

Hydrogeological Investigations of Pt-6 Watershed in Akola District, Ms, India Using Remote Sensing and GIS Techniques with Reference to Watershed Management

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Abstract - The interpretation of satellite data for geomorphological study is best accomplished by visual interpretation techniques with the understanding of spectral property of rock material and image characteristic of landforms. The criteria of interpretation may, however, change from region to region due to climatic influence on weathering, vegetation cover and mass movements. Effective data regarding surface water availability for watershed management demands application of geospatial techniques such as remote sensing, image processing techniques and GIS. In this study, detailed hydrogeological investigations were carried out for the PT-6 watershed in Akola District, MS, India using remote sensing and GIS techniques with reference to watershed management. The database is created using various techniques for the watershed management and morphometric analysis. The drainage map is digitized from Survey of India toposheets and open source satellite image using Arc Map software. The land use /land cover map is created using supervised and unsupervised classification method in ERDAS Imagine software and Arc GIS 10 versions. Other thematic layers like soil, geomorphology, DEM, slope, land use land cover, and drainage density are also generated using Arc Map software using the available reference data. The Morphometric analysis is mathematical calculation of the parameter likes stream order, bifurcation ratio, and drainage density and so on. For the Morphometric analysis Geographic information system techniques has been used and Strahler (1964) stream order method used for stream ordering. The drainage density of the basin is high at Adsul region indicating the potential groundwater conditions of the aquifers in the region. The results of this study have provided useful information regarding the hydrogeological parameters of the PT-6 watershed. This study has provided information regarding the soil map, land use land cover, slope map, Geomorphological parameters, drainage density map, drainage pattern, Morphometric analysis and Digital Elevation Model investigations and watershed Management response in PT-6 Watershed in Purna region area in Akot Taluka in Akola District Maharashtra, India. The relationship between geological setup and drainage pattern is analyzed using a topographic maps and triangulated irregular network (TIN). Regional and local trends of geological setup are reflected in the variable orientation of channels of different rank in the catchment.

Index Terms - Geomorphology, GIS, land use land cover, Morphometric analysis, Remote sensing, Soil map

1 INTRODUCTION

Water is the most important renewable and finite natural resources since it is required for agriculture, industry and domestic purposes. Managing water resources is a major challenge for the country. Land and water are valuable and essential resources which form the basis of all the life and forms key resource in all economic activities ranging from agriculture to industry (Rokade, et al. 2004). Arc GIS is a composite of computer based decision support tools for the integration of spatial data from different sources and for the analysis, manipulation and display of these data (Anji Reddy, 2001). The Remote Sensing and GIS have been widely used for

understanding the causes of study area. Utility of the Remote Sensing data has also been amply demonstrated through a number of studies (Tiwari and Kudarat 1988; Bhan et al. 1989; Tiwari et al. 1991; Raghubanshi et al. 1991). Therefore, present study is to understand the Morphometric analysis and watershed management in Akola district using RS and GIS approaches. To effectively interpret the Morphometric parameters, the remote sensing and geographic information system (GIS) based techniques have been used. Remote sensing technique is rapid, precise and effective in modern day Morphometric studies. Many workers have carried out Morphometric analysis using remote sensing and GIS techniques. Srivastava (1997) studied drainage pattern of Jharia coalfields (Jharkhand) using remote sensing technology.

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The satellite imagery was visually interpreted into geomorphic units/ landforms based on image elements such as tone, texture, shape, size, location and association, physiographic, genesis of landforms, nature of rocks/ sediments, and associated geological structures. The topographic information in Survey of India aids in interpreting satellite imagery. Three major geomorphic units – hills and plateaus, piedmont zones, and plains- based on physiographic and relief. Within each zone different geomorphic units will be mapped based on landform characteristics, their areal extent, depth of weathering, thickness of deposition, etc. Specific stream pattern develops in response to the initial topography of an area and the distribution of the rock types of varying erosion resistance. The shape of the pattern depends on rock, soil, climate and the changes made to the river. Drainage patterns are good indicator of the underlying rock types, structural features, nature of terrain and topography.

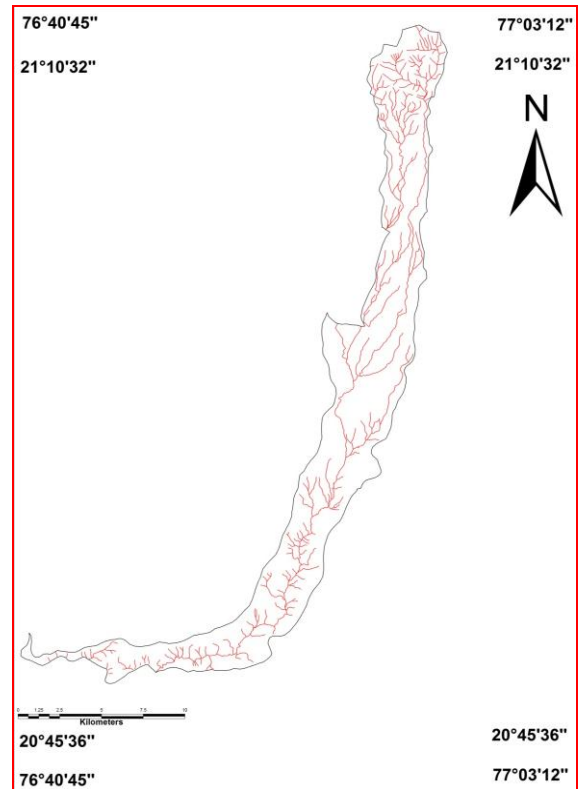
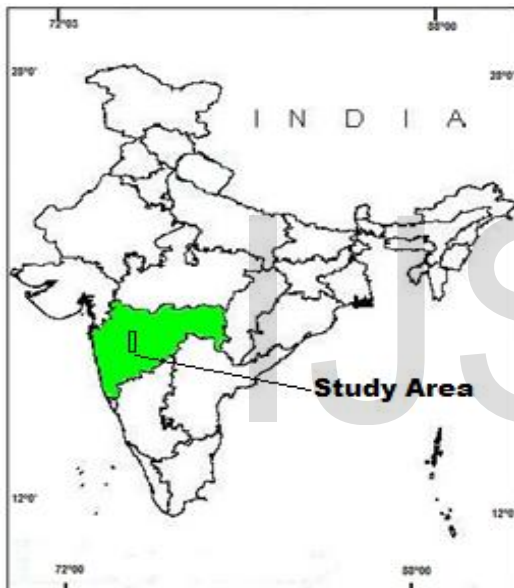


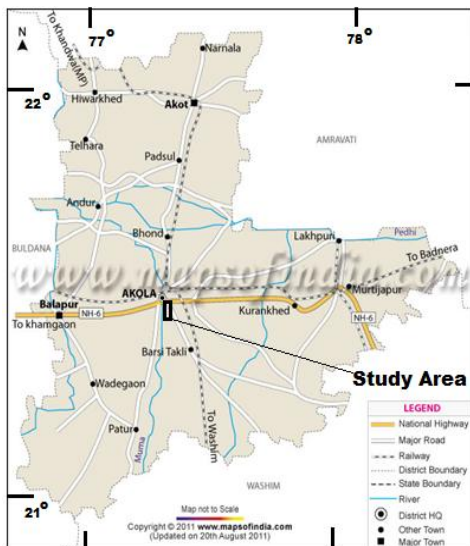
Fig. 1 Location map of PT-6 Watershed Area

2.0 Study Area

The study area lies in the Survey of India Topographic Sheets No. 55 D/13, 55 C/16 is bounded by 20°46'35" - 21°10'32" N latitudes and 76°40'45" - 77°18'24" longitudes (Fig. 1) and is located at Akota Taluka in Akola District. The area of investigation is characterized by the presence of Deccan Trap lava flows with minor occurrence of alluvial zone. Soils in the area are basically derived from basaltic lava flows and alluvial deposits. The soils in the vicinity of part of Purna River are generally deep black to dark brownish grey in colour with calcareous concretions. Land use / Land cover: vegetations and manmade features and omits bare rocks and water. In the study area agriculture is the main land use. Other than the agriculture the area comprises of wasteland, forest land, water bodies and built up areas.

3.0 Methodology

The LISS-III Open Source satellite image was used for linear, aerial for drainage basin analysis and interpretation (Fig. 2). The image interpretation characteristics such as tone, texture, shape, size, pattern and association along with sufficient ground truth and local knowledge were used to finalize the maps of the PT-6 watershed area. The maps were georeferenced and digitized using the Arc GIS 10 and attributes were assigned to create the digital database. The slope map is generated using SRTM data and spatial analyst tool used from Arc Map software. The Survey of India toposheets of scale 1: 50,000 are used for delineating the watershed boundary, drainage pattern for the preparation of



base map and extracting different thematic layers for the various part of analysis namely drainage, road and water bodies etc. Geomorphology map is prepared using visual interpretation technique and interpretation keys such as tone, texture, size, shape, pattern, shadow and association. The land use/cover categories will be visually interpreted into line maps; the mapped categories may vary from map sheet to map sheet depending on ground conditions.

Land Use/Land Cover analysis is carried out with the help of LISS III open source satellite image. The supervised, unsupervised classification techniques and ground truth verification method used for the preparation of land use/ land cover map. Various features are identified and distinguished using interpretation key and visual interpretation technique. In this study multi-criteria overlay analysis has been used to prepare the watershed management and Morphometric analysis of PT-6 sub-watershed in Purna Tributary. Slope, drainage, geomorphology, land use/land cover, soil texture, the themes were prepared from various sources. The PT-6 Sub-watershed area of Purna tributary is 150.913 sq. km. The previously mentioned DEM and TIN are used to understand the detail nature PT-6 Sub-watershed area (Fig.2). The average elevation of the PT-6 Sub-watershed ranges between 233 to 925 m. The surface features of the study area carried out from toposheet map and open source satellite data with ground truth generally reveals various geomorphic features as highly dissected plateau, moderately dissected plateau, lower dissected plateau, ridges, basin, valley fill, alluvial plains, and flood plains.

4.0 Morphometric analysis

Morphometric analysis is giving very important in evaluating drainage pattern and watershed management programs of the watershed area. The study area is dominated by erosional land forms like lava plateau, lava plains, linear ridges, conical hills, mesa, butte and escarpments, and depositional landforms such as alluvial cones, alluvial fans, and Bajada deposits. The PT-6 Watershed area, which is one of the tributary of the Purna River, rise in the southern part of Adsul Village and flows to the northern side for about 40 km length and merges into the Purna river near Adsul Village of Akot Taluka in Akola District. Remote Sensing (RS) and Geographical Information System (GIS) techniques has in delineation of drainage pattern and it provides effective solutions to overcome most of the problems of land and water resources planning and management arising due to usage of conventional methods of data collection. Morphometric is the measurement and mathematical analysis of configuration of the earth surface and the shape and dimensions of its landforms (Thornbury, 1969). The drainage basin analysis of PT-6 Watershed in Purna tributary has been carried out quantitatively including linear aspects, and aerial and relief aspects. In the linear aspects, the stream order, stream length, bifurcation ratio, mean lengths of streams, stream length ratio, and mean stream length ratio are analyzed (Table 1). In the basin geometry, the factors such as area of the basin, total stream length, stream length ratio and perimeter of the basin were computed using Arc GIS and remote sensing techniques (Fig.3).

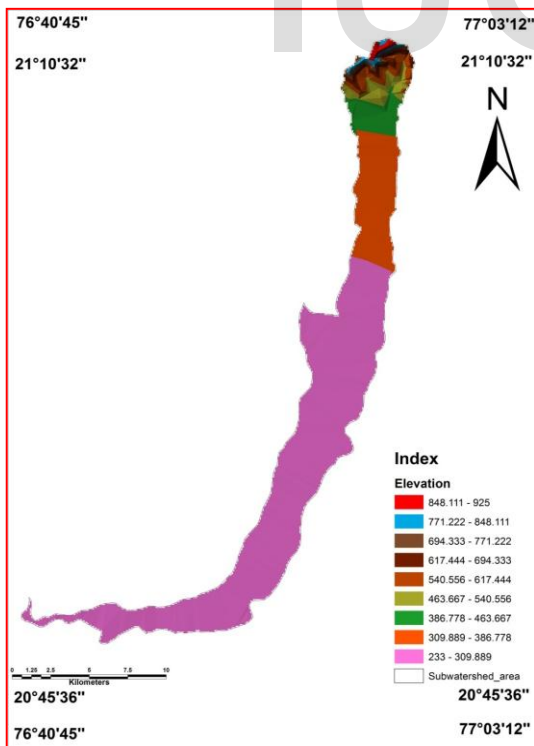


Fig. 2 Digital Elevation Model (DEM/TIN) of PT- 6 Watersheds area

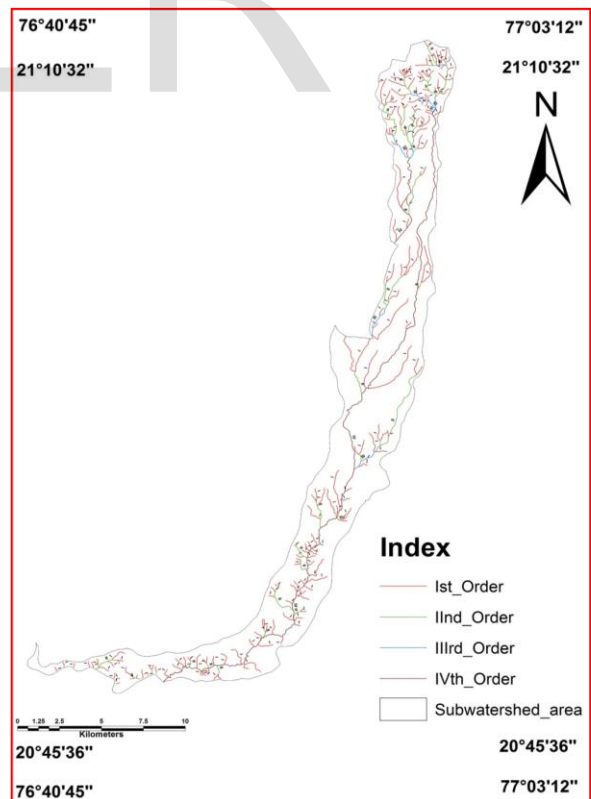


Fig. 3 Morphometric analysis map of PT- 6 Watershed area

In the study area, the drainage density is calculated as total channel length/ basin area. In order to calculate drainage density for a basin or sub-basin, one must first ensure that you have the lengths of all channels within its boundaries (rivers, streams, etc) as well as the area for the entire basin. It is very important to note that before any calculations are made, the data must be projected and units must be set. If this is not the case then calculations will yield incorrect results. It is suggested from the results of the study area that the low drainage density indicates that the watershed is highly permeable having sub-soil and thick vegetation cover. The drainage density or network is maximum in Adsul area (Fig.4).

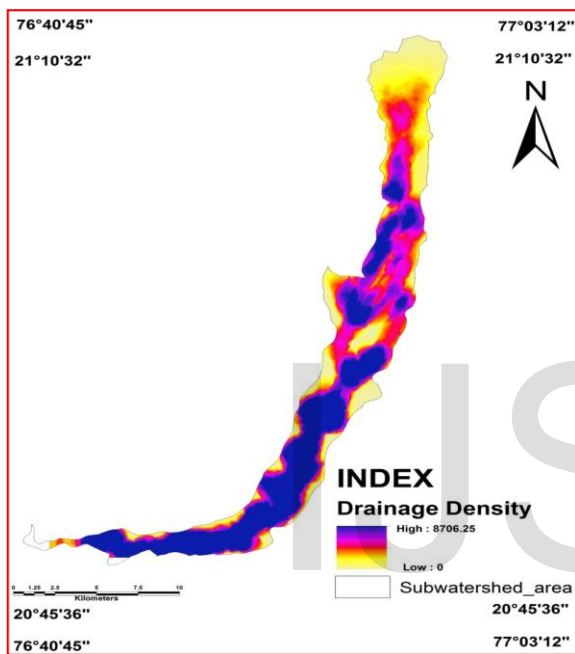


Fig 4 Drainage density map of PT- 6 Watershed area

thus it is necessary to be able to simulate changes. Land use refers to man's activities and the varied uses which are carried on over land and land cover refers to natural vegetation, water bodies, rock/soil, artificial cover and others noticed on the land (NRSA, 1989). The land use/ land cover is derived from the LISS-III Open Source satellite image using image classification techniques such as supervised and unsupervised. The most of the land is under agricultural crop land in the present study area and other area is covered by forest, built up, waste land, and Water body. Land use describes how a parcel of land is used such as for agriculture, settlements or industry, whereas land cover refers to the material such as vegetation, rocks or water bodies that are present on the earth surface. The water bodies include river, canal, tank, pond and reservoir etc (Fig.5)

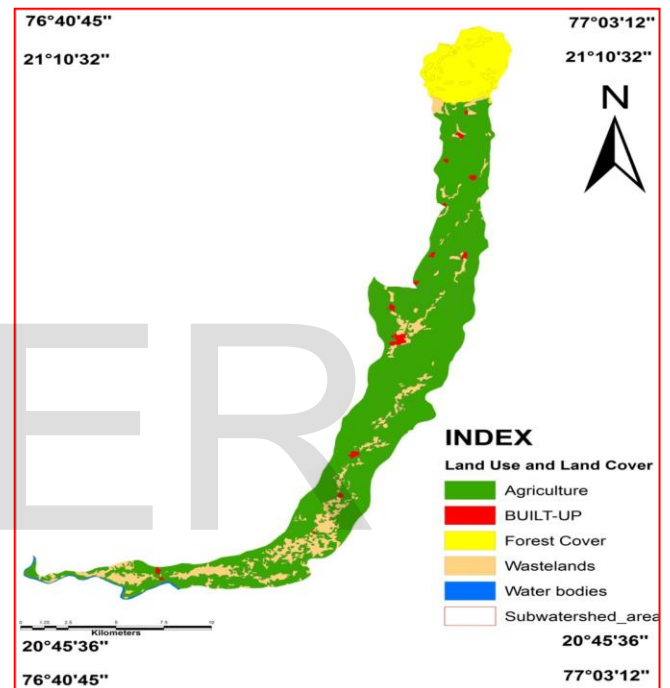


Fig. 5 Land use and land cover map of PT- 6 Watershed area

4.1 Thematic Layers

The study is based on various thematic layers such as drainage, soil texture, slope, DEM/TIN Model, Drainage Density, Flow Direction Map geomorphology, and land use / land cover. These thematic layers were prepared using various spatial and non spatial databases and analyzed using various GIS and digital image processing software like Arc GIS Desktop 10 and ERDAS 9.2 respectively. GIS based approach for the suitable site selection gives effective solution where different thematic layers are overlay using GIS techniques. Appropriate ancillary data is used for generation of respective thematic layers.

4.2 Land Use / Land Cover

Land Cover, defined as the assemblage of biotic and a biotic components on the earth's surface is one of the most crucial properties of the earth system. Land use and land cover is an important component in understanding the interactions of the human activity with the environment and

4.3 Soil Characteristics of the watershed

Soil is important upper layer of the earth surface to support crop and vegetation for the economic development and food requirement of the human. The soil information for the study area was digitized from the soil map. Generally, seven (7) types of soil had been identified in the study area. At the lower area of watershed consists of clayey soil. The soil types of study area are clayey soil, clay loam, clayey, gravely clay, gravely clay loam, gravely sandy loam, sandy clay, and gravely sandy clay. The erosion of the top soil decreases the productivity of land and leads to failure of crops. (Fig .6). Since soil spectral reflectance can be rapidly and easily obtained with high repeatability, numerous samples can be studied to establish trends of change in soil hydraulic properties in a watershed. In order to spatially extrapolate the soil physical condition in the watershed, the spectrally defined physical condition indices were calibrated to pixel reflectance extracted from the IRS image of the study area. However, the

conditional dependency model was developed to remove potential errors in the calibration model due to correlation between factors. Figure 4 below shows the graphical illustration for the conditional dependency model. There was significance relationship between soil physical condition indices and reflectance values from band 3, band 5 and band 7 (at 5 % significance level)

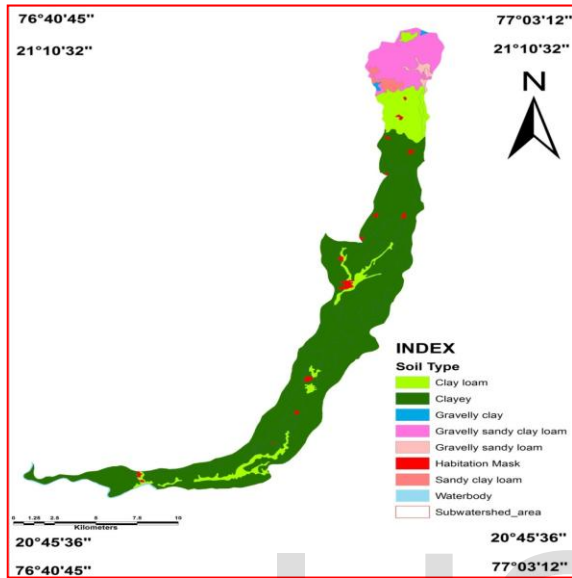


Fig. 6 Soil type map of PT- 6 Watershed Area

4.4 Slope Characteristics

Slope is an important factor in the land. The inclination of the terrain is the result of several factors, such as relief, drainage, climate, geology, and tectonics operates in the area. The slope of the study area ranges from 0.00 - 17.99% to 71.99 - 89.99%. The most of study area is having slope between 0.00 - 17.99% which covered by lower part of the study area. The upper area is having slope between to 71.99 -89.99%.The runoff rate and soil erosion controlled by the slope of the area. (Fig.7)

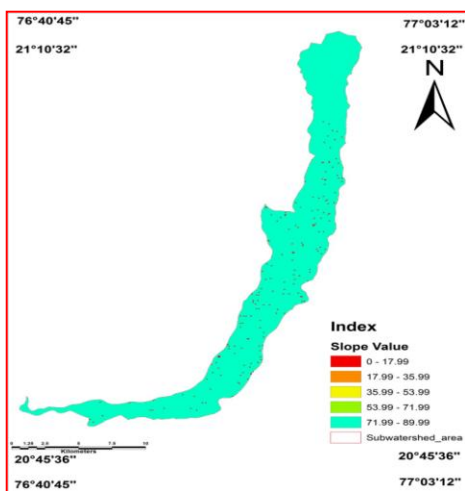


Fig. 7 Slope map of PT- 6 Watershed Area

4.5 Geomorphology

The surface features of the study area were carried out from open source satellite image; toposheet map with field observation generally reveals various geomorphic features as highly dissected plateau, moderately dissected plateau, lower dissected plateau, ridges, basin, valley fill, alluvial plains, flood plains. Geomorphologic studies of the study area were carried out through detailed remote sensing analysis and detailed geomorphologic of the study area with the aim to establish the elevation or geomorphic parameters to those of watershed management Morphometric analysis of the PT-6 watershed was used RS and GIS technique. The geomorphology of the watershed is having landforms features area moderate dissected plateau, denudational slope and alluvial Deposit in the lower and Middle part of the PT-6 sub-watershed and Plateau and Piedmont zone in the upper part of the PT-6 Sub-watershed of Purna tributary in Akot district (Fig.8).

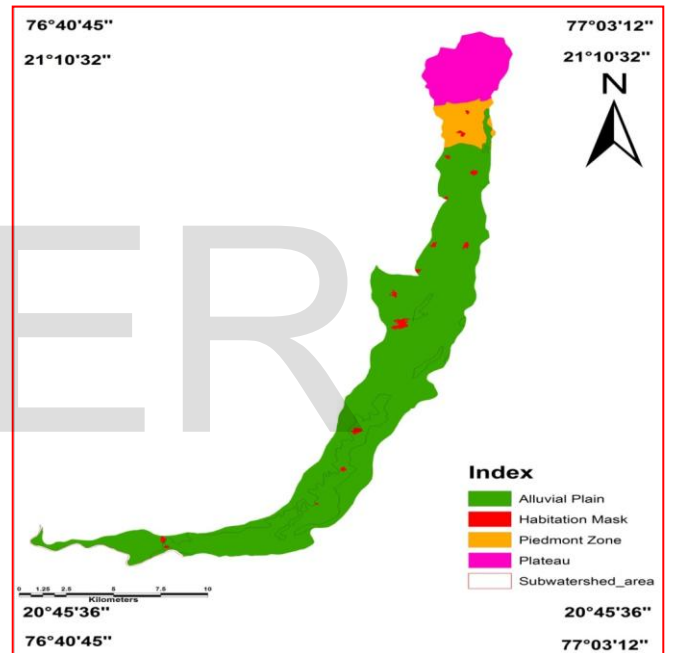


Fig. 8 Geomorphological map of PT- 6 Watershed Area

5.0 Results and Discussion:

The morphometric parameters i.e., bifurcation ratio (Rb), basin shape (Bs), Length of overland flow (Lo), Form Factor (Rf), Circularity Ratio (Rc), and Elongation ratio (Re) are also termed as erosion risk assessment parameters and have been used for prioritizing watersheds (Biswas et al., 1999) and (Nooka Ratnam et al., 2005). The linear parameters such as Stream Length, bifurcation ratio, have a direct relationship with erodibility, higher the value, more is the erodibility. Hence for prioritization of watersheds, the highest value of linear, Areal and Relief parameters such as Bifurcation ratio, % of 1st order streams, Drainage Density, Stream Frequency, Form Factor, Circulatory Ratio, Length of Overland Flow, Basin Relief, Relief Ratio, Ruggedness Number was rated as rank 3, second highest value was rated as rank 2, and the least

value was rated as rank 1. Drainage density, stream frequency, circularity ratio, Investigation of Natural Resources and Hazards in Vashista, Swetha and Mayura Watersheds of Vellar basin, Tamil Nadu Using Geospatial Techniques Hemalatha et al., Int. Journal of Advances in Remote Sensing and GIS, Vol. 1, No. 2, 2012 151 basin shape form factor, length of overland flow have an inverse relationship with erodibility. Hence, the ranking of the watersheds has been determined by assigning the highest priority/rank based on highest value in case of shape parameters (Table 1 and 2). Ranking has been done based on every single parameter, the ranking values for all the linear and areal and shape parameters of each watershed. Based on average value of these parameters, the watersheds having the least rating value was assigned higher priority, next higher value was assigned second priority and so on. Hence, on the basis of morphometric analysis, the watershed number is to be given as high priority watershed. Based on Land use / Land cover analysis, common land use categories i.e., Crop Land, Fallow Land, Built up land, Land With Scrub, Land without Scrub, Barren Rock and Reserved Forest in all the 3 watersheds were considered for prioritization of watersheds based on land use/land cover change analysis. The change in area under each category of land use was converted in percentage and ranking was assigned on the basis of area under each land use category All watersheds have reported negative change in respect of cultivated and uncultivated land, i.e., there has been overall increase in uncultivated land across all watersheds and at the same time decrease in cultivated land area from 2002 to 2010. For prioritization of watersheds the highest value (per cent area) under land use categories of cultivated land, Fallow land, were rated as weightage 1, second highest value as weightage

Table 1 Stream order and number of streams exposed in the study area

Order of Stream	No. of stream segments	Bifurcation Ratio	Length of Stream
I	197	2.7335	138.37km
II	83	3.32	43.79 km
III	25	12.5	11.17 km
IV	2	-	10 km
Total Streams	304		202.96 km

Table 2 Morphometric parameters of PT-6 Watershed

Sr. No	Parameters	Symbols	Values Obtained
1	Area of the basin	A	150.91km
2	Total Stream Length	L _b	202.96km

3	Mean Stream Length	L _{SM}	0.66km
4	Stream Length Ratio	R _L	
5	Total No. of Streams	P	304
6	Basin Length	N	40km
7	Perimeter	L _b	20km

6.0 Summary and Conclusions

Optimal utilization of land and water resources is essential for sustainable development. Resource management using watersheds as an organizing unit has proven to be an effective scale for natural resource management. It presents a common reference point for the many different activities and actors that affect the system, and promotes greater integration and collaboration among those actions. Remote sensing and its image processing technology provide access to spatial and temporal information on watershed, regional, continental and global scales (Yassir Arafat 2010). Further, new sensors and imaging technology are increasing the capability of remote sensing to acquire information at a variety of spatial and temporal scales. The scope of hydrological applications has broadened dramatically, although the problems of flood protection and water resources management continue to be of importance and relevance for the security of communities and for human, social and economic development (Rokade, et al. 2004). GIS and remote sensing applications have proved to be indispensable tools in decision making in the case of problem involving watershed conservation because of the enormity of spatial data involved. In this present study, illustration of how we can benefit from remote sensing and GIS technologies in watershed management and planning. Watershed management is the process of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities within a watershed boundary. The remote sensing data combined with field survey data can provide a unique and hybrid database for optimal planning and management of watershed. Space borne remote sensing technology is a unique tool to provide spatial, multi-spectral and repetitive information for effective planning. The land forms along with slope gradient and relief intensity are other parameters to determine the type of water harvesting and water conservation structures. This study has provided information regarding the soil map, land use land cover, slope map, Geomorphological parameters, drainage density map, drainage pattern, Morphometric analysis and Digital Elevation Model investigations and watershed Management response in PT-6 Watershed in Purna region area in Akot Taluka in Akola District Maharashtra, India. The relationship between geological setup and drainage pattern is analyzed using a topographic maps and triangulated irregular network (TIN). Regional and local trends of geological setup are reflected in the variable orientation of channels of different rank in the catchment.

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