# SPACE-BASED INFORMATION SUPPORT TOWARDS PREPARATION OF DEVELOPMENTAL PLANS FOR NATURAL RESOURCES MANAGEMENT IN RURAL AREAS

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**KEY WORDS:** NRM, Developmental Activity Planning, Multi-Criteria Analysis, Decision Support System (DSS)

**ABSTRACT:** Planning for natural resources management (NRM) demands an integrated approach, considering numerous thematic inputs to be relatively studied in a GIS environment. In India, with a decentralized governance setup, the task of developmental planning in the rural areas is entitled to Panchayati Raj Institutions (PRIs) as per the 73rd Constitutional Amendment Act. In order to assist PRIs in making informed decisions with scientific justifications, a geospatial enabling platform is needed where NRM activities are planned based on logically-derived micro-zones of suitability. A platform with such an objective, named 'Bhuvan Panchayat' is developed and hosted under SIS-DP project of ISRO, which integrates the high resolution satellite imagery and associated spatial and non-spatial database in a web-GIS framework. This study attempts towards developing an operational methodology for generating land and water resources developmental plans (LRDP and WRDP), which dovetails with annual action plans of respective Gram Panchayats, using geospatial layers such as land cover, slope, drainage, soil, geomorphology and groundwater prospects. When examined with the existing NRM asset data, it will help in finding the gap areas where the new activities may be planned.

## 1. INTRODUCTION

### 1.1 Natural Resources Management: Rural Perspective

The management of natural resources encompasses the approach of physical improvement of land, with emphasis on soil and water conservation (Dalal-Clayton et al., 2013). For Asian countries, three-fourth of the poor resides in rural areas, whose livelihood is majorly dependent on the natural resources (Rao et al., 2016). In this view, the natural resources are under huge pressure, with a rising need to manage them, ensuring that they are neither degraded nor depleted (Srivastava et al., 2016). It is a challenging task for the existing rural developmental schemes to incorporate the vision of natural resource management as their implementation is often based on short term interests (Yoon, 2006). Adoption of watershed based approach in the governmental policies was much appreciated in general, as it reaped visible benefits in rural areas with active participation from common masses (Prasad et al., 2016). Further to this, we need to define the agro-ecological zones where natural resources management systems may be adopted in a sustainable manner (Rao et al., 2016). To improve the plot-wise productivity, conservation plans and management strategies need to be regulated based on scientific farm-specific land resources database (Natarajan et al., 2016).

### 1.2 Participatory NRM Planning

It is often advocated that planning for NRM must include the users of natural resources (Vincent, 2003). Planning should not be formulated by the persons remote from the area concerned (Dalal-Clayton et al., 2013). Local people must play an active role by participating in the planning process. Participatory methods help lessen the adoption of inappropriate technologies (Vincent, 2003). Sharing of knowledge among stakeholders is an important characteristic of participatory NRM (Ashby, 2003). In India, numerous Central and State Governmental schemes are operational that strive to converge serving for an NRM component. Constitutionally, the Gram Panchayats, which act as a basic administrative unit in India, are entrusted with the tasks that include land and water resource development activities (Schedule XI, Constitution of India). Further, with the 73rd Constitutional Amendment in 1993, the power to formulate own developmental plans is entrusted to the Panchayati Raj Institutions (PRIs).

Requirement stands high for a single integration platform where (i) Panchayat-level interlinked database is available with visualizing and analysing capabilities; (ii) technical experts are provisioned to suggest; (iii) local planners are provisioned to propose plans as per experts' suggestions and local needs; and (iv) decision makers approve or reject the plans as per the inputs from all the participants in the process.

### 1.3 Public Participation GIS (PP-GIS) Platform for Integration

Geographic Information System (GIS) has an important role to play in the spatial planning practice, with participatory methods contributing to the success of planning support systems (Geertman, 2002). GIS for sustainable rural development should assist decision makers and planners in formulating policies at the regional and national levels (Kumar and Misra, 2003). PPGIS is a perfect answer to the problem of integrating experts' knowledge with lay knowledge (Figure 1). But, technological complexity acts as a hindrance for any participatory research towards sustainable NRM (Vincent, 2003). There is a need to marry local and external knowledge with a focus on local needs and user-friendliness. The technology needs to move from 'laboratory to land' and should focus from 'doers to users' (Adinarayana et al., 2006). Often focus is limited to dissemination of data and information to people; enabling a participatory environment is absent, which, if created, would be crucial to convert information into knowledge (Yoon, 2006).

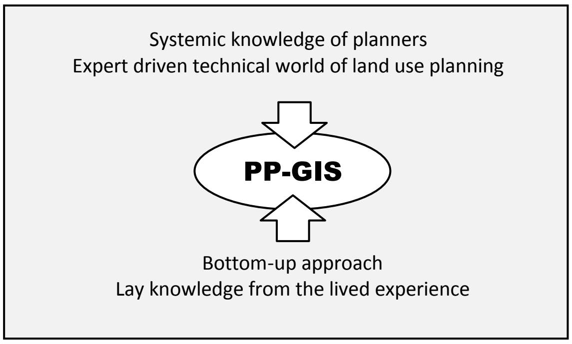



**Figure 1:** Conceptual representation of PP-GIS (Modified from Brown and Kytta, 2014)

### 1.4 Bhuvan Panchayat Platform

An enabling environment named Bhuvan Panchayat Portal is developed and hosted by NRSC (ISRO) under the project named 'Space-based Information Support for Decentralized Planning (SIS-DP)'. The web-portal integrates geospatial layers derived from space-based inputs in a web-GIS framework with interactive modules like Area Profile Report Generation, Asset Mapping, Activity Planning and Implementation-Monitoring for facilitating effective developmental planning in the light of Gram Panchayat Developmental Plan (Rao et al., 2015).

### 1.5 Problem Statement

For the task of NRM planning, a systematic study of databases on natural resources is the need of the hour (Rao et al., 2016). With the datasets available on spatial platform of Bhuvan Panchayat, and with scientific inputs, suggestive layers with micro-zonation are to be derived, that may serve as a guide for planners in a bottom-up model. Local-level plans prepared as per these suggestions would ensure a sustainable NRM.

## 2. STUDY AREA

Masooda Block of Ajmer District in Rajasthan was chosen as the study area (Figure 3). The block consists of 34 Gram Panchayats (LGD, 2017). The Block is listed under the head 'over-exploited' in terms of groundwater, by Central Ground Water Board, Govt. of India.

## 3. DATASETS USED

The following were the datasets used in this study:

**Satellite Imagery:** A 2.5m spatial resolution natural colour composite was prepared using the fused product of ortho-rectified CartoSAT-1 and LISS-IV, to use in the study as a base layer (Figure 4). The fused imagery was prepared as part of the SIS-DP project.

**Raster DEM:** The digital elevation model (DEM) was prepared using Bundle Block Adjustment performed on CartoSAT-1 stereo pairs and the raster DEM with 10m posting was generated after necessary editing using breaklines (Figure 4). The product was one amongst the various outputs of SIS-DP project.

**Land Cover:** Land cover refers to physical state of the land surface. The land cover layer was prepared based on the 2.5m satellite imagery with a mapping scale of 1:10,000 and was classified in to 30 classes which extensively included all the important features (Figure 5a).

**Slope:** The slope layer, expressed in percentage, was derived from DEM and was classified into 7 classes as shown in Figure 5b.

Apart from the above datasets, a few of the legacy database, with the mapping scale of 1:50,000 prepared under various projects by NRSC/ISRO were also used. Among them are Land Capability Classification layer (Figure 5c), Ground Water Prospects layer (Figure 5d) and Geomorphology layer (Figure 5e).

## 4. METHODOLOGY

With the aim to create homogeneous micro-zones, a composite mapping unit was generated using the input datasets over which multi-criteria analysis was performed (Figure 2).

### 4.1 Generating Land Resource Development Plan (LRDP)

For LRDP, the input datasets used were (i) existing land cover, (ii) percentage slope, (iii) land capability classes and (iv) ground water prospects. Vector-based union operation was performed to arrive at the homogeneous micro-zones. With the union operation, sliver polygons were generated which were removed using elimination operation in ArcGIS. During this operation, polygons with the area less than 0.14 hectare were merged with one of their neighbouring polygons having the longest shared border (the threshold of 0.14 ha was chosen considering the pragmatic conditions while ground level implementation of the action plans). Subsequent to this, the micro-zones were classified based on the criteria as shown in Table 1. Technical guidelines of various governmental schemes like MGNREGA, IWMP and PMKSY as well as guidelines from Integrated Mission for Sustainable Development (IMSD, 1995) were considered while consolidating the various criteria. While classification the priority order was considered from top to bottom in the table. In this way, intensive agriculture was given the top priority given the conditions matched as per requirement. The output LRDP is shown in Figure 6.

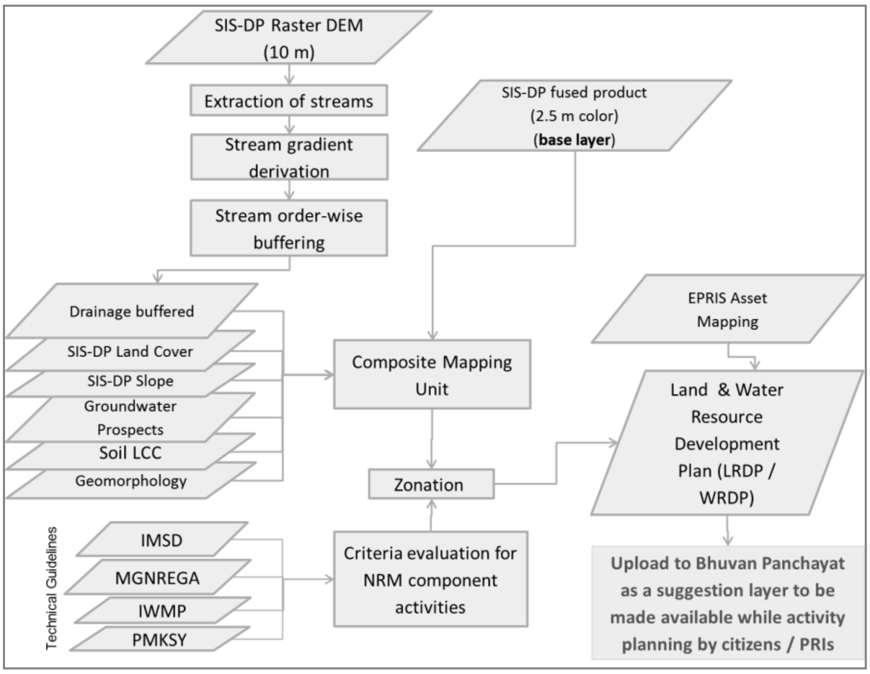


**Figure 2:** Flowchart of the methodology adopted

### 4.2 Generating Water Resources Development Plan (WRDP)

For WRDP, firstly, the ordered streams were derived from the SIS-DP raster DEM using the hydrology toolset of ArcGIS (Figure 5f). Secondly, gradient for each segment of the derived stream network was calculated using DEM values at each of the vertices of the stream segment and length of that segment. Thirdly, the stream network was given a buffer area based on the stream order (streams with higher order bearing the larger buffer size). This buffered drainage layer was then used as one of the inputs during the union operation along with land cover, percentage slope, and geomorphology layers. Slivers generated were eliminated as described in LRDP generation process. The homogeneous micro-zones were then classified based on criteria as shown in Table 2. Canal command area was delineated and areas falling under this region were kept separated from all of the above operations. The output WRDP is shown in Figure 7.

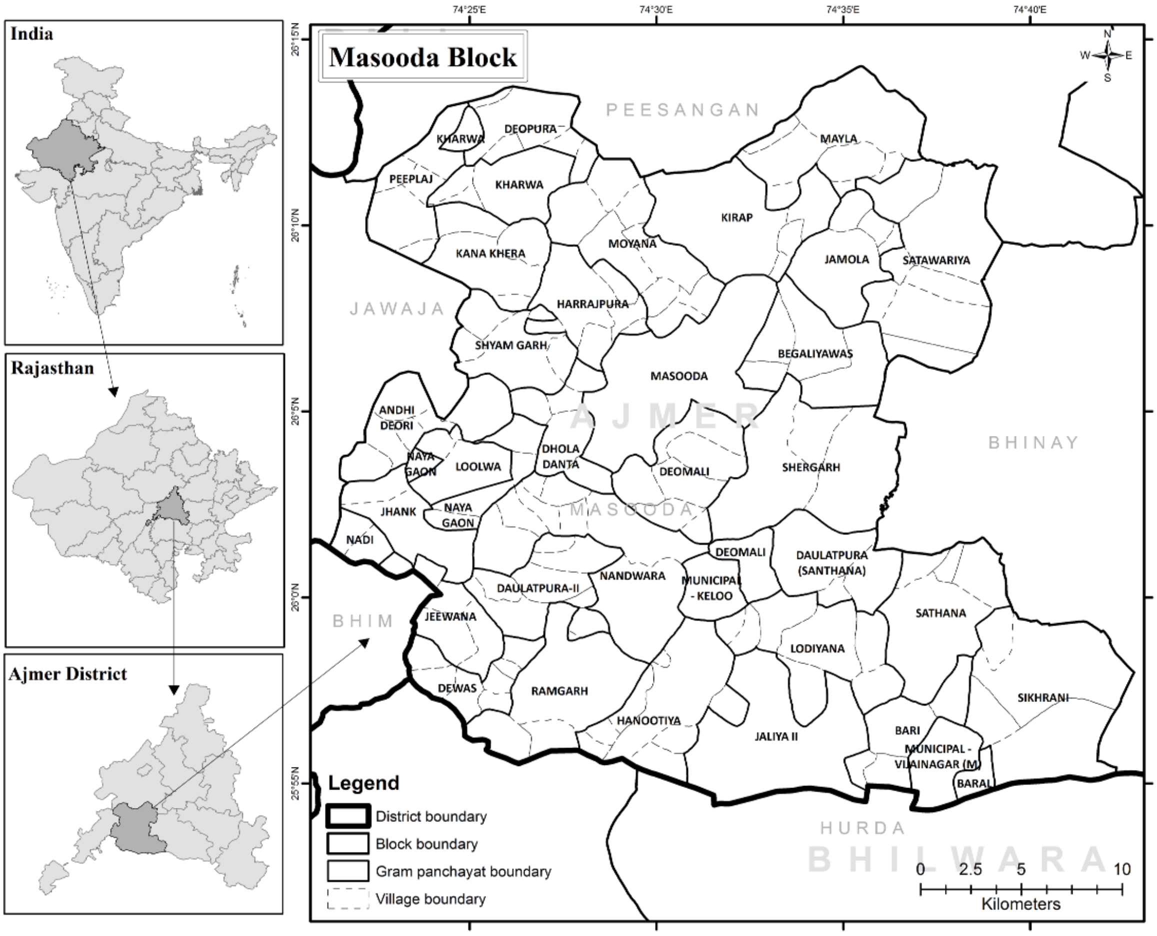



**Figure 3:** Index map of the study area – Masooda Block of Ajmer District in Rajasthan

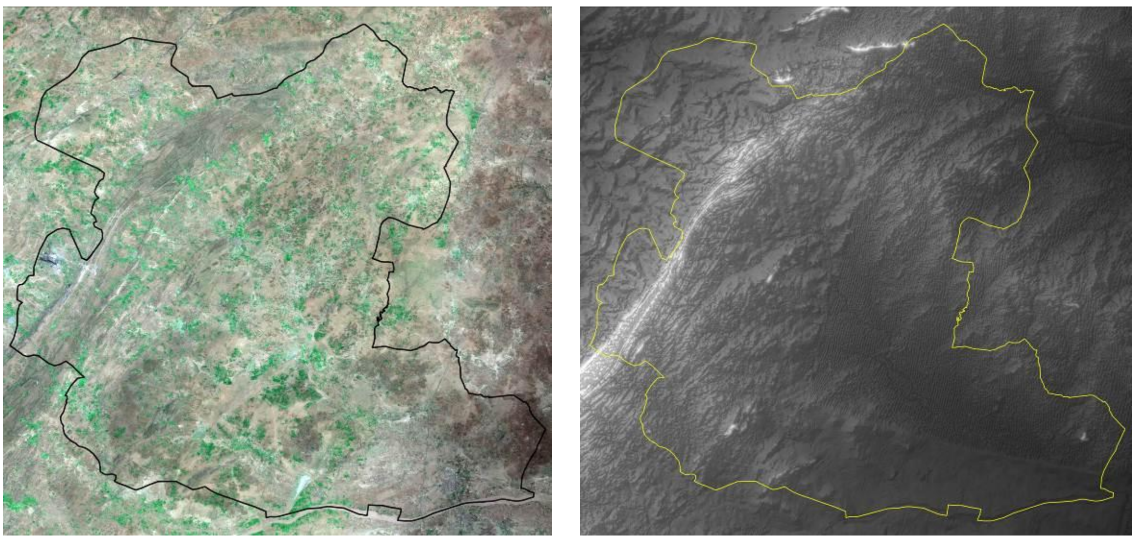
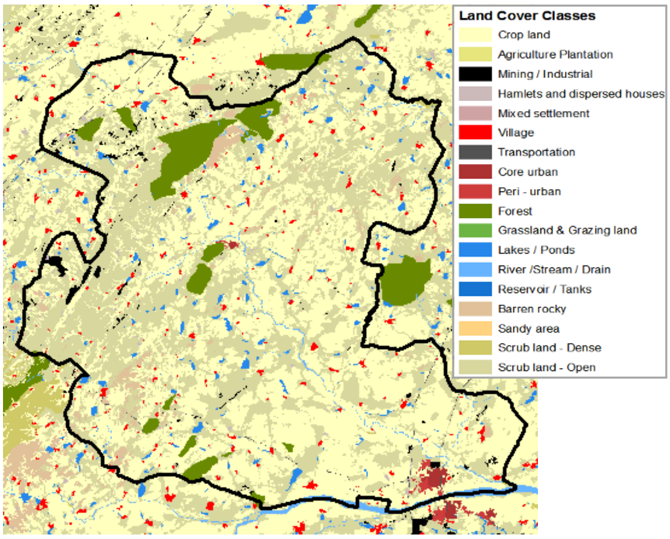
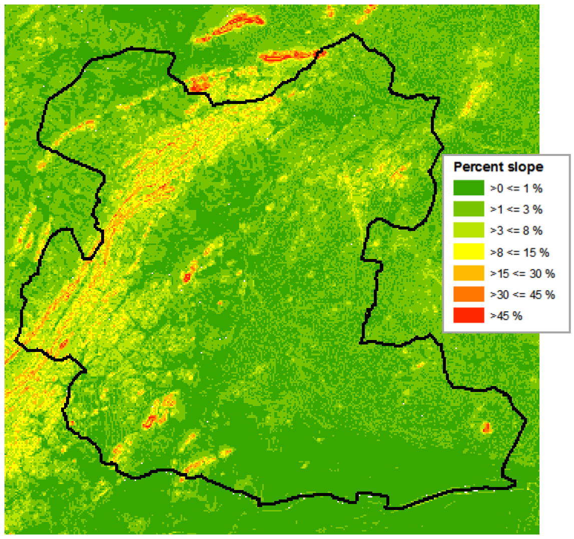


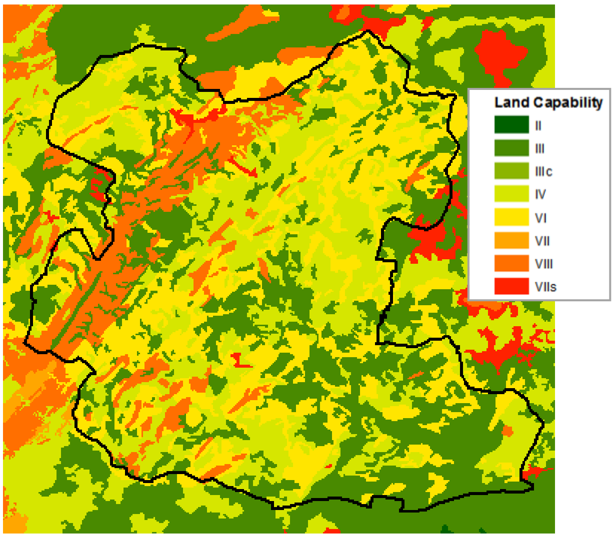
**Figure 4:** Satellite imagery **–** a natural colour composite *(left)* and DEM of the study area displayed with a hillshade effect *(right)*



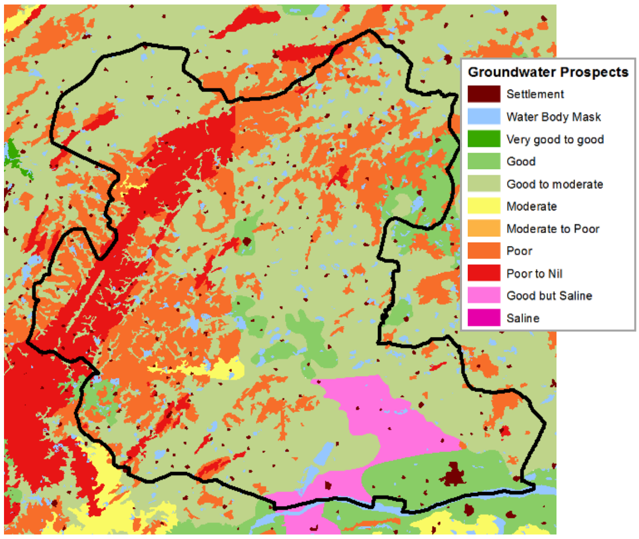

(a) Existing land cover map (Mapping scale 1:10,000)



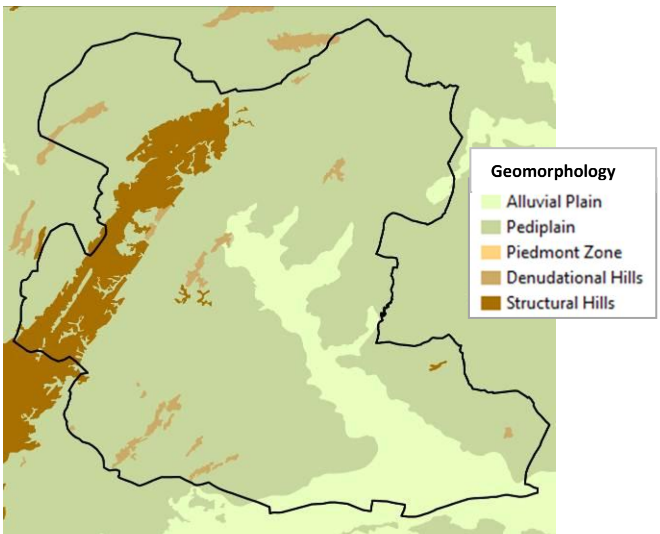

(b) Percentage slope map (derived from 10m DEM)



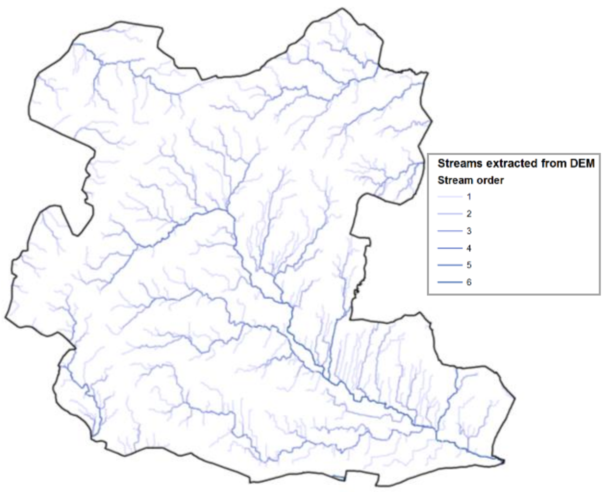

(c) Land Capability Classes map (Mapping scale 1:50,000)




(d) Groundwater Prospects map (Mapping scale 1:50,000)




(e) Geomorphology map (Mapping scale 1:10,000)




(f) Streams extracted from 10m DEM

**Figure 5:** Various space-based thematic inputs used in the study

**Table 1:** Generalized Criteria for Land Resource Development Plan (in order of priority)

| Existing land cover | % Slope | Land capability | Groundwater prospects | Development plan |
|---|---|---|---|---|
| Crop land | 0 – 8 | I, II, III, IIIc | Excellent, Very good to good, Good, Good but Saline, Good to moderate, Moderate | Intensive agriculture |
| Scrub land | 0 – 3 | I, II | Excellent, Very good to good, Good, Good but Saline, Good to moderate | |
| Crop land | 0 – 3 | I, II | Moderate to Poor, Poor, Poor to Nil | Agro-horticulture |
| | | III, IIIc | Moderate | |
| | | IV | Excellent, Very good to good, Good, Good but Saline, Good to moderate | |
| | 3 – 8 | III, IIIc | Excellent, Very good to good, Good, Good but Saline, Good to moderate | |
| | 8 – 15 | I, II | Moderate, Moderate to Poor, Poor, Poor to Nil | |
| | | IV | Excellent, Very good to good, Good, Good but Saline, Good to moderate, Moderate | |
| Scrub land | 3 – 8 | I, II | Excellent, Very good to good, Good, Good but Saline, Good to moderate | |
| Crop land | 0 – 3 | IV | Moderate, Moderate to Poor, Poor, Poor to Nil | Agro-forestry |
| | 3 – 8 | IV | Excellent, Very good to good, Good, Good but Saline, Good to moderate | |
| | 8 – 15 | III, IIIc, IV, V ,VI , VII, VIIs, VIII | Excellent, Very good to good, Good, Good but Saline, Good to moderate, Moderate, Moderate to Poor, Poor, Poor to Nil | |
| Scrub land | 8 – 15 | I,II | Excellent, Very good to good, Good, Good but Saline, Good to moderate | |
| Scrub land | 8 – 15 | I,II | Moderate, Moderate to Poor, Poor, Poor to Nil | Horticulture |
| | | III ,IIIc, IV | Excellent, Very good to good, Good, Good but Saline, Good to moderate | |
| Scrub land | 8 – 15 | III ,IIIc, IV | Moderate, Poor, Poor to Nil | Silvipasture |
| | | V ,VI , VII, VIIs, VIII | Excellent, Very good to good, Good, Good but Saline, Good to moderate, Moderate, Moderate to Poor, Poor, Poor to Nil | |
| Scrub land | 0 – 8 | III ,IIIc, IV | Moderate, Moderate to Poor, Poor, Poor to Nil | Fuel wood plantation |
| Barren rocky, Gullied / ravenous | Any | Any | Any | Vegetative barriers |

**Table 2:** Generalized Criteria for Water Resource Development Plan (in order of priority)

| Geomorphology | Existing land cover | % Slope | Stream order | Stream gradient | Development plan | |
|---|---|---|---|---|---|---|
| Structural hills and denudational hills | - | - | - | - | Contour trenches | Ridge Area Treatment |
| Pediment-Inselberg Complex, Piedmont Slope | - | - | - | - | Earthen contour bunds | |
| - | NOT Lakes/Ponds | - | $1^{st}$ , $2^{nd}$ | < 5% | Loose boulder checks | Drainage Line Treatment |
| - | NOT Lakes/Ponds NOT Crop Land | - | $3^{rd}$ , $4^{th}$ | < 1% | Gabion structures | |
| - | - | - | $5^{th}$ , $6^{th}$ | < 5% | Earthen dams (percolation) | |
| - | - | - | $6^{th}$ and above | | Minor irrigation tank (surface water) | Drainage Line Treatment & Water Harvesting |
| - | - | - | $6^{th}$ and above | < 1% | Underground dykes (groundwater recharge) | |
| - | Crop land | 8-15% | - | - | Khadins | Arable Areas Treatment |
| - | Crop land | 3-8% | - | - | Farm bunds | |
| - | Crop land | 0-3% | - | - | Dugout farm ponds | |

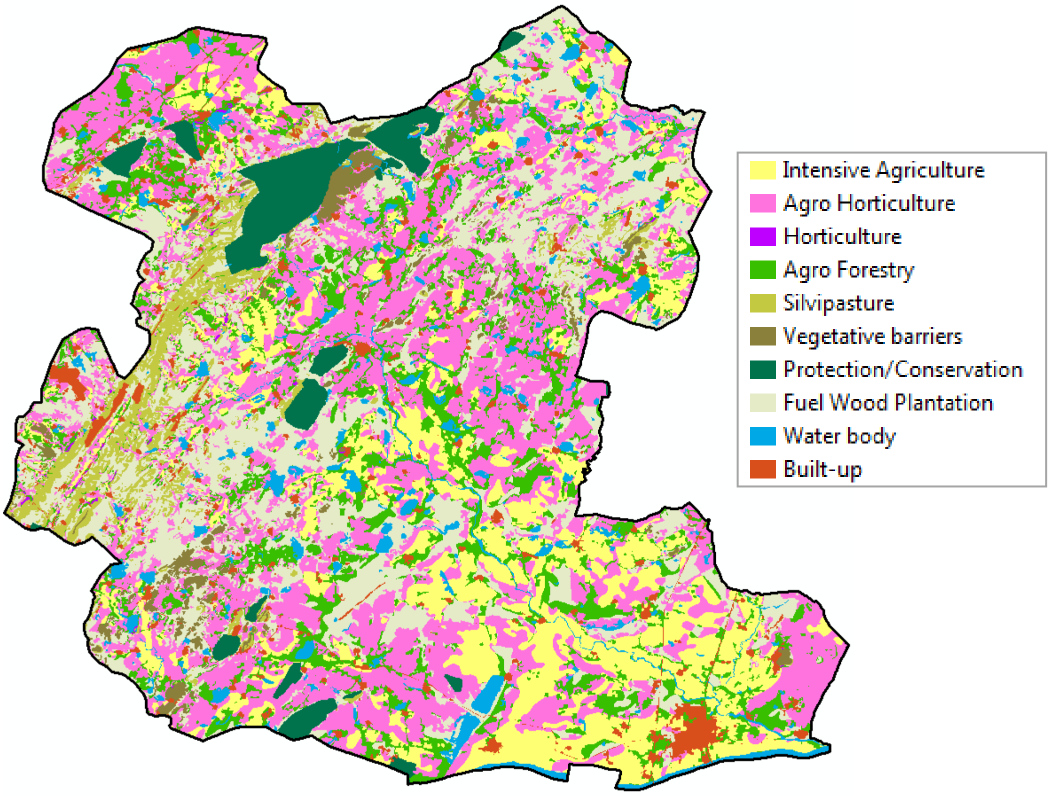



**Figure 6:** Land Resources Development Plan for the study area

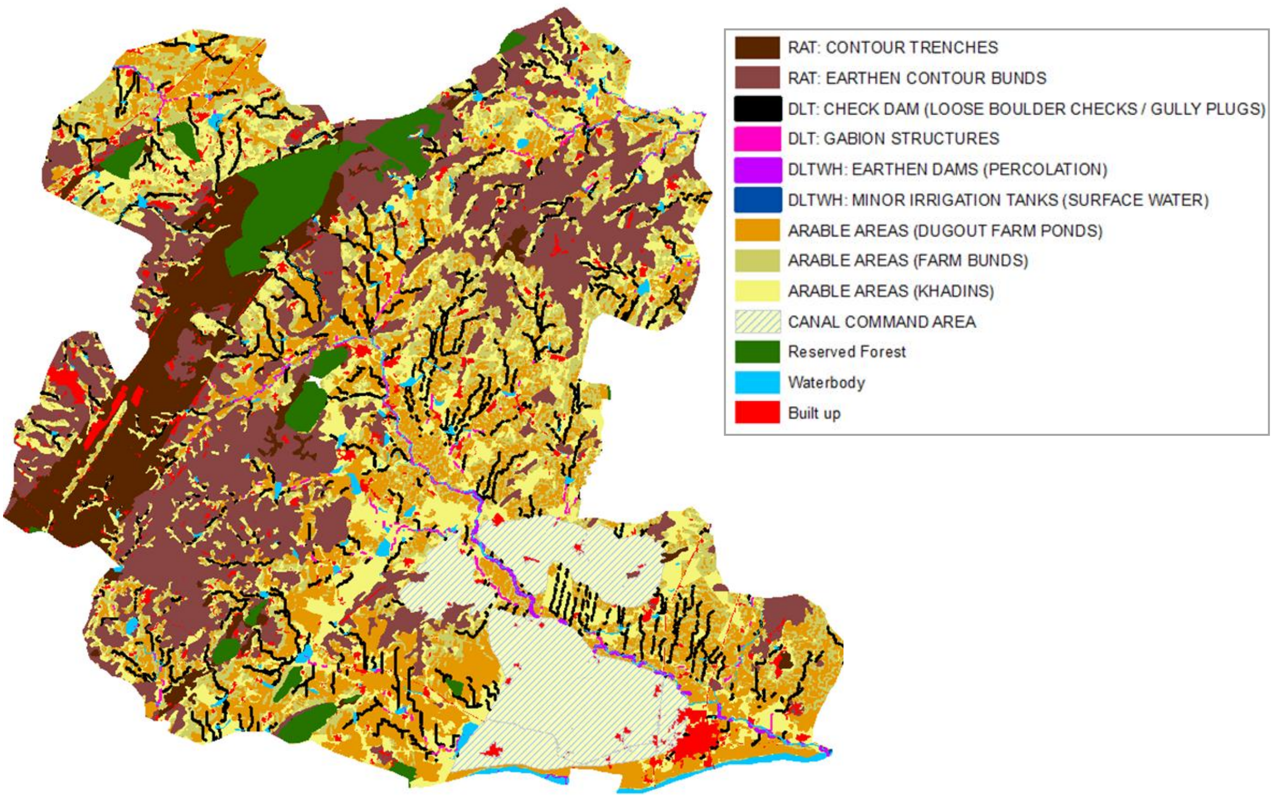



**Figure 7:** Water Resources Development Plan for the study area (Abbreviations: RAT = Ridge Area Treatment; DLT = Drainage Line Treatment; DLTWH = Drainage Line Treatment & Water Harvesting)

## 5. RESULTS AND DISCUSSIONS

From the output LRDP (Figure 6), it may be observed that much of the intensive agriculture is recommended towards relatively flatter regions in the valley side of the Block under study. Fodder and fuel wood plantation is recommended as a lower priority measure when no other plan is found suitable for recommended up-gradation. The areas under reserved forest, water bodies and settlements are kept untouched.

Table 3 shows the area statistics for recommended land resource development vis-à-vis existing land cover for a Gram Panchayat in the study area. About 21% of the agricultural land is recommended for upgrading to intensive agricultural practices, while 74% of the land under agriculture is recommended for agro-horticulture. The remaining about 5% of the agricultural land is found to be suitable for agro-forestry. Similarly, out of the total wastelands in Shergarh GP, about 62% is suitable for agro-forestry, while fuel wood plantation is recommended for about 38% of existing wasteland. The land areas for protected forests, water bodies and built-up in the plan remain same, as existing.

The methodology described here is based on the spatial structure at a given time. The outputs may be viewed as just one realization of many potential outcomes with the input conditions. For meaningful interpretations, assumption regarding the stationarity of the process is to be made (Dale & Fortin, 2014). The development block in this study is assumed to be regionally having a condition of stationarity. For implementation of the same model at the country-wide scale, one has to apply spatial partitioning methods to identify homogeneous sub-regions, for the process to remain stationary. Thereafter, the criteria for classification of the zones may be modified as per the prevailing affecting conditions in the partitioned sub-region.

Even after the recommended plans are prepared, one may find that ground level measures are already been taken as per the suggestions. Hence, the spatial inventory of assets plays a key role here, using which focus may be made only on the gap areas in the spatial distribution of existing assets (Figure 8). Empowering Panchayati Raj Institutions Spatially (EPRIS) is one such programme under which Gram Panchayat level assets are being mapped and are integrated in the database hosted by Bhuvan Panchayat Platform (Section 1.4).

The end-user utilization of the recommended plans lies with representation efficiency of the user interface design on the integration platform. Ideally, local planner at the Gram Panchayat level should be able to see recommendations at the very time of identifying works for preparing annual action plans in his/her area (Figure 9). This would ensure that the ground level measures are taken inside the scientifically planned micro-zone.

**Table 3:** Recommended land resource development vis-à-vis existing land cover in Shergarh Gram Panchayat of the study area

| **S. No.** | **Existing land cover** | | **Recommended development** | |
|---|---|---|---|---|
| | **Class** | **Area (ha)** | **Class** | **Percentage** *w.r.t. existing land cover* |
| 1 | Agricultural land | 2890 | Intensive Agriculture | 21.06 % |
| | | | Agro Horticulture | 73.64 % |
| | | | Agro Forestry | 5.30 % |
| 2 | Wastelands | 1298 | Agro Forestry | 62.23 % |
| | | | Fuel Wood Plantation | 37.61 % |
| | | | Silvipasture | 0.03 % |
| | | | Vegetative barriers | 0.13 % |

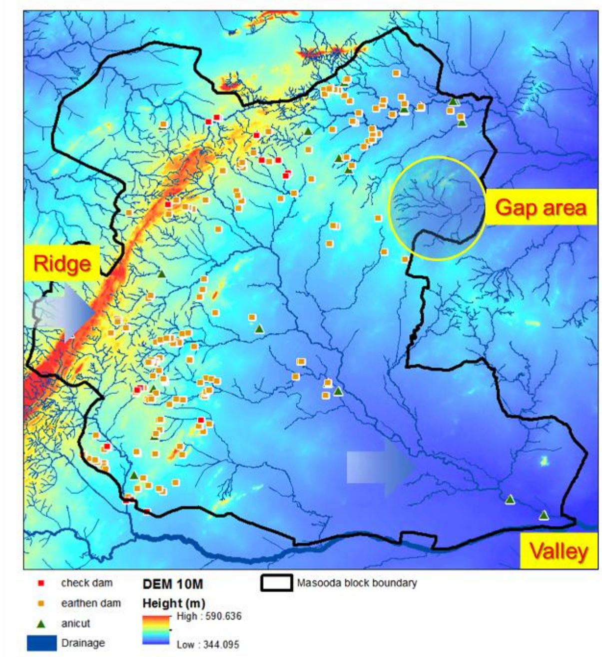



**Figure 8:** Gap areas in the spread of water harvesting structures from ridge to valley in the study area as identified on an overlaid display of assets mapped with the drainage and DEM in the background


**Figure 9:** Utilization of LRDP output layer on Bhuvan Panchayat while creating a plan. In this illustration, agro-horticulture activity is being planned within the area suggested by LRDP. The user first queries about the areas where agro-horticulture is suggested, and then creates a plan accordingly.

## 6. CONCLUSION

The study shows that with the advancement in geo-enabled services, it is now possible for scientific expert recommendations to be directly available at the time of local level bottom-up planning, which is often being attributed to be stand-alone and thus non-scientific. Preparation of region-level land and water resources development plans using the available space-based inputs in a GIS environment assist in making informed decisions. With an integration platform of detailed spatial and non-spatial datasets, ground-level asset details, expert recommendations, planning modules and analysis windows for decision support, the process of management of natural resources is expected to be streamlined towards sustainability.

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