

GEO INFORMATICS BASED SUSTAINABLE CADASTRAL LEVEL WATERSHED PLANNING – A CASE STUDY OF KUNDEIMAL MICRO WATERSHED, BOLANGIR DISTRICT, ODISHA, INDIA

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ABSTRACT

In the present study, an attempt has been made to characterize the natural resources and terrain condition and prescribe suitable action items towards sustainable development of Kundeimal micro watershed using geo informatics tools like satellite remote sensing, Global Positioning System and Geographic Information System. Satellite image of WORLDVIEW-II sensor and limited ground observations have been utilized for generating the thematic layers. The spatial layers have further been integrated and analysed using different geo informatics tools in GIS platform to generate alternate sustainable land use plan and watershed based suitable soil & water conservation measures for the micro watershed. The logic used in this study to generate the site specific action plan items is based on concept of sustainability.

Keywords: Worldview-II, GPS, GIS, Watershed, Sustainable Development

1. INTRODUCTION:

Watershed management is considered as the process of formulating and carrying out a course of action involving manipulation of natural, agricultural and human resources of the watershed to provide resources that are desired by and suitable to the watershed community, but under the condition that land and water resources are not adversely affected. It must consider the social, economic and institutional factors operating

within and outside the watershed. Watershed planning is an integrated and interdisciplinary approach. Because of the highly complex nature of human and natural systems, the ability to understand them and plan sustainable conditions using a watershed approach has increasingly taken a geographic dimension. Geo informatics technology has played critical roles in all aspects of watershed management, from assessing watershed conditions to visualizing impacts of alternative management scenarios. A detailed database on natural resources, terrain conditions, infrastructures, etc. at plot level for one micro watershed derived through geo informatics become a prerequisite to prepare an action plan keeping in view the underlying concept of sustainability.

An attempt has been made in this study to use different Geo Informatics to derive watershed development plan for the Kundeimal micro watershed of Odisha state, India.

2. OBJECTIVES OF THE STUDY

The objectives of this study are:

- i) To characterise and create spatial database on natural resources and terrain of the micro watershed at cadastral level using remote sensing derived information in GIS environment.
- ii) To prepare the micro watershed treatment plan (both land management &

water management) of the micro

watershed.

3. STUDY AREA

The Kundeimal Micro Watershed is located between the parallels of $20^{\circ} 32' 47.284''$ N and $20^{\circ} 34' 27.542''$ N latitudes and meridians of $83^{\circ} 20' 32.99''$ E and $83^{\circ} 33' 26.911''$ longitudes at a distance of about 20 kms from the block headquarter Deogaon and 28 kms from the district headquarter Bolangir in the state of Odisha, India. The natural boundary of this hydrologic unit lies within the administrative boundaries of part of villages of Kundeimal, Kukurkhai and Sargipali of Mahalei Gram Panchayat & Bandhapali of Makundapur Gram Panchayat and part Bhimdunguri Reserved Forest of Deogaon block of Bolangir district of Odisha state and is a part of Lower Mahanadi Micro Watershed. The areal extent of the micro watershed is 821.712 hectare.

4. DATA BASE USED

Topographical Sheet 64P/10
Satellite Image Used: Worldview-II (50 cm resolution)
Digital georeferenced cadastral layers

5. METHODOLOGY

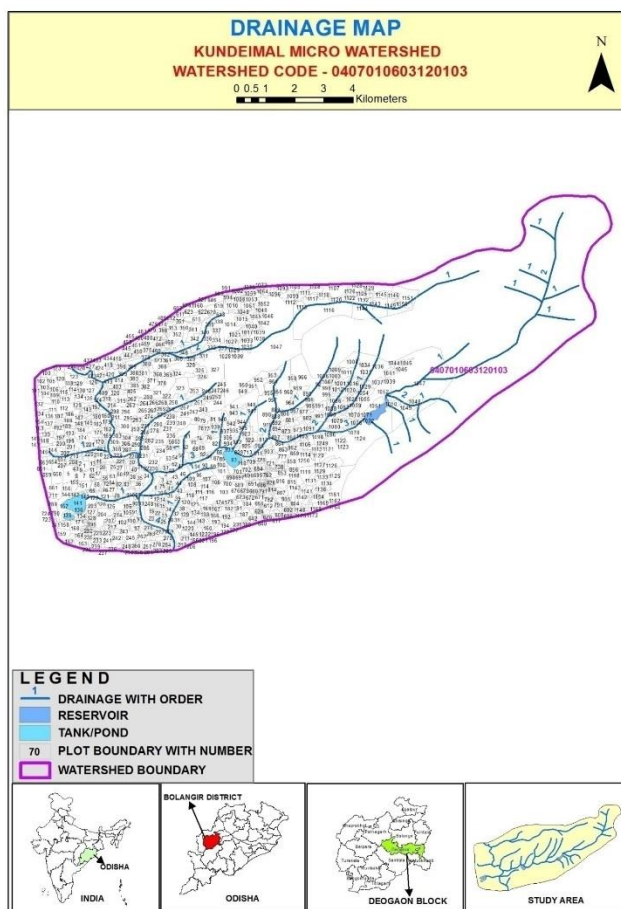
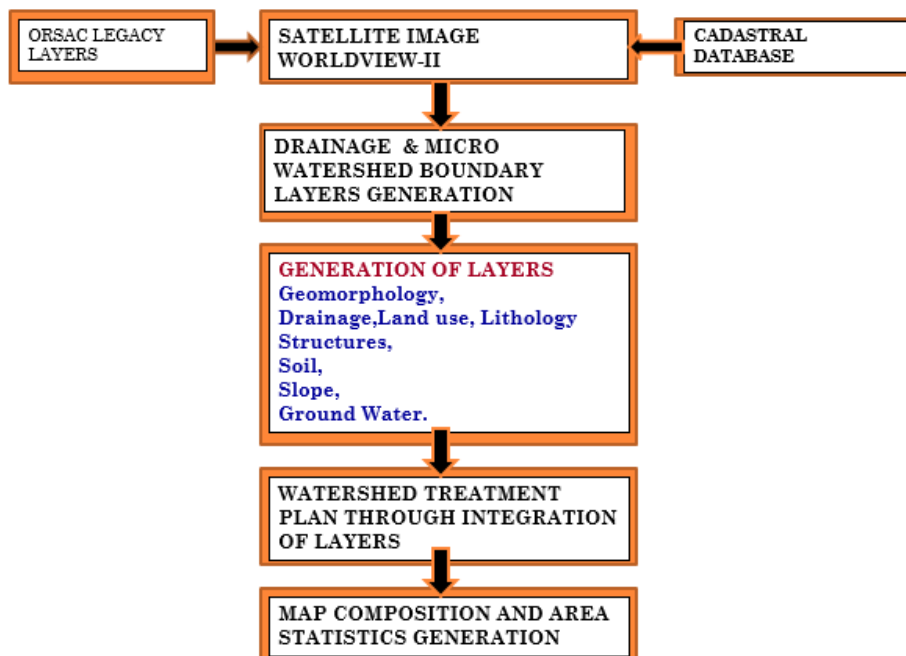


Figure 1: Drainage Map



The geo spatial procedure adopted in this study is described below-

Scanning:

- Raster legacy layers relating to the project have been scanned using A0 size colour scanner.

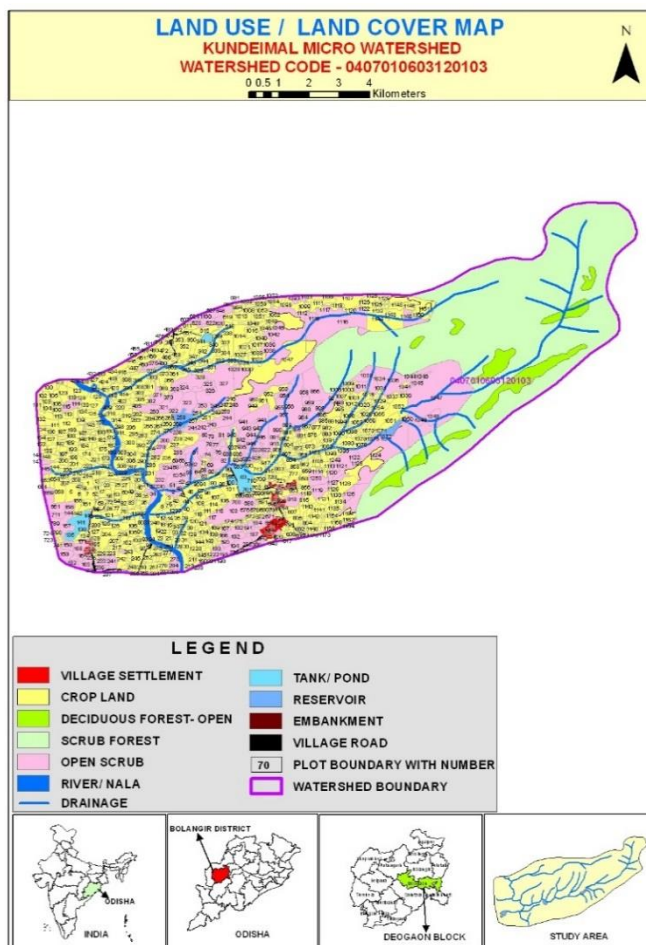
Rectification/ Geo-Referencing:

- The scanned layers are then geo-referenced (Geographic Lat/long WGS-UTM-ZONE-44N) using ground control points obtained through Global Positioning System(GPS) by ERDAS-2010-IMAGINE Classic software.

Digitization/Creation of various map layers:

- ArcGIS 9.3 software has been used to digitize and create different shape files and for different layers for the study. Road, drainage and administrative units like village and forest boundary have been created with reference to topographic sheets.

- Land use/ land cover, geomorphology, lithology, soil, water bodies, structural trends and lineaments have been generated by on screen interpretation with the help of image interpretation elements and supplemented by limited



ground observations.

- Integration of thematic layers in GIS platform for generation land management and water management plans.

6. RESULT AND DISCUSSION

The following spatial layers on natural resources and terrain of the Micro Watershed have been generated using geospatial tools and discussed below.

6.1 Current Land Utilisation and Cover Pattern

The output has been generated at 1:4000 scale matching the plot boundaries of the micro watershed. In total eleven land use and cover units have been delineated. The Kundeimal Micro watershed can be broadly divided in to three classes i.e. the forest in the north eastern portion, the scrub areas in the transitional zones and the agricultural lands in the western side of the micro watershed. The Bhimdunguri Reserved Forest is mostly of scrub forest nature in terms of density with less than 10 % canopy density. The satellite image indicates that

6.2 Water Resource

(a) Surface Water

Assessment of surface water resources from the satellite image coupled with SOI topomaps indicate that five water bodies exist in Kundeimal micro watershed along with the drainage/streams. The water bodies have been categorized in to tank/pond, reservoir (water storage of WHS) and drainage/streams.

(b) Ground Water Prospects

only 24.348 ha of forests in the Reserved Forest belong to open category i.e. crown density remaining within 10 to 40 %.The uplands outside the Reserved forest are mostly scrub lands with a total extent of 202.745 hectares. These lands are treated as wastelands inside the micro watershed. Total surface water source in shape of tank, pond and water harvesting structure inside the micro watershed is nearly 10 hectare. Village settlements occupy nearly 4.715 ha

Figure 2: Land use / Land cover map

of lands along with village roads of 4.206 ha.

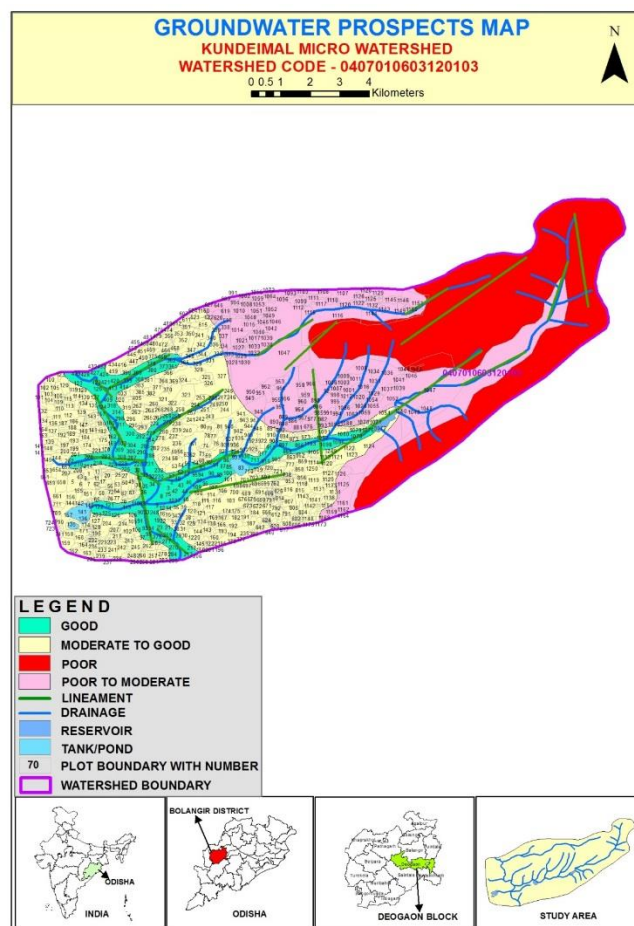


Table 1: Ground Water Prospects

Gw_Prospects	Area_Ha	% To Total Area
Good	90.780	11.05
Moderate to good	287.166	34.95
Poor to moderate	218.724	26.62
Poor	225.041	27.38
	821.712	

Ground Water is a sub-surface feature and cannot be captured directly from satellite images. For extracting information on ground water a complex analysis of different thematic layers through geoinformatics is needed. Geo spatial datasets on Ground Water prospects of the micro watershed has been generated through the analysis of spatial layers of lithology, structure

(lineaments) and geomorphology in GIS

Figure 3: Groundwater Prospects Map

environment.

The micro watershed is divided in to Poor, Poor to moderate, Moderate to Good and Good categories. 46 % of the micro watershed area has moderate to good and good prospects for ground water exploitation. The hills seem to have poor while the valley portion of the micro watershed has good ground water prospects. Table No. 1 depicts the spatial extent and percentage to total geographical area for each ground water prospect zone.

6.3 Soil Resource

Table 2: Soil Taxonomic Unit

SOIL TAXONOMIC UNIT	AREA_Ha	% TO TOTAL AREA
Clayey Skeletal, Mixed Hyperthermic, Typic Ustochrepts.	11.899	1.45
Coarse Loamy, Mixed Hyperthermic, Typic Ustochrepts.	8.113	0.99
Coarse Loamy, Mixed Hyperthermic, Typic Ustorthents	56.166	6.84
Fine Loamy, Mixed Hyperthermic, Aquic Ustochrepts.	9.612	1.17
Fine Loamy, Mixed Hyperthermic, Dystric Ustochrepts.	62.530	7.61
Fine Loamy, Mixed Hyperthermic, Typic Ustochrepts.	220.493	26.83
Loamy Skeletal, Mixed Hyperthermic, Lithic Ustorthents	200.932	24.45
Loamy Skeletal, Mixed Hyperthermic, Typic Ustochrepts.	242.620	29.52
Waterbody	1.864	0.23
HABITATION	7.483	0.91
	821.712	

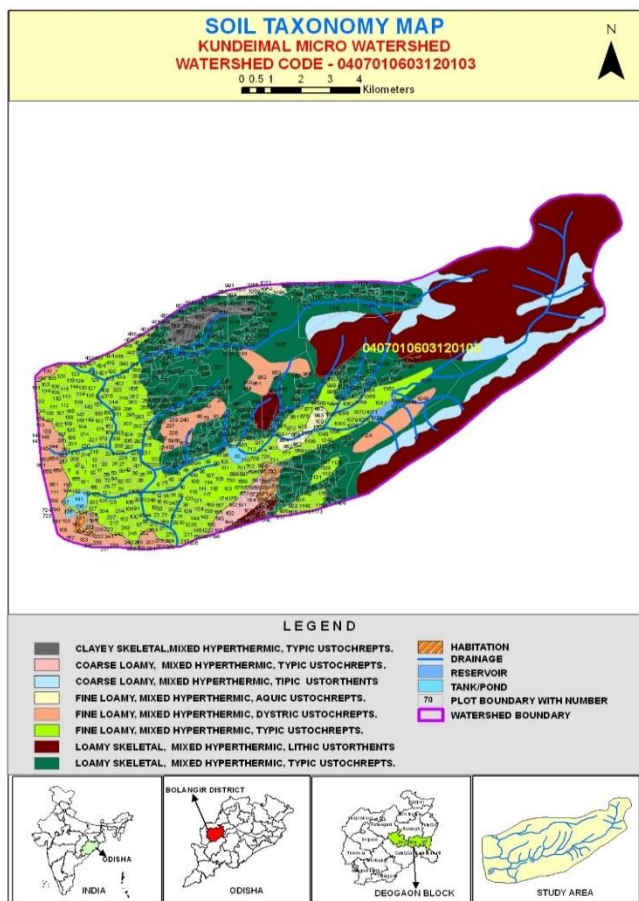


Figure 4: Soil Taxonomy Map

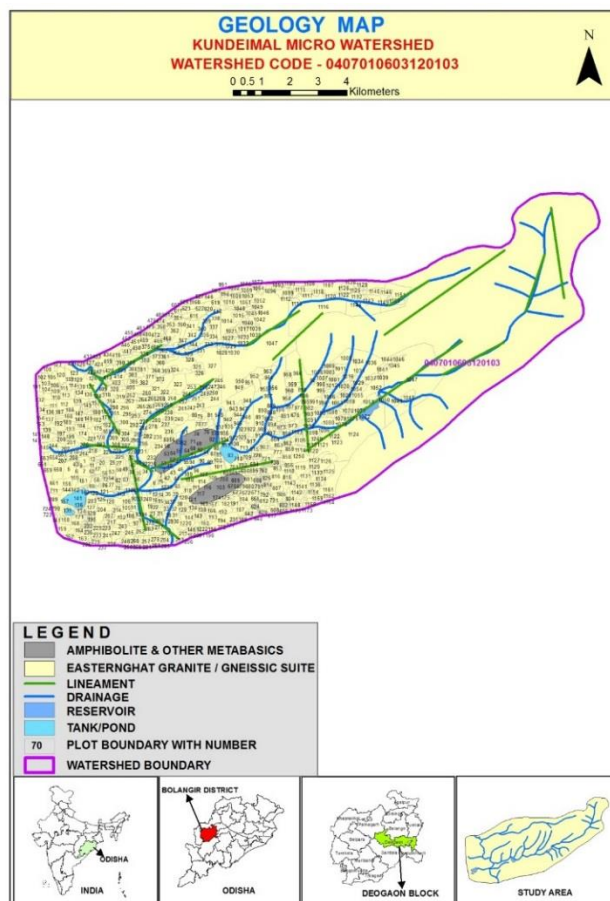


Figure 5: Geology Map

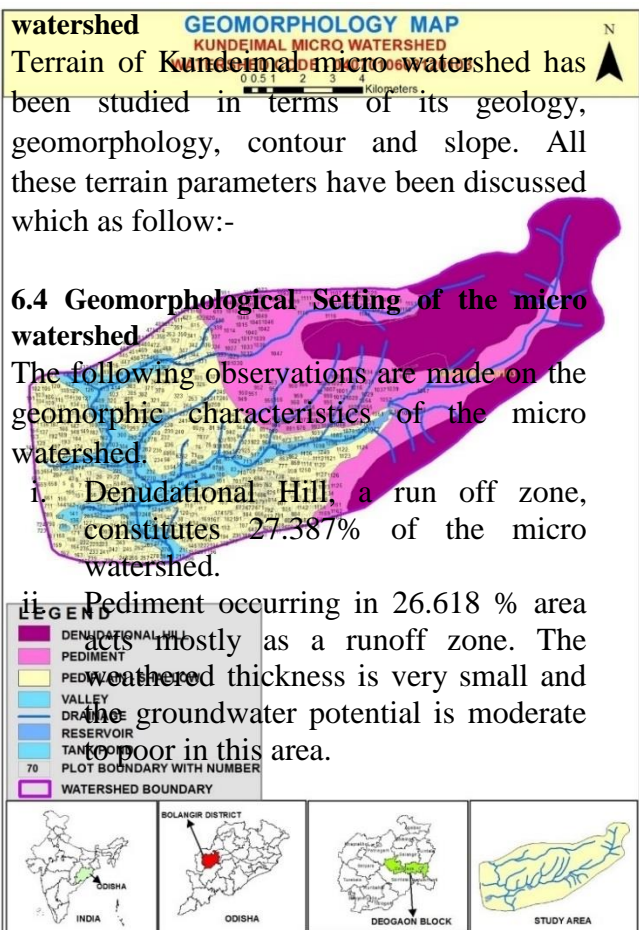
6.3 Terrain Characteristics of the micro watershed

Terrain of Kundeimal micro watershed has been studied in terms of its geology, geomorphology, contour and slope. All these terrain parameters have been discussed which as follow:-

6.4 Geomorphological Setting of the micro watershed

The following observations are made on the geomorphic characteristics of the micro watershed.

- i. Denudational Hill, a run off zone, constitutes 27.387% of the micro watershed.
- ii. Pediment occurring in 26.618 % area acts mostly as a runoff zone. The weathered thickness is very small and the groundwater potential is moderate to poor in this area.

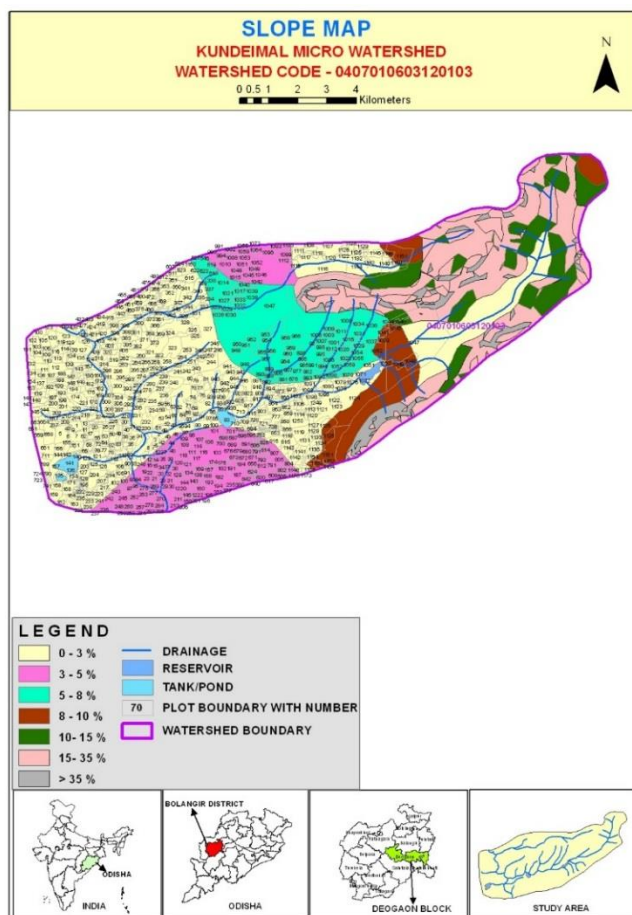


- iii. Pediplain-shallow consists of a shallow over burden of weather materials (0.5m thickness). Infiltration is moderate and groundwater potential is moderate to good. It covers an area of 287.166 ha. which is about 34.947 per cent of the total area of the watershed.
- iv. Valley consists of unconsolidated alluvial materials consisting of sand, silt and gravel etc. deposited along a valley. This unit acts as both recharging and discharging zones for groundwater. Groundwater occurs at shallow depths in this zone. The groundwater potential is good due to its topographical location and geological composition consisting of highly porous materials. Depending

Figure 7: Slope Map

upon the thickness of the fill, the prospect varies. It covers an area of 90.780 ha. which is about 11.048% of the total area of the watershed.

6.3.3 Slope Characteristics



7. Alternate Land Management Plan generation for Kundeimal micro watershed through geo informatics

While generating the action plan, a short deliberation is made on the optimality of the present land use especially keeping in view the sustainable production and quality of

ecosystem. If the present land use is considered suboptimal, then a few possible options for such a site are discussed with an aim to achieve optimality within the overall framework of sustainability of production. Unless and otherwise the present land use is beyond the threshold limit of some land parameters, a drastically different option is not recommended since such a change will not meet with high level of acceptability. Further while making alternate recommendations for land use practice, futuristic considerations such as exploitation of ground water, if presently not exploited and possibility of adopting more efficient system of irrigation and water management and other site improvements through soil and water conservation are also kept in view. Availability of improved varieties of crops, trees, shrubs and grasses and advantages of interdependency of agriculture, livestock and other practices as in case of integrated farming system that have been made available through contemporary research are also considered.

Thus with these considerations, finally an alternate land use practice is recommended showing the sites suitable for its recorded parameters.

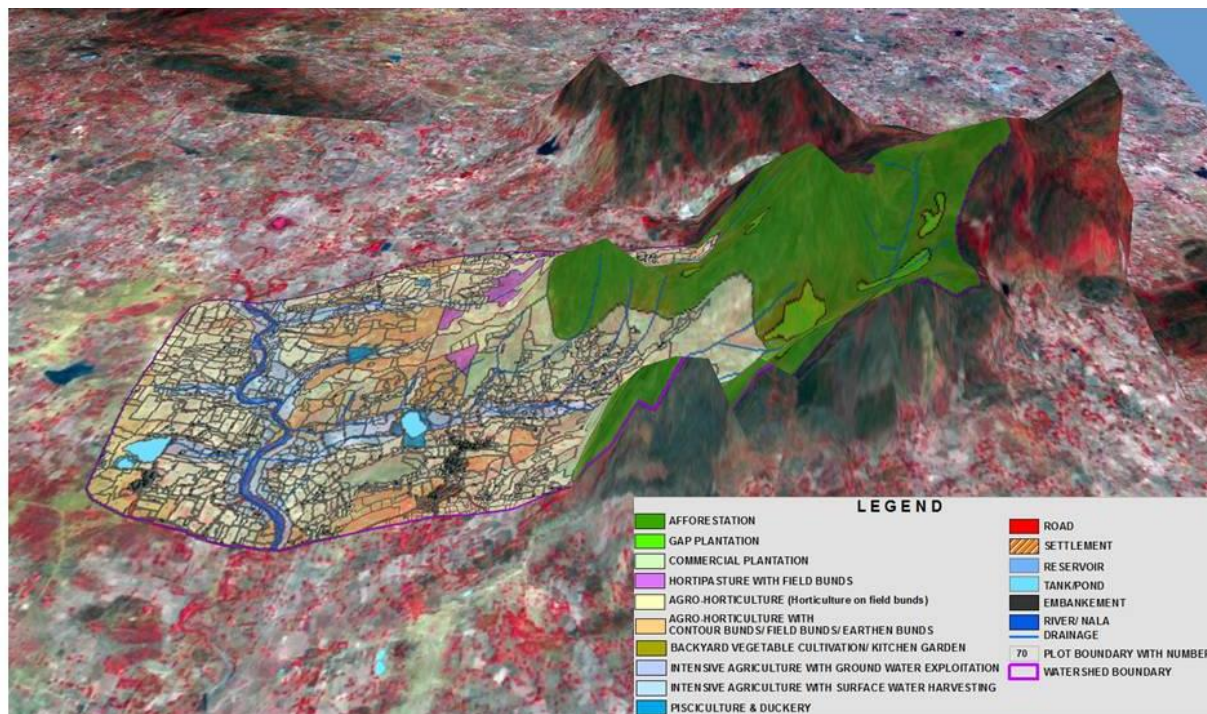


Figure 8: 3D perspective view of Land management action plan

Table 3: Logic for Land Management solution

S. No	ACTION_PUGGESTED ACTION PLAN	EXISTING LAND USE	GEOMORPHOLOGY	GROUND WATER POTENTIAL	SLOPE	SOIL TAXONOMY	AREA_Ha
1	AFFORESTATION	SCRUB FOREST	-	-	-	LOAMY SKELETAL, MIXED HYPERTHERMIC, LIT HIC USTORTHENTS	234.56
2	AGRO-HORTICULTURE (Horticulture on field bunds)	CROP LAND	BURRIED PEDIPLAIN - SHALLOW	MODERATE TO GOOD	0-3 %	FINE LOAMY, MIXED HYPERTHERMIC, DYSTRIC USTOCHREPTS	263.20
3	AGRO-HORTICULTURE WITH CONTOUR BUNDS/ FIELD BUNDS/ EARTHEN BUNDS	OPEN SCRUB	PEDIMENT/BURRIED PEDIPLAIN - SHALLOW	MODERATE	3-7 %		81.80
4	BACKYARD VEGETABLE CULTIVATION/ KITCHEN GARDEN	VACANT LAND WITHIN SETTLEMENT	-	-	-	COARSE LOAMY, MIXED HYPERTHERMIC, TYPIC USTOCHERPTS	0.22
5	COMMERCIAL PLANTATION	OPEN SCRUB	PEDIMENT	MODERATE	5-7 %	LOAMY SKELETAL, MIXED HYPERTHERMIC, TYPIC USTOCHERPTS	110.04
6	GAP	OPEN	-	-	-	COARSE LOAMY,	24.35

S. No	ACTION_PSUGGESTED ACTION PLAN	EXISTING LAND USE	GEOMORPHOLOGY	GROUND WATER POTENTIAL	SLOPE	SOIL TAXONOMY	AREA_Ha
	PLANTATION	FOREST				MIXED HYPERTHERMIC ,TYPIC USTORTHENTS	
7	HORTIPASTURE WITH FIELD BUNDS	OPEN SCRUB	PEDIMENT	MODERATE	5-7 %	LOAMY SKELETAL, MIXED HYPERTHERMIC,TYPIC USTOCHERPTS	13.50
8	INTENSIVE AGRICULTURE WITH GROUND WATER EXPLOITATION	CROP LAND	VALLEY-UPPER	GOOD	0-3 %	FINE LOAMY , MIXED HYPERTHERMIC, TYPIC USTORCHERPTS	14.47
9	INTENSIVE AGRICULTURE WITH SURFACE WATER HARVESTING	CROP LAND	VALLEY-LOWER	GOOD	0-3 %	FINE LOAMY , MIXED HYPERTHERMIC, TYPIC USTORCHERPTS	52.25
10	PISCICULTURE & DUCKERY	TANK/POND/RESERVOIR	-	-	-		9.98

The following alternate land use units have been suggested in Kundeimal micro watershed:

- (i) Afforestation
- (ii) Gap Plantation
- (iii) Commercial Plantation
- (iv) Horti-pasture with field bunds
- (v) Agro-Horticulture(horticulture on field bunds)
- (vi) Agro-Horticulture with contour bunds/field bunds/earthen bunds
- (vii) Backyard Vegetable cultivation/Kitchen Garden
- (viii) Intensive Agriculture with Ground Water Exploitation
- (ix) Intensive Agriculture with surface water harvesting
- (x) Pisciculture & Duckery

a) Study on management solutions to underutilized/degraded lands:-

In general, land degradation implies temporary or permanent recession from a higher to a lower productivity through deterioration of physical, chemical and

biological aspects. It is the temporary or permanent lowering of the productive capacity of the land(UNEP,1992b). In the present research area of Kundeimal micro watershed nearly 554.25 hectare of underutilized or degraded land exist as revealed from analysis of recent high resolution satellite image. The development of productivity of these lands has been planned through geoinformatics in this paper and the details in this regard are described below.

i. Afforestation

The lands under scrub forests (with less than 10 % canopy cover) inside reserve forest must be brought back to vegetation cover through afforestation. Varieties like teak, accacia, eucalyptus, etc. may be planted following the proper package of practice. Social fencing may be advisable to restrict the cattle grazing inside this area without any cost involvement or artificial bio fencing is to be provided. An area of 234. 56

ha, is suggested for afforestation in the micro watershed.

ii. Gap plantation

Gap plantation is suggested in an area of 24.35 ha. in the open forests(with canopy cover of 10-40%). Since there is a shortage of fuel-wood for domestic use of the people in the micro watershed, it is necessary to take up plantation of fuel-wood species by way of gap filling. The different fuel-wood species to be planted are Chakunda, Accacia, Gambhari etc. This will not only help to meet the fuel-wood requirement of the area, but also largely available for ecological balance and better environment.

iii. Commercial Plantation

In this system, tree species of commercial value are selected and planted. Before planting the trees, protection of the trees by the community is to be ensured. After 2 to 3 years of growth of the trees, livestock are to be allowed to graze and the people given the right over fodder, fuel-wood and other NTFP. The lands with scrub which come under pediment have been planned for commercial plantation. An area of 234.5 ha. is suggested for commercial plantation in the watershed.

iv. Horti- pasture with field bunds

In the plan, it is suggested to go for pasture land development mixed with horticulture in the land presently with open scrubs under the pediments with moderate ground water potential. The people of the watershed area are to be motivated to adopt cut and carry system for the above purpose. Open grazing is to be restricted and stall-feeding is to be encouraged. An area of 13.5 ha. is suggested for this purpose. Horticulture will serve as a sustained source of regular income over very long periods and in addition to fruits, these trees provide fuel, fodder and small timber. Selection of proper tree species should be

ascertained based upon the need and the potential. There should be an intermix of early fruiting and late fruiting trees such that the economic returns should be immediate as well as late. Field bunds are suggested on these lands to avoid soil erosion and for moisture conservation in dry seasons.

b) Study on alternate cropping pattern of Kundeimal micro watershed

The existing cropping pattern has been analysed through remote sensing and GIS and then suitable alternate cropping pattern has been suggested. The various aspects of the proposed cropping pattern of Kundeimal micro watershed are discussed below.

i. Agro-Horticulture (horticulture on field bunds)

In Agro horticulture crops and food trees are grown together where crops are practiced on fields in association with horticultural plants on field bunds. The horticulture plantation includes rainy season vegetables, winter vegetables beans, and fruit plants like banana, papaya, pineapples, etc. Agro horticulture is recommended in the existing crop land areas of the micro watershed with moderate to good ground water potentials and 0 to 3 % of slope. This land management is suggested in an extent of area of 263.20 ha.

ii. Agro-Horticulture with contour bunds/field bunds/earthen bunds

Agro horticulture is also recommended in pediments and shallow weathered buried pediments areas with moderate slope (0 to 3%) under open scrub areas .Here contour bunds /field bunds /earthen bunds are recommended to check soil erosion along the moderate sloping lands. A total 81.80 ha of lands are suggested under this category.

iii. Backyard Vegetable cultivation/Kitchen Garden

It is observed that open spaces to an extent of 0.22 ha exist in the backyards of the households of the rural people inside the micro watershed. These lands can be proposed for backyard vegetable cultivation or kitchen gardens. The female population of the micro watershed can be trained with proper tips by the horticulture officials in this regard.

iv. Intensive Agriculture with Ground Water Exploitation

Despite high risk of failure, farmers of the locality use to grow low yielding paddy under primitive technology. Due to erratic rainfall and practice of growing a single crop the annual production gets reduced. So, intensive agriculture with ground water exploitation is planned in the upper portions of the valleys with good ground water availability and 0-3% slope currently used under single crop. Suitable crop rotation with the use inputs like high yielding variety seed, recommended fertilizer and pesticide dose is to be followed for getting a high return from the same land. Here the farmers are in a habit of growing only paddy which is to be restricted and minimum two crops (non paddy crops) are to be taken for increasing the cropping intensity and net return from the same area of land. An area of 14.47 ha. is recommended for this item in the action plan.

v. Intensive Agriculture with surface water harvesting

Intensive agriculture with surface water harvesting is planned in the lower portions of the valleys with good ground water availability and 0-3% slope currently used under single crop. These patches of lands with spatial extent of 52.25 ha are the highly suitable lands for agriculture inside the micro watershed. The Agriculture department officials need to guide the

farmers of these plots to initiate multi cropping.

vi. Pisciculture & Duckery

The existing tanks, ponds and reservoirs located inside the watershed can be used for pisciculture and duckery. The suggested water harvesting structures may also be used for pisciculture. The earthen bunds surrounding the tanks/ponds can be used with plantation of horticultural species. This will add to the net return from the same piece of land. An area of 9.98 ha. is suggested for pisciculture and duckery in the watershed.

Table 7.2 spatial distribution of suggested land management action plan items for Kundeimal micro watershed

7.4 Alternate Water Management Plan generation for Kundeimal micro watershed through geo informatics:-

The alternate water management plan generated for Kundeimal micro watershed envisages optimal utilization scenario both for ground and surface water. Engineering structures have also been suggested in the micro watershed considering the drainage, slope, catchment area, water requirement and lithology, etc.

7.4.1 Plan for Ground Water management

The lithology, lineaments, drainage, slope, etc. of Kundeimal micro watershed have been studied from multispectral high resolution satellite image.

Depending upon the availability of water resources, their mode of occurrence and problems associated with developmental activities the micro-water shed is divided into three zones for the exploitation of groundwater resource.

a) Suitable Site for bore well.

The deep seated fracture zones or the zones of prominent lineaments and lineament intersections are suited for exploitation through deep bore well. The exact site location should be confirmed by detailed hydrological study and electrical resistivity survey to understand the subsurface distribution of fracture and aquifer system.

The bore wells constructed in the fractures have limited yield which varies from 1 to 6 liters per second. For ensuring economic returns, the water available from these wells can be utilised for irrigation of plantation crops, vegetables, oil seeds, etc.

b) Suitable Site for Dug well.

Areas covered by shallow thickness of alluvium, valley fills etc. are suited for dug wells. Site for dug wells is demarcated considering the weathered thickness with joints and fractures and nature of alluvium deposits. The unconsolidated alluvial deposits include alternate zones of clay and sand. The porous sand occurring next to ground surface or lying between two impervious zones of clay formation serves as the chief aquifer supporting different types of irrigation wells installed in this tract. The formation with a mixture of fine, medium and coarse sand as well as gravels in some locations in different proportions holds and easily yields sufficient water to support the installation of dug wells.

c) Site for Production Well

Generally production wells are recommended in areas with very good ground water potentials and where the demand is more for drinking and irrigation purposes. These are deep bore wells constructed for pipe line supply to the concerned habitation. These bore wells are large diameter wells (normally 4" to 6") with high yield (about 100 to 200 LPM)

depending upon suitability of the area. A production well is recommended in Kundeimal watershed near village Kundeimal (PLOT NO-1114) at the intersection of lineaments near valley region where groundwater prospects is very good.

7.4.2 Plan for Surface Water Management

a) Sites suitable for Nala Bunds

Nala bund is an earthen dam constructed to impound water flowing in a nail or nala for the primary purpose of increasing water percolation and improving soil moisture regime. Considering the site conditions, three numbers of nala bunds are proposed for the groundwater recharge in Kundeimal micro watershed.

b) Sites suitable for Check Dams

Check dams are the gully control structures made on the drainage lines to reduce the velocity of runoff and to help in percolation of retained water. Four numbers of check dams are proposed for sustainable water resources management in the watershed.

c) Water harvesting structures

Water harvesting structures are those structures constructed across the stream which harvest surface runoff during the monsoon rains. One number of water harvesting structure (impounding type) is proposed in the water resources management plan for Kundeimal micro watershed.

d) Percolation Tank

Percolation tanks are recharge structures which are suggested with the existing site conditions.

Two numbers of Percolation Tanks are proposed in the water resources management plan for Kundeimal micro watershed.

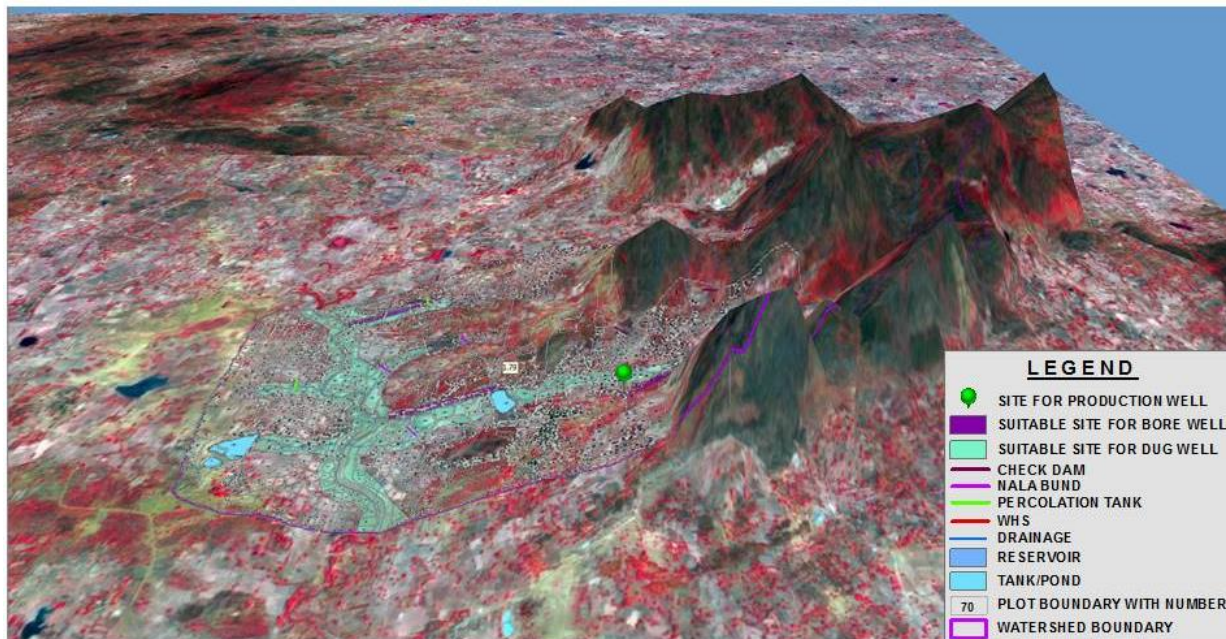


Figure 9: 3D perspective view of Water management action plan

Table 4: Details of suggested Water Management sites in Kundeimal micro watershed

SL_NO	ACTION_ITEM	PLOT_NO	VILLAGE NAME
1	Check Dam	1036	
2	Check Dam	1047	
3	Check Dam	1151	
4	Check Dam	966	
5	Nala Bund	254	
6	Nala Bund	277	
7	Nala Bund	44	
8	Percolation Tank	220	
9	Percolation Tank	375	
10	Production Well	1114	Kundeimal
11	WHS	1116	Bandhapali

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