ASSESSMENT OF MORPHOMETRIC CHARACTERISTICS OF KARWADI- NANDAPUR MICRO WATERSHED USING REMOTE SENSING AND GEOGRAPHICAL INFORMATION SYSTEM

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Abstract

The study area is Karwadi-Nandapur watershed is a micro watershed which falls in the Kayadhu river watershed in Marathwada region of Maharashtra.Using the remotely sensed images of the Indian Remote Sensing Satellite P6 (IRS P6), Linear Imaging Self Scanner III(LISS III) images captured in October 2010 and November 2011 having resolution of 23.5m X 23.5m and images from Google Earth Pro of study area were used and cartosat satellites. Map of India with scale 1:15,00,000 and soil maps of India were used for the experimental study. The thematic maps like drainage map, land use and land cover map, soil maps and contour map were prepared adopting the PCI Geomatica10.0 software. The geographical information systems (GIS) analysis was made for the said themes using the Arc GIS – ArcMap10.0. The Karwadi- Nandapur watershed was found to be the third order basin. The present study aims to assess the morphometric characteristics of the watershed basin and it has been assessed by applying GIS techniques. Strahler's method has been employed to assess the fluvial characteristics of the study watershed. Each morphometric characteristic is considered as a single parameter and knowledge based weight age has been assigned by considering its role in soil erosion. The morphometric properties determined for this watershed as a whole and for each watershed will be useful for the efficient planning of water harvesting and groundwater projects on watershed basis.

Key words: Morphometric, Remote sensing.

Introduction

A Watershed is an ideal unit for management of resources like land and water for mitigation of the impact of natural disasters for achieving sustainable development .Soil conservation is the most important measure taken to check the ravages of soil erosion in India. Land is a precious resource as it is the physical base of biomass on the earth. Conservation of such type of natural resources is important to mitigate the increasing demand of land and mathematical analysis of the Configuration of the earth surface, shape and dimension of its landforms (Agarwal, 1998. Reddy et al; 2002). The relationship between various drainage parameters and the aforesaid factors are well recognized by many workers. Recently, many researchers have used remote sensing (RS)data and analyzed them on geographical information system (GIS) parameters namely ordering of various streams and measurement of area of basin ,perimeter of basin ,length of drainage channels ,drainage density (Dd); drainage frequency ,bifurcation ration (Rib), texture ratio (T) and circulatory ratio (Rc) (Kumar et al ;2000). The close relationship between hydrology and geomorphology play an important role in the drainage morphology analysis (Horton ,1932). River basins comprise a distinct morphologic region and have special relevance to drainage pattern and have geomorphology (Doornkamp and King ,1971;)Strahler,1964). In a particular basin sprawl, a drainage type is developed when a drainage network of channel lines have adjusted together with the subsurface structure. Morphometric analysis of a watershed provides a quantitative aspects of the characterization of watersheds (Stealer ,1964). Various scholars have carried out morphometric analysis of river basins by using RS and GIS techniques . Shrimplike et al. (2001) have worked on Sukhumi lake catchment in the Shiwalik hills for the delineation and prioritization of soil erosion areas by GIS and RS.

Study area

The study area is Karwadi-Nandapur watershed is a micro watershed which falls in the Kayadhu river watershed in Marathwada region of Maharashtra. **(figure 1).** The study area is lying between 77^0 14' 00" to 77^0 15'00" E longitude and 19^0 35' 30" to 19^0 34' 00" N latitude and covers an area of 7.72 $km^{2.}$ The climate of the study area can be classified as sub – tropical. Agriculture is the main occupation in the area. The Kayadhu river watershed falls under the sub catchment of Upper Penganga upstream from conflict with Kayadhu in the catchment of Wardha river. Catchment of Wardha river falls under the Godavari river basin. Finally the study area falls under the region of Bay of Bengal. The GSDA has named the watershed under study as PPG8/01/13.

Karawadi –Nandapur watershed receives on an average 773mm rainfall annually . South west monsoon is the chief source of rainfall receiving about 94% annual rainfall during June to September .Ground water through open wells as well as through bore well is the chief source of irrigation and drinking water . The upper reach of watershed is occupied by hilly areas with steep slopes in the range of 8-20 percent .Hill slopes are covered with the trees, shrubs , like teakwood, neem, and other local species in sparse density .

Middle and lower portion of the watershed comprising of main nala course were not having definite deep soil , land use and drainage network , infiltration to the ground water was limited . Before implementation of soil and water conservation works, the ground water table of karawadi –nandapur watershed was declined tremendously . Ground water in the open wells and bore wells was available only up to the month of January . This was resulted in the imbalance between the demand of drinking and irrigation water and the supply. The farmers of Karawadi –Nandapur watershed were able to grow only one crop in Kharif season. The area under cultivation in Rabi season was very less and there was no crop cultivated during summer season before implementation of the watershed development programme.

Climate

The watershed falls in the semi arid tropics with seasonal rainfall and high evaporative demands. The average annual rainfall is 773mm,the rainfall is uneven ,erratic and varies from year to year . About 94 % of the total rainfall is received during the months from June to October and 6 % of the total rainfall received during the remaining months of the year . The mean maximum temperature of 43^0 C is normally recorded during April to June , while the minimum temperature of 15^0C is normally recorded during December -January . During rainy season temperature varies from 30^0C to 35^0C with high relative humidity 75 to 90%. The sunshine hours are less because of cloudy weather in monsoon. During summer, the climate is mostly hot and dry with high evaporative demands.

The RS and arc GIS software used for the study is PCI Geomatica 10.1 and Arc GIS –Arc Map 10.0. The satellite images of Indian Remote Sensing Satellite P6(IRSP6),Linear Imaging Self Scanner III (LISSIII) captured in October 2010 and November 2011 having resolution of 23.5* 23.5*m and images from Google Earth Pro of study area were used ,Map of India with scale 1:15,00,000 and soil maps of India were used for the experimental study. The thematic maps like drainage map, land use and land cover map, soil maps and contour map were prepared using Arc GIS –ArcMap10.0 IRS p6-LISS III . Based on visual interpretation of geo-coded and watershed atlas of All India Land Use Survey (AISLUS) the demarcation of watershed area was done in kayadhu river basin. Digitization work has been carried out for analysis of watershed morphometric characteristics using GIS software (Arc GIS version :10.0). The order was given to each stream by following Stealer (1964) stream ordering technique .The attributes were assigned to the create the digital data base for drainage layer of the river basin. The map showing drainage pattern in the study area **(Figure 3)** was prepared .

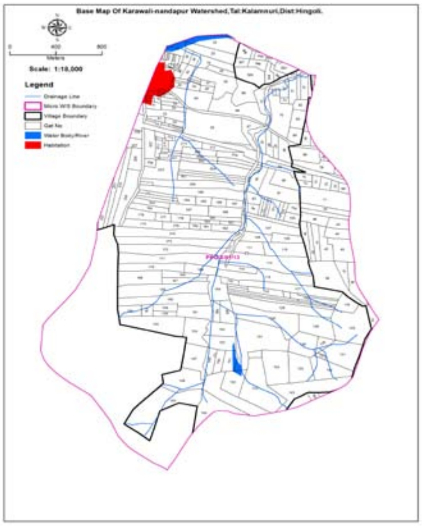

Figure 1. Base Map showing the drainage pattern of Karwadi-Nandapur Micro-watershed

Results and discussion

The GIS analysis of the land use showed that area of 17.48.,17,82,33,32, and19.%were under water body ,wasteland ,built up agriculture and forest , respectively .The GIS analysis showed that 25.92,5.19, 37.80,5.27and 36.27% area is having soli type of clayey, skeletal clayey ,fine montmorillonitic , fine loamy and loamy ,respectively .It was seen that the fine soil exist in major part of the basin .It could be seen that the major land area of the basin is having the slope less than 1% The land slope of the basin in different watershed varied from 0 to 50% The contour values in the basin varied from 0 to 605m. The large difference in the contour of the basin indicated hilly ranges, while wider spacing indicates flat topography. Drainage patterns of stream network from the basin have been observed as mainly dendrite type which indicates the homogeneity in texture and lack of structural control.

Linear aspects of the watershed

Linear aspects of the watershed related to the channel patterns of drainage network where in the topological characteristics of the stream network system is analyzed. The parameters such as stream order, number of overland flow and stream length ratio are taken into account for the present study and results have been discussed.

This study area is a 3rd order drainage basin covering an area of 7.7289 km^2 .The total number of 27 streams were identified of which 20,6 and 1 were 1st ,2nd and 3rd order streams respectively . The lesser amount of stream order indicates higher permeability and infiltration in the micro watersheds. The total length of the 1st order is stream is highest that is 9.7249km and that of 2nd order 6.2909 km and the length of 3rd order stream is 2.8925 km respectively. Generally, the higher the order, the longer the length of stream is noticed in the nature. Longer length of stream is advantageous over the shorter length, in that the former collects water from wider area and greater option for construction of a bund along the length, the lower stream lengths are likely to have lower runoff (Chitra *et al.* 2011)

Bifurcation ratio (R_b):

The R_b was computed using Horton's law of stream numbers (Horton, 1945) which was stated as, "the number of stream segments of each order form an inverse geometric sequence with order number".

$$Rb = \frac{\mathrm{Nu}}{\mathrm{Nu} + 1}$$

Where N_u = number of segments of order 'u' and

N_{u+1}= number of segments of higher order 'u+1.

In general, the value of R_b normally varies in between 2 to 5 and tend to be more for elongated basins (Beaumont, 1975), and it is a useful index for hydrograph shape for watershed similar in other respect. High value of R_b might be expected in region of steeply dipping rock strata. An elongated basin is likely to have high R_b whereas a circular basin is likely to have low R_b. The analysis of bifurcation ratio value shows that the watershed possesses well developing drainage network as the bifurcation ratio ranges between 3.33 to 6.0 that is a medium value. The watershed is neither elongated nor circular in shape. The shape of watershed is more or less like a polygon.

Stream Length ratio

The value of stream length ratio ranges widely between 2.156 to 2.759 which show the early stage of maturity of the watershed.

Horton `s law of stream numbers

The number order relationship can be best explained by Horton`s law of stream numbers which states that " the number of stream segments of successively lower orders in a given basin tend to form a geometric series beginning with the single segment of the highest order and increasing according to constant bifurcation ratio ."

Horton`s law of stream length

The cumulative mean lengths of stream segments of succeeded higher orders increase in geometrical progression starting with the mean length of the 1st order segments with constant length ratio.

Length of overland flow

Length of overland flow is defined as the length of flow path , projected to the horizontal, non –channel flow from point on the drainage divide to appoint on the adjacent stream channel . The length of overland flow for watershed is 0.8392 km. The watershed having length of overland flow greater than 0.25 are under very less structural disturbance, less runoff condition and having higher overland flow.

Aerial aspects of the watershed

The parameters which are governed by the area of the drainage basin are classified as the aerial aspects of the basin .The aerial parameters include drainage density , stream frequency ,elongation ratio, form factor ,circularity ratio, compactness coefficient and drainage texture have been identified and results have been given in Table 2.

Drainage density

It was estimated as the ratio of total length of channels of all orders in the basin to the drainage area of the basin. Horton **(1964)** has introduced drainage density (Dd) as an expression to indicate the closeness of spacing of channels. The drainage density of the watershed is 0.5958 km/km^2 which come under low drainage density of highly permeable subsoil material which is under dense vegetative cover and where the relief is low. The watershed which falls under low drainage density (<2 Km/Km^2) indicate that the region has highly permeable subsoil and dense vegetation cover. (Sethupathi et.al.2011).

Stream frequency

The stream frequency is defined as the total number of stream segment of all order per unit area. The stream frequency for the watershed is 0.0349. It is low due to permeable rocks, the surface runoff is low and infiltration capacity is high within in the study area (Chitra et. al., 2011). The stream frequency of the study area shows direct relation with the drainage density which indicates that the stream population increases with the increase of drainage density (Rao et. al., 2011)

Elongation ratio

It is defined as the ratio between the diameter of a circle (d_c) with the same area as the basin and maximum basin length (L_b). The value of R_e approaches to 1 as shape of the basin approaches to a circle and it varies from 0.6 to 1.0 over a wide variety of climatic and geologic regimes. Typical values of R_e are close to 1 for areas of very low relief and varies between 0.6 to 0.9 for regions of strong relief and steep ground slope. The elongation ratio was estimated by using equation …..

$$\mathrm{Re} = \frac{2\sqrt{\mathrm{A}/\pi}}{Lb}$$

$$\mathrm{Re} = \frac{\mathrm{dc}}{\mathrm{Lb}}$$

It is the ratio of diameter of the circle of the same area in the basin to the maximum basin length. The elongation ratio (R_e) for the watershed is 0.7844 indicating the watershed is less elongated in nature.

Form factor

The ratio of basin area to the square of basin length is called the form factor. The form factor for the study area is 0.483. The low value indicates that watershed is having flatter peak flow for longer duration. The watersheds which are circular in shape showing less side flow for shorter duration and high main flow for longer duration. The watershed which is a oblong in shape , indicating that it will have a flatter peak flow for longer duration are easier to manage than from the circler basin (Chitra et. al., 2011).

Circularity ratio

Circularity ratio is the ratio of the basin area to the area to the area of a circle having the same circumference perimeter as the basin .The circularity ratio for watershed under study 0.7355 indicating that the watershed is oblong in shape with low discharge of runoff and highly permeability of the subsoil condition (Miller,1953).

Drainage texture

It is total number of stream segments of all ordered per perimeter of the watershed area. The texture ratio for watershed is 3.493. For watershed the value of drainage texture it is greater than 8 indicating very fine texture indicating higher runoff potential of the watershed. ,while the watershed having medium value is moderate in nature .The watershed having the lower value is coarser in nature indicating less runoff potential (Smith,1950).

Relief aspects of the watershed

The relief aspects of drainage basin are also important in water resources studies. The character of the distribution of slope, angles sampled over the whole basin depends on the height distribution within it Relief aspects like relief, relative relief, relief ratio, channel slope and ground slope were measured.

Basin Relief

It is defined as the elevation difference between the reference points located in the drainage basin. Relief of the watershed area is 0.0805km. The study watershed area is of low relief region as it is less than 0.3 km. The low relief value indicates high gravity of water flow as well as high infiltration rate and low runoff conditions. The high relief value indicates low gravity of water flow as well as infiltration into the ground and high runoff conditions.

Relief ratio

It is the ratio of the horizontal distance on which relief was measured .The relief ratio for basin is 0.02014. It was noticed that the higher values of relief ratio indicated steep slope and high relief, while the lower values in case of the study watershed area indicated the presence of basement rocks that are exposed in the form of small ridges and mounds with lower degree of slope. (GSI, 1981).

Relative relief

It is the ratio of relief the perimeter of basin. It is an important morphometric variable used for the overall assessment of morphological characteristics of terrain (Suresh, 2002). The relative relief for watershed is 0.007.The study watershed area is having lower relative relief indicating the lowest runoff potential.

Channel slope

For watershed, the channel slope is 0.0175 km/km. The higher channel slopes in watershed indicated less time of concentration that is peak flow occur in short time. While lower channel slope in watershed indicated less peaked flow for longer duration .Therefore, while constructing the water harvesting structures on higher channel of study watershed, the outlet and the rest components like headwall, sidewall and wing wall should also be of higher height for the designed storage capacity (Suresh ,2002). The drop structures in series in the Channels of this watershed are recommended.

Ground slope

It is the product of drainage density and relief of the basin (Suresh ,2002). For watershed ,it is obtained as 0.0480 km/km. The higher ground slopes incase of upper reach of the watershed area indicates lower time of concentration of overland flow .Also, the possibilities of soil erosion will be higher in the watershed basin.

Ruggedness Number

It is the product of the basin relief and drainage density. The ruggedness number of the basin is 0.048. The low value of ruggedness number indicates low erosion intensity in the basin.

Conclusion

One of the purposes of fluvial morphometry is to derive information in quantitative form about the geometry of the fluvial system that can be correlated with hydrologic information. Usually, the morphometric analysis is a prerequisite to any hydrological study. The watershed is having low drainage density due to presence of highly permeable subsoil material which is under dense vegetation and the relief is low. The development of stream segments in the watershed area is more or less affected by rainfall. The present study demonstrates the usefulness of GIS for the morphometric properties determined for this watershed will be useful for the sound planning of water harvesting and groundwater recharge projects on watershed basis.

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