Sustainable Water Resource Planning and Management of Thorli Watershed Using GIS

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Research Article

Abstract: Sustainable water resource planning and management of any of the watershed is essential. This may be achieved by Geomorphometric alalysis using GIS and remote sensing. In this paper the study of Thorli Watershed from Ratnagiri District of Maharashtra state is presented. Sustainable development and management of the Thorli Watershed is influenced by topography of the area and the geomorphologic features. Geomorphometry supplies quantitative drainage network analysis and geomorphic evolution of the Thorli basin have been carried out. The various aspects of Geomorphometric parameters such as Drainage Density, Slope, Shape of the Basin, Bifurcation ratio, Length ratio and landuse & landcover map along with geological parameters gives the precise and objective overview about the watershed. This is the seasonal rain fed watershed, hence needs better management. Sustainable developments and management of the watershed is influenced by topography of the area and the geomorphologic features. Geomorphometry supplies the quantitative values to geomorphology and hydrology.

The remote sensing (RS) and Geographical Information System (GIS) has been adopted for geomorphometric analysis of the study area. The software ILWIS (developed by ITC, Netherlands) has been used for inputting managing, analyzing, interpreting and presenting the data. The generated geoinfromatics can be readily used for decision-making. The attempt has been made to study some geomorphometric parameters of Thorli basin. The manual estimation of geomorphic parameters is tedious and cumbersome process. However, through this attempt, it has been found that integration of RS & GIS allows reliable, accurate and most updated data base tool for handling spatial data, very useful in deriving geomorphometric parameters which are essential for planning future infrastructural, sustainable water resources planning of the study area.

Introduction

Watershed is a smaller unit of the river basin which contributes runoff to a common point and lies within 4000 to 40,000 hectare area. It is a natural geographic convenient basic unit for development and planning. It is physical system in terms of input of precipitation and solar radiation and output of discharge and evapotranspiration. Assessing, managing and planning of water resources for sustainable use becomes an important issue in human life, especially in water scarcity regions. Topography of an area along with geological structures and lithology play an important role for watershed development. Thus, the geomorphometry denotes the measurement of the form of the earth's surface. Geomorphometry supplies the quantitative values of geomorphology and hydrology.

The Geographical Information System (GIS) has been adopted for the geomorphometric analysis of the study area. GIS is the data handling and analysis system based on sets of data distributed spatially in two dimensions (Borrough, 1998). Geographic data has three major components: geographic position. Properties (attributes) and time. The GIS software (ILWIS) allows inputting, managing, analyzing and presenting geographic data by which information can be generated.

Spatial map data (Vector/raster) and attribute data get combined as they are referenced in relative terms to a specific location on the earth's surface. Application of GIS makes the computation of geomorphometic parameters easy, less time consuming and more accurate.

Integration of Remote Sensing (Floyd; Lillisand and Kiefer, 2000) GIS techniques provide reliable, accurate and update database on land and water resources, which is a prerequisite for an integrated approach in identifying runoff potential zones and suitable sites for water harvesting structures (Meijerink et al. 1994)

Study Area

The Thorli basin lies between Bhatya creek in North and Pawas the South west coast of Maharashtra Dist. Ratnagiri. (fig.1) The whole area can be obtained in a single toposheet Nos. 47H/5, covering the area of 66.122sq.km, acquired from Survey of India. The area is approachable through the road link, 12km. far from Ratnagiri, City. The area under study experience humid tropical climatic condition during the period from June to October, it receives heavy rainfall, the annual rainfall being 1200 to 1300 mm.

Geology of the Area

The basin under present investigation forms a part of Deccan Volcanic basalt with laterites capping the hills or the plateau. The tertiary sediments have been exposed in well section and in the adjacent areas.The lignite layers are sandwithched between laterite layers.This topography is a result of the variation in hardness of different flows.The include varieties of basalts alternating with each other.The compact basalts, amygdaloidal basalts, vesicular basalts etc are common. Alluvium deposits formed during Pleistocene to recent are common in the lower regions providing a good agricultural land alongside of Thorli and marked by alternate criss-cross concave-convex slopes. Along the tributaries they form very good gently sloping soil cover called 'Lavans'. The basalts near the surface and just below these deposits are highly weathered. Spheriodal weathering is common in the area. Thorli river is in youthful stage and basalts are exposed as a bed rock. Cascades, water falls potholes, are common in the upper parts. From civil engineering point of view the rock provides good foundation conditions for any civil Engg. Structure.

1.1 Geomorphometry

Geomorphometry is essential quantitative, involving numerical variables whose values may be recovered from topographic maps. Morphometry is the precise measurement of the shape or geometry of any natural form (Strahler, 1964). In other words morphometry may be defined as the measurement and mathematical analysis of the configuration of the earth's surface and of the shape and dimensions of its landforms (Dury, 1970).

The geomorphological and climatic characteristics of a basin govern its hydrological response to a considerable extent. The geomorphological characteristics of a basin represents its attribute, which may be employed in synthesizing its hydrological response. The importance of geomorphic factors like basin shape, relief etc., cannot be overlooked in accurate prediction of runoff. Basin characteristics when measured and expressed in quantified geomorphic parameters can be studied for their influence on runoff. Hence, linking of the geomorphologic parameters with the hydrologic characteristics of the basin can lead to a simple and useful procedure to simulate the hydrologic behavior of various basins, particularly the engaged ones. Interpretation and quantitative analysis of various drainage parameters enables qualitative evaluation of surface runoff, infiltration and susceptibility to erosion within the basin.

The geomorphometric analysis of dendritic drainage of Thorli river basin deals with the computation of stream order, length ration, relief aspects, drainage density, slope and form factor etc.

Computation of Morphometric Parameters

Various important morphometric parameters of the watershed (as in the table) are analyzed as follows:

Geomorphometric Parameters

Table 1

Stream Order	Stream Number	Stream Length Mts.	Bifurcation Ratio	Mean Stream Length Mts.	Length Ratio
1	134	76.0161	4.963	76.0161	-
2	27	29.9638	3.857	105.9799	1.394
3	7	15.9951	3.5	121.975	1.1509
4	2	4.69932	2.00	126.674	1.0385
5	1	8.03598	-	134.7103	1.0634

TOTAL NO. OF STREAMS : 171
DRAINAGE AREA : 66.122 Sq.Km.
DRAINAGE DENSITY : 1.21 Km/Sq. Km.
ELONGATION RATIO : 0.408
DRAINAGE FREQUENCY : 4.049
FORM FACTOR : 0.200
BASIN LENGTH : 12.22 Km.
TOTAL RELIEF : 500 Mts.
RUGGEDNESS NO. : 0.98
CIRCULATORY RATIO : 0.59
RELATIVE RELIEF : 0.0177

Roll of Remote Sensing

IRS 1D LISS III Data with spatial resolution of 23.5 mts, has been processed and used to correlate the geomorphometric studies . The cloudfree data of 24th January 2002 have been selected and procured for study.The image area has been georeferenced as per the earlier GIS layers and assigned with coordinate system.

The three dimensional terrain models have been prepared for the imageries (Fig.11)and also for the aspect and slope maps .The watershed is studied further by adding the digitized segment layers of contour and drainage ,on the generated stereo data which may be represented in the from of stereo pairs or anaglyphs as shown in fig.

Result and Discussions

From the contour map and imageries (fig. 5 to 6) it has been observed that the area has got high relief in upper part and moderately sloping ground. The main Thorli river is found to be in the youthful stage of its erosion, containing deep gorges, cascades. The contours are ranging from 0 m to 200m. Some areas are covered with pleistocene deposits.

The satellite data indicates that the main Thorli river emerges out from hilly mountain terrain of Kokan coastal belt of Maharashtra ranges in the most of Eastern part of the watershed area. The river flows towards West and confluence with Arabian Sea.
With the help of stretched FCC of the present LISS-III data the watershed can be classified and the vegetation land use classification map can be produced for the reference. The river profile of the basin has been preferred, it indicates that the river flows from its upper part to the lower part of the basin has moderately steep slopes.

Agriculture & forests
It has been observed that the most of the agriculture consist of rice crops. The Northern hills are covered by the dense forest and Southern hills are covered by open forest with little exposure of rock outcrops and barren land (fig.7)

Settlement
Number of small scattered settlements have been observed in the area. Very small hamlets have been located in the agriculture field. There is large settlement with 17 villages in the watershed. The biggest one is Thorli near the coast.

Drainage
The watershed contains the dendraitic drainage (Fig.4). The elongation ratio of 0.408 indicates that the basin in fairly elongated and observed to be so, from SE to NW and opening its month towards west. Out of five orders a stream of 1st order has the total length of 76.01 km, while a stream of IInd order has total length of 29.96km., IIIrd order has a total stream of 15.99 km. the maximum length of IVth order stream has 4.69km. and that Vth is 8.03 km. The fairly high bifurcation ratio (4 to 5) indicate that the area in very intensively fragmented. The present configuration and geomorphometrical features of a river network reflects the effects of climatic change, tectonic movements, stratigraphic conditions and erosion over a period extending from the geo-chronological part.

Normally the form factors occur less than 0.45 indicates very elongated basins which has also marked by Vth order river length (8.03km).the form factor of the Thorli river basin is calculated to be 0.2 indicates that there is a marked disproportion between the length of the main stream and the summed length of streams of lower orders. The highest length of a stream of each order in sum total (28.22 km) is almost equal to the river channel flow length.

Being an important parameter in the characterization of river systems, drainage density has been a subject of many regional studies intended to simplify calculation methods, to establish its relationship to environmental conditions and to other geomorphometrical elements, or to determine how it is affected by the changes. However, no study has expressed quantitatively all the factors on which drainage density depends.

It has been observed that mountain drainage basin have densities ranging from 2 to 4 km/km^2. The drainage density of the present watershed is 1.21km/km^2. It indicates the physio-mechanical properties of the rock in this region together with less relief fragmentation and even the intensified surface runoff is unable to increase much of the sedimentary load since the lithology is of compact massive basalt and it is converted into laterite.

The relief of the 1st order basin which are inversely proportional to drainage density explains the mechanism of accelerated erosion by which the surrounding conditions are modified, demonstrating that the geometry of the drainage system tends to adjust continuously so as to achieve a study equilibrium state (graded profile), between the process resulting from erosive energy and the forms thereby created. The low drainage density in the present area indicates resistance to erosion and less permeable substratum forming a relief with steep slops. The drainage frequency (4.049) also supports the above discussed moderate erosional and structural layout of the basin. The ruggedness number of the basin has been found to be 0.98 which indicates that the basin has moderate to low roughness, which also can be confirmed from the imagery and the contour map. Thus the various geomorphometrical factors like stream order, stream numbers, stream length, length ratio bifurcation ratio, drainage density, elongation ratio, from factor, ruggedness number etc. are helpful for future engineering studies of this hydrological unit.

Slope
The digital elevation model (Fig.8) has been prepared by interpolating the contour information the DEM gives the height information at any particular place. The created DEM has been stored in the form of a raster map in ILWIS for further applications. From the DEM the slop steepness map (slope map, degree), slope direction map (slop aspect map), slop convexity map (slop shape map), hill shading map have been prepared.

Slope may be defined as the tangent of the angle of inclination of a line or plane defined by a land surface. It is the result of complex and continuous interaction between internal and external forces acting upon the earth surfaces. It depends in lithology; soil texture, thickness and mobility depended on the climate. In a drainage system, valley side and channel slope control directly the potential and kinetic energy of water flows and thus the intensity of runoff, erosion and transport processes.

Slope degree map clearly indicate the main stream flows at 0-1º but at the head it has very high relief and the second and third orders tributaries contains many water falls and cascades indicating the youth stage of erosion. In all the slop of the area is divided into seven classes. The south western hilly part of the basin shows the maximum slopes. Central hilly part of the basin shows maximum slop ranging from 20 to 45º and above.

The slope aspect map (Fig 9 &10) shows that the general slope of evaluated surfaced are either towards NW or towards SW after observing the slope shape map it can be concluded that the basin has straight slops except very little and very rate concavo-convex slopes along the hard and steeper middle lava flows and in some rate parts occupying unsorted Pleistocene alluvial deposits.

Conclusion

Integration of remote sensing and GIS allows reliable, most accurate and most updated database on land and water resources. It has been found to be very useful tool in combination of spatial data and very useful in deriving geomorphometric parameters. Some geomorphometric parameters of Thorli watershed shows that the watershed in elongated, having low drainage density, low ruggedness number, high relief and almost straight slopes allowing quick disposal of water indicating high rate of erosion but which is retarded due to hard rocks. It has been experienced that the manual estimation of the geomorphometric parameters is a tedious and cumbersome process and often discourages the field engineers form developing the regional methodologies for solving various hydrological problems of the basins.

Since the river is not perennial it is advisable to develop the water harvesting structures like earthen dams, especially in the central part of basin so as to irrigate the gently sloping agriculture land in the lower parts of the basin. Trenching and furrowing in the area of 2^{nd} and 3^{rd} ordered streams is advisable so that run off water may percolate through the columner and mural joints as well as spheroidal weathering zones and increase the ground water potentials in the low lying areas surrounding main stream.

The thick forest in the southwest U/S zones has to be protected to conserve the soils and the biodiversity characteristics in the area. There is a need to develop a road network for connecting the hamlets and villages to the main road of Thorli-Ratnagiri. It is recommended that the further high resolution PAN imageries and 1:25000 contoured top sheet may be used in modern RS & GIS environment, for planning the future infrastructural developments of the Thorli Watershed.

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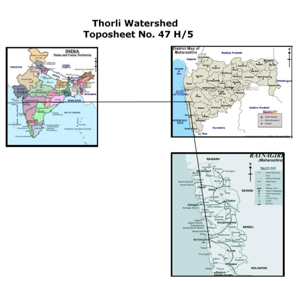


Figure 1 Location Map

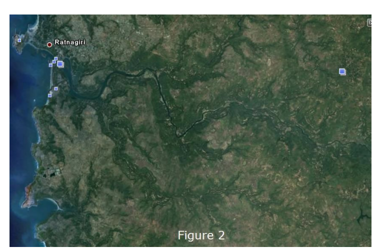
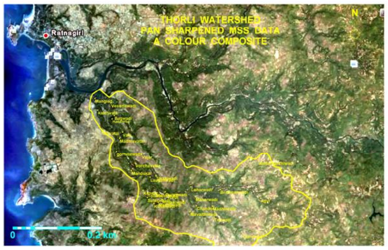


Figure 2



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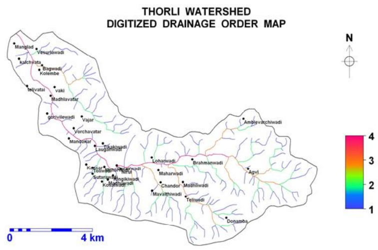

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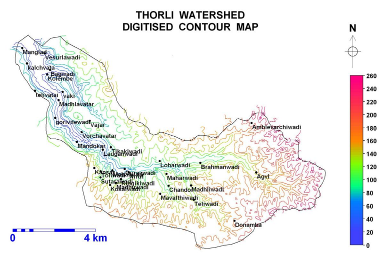

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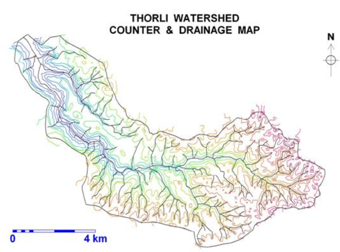

Figure 6

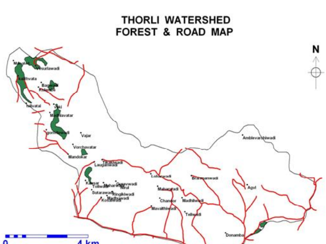

Figure 7

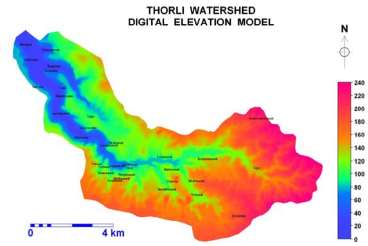

Figure 8

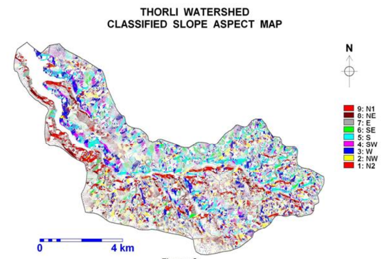

Figure 9

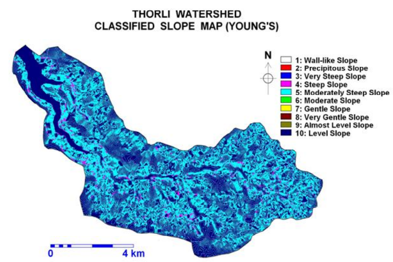

Figure 10

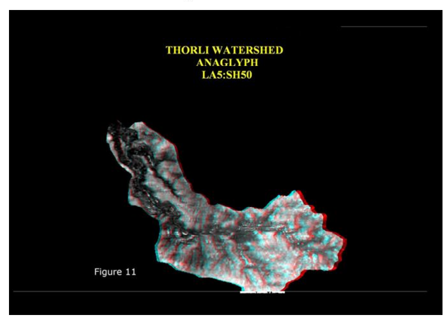

Figure 11