	CV(TCNL)	CV(YBJR)$\uparrow$	CV(YMZE)$\uparrow$
CV(TBWL)$^{H}\downarrow$	CV(ACI)$^{L}\uparrow$			CV(SWTR)^{H}	CV(SWTR)	CV(TANK)$\uparrow$	CV(TBWL)$\downarrow$
CV(GWTR)$^{H}\downarrow$				CV(OTWL)^{H}	CV(GWTR)	CV(OTWL)$\downarrow$	CV(DSRC)$\downarrow$
CV(DSRC)$^{H}\downarrow$				CV(IRCE)^{L}	CV(IJWR)	CV(TNAS)$\downarrow$	CV(IRCE)$\uparrow$
CV(TNAS)$^{H}\downarrow$				CV(IJWR)^{H}		CV(IBJR)$\downarrow$	CV(IRGI)$\uparrow$
CV(IMZE)$^{H}\downarrow$				CV(IRGI)^{H}		CV(IMZE)$\downarrow$	CV(FRT)$\downarrow$
CV(FRT)$^{H}\downarrow$						CV(ACI)$\uparrow$	

Notes: F-Test for equality of variance conducted at 20% level of significance (see Appendix 10.A1);

1 : Null hypothesis H_o: the mean levels of CV are equal in the two sub-periods;

L : CV is low ($\leq$ 0.3); H : CV is high (> 0.3);

$\uparrow(\downarrow)$: The mean level/variance of CV is higher (lower) in the second sub-period than in the first sub-period;

2) Rainfall disparities are high, with North-East rainfall showing higher disparity than South-West rainfall.

3) Canal irrigation proportion shows high disparity which decreased. Tank irrigation proportion too shows high disparity which, however, increased. As a result, the high disparity in surface water irrigation proportion remained unchanged.

4) Tubewell irrigation proportion shows high disparity which decreased while the high disparity in other well irrigation proportion remained unchanged. Ground water as a whole shows high disparity which has decreased.

5) Other source irrigation proportion shows high disparity which decreased.

6) Total (by all sources together) net irrigation proportion shows high disparity which decreased.

7) Aggregate cropping intensity shows low disparity which increased.

8) The cropwise irrigation intensities of rice show low disparity which has remained unchanged. The cropwise irrigation intensities of jowar, bajra, ragi and maize show high disparities of which the disparities in the irrigation intensities of jowar and ragi remained unchanged; while the disparity in the irrigation intensity of bajra increased and that of maize decreased.

9) Fertilizer intensity shows high disparity which decreased.

10) a) Rice is an irrigated crop in all districts; the major contributors to State's total rice production are EG, WG, KR and GN, where the crop is mostly irrigated.

b) In the case of inferior cereals (jowar, bajra, ragi and maize) the major contributing districts to the respective State's total output are the ones where these crops are mostly unirrigated.

Thus in the case of rice, major part of the State depends on irrigation, while in the case of inferior cereals the major part still depends on rainfall but not irrigation. In the next section the relation between CV(yields) and the CVs of explanatory factors are analysed.

10.3 Factors Explaining Spatial Variability in Crop Yields.

Though agriculture is in the hands of millions of farmers, the farmers' cultivation decisions are largely influenced by the role the Government plays towards economic development. In agricultural sector, Government, for example, takes up all major and medium irrigation schemes. For a large number of small schemes too the Government helps farmers by giving loans through agriculture development banks. In the case of fertilizers, its import and price (which often includes a subsidy) decisions influence to a great extent the levels of fertilizer available for cultivation purposes. Even the decision in regard to modern technology based on HYV seeds is largely governmental which was of course welcomed and adopted by millions of farmers. Thus it is obvious that the development effort put in by the Government explain significantly the agricultural performance.

However, due to paucity of funds, the Government cannot develop all regions simultaneously at the same time. Priorities do exist. For example, today the Godavari districts, Krishna, and Guntur + Prakasam + Nellore districts are vastly forward in terms of agricultural performance relative to other districts in AP. Only after the Nagarjuna Sagar irrigation & power project came up recently most of the Telangana districts have started agriculturally developing. Even now, farmers in Rayalaseema region agitate quite vigorously that the AP Government has been neglecting irrigation development in that region. The Telugu Ganga project (for providing drinking water to Madras city) is hoped to redress some of their grievances. Thus regional differences in the development effort can explain regional differences in agricultural performance.

Since crop yields depend on irrigation amongst various factors, the extent of irrigation availability may act as a determinant/constraint to some extent influencing cropping pattern in a district. Provision of adequate irrigation facilities can remove this constraint. Besides, the districtwise differences in sourcewise composition within the total irrigation and the rates of utilisation of these sources could also lead to differences in cropwise irrigation intensities which in turn would cause differences in crop yield levels across districts. Thus the disparities in crop yields could depend on the differences in the development levels across districts.

Here, the relation between the disparities in development levels and disparities in crop yields is analysed. This is done by relating CV(yields) to the CVs of the sourcewise irrigation proportions, apart from the CVs of other variables which include fertilizer availability, cropping intensity and (to take into account climatic differences) seasonal rainfalls. Since the perspective maintained here is to analyse districtwise crop yield disparities in terms of disparities in development levels, only the aggregates of infrastructural variables such as sourcewise irrigations enter into our analysis. Hence, the disparities in cropwise irrigation intensities remain only in the background since these intensities are essentially determined by the sourcewise irrigation availabilities. In any case, relations between crop yields and cropwise intensities in terms of yield response functions have already been analysed districtwise in chapter 8.

In this section, the relationship between CV(yields) of the 5 cereal crops and the CV in these factors are econometrically analysed. For each crop under study, a linear relationship is estimated. Thus in these regressions CV(YRCE), CV(YJWR), CV(YBJR), CV(YRGI) and CV(YMZE) reported in table 10.1 are the dependent variables. The explanatory variables considered here are the CVs of the rainfalls (RSW, RNE) individual sourcewise net irrigation proportions (the 5 individual sources ale TCNL, TANK, TBWL, OTWL and OSRC / the aggregated (at an intermediate level) net irrigation variables SWTR and GWTR / TNAS (aggregated over all the sources)), aggregate cropping intensity (ACI), and fertilizer availability (FRT). The CVs of these variables were reported earlier in tables 10.4, 10.5 and 10.7.

Amongst the different individual sources of irrigation, TBWL and OSRC are negligible in most districts and hence these 2 sources of irrigation are not considered in this analysis. TCNL, TANK and OTWL are the most important sources of irrigation in all the districts. All of surface water and most of the ground water are accounted for by these 3 sources in all the districts.

Before estimating any regression simple correlation coefficients between the explanatory variables are computed to check for multicollinearity, if any, among these variables. Table 10.10 presents these correlations. From this table it can be seen that the correlations amongst the CVs of the explanatory variables are generally low implying that multicollinearity is not a serious problem among the explanatory variables.

Initially keeping SWTR and GWTR along with the rainfall, fertilizer availability and cropping intensity as the explanatory variables to explain CV(yield), for each crop the following linear relationship is estimated:

$$CV(Y)_{it} = \beta_{oi} + \beta_{1i}CV(RSW)_t + \beta_{2i}CV(RNE)_t + \beta_{3i}CV(FRT)_t + \beta_{4i}CV(ACI)_t + \beta_{5i}CV(SWTR)_t + \beta_{6i}CV(GWTR)_t + U_{it} \quad (10.1)$$

i = 1,...,5 are the crops; t = 1,...,T are the years (25).

Thus equation (10.1) covers 5 cases - one for each of the 5 cereal crops rice, jowar, bajra, ragi and maize, studied here. Note that all the explanatory variables are same in all the 5 equations of (10.1). SWTR is all the net area irrigated by surface water sources (canals & tanks) as a proportion to total net sown area. SWTR, thus defined, is a measure of the availability of irrigation from surface water sources for crop cultivation in general. Various crops may compete with each other in utilizing this available surface water irrigation. This would imply that the 5 equations of (10.1) are not completely un-related regressions. Under such a situation, the random disturbances in say CV(YRCE) may be correlated with the random disturbances in say CV(YMZE) during the same period; i.e., we may expect contemporaneous correlation in the random disturbances of the 5 equations of (10.1). In the presence of such contemporaneous correlations single equation estimators would not be efficient. Hence the 5

Table 10.10 – *Correlation Matrix of Coefficient of Variations of Explanatory Variables.*

Variable	RSW	RNE	TCNL	TANK	SWTR	TBWL	OTWL	GWTR	OSRC	TNAS	ACI	IRCE	IJWR	IBJR	IRGI	IMZE	FRT
RSW	1.00	0.38	-0.57	0.69	0.30	-0.27	-0.25	-0.54	-0.15	-0.21	0.54	-0.22	0.29	0.03	-0.36	-0.43	-0.39
RNE	0.38	1.00	-0.07	0.11	0.02	0.16	-0.22	-0.08	-0.02	-0.11	-0.10	-0.26	0.09	0.15	-0.12	-0.03	0.01
TCNL	-0.57	-0.07	1.00	-0.31	0.15	0.40	0.19	0.79	0.50	0.64	-0.61	0.25	-0.13	-0.28	0.04	0.61	0.76
TANK	0.69	0.11	-0.31	1.00	0.80	0.01	0.14	-0.30	0.05	0.31	0.31	-0.08	-0.05	0.22	-0.17	-0.52	-0.45
SWTR	0.30	0.02	0.15	0.80	1.00	0.25	0.32	0.17	0.42	0.74	-0.02	0.10	-0.11	0.08	-0.01	-0.34	-0.16
TBWL	-0.27	0.16	0.40	0.01	0.25	1.00	0.36	0.55	0.31	0.50	-0.61	0.05	-0.22	0.43	0.14	0.06	0.07
OTWL	-0.25	-0.22	0.19	0.14	0.32	0.36	1.00	0.55	0.25	0.37	-0.28	0.25	-0.06	0.34	0.19	-0.09	-0.08
GWTR	-0.54	-0.08	0.79	-0.30	0.17	0.55	0.55	1.00	0.70	0.69	-0.62	0.30	-0.08	-0.11	0.11	0.40	0.59
OSRC	-0.15	-0.02	0.50	0.05	0.42	0.31	0.25	0.70	1.00	0.74	-0.42	0.17	0.15	-0.32	0.01	0.20	0.40
TNAS	-0.21	-0.11	0.64	0.31	0.74	0.50	0.37	0.69	0.74	1.00	-0.48	0.30	-0.26	-0.09	0.01	0.09	0.27
ACI	0.54	-0.10	-0.61	0.31	-0.02	-0.61	-0.28	-0.62	-0.42	-0.48	1.00	-0.25	0.28	-0.10	-0.28	-0.39	-0.29
IRCE	-0.22	-0.26	0.25	-0.08	0.10	0.05	0.25	0.30	0.17	0.30	-0.25	1.00	-0.19	-0.14	0.28	0.21	0.21
IJWR	0.29	0.09	-0.13	-0.05	-0.11	-0.22	-0.06	-0.08	0.15	-0.26	0.28	-0.19	1.00	-0.22	-0.25	0.30	0.24
IBJR	0.03	0.15	-0.28	0.22	0.08	0.43	0.34	-0.11	-0.32	-0.09	-0.10	-0.14	-0.22	1.00	0.20	-0.27	-0.44
IRGI	-0.36	-0.12	0.04	-0.17	-0.01	0.14	0.19	0.11	0.01	0.01	-0.28	0.28	-0.25	0.20	1.00	-0.24	-0.15
IMZE	-0.43	-0.03	0.61	-0.52	-0.34	0.06	-0.09	0.40	0.20	0.09	-0.39	0.21	0.30	-0.27	-0.24	1.00	0.67
FRT	-0.39	0.01	0.76	-0.45	-0.16	0.07	-0.08	0.59	0.40	0.27	-0.29	0.21	0.24	-0.44	-0.15	0.67	1.00

Variable: RSW : Rainfall during South-West monsoon;

RNE : Rainfall during North-East monsoon;

TCNL : Net area irrigated by canals as a proportion to net sown area over all crops;

TANK : Net area irrigated by tanks as a proportion to net sown area over all crops;

SWTR : Net area irrigated by surface water (= canals + tanks) as a proportion to net sown area over all crops;

TBWL : Net area irrigated by tubewells as a proportion to net sown area over all crops;

OTWL : Net area irrigated by other wells as a proportion to net sown area over all crops;

GWTR : Net area irrigated by ground water (= tubewells + other wells) as a proportion to net sown area over all crops;

OSRC : Net area irrigated by other sources as a proportion to net sown area over all crops;

TNAS : Net area irrigated by all sources as a proportion to net sown area over all crops;

ACI : Aggregate Croping Intensity (= gross cropped area over all crops / net sown area over all crops);

IRCE : Gross irrigation proportion for rice (= gross irrigated area under rice / total cultivated area under rice);

IJWR : Gross irrigation proportion for jowar (= gross irrigated area under jowar / total cultivated area under jowar);

IBJR : Gross irrigation proportion for bajra (= gross irrigated area under bajra / total cultivated area under bajra);

IRGI : Gross irrigation proportion for ragi (= gross irrigated area under ragi / total cultivated area under ragi);

IMZE : Gross irrigation proportion for maize (= gross irrigated area under maize / total cultivated area under maize);

FRT : Fertilizer availability (= Total fertilizer consumption divided by area under 5 cereals;

equations are simultaneously estimated using Zellner's Seemingly Unrelated Regressions (ZSUR) procedure (Zellner (1962)) with the following specification on the error terms:

(1) $E(U_{it}) = 0$ for all i and t;

(2) $E(U_{it}, U_{is}) = \sigma_i^2$ for $t = s$;
$= 0$ for $t \neq s$;

(3) $E(U_{it}, U_{ks}) = \sigma_{ik}$ for $t = s$;
$= 0$ for $t \neq s$;

σ_{ik} gives the cross-equation covariances. Then, the contemporaneous correlations r_{ik} is

$$r_{ik} = \frac{\sigma_{ik}}{\sqrt{\sigma_i^2}\,\sqrt{\sigma_k^2}}$$

If $r_{ik} = 0$ (or is very small) it would imply that contemporaneous correlations do not exist (or is not severe) between the random disturbances across equations. In such situations there is no efficiency loss due to estimation as single equations. The results from the simultaneous (ZSUR) estimation of the 5 equations of (10.1) are presented in table 10.11.A. The variance-covariance matrix (Σ) of errors for the 5 equations and the matrix of correlations (R) of errors across equations are also given in table 10.11.A. From the correlations matrix R it can be seen that contemporaneous correlations between the random disturbances across equations are all mostly small. Hence, the results of the single equation estimations can be taken as valid. The results of the single equation estimations of equation (10.1) are presented in table 10.11.B.

Comparing the estimates from the single equation estimations (table 10.11.B) with those from the simultaneous estimations (table 10.11.A), it can be seen that the magnitude of the coefficients are exactly same from the 2 sets of estimations with same signs too; though the standard errors of the coefficients are marginally higher in the single equation estimations. Thus analysis based on single equation estimations seems to be appropriate.

Turning now to the above estimation results, in the case of

Table 10.11.A – Estimation Results of Equation 10.1' by ZSUR Method.

CV(Crop)	CONSTANT	CV(RSV)	CV(RNE)	CV(FRT)	CV(ACI)	CV(SVTR)	CV(GVTR)	$\bar{R}^2$	D-W
CV(YRCE)	-0.4097†	-0.1825	0.0936†	0.0983†	0.4289	0.6540†	-0.0828	0.4387	1.7993
	(0.1763)	(0.1199)	(0.0298)	(0.0551)	(0.7486)	(0.1494)	(0.1751)		
CV(YJVR)	0.1110	0.0680	0.0211	-0.1276	0.5763	-0.0153	0.1721	-0.1044	1.2478
	(0.2503)	(0.1703)	(0.0424)	(0.0783)	(1.0627)	(0.2121)	(0.2485)		
CV(YBJR)	0.6024	0.3293	-0.0406	-0.1364	-4.0908†	1.0897†	-0.8130†	0.4602	1.7504
	(0.4102)	(0.2790)	(0.0694)	(0.1283)	(1.7416)	(0.3476)	(0.4073)		
CV(YRGI)	0.5398†	-0.1217	0.0955†	-0.2007†	-2.5885†	0.5995†	-0.4092	0.4097	1.4936
	(0.2932)	(0.1995)	(0.0496)	(0.0917)	(1.2451)	(0.2485)	(0.2912)		
CV(YMZE)	0.3293	0.1024	0.0293	-0.0348	1.0112	0.0753	-0.4601	0.2144	2.1078
	(0.3255)	(0.2214)	(0.0551)	(0.1018)	(1.3821)	(0.2758)	(0.3232)		

Variance - Covariance Matrix (Σ)

	Crop	Rice	Jowar	Bajra	Ragi	Maize
	Rice	0.0012	0.0005	0.0005	0.0012	-0.0001
	Jowar	0.0005	0.0024	0.0015	0.0003	0.0013
Σ =	Bajra	0.0005	0.0015	0.0064	0.0016	-0.0002
	Ragi	0.0012	0.0003	0.0016	0.0033	0.0004
	Maize	-0.0001	0.0013	-0.0002	0.0004	0.0041

Correlations Matrix (R)

	Crop	Rice	Jowar	Bajra	Ragi	Maize
	Rice	1.00	0.30	0.18	0.61	-0.01
	Jowar	0.30	1.00	0.38	0.21	0.43
R =	Bajra	0.18	0.38	1.00	0.36	-0.04
	Ragi	0.61	0.21	0.36	1.00	0.11
	Maize	-0.01	0.43	-0.04	0.11	1.00

ZSUR : Zellner's Seemingly Unrelated Regressions Procedure.

Other notes are given at the end of the table.

Table 10.11.B - Estimation Results of Equation $10.1^{\#}$ by Single-Equations Method.

Crop	CONSTANT	CV(RSV)	CV(RNE)	CV(FRT)	CV(ACI)	CV(SVTR)	CV(GVTR)	$\bar{R}^2$	D-W
Rice	-0.4097^{+}	-0.1825	0.0936^{+}	0.0983	0.4289	0.6540^{+}	-0.0828	0.4387	1.7993
	(0.2078)	(0.1413)	(0.0352)	(0.0650)	(0.8823)	(0.1761)	(0.2063)		
Jowar	0.1110	0.0680	0.0211	-0.1276	0.5763	-0.0153	0.1721	-0.1044	1.2478
	(0.2950)	(0.2007)	(0.0499)	(0.0923)	(1.2524)	(0.2509)	(0.2929)		
Bajra	0.6024	0.3293	-0.0406	-0.1364	-4.0908^{+}	1.0891^{+}	-0.8130	0.4602	1.7504
	(0.4834)	(0.3288)	(0.0818)	(0.1512)	(2.0524)	(0.4096)	(0.4800)		
Ragi	0.5398	-0.1217	0.0955	-0.2007^{+}	-2.5885^{+}	0.5995^{+}	-0.4092	0.4097	1.4936
	(0.3456)	(0.2351)	(0.0585)	(0.1081)	(1.4673)	(0.2928)	(0.3432)		
Maize	0.3293	0.1024	0.0293	-0.0348	1.0112	0.0753	-0.4601	0.2144	2.1078
	(0.3836)	(0.2610)	(0.0649)	(0.1200)	(1.6288)	(0.3251)	(0.3809)		

Notes: Standard error of the coefficient is given in brackets.

+ : Indicates the coefficient is significant at the 10% level.

: The form of equation 8.1 is as follows: let i (= 1,...,5) denote the crops, and t (= 1,...,25) denote the years.

$$CV(Y)_{it} = b_{0i} + b_{1i}CV(RSV)_t + b_{2i}CV(RNE)_t + b_{3i}CV(FRT)_t + b_{4i}CV(ACI)_t + b_{5i}CV(SVTR)_t + b_{6i}CV(GVTR)_t + U_{it}$$

Y : is the yield. RSV, RNE, FRT, ACI, SVTR and GVTR are as defined in the notes to table 8.9.

U : is the random disturbance.

rice, RSW, ACI and GWTR have insignificant coefficients, while in the case of bajra, RSW, RNE and FRT have insignificant coefficients and in the case of ragi, RSW and FRT have insignificant coefficients. For jowar and maize, however, specification (10.1) has fared badly and alternative explanatory variables to SWTR and GWTR may have to be considered. The individual sources of irrigation, (TCNL, TANK and OTWL), i.e., the disaggregated components of surface water and ground water, are the alternative explanatory variables considered.

10.3.1 Final Results.

In the case of CV(YRCE) the disaggregation of the explanatory variables did not help at all. Hence only CV(SWTR) and CV(GWTR) are retained here along with the other explanatory variables of which CV(GWTR) turned insignificant. In the case of CV(YBJR) the tank component of surface water and total ground water both turn significant along with other explanatory variables. Coming to ragi and maize, while only the tank component of surface water is significant but not ground water in the case of CV(YRGI), only the other wells component of ground water but nothing of surface water is significant in the case of CV(YMZE). In the cases of CV(YRCE), CV(YRGI) and CV(YMZE), the disparities in rainfall and fertilizer availability also explain their CV(Yields). Only in the cases of CV(YBJR) and CV(YRGI), the disparity in ACI also appears as explanatory variable. However, in the case of jowar none of these variables could explain the disparities in its yields. The final results of our regression analysis are presented in table 10.12. It can be seen from this table that, the fits obtained in terms of R^2 and $\bar{R}^2$, have still been only moderate, though in the case of bajra and maize the increase in their fits is substantial. CV(YBJR) has the highest fit ($\bar{R}^2$ = 0.6546, R^2 = 0.6978) followed by CV(YRCE) and CV(YRGI).

Coefficient of variation in rice yields: The explanatory variables that figure in the regression for CV(YRCE) are CV(RNE), CV(FRT) and CV(SWTR), all of them with significant positive

Table 10.12 - Final Estimation Results of Coefficient of Variation (CV) in Crop Yields, by Single-Equations Method.

Rice

$$CV(YRCE)_t = -0.3923 + 0.0698 \ast CV(RNE)_t + 0.1033 \ast CV(FRT)_t + 0.5467 \ast CV(SVTR)_t + U_t$$

$$(-3.06)^{*} \quad (2.50)^{**} \quad (2.18)^{**} \quad (3.93)^{*}$$

$$R^2 = 0.5399 \qquad \bar{R}^2 = 0.4742 \qquad D\text{-}W = 1.81$$

Bajra

$$CV(YBJR)_t = 0.5807 - 3.5118 \ast CV(ACI)_t + 1.4056 \ast CV(SVTR)_t - 1.2197 \ast CV(GVTR)_t + U_t$$

$$(1.31) \quad (-2.02)^{***} \quad (4.29)^{*} \quad (-3.53)^{*}$$

$$R^2 = 0.5519 \qquad \bar{R}^2 = 0.4879 \qquad D\text{-}W = 1.82$$

$$CV(YBJR)_t = 0.8002 - 4.1322 \ast CV(ACI)_t + 0.8966 \ast CV(TANK)_t - 0.6719 \ast CV(GVTR)_t + U_t$$

$$(2.34)^{**} \quad (-2.87)^{*} \quad (6.12)^{*} \quad (-2.39)^{**}$$

$$R^2 = 0.6978 \qquad \bar{R}^2 = 0.6546 \qquad D\text{-}W = 1.81$$

Ragi

$$CV(YRGI)_t = 0.5575 + 0.0784 \ast CV(RNE)_t - 0.1977CV \ast (FRT)_t - 2.9131 \ast CV(ACI)_t + 0.5280 \ast CV(SVTR)_t - 0.356 \ast CV(GVTR)_t + U_t$$

$$(1.65) \quad (1.63) \quad (-1.87)^{***} \quad (-2.24)^{**} \quad (2.09)^{***} \quad (-1.11)$$

$$R^2 = 0.5507 \qquad \bar{R}^2 = 0.4325 \qquad D\text{-}W = 1.51$$

$$CV(YRGI)_t = 0.5174 + 0.0773 \ast CV(RNE)_t - 0.2186CV \ast (FRT)_t - 2.6677 \ast CV(ACI)_t + 0.3029 \ast CV(TANK)_t + U_t$$

$$(3.01)^{*} \quad (1.66) \quad (-2.51)^{**} \quad (-2.61)^{**} \quad (2.22)^{**}$$

$$R^2 = 0.5549 \qquad \bar{R}^2 = 0.4659 \qquad D\text{-}W = 1.75$$

Maize

$$CV(YMZE)_t = 1.0111 + 0.2130 \ast CV(RSV)_t - 0.1676 \ast CV(FRT)_t - 0.8642 \ast CV(OTVL)_t + U_t$$

$$(3.20)^{*} \quad (1.41) \quad (-1.99)^{***} \quad (-2.89)^{*}$$

$$R^2 = 0.4971 \qquad \bar{R}^2 = 0.4252 \qquad D\text{-}W = 2.23$$

Notes: t-values are given in brackets. */**/*** : Indicates significance at 1%, 5% and 10% level, respectively.

YRCE, YBJR, YRGI and YMZE are the yields of rice, bajra, ragi and maize, respectively.

RSV : Rainfall during South-West monsoon; RNE : Rainfall during North-East monsoon;

TANK : Net area irrigated by tanks as a proportion to net sown area over all crops;

SVTR : Net area irrigated by surface water (= canals + tanks) as a proportion to net sown area over all crops;

OTVL : Net area irrigated by other wells as a proportion to net sown area over all crops;

GVTR : Net area irrigated by ground water (= tubewells + other wells) as a proportion to net sown area over all crops;

ACI : Aggregate Croping Intensity (= gross cropped area over all crops / net sown area over all crops);

FRT : Fertilizer availability (= Total fertilizer consumption divided by area under 5 cereals;

U : is the random disturbance.

coefficients. As noted earlier in section 10.2.1 CV(YRCE) is low and has not shown any significant change over time. Earlier we also noted that all the explanatory variables here, i.e., disparities in North-East rainfall, fertilizer availability and surface water irrigation proportion are high. That is, their CVs are all greater than 0.3.

Yields depend on several factors including fertilizer used and the quantum of water provided to the crop. Rice is a water intensive crop. Water input comes from rainfall and/or irrigation sources. We noted earlier that CV(RSW) is, however, much smaller than CV(RNE) which alone turns out to be significant in the regression among the two rainfall terms. CV(RNE), being a climatic aspect, is unlikely to change over time (atleast in the short run). Apart from this, as far as irrigation is concerned, almost all the districts have high irrigation intensity for this crop. This irrigation obviously has to come from surface water and/or ground water sources. In the regression equation only CV(SWTR) turns out to be significant and not CV(GWTR). Recall that CV(SWTR) is generally high (see table 10.5) with a further feature that it has not changed over time. Thus the two variables, CV(RNE) and CV(SWTR), which are stationary over time, are likely to maintain a stationary level of disparity in rice yields (CV(YRCE)).

With regard to fertilizers, CV(FRT) has fallen significantly over time as we had seen in section 10.2.4. With a positive relation with CV(YRCE) as the estimated regression equation shows, the falling trend in CV(FRT) brings forth a falling tendency in the latter. Indeed the time series of CV(YRCE) reported in table 10.1 seem to show a slight, though not a significant, fall over time.

Two points need to be noted here. (1) Fertilizer consumption and HYV adoption are highly related as mentioned in chapter 8.
(2) HYV adoption for rice in AP is very high (81% in 1984-85) but not 100% though. Thus, it is possible that with further spread of HYV the disparities in fertilizer consumption rate could fall further which, as the results point, may reduce the low disparities

in rice yields further. However, note that CV(YRCE) is low even before the introduction of modern technology. But that may be because of the near uniformly high irrigation intensity for rice (i.e., low CV(IRCE) as can be seen from table 10.7) despite disparities in irrigation infrastructure.

Coefficient of Variation in Jowar Yields: None of the explanatory variables considered here including the disparities in the rainfalls could explain the disparities in jowar yields across districts. The R^2s and $\bar{R}^2$s turned out to be too poor. These estimation results are hence not reported.

Coefficient of Variation in Bajra Yields: Two estimated regression equations have been reported in table 10.12. The first equation has CV(ACI), CV(SWTR) and CV(GWTR) as the explanatory variables. While CV(ACI) and CV(GWTR) have significant negative coefficients, CV(SWTR) has a significant positive coefficient. Note that none of the 2 rainfall variables nor fertilizer figure in this regression. As pointed out earlier CV(YBJR) is high and has increased over time (see table 10.9). The positive coefficient of CV(SWTR) which is high and unchanging over time and the negative coefficient of CV(GWTR) which is also high but falling over time - both explain the high and increasing value of CV(YBJR). The rising trend of CV(ACI) due to its inverse relationship with CV(YBJR), however, dampens the rising trend in the latter.

In most of the districts where some bajra is grown under irrigated conditions, surface water is the dominant source of irrigation. For example, see SV(90%), WG(76%), GN(80%), KU(81%), NZ(76%), KH(72%), KM(55%) and AD(80%) where the bracketed figures are the percentages of surface water component in the total irrigation in 1984-85. Even in CU and CH, this component has been dominant until recently. Of all these districts, GN, CU, CH, NZ and KM are in fact HVD(IBJR); i.e., relatively more irrigation intensity for bajra than in other districts. Thus it appears that surface water is the main source for irrigated cultivation of bajra. Then our results suggesting that the disparities in surface water proportions are positively related to the disparities in bajra yields are tenable.

However, the growth rates in the area irrigated by surface water as a whole are negligible whereas growth rates in the area irrigated by ground water are significantly positive in most of the districts. The latter has grown in all the districts except KU and NA where it has remained stagnant and in SV it has declined over time (see table 10.3). This pattern of growth in ground water irrigation across the districts has resulted in a significant decline in CV(GWTR) where GWTR is the proportion of ground water irrigation in total net sown area. At the same time YBJR, on the other hand, has remained stagnant in most districts with only SV, WG, KR and CU registering a growth. Thus it is clear that growth in ground water irrigation did not contribute to growth in YBJR in most of the districts. However, CV(GWTR) still figures in the estimated regression as significant explanatory variable. This is perhaps explainable by taking into account the possible changes in the cropping pattern as irrigation develops. For example, when ground water becomes available for irrigation, some other crops (including cash crops) may be cultivated now where bajra was being cultivated earlier. That is, bajra continues to remain under unirrigated cultivation and hence bajra yields do not grow. While this is the general pattern applicable to most of the districts, however, 4 districts - SV, WG, KR and CU - stand as exceptions. Here in fact the bajra yields grew up significantly while in all other districts it did not grow. Thus CV(YBJR) could go up while CV(GWTR) has fallen over time.

Disaggregation of GWTR into its component sources (TBWL and OTWL) did not give satisfactory results. Hence CV(GWTR) is retained here. Disaggregation of SWTR into its component sources, TCNL and TANK, however, was found to explain CV(YBJR) better. Of these 2 individual surface water sources only CV(TANK), but not CV(TCNL), was found to be an important variable in explaining CV(YBJR). CV(TANK), with significant positive coefficient (same as that of CV(SWTR)), as an explanatory variable instead of CV(SWTR) improved the fit substantially as shown by the high R^2 (= 0.6978) and $\bar{R}^2$ (= 0.6546) (see table 10.12). CV(TANK) is high and increasing over time (see table 10.9) as a result of the fall in irrigated area under tanks in some districts while it remained stagnant in other districts. The high and increasing levels of disparities in tank irrigation proportion seem to push up the disparities in bajra yields across districts.

ACI, which is a measure of multiple cropping, increases with increase in irrigation facilities. When irrigation becomes available it is possible, for example, to raise two crops instead of one crop in a year. Then it is likely that one crop is grown under irrigation, while the other may be less/unirrigated crop. Obviously, given the farmers' preferences, rice would be the irrigated crop and inferior cereals such as bajra, ragi, etc., would be the unirrigated crop. Thus bajra yields continue to remain unirrigated in most of the districts which would result in a fall in CV(YBJR). Thus an increase in CV(ACI) is likely to result in a fall in CV(YBJR). Thus, the net effect of the increase in CV(ACI) through its negative relation with CV(YBJR) has been to dampen the increase in the latter.

Coefficient of Variation in Ragi Yields: Two estimated equations have been reported in table 10.12. The explanatory variables in the first regression (see table 10.12) for CV(YRGI) are CV(RNE), CV(FRT), CV(ACI), CV(SWTR) and CV(GWTR). Of these CV(RNE) and CV(SWTR) have significant positive coefficients, while CV(FRT) and CV(ACI) have significant negative coefficients. The coefficient of CV(GWTR) is negative but insignificant. From table 10.9 we know that CV(YRGI) is high and has increased over time. All the explanatory variables except CV(ACI) are high valued (i.e., the CVs are > 0.3) and this explains the high levels of CV(YRGI). CV(SWTR) which has not showed any change over time is likely to keep CV(YRGI) stationary. The downward trend in both (the high valued) CV(FRT) and CV(GWTR), because of their negative coefficients results in an upward trend in CV(YRGI). The upward trend in CV(ACI) with a negative coefficient, however, dampens the upward trend in CV(YRGI).

The positive coefficient of both CV(RNE) and CV(SWTR) imply a direct relation between these 2 variables and CV(YRGI) in a way similar to that in the case of rice described earlier. Disaggregation of SWTR into its component sources (TCNL and TANK) was found to explain CV(YRGI) better. Of these 2 sources only CV(TANK), but not CV(TCNL), was found to have significant and positive coefficient. The fit also improved slightly (see table 10.12). CV(TANK), as noted earlier, is high and increasing over time. Thus the high and increasing levels of disparities in tank irrigation proportion has resulted in a high level of disparity in ragi yields which too is increasing over time. Coefficient of CV(GWTR) is insignificant and its disaggregation into OTWL did not help in explaining CV(YRGI). In fact, CV(GWTR) is dropped in the second regression reported in table 10.12.

Turning to FRT, CV(FRT) is high but falling over time and it has a negative coefficient in the regression for CV(YRGI). That is the falling levels of disparity in fertilizer availability would actually push up the disparities in YRGI across districts. This may be explained as follows:
Note that CV(FRT) has a positive coefficient with respect to CV(YRCE) which implies that falling disparities in fertilizer availability would lead to falling disparities in YRCE. Rice is mostly a high yielding variety seeds based crop in AP which is both irrigation and fertilizer intensive. In 1984-85, 81% of rice acreage in AP was under HYV seeds while ragi is fully a traditional variety seeds based crop. Rice, being a superior cereal unlike ragi, is also a more remunerative crop. Thus not only rice takes away a large share of the total fertilizer that is usually available only in limited quantities, but also with increased fertilizer availability (often accompanied with increased HYV adoption) farmers may prefer to allocate more land for rice cultivation. Besides, a falling CV(YRCE) implies that yield levels in LVD(YRCE) are moving closer to those levels in HVD(YRCE). This implies that relatively fertile land gets allocated to rice rather than to other crops - thus ragi, etc., moving over time to less and less fertile lands and also ending up with only marginal amounts of the limited available fertilizers. Thus a falling CV(FRT) is associated with a rise (fall) in CV(YRGI) (CV(YRCE)). This pattern can be

seen in the case of CV(YMZE) also to be discussed later. These results might change once fertilizers become freely available at prices affordable by farmers.

The negative coefficient of CV(ACI) in these regressions can be explained exactly in the same way as in the case of bajra earlier.

Coefficient of Variation in Maize Yields: The finally chosen regression for CV(YMZE) (table 10.12) has CV(RSW), CV(FRT) and CV(OTWL) as the explanatory variables. CV(FRT) and CV(OTWL) have significant negative coefficients. The coefficient of CV(RSW), which is positive, is significant only at 17% significance level.

As mentioned earlier, CV(YMZE) is low but it has increased over time (see table 10.9). From the same table, we also know that all the 3 explanatory variables here are high valued. The constant term and the high values of CV(RSW) with positive coefficient seem to compensate to a large extent the high values of CV(OTWL) and CV(FRT), both of which have negative coefficient, resulting in a low valued CV(YMZE).

The observed trend in CV(YMZE) must be explained in terms of trends in the explanatory variables. RSW being a climatic variable, no trend is expected in its pattern across districts; i.e., CV(RSW) is taken to show no trend. From table 10.9, we find that CV(OTWL) does not show any trend but CV(FRT) has fallen over time. It is this fall in CV(FRT) which, due to its inverse relationship with CV(YMZE), explains the rise in the latter.

Disparities in rainfall (South-West rather that North-East monsoon) has a direct effect on the disparities in maize yield levels. This is similar to the relationship between CV(RNE) with CV(YRCE) explained earlier.

The negative coefficient of both CV(OTWL) and CV(FRT) imply an inverse relationship with these 2 variables, which need some explanation. Note from table 10.3 that in 13 out of 18 districts

YMZE shows significant positive growth rates. In 7 (GN, AN, CU, CH, MB, WA and KM) of these 13, other wells irrigation area also simultaneously recorded significant positive growth rates with surface water irrigation area not growing at all (except in GN). In the remaining 6 districts (SV, EG, WG, KR, KU and NA) YMZE grew despite stagnant/falling levels of other wells irrigation area. Thus it appears that other well irrigation area's contribution, if any, to growth in YMZE is restricted to only the above mentioned 7 districts.

But it also turns out that in these 7 districts where other wells may have contributed to growth in YMZE, 4 (GN, CU, CH and WA) of them are LVD(YMZE) and HVD(OTWL) showing growth in both of them. Growth in OTWL in already HVD(OTWL) implies an increase in over all CV(OTWL). Whereas growth in YMZE in LVD(YMZE) implies a decrease in over all CV(YMZE). Thus the possibility of the negative coefficient for CV(OTWL) in the estimated regression equation.

However, the growth in OTWL across all districts has not resulted in any significant increase/decrease in CV(OTWL) (see table 10.9). That is the stationary levels of CV(OTWL) would only maintain a stationary level of CV(YMZE). However, from table 10.8, we also know that CV(YMZE) has increased over time. The increase in CV(YMZE) is due to its negative relationship with CV(FRT) which has been falling over time. This negative relationship can be explained, as in the case of CV(YRGI), in terms of changes in cropping pattern and cropwise fertilizer allocations.

10.4 Conclusions.

In this chapter, spatial variability in yields of the 5 cereal crops across the districts of AP were studied. As measured by coefficient of variation across the districts, the pattern of growth and spatial variability is as follows:

Yields of all 5 crops show either positive growth or is stagnant. None of the 5 crops show falling yields in any district. Yield disparities across districts for rice and jowar are low and remained unchanged over time. Yield disparity for maize is also low but shows an increase over time. Yield disparity for ragi and bajra are high and have increased over time.

The overall growth pattern of the crop yields is as follows: The superior cereal rice has experienced growth in almost all districts, particularly the LVD(YRCE) showing faster growth than the HVD(YRCE). Among the inferior cereals, while jowar yields have remained stagnant in almost all districts, bajra and ragi yields grew only in a few districts which are already HVD(YBJR) and HVD(YRGI). The case of maize is opposite to that of rice, where several districts show growth but HVD(YMZE) growing faster than LVD(YMZE). This explains the movement over time in CV(Yields) presented above.

Rainfall disparities are high, with North-East rainfall showing higher disparity than South-West rainfall.

Canal irrigation <u>area</u> shows growth in most districts while tank irrigation <u>area</u> is either falling/stagnant in all the districts. Total surface water irrigation <u>area</u>, however, is stagnant in most districts. Canal irrigation <u>proportion</u> shows high disparity which decreased over time. Tank irrigation <u>proportion</u> too shows high disparity which, however, increased over time. As a result, the high disparity in surface water irrigation <u>proportion</u> remained unchanged over time.

Tubewells irrigation <u>area</u> shows positive growth in most of the districts while other wells irrigation <u>area</u> shows positive growth in some, but not all, districts. Thus, the total ground water irrigation <u>area</u> is growing in almost all districts. Tubewell irrigation <u>proportion</u> shows high disparity which decreased over time while the high disparity in other well irrigation <u>proportion</u> remained unchanged over time. Ground water irrigation <u>proportion</u> as a whole shows high disparity which decreased over time.

Other source irrigation <u>proportion</u> shows high disparity which decreased over time.

Total (by all sources together) net irrigation <u>area</u> is growing in almost all districts; total net irrigation <u>proportion</u> shows high disparity which decreased over time.

Thus in general, efforts at irrigation development seem to be somewhat non-uniform across various districts in different regions in Andhra. In particular, the districts in Rayalaseema seem to be unfavourably positioned in this context.

Aggregate cropping intensity is increasing in all districts; it shows low disparity but increasing over time. ACI is shown to be positively related to canal and other wells irrigation proportions. However, CV(ACI) is far lower than CV(TCNL) and CV(OTWL). This only implies that though irrigation facilities do contribute to ACI, the response of ACI with respect to irrigation development is different in different districts. The above relation between ACI and irrigation actually suggests that the elasticity of ACI with respect to irrigation is likely to be higher the higher the irrigation proportion. This suggests that CV(ACI) is likely to go up over time.

The cropwise irrigation intensities of rice show low disparity which has remained unchanged over time. The cropwise irrigation intensities of jowar, bajra, ragi and maize show high disparities of which the disparities in the irrigation intensities of jowar and ragi remained unchanged; while the disparity in the irrigation intensity of bajra increased and that of maize decreased over time.

Fertilizer intensity shows high disparity which decreased over time.

In the case of superior cereal rice the major contributors to the State's output are the districts where the crop is mostly under irrigated conditions, whereas in the case of inferior cereals, the major contributing districts are the ones where these crops are mostly under unirrigated conditions.

The spatial variability in crop yields was studied here using aggregated variables on irrigation, fertilizer, cultivation intensity, apart from rainfall in the two major seasons (South-West and North-East monsoons). The conclusions of this analysis are as follows:

(1) Rainfall (during South-West monsoon or North-East monsoon or both) was found to affect directly the spatial variability of yields of all crops except bajra;

(2) Among the infrastructural factors the disparity across districts in sourcewise net irrigation proportions was found to affect the spatial variability in yields of all cereal crops grown in AP except jowar.

(3) Among the various sources, the disparities in surface water sources proportion as a whole affect directly the disparities in the yields of rice, bajra and ragi. In the case of bajra and ragi yields, disparities in tank irrigation proportion in particular affect directly the disparity in their yields.

(4) Disparities in ground water sources proportion as a whole affect inversely the disparities in bajra yields, and in the case of maize, it is the disparities in the other wells component of ground water that affects (inversely) the disparities in maize yields.

(5) Disparities in ACI was found to have an inverse relation with the disparities in bajra and ragi yields only.

(6) Differences in fertilizer intensity affects directly the disparities in rice yields, and inversely ragi and maize yields.

Among several factors that may affect the spatial variability of yields some important ones like seed variety (HYV or traditional - though indirectly accounted for by the fertilizer variable), labour, mechanization, cost of cultivation of different crops and various other institutional factors could not be incorporated here for want of appropriate time series data on these factors at the districts level. Inclusion of these variables in our analysis, though not possible given the current data availability, might further improve our understanding of the spatial variability in yields. In the absence of such data some of the explanations offered in interpreting the results obtained, particularly those relating to inter crop substitutions, may seem hypothetical. These explanations, however, can be confirmed when detailed crop specific data on the various explanatory variables become available. Also, detailed acreage response studies may help in this context.

In chapter 8 we analysed the relation between irrigation levels and the yield levels of all the crops. In the previous chapter we found that increasing irrigation intensity for a crop does not lead to instabilities in yield variance for any crop. This chapter has brought out the effect of disparities in various sources of irrigation on the spatial variability of cereal crop yields. In particular, the all round neglect of tank irrigation that led to a worsening of its disparities across districts, has resulted in an increase in the disparities in bajra and ragi yields. Disparities in surface water development affect the disparities in rice yields, while the disparities in other wells irrigation affect disparities in maize yields. Thus it is obvious that irrigation plays a very important role in agricultural development. Leaving now the aspects of growth, stability and variability in crop yields, let us ask an important question: "What happens if irrigation development is neglected in an economy dominated by agricultural sector?".

Neglect of irrigation development would have serious consequences on agricultural development in particular and also on the economy as a whole. Unfortunately, such a neglect seems to have occurred since the 1980s in the form of a fall in the levels of agricultural investment necessary for irrigation development. In the next chapter, the consequences of neglecting irrigation development on agricultural performance and on the economy as a whole are studied at the all India level.

Appendix 10.A1 - T-Test for Equality of Means.

This appendix elaborates the non-parametric approach adopted to assess changes over time (increase/decrease), if any, in the CVs of yields and the explanatory variables. Essentially, this involves a T-test and an associated F-test as detailed below.

Given a series X_t (t = 1, 2, ..., n; n is the sample period) the sample period is split into 2 sub-periods denoted I and II. The mean levels $\bar{X}_I$ and $\bar{X}_{II}$ are then computed for the 2 sub-periods separately and a T-test for the equality of means in the 2 sub-periods is then conducted. At a given level of significance, a significant positive (negative) T statistic would indicate a significant increase (decrease) in X in period II compared to period I. An insignificant T statistic would indicate equality of the mean levels between the 2 sub-periods; i.e., X is more or less constant over the full sample. However, the mathematical expression for the T-statistic depends on whether the variances of X series in the two sub-periods are equal or not. Thus we conduct an F-test first to test for the equality of variances between the sub-periods. The entire procedure of conducting the F-test and appropriate T-test involves the following steps:

<u>Step i)</u> Conduct a F-test for the equality of variances of the 2 sub-periods. The expression for the F-test is,

$$F = S^2_{II} / S^2_I$$

degrees of freedom = $(N_{II} - 1)$ and $(N_I - 1)$

where, S^2_I and S^2_{II} are the estimated variances in the series of X_t in sub-periods I and II;

N_I and N_{II} are the sub-sample sizes of the 2 sub-periods;

Insignificance/significance of the F at a given level of significance would imply that the variances are equal/un-equal, respectively, between the 2 sub-periods. Significance at 20% is used here to determine the equality of variances between the 2 sub-periods.

Step 2) Based on the result of the F-test in step 1, an appropriate T-test, (a) or (b) below is conducted, for equality of sample means.

a) Variances are equal between the 2 sub-periods: If the computed F in step 1 is insignificant at 20% level of significance, then the expression for the T-test is

$$T = \frac{\bar{X}_{II} - \bar{X}_{I}}{\sqrt{S_p^2 \left(1/N_I + 1/N_{II} \right)}}$$

degrees of freedom = $(N_I + N_{II} - 2)$

where, $\bar{X}_I$ and $\bar{X}_{II}$ are the sample means of sub-periods I and II;

S_p^2 is the pooled sample variance defined below;

$$S_p^2 = \frac{(N_I - 1)S_I^2 + (N_{II} - 1)S_{II}^2}{N_I + N_{II} - 2}$$

b) Variances are un-equal between the 2 sub-periods: If the computed F in step 1 is significant at 20% level of significance, then the expression for the T-test is

$$T = \frac{\bar{X}_{II} - \bar{X}_{I}}{\sqrt{\dfrac{S_I^2}{N_I} + \dfrac{S_{II}^2}{N_{II}}}}$$

$$\text{degrees of freedom} = \frac{\left[(S_I^2 / N_I) + (S_{II}^2 / N_{II}) \right]}{\dfrac{(S_I^2 / N_I)^2}{N_I} + \dfrac{(S_{II}^2 / N_{II})^2}{N_{II}}}$$

For more details on these test procedures, see Brockett and Levine (1984).

This procedure has been adopted in this chapter to assess changes over time in various variables such as disparities in crop yields, irrigation availability, etc. The full sample period is 25 years (1960-61 to 1984-85). The two sub-samples correspond to 1960-61 to 1970-71 and 1974-75 to 1984-85. The three middle years corresponding to 1971-72 to 1973-74 have been left out. Thus the sub-sample size is 11 years.

The results of these tests on the CVs of yields (CV(YRCE), CV(YJWR), CV(YBJR), CV(YRGI) and CV(YMZE)), sourcewise net irrigation proportions (CV(TCNL), CV(TANK), CV(SWTR), CV(TBWL), CV(OTWL), CV(GWTR), CV(OSRC) and CV(TNAS)), aggregate cropping intensity (CV(ACI)), cropwise irrigation intensities (CV(IRCE), CV(IJWR), CV(IBJR), CV(IRGI) and CV(IMZE)) and fertilizer availability (CV(FRT)), are as follows:

	F-test[1]	T-test	T-test Degrees of Freedom
CV(YRCE)	1.8747@	-1.1712	20
CV(YJWR)	1.0073	0.5470	20
CV(YBJR)	1.7743@	3.0683+	20
CV(YRGI)	3.6926*	1.5406#	16
CV(YMZE)	3.2944*	2.1983*	17
CV(TCNL)	1.4091	-3.1933+	20
CV(TANK)	2.5459#	2.5812*	18
CV(SWTR)	1.2263	-0.0163	20
CV(TBWL)	4.8895+	-2.9860+	15
CV(OTWL)	2.0039@	-0.5288	19
CV(GWTR)	1.2085	-3.1821+	20
CV(OSRC)	3.8795*	-3.5117+	16
CV(TNAS)	2.2809@	-4.8599+	19
CV(ACI)	3.3824*	2.7162*	16
CV(IRCE)	10.2773+	-0.5253	13
CV(IJWR)	1.2140	0.0365	20
CV(IBJR)	3.5755*	1.2918$	16
CV(IRGI)	2.2034@	0.8349	19
CV(IMZE)	8.8643+	-3.4022+	13
CV(FRT)	5.3293+	-5.2378+	19

Notes: 1 The degrees of freedom for the F-test are (10,10).
+, *, #, @ and $ denotes significance at 1%, 5%, 15%, 20% and 25%, respectively.

Implications of these results are discussed in the main text.

CHAPTER 11 - FALLING AGRICULTURAL INVESTMENT & ITS CONSEQUENCES*.

"Aapoehishthaa, Mayoe bhuvaha; Taa na Urje Dadhaatana"

Veda.

(Oh waters! you cause happiness; Please give us strength (food)!)

11.1 Introduction.

One of the conclusions that emerges from the analysis thus far is the important role played by irrigation in the overall performance of crop yields. The yield response functions reported in chapter 8 show that the level of irrigation is an important factor directly affecting yield levels of all the cereal crops. Chapter 10 highlighted the effect of disparities in various sources of irrigation on the spatial variability of cereal crop yields. In particular, the all round neglect of tank irrigation that led to a worsening of its disparities across districts, has resulted in an increase in the disparities in bajra and ragi yields. Disparities in surface water development affect the disparities in rice yields, while the disparities in other wells irrigation affect disparities in maize yields. Apart from these direct effects, irrigation development resulting in an increase in the aggregate cropping intensity also helps reduce the spatial variability in crop yields. Also, the results of chapter 9 point out that irrigation provision for any of the cereal crop yields in the districts of Andhra Pradesh did not lead to destabilizing effect, though that was not the case with fertilizer application in the case of maize yields. Thus it is obvious that irrigation development can play an important role for balanced agricultural development of regions as well as sustainability of agricultural sector in general.

The importance of irrigation is not limited to agriculture in Andhra Pradesh alone but is true for the entire country. Hence the analysis in this chapter will be done at the all India level. Moreover, the data on investments in agriculture are available only at the all India level (see chapter 5, Part c) implying only a national level analysis is possible.

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* This chapter is based on my paper "Falling Agricultural Investment and its Consequences"; see Ganesh Kumar (1992).

Irrigation development requires substantial investment. In India most of canal and tank irrigations are under government control. Thus, development of these two surface water sources of irrigation depends on government investment. On the other hand, tubewells and other well irrigations are largely under the control of private farmers, although some public wells do exist. Thus, development of these ground water sources of irrigation depends mainly on private investment, although the government also plays a substantial role by providing loan and credit facilities to farmers through agricultural development banks, etc. That is irrigation development in India depends on both public and private investment.

Recognizing the critical role of irrigation in agricultural development successive governments have invested vast amounts on irrigation projects. In fact, the 20-Point Programme for economic development initiated by the late Prime Minister Mrs.Indira Gandhi, announced first on July 7, 1975 and modified later on January 14, 1982, states as its first point, "Increase in irrigation potential and provision of inputs for dry land agriculture". Similarly, private investment towards the development of ground water irrigations has also been forthcoming. Although the end result of these investments can be seen in the form of irrigation facilities actually developed, however, it is not possible to get data on the actual amounts invested for irrigation development since time series data do not exist even at the national level. Only the data on investment in agriculture sector as a whole are available. Agricultural investment in India has grown, at 1980-81 prices (New series), from Rs.1777 crores in 1960-61 to about Rs.4864 crores in 1980-81. This is reflected in the gross irrigated area which grew from 27980 thousand hectares in 1960-61 to about 49875 thousand hectares in 1980-81. However, much of Indian agriculture is still largely unirrigated and dependent on rainfall. Though by 1986-87, only 30% of cultivable land in the country is under irrigation, it has acquired a crucial role in determining the performance of Indian agriculture since use of high yielding variety (HYV) seeds is generally associated with chemical fertilizers and irrigation as complementary inputs.

However, since 1980-81, agricultural investment has shown a clear fall, both in level and also as a percentage of the total investment. It had fallen to Rs.4360 crores in 1986-87 from Rs.4864 crores in 1980-81 at 1980-81 prices. The share of agriculture in total investment which was about 15% to 20% before 1980-81 fell down to about 11% in 1986-87. This fall in agricultural investment has resulted in a slow down in the development of irrigation in the country. The annual compound rates of growth of gross irrigated area were 2.87%, 2.46% and 1.57% during the periods of 1961-1971, 1971-1981, 1981-1987, respectively.

The slow growth in gross irrigated area if continued in future also is likely to have an adverse effect on agricultural output in the long run. What are the consequences of such a resultant fall in the growth in output within the agricultural sector and also on the rest of the economy? In this chapter the long run impacts of the fall in agricultural investment on agricultural sector and on the rest of the economy are analysed. The analysis is done using a computable general equilibrium model since economywide consequences of policies are better captured in a general equilibrium framework.

In section 11.2 the problem of a fall in agricultural investment and irrigation development is discussed. The features of the computable general equilibrium model used as well as the methodology adopted in this analysis are discussed in section 11.3. The results of this analysis are discussed in section 11.4 and conclusions are provided in the final section.

11.2 The Problem.

Let us denote some variables as follows:

TAI : Total agricultural investment.

PBAI : Public agricultural investment.

PRAI : Private agricultural investment.

TINV : Total investment (agricultural + non-agricultural).

SAGR : Share of agriculture investment in total investment

= TAI/TINV

GDPA : Agricultural gross domestic product.

GDPN : Non-agricultural gross domestic product.

GDPT : Total gross domestic product (agriculture + non-agriculture).

TGIA : Total gross irrigated area over all crops.

NIA : Total net irrigated area over all crops.

TOT : Terms of trade = $\frac{\text{Agricultural price deflator}}{\text{Non-agricultural price deflator}}$.

Data on public, private and total agricultural investment (PBAI, PRAI, TAI respectively) and their shares as also the proportion of TAI in total gross domestic product (GDPT), and in agricultural gross domestic product (GDPA), are presented in table 11.1. The figures in table 11.1 are all based on the New Series of National Accounts Statistics (NAS) at 1980-81 prices, published by the Central Statistical Organisation (CSO). The data on total gross irrigated area (TGIA) as a proportion to total cultivated area are also presented in the same table.

From this table it can be observed that while TAI has grown by 2.74 times between 1960-61 to 1980-81, its share (SAGR) in total investment has been fluctuating between 15% and 20% approximately. Further, it can be noticed that agricultural investment fell in the 80s both in levels and also as a percentage in the total investment. The TAI as percentage in GDPT has also fallen in the 80s to levels below those prevailing in the 60s; i.e. from a peak of 4.74% in 1979-80 to 2.46% in 1988-89. As a percentage to GDPA, TAI has shown a fall in the 80s from a high of 13.1% in 1979-80 to 7.49% in 1988-89.

From the same table it can also be seen that this fall in the TAI in the 80s has come about mainly due to a fall in public investment in agriculture. Public investment in agriculture fell from Rs.1796 crores in 1980-81 to Rs.1346 crores in 1988-89 whereas private agricultural investment during the same period has been fluctuating around Rs.3000 crores without showing any clear trend. This is reflected in the falling share of public investment

Table 11.1 - Agricultural Investment and its Share at 1980-81 Prices (New Series)

Year	TAI	SAGR (%)	TAI/GDPT	TAI/GDPA	PBAI	% in TAI	PBAI/PBGDPT	PBAI/PBGDPA	PRAI	% in TAI	PRAI/PRGDPT	PRAI/PRGDPA
1961	1777.0	15.091	0.0282	0.0555	589.0	33.146	0.1166	3.075	1188.0	66.854	0.0205	0.0373
1962	1773.0	16.397	0.0273	0.0554	600.0	33.841	0.1062	2.941	1173.0	66.159	0.0198	0.0369
1963	1928.0	15.191	0.0291	0.0614	694.0	35.996	0.1052	3.337	1234.0	64.004	0.0207	0.0396
1964	2094.0	15.471	0.0301	0.0652	725.0	34.623	0.1001	2.832	1369.0	65.337	0.0220	0.0430
1965	2262.0	15.904	0.0302	0.0645	765.0	33.820	0.0970	2.452	1497.0	66.180	0.0224	0.0431
1966	2478.0	16.808	0.0344	0.0794	798.0	32.203	0.0924	2.117	1680.0	67.796	0.0265	0.0545
1967	2486.0	16.085	0.0341	0.0808	696.0	27.997	0.0759	1.642	1790.0	72.003	0.0281	0.0590
1968	2714.0	18.226	0.0344	0.0768	688.0	25.350	0.0704	1.543	2026.0	74.650	0.0294	0.0581
1969	2838.0	21.421	0.0351	0.0804	775.0	27.308	0.0731	1.505	2063.0	72.692	0.0294	0.0593
1970	3016.0	19.971	0.0350	0.0803	775.0	25.696	0.0677	1.556	2241.0	74.304	0.0300	0.0605
1971	2884.0	17.426	0.0319	0.0717	789.0	27.358	0.0633	1.283	2095.0	72.642	0.0269	0.0529
1972	3059.0	17.050	0.0335	0.0775	851.0	27.819	0.0644	1.344	2208.0	72.181	0.0283	0.0569
1973	3317.0	18.808	0.0364	0.0885	1049.0	31.625	0.0746	1.631	2268.0	68.375	0.0285	0.0616
1974	3352.0	16.754	0.0352	0.0834	993.0	29.624	0.0641	1.511	2359.0	70.376	0.0296	0.0597
1975	3123.0	15.066	0.0324	0.0789	919.0	29.427	0.0580	1.336	2204.0	70.573	0.0274	0.0567
1976	3556.0	15.523	0.0339	0.0796	1041.0	29.275	0.0604	1.442	2515.0	70.725	0.0287	0.0572
1977	4457.0	19.811	0.0419	0.1059	1378.0	30.918	0.0724	1.842	3079.0	69.082	0.0353	0.0745
1978	4281.0	19.099	0.0375	0.0924	1534.0	35.833	0.0766	1.937	2747.0	64.167	0.0292	0.0604
1979	5447.0	19.354	0.0452	0.1150	1697.0	31.155	0.0790	1.902	3750.0	68.845	0.0379	0.0806
1980	5414.0	19.807	0.0474	0.1310	1772.0	32.730	0.0791	2.058	3642.0	67.270	0.0397	0.0900
1981	4864.0	18.857	0.0397	0.1043	1796.0	36.924	0.0743	1.948	3068.0	63.076	0.0312	0.0671
1982	4741.0	13.856	0.0365	0.0960	1779.0	37.524	0.0710	1.913	2962.0	62.476	0.0283	0.0611
1983	4865.0	14.613	0.0363	0.0997	1725.0	35.457	0.0624	1.767	3140.0	64.543	0.0295	0.0657
1984	4406.0	14.070	0.0304	0.0815	1707.0	38.743	0.0580	1.675	2699.0	61.257	0.0234	0.0509
1985	4888.0	14.801	0.0325	0.0904	1673.0	34.227	0.0526	1.590	3215.0	65.773	0.0271	0.0606
1986	4641.0	12.131	0.0296	0.0855	1516.0	32.665	0.0435	1.419	3125.0	67.335	0.0257	0.0588
1987	4360.0	11.344	0.0268	0.0817	1428.0	32.752	0.0374	1.302	2932.0	67.248	0.0235	0.0561
1988	4486.0	11.754	0.0264	0.0838	1456.0	32.457	0.0354	1.292	3030.0	67.543	0.0235	0.0578
1989	4625.0	10.492	0.0246	0.0749	1346.0	29.103	0.0298	1.213	3279.0	70.897	0.0230	0.0540

Notes: 1961 refers to 1960-61 and so on.

TAI : Agricultural Investment (Rs.Crores); SAGR : Share of agriculutral investment in total investment;

GDPA : Agricultural gross domestic product; GDPT : Total gross domestic product;

PBAI : Public agricultural Investment (Rs.Crores); PBGDPA : Public agricultural gross domestic product;

PBGDPT : Public total gross domestic product; PRAI : Private agricultural Investment (Rs.Crores);

PRGDPA : Private agricultural gross domestic product; PRGDPT : Private total gross domestic product;

in total agricultural investment. In terms of proportion in public (private) GDPT, public (private) agricultural investment has shown a steep (marginal) fall in the 80s. The picture is similar with respect to (w.r.t.) proportion in public/private GDPA. Thus while private agricultural investment has been more or less stagnant public agricultural investment has been falling. A fall in public investment in agricultural sector reflects a shift in government policy in favour of non-agricultural sector over agricultural sector.

Agricultural investments are aimed at (1) creating irrigation facilities, (2) land improvement activities like contour bunding, preventing soil erosion, reclaiming waste and fallow lands for crop cultivation, etc., (3) promoting modern agricultural practices, through both research and extension, involving the use of high yielding variety seeds and chemical fertilizers to improve yields, use of pesticides to prevent/reduce attack by pests thereby reducing production losses, use of farm equipment like tractors, tillers, harvesters, etc., which improve labour efficiency, etc., (4) various other activities aimed at promoting agricultural development like farmers' education, developing markets and co-operatives for both farm inputs and farm produce, etc. While investment under some of these heads are undertaken solely by the government (example, major irrigation projects, etc.), only investment under other heads are undertaken by individual farmers (example, investment on minor irrigation projects, especially, well irrigation, farm equipment, etc.) for which government assists by providing loans to farmers through rural development banks. Thus public investment is very important for agricultural development.

The fall in TAI seems to have resulted in slowing down the development of irrigation. Details of potential created and utilisation of irrigation facilities are given in table 11.2. From this table it can be noticed that, by 1988-89, out of an ultimate potential of 113.5 million hectares (m.ha.) only 77.5 m.ha. (68.28%) of irrigation potential had been created leaving still a great scope for irrigation development. Further, the pace of

Table 11.2 - Irrigation Potential & Utilisation (Million Hectares).

	1951	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
<u>Potential Developed</u>													
Major & Medium (58.5)[*]	9.7 (16.6)[+]	24.8	25.9	26.6	27.3	28.2	29.1	30.0	30.0	30.5	31.0	31.7	32.3 (55.2)[+]
Minor (55.0)[*]	12.9 (23.5)[+]	27.3	28.6	30.0	31.4	32.8	34.2	35.8	37.5	39.0	40.7	42.3	45.2 (82.2)[+]
Total (113.5)[*]	22.6 (19.9)[+]	52.1	54.5	56.6	58.7	61.0	63.3	65.6	67.5	69.5	71.7	74.0	77.5 (68.3)[+]
<u>Utilisation</u>													
Major & Medium	9.7	21.2	22.1	22.6	22.7	23.2	24.0	24.6	25.3	25.8	26.5	26.8	27.2
Minor	12.9	27.3	28.6	30.0	31.4	32.8	34.2	34.0	35.2	36.5	37.9	39.3	41.0
Total	22.6	48.5	50.7	52.6	54.1	56.0	58.1	58.6	60.5	62.3	64.4	66.1	68.2
Utilisation / Potential (%)													
Major & Medium	100.0	85.5	85.3	85.0	83.2	82.3	82.5	82.0	84.3	84.6	85.5	84.5	84.2
Minor	100.0	100.0	100.0	100.0	100.0	100.0	100.0	95.5	93.9	93.6	93.1	92.9	90.7
Total	100.0	93.1	93.0	92.9	92.2	91.8	91.8	89.3	89.6	89.6	89.8	89.3	88.0

Notes: 1951 refers to 1950-51 and so on.

* : Ultimate potentials are reported in brackets;

\+ : As percentage of the respective ultimate potentials;

Source: Economic Survey various issues.

development of major & medium irrigation and minor irrigation has not been uniform. While minor irrigation has grown from 27.3 m.ha. (49.64% of ultimate potential) to 45.2 m.ha. (82.2% of ultimate potential) the development of major & medium irrigation, however, has been slower. In terms of percentage in ultimate potential it has grown to 55.7% in 1988-89 from 42.39% in 1977-78. Further, since 1984-85 there seems to have been a slow down of the already slow pace of development of the major & medium irrigation. In the 5 years between 1983-84 and 1988-89 only 2.3 m.ha. of additional capacity was created in this segment. It is obvious that further development of irrigation potential has to come mainly from major & medium irrigation. Note that these irrigations are largely government controlled and their development depends on public investment.

Turning to the utilisation of the irrigation potential, we find that the rate of utilisation of major & medium irrigation has remained more or less constant at around 85%. Utilisation of minor irrigation, however, has not kept pace with the growth in its potential created, especially since 1983-84. This has resulted in a fall in rate of utilisation of total irrigation since 1983-84. As it is the utilisation of the irrigation which determines crop yields and output we therefore, in this analysis, focus attention on the consequences of changes in gross irrigated area, thus taking into account the aspect of the utilisation rate also.

From table 11.3 it can be seen that the addition to TGIA between 1961 and 1971 was 10214 thousand hectares (t.ha.) which means on average 928.5 t.ha. was added every year in the 60s. Between 1971 and 1981, the addition to TGIA was 11681 t.ha. implying an average of 1061.9 t.ha. per year of additional TGIA. In the 80s, however, irrigation development has slowed down considerably. Between 1981 and 1987 the addition to TGIA was only 5761 t.ha. implying an yearly average addition of 823 t.ha. In terms of annual compound growth rates, it was 2.87%, 2.46% and 1.57% in 1961-1971, 1971-1981, 1981-1987, respectively.

The slowing down of irrigation development during the 80s is

Table 11.3 - Gross and Net Irrigated Area, Sourcewise (Thousand Hectares).

Year	TGIA	Net Irrigated Area							
		Canals	Tanks	Surface Water[1]	Tubewells	Other Wells	Ground Water[2]	Other Sources	Total
1961	27980.0	10370	4561	14931	7290$	--	7290	2440	24661
1965	30705.0	10958	4258	15216	8653$	--	8653	2475	26344
1970	36970.0	12838	4112	16950	11887$	--	11887	2266	31103
1975	41740.0	13484	3351	16845	6546	7712	14258	2427	33530
1980	49178.0	15108	3918	19026	8180	8232	16412	2525	37963
1981	49875.0	15292	3198	18490	9527	8207	17734	2581	38805
1982	51554.0	15529	3511	19040	9898	8224	18122	2567	39729
1983	52121.0	15370	3112	18482	10684	8428	19112	2375	39969
1984	53937.0	16240	3783	20023	10973	8548	19521	2411	41955
1985	54083.0	15861	3330	19191	11265	8723	19988	2600	41779
1986	54652.0	15879	3070	18949	11544	8621	20165	2646	41760
1987	55636.0	16320	2983	19303	12211	8835	21046	2700	43049

Notes: 1980 refers to 1979-80 and so on. TGIA : Total gross irrigated area; $ Pertains to total wells;
1 Surface water = Canals + Tanks; 2 Ground water = Tubewells + Other Wells;

also clear from the data on sourcewise net irrigated area (NIA) presented in table 11.3. From this table it can be seen that the NIA by canals has shown a marginal increase of about 1.2 million hectares (m.ha.) between 1979-80 and 1986-87. This marginal increase has, however, been offset by a fall of about 1 m.ha. of NIA by tanks in the same period. As a result the NIA by surface water sources (canals & tanks) has been stagnating over this period. Note that these two sources are largely government controlled and their development is dependent on public investment. On the other hand the NIA by ground water (tubewells & other wells), to which private investment also contributes, has shown an increase of about 4.6 m.ha. over the same period. Thus it seems that the source of the problem seems to be the fall in public agricultural investment in general and neglect of tank irrigation in particular.

Before asserting that TAI indeed fell and hence analysing its short and long term consequences we must take note of differences in certain features of the CSO data on TAI between the "old" (at 1970-71 prices) and the "new" series (at 1980-81 prices). One can obtain the figures for TAI upto 1984-85 from the old series also. The figures at current and constant prices from the old and new series are given in table 11.4.

The picture of TAI as obtained for the period 1980-81 to 1984-85 from the two series is somewhat different. While the new series presents a picture of falling TAI at 1980-81 prices with a lot of fluctuations in this period, according to the old series TAI at 1970-71 prices in this period showed a gradual fall initially but started growing again to a level marginally higher than in 1980-81. Further, quite frequently, the two series show a movement in TAI in the opposite directions. For eg., according to the old series TAI in 1980-81 showed an increase over the previous year, whereas according to the new series TAI in 1980-81 shows a fall over the previous year. The reverse is also noticed in a few years; for example, in 1982-83.

This raises the question of not only comparability of the two

Table 11.4 – TAI (Rs.Crores) as per New Series & Old Series.

Year	New Series		Old Series	
	Current Prices	1980-81 Prices	Current Prices	1970-71 Prices
1960-61	448.0	1777.0	416.0	786.0
1965-66	720.0	2478.0	777.0	1200.0
1970-71	1214.0	2884.0	1365.0	1365.0
1975-76	2523.0	3556.0	2225.0	1278.0
1979-80	4976.0	5414.0	4900.0	2135.0
1980-81	4864.0	4864.0	6002.0	2364.0
1981-82	5385.0	4741.0	6224.0	2220.0
1982-83	6088.0	4865.0	6538.0	2156.0
1983-84	6055.0	4406.0	7855.0	2333.0
1984-85	7006.0	4888.0	8960.0	2472.0

Notes: TAI : Total Agricultural Investment.

series but also in some sense trust that one can have in the observed trends in either of the series. The comparability question has attracted the attention of other researchers too. For example, see Choudhury (1988).

Gross capital formation (GCF) consists of gross fixed capital formation (GFCF) and changes in stocks (CSTK). The difference between the two series in GCF is due to differences in the estimates of GFCF and CSTK. The NAS (1988) mentions (para 3.10, page 28) that the new series uses latest data in estimating the GFCF and this would bring about some differences between the two series.

. With respect to CSTK, two changes were made in the new series. First the new series assumes the stocks with producers of agricultural commodities to be negligible. In the old series while foodgrains stocks with producers were taken to be negligible, stocks of agricultural commodities other than foodgrains were computed on the basis of data on bank advances (para 3.11 (i), page28). These advances, it notes, were meant for purchase of fixed assets and not for keeping stocks of these commodities. To that extent then, the old series would report a higher figure for CSTK.

The second change w.r.t. CSTK introduced in the new series is w.r.t. the stocks of cereals and cereal substitutes with the private traders. In the old series this was taken to be 25% of marketable surplus less government procurement. In the new series a different procedure adopted by Dandekar has been used. According to this procedure, consumption of foodgrains has been subtracted from the net availability with the public to arrive at the estimates of stocks (para 3.11 (ii), page 30).

With respect to GCF in public, private and household sectors, Choudhury (1988) raises certain questions on methodology used in the new series. These relate to the way depreciation allowance has been treated in estimating the capital formation in public sector. With respect to the private sector also she questions the data used and some small methodological changes made in the new series. These questions are relevant for long term comparability of the estimates. For further details see Choudhury (1988).

Thus while the new series seems to still have certain methodological shortcomings, the old series seems to overestimate GCF. These methodological issues while important are beyond the scope of this study. However, even with the old series data the picture of falling agricultural investment in the early 80s remains and the growth observed from 1983-84 has been only marginal.

The fall in agricultural investment and slowing down of irrigation during the entire 1980s obviously would affect the level of agricultural growth. Given the growing demand for food and other agricultural products due both to growing population and general economic growth, fall in agricultural growth is likely to result in imbalances between demand and supply. What are the consequences of such a fall on prices of agricultural commodities, consumption levels of food, income distribution effects and poverty in the country? We analyse this in a computable general equilibrium (CGE henceforth) framework.

11.3 *Methodology.*

In this study no attempt is made to construct a new CGE model; instead the the "Agriculture, Growth and Redistribution of Incomes Model (AGRIM)" a computable general equilibrium model of Narayana, Parikh and Srinivasan (1991) (NPS henceforth) is used. Their model covers agricultural sector quite extensively. The salient features of this model are, in brief, as follows[1]:

The model considers the economy as made up of ten sectors - nine agricultural and one non-agriculture. The ten sectors are

Sector 1 : Wheat (thousand tons);
Sector 2 : Rice (thousand tons);
Sector 3 : Coarse grains (thousand tons) consisting of bajra, barley, jowar, maize, ragi and small-millets;

1 For details see Narayana, Parikh and Srinivasan (1991).

Sector 4 : Bovine and ovine meats (thousand tons of carcass weight) consisting of beef and mutton.

Sector 5 : Dairy products (thousand tons of fresh milk equivalent);

Sector 6 : Other animal products (thousand tons of protein equivalent) consisting of eggs, poultry, pork & fish;

Sector 7 : Protein feeds (thousand tons of protein equivalent) consisting of cakes of all oil seeds;

Sector 8 : Other food (million 1970 US dollars) consisting of sugar, oils of groundnut, cotton, rape & mustard, sesamum, coconut and other oil seeds, gram and other pulses, tea, coffee, fruits and vegetables and condiments and spices;

Sector 9 : Non-food agriculture (million 1970 US dollars) consisting of cotton lint, raw jute, raw mesta, tobacco, sannhemp, rubber, hides and skins, wool and hair and other livestock products; and

Sector 10 : Non-agriculture (million 1970 US dollars);

In the agricultural sector, 16 major and 9 minor, i.e. total 25 crops are considered separately. For each of these crops, the gross irrigated acreages, cropwise acreages and the yields are estimated separately. An important feature of the model is that the cropwise acreages, irrigation and yields are all econometrically estimated. The cropwise gross irrigated acreages are obtained from the total gross irrigated area which is a function of the agricultural investment. Acreage under a crop is specified as a Nerlovian partial-adjustment model but with revenue expectations following an ARIMA process instead of the Nerlovian adaptive expectations. Crop yields in general depend upon fertilizer used, HYV adoption rates and irrigation intensity. In the case of rice and wheat yields alone, four crop regimes based on seed varieties used (HYV/Traditional) and water regime (irrigation/rainfed) are distinguished and a model to optimize fertilizer use is specified. The output under each crop is then obtained and then aggregated over different crops to obtain the nine agricultural sectoral outputs and also to obtain the total GDPA. Along with the GDPN (non-agricultural gross domestic product) estimated as a function of non-agricultural investment and incremental capital output ratio, the GDPT is obtained. All these sectoral outputs are then distributed to different sections of the population in the country divided into 10 expenditure classes - 5 rural and 5 urban. The expenditure classes, same for both rural and urban, are defined based on per capita annual consumer expenditure at 1970 prices, as follows:

i) < Rs.216
ii) > 216 ≤ 336
iii) > 336 ≤ 516
iv) > 516 ≤ 900
v) > 900

This forms the aggregate supply component of the model.

On the demand side, for each of the 10 expenditure classes the demand is characterised by a linear expenditure system (LES) model and the classwise demands for various commodities are obtained. These classwise demands are then aggregated to obtain commoditywise the total household demands in the economy. The aggregate demand and the aggregate supply are then solved at national level to obtain the equilibrium prices that clear the markets under the influence of government policies on the following:

1) public distribution systems,
2) procurement levels of foodgrains,
3) targets on total and public investment,
4) targets on trade levels,
5) targets on taxes,
6) targets on domestic prices, etc.

The model is a dynamic simulation one. It is solved sequentially for year to year from 1971 to 2000. The percentage of balance of trade in total gross domestic product is exogenously fixed in this model. Given this, the exchange equilibrium of each year determines that year's domestic prices, values of classwise incomes and their commoditywise consumptions and hence household savings, tax levels, commoditywise net trade, public buffer stocks, tariffs and total investment. The realized total investment is then split into non-agricultural and agricultural investment.

In the AGRIM described above the share of agriculture (SAGR) in total investment is specified as a function of the terms of trade (TOT) between agricultural and non-agricultural sectors (agricultural price deflator over non-agriculture price deflator) as follows:

$$SAGR_t = \left(0.190879 - \frac{0.158848}{TIME} \right) \times (TOT)_t^{0.25} \qquad (11.1)$$

However, the elasticity of TOT, 0.25, was specified exogenously. In view of this, in this analysis the SAGR is reestimated using the latest available data.

SAGR at constant prices is specified to be a function of TOT and the ratio of GDPA to GDPT at constant prices. The TOT is measured as the ratio of agricultural price deflator to non-agricultural price deflator. Agricultural (non-agricultural) price deflator is obtained as the ratio of GDPA (GDPN) at current prices to GDPA (GDPN) at constant prices.

$$SAGR_t = f\left(TOT_t, \frac{GDPAt}{GDPTt}\right) + U_t \qquad (11.2)$$

A double logarithmic specification of SAGR, with a first order auto regressive scheme to correct for autocorrelation, was then estimated using the new series data, for the period 1951-52 to 1988-89, by the Hildreth-Lu procedure. The estimation result is as follows:

$$\ln(SAGR)_t = \underset{(-3.11)^{+}}{-0.952} + \underset{(1.90)^{+++}}{0.599} \times \ln(TOT)_{t-1} + \underset{(2.89)^{+}}{0.990} \times \ln\left(\frac{GDPA}{GDPT}\right)_{t-1} + \underset{(5.25)^{+}}{0.681} \times U_{t-1} \qquad (11.3)$$

$$R^2 = 0.7283 \qquad \bar{R}^2 = 0.7123$$

Notes: t-statistics are given in brackets. +/+++ indicates significance at 1% and 10% confidence levels respectively.

From the above equation we notice that TOT and the ratio of GDPA to GDPT explain a major portion of the variation in SAGR as given by the high R^2 (0.7283). The t-statistics of these variables are also significant and have the expected signs. In the CGE analysis later on, equation (11.3) instead of equation (11.1) is considered as another variant.

Now it follows that

$$\text{Agricultural Investment}_t = \text{SAGR}_t \times \text{Total Realized Investment}_t \quad (11.4)$$

Further, the total gross irrigated area for the next year follows as:

$$\text{TGIA}_t = f(\text{Rain}_t, \text{Agricultural Investment}_{t-1}, \text{Time}_t)$$

The estimated equation used here (as per NPS (1991)) is

$$\text{TGIA}_t = 19135.2 + 5.2369(\text{Rain}_t) + 4.1667(\text{TAI}_t) + 626.412(\text{Time}_t)$$

11.4 CGE Analysis.

In this section economywide consequences of falling TAI are analysed in comparison to maintaining it at pre-80s rate. Towards this 4 alternative policy variants (PV1 to PV4) are constructed with regard to agricultural sector's share in total investment as follows:

PV1: SAGR = 0.2

This implies a constant 20% of the total investment goes to agricultural sector every year. In this variant, the SAGR is maintained at 20%, which corresponds to the observed levels during late 1970s. This variant is taken as the base scenario against which the other variants are to be compared.

PV2: SAGR is as given in equation (11.1) (NPS specification).

This variant is considered to compare the results of this study with those of NPS. Results reported here under this variant correspond to their reference run of AGRIM (see NPS (1991)).

PV3: SAGR is as given by the estimated equation (11.3) above.

The estimated SAGR equation represents the behaviour of the SAGR and hence the agricultural investment given the terms of trade between agricultural and non-agricultural sectors and also the weight of agriculture in the GDPT. This variant, based on econometric estimation using the latest available data reflects the current behavioural aspect of agricultural investment.

PV4: SAGR = 0.1

In this variant the SAGR is fixed at a constant 10%. This variant for the SAGR is considered since in 1988-89 its realised value was indeed around 10%. The performance of the economy if the SAGR continues to remain at this level is simulated under this variant.

These 4 variants of the SAGR are assessed in the light of comparative results obtained for the years 1971 to 2000 by simulating the computable general equilibrium model AGRIM. Each alternative variant is introduced to be effective from 1980. Specifically, the following variables are of interest for the analysis: GDPA, GDPN, GDPT, TINV, terms of trade, rural income, urban income, net sown area, gross cropped area, TGIA, cropwise acreage, yields, production, net exports, irrigation and price of wheat, rice and coarse grains, expenditure classwise population proportions. The results of the model simulations obtained under the above policy variants for the years 1980 and 2000 are given in table 11.5. From this table we notice that the results of the simulation obtained for the year 1980 from the 4 scenarios are very close. However, by the year 2000, the differences between these scenarios are quite substantial thus indicating the long run impacts. The results of the simulations for the year 2000 are discussed below.

At the outset we notice that the results obtained from the base scenario (PV1) are very close to those of NPS (PV2). The differences between these two scenarios are marginal. The results of the scenarios PV3 and PV4 are, however, substantially different

Table 11.5 - Results of CGEM Analysis.

I) Specification of share (SAGR) of agriculture in total investment.

1) PV1 (Base scenario): $SAGR_t = 0.2$; 2) PV2: SAGR as per equation (1) (NPS specification);

3) PV3: SAGR as per equation (3); 4) PV4: SAGR = 0.1;

II) Simulation Results for years 1980 and 2000.

Variable		1980 Base scenario	1980 % change over Base scenario PV2	PV3	PV4	2000 Base scenario	2000 % change over Base scenario PV2	PV3	PV4
GDP AGRICULTURE[1]		221154.0	-0.37	-1.07	-2.06	351643.0	-0.82	-7.00	-5.96
GDP NON-AGRICULTURE[1]		309313.0	0.11	0.32	0.61	1051200.0	1.87	5.03	8.33
GDP TOTAL[1]		530466.0	-0.10	-0.26	-0.51	1402844.0	1.19	2.01	4.74
TOTAL INVESTMENT[1]		110020.0	-0.07	-0.21	-0.40	483964.0	1.48	3.92	7.03
SAGR		0.2	-14.19	-23.18	-50.00	0.2	-9.14	-55.17	-50.00
TERMS OF TRADE		0.92573	-0.06	-0.09	0.98	0.90222	1.55	11.78	13.11
RURAL INCOME[6]		1177.4	-0.20	-0.55	-0.37	2560.7	1.39	4.44	7.35
URBAN INCOME[6]		2225.0	0.13	0.36	0.63	4789.0	1.84	5.03	8.27
NET SOWN AREA[2]		144779.0	0.00	0.00	0.00	152709.0	0.00	0.00	0.00
GROSS CROPPED AREA[2]		172953.0	-0.25	-0.73	-1.38	203878.0	-0.69	-5.27	-4.70
GROSS IRRIGATED AREA[2]		46409.0	-1.71	-4.86	-9.25	87451.0	-2.90	-22.06	-19.66
WHEAT	ACREAGE[2]	21911.0	-1.20	3.41	-6.54	36698.0	-0.69	-13.99	-11.91
	YIELDS[3]	1.64168	0.50	1.46	2.87	2.34326	-0.80	-3.58	-3.68
	PRODUCTION[4]	33812.0	-0.70	-2.00	-3.86	80834.0	-1.48	-17.07	-15.15
	NET EXPORTS[4]	1973.0	-8.31	-24.01	-50.04	13252.0	-5.80	-81.94	-76.93
	IRRIGATION[2]	12804.0	-1.11	-3.14	-5.98	27189.0	-3.29	-22.81	-21.15
	PRICE[5]	1.37378	0.00	0.00	0.00	1.20787	2.98	12.29	12.29
RICE	ACREAGE[2]	39241.0	-0.80	-2.29	-4.43	51888.0	-1.73	-11.80	-10.47
	YIELDS[3]	1.26222	-0.07	-0.20	0.38	1.83120	-0.25	-2.53	-2.03
	PRODUCTION[4]	47054.0	-0.87	-2.49	-4.79	90267.0	-1.98	-14.03	-12.29
	NET EXPORTS[4]	-1420.1	22.77	61.71	57.95	2116.0	-105.68	-286.13	-289.95
	IRRIGATION[2]	16786.0	-2.08	-5.73	-10.67	28876.0	-2.68	-21.06	-18.26
	PRICE[5]	1.98092	0.00	0.27	5.53	2.06582	0.00	24.53	21.73
COARSE GRAINS	ACREAGE[2]	42303.8	0.40	1.18	2.33	38373.8	0.24	4.93	4.09
	YIELDS[3]	0.61942	-0.15	-0.44	-0.85	0.91417	-0.34	-4.21	-3.48
	PRODUCTION[4]	26204.0	0.25	0.73	1.47	35080.0	-0.11	0.51	0.47
	NET EXPORTS[4]	-3837.2	-1.61	-4.61	-6.47	-5483.7	-0.13	-0.04	2.85
	IRRIGATION[2]	4589.9	-2.30	-6.49	-12.19	9847.0	-3.33	-25.66	-22.58
	PRICE[5]	1.05515	0.00	0.00	0.00	1.23058	1.44	11.40	11.72

Notes: 1 - Rs. million at 1970-71 prices; 2 - 000 Hectares [illegible]

6 - Rs. per capita per annum at 1970-71 prices; [illegible]

from the base scenario.

From table 11.5 we notice that the lower TAI in PV3 and PV4 leads to much lower TGIA in these scenarios than in the base scenario. It is lower by about 22.06% in PV3 and 19.66% in PV4. The lower TGIA in the PV3 and PV4 scenarios results in lower cropwise irrigated acreages as in the case of wheat, rice, coarse grains. The cropwise irrigations are lower in PV3 by 22.81%, 21.06% and 25.66% in the case of wheat, rice and coarse grains respectively. In PV4 these are lower by 21.15%, 18.26% and 22.58% respectively.

The lower cropwise irrigations compared to the base scenario have an adverse effect on the crop yields which along with lower crop acreages result in lower output in the case of wheat and rice. In the case of wheat, yield is lower by 3.58% and 3.68% in PV3 and PV4 respectively while output is lower by 17.07% and 15.15% in the two scenarios respectively. These percentages of shortfall in the case of rice are somewhat less than that of wheat. In the case of coarse grains, however, the lower yield in PV3 and PV4 is compensated by higher acreage with the result that output is marginally higher in these scenarios than in the base scenario.

Though in the initial years cereal price differentials are only marginal between the scenarios, by 2000 they become quite substantial. The lower agricultural outputs in PV3 and PV4 result in higher prices for agricultural commodities than those in the base scenario. The price of wheat, rice and coarse grains are higher in PV3 by 12.29%, 24.53% and 11.40% respectively while in PV4 they are higher by 12.29%, 21.73% and 11.72% respectively. In both these scenarios the higher agricultural prices result in the terms of trade favourable to agricultural sector (greater than 1.0) against non-agricultural sector.

However, the favourable terms of trade for agriculture in the PV3 and PV4 scenarios do not result in higher GDPA over the base scenario. On the contrary GDPA is substantially lower in these scenarios than in base scenario. The GDPA is lower by 7.0% and 5.96% in these two scenarios. Note that total investment has been higher in these scenarios with a greater share going into non-agriculture. Thus GDPN is substantially higher in these scenarios and the increase here more than compensates the reduction in GDPA, resulting in higher GDPT than in the base scenario. GDPN and GDPT are higher by 5.03% and 2.01% respectively in PV3 while in PV4 these are higher by 8.33% and 4.74% respectively.

Thus it seems that shift of investment in favour of non-agriculture results in an accelerated growth in GDPT, brought about mainly through higher output of non-agricultural sector. This accelerated growth results in higher incomes in both rural and urban areas in PV3 by 4.44% and 5.03% respectively and PV4 by 7.35% and 8.27% respectively. Note, rural income consists of both agricultural income and rural non-agricultural income.

Before discussing the income distributional aspects, look at the net exports (exports - imports) of agricultural commodities. From table 11.5 it is clear that the neglect of agricultural sector as in PV3 and PV4 has adverse impacts on net exports of agricultural commodities. In the case of wheat, the quantity available for exports is far less in the PV3 and PV4 scenarios than in the base scenario. While exports of wheat was about 13.3 million tonnes (m.t) in the base scenario it is lower in the PV3 and PV4 scenarios by about 81.94% and 76.93% respectively; in quantity terms the exports fall down to 2.4 m.t. and 3.1 m.t. respectively. In the case of rice, the situation changes from one of exportable surplus of about 2.1 m.t in the base scenario to a situation of importing about 4 m.t. in the PV3 and PV4 scenarios. In the case of coarse grains also imports are higher in these scenarios over the base scenario.

Turning now to the distributional aspects, table 11.6 presents the population proportions of the 10 expenditure classes, for the years 1980 and 2000, under the 4 scenarios. The results show that compared to the base scenario the population proportions in the lowest 2 expenditure classes in rural areas are higher in

Table 11.6 - Expenditure Classwise Population Proportions.

	1980				2000			
	Base scenario	PV2	PV3	PV4	Base scenario	PV2	PV3	PV4
I) Rural (Rs. per capita per annum)								
≤216	0.31459	0.31558	0.31747	0.32018	0.20646	0.20755	0.23211	0.22687
		(0.31)	(0.92)	(1.78)		(0.53)	(12.42)	(9.89)
> 216 ≤336	0.17873	0.17975	0.17978	0.17982	0.15932	0.15960	0.16156	0.16145
		(0.01)	(0.03)	(0.05)		(0.18)	(1.41)	(1.34)
> 336 ≤516	0.17903	0.17876	0.17824	0.17750	0.18971	0.18934	0.18101	0.18276
		(-0.15)	(-0.44)	(-0.85)		(-0.20)	(-4.59)	(-3.66)
> 516 ≤900	0.18205	0.18160	0.18075	0.17953	0.21682	0.21538	0.20480	0.20583
		(-0.25)	(-0.71)	(-1.38)		(-0.66)	(-5.54)	(0.21)
> 900	0.14460	0.14432	0.14377	0.14298	0.22769	0.22814	0.22052	0.22309
		(-0.19)	(-0.57)	(-1.12)		(0.20)	(-3.15)	(-2.02)
II) Urban (Rs. per capita per annum)								
≤216	0.01949	0.01949	0.01932	0.01910	0.00491	0.00473	0.00532	0.00490
		(-0.56)	(-1.43)	(-2.55)		(-3.67)	(8.35)	(-0.20)
> 216 ≤336	0.07890	0.07870	0.07835	0.07788	0.03425	0.03331	0.03590	0.03398
		(-0.25)	(-0.70)	(-1.29)		(-2.74)	(4.82)	(-0.79)
> 336 ≤516	0.18734	0.18713	0.18673	0.18618	0.12916	0.12691	0.12783	0.12434
		(-0.01)	(-0.01)	(-0.04)		(-1.74)	(-1.03)	(-3.73)
> 516 ≤900	0.33970	0.33969	0.33965	0.33958	0.33308	0.33103	0.32402	0.32208
		(0.02)	(-0.05)	(-0.51)		(-0.62)	(-2.72)	(-3.30)
> 900	0.37447	0.37499	0.37595	0.37726	0.49861	0.50402	0.50693	0.51470
		(0.14)	(0.40)	(0.75)		(1.09)	(1.67)	(3.23)

Notes: Percentage change over base scenario is given in brackets.

PV3 and PV4 implying a worsening of the situation w.r.t. income distribution. By year 2000, percentages of the people in total rural population that would be more in the 2 poorest rural classes under PV3 and PV4 than under the base scenario come to 2.8% and 2.3% respectively. The changes in population proportions in the lowest 2 classes in urban areas are only marginal. These results imply that with investment shifting away from agriculture towards non-agriculture, while non-agricultural growth would hardly change the urban inequalities, the slow down in agricultural growth results in greater rural inequality with substantial increase in the number of rural poor. In the rural areas, agriculture being a dominant activity, the sharp fall in agricultural income is likely to be the factor behind the increase in income inequality. Thus we find that even though a faster growth in GDPT could be brought about by a shift towards non-agricultural sector, it could have serious distributional consequences.

11.5 Conclusions.

Neglect of agriculture, an important sector of the Indian economy, is likely to have an adverse impact on the country. Such a neglect has been observed as a fall in agricultural investment during the 80s. Simulations using a CGE model help in assessing the adverse impact of the fall in TAI on agriculture in particular and the economy in general.

Though shifting investment resources away from agriculture to non-agriculture may result in a faster growth in GDPT, the growth across sectors is likely to be uneven, with non-agriculture likely to show a far higher growth than agriculture. However, slowing down agricultural growth would lead to growing income inequality in rural areas. Besides, though the country is right now deemed to be self sufficient in foodgrains, if the present trends of investment policy are continued, not only large scale imports to meet the domestic demand may become necessary, but also despite such imports food prices would go up substantially. Price increases of foodgrains are known to hit the poor most.

CHAPTER 12 - CONCLUSIONS AND LIMITATIONS

"We judge ourselves by what we feel capable of doing, while others judge us by what we have already done!"

H. W. Longfellow.

Agricultural growth is important for employment and income generation as well as to meet the food requirements of a growing population. Agricultural growth, however, is rarely smooth. Crop outputs and yields usually fluctuate from one year to the next, even as they may show a trend (positive/negative) over time. In India, like in many other countries, yields and outputs were observed to show such year to year fluctuations. Output fluctuations have serious consequences on price stability and long term viability of agriculture. This thesis is devoted to studying the stability of cereal crop yields' performance in India.

Instability in agricultural output and crop yields, as elaborated in chapter 1, could lead to quite undesirable short run and long run consequences in terms of food price levels, food security and gross investment levels in both agricultural and non-agricultural sectors. After establishing the problem of fluctuations, chapters 2 and 3 attempt to evaluate the agricultural performance in general at both all India level and Andhra Pradesh level (including its districts). In passing, we noted that in general it is quite difficult to make judgments and comparative assessment of agricultural growth before and after the arrival of modern technology during the mid-1960s especially in the presence of fluctuations.

12.1 A Brief Summary of the Conceptual and Methodological Issues.

Conceptually, four aspects of stability of crop yields were defined. These are:

1) Stability of yield levels - which relates to the constancy of yields levels themselves over time.

2) Stability of growth rates - which relates to the constancy of growth rates over time.

3) Stability of yield variance around the expected values - which relates to the constancy of the order of fluctuations of yields around the expected values. Variance of the absolute gaps between observed yields (Y) and estimated/expected yields ($\hat{Y}$) relates to "absolute variability" while variance of the ratios between Y and $\hat{Y}$ relates to percentage/relative variability. When the gaps (absolute) and/or ratios (relative) change systematically, either successively increasing/ decreasing, yield variability (absolute and/or relative) is considered to be changing or unstable. This part of the analysis is referred to as "variability analysis".

4) Stability of growth path - which relates to constancy of the growth path. This analysis, assessing the changes in the parameters of the yield growth path, is referred to as "structural change analysis".

5) Besides, the above analyses with respect to a crop's yield performance within a region (India / Andhra Pradesh (AP) / Districts in AP), analysis is also done for assessing the disparities in the yield levels across districts in AP. This analysis is referred to as "spatial variability".

The method of analyses is essentially econometric. Discussing the various conceptual and econometric issues it was noted that

a) the conceptual issues and econometric procedures are deeply interrelated;

b) for a complete analysis, it is necessary to make a distinction between two analytical frameworks, viz. (i) time trend framework (TTF) - where stability of yields are analysed in the time domain with time alone as the explanatory variable; and (ii) response function framework (RFF) - where stability of yields are analysed using yield response functions that relate yields to inputs like fertilizer, irrigation, high yielding variety (HYV) seeds, etc., and rainfall. These 2 frameworks differ in their analytical scopes. In the TTF yield variability over time alone could be analysed, while in the RFF yield variability with respect to use of individual inputs, besides yield variability over time, could be analysed.

c) the estimation results can have a tremendous bearing on the functional form specification, the error specification (additive/ multiplicative) and the estimation procedure; and

d) different error specifications have different meanings particularly in the context of variability.

Based on the discussion of these conceptual and econometric a methodology covering the stability of all the aspects of yields is described. The salient features of our methodology are,

i) a procedure to select an appropriate (to the data) functional form for the estimated time trend / response function, based on certain measures of nonlinearity developed by Beale (1961) and Bates and Watts (1980), skewness measure of Hougaard (1985), bias measure of Box (1971), etc.; and

ii) a procedure based on tests developed by Hsu (1977) which avoids splitting of a sample arbitrarily into two sub-samples but can still detect a variability change point (if such a change is significant) which was unknown to begin with.

iii) a procedure using dummy variables that detects the structural change point.

The stability of yields was analysed in both TTF and RFF, using this methodology.

12.2 Results of the Analysis in the Time Trend Framework.

The analysis in the TTF was done at the all India level for yields of 7 cereal crops (rice, wheat, jowar, bajra, ragi, maize & barley) covering the period 1949-50 to 1988-89, and for Andhra Pradesh at the State and districts level for yields of 5 cereal crops (rice, jowar, bajra, ragi & maize) covering the period 1955-56 to 1984-85. Here, the growth, changes in both absolute and relative variabilities and structural change in the growth path were analysed.

Following are the results of the analysis in the TTF. Denoting that t- : refers to total (aggregate/annual),

k- : refers to kharif,

r- : refers to rabi,

i- : refers to irrigated,

u- : refers to unirrigated,

AI : refers to all India,

AP : refers to Andhra Pradesh,

All India: 1) 6 (t-rice(AI), t-wheat(AI), t-jowar(AI), t-ragi(AI), t-maize(AI) and t-barley(AI)) of the 7 aggregate crop yields showed growth over time; and

2) 3 (k-rice(AI), r-rice(AI) and k-jowar(AI)) of the 4 seasonal crop yields showed growth over time;

3) only for one crop yield - t-maize(AI) - growth was accompanied by an increase in absolute, but not relative, variability;

4) 5 aggregate crop yields (t-rice(AI), t-wheat(AI), t-jowar(AI), t-ragi(AI) and t-barley(AI)) showing growth showed structural changes in their growth paths.

5) 2 crop yields - t-bajra(AI) and r-jowar(AI) - show neither any growth (positive/negative) over time nor any variability change around their stagnant yield levels.

The results indicate that amongst superior cereals wheat yields grew at almost twice the rate of growth in rice yields. The growth rates of yields of the rain dependent inferior cereals are far lower than those of the superior cereals. The necessity of developing yet a satisfactory dry crop technology is further confirmed by the analysis of seasonal crop yields also.

Andhra Pradesh State: 1) 7 (t-rice(AP), k-rice(AP), r-rice(AP), i-rice(AP), t-jowar(AP), t-maize(AP) and u-ragi(AP)) of the 16 crop yields at the AP State level show growth over time;

2) in the case of t-maize(AP) yields growth was accompanied by an increase in absolute but not relative variability, and

3) in the case of r-rice(AP) and i-ragi(AP) the growth over time was accompanied by a fall in both absolute and relative

variability.

4) The yields of only t-jowar(AP) shows structural change in the growth path.

5) 9 crop yields (t-bajra(AP), u-bajra(AP), i-bajra(AP), t-ragi(AP), u-ragi(AP), k-jowar(AP), r-jowar(AP), u-jowar(AP) and u-maize(AP)) do not show any growth over time;

6) in 2 of these cases, (yields of t-bajra(AP) and u-bajra(AP)) there was a rise in absolute variability (and relative variability also in the case of t-bajra(AP)) around the stagnant yields, and

7) in the case of yield of u-ragi(AP) there is a fall in both absolute and relative variability around the stagnant yields.

As far as growth and variability are concerned, the results for AP show the following pattern:

a) Growth has no effect on variability change;

b) Crop yields under traditional technology with or without irrigation and under modern technology with irrigation do not show variability change as shown by ragi(AP) yields; and

c) Only crop yields under modern technology not supported by irrigation show variability change over time as shown by bajra and maize yields.

Such a pattern is not easily discernible at AI level perhaps due to too much aggregation over different States.

The comparison of the rice yield performance between kharif and rabi seasons suggests that greater control over the water input during rabi season led not only to higher yield levels but also to a reduction in yields' variance around the trend.

Andhra Pradesh Districts[1]: 1) 29 out of total 52 crop cases showed growth in yields. These are rice(EG, WG, KR, GN, KU, AN,

1 District codes: SV - Srikakulam + Vizianagaram + Vishakhapatnam; GN - Guntur + Prakasam + Nellore; RH - Ranga Reddy + Hyderabad; EG - East Godavari; KR - Krishna; KU - Kurnool; AN - Anantapur; WG - West Godavari; CU - Cuddapah; ME - Medak; CH - Chittoor; MB - Mehboobnagar; NA - Nalgonda; KH - Khammam; NZ - Nizamabad; KM - Karimnagar; WA - Warangal; AD - Adilabad;

CU, CH, RH, NZ, ME, MB, NA, WA, KH, KM, AD); jowar(KU, AN, CU); bajra(SV, CU); ragi(GN, AN, CU); and maize(NZ, WA, KM, AD).

2) Only in 4 of them (rice(WG, GN), jowar(CU) & maize(KM)) the growth was accompanied by an increase in (absolute) variability over time.

3) Of the 25 growth cases that did not show any change in variability 8 (rice(AN, RH), jowar(KU, AN), ragi(GN, AN, CU) & maize(WA)) show a structural change in the growth path.

4) 23 out of 52 crop cases do not show any growth in yield. These are: rice(SV); jowar(GN, CH, RH, NZ, ME, MB, NA, WA, KH, KM, AD); bajra(GN, AN, CH, MB, NA); ragi(SV, CH, RH, MB); & maize(RH, ME).

5) While 2 (rice(SV), bajra(CH)) of them face an increase in absolute variability over time around a stagnant yield level.

6) 1 (ragi(CH)) shows a reduction in variability (both absolute and relative) over time around a stagnant yield level.

The above pattern at the districts level is broadly consistent with the pattern observed at the State level in the previous chapter.

The structural change analysis shows that except in 2 districts, the trends in rice yields in Andhra Pradesh could not be substantially pushed upwards during the era of modern technology.

12.3 Results of the Analysis in the Response Function Framework.

The analysis in the RFF done only at the districts level of AP, starts with the estimation of yield response functions. Change in yield variability in the response function framework was analysed, with respect to time, fertilizer use and irrigation intensity, using the estimated residuals obtained from the yield response functions. With respect to absolute variability change over time:

1) 10 (rice(WG); bajra(CH) & maize(SV, EG, KR, GN, AN, CU, CH, KM) out of the 62 crop cases analysed in this chapter showed an increase in variability over time,

2) 1 (rice(KU)) showed decrease in variability

3) while the remaining 51 crop cases did not show any change in variability over time.
In most of the crop cases, these results were found to be similar to those obtained under TTF. Putting together the results obtained under the TTF as well as RFF, we find that only 15 crop cases (4, 1, 1, 1, 8 cases under rice, jowar, bajra, ragi & maize, respectively) showed changes in yield variability over time.

As regards changes in yield variability with regard to fertilizer use, only 9 crop cases show an increase in variability. Yield variability in these 9 cases (8 are maize(SV, EG, KR, GN, AN, CU, CH, KM) & 1 is bajra(CH)) increased at different levels of fertilizer use. 53 cases did not show any change in yield variability with respect to fertilizer use.

Similar analysis with respect to irrigation intensity was also carried out. This analysis, however, was restricted to only 35 crop cases for which irrigation intensity was never zero in any of the years. The results indicate that only 2 crop cases (maize(RH) and maize(KM)) show an increase in yield variability with respect to irrigation intensity. Variability in these 2 crop cases increased at different levels of irrigation intensity. Remaining 33 crop cases did not show any change in variability with respect to irrigation intensity.

Thus, an overwhelming number of crop cases do not show any variability either over time or with respect to use of both fertilizer and irrigation. Notably rice in all 18 districts do not show any change in variability with respect to any of the inputs though in 3 districts (SV, WG & GN), yield variability increased over time while in one district (KU), it decreased.

In the 6 districts (KU, AN, CU, NA, KM, KH) analysed for jowar, yield variability did not change over time (except in the district CU) nor with respect to fertilizer use. Jowar being mainly an unirrigated crop variability of jowar yields with respect to irrigation was not analysed.

In the case of bajra, of the 11 districts (SV, GN, AN, CU, CH, RH, NZ, ME, MB, NA, KM) analysed yields in 10 districts do not show any change over time and also with respect to fertilizer use. Only in CH bajra yield shows change in variability over time and also with respect to fertilizer use. Bajra yield variability with respect to irrigation intensity was analysed for 3 districts only (GN, CU & KM) all of which do not show any change in yield variability.

In the case of ragi, yields in 14 districts (SV, EG, WG, KR, GN, KU, AN, CU, CH, RH, NZ, ME, MB, NA) were analysed. All districts showed no change in variability over time (except CH), and also with respect to use of fertilizer and irrigation.

In the case of maize yield, 13 districts (SV, EG, KR, GN, AN, CU, CH, RH, NZ, ME, MB, WA, KM) were analysed, of which 8 districts (SV, EG, KR, GN, AN, CU, CH & KM) show increase in yield variability over time and also with respect to fertilizer use. Variability with respect to irrigation intensity was analysed only for 10 (KR, GN, AN, CU, CH, RH, NZ, ME, WA & KM) of these 13 districts. Of these 10 districts, only in RH and KM maize yields show an increase in yield variability with respect to irrigation. Notably in KM, which is the most important district for maize cultivation in Andhra Pradesh, maize yields show increase in variability over time and also with respect to use of both fertilizer and irrigation.

Summary of the Conclusions on Yield Variability From Both TTF and RFF.

From our analysis in the 2 frameworks, we conclude the following:

a) Most of the crop yields, except those of maize, in various districts of AP do not suffer from the problem of increasing yield variability over time. The analyses under TTF as well as RFF support this result.

b) Though rice yields in a few districts (SV, WG, & GN) seem to face increasing yield variability over time, their fluctuations over time could be explained in terms of fluctuations in the associated input levels of fertilizer application and irrigation intensity.

c) Maize yields in almost all the districts where the crop is important suffer from the problem of increased variability over time as well as with respect to increasing levels of fertilizer. Maize(KM) is the lone case that showed increased variability over time and with respect to increases in fertilizer application and irrigation intensity also.

d) The factor of growth does not have any relation with changing yield variability. Our analysis shows that a crop with growing yields need not have increased variability (over time as well input levels, some examples are: rice(EG, KE, AN, CU, CH, KH, NZ, ME, MB, NA, WA, KH, KM & AD), bajra(CU), ragi(GN) and maize(NZ & WA)); nor is it necessary that a crop with no growth at all should have unchanging variability (see the result of bajra(CH)).

e) Unirrigated yields of several crops in various districts did not show a change in yield variability over time. Likewise, not all irrigated yields showed unchanging variability over time. However, in the latter case, there is no evidence to suggest that irrigation intensity led to this variability change. In fact, the relation between irrigation intensity and yield variability over time seems to be generally weak.

f) An overwhelming proportion of the number of crop cases (33 out of 35) analysed show that increasing the irrigation intensity of a crop does not lead to increase in yield variability.

g) Excepting in the case of maize yields, yields of other crops do not show increase in variability with respect to increase in fertilizer application.

12.4 Results of the Analysis of Spatial Variability.

12.4.1 Trends in Spatial Variability.

The analysis of spatial variability of yields was done for the yields of the 5 cereal crops at the districts level for Andhra Pradesh. Spatial variability or disparities across districts was measured by the coefficient of variation (CV) computed across districts. CVs were computed for yields, rainfall, sourcewise net irrigation proportions, aggregate cropping intensity, cropwise gross irrigation intensities and fertilizer availability. From a time series of CVs over the period 1960-61 to 1984-85 trends in spatial variability of yields and of the other variables mentioned above were analysed. The pattern of growth and spatial variability across the districts are as follows:

Yields of all 5 crops show either positive growth or is stagnant. None of the 5 crops show falling yields in any district. **Yield disparities across districts for rice and jowar are low and remained unchanged over time. Yield disparity for maize is also low but shows an increase over time. Yield disparities for ragi and bajra are high and have increased over time.**

Rainfall disparities are high, with North-East rainfall showing higher disparity than South-West rainfall.

Canal irrigation area shows growth in most districts while tank irrigation area is either falling/stagnant in all the districts. Total surface water irrigation area, however, is stagnant in most districts. Canal irrigation proportion shows high disparity which decreased over time. Tank irrigation proportion too shows high disparity which, however, increased over time. As a result, the high disparity in surface water irrigation proportion remained unchanged over time.

Tubewells irrigation area shows positive growth in most of the districts while other wells irrigation area shows positive growth in some, but not all, districts. Thus, the total ground water irrigation area is growing in almost all districts. Tubewell irrigation proportion shows high disparity which decreased over time while the high disparity in other well irrigation proportion remained unchanged over time. Ground water irrigation proportion as a whole shows high disparity which decreased over time.

Other source irrigation proportion shows high disparity which decreased over time.

Total (by all sources together) net irrigation area is growing in almost all districts; total net irrigation proportion shows high disparity which decreased over time.

Thus in general, efforts at irrigation development seem to be somewhat non-uniform across various districts in different regions in Andhra. In particular, the districts in Rayalaseema seem to be unfavourably positioned in this context.

Aggregate cropping intensity (ACI) is increasing in all districts; it shows low disparity but increasing over time. ACI is shown to be positively related to canal (TCNL) and other wells (OTWL) irrigation proportions. However, CV(ACI) is far lower than CV(TCNL) and CV(OTWL). This only implies that though irrigation facilities do contribute to ACI, the response of ACI with respect to irrigation development is different in different districts. The above relation between ACI and irrigation actually suggests that the elasticity of ACI with respect to irrigation is likely to be higher the higher the irrigation proportion. This suggests that CV(ACI) is likely to go up over time.

The cropwise irrigation intensities of rice show low disparity which has remained unchanged over time. The cropwise irrigation intensities of jowar, bajra, ragi and maize show high disparities of which the disparities in the irrigation intensities of jowar and ragi remained unchanged; while the disparity in the irrigation intensity of bajra increased and that of maize decreased over time.

Fertilizer intensity shows high disparity which decreased over time.

In the case of superior cereal rice the major contributors to the State's output are the districts where the crop is mostly under irrigated conditions, whereas in the case of inferior cereals, the major contributing districts are the ones where these crops are mostly under unirrigated conditions.

12.4.2 Factors Affecting Spatial Variability of Yields.

The spatial variability of cereal crop yields across the districts of Andhra Pradesh were then analysed by relating the yield disparities to the spatial variability of rainfall, fertilizer availability and other infrastructural variables like sourcewise net irrigation proportions, and aggregate cropping intensity. The conclusions of this analysis are as follows:

1) Rainfall (during South-West monsoon or North-East monsoon or both) was found to affect directly the spatial variability of yields of all crops except bajra;

2) Among the infrastructural factors the disparity across districts in sourcewise net irrigation proportions was found to affect the spatial variability in yields of all cereal crops grown in AP except jowar.

3) Among the various sources, the disparities in surface water sources proportion as a whole affect directly the disparities in the yields of rice, bajra and ragi. In the case of bajra and ragi yields, disparities in tank irrigation proportion in particular affect directly the disparity in their yields.

4) Disparities in ground water sources proportion as a whole affect inversely the disparities in bajra yields, and in the case of maize, it is the disparities in the other wells component of ground water that affects (inversely) the disparities in maize yields.

5) Disparity in ACI was found to have an inverse relation with the disparities in bajra and ragi yields only.

6) Differences in fertilizer intensity affect directly the disparities in rice yields, and inversely ragi and maize yields.

12.5 Results of the Analysis on the Consequences of Falling Agricultural Investment.

The analyses in chapters 6 through 10 brought out the importance of irrigation in

1) raising yield levels,

2) explaining the spatial variability of yields.

3) It was also noted that irrigation unlike fertilizers does not lead to any instability in yields.

Given the important role played by irrigation, neglect of irrigation development would have serious consequences on agricultural development in particular and also on the economy as a whole. Unfortunately, such a neglect seems to have occurred during the 1980s in the form of a fall in the levels of agricultural investment necessary for irrigation development. The consequences of the fall in agricultural investment on agricultural sector and also on the rest of the economy were analysed using a computable general equilibrium model already available in the literature.

The results of this analysis are the following:
Though shifting investment resources away from agriculture to non-agriculture may result in a faster growth in GDPT, the growth across sectors is likely to be uneven, with non-agriculture likely to show a far higher growth than agriculture. However, slowing down agricultural growth would lead to growing income inequality in rural areas. For example, if the percentage of agricultural investment in the total is maintained at the prevailing current trends as observed since 1980s instead of at 20% as earlier, it would result in an increase of 2.8% in the rural population having a per capita annual consumption below Rs.336 (at 1970-71 prices). Besides, though the country is right now deemed to be self sufficient in foodgrains, if the present trends of investment policy are continued, not only large scale imports to meet the domestic demand may become necessary, but also despite such imports food prices would go up substantially. Price increases of foodgrains are known to hit the poor most.

12.6 Limitations and Scope for Further Research.

12.6.1 Limitations.

Some of the limitations of this thesis arise due to non-availability of all the relevant data. These limitations are rather unavoidable. We list some of these limitations now.

The heterogeneity in soil, climate, infrastructure, agricultural practices, economic conditions, etc., that exists in a large country such as India calls for as much geographical disaggregation in the analysis as possible. In this thesis districts are the smallest geographical unit at which the analyses were done. But even within a district there may be differences in the various factors affecting crop yields. (See for example, the rainfall pattern at the Taluk level presented in Chapter 8, Appendix 8.A1). Ideally, though analysis at still further levels of regional disaggregation would be preferred such detailed analysis could not be done since time series data on yields, inputs use, etc., below the level of a district are not available.

Even at the districts level, only aggregate annual yields could be analysed. Lack of time series data on yields and inputs usage in the 2 main cropping seasons (kharif and rabi), and according to seed (HYV hybrids/ Traditional) and water (Irrigated/ rainfed) regimes, does not permit a more detailed analysis.

Even the analysis of aggregate yields at the districts level had to be done without accounting for some important input variables like cropwise labour use, mechanization, pesticides, etc. since there are no continuous time series data at the districts level on these variables. The districtwise HYV adoption rates could only be indirectly accounted for through fertilizer availability on account of non-availability of such data. Nor could institutional factors that may affect yields be covered in our analysis. Inclusion of these variables in our analysis, though not possible given the current data availability, might further improve our understanding of the different aspects of the stability of yields.

Although the overall fertilizer availability for the cereal crops was accounted for in the analysis, it would have been better if cropwise fertilizer usage could be accounted for. But such time series data are not available.

Scope for Further Research.

As mentioned earlier, a salient feature of our methodology is a procedure to select an appropriate functional form for the time trend / yield response function, most appropriate to the data. In the time trend framework, the analysis started with a set of 7 commonly used time trend functions. It is from amongst these 7 functional forms that an appropriate functional form was selected. It is still conceivable that there exists some other time trend function, not contained in our set of 7, which is better suited (in terms of our selection criterion) to the data in hand.

One feature of our analysis is the detection of the variability change point using Hsu tests. The Hsu tests, in principle can detect only one variability change point in a given sample and provides an "estimate" of the change point that was unknown in the beginning. However, a given data series may consist of multiple change points in its variance. Though one could manipulate with the sample sizes and still use Hsu tests to detect such multiple change points, this was not done in this study in view of the problem due to degrees of freedom.

One test procedure that allows for multiple change points of variability is by Ali and Giaccotto (1982). Their test procedure, however, requires the pre-specification of the multiple variability change points, which essentially is arbitrary in nature. Hence this test procedure was not adopted in our study.

While analysing the consequences of falling agricultural investment, the share of agriculture in total investment was modeled by relating it to the share of agriculture in total gross domestic product and the terms of trade between agriculture and non-agriculture sectors. The behaviour of the public and private components of agricultural investment were not modeled separately. It would perhaps be more enlightening if the behaviour of private investment is modeled taking also into account the expectations of the farmers. This is still largely an unexplored area in the context of the Indian economy.

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