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Delineation and prioritization of Jumar sub-watershed for sustainable development using geospatial techniques

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ABSTRACT

The present study attempts to delineate and prioritize Jumar sub-watershed (subernarekha watershed) for sustainable development using geospatial techniques. The remote sensing products in conjunction with Survey of India toposheet were used to delineate different physiographic units. Seven classes were identified based on depth, slope, erosion, texture, acidity and rock out crops. Out of these classes moderately well drained and very strongly acidic soils occupy largest area *i.e.* 7765.4 ha (27.07% of TGA). Based on the severity of the problems, the identified classes were again grouped under various priority zones *viz*., high (severe limitations), medium (moderate limitations) and low (minimum limitations). About 32.38% area was classified under high priority, followed by 29.07% under medium and largest area *i.e.* 7765.4 ha (27.07%) under low priority zones. The high and medium priority zones require immediate protection and amelioration and hence suggested land use plan for sustainable development.

1. INTRODUCTION

Land, a basic factor of production is limited in nature and has to be operated in a given natural environment. Man has made a tremendous progress in science however; the basic importance of land has not reduced. On the contrary, because of increasing population, it requires more attention for proper utilization and management. The resource development programmes are applied generally in watershed basis and thus prioritization is essential for proper planning and management of natural resources for sustainable development.

The need for prioritizing is largely done to make the best use of limited natural resources and the need to protect or restore lands before further degradation (Noss, *et al.,* 2009). The watershed forms an appropriate unit for analyzing the development linked resource problems, designing the appropriate solutions for problems identified and eventually testing the efficacy of the prescribed solutions (Tejwani, *et al.* 1987). The watershed approach is a system-based approach that facilitates the holistic development of agriculture, forestry and allied activities in the watershed (Tideman, 2000). The geospatial tools can provide a effective support in terms of relevant, reliable and timely information (Marble, *et al.* 1983; Trotter *et al.,*1991; Kushwaha, 1993; SAC, 1998). By interfacing remote sensing with GIS, different management scenarios could be generated, to assess the feasibility of various alternatives before selecting the one that would be most suitable (Nellis *et al.,* 1990*;* Nasre *et al.,* 2013; *Kalgapurkar et al.,* 2012). In this back drop a study was conducted on jumar sub-watershed to delineate the priority areas for implementing the developmental activities/conservation measures because the Jumar sub-watershed is of undulating topography and degraded forestlands due to which there is higher rate of soil loss through runoff. As a result, the productivity of this area is miserably low due to the accelerated erosion and in turn with the development of induced acidity. Therefore, to make the sub-watershed sustainable with its own resource base and to focus on the areas for immediate attention this study has been conducted.

2. MATERIALS AND METHODS

Study Area

The study area is a sub-watershed (23°22'15" to 23°32' 00"N; 85°10'30" to 85° 26'30" E) of Subernarekha watershed (Fig.1) in Ranchi district, Jharkhand. The total geographical

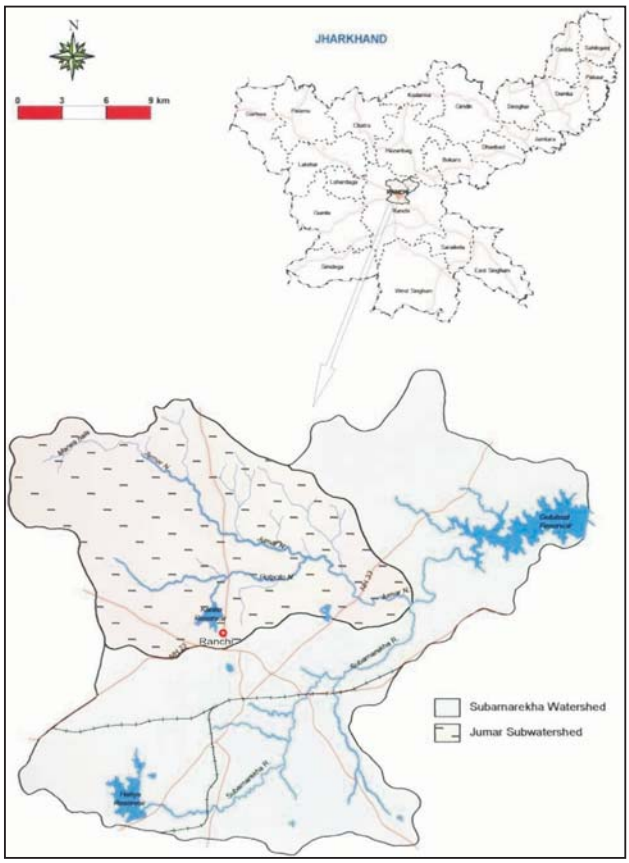

Fig. 1. The study area

area of sub-watershed is 28689.7 ha. In general, the area is characterized by undulating and degraded forestland, which was under mixed deciduous forest but currently under agriculture (70.08% in study area). The climate of the area is sub-humid and sub-tropical with mean annual rainfall 1500mm of which 97% is received between June to September. The mean summer temperature is 22.9°C and the winter temperature is 11.7 °C, respectively. The soil moisture and temperature regime of the area are Ustic and Hyperthermic, respectively. Geology of the area is granite-gneiss. The drainage network shows dentritic pattern. The dominant land use in the study area is cropland (70.08%), the remaining is under grazing (12.22%), urban settlement (7.11%), water bodies (1.355), forest cover (0.62%) and other miscellaneous (stony waste- 5.17%, gullied /ravines- 0.43% and others 3.02%).

The sub-watershed boundary was delineated with the help of satellite imagery (IRS-1C LISS III) and Survey of India toposheets (No. 73E/2, 73E/6, 73E/7) on 1: 50,000 Scale. Physiographic units were demarcated. Soil resource information was obtained by carrying out soil survey (AIS&LUSO, 1971). Representative pedons were studied and horizon-wise soil samples were processed and analysed by standard procedures. The pedons were taxonomically classified following keys to soil taxonomy (Soil Survey Staff, 2006). Sixteen soil series were tentatively identified and mapped as soil series dominant association. However,

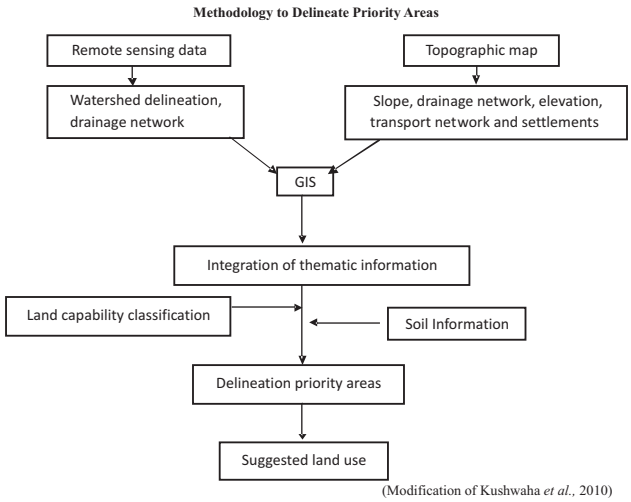

Fig. 2. Step-wise procedure followed in delineation of priority areas

the prioritization is based on dominant series and hence same has reported in Table.1. The soil series were grouped into different land capability sub-class (Klingebiel and Montgomery, 1966). Various thematic maps (physiography, erosion, texture, pH) were prepared and inturn the priority areas were identified using Geomedia *ver* 3.0 and ArcMap.

Prioritization Methodology

Considering the miserable loss of productivity in the study area a plan has been developed to delineate the area for making the area priority for conservation activities. In this present study the land has been classified according to the capability along with slope, soil depth, drainage, surface texture, erosion and soil acidity classes has been taken for watershed prioritization after careful observation of the field situation and the methodology adopted is depicted in Fig. 2.

3. RESULTS AND DISCUSSION

Five physiographic units *viz.,* monadnocks (0.89%), pediments (0.65%), plateau top (15.25%), undulating plateau (63.12%) and valley (8.61%) of TGA were identified. The soils of Bharamdih, Sanga, Baraudi, Murcho, Marwa and Kathatoli series have been identified from weathered rock, whereas others are developed from alluvium. The soils of Jumar sub-watershed are dominated by Inceptisols with an area of 17948.95 ha (62.59% TGA) followed by Alfisols (23.15% TGA) and with few Entisols covering 2.78 % TGA. The physiography, soil series, Taxonomy, and their descriptions have been shown in Table 1.

The land Capability Classification is an interpretative grouping of different soil units and serves as an important role in land use planning to show the relative stability of soils for cultivation of crops, pasture and forestry in addition to focusing the problems that need preventive measures. This provides clues to the management and helps in improvement of different soils for increasing production

Table: 1
Tentative soil series and their brief descriptions

Physiographic units	Series name	Taxonomy	Description
Monadnocks	Bharamdih	Loamy-skeletal Lithic Ustorthents	Shallow, excessively drained, brown gravelly sandy loam (surface) and brown gravelly sandy loam (sub soil), occurring on 15 to 30 per cent slope, severely eroded.
Pediments	Sanga	Loam-skeletal Typic Haplustalfs	Slightly deep, somewhat excessively drained, gravelly sandy loam (surface) and dark brown gravelly sandy loam (sub-soil), 15 to 30 per cent slope, severely eroded.
Pediments	Khakhra	Fine-laomy Typic Paleustalfs - Fine-loamy Typic Haplustalfs	Very deep, well drained, yellowish red loam (surface) and reddish brown clay loam (sub soil) on 3 to 8 per cent slope, moderately eroded.
Plateau top flat and broad rounded ridge	Hurhuri	Fine Typic Haplusteps - Fine-loamy Typic Haplustalfs	Very deep, moderately well drained, yellowish brown silt loam (surface) and dark yellowish brown silty clay (sub soil) on 1 to 3 per cent slope, very slightly eroded.
Sloping plateau	Sukurhutu	Loamy-skeletal Lithic Haplustepts	Shallow, excessively drained, brown gravely loam (surface) and brown to dark brown gravelly sandy clay loam (sub soil) on 3 to 8 per cent slope, severely eroded.
Gently sloping plateau	Kaditoll	Fine Typic Haplustalfs - Fine Typic Haplustepts	Deep, well drained, brown to dark brown, silt loam (surface) and dark brown silty clay (sub soil) on 1 to 3 percent slope, very slightly eroded.
Plateau top (very gently sloping)	Tangtangtoli	Fine-loamy Typic Haplustalfs - Fine Typic Haplustepts	Very deep, well drained, yellowish brown sandy loam (surface) and and reddish brown clay loam (sub soil) on 1 to 3 percent slope, moderately eroded.
Undulating plateau (upper reaches)	Edalatu	Fine Typic Haplustepts - Fine Typic Haplustepts	Very deep, moderately well drained, yellowish brown silt loam (surface) and brown to dark yellowish brown silt clay loam (sub soil) on 1 to 3 per cent slope, slightly eroded.
Undulating Plateau (upper reaches)	Baraudi	Fine-loamy Aeric Haplustepts-Fine-loamy Typic Paleustalfs	Moderately deep, well drained, brown sandy loam (surface) and dark brown sandy clay loam to gravelly sandy clay loam (sub soil) on 3 to 8 per cent slope, moderately eroded.
Undulating Plateau (upper reaches)	Boreya	Fine Typic Haplustepts - Coarse-loamy Typic Ustorthents	Very deep, well drained,yellowish brown, loamy sandy (surface) and yellowish brown loamy sand (sub soil) on 3 to 8 per cent slope, moderately eroded.
Undulating plateau (upper reaches)	Murcho	Fine Typic Haplustepts - Fine, Typic Haplustalfs	Deep, well drained, brown sandy loam (surface) and brown to reddish brown clay loam (sub soils) on 3 to 8 per cent slope, moderately eroded.
Undulating plateau (upper reaches)	Marwa	Fine-loamy Aeric Haplustepts - Loamy-skeletal Typic Haplusteps	Moderately shallow, well drained, brown gravelly sandy loam (Surface) and dark brown gravelly sandy loam (sub soil) 3 to 8 per cent slope, moderately eroded.
Undulating plateau (lower reaches)	Sugnu	Fine-loamy Typic Endoaquepts - Fine Typic Endoaqualfs	Very deep, imperfectly drained, brown silt loam (surface) and brown to dark grayish brown clay (sub soil) on 1 to 3 per cent slope, very slightly eroded.
Undulating Plateau (lower reaches)	Husir	Fine Typic Endoaquepts Fine-loamy Typic Paleustalfs	Very deep, imperfectly drained, dark yellowish brown loamy (surface) and olive brown to dark grayish brown clay loam (sub soil), 1 to 3 per cent slope slightly eroded.
Undulating plateau (lower reaches)	Kathartoli	Fine-loamy Typic Endoaquepts - Fine Typic Endoaqualfs	Very deep, imperfectly drained, yellowish brown silty clay (surface) and dark grayish brown to dark gray silty clay (sub soil), 1 to 3 per cent slope, slightly eroded.
Valley	Premnagar	Fine Aquic Haplustepts - Fine Typic Endoaquepts	Very deep, poorly drained, brown, silt loam (surface) and brown to dark gray silty clay (sub soil), 1 to 3 per cent slope, very slightly eroded.

(Dent and Young, 1981). The capability classification system is designed primarily for soil conservation and is intended for determining the maximum intensity of land use consistent with low erosion risk and sustained productivity. In Jumar sub-watershed four land capability classes and six land capability subclasses have been identified (Fig. 3).

The data indicates (Table 3) that the soils under land capability sub-class IIw occur on very gentle sloping land with slight limitation of wetness in *kharif* season. The land capability class II (good cultivable land) covers an area of 3238.7 ha (11.29%). The capability class III (moderately good cultivable land) comprising subclass of IIIw and IIIes occupies an area of 18060.8 ha (62.97%) which is having severe limitation of wetness and severe limitation of water erosion with moderate soil problems, respectively. The land capability subclass IVw and IVes have 2729.65 ha (9.5%) areas are fairly good for cultivation and require careful management of excess water and soil erosion. The limitations are soil texture, soil reaction, shallow depth and/or gravelliness. The soil unit 1 and 8 are classified under capability subclass VIes is not suitable for cultivation due to severe limitations of strong slope, undulating topography, stoniness and soil erosion and covers about 1365.6 ha (4.76%) area. Jumar Sub-watershed mainly faces water related problems which make most of its part (62.97% of TGA) moderately good for crop cultivation. The fertility status of the soils of Jumar sub-watershed was evaluated for surface soil properties (Table 2) of some dominant soils.

Based on the severity of the problems, the identified critical classes were again grouped under various priority zones *i.e.* high (severe limitations), medium (moderate limitations) and low (minimum limitations). High and medium zones require immediate attention regarding suitable protection or amelioration. In the Jumar sub-watershed 32.38%, 29.07% and 27.07% area are under high, medium and low priority zones, respectively (Table 4, Fig. 4). As per the level of deterioration, the land use has been suggested (Table 5) for effective use of both natural and social capitals for overall socio-economic development of rural people.

4. CONSLUSIONS

Watershed prioritization is one of the most important aspect of planning for implementation of its development and management programmes. The present study attempted to prioritize a sub-watershed taking into consideration of different soil parameters *viz*., slope, soil depth, drainage, surface texture, erosion and soil acidity. Based on severity

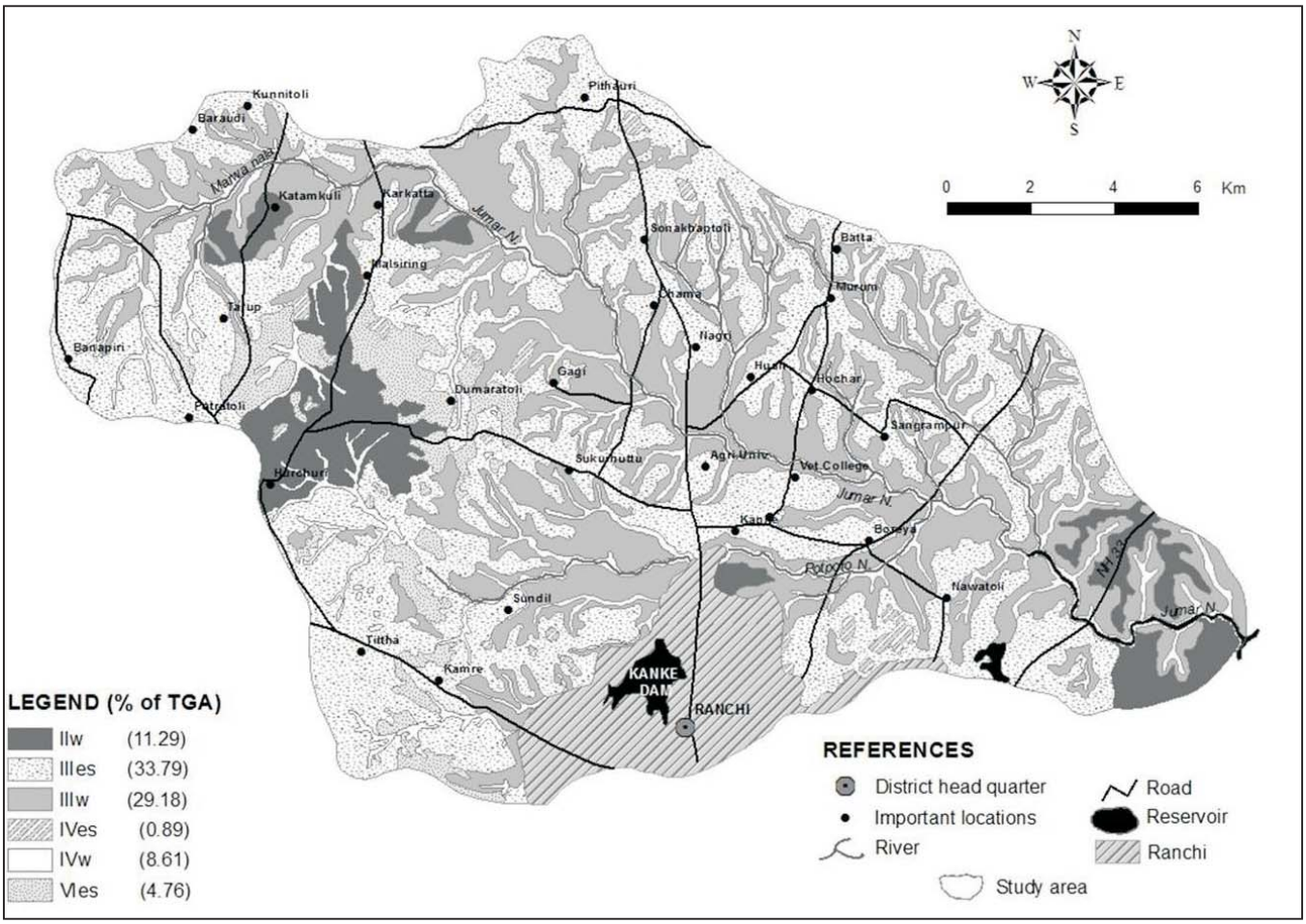

Fig. 3. Land capability classes

Table: 2
Fertility status of some dominant soil series

Major Physiograpy	Dominant soil series	E.C. (µs)		pH(1:2.5)		Org. C %		Av. N (kg ha^{-1})	Av. P_2O_5 (kg ha^{-1})	Av. K_2O (kg ha^{-1})
		0-15 (cms)	15-30 (cms)	0-15 (cms)	15-30 (cms)	0-15 (cms)	15-30 (cms)		0-15 (cms)	
Monadnocks	Bharamdih	0.203	-	5.6	-	0.72	-	134.4	Tr.	75
Pediment	Khakhra	0.173	0.172	5.5	5.7	0.68	0.68	95.2	Tr.	120
Plateau top	Hurhuri	0.191	0.221	4.7	4.8	0.78	0.68	89.6	Tr.	145
Undulating plateau	Edalatu	0.318	0.338	5.0	6.8	0.96	0.29	134.4	Tr.	125
Valley	Premnagar	0.438	0.396	5.2	6.2	0.95	0.32	134.8	Tr.	146

Tr. Traces

Table: 3
Land capability classes

Land Capability Sub-Classes	Description	Area in ha (% TGA)
IIw	Good cultivated land, good soil on very gently sloping land with slight problems of wetness.	3238.7 (11.29)
IIIw	Moderately good cultivable land, good soil on nearly leveled land with severe limitation of wetness.	8369.3 (29.18)
IIIes	Moderately good cultivable land, good soils on gently to moderately sloping land with severe limitation of erosion and moderate soil problems (soil texture, depth etc.)	9691.5 (33.79)
IVw	Fairly good land developed on very gently sloping low land suited for cultivation with careful management of excess water and selection of crops suited to wet conditions.	2473.9 (8.61)
IVes	Fairly good land, suited for occasional or limited cultivation on strongly sloping upland with very severe limitation of erosion and soil limitation due to gravelly substratum and unfavorable slope.	255.75 (0.89)
VIes	Land well suited for grazing or forestry moderate to strongly sloping upland with severe water erosion and soil limitations like soil depth, stony/ gravelly substratum, which require good range and forestry management practices.	1365.6 (4.76)

Table: 4
Priority areas identified based on production limitations.

Priority areas	Soil limitations	Area in ha (% TGA)
1	Shallow, steep sloping, somewhat excessively drained, severely eroded, gravelly sandy loam, moderately acidic, with rock out crops (ROC).	260.00 (0.89)
2	Shallow, gently sloping, somewhat excessively drained, severely eroded, gravelly sandy loam, moderately acidic, with rock out crops (ROC).	1178.50 (4.11)
3	Moderately Shallow, steep sloping, some what excessively drained, severely eroded, gravelly sandy loam, strongly acidic, with stony waste.	187.10 (0.65)
4	Slightly deep to moderately deep, gently sloping, moderately eroded, sandy clay loam, very strongly acidic.	7666.60 (26.73)
5	Sandy loam, moderately eroded, strongly acidic	2025.10 (7.06)
6	Imperfectly to poorly drained, moderately to strongly acidic.	6312.05 (22.01)
7	Moderately well drained, very strongly acidic.	7765.40 (27.07)
	Miscellaneous	3294.95 (11.48)
	Grand total	28689.7 (100)

Table: 5
Grouping various priority zones and suggested land use

Sl. No.	Priority zones	Priority areas (Grouping)	TGA (%)	Suggested land use
1.	High	1,2,3,4	32.38	Soil conservation practices+Social forestry/Agri-silviculture +Upland crops (pulses, vegetables)+liming+Integrated Nutrient Management (INM)
2.	Medium	5,6	29.07	Contour/graded bunding+dug well+Upland rice followed by pulses, oilseeds, vegetables+liming+INM
3.	Low	7	27.07	Dug well+Double cropping (upland rice followed by cereals/ pulses/oilseeds)+vegetables+liming.
		Miscellaneous	11.48	
		Grand total	100	

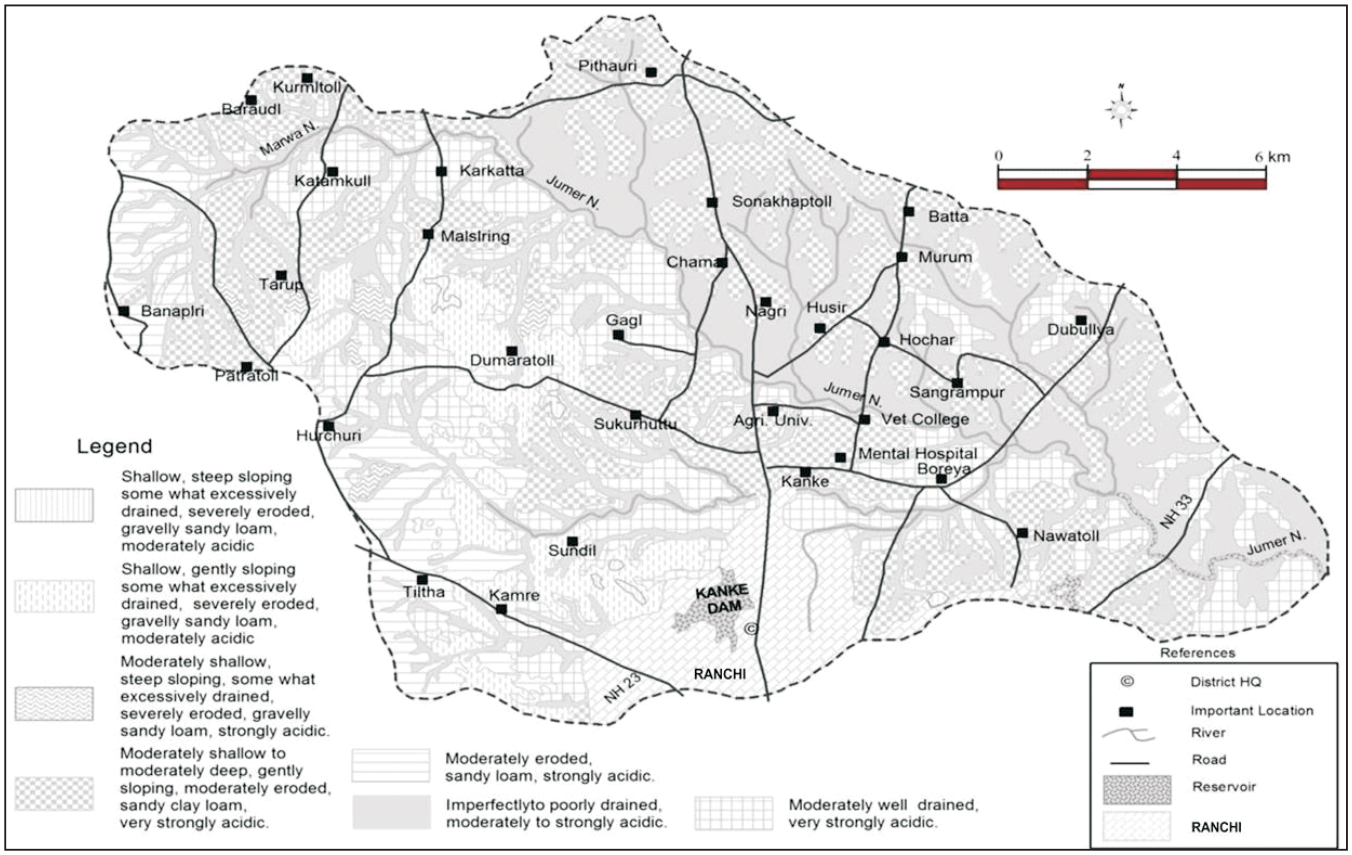

Fig. 4. Characteristics of priority areas

of problems, the priority areas were grouped under various zones *viz.,* high (severe limitation), medium (moderate limitation) and low (minimum limitation). These high and medium zones require immediate attention for protection /amelioration. Considering the level of deterioration, an suggested land use option has also been denounced since ~70% sub-watershed is under agriculture crops. The generated database may help immensely in scientific decision making to ensure sustainable development in Jumar sub-watershed.

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