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Physiographic Mapping of Sonar Sub-Basin Using Remote Sensing and GIS

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ABSTRACT: The present study has been carried out to map the land use/land cover, soil, geology and hydrogeology of the Sonar sub-basin using IRS-P6 LISS III images of October-November 2006. It indicated that about 23% of Sonar sub-basin is covered by forest which is mainly concentrated in the lower part of the basin i.e in the south-west region and sparsely spread in north-east and south-east regions. Agricultural land covers 63.2% of the sonar sub basin and is mainly occupied by two soil groups' i.e ID 247 and ID 283. This land is situated in the lower middle to lower part i.e. toward central to north part of the entire basin. The soil ID 247 covering 25% of the basin is a loamy shallow soil with excessive drainage and quite vulnerable to erosion, whereas soil ID 283 covering 21% of the basin is a deep moderately drained clayey soil on gently sloping plain lands having moderate erosion. The geology of the basin is mainly occupied by three groups basaltic flow, ganurgarh (simrawal) shale covers or sandstone. The basaltic flows of deccan trap covers an area of 1064 km^2. The ganurgarh (simrawal) shale covers an area of 219.82 km^2 and the sandstone covers 200 km^2. Most parts of the Sonar sub-basin (1399 km^2) have low to moderately high permeability and showed poor to moderately good groundwater potential. Whereas a small part of the Sonar sub-basin of area (139 km^2) showed good to excellent ground water potential.

Key words: Land use/land cover, soil map, geology, hydrogeology, remote sensing, GIS

The socio-economic development of any country is based on natural resources. Due to increase in population, these resources are over stretched often leading to resource depletion. India is a country, which has huge source of natural resources i.e. land, water and minerals. The spatial extent of the resources in the world is widespread and the spatial distribution plays vital role in natural and human interfered activities in the world. The natural phenomenon on the earth is interrelated to land, water and ultimately with atmosphere. As land, water and other natural resources play vital role in livelihood of the people, the spatial distribution and extent of resources and its type are also important in resource planning and management. The geographic extent and distribution of resources will act majorly in resource management. The quality and type of forest and the distance from the villagers to the forest resources is crucial while talking about the local peoples' livelihood and dependency on forest products (Shrestha, 2005).

Satellite remote sensing provides a more practical way to map and monitor land use/land cover, especially over large geographic areas. Land use constitutes soil characteristics, climate, topography, and vegetation. It is an important resource for most human activities including agriculture, industry, forestry, energy production, settlement, recreation, and water catchment and storage. Land is a fundamental factor of production, and contributes to economic growth of the nation. Often, improper land use is causing various forms of environmental degradation. For sustainable utilization of the land ecosystems, it is essential to know the natural characteristics, extent and location, its quality, productivity, suitability and limitations of various land uses. Land use is a product of interactions between a society's cultural background, state, and its physical needs on the one hand, and the natural potential of land on the other (Ram and Kolarkar, 1993). In order to improve the economic condition of the area without further deteriorating the bio environment, every bit of the available land has to be used in the most rational way. This requires the present and past land use/land cover data of the area (Chaurasia *et al.,* 1996). Temporal changes in land cover have become possible in less time, at lower cost and with better accuracy through remote sensing technology (Kachhwala, 1985). The information being in digital form can be brought into a Geographical Information System (GIS) to provide a suitable platform for data analysis, update and retrieval. Improvements in satellite remote sensing, global positioning systems and geographic information systems techniques in the past decade have greatly assisted the collection of land cover data and the integration of different data types (Star *et al.,* 1997). The present study was carried out to evaluate the physiography in Sonar sub-basin (Madhya Pradesh) on 1:50,000 scale by using IRS-P6 and LISS III data and base information from toposheets.

Materials and Methods

The Sonar sub-basin lies between longitudes 78^{o}35′48″ to 79^{o}10′50″ E and latitudes 23^{o}21′14″ to 23^{o}50′05″ N. It is a leaf shaped elongated catchment. The Sonar sub-basin falls under the Sagar district of Madhya Pradesh (Figure 1). It occupies an area of 1538 km^2. The basin has a perimeter of 284 km and basin length of 72.12 km and an average width of about 40 km. Average annual rainfall of the region is about 1100 mm. The average number of rainy days is 45. The average annual potential evapotranspiration is 1852 mm. The mean annual temperature varies from 18^{o}C to 33^{o}C.

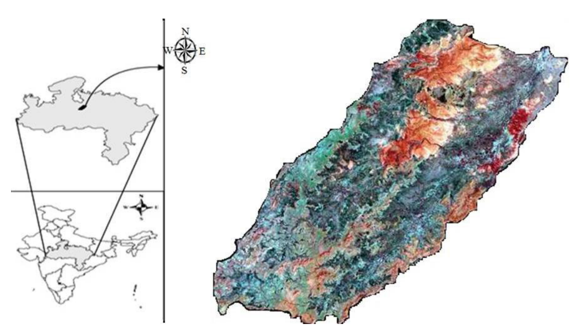


Fig. 1: Location of the study area

Methodology and Database

The primary data was obtained in the form of digital data on CDROMs for interpretation and analysis, the details of which is given in Table 1. The mask of the entire Sonar sub-basin, including the project site, was generated from the IRS-P6, LISS III data. Survey of India (SOI) toposheets on 1:50,000 scale was used for the preparation of base maps.

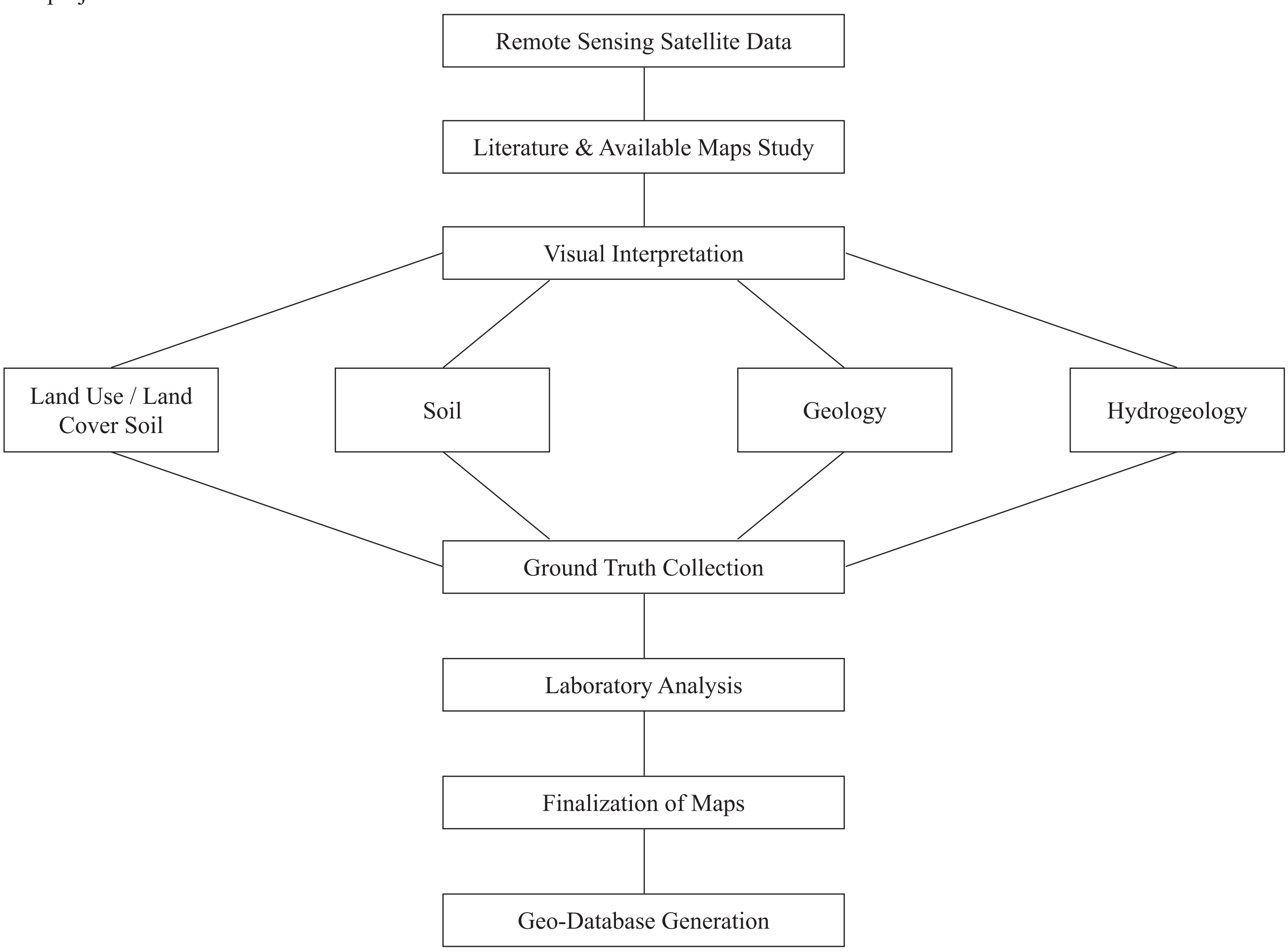
Table 1 : Database used in the study

Satellite	Sensor	Path/Row	Time
IRS-P6	LISS III	99/55	October-November 2006

IRS-P6 LISS III data images of October-November 2006 were used. The standard false color composite (FCC) images of the study area was prepared using bands 4 (NIR), 3 (Red), and 2 (Green) and discrimination of features were made by visual interpretation (on screen) using these images. The interpretation key was based on the relationships between ground features and image elements like, texture, tone, shape, location and pattern. The satellite data from IRS-P6 LISS III data of the study area has been used for geology, geo-morphological, soil, vegetation and land use land cover studies. Published soil maps, topographic maps, climatic data etc. were also collected and used as collateral data. The satellite data were geo-referenced and suitable image enhancements were applied to facilitate the delineation and interpretation of different thematic information.

Visual and digital interpretation methods were used to prepare pre-field interpreted map. The satellite data were interpreted based on photo elements like tone, texture, size, shape, pattern, aspect, association etc. These pre-field interpreted maps and digitally enhanced satellite data were used on the ground to identify different elements of various themes. Suitable field sampling designs in terms of line transects/ quadrants were used to assess the interpreted elements and relate with satellite data. The field data collections were aided by GPS in order to locate the ground verification points on the image and for further incorporation of details. For all the sample collection and field points, attribute information on vegetation, geomorphologic, soil and topographic parameters were also collected. The detailed soil-site study was undertaken in each soil-mapping unit by general traversing and by collecting surface soil, minipit and soil profile observations at intervals depending on soil variability. The sample points were decided based on the geological / geo-morphological / soil heterogeneity mapped from the satellite data.

The project flow chart is as follows-



Results and Discussion

Land use/land cover

The land use/land cover of the Sonar sub-basin includes agriculture, forest land, waste land, settlement, water body, (Figure 2). About 972 km^2 area of the Sonar sub-basin is covered by agriculture, which occupies 63.20% of the total area. It is prominently spread in most part of the basin and forest lands occupy 357 km^2, which is 23.21% of the total area. Forest cover is spatially spread in the south-west part of the basin. However, wasteland is sparsely spread over an area coverage of 202 km^2, which is 13.13% of the total area. Settlement occupies an area of 6 km^2, which forms only 0.40% of the total area. Water bodies occupy 1 km^2, which is 0.06% of the total area. All the types of land use/land cover and their geographic area are summarized in Table 2 and Figure 2.

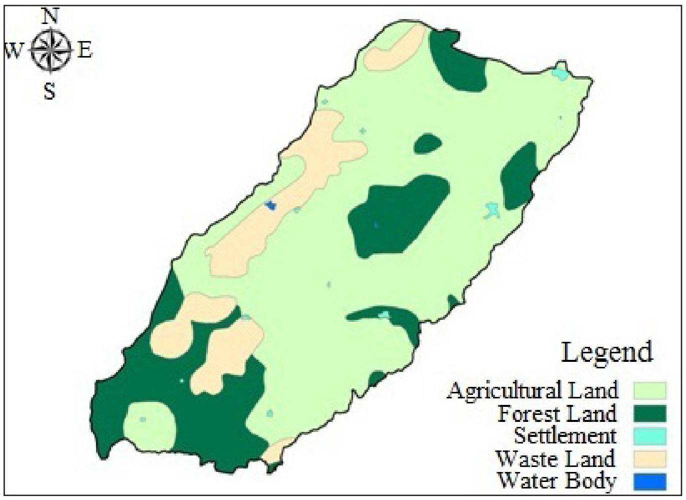


Fig. 2 : Land use/land cover details in the Sonar sub-basin

Table 2 : Land use/land cover details in the Sonar sub-basin

Land use type	Area (km^2)	Area (%)
Agricultural land	972	63.20
Forest land	357	23.21
Waste land	202	13.13
Settlement	6	0.40
Water body	1	0.06

Figure 2 indicated that about 23% of Sonar sub-basin is covered by forest which is mainly concentrated in the lower part of the basin i.e in the south-west region and sparsely spread over north-east and south-east regions. Agricultural land is situated in the lower middle to lower part i.e. toward central to north part of the entire basin. The basin is mainly used for agricultural activities (63.2%). The agricultural land is spread over the entire basin except the south-west region. Waste land is sparsely spread over the south-west to north-west part of the basin indicating that the slope is higher in the south-west to north-west part. Agricultural land is mainly occupied by two soil groups, namely, Soil ID 247 and Soil ID 283 (Figure 3). The soil ID 247 is a loamy shallow soil with excessive drainage and is located in the north-west middle land with undulating topography. This land is quite vulnerable to erosion and requires intensive soil conservation practices for its sustainable production. The other soil group, ID 283 is situated in the lower part of agricultural land. This land is quite fertile with good clayey soil and forms the lower part of the Sonar sub-basin. The agricultural land situated in the hilly and undulated north-west part of the basin suffers from water scarcity due to excessive runoff from the basin. These areas need to follow rainfed farming practices. For sustainable agricultural production in these areas, rainwater harvesting and soil conservation practices need to be adopted intensively.

Soils

The soil is mapped using remote sensing satellite data, IRS-P6 LISS III. The soil information generated in Figure 3 & Table 3 indicated that about 18.5% of the total area of 1538 km^2 of Sonar sub-basin is severely eroded. This area has very shallow loamy soil with excessive drainage. The land situated in the north-west region is more vulnerable to erosion. For maintaining soil health of the region, the agronomical soil conservation practices like trenching contour cultivation, strip cropping, etc. should be supplemented with mechanical measures like trenching, bunding, check dams, etc to check erosion and for sustainable production. The remaining land covering about 81.5% of the area has moderate erosion. The soil in such areas is well drained with depth varying from extremely shallow to deep. The study indicated that about 30% of the soil is clayey which is spread over gently sloping to plain lands. This soil is most suitable for agriculture. The soil ID 247 is loamy shallow soil with excessive drainage. The other soil group ID 283 is quite fertile with good clayey soil and forms the lower part of the Sonar sub-basin valley.

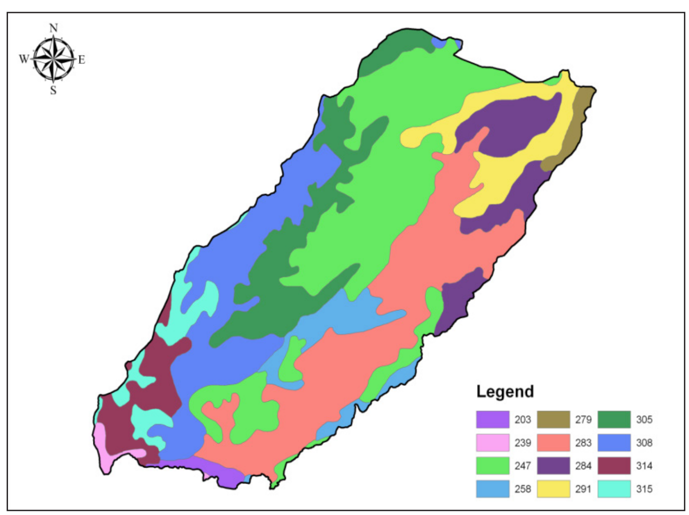


Fig. 3 : Types of soil in the Sonar sub-basin

Table 3 : Types of soil in the Sonar sub-basin

Soil I.D.	Types of soil	Area (km^2)	Area (%)
203	Shallow, well drained, loamy soils on very gentle sloping hills with escarpments with moderate erosion	15	1.0
239	Deep, well drained, calcareous, loamy soils on very gently sloping intervening valleys with moderate erosion	11	0.7
247	Extremely shallow, somewhat excessively drained, loamy soils on gently sloping undulating plateau with moderate erosion	386	25.1
258	Extremely shallow, somewhat excessively drained, loamy soils on moderately sloping undulating plateau with severe erosion	71	4.6
279	Deep, moderately well drained, calcareous, clayey soils on very gently sloping plain land with moderate erosion	18	1.2
283	Deep, moderately well drained, clayey soils on gently sloping plain land with narrow valleys with moderate erosion	326	21.2
284	Deep, moderately well drained, calcareous, clayey soils on very gently sloping plain land with narrow valleys with moderate erosion	108	7.0
291	Deep, moderately well drained, calcareous, clayey soils on very gently sloping undulating plain with moderate erosion	96	6.2
305	Deep, well drained, loamy soils on gently sloping hills with upper pediments with moderate erosion	169	11.0
308	Very shallow, somewhat excessively drained, loamy soils on moderately sloping hills with narrow valleys with severe erosion	213	13.9
314	Moderately deep, well drained, calcareous, clayey soils on gently sloping plateau with escarpment with moderate erosion	69	4.5
315	Deep, moderately well drained, calcareous, clayey soils on gently sloping plain land with narrow valleys with moderate erosion	56	3.6

Geology

The geology of the basin as shown in Figure 4, is characterized into three stratiographical groups. Each group has different geological characteristics and is classified into seven geological subgroups (Table 4). The basaltic flows of deccan trap occupies an area of 1064 km^2, and occupies the major part of the basin whereas ganurgarh (simrawal) shale, spread over an area of 219.82 km^2 followed by sandstone covering 200 km^2 area. (Table 4, Figure 5).

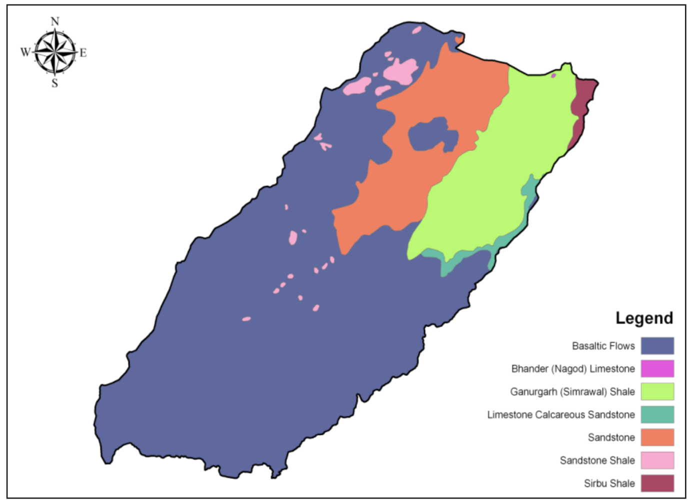


Fig. 4 : Geological distribution of the Sonar sub-basin

Table 4 : Area of geology in the Sonar sub-basin

Stratiography status	Geology	Area (km^2)
Deccan Trap	Basaltic flows	1064
Lameta Group	Limestone, Calcareous, Sandstone	20
Vindhyan Supergroup	Bhander (Nagod) Limestone	0.18
	Ganurgarh (Simrawal) Shale	219.82
	Sandstone	200
	Sandstone, Shale	22
	Sirbu Shale	12

Hydrogeology

A major part of 1399 km^2 of the Sonar sub-basin has low to moderate permeability. This part is mainly occupied by Deccan trap (1064 km^2) which has basaltic flow. Some portion of the lameta group and Vindhyan Supergroup has also the same hydrogeological characteristic. Such geological parts of the basin, having moderate permeability, have poor to moderate groundwater potential. A small part of the Sonar sub-basin, partly covered by Ganurgarh (Simrawal) shale and Sandstone (Figure 4), showed good to excellent permeability and ground water potential as shown in Figure 5 and Table 5.

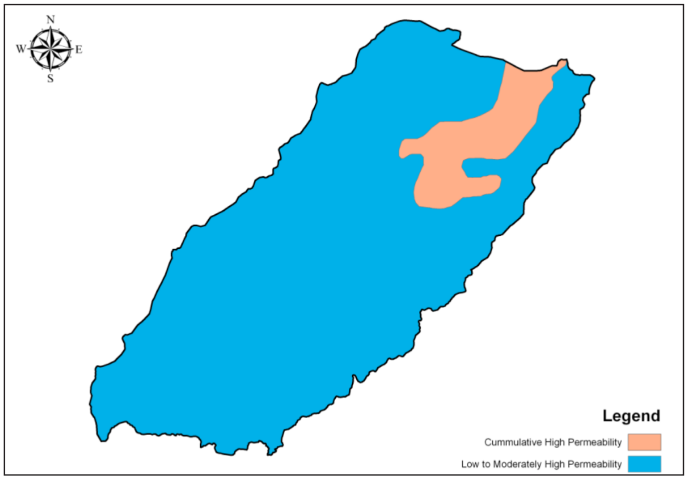


Fig. 5 : Hydrogeological conditions of the Sonar sub-basin

Table 5 : Rock permeability and groundwater potentiality in the Sonar sub-basin

Permeability of rocks	Groundwater potentiality	Area (km^2)
Cumulative high permeability	Good to excellent	139
Low to moderate permeability	Poor to moderate	1399

Conclusions

IRS-P6 LISS III remotely sensed satellite digital image data have been used to classify the different land use/land covers, soil map, geology and hydrogeology. The generated theme can be implemented for further planning of the urban and rural area. The action plan report can be created using the geo database and total decision support system can be developed to depict location and type of action/control measures recommended for sustainable development plan of natural resources. Zonal and community wise soil resource development plan, water resource development plan, land use/land cover plan can be developed using the personal geo database of the respective theme.

The soil map generated with the help of IRS-P6 data helps in recognizing the different types of land in Sonar sub-basin based on the degree of erosion. It clearly indicates that 18.5% of the basin is severely affected by erosion and needs intensive conservation measures for sustainable use of land. The remaining 81.5% of the land is moderately eroded and requires little management practices for its sustainability. About 91% of the basin has low to moderately high permeability shows poor to moderately good groundwater potential whereas 9% of the area shows good to excellent ground water potential.

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