# Natural Resource Inventory of Luppi Village, Eastern Plateau of India: Implications for Sustainable Agricultural Development

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**ABSTRACT.** Degradation of land and denudation of forest resources, instability in production, erosion of soil, and depletion of native fertility status necessitates a thorough understanding for sustainable agricultural development for conservation of natural resources for present and future generations. We studied the natural resource inventory of Luppi village, situated at eastern plateau of India using a Geographic Information System and satellite imagery (IRS 1C LISS III satellite imagery) and Participatory Rural Appraisal Technique, a procedure for rapid acquisition of knowledge, development activity, and decision-making done with the involvement of rural people and household survey. A base map and resource map of the village were developed using GEOMATICA software. Toposequence based micro-level study revealed that there were

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four types of land situations: upper terraces locally called *Tanr*, *Bahri* (land close to homesteads), *Baad* (middle terraces), and *Garha* (lower terraces). Adverse bio-physical and socio-economic conditions and age-old, traditional, unscientific agricultural activities in the region act as deterrents for crop production and natural resource management. Based on the study, it can be concluded that priority should be given to long term strategies encompassing silviculture or silvi-pastoral system (cultivation of trees and pasture simultaneously) on upland, cultivation of short-duration, flash-flood tolerant, high-yielding rice variety for *Aman* (wet) season, and cold-tolerant rice variety for winter season in low land areas; social forestry in degraded land; agro-ecologically suited cropping systems with suitable variety choice for problem areas; and judicious nutrient management in homestead gardens that is ecologically suitable, socio-economically acceptable, technologically sound, and environmentally sustainable. 

**KEYWORDS.** Cropping system, natural resource inventory, participatory rural appraisal, satellite image, village, weather data

## *INTRODUCTION*

The need to identify exit paths from natural resource degradation in rural areas of eastern India should be a high research priority. The eastern plateau occupies a sizable portion of cultivable land, but remains almost neglected and unexploited. This region is truly a representative of degraded soil with fragile ecosystem. In most rural areas of eastern India, households rely on agriculture–often subsistence-oriented farming–for most of their income.

In much of eastern plateau the natural resource base can be characterized as poorly suited to agriculture because of climatic, water resource, and soil conditions. The degradation of available forest and land resources also appears to be proceeding rapidly. Deforestation due to poaching of remaining forest areas and soil erosion due to erosive south-west Monsoon rains (heavy flush of precipitation, which occurs during June to September) and unsustainable land use practices are proceeding rapidly in many parts of eastern India. Moreover, increase in population pressure per unit area, shrinking arable land resources, soil degradation, and depletion of nutrients from soil call for holistic approaches for sustainable development of natural resources to face the long march towards human resource development. Under such perspective, an attempt has been made to integrate modern technology and the farmers' traditional wisdom. Trends with respect to the state of natural resources combined with the paucity of options for non-agricultural income make the prognosis for the future of the area and of the families that live there, worrying.

### *The Study Area*

The study area, Luppi village, is situated between latitude 24° 21′ 0″ and 24° 21′ 40″ North and between longitude 86° 29′ 38″ and 86° 32′ 54″ East in the Chhotanagpur plateau, a part of the eastern plateau of India. Geographical area of the study village is 35534 ha with 503 households and with a population density of 10.8 per square kilometer. Total population of the area is 3826, of which 51% are male and 49% are female. Forest occupies about 291 ha whereas cultivated area is about 377 ha with 114 ha area under irrigation. The major sources of irrigation are dug well, river, tank, and shallow tubewell. Rice is the predominant crop and the principal focus of agricultural and economic activities in the Giridih District. The land surface is rugged and has an undulating topography ranging from flat land to steep slopes. The elevation of the study area ranges from 250 to 450 m above sea level. The topography creates distinct landscapes that give rise to unique short-range variation in soil and water conditions. In general, the climate of this region is characterized as sub-humid, mega-thermal with a deficiency of water during the winter season. The historical annual average rainfall in the area is 1183 mm (Banik, 1996), but ranges from 771 to 2028 mm per year. Rainfall is highly seasonal, with about 86% of total annual rainfall concentrated between June and September (months corresponding to Monsoon season).

Ethnically, the Chhotanagpur plateau lies in the so-called *tribal belt* of eastern India. The population from scheduled tribe or scheduled caste (socio-economically backward and under privileged group of people under Indian constitution Schedule Number 9/Article 244-244 A) families represents a large proportion of the population. Individuals from tribal and scheduled castes represent around 40% of the total population in Giridih district.

Rice (*Oryza sativa*) monocropping system is the predominant practice of the region. In low and medium lands farmers generally grow traditional rainfed rice with less amount of fertilizers. In uplands, a variety of crops like finger millet (*Eleusine coracana*), sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum typhoideum*) with pigeon pea (*Cajanus cajan*), green gram (*Phaseolus aureus*), blackgram (*Vigna mungo*), horse gram (*Dolichos biflorus*), etc., are grown either solely or in a mixed culture. Animal husbandry like rearing of domestic cattle, poultry, etc., along with crop husbandry constitutes households farming system. Low input agricultural system encompassing sub-optimal use of fertilizers, application of farm yard manure is the traditional soil management system. Tillage operation is traditionally based on country plough. Crop management is mainly subsistence-oriented. Use of pesticides for controlling pests is very uncommon in this region. Mechanical weed control, hand weeding, is commonly practiced to control weeds. Application of fertility inputs is not adequate and not based on soil test or crop response. Household incomes depend on the natural resource base, and agricultural conditions in the area make seasonal underemployment pandemic.

### *Surface Water and Ground Water Resources*

During the dry season, many of the smaller streams/rivulets in the study area typically dry out; as a result, surface water is not readily available. The main sources of water for domestic and agricultural use are dug wells, supplemented with water stored in reservoirs and ponds. The water-table depth varies from shallower than 3 m to more than 12 m during the summer months, and many of the shallow wells yield scanty water or dry up completely. Hence irrigation potential during the dry season is relatively low (Bhattacharya et al., 1985, Maiti and Bagchi, 1993)

### *Soil Resource*

The undulating topography and highly dissected landscape give rise to short-range variations in terrain and soil and water conditions, which influence the kinds of crops that can be grown, the time windows for cropping, and the possible cropping systems in different parts of the toposequence. Taxonomically soil of the region comes under Ultisol, dominated by Kaolinite clay minerals with low water holding capacity and nutrient status of the soil is also low. Organic carbon is low and available N, P, K are limiting. Soils are acidic (pH 5.0-6.0).

The most effective way to develop the area is to develop the agricultural systems, as 90% of the inhabitants maintain their livelihood through subsistence agriculture and its allied enterprise. Non-agricultural income generating sources are limited. The agricultural systems that are now practiced by the local inhabitant are unsustainable considering the limited availability of natural resources. Developing sustainable agricultural systems might be considered the prime concern for developing the area where natural resource inventory will play a key role to support developmental planning and decision-making and to provide a base line for technological intervention.

### *Objectives of the Study*

The study was undertaken to identify the existing natural resources using remote sensing, image processing, and GIS (Geographic Information System) tools and to study the agricultural scenario of the area to foster site specific, need based, socially acceptable, eco-friendly technologies for sustainable agricultural development of the area.

## *MATERIALS AND METHODS*

### *Data Used*

Base map and Indian Remote Sensing (IRS) 1C Linear Imaging Self Scanning Sensor (LISS) III satellite imagery of Luppi village were used for our study. It has four spectral bands: 0.52-0.59 μm, 0.62-0.68 μm, 0.77-0.89 μm, and 1.55-1.70 μm with a ground resolution of 23 m. The swath width was 141 km with a 24-day revisit cycle. We also used the resource map made by the local key personnel using participatory rural appraisal technique, a qualitative investigation methodology that aims to involve a group of people in describing their shared situation and process of change in their own terms. Daily rainfall along with the historical rainfall data was also considered for this work.

A household level survey was done in 1997 at Luppi village where we tried to learn the agricultural systems practiced by the farmers and the ethnic composition of different *Tolas,* a cluster of houses in the village separated by man-made boundaries; each *Tola* commonly represents a particular ethnic group. Soil samples were collected from different agro-ecosystems at 0-30 cm depth and analyzed to estimate the nutrient (NPK) content to determine the extent of degradation.

Daily rainfall data were collected from Damodar Valley Corporation (River Project under Government of India) and Indian Statistical Institute, Giridih, Jharkhand, for the years 1969-2001. Rainfall was measured using manual and automatic rain gauges specified by India Meteorological Department (IMD), Government of India. To study the characteristics of monsoon, the individual years were grouped according to the weeks of commencement of rainy season. Onsets of monsoon during different years were identified as the week which received more than 20 mm of rain in one or two consecutive days, provided that the probability of at least 10 mm of rain in the subsequent week was more than 0.7 (Virmani, 1975). Similarly, the date of withdrawal of monsoon was defined as the date up to which a rainfall of at least 30 mm had been received in a week with no subsequent rainfall for at least 3 consecutive weeks towards the end the monsoon season (Shanker et al., 1992). Weekly total rainfall for standard meteorological weeks was computed for all years. The mean, mode, and median dates, standard deviation, and co-efficient of variation regarding onset, withdrawal, and duration of south-west monsoon were calculated as advocated by Chandel (1978). Rainfall at different confidences was done using mixed Gamma distribution (Shanker et al., 1992).

Resource mapping was done with the help of participatory rural appraisal (PRA) technique and then digitized using ARC/INFO software. We selected 14 aged villagers (above 55 years), two from each *Tola*, from the farming community as key informants to carry out the natural resource mapping of the village. Local farmers drew a rough sketch of soil using wheat flour, turmeric powder, brick dust, etc., and then the resource map was prepared on paper and digitized. Natural resource mapping was also done on IRS 1C LISS III imagery using GEOMATICA software using *SUPERVISE CLASSICATION* module followed by reclass and ground truthing.

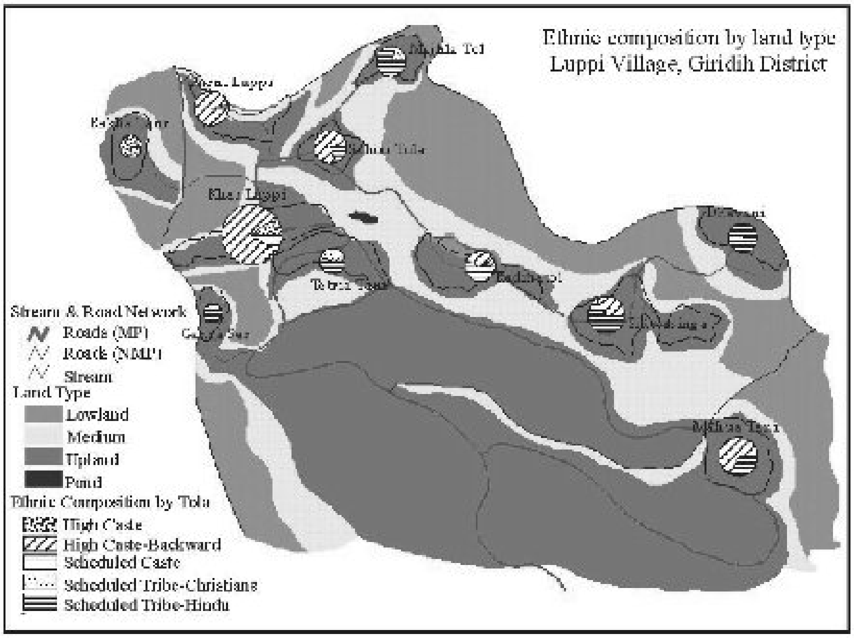
Altogether, 42 soil samples were collected from the depth of 0-30 cm during the study, 2 weeks after harvesting of crops. We covered 14 different crop ecosystems and three replicated unit of land area for each ecosystem. The soils were partially dried to facilitate sieving (2 mm) and analyzed in duplicate for organic C and available N by the wet digestion (Jackson, 1967) and alkaline $KMnO_4$ (Subbiah and Asija, 1956) methods, respectively. P and K contents were estimated by Olsen method (Olsen et al., 1954) and by using neutral normal ammonium acetate (Jackson, 1967), respectively.

## RESULTS AND DISCUSSION

### Ethnic Composition and Land Use Pattern of Luppi Village

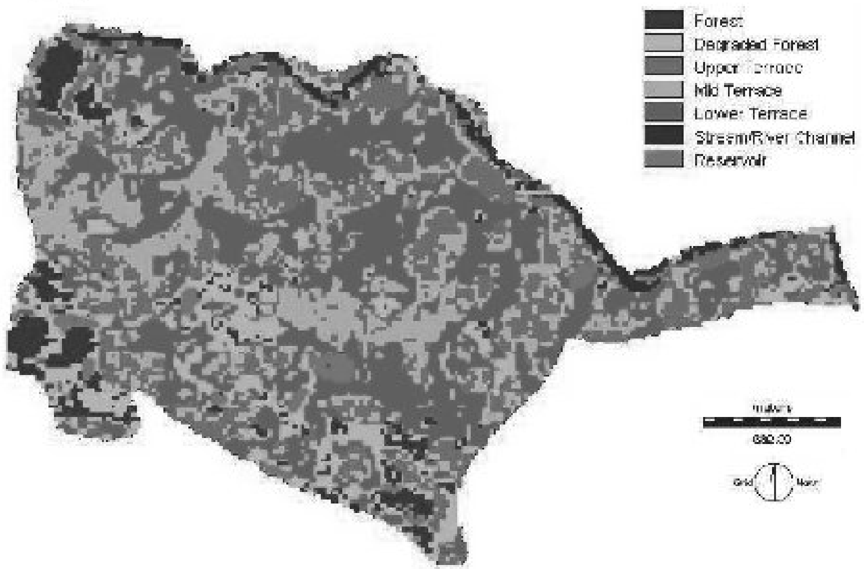
Figure 1 shows the physical separation of families of different caste across *Tolas* (or sub-village clusters) and also the topographic classification of

FIGURE 1. Ethnic composition by land type of Luppi village.




land like lowland, medium land, upland etc., of Luppi village in Giridih district. Pie charts represented ethnic composition of the total population of different *Tolas* and the size of the pie charts represented the total population of each *Tola*. There were 11 *Tolas* in the village namely, *Gansa Ser*; *Rakha Tanr*; *Purni Luppi*; *Khas Luppi*; *Schoo Tola*; *Mahula Tol*; *Tetria Tanr*; *Kadma Tol*; *Sidwasinga*; *Dhavani*; and *Mahua Tanr* (Figure 1). Among different *Tolas* lowest population was noted at *Gansa Ser*, and the highest was at *Khas Luppi*. Within village with heterogeneous castes, residential segregation according to caste was observed, the tribal and backward communities tended to be physically segregated from the higher castes into clusters of households or *Tolas*. The ethnic groups mainly comprised scheduled caste (SC), scheduled tribes-Hindu (STHinu), scheduled tribes-Christian (ST-Christi), High caste (Hicaste), and High-backward (Hicaste-ba–basically these are high caste Muslim, but economically backward). Figure 1 also indicates that the *Tolas* are separated depending on different ethnic groups. There were distinct social barriers, which prevented interactions among *Tolas* of different

FIGURE 2. Land use pattern of Luppi village from IRS 1C LISS III satellite imagery.




castes within the same village. The marginalized groups (SC and STs) also tended to be associated with the less productive lands and forest fringes, and were among the poorest of the rural households. Many of them maintain their livelihood by hunting in the forest, or depend on forest resources. Two types of road network exist in the village. One is accessible to vehicles (MP Roads) and the other is not (NMP), making a few *Tolas* accessible by vehicles. Although the village is surrounded by two streams, namely *Patra* (Northwest to Northeast) and *Chhutki Nadi* (North to South), scarcity of water particularly in winter season is inevitable, and cultivation of a second crop after wet rice is difficult in the study area.

Figure 2 represents the land use pattern of Luppi village derived from IRS 1C LISS III satellite imagery. A fringe of forest area (dense forest and degraded forest) is noted within the village. The degradation of forest is mainly due to illegal harvesting of forest trees by the local inhabitants, as unsustainable practice. Upper terrace (upland), mid terrace (medium land), and lower terrace (low land) are very much distinct. Initially the classification of the imagery was done and then conformed by ground truth. Imagery shows more water reservoirs than the map prepared by the local inhabitants through PRA. Classified image of Luppi (Figure 2) shows that the majority of the area is low land (Lower terrace), which gives an opportunity to grow rice with high yield potential.

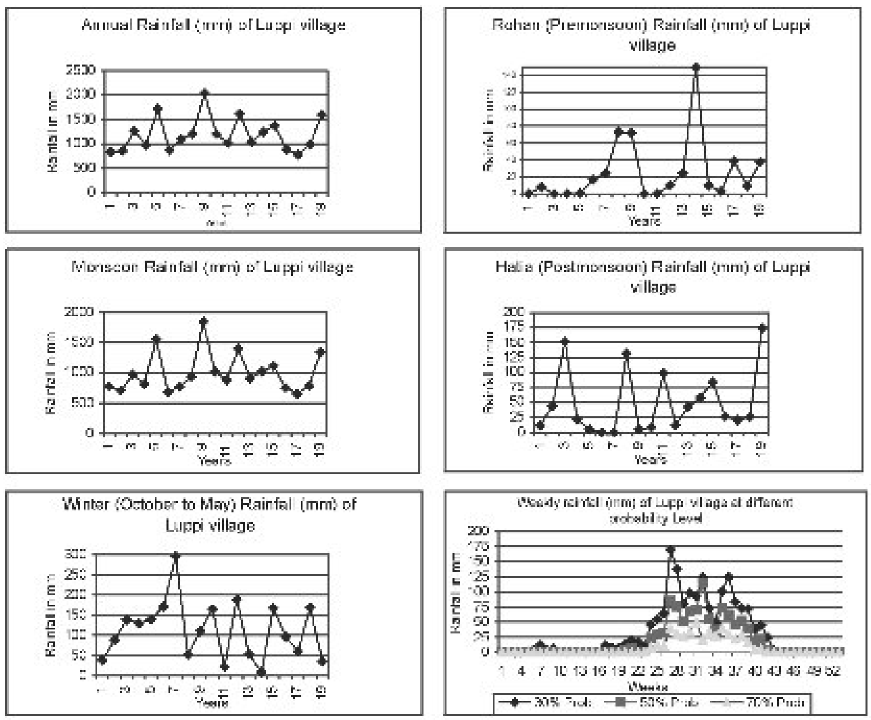
### *The Monsoon and the Cropping Calendar*

The average onset of monsoon was in 24 Standard Meteorological Week (SMW) (June 11-17; 1 SMW means January, 1-7) and it ranged from 21-27 SMWs over the years of study. Monsoon commenced as early as 21 SMW in 1989 (May 28), and as late as 27 SMW in 1976 (July 7). The average withdrawal of monsoon was 39 SMW ( September 24-30). The earliest and latest dates of withdrawal of south-west monsoon were September 7 in 1971 and October 14 1973. Traditionally and culturally, farmers in the study area use the appearance of the *Rohan* star, a star that first appears in the sky over India from May 25 to June 7 at SMW 20 as an expectation of pre-monsoon precipitation for carrying out nursery planting and land preparation for rice. Similarly, the appearance of the *Hatia* star, a star that first appears in the sky over India between September 27 and October 9 (SMW 40-41) indicates the possibility of using residual moisture for cultivating winter crops (Figure 3). Under normal circumstances the available moisture over the entire monsoon with its pre- and post-monsoon periods determines the time window of opportunity for the various cropping systems practiced by farmers in the study area (Figure 4).

There is considerable variation in the onset and withdrawal of the south-west monsoon in the study area. This large variation in both the onset and withdrawal gives a considerable amount of uncertainty for farmers in implementing their cropping calendar in the study area. A delay in the onset of the monsoon means that farmers who take advantage of the *Rohan* (Pre-monsoon) rain (rainfall received after visibility of *Rohan* star) to start their crops would encounter early season drought. An early withdrawal and/or lack of *Hatia* (Post-monsoon) rain would affect yields of long duration (140-160 days) rice and the ability to grow winter crops in a multiple cropping system where more than one crop is taken in a year in a single piece of land. *Hatia* rain (over a 2-week period) can vary from 0 to 151 mm (Figure 3). On average, only about 4% of the total annual rainfall occurs outside the monsoon (plus pre- and post-) period. Although this constitutes a small amount of rainfall, it is nevertheless important in giving reasonable yields for winter crops (e.g., barley and oilseeds).

Rainfall at different confidence levels (Figure 3) indicates that rain started on 16 SMW at 0.3 confidence level whereas it was on 23 SMW

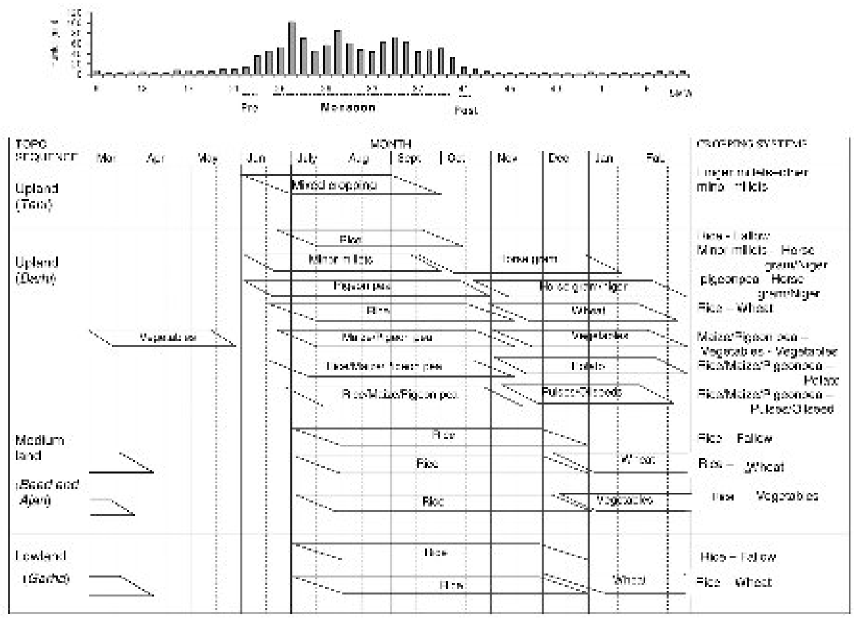
FIGURE 3. Annual and periodical rainfall pattern and weekly rainfall at different probability levels of Luppi village.




when confidence level is 0.7. The cessation of monsoon was 41 SMW at 0.3 confidence level and 39 SMW at 0.7 confidence level.

The undulating topography and highly dissected landscape (Figure 4) give rise to short-range variation in terrain, soil, and water conditions. The existing cropping pattern at different land positions along with the average weekly rainfall pattern of Luppi village (Figure 4) indicated that different crops were grown on different plots particularly in upland (*Barhi*). Rice is the predominant crop in Luppi, but different varieties of rice were cultivated at different land positions. Figure 4 also indicated that double cropping or even triple cropping was done on Barhi lands only where watering could be possible from dug well. On medium lands rice-wheat and rice vegetables were practiced through surface water (residual soil moisture and/or river/tank). These largely influence constraints and opportunities for cropping systems in the study area.

FIGURE 4. Average weekly rainfall (in mm) and existing cropping calendar of Luppi.

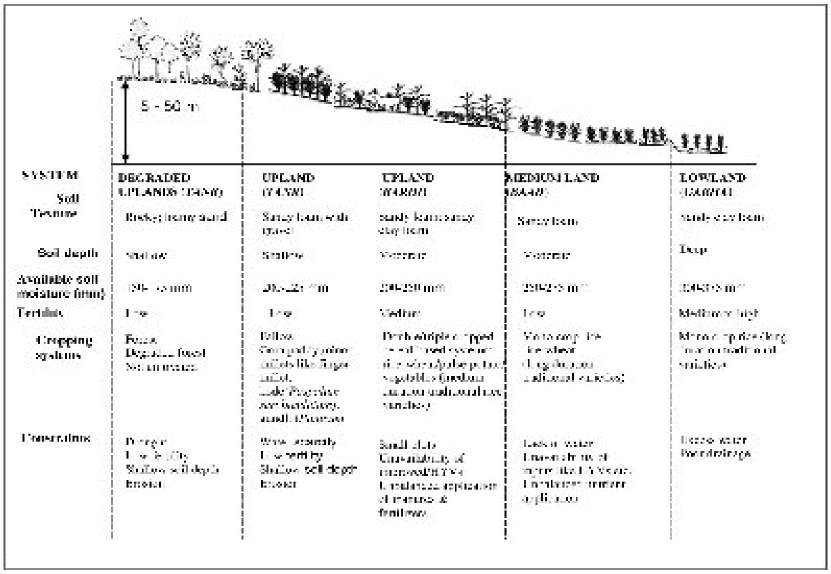


Topographically, four main landscape types are identified (Figure 5):

1. The upper terraces or upland locally called *Tanr* land, which are associated with very light-textured soils. The very gravelly *Tanr* lands are difficult for cultivation; these may be under degraded forests or completely barren.
2. Those *Tanr* lands with higher silt content (sandy loams) can be used for cultivation; particularly areas close to the homesteads (called *barhi* land) are more intensively cultivated and partially irrigated.
3. The middle terraces, or medium (*baad)* land, have slightly heavier textured soils (e.g., loamy sands and sandy loams).
4. The lower terraces, or low (*garha*) land, have increasingly heavier textured soils (e.g., sandy clay loam).

Farmers may distinguish different levels of the upper, middle, and lower terraces, called by different local names, where they plant different crops and different varieties of the same crop suited to the specific soil

FIGURE 5. Land types of Luppi village defined by low-scale differences in topography.




and water conditions at these terraces. The soil fertility characteristics also vary with landscape position and with intensity of cultivation. Table 1 summarizes the soil chemical properties for samples taken from rice fields at different landscape positions in Luppi village. There was a marked difference in the soil fertility level of the *Barhi* and *Tanr* in the uplands because of the higher inputs applied to the *Barhi* lands, which are the most intensively cultivated. Apart from the *Barhi* land, there is a systematic trend of increasing soil fertility from the uplands to the lowland except in the case of K.

### *Current Cropping Practices and Recommendations of Agricultural Practices to Landscape Positions*

The short-range variation in soil and moisture characteristics affects the suitability for agriculture and influences farmers' strategies of diversification and adaptation of crops and cropping practices to landscape positions (Figures 4 and 5).

Because of the harsh soil and water conditions, the gravelly upland is not suitable for cultivation. Where the natural forests are degraded, the

TABLE 1. Chemical soil properties for samples taken from rice fields at different landscape positions in Luppi village.

| Ecosystem | # of Samples | pH | Org. C (%) | Av. P (kg/ha) | Av. K (kg/ha) | Total N (%) | C/N Ratio |
|---|---|---|---|---|---|---|---|
| Upland (*Tanr*) | 3 | 5.5 | 0.38 | 11.60 | 83.60 | 0.03 | 10.93 |
| Upland (*Barhi*) | 6 | 6.6 | 0.75 | 23.40 | 249.30 | 0.07 | 10.40 |
| Mid upland | 6 | 5.5 | 0.53 | 18.45 | 81.88 | 0.05 | 11.58 |
| Medium | 6 | 6.3 | 0.56 | 21.00 | 267.00 | 0.05 | 11.75 |
| Lowland | 21 | 6.4 | 0.77 | 24.17 | 185.06 | 0.07 | 11.15 |

uncultivated areas are subjected to severe erosion, causing further land degradation and increasing the extent of uncultivable area.

In the cultivable *Tanr* land (upland), cropping of *Gora* rice (short-duration; 85-90 days, drought tolerant, low-yielding upland rice variety), and traditional minor millets [finger millet (*Elusine coracana*), *kodo* (*Paspalum scrobiculatum*), *gundli* (*Panicum antidotale*)], either as monocrop or in mixed cropping, is possible during the monsoon period only.

Close to the homesteads where water is supplied from dug wells, the *Barhi* land is used for intensive cultivation of vegetables, and high-yielding potato, wheat, and rice varieties. The relatively higher level of inputs like irrigation, fertilizer, etc., into these *Barhi* lands compensates for the low natural fertility of the soils and enables these areas to support crop diversification and intensification, with cropping intensities (ratio of net cropped area to total cultivable area multiplied by 100) of 300-400%.

In the medium lands, crops like rapeseed (*Brassica campestris)*, linseed (*Linum usitatissimum*), barley (*Hordeum vulgare* L.), lentil (*Lens culinaris* L. Medicus), and gram (*Cicer arietinum* L.) are cultivated successfully following the monsoon season rice crop, using residual soil moisture (moisture retained in the soil after receipt of rain or harvest of previous crop).

While the lowlands are the most fertile, excessive moisture and poor drainage limit crop suitability to rice, and constrain growing of winter crops after the main rice season. Presently most farmers grow traditional long duration rice varieties with low inputs of manure.

### *Possible Technical Interventions*

Despite the generally unfavorable bio-physical and socio-economic conditions in the eastern plateau, there are potential opportunities for technical interventions to improve the productivity and the natural resource base at different landscape positions. The findings from various experiments conducted at the Agricultural Experimental Farm, Indian Statistical Institute, Giridih, indicate a variety of potential agronomic interventions. These take into account crops that are agro-ecologically suitable, nutritionally enhancing, culturally acceptable, as well as cropping practices that require minimal cash input, enhance soil fertility, and check land degradation, etc., and could be recommended to increase the productivity of the area and sustain the natural resources.

### *Possible Intervention in General*

Toposequence-wise micro-level planning, involving plantation of fruits like mango (*Mangifera indica*), jack fruit (*Artocarpus heterophylla*), cashew nut (*Anacardium occidentale*), papaya (*Carica papaya*), Bel (*Agel marmalos*), citrus (*Citrus chinensis*), social forestry (community forestry maintained by rural people) with *Arjun (Terminalia arjuna)* for sericulture, rearing of silk worm for the production of silk, and *Palash (Beutia frondosa)* for Lac culture, rearing of an insect of hemiptera group for the production of a dark red resin, trees and fodder cultivation on uplands, drought resistant, short-duration, non-rice crops for *Aman* (wet) season, and mixed/intercropping on mid-uplands and better management of medium and lowland rice can be better alternatives to develop the area.

Formation of farmers' cooperatives for accessibility of all agricultural inputs and better marketing for harvested products and processing and preservation for perishable products like cashew nut (*Anacardium occidentale* L.), baby corn (*Zea mays* L.). At present, there is no farmers' cooperatives at the village.

Increasing scope of employment through animal husbandry, and village-level enterprises like vermicomposting, biopesticides, etc.

### *Possible Intervention on Different Toposequences*

The main interventions for the degraded uplands should be targeted at checking further land degradation through effective reforestation using appropriate and relevant tree species that can also provide products of use to the local residents, e.g., medicinal plants, fruit trees, bamboo (*Bamboosa arundanacia*) plantation and the *Sal* tree (*Shorea robosta*) for harvesting leaves that are used as disposable plates.

Given the poor water availability and soil conditions of the cultivable uplands, the present practice of growing low-yielding, traditional rice should be replaced with planting of high-yielding, non-rice crops that have lower water requirements and higher drought tolerance. Mixed or intercropping with legumes would help to increase soil fertility. Organic sources of nutrients like vermicompost and locally available farm yard manure should be judiciously applied along with chemical fertilizers for better yield and restoration of soil fertility. Liming will also help to reclaim the soil from acidity. Although the adaptation of high-yielding varieties as also the adaptation of commercial crops require high rate of fertilizers which is available rurally but presently not affordable by the majority of the farmers. Institutional intervention particularly intervention of formal banking system may change the scenario. To check soil erosion, plantation crops, especially fruit plants, should also be tried in some parts of cultivable uplands.

In the homestead (*Barhi*) lands where farmers are already cultivating intensively and applying high levels of inputs like improved seeds, balanced fertilizers, irrigation from nearby well, there is need to identify appropriate high-yielding varieties and to increase input efficiency through experimental trials.

The medium lands provide the highest potential for supporting a variety of crops over an extended cropping period, particularly if there is supplementary irrigation and if farmers plant medium-duration, high-yielding rice varieties requiring moderate inputs of manure and fertilizer in the main season. Construction of water harvesting structures to conserve rainwater for irrigation should be considered. A watershed development approach would be promising in this respect for soil and water conservation.

The most important intervention in the lowlands is to improve short-duration, flash-flood tolerant, high-yielding rice variety for *Aman* season (wet/monsoon) and cold-tolerant, high-yielding rice variety for winter season so that rice-rice system can be practiced. Second, improve the drainage system so that the area can be used for (1) switching from traditional to high-yielding rice varieties, and (2) allowing multiple cropping hence taking advantage of the inherently higher fertility status of the soil.

These technological interventions would be feasible, however, only if they are consistent with the livelihood strategies of the farmers, if the enabling conditions are in place, or if accompanied by other appropriate policy environments, e.g., infrastructure improvement, price policies, etc.

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