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Full Research Article

Efficient Natural Resources Management of Tahakapal Cluster Villages using Geospatial Technologies

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Abstract

False colour composite (FCC) of IRS-P6 LISS IV geocoded data was interpreted in conjunction with survey of India (SOI) toposheet on 1:50000 scale to extract information on existing land use/ land cover, slope, aspect and physiography for characterization and mapping of soils in the cluster village Tahakapal, Block-Tokapal, Dist.-Bastar (Chhattisgarh) under NAIP-3 project. The revenue maps of 1:4000 scale was digitized and converted to vector shape file with attributes of field details like owners name & caste and coverage area, perimeter etc. This revenue map was overlapped to the FCC of mosaic satellite data for retrieving the true land characterization of the project area. Five farming situations were characterized and mapped as per the local names of the agro climatic zone viz. *Badi, Marhan, Tikra, Mal* and *Gabhar*. The *badi* (10.7%) comprises of upland settlement, *marhan* (40.5%) is the upper upland, *tikra* (17%) is the lower upland, *mal* (16.1%) comprises the midland part and *gabhar* (15.7%) is the low lying situation. *Marhan* are un-bunded with steep sloped situation. *Tikr*a is the un-bunded upland entisols with steep slope. *Mal,* the midland, is characterised as Inceptisol, Alfisol, bunded, flat lands and *Gabhar*, the lowland, comprises of bunded, Alfisol/ Vertisol supports crops like long duration paddy in *Kharif* followed by gram, linseed, pea in *Rabi*. Additional water resources in the shape of shallow dug well and farm ponds were constructed following the drainage line of the area. Site specific land use have been suggested and demonstrated with suitable soil and water conservation measures for sustainable land resource management.

1. Introduction

Land resources are under intense pressure due to ever increasing human and livestock population as well as over exploitation, resulting in acceleration of soil degradation (Velayuthum and Bhattacharya, 2000). The per capita land availability is reducing and by the end of 2025, only 0.1 ha will be available (Sarangi et al., 2005). Water is also rapidly failing with unregulated over exploitation of ground water. Statistics on water budget indicates that our country gets about 400 mham of precipitation annually, out of which 200 mham are lost in evapotranspiration. About 135 mham is available on the surface and remaining portion of precipitation joins groundwater through percolation (Sharma and Paul, 1998). As per estimate about 92 mham of the available surface water ultimately goes to the seas despite of constructions of large dams, reservoirs, check dams, water harvesting structures etc. (Sharma and Paul, 1998). The soils and farming situations differ in their morphology, physico-chemical characteristics, inherent productivity and fertility and their response to management practices vary accordingly. Thus, it is imperative to study the soils and farming situations of a particular area for sustainable land use. Due to their influence on many of the environmental issues both direct and indirect, such as loss of biodiversity, changes in hydrological, carbon and nitrogen cycles, and climate change (Vitousek, 1994; Schilling et al., 2010; Gao et al., 2010), it is important that the areas under different land use land cover (LULC) be categorized for adapting suitable management strategies. Improper practices of LULC including deforestation, uncontrolled and excessive grazing, expansion of agriculture, and infrastructure development are deteriorating watershed conditions (Bishaw, 2001), at various temporal and spatial scales (Bisht and Tiwari, 1996). Farming situation comprises of similar conditions of soil type and land use land cover with acute correlation to the land slope. The topography is bifurcated in five local farming situations which was distributed mainly based on soil, land use and slope criteria. The spatial variability of fields is generally overlooked while preparing the natural resource management plan of any region, which questions the adaptability and suitability of the proposed management plan. To make any developmental programme successful, site specific management plan has to be generated and implemented depending on the need of the field. Then only the natural resource management plan will be effectively sustainable and will be widely accepted. Cadastral level plan, based on the farming situations of the field need to be prepared for site specific sustainable natural resource management using geospatial technologies.

Remote sensing technologies have emerged as a powerful and efficient technology for mapping and monitoring of natural resources of earth surface environment. The synoptic coverage, multispectral and multi temporal sensing capabilities offered by space borne sensors are well suited to inventorying natural resources. Several workers have utilized this technology for characterization of land resources on different conditions at different scales (Shrivastava and Saxena, 2004; Velmurugan and Carlos 2009) and on watershed basis (Shukla et al., 2009; Patil et al., 2010; Patil et al., 2010). It also provides adequate information in terms of landform, terrain, vegetation as well as characteristics of soils which can be utilised for land resources management and development (Manchanda et al., 2002).

The present study was undertaken with a specific objective of developing site specific land and water resource management plan at cadastral/ field level for providing management plan to individual farmer, looking to the availability of natural resources at their disposal.

2. Materials and Methods

2.1. Study area

Tahakapal cluster village under National Innovation Agriculture Project, sub component III, comprises of three villages namely, Tahakapal, Tandpal and Gumiyapal. The villages comes under Tahakapal Panchayat, Block-Tokapal, District-Bastar (Chhattisgarh) and is located between 81°50' and 81°53' E longitudes and 19°8' and 19°6' N latitudes with an area of 970.45 ha. The project was implemented during 2008-2012 with the objective of improving and providing sustainable livelihood to the tribal farmers of the region. The general elevation of the area ranges from 534 to 661 m above mean sea level (MSL).

2.2. Climate

The climate of Chhattisgarh state in general is sub-humid type with an average rainfall of about 1400 mm. The day time temperatures during peak summer season are usually very high in the entire area varying to 38°C at Jagdalpur in the second-fortnight of May. The monsoon sets in around 10th June in the southernmost tip of Bastar district and finally extends over the entire area by 25th June. Rainfall during July and August is high (about 350-400 mm) at all places. It is assured and stable till mid September. The monsoon normally starts withdrawing from northern part from 15th September and withdraws from the entire area by 1st October. The winter conditions set in by mid November when the average minimum temperature reaches around 15°C. The atmospheric humidity is usually low (maximum humidity around 30-40%) during summer months (March-May). However, right from second fortnight of May, the humidity slowly starts building up and as soon as the monsoon onset, it reaches a peak value of over 90%. The high humidity conditions persist till end of October in most of the places. During July and August, the average bright hours of sunshine are around 2-3 hours day^{-1}. During active monsoon season, the bright sunshine hours become zero continuously for more than 10 days. As regards evaporation rates, peak rates of evaporation exist during the summer months. Also the evaporation and evapotranspiration value increases by two to three folds during May. The major crops grown in the area are paddy, maize, small millets, niger, horse gram in *kharif* and chickpea, lentil, pea, lytharus in *rabi* on residual moisture.

Bastar Plateau Agro Climatic zone comprises of 29% of total geographical area of the State and includes Bastar, Dantewada, Bijapur, Kondagaon, Narayanpur, Sukma along with some parts of Kanker District. The major soil groups of the agro climatic zone are Entisol (26%), Alfisol (25%), Inceptisol (34%), Vertisol (10%) and Alliuvial soil (5% of geographical area). Entisols of Bastar are coarse textured, well drained and eroded soils with low water holding capacity. The soil have 15-25 cm rooting depth, occur on strongly slopping escarpment or on gently sloping plateau, have developed from granite or shale and are under deciduous forest and mixed vegetation. Inceptisols of Bastar, excluding vertic Inceptisols, are light textured, shallow and have poor water holding capacity. They have developed on upper piedmont from granite gniess and quartzite schist and are under forest and natural vegetative cover. Alfisols have been derived from feldspathic quartzitic schist, alluvium or colluvium and occur on gently sloping subdued plateaus, as well as on upper and lower piedmonts. Vertisols have good production potential due to high water holding capacity, ample depth, high clay content, good fertility and response to fertilizer use (Singh et al., 2010).

2.3. Methodology

Multispectral satellite data of IRS P6, LISS IV sensor with 5.8 m spatial resolution and panchromatic satellite data of Cartosat-1 with 2.5 m spatial resolution was acquired of the project area under National Agriculture Innovation Project (NAIP) sub component-3 (sustainable livelihood security), and were merged to get high resolution multispectral satellite data of 2.5 m spatial resolution. The toposheets on 1:50000 scale from Survey of India was used to prepare the base map and derivation of contour lines for the DEM. The cadastral map of 1:4000 scale was acquired for the Department of Land Revenue, Government of Chhattisgarh, for the field level information of the cluster village. The toposheet and cadastral maps were digitized and georectified. The database of field level information from the land records and cadastral maps was generated to give the clear picture about the land holdings of the inhabitants. ERDAS Imagine 10 and ArcGIS 10 software were used for image processing and GIS work. Pixel based classification was adopted for the classification of land use/ land cover from the satellite image. Digitized revenue or cadastral map was used to delineate each and every field with the creation of digital database of the land records.

Following resampling and geometrically corrected near-infra red, red and green bands of the merged MX LISS IV+PAN data was used to generate a false color composite (FCC) of the study area. Supervised classification was used to identify the various land cover pattern of the area and delineation of water bodies. Data obtained by GPS (global positioning system) were used for pixel based image classification. Various thematic maps were generated like soil, land use, land cover, drainage network, DEM, slope and aspect map. Soil sampling density of 5 ha was considered to get representation of the five farming situations for analyzing the profile of the study area. Standard image interpretation characteristics such as tone, texture, shape, size, pattern, association along with sufficient ground truth and local knowledge were used to finalize these maps. The soil sample of all the villages were analyzed for giving the field condition of the project area in perspective of farming situation and fertility. The appropriate locations for excavating farm ponds and RCC shallow dug out wells were identified based on the farming situation, slope, aspect, land use and cover maps.

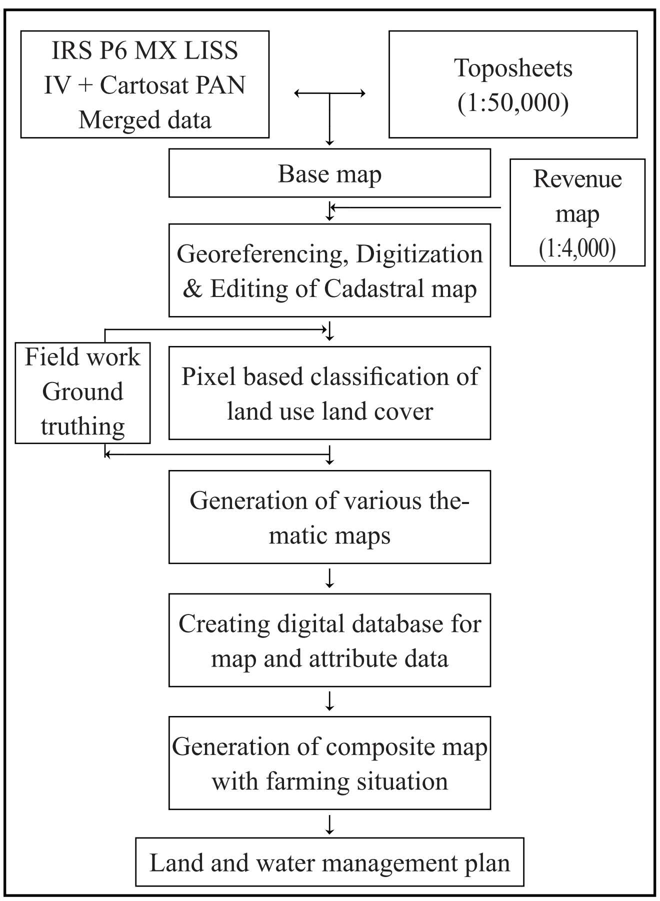

Figure 1: Layout showing methodology of the study

3. Results and Discussion

3.1. Land use/ land cover

Based on image characteristics, the major land use/ land cover identified (Figure 2) are agricultural land (267.8 ha), Barren land (289.3 ha), present fallow (190.2 ha) and open land with shrubs (114.4 ha). Other land use were delineated as settlements, open forest, shallow and deep water bodies with 55.2 ha, 43.2 ha, 5.7 ha and 4.5 ha area respectively. On analyzing the present land use/ land cover pattern it can be clearly identified that more than 49% of land is still unused and has to be brought under cultivation by adopting suitable and sustainable management plan.

3.2. DEM and slope

Digital Elevation Model (DEM) was generated (Figure 3) using the contour map along with the field surveys done using global positioning system (GPS). The elevation of the project area was found to be in the range of 534-661 m above mean sea level. The DEM was generated by the classifying the relief in seven classes. Five slope classes (Figure 4) viz. (a) flat (0-1.2% slope) covering an area of 483 ha (b) gently slope (1.3-3.8% slope) covering an area of 243 ha, (b) moderate gently slope (3.9-7.9% slope) covering an area of 181 ha, (c) moderately steep slope (8-14.5% slope) covering an area of 48 ha and (d) steep slope (25-35% slope) covering an area of 15 ha has been derived (Figure 4). The slope map played the major role in delineating the farming situations for preparation of site specific management plan.

3.3. Soils

The soil texture of the Tahakapal cluster village (Figure 5) varies from sandy loam to clay loam with six classes comprising of the least dominance of clay loam, loamy sand and sandy loam contributing merely 2%, 2% and 4% area respectively. The dominating soil texture in the project site are sandy clay loam, gravelly loamy sand and very gravelly clay loam with 47%, 28% and 17% area respectively. The soil depth of the project site (Figure 6) varies from 0 to 175 cm with soil depth map generated and classified in seven classes. The major portion of the cluster is dominated by deep to very deep soil depth in the range of 90-175 cm covering an area of 496.53 ha. Moderate deep (45-90 cm), shallow (22.5-45 cm) and very shallow (0-45 cm) depth range of soil (Anonymous, 1998) is occupied by 167.23 ha, 17.2 ha and 289.47 ha of land of the cluster village respectively. The soil depth classified played major role in identifying and delineating the farming situation of the Bastar plateau agro climatic zone. The maximum depth was obtained in the low lying area of the cluster whereas the midland and upland comprises of medium and low range of soil depth respectively. Land use was found to be highly correlated with the soil characters. Very shallow depth soil was occupied largely by barren land and settlement, shallow to moderate deep soil depth were occupied mainly by present fallow, open land with shrubs and agricultural land whereas deep to very deep soil largely comprises of agricultural land and water bodies.

3.4. *Socio-economics*

The data on farm holdings in Tahakapal cluster village of NAIP-3 (Table 1) as per the attributes of cadastral map (Figure 7) indicate that 86.50% of farm holdings are marginal giving the impression of very small sizes of farm of the cluster village, 10.34% of farm holdings are small, 2.53% are medium and 0.63% are large. This statistics revealed that the management plan has to be developed for dominant very small farm holdings. The data collected from farmer's field by survey indicated that paddy is mainly grown in the area with some small fields covered under of small millets, horse gram, niger and maize.

Table 1: Farm holdings in Tahakapal cluster village under NAIP-3

Farm holdings	Farm size (ha)	Gumi-yapal	Taha-kapal	Tan-dapal	Total	%
Marginal	< 1.0	235	300	285	820	86.50
Small	1.0-1.99	29	42	27	98	10.34
Medium	2.0-3.99	11	5	8	24	2.53
Large	> 4.0	3	2	1	6	0.63

3.5. *Farming situations*

Based on the visual interpretation and field survey, five farming situations (Figure 10) viz. *badi, marhan, tikra, mal* and *gabhar* were identified and characterized based on soil morphology, land use, land cover, drainage, slope and aspect. *Badi* is the settlement area of the village*, marhan* and *tikra* are the upper and lower upland respectively, *mal* is the midland and *gabhar* is the low lying area of the region. The *badi* (10.7%) comprises of upland settlement, *marhan* (40.5%) is the upper upland, *tikra* (17%) is the lower upland, *mal* (16.1%) comprises the midland part and *gabhar* (15.7%) is the low lying situation. *Marhan* are un-bunded with steep sloped situation, *Tikr*a is the un-bunded upland entisols with steep slope, *Mal is* the midland and is characterised as Inceptisol, Alfisol, bunded, flat lands whereas *Gabhar* is the lowland, comprises of bunded Alfisol/ Vertisol. The characteristics of different farming situations is

Table 2: Soils of bastar plateau agro climatic zone

Farming situations	*Badi*	*Marhan*	*Tikra*	*Mal*	*Gabhar*
Condition	Homestead garden	Upper upland	Lower upland	Midland	Lowland
Slope	Undulating slope	Undulating slope	Undulating slope	Plain	Plain
Soil type	Entisol/ Inceptisol	Entisols	Entisols/ Inceptisols	Inceptisol/ Alfisol	Alfisol/ Vertisol
Soil Texture	Sandy clay loam/ Very gravelly clay loam	Gravelly loamy sand/ gravelly sandy loam/ sandy clay loam/ Very gravelly clay loam	Gravelly loamy sand/ Sandy Clay Loam/ sandy loam	Gravelly loamy sand/ Sandy Clay Loam/ sandy loam	Sandy Clay Loam/ Clay loam
Soil Depth	0-45 cm	0-45 cm	45-75 cm	75-125 cm	125-175 cm
Cropping pattern	*Kharif* maize, Urd, Vegetables, tomato	*Kharif* Millets and maize, Mid *kharif* horse gram, niger	*Kharif* Millets and maize, Mid *kharif* horse gram, niger	Early to medium maturing paddy	Long duration paddy
Properties	Backyard garden, can be used for protected cultivation	Light gravelly and acidic associated with poor fertility	Light textured, shallow, poor fertility	Deep, medium, texture, moderate fertility	Deep, heavy texture, medium fertility
WHC	Moderate	Poor	Poor	Moderate	High
Production potential	High	Poor	Moderate	High	High
Tree	Tamarind, Mahua, Subabool, Ber, Mango, Sulfi	Tamrind, Ber, Chhind, Mango, Mahua	Tamrind, Ber, Chhind, Mango, Mahua	Ber, Mango, Tamarind, Chhind	Ber, Chhind
Livestock	Poultry, Goat, Cattle, Buffalo	Grazing land for animals	Grazing land for animals	---	---

characterized in tabular format (Table 2)

3.6. Land and water resource management

The integration of physiography, soil, land use, land cover, slope and cadastral maps under GIS environment has brought out the five farming situations of Tahakapal cluster village for implementation under NAIP-3 programme, which leads to identify the areas for alternate land use, resource development and conservation. Land use capability classification (LUCC) map of the study area (Figure 8) shows the dominance of class II and class IV with small portion of class III land. The study area also has a major part of class VI land which can also be utilized for plantation and fodder crops. The topography of the area with *marhan* and *tikra* were identified for upland early maturing variety (*samleshwari, danteshwari, poornima* etc.) of paddy farming, *mal* was identified for cultivation of medium variety of paddy (MTU-1010, IR-64, IR-36, *Karma masuri* etc.) cultivation and *gabhar* farming situation was identified for cultivation of late maturing variety of paddy (MTU-1001, *Swarna* etc.). *Marhan* and *tikra* farming situations were identified for mid *kharif* crops like horse gram (AK-21) and niger (JNC 6) along with finger millets (GPU 28) and Kodo millet (JK 48, JK 41) cultivation. Maize (JM 216) was proposed for protected cultivation in *badi* farming situations. During *rabi*, wheat and chickpea was proposed in the *gabhar* and *mal* farming situation. As *badi, marhan* and *tikra* farming situations covers more than 68% of the total geographic area, it was supposed to be given substantial importance for improving the production and in turn the productivity of the project area. The lithology map of the study area (Figure 9) shows the dominance of shale formation, which supports the horizontal movement of water and in turn, the losses from RCC well will be minimum, as only the bed is unlined. Sites on *bad*i were given priority so as to create the water resource on the backyard space of farmer's which in turn will promote the cultivation of *rabi* vegetables by judiciously utilizing the harvested well

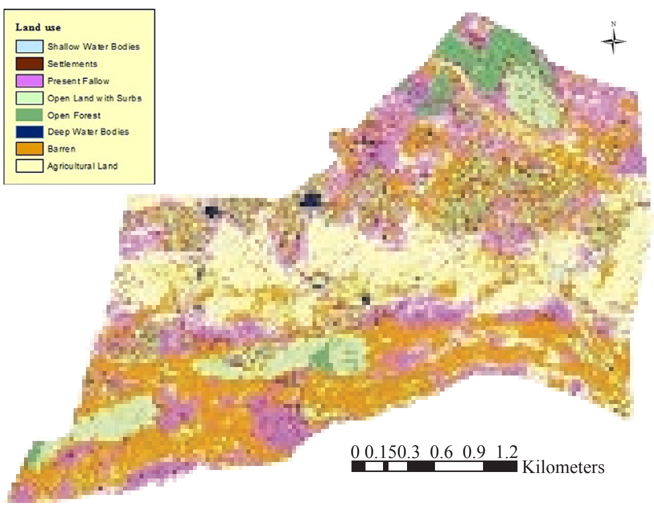

Figure 2: Land use map of study area

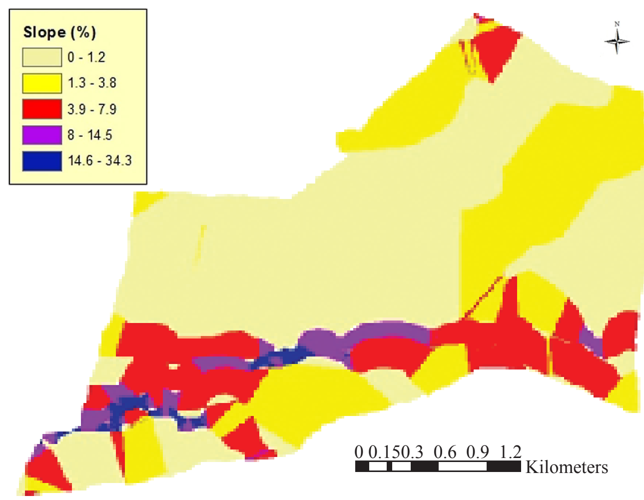

Figure 4: Slope map of study area

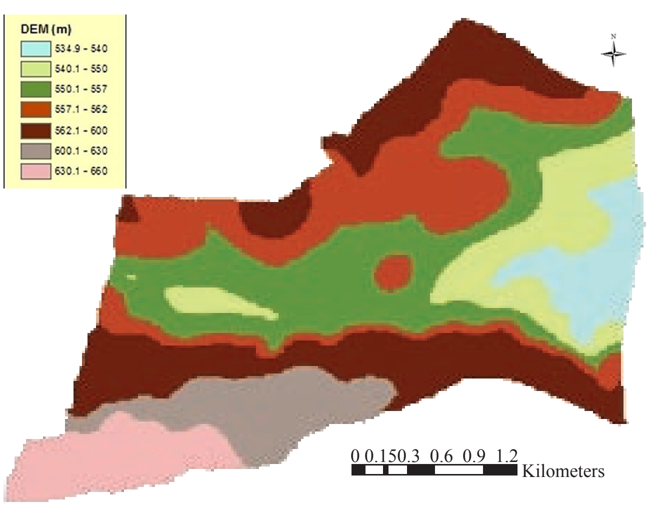

Figure 3: Digital Elevation Model of study area

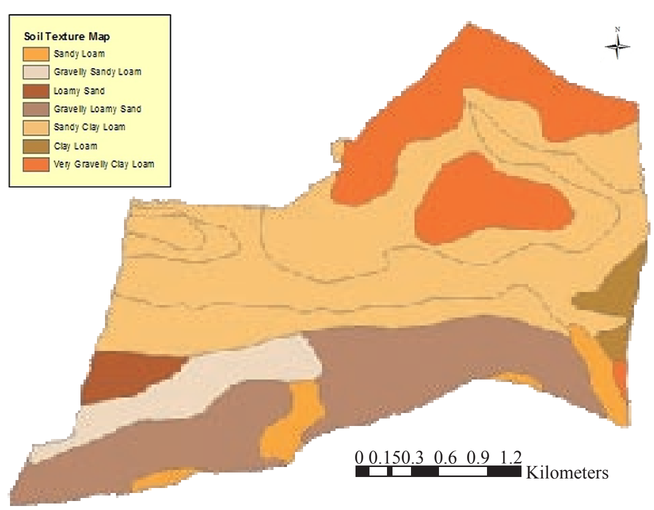

Figure 5: Soil Texture map of study area

water through designed gravity operated drip irrigation system. As the protected upland land viz. badi farming situation were deprived of availability of irrigation water, so water resources in the form of shallow dug out RCC well of 30’ depth and 6’

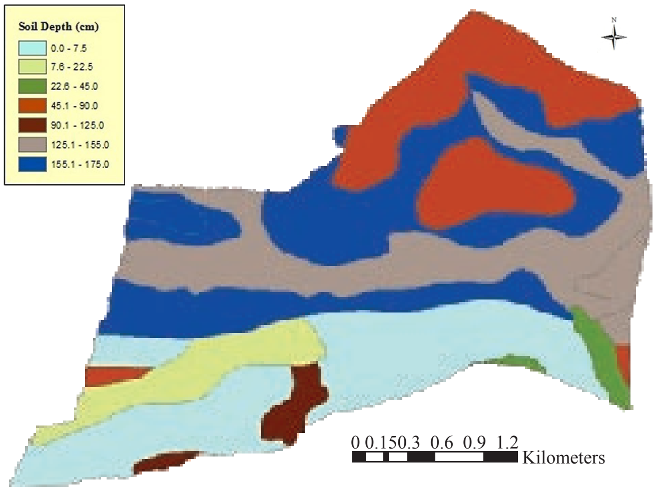

Figure 6: Soil depth map of study area

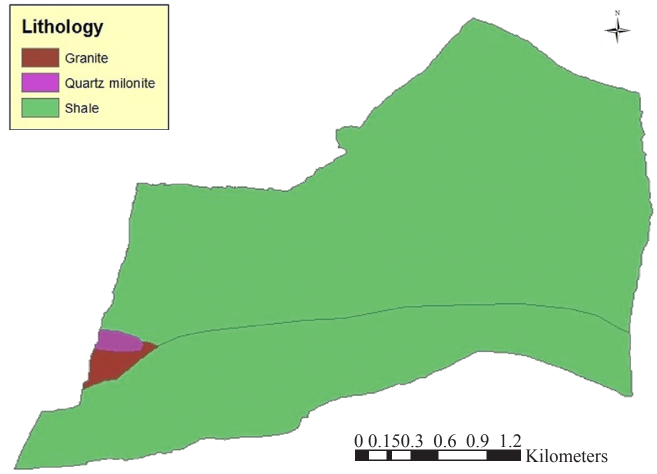

Figure 9: Lithology map of study area

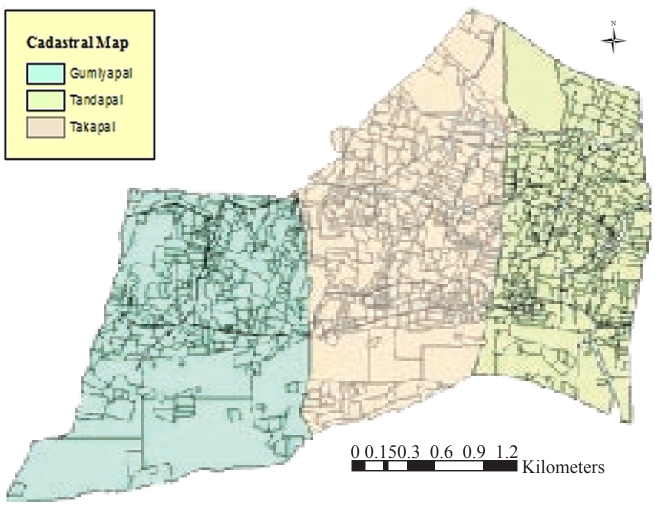

Figure 7: Cadastral map of cluster village

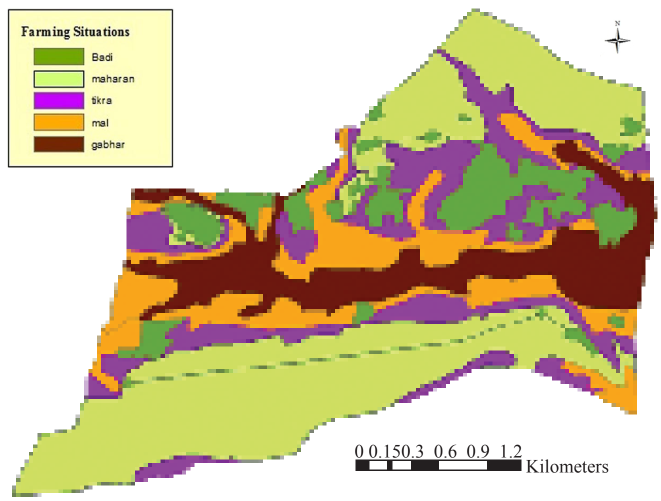

Figure 10: Farming situations of the cluster

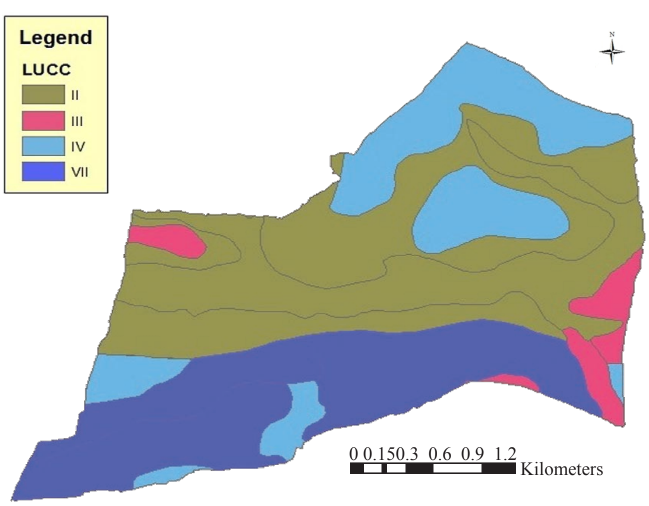

Figure 8: LUCC of the study area

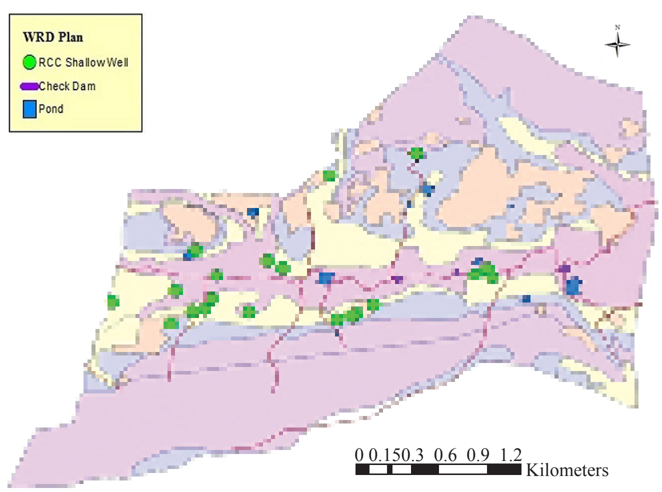

Figure 11: Water resources development plan

diameter were designed to be dug out on suitable sites (Figure 11) conserving and harvesting more than 26000 ltr of water. *Marhan* and *tikra* farming situations were targeted to excavate farm ponds of appropriate sizes based on the catchment command relationship and on the basis of farm availability. These water resources have helped in increasing the production and productivity of the moderately fertile farming situations. Vegetables like tomato, brinjal, chilli, okra etc were grown successfully by the tribal farmers in their small *badi's* which occurred as additional source of income and nutrition to sustain their livelihood. The productivity of crops has doubled due to the interventions along with the increased area of production due to the additional harvested water.

4. Conclusions

In order to make sustainable management plan, due emphasis was given to utilize geospatial techniques for identifying different farming situation and to enhance its potential be adopting necessary land and water resources developmental measures. Appropriate crops with variety and conservation structures were proposed for various farming situations to utilise their maximum potential. The increase in production and productivity of crops reflects the impact of operational strategy for land and water conservation structures based upon geospatial technologies.

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