www.cafetinnova.org

ISSN 0974-5904, Volume 10, No. 02

DOI:10.21276/ijee.2017.10.0222

International Journal of Earth Sciences and Engineering

April 2017, P.P. 298-303

Morphometric Analysis approach for Recharge and Soil Erosion Potential in Agaram Watershed, Javadi Hill Range, Vellore District, Tamil Nadu, India

SARANAATHAN S E AND SOOSAI MANICKARAJ D

SASTRA University, Thanjavur – 613 402, Tamil Nadu, INDIA

Email: *esaranathan@yahoo.co.in*

Abstract: *The present study makes an attempt to study drainage morphometry and its influence on hydrology of Agaram Watershed, Tamil Nadu, India. For detailed study, Shuttle Radar Topographic Mission (SRTM) data was used to create Digital Elevation Model (DEM), aspect grid and slope maps. Geographical Information System (GIS) was used in evaluation of linear, areal, relief and gradient aspects of morphometric parameters. The study reveals that the elongated shape of the basin is mainly due to the guiding effect of thrusting and faulting. The lower order streams are found mostly dominating in the basin. The mean Bifurcation Ratio of the entire basin is 3.80, indicating that the drainage pattern is not much influenced by geological structures. The Relief ratio of the basin is 0.018. This indicates that the discharge capability of the watershed is very high and the groundwater potential is meager. Morphometric analysis of Agaram watershed reveals that about 38% of the area was highly suitable for rainwater harvesting and about 25% of the watershed coming under high alarming of soil erosion. This study is very useful for planning rainwater harvesting and watershed management.*

Keywords: *Morphometric analysis, SRTM data, GIS, Agaram watershed, Tamil Nadu, India.*

1. Introduction

The drainage basin analysis is important in any hydrological investigation like assessment of groundwater potential, groundwater management, pedology and environmental assessment. Various important hydrologic phenomena can be correlated with the physiographic characteristics of drainage basins such as size, shape, slope of drainage area, drainage density and drainage length etc., [6] [17].

Morphometric analysis of a watershed provides a quantitative description of the drainage system, which is an important aspect of the characterization of watersheds [25]. Morphometric analysis requires measurement of linear features, areal aspects, gradient of channel network and contributing ground slopes of the drainage basin [15]. The drainage characteristics of Agaram watershed were studied by analyzing topographical map and SRTM data. The watershed development schemes become important for developing the surface and groundwater resources in this area. SRTM data was used for preparing DEM map, slope and aspect maps. GIS was used in evaluation of Linear, Areal and Relief morphometric parameters.

2. Study Area

Agaram watershed is located in Vellore and Thiruvannamalai districts of Tamil Nadu, India is an area of about 467.82 km². It falls between 78º 44’ and 78º 57’ E longitude and 12º 34’ 30” and 12º 55’ N latitude in the Toposheets No. 57 L/10,13 and 14 (Figure 1). The maximum and minimum elevations are present in the watershed 980 m and 260 m above MSL, respectively. The main Agaram stream flows almost south to north and joins the Palar River near Agaramcherry village. It is one of the tributary of Palar River. The climate of the study area is tropical climate of warm and semi arid region with an average annual rainfall of about 72.17 mm with maximum 171 mm for the month of October 2008. The maximum temperature rises up to 32 ºC in May, while minimum temperature can be as low as 12 ºC in December.

3. Drainage

The dendritic pattern of drainage, characterized by irregular branching of tributary streams in many directions joining the main channel is observed. The watershed was divided into 8 Sub Watersheds and further to 24 Macro Watersheds based on the drainage pattern. The total area of the watershed is 467.82 km² (Figure 2). The total number of streams recognized in the area is 1422, out of which 76.9 % falls in the first order, 18.3 % in second order, 4.2 % in third order and 0.67 % in fourth order streams. In the watershed the most dominant streams are first order streams. First and second order streams are located in high elevation area. In these areas, runoff is more subject to less recharge.

4. Geomorphology

The area is well represented by Structural hill and valley occupying almost half of the watershed. The remaining area is covered by residual hills, valley fills

Received: December 15, 2016; Accepted: February 17, 2017; Published: April 26, 2017
International Journal of Earth Sciences and Engineering, 10(02), 298-303, 2017, DOI:10.21276/ijee.2017.10.0222

(Figure 3) forming soil covers of alluviam, silt clay, red sandy and red loomy, pediments, flood plain and buried pediment. Topographically, the area is undulated with eroded hillocks. The general slope of the watershed is towards north – northeast. The watershed area can be classified into hills upland in southern portion and pediment undulating plain in northern portion. The predominate soil in region are red sandy soil in nature.

5. Geology and Structure

Geologically, the area forms a part of the hard rock terrain in Agaram watershed and includes gneissic and charnockite [10]. The watershed area forms an integral part of the Eastern Ghat hill ranges comprising rocks of Khondalite groups (quartz-feldspar-garnet-sillimanite-gneiss) and charnockite of Achaean age (Figure 4). The area experiences substantial structural disturbances like faulting and folding resulting in development of well-formed joints and fractures. The major set of lineaments trends in NE and SW are mostly vertical in nature.

6. Methodology

The drainage map of the Agaram watershed was initially derived from scanned Survey of India toposheets through digitization (1:50,000). An unparalleled data set of global elevations was created from SRTM data available for modeling and environmental applications for free of cost. The Consultative Group compiled the entire globe for Spatial Information (CGIAR-CSI) in SRTM version 3.0 by creating 90m DEM.

The morphometric analysis was carried out at macro watershed level using Arc GIS 9.2 version. Based on the drainage order, the drainage channels were classified into different orders [25]. The morphometric parameters were divided into four categories: Linear, Areal, Relief and Gradient aspects of the watershed. Linear parameters like area, length, stream number, stream length, stream orders, average stream length, stream length ratio and bifurcation ratios were also calculated. Areal parameters such as drainage density, drainage texture, stream frequency, elongation ratio, circularity ratio, and form factor and infiltration number were also calculated. Relief parameters like relief, relief ratio and slope were also calculated. Gradient parameters such as elevation at source and mouth, length of mainstream and gradient ratio were evaluated with the help of established standard methods and formulae are shown in Table 1 [2] [3] [8] [12] [23] [24] [25] [26].

Watershed delineation was done adopting the system developed by All Indian Soil Survey and Land Use Organization, Government of India [1], based on the toposheets of Survey of India. According to this classification, the mean area of watershed is less than 500 km^2. Further watershed is classified into sub-watershed of about 30 to 50 km^2 and macro watershed of about 10 to 30 km^2. The entire watershed was divided into 8 sub-watersheds and 24 macro watersheds designated as 4C2B1a (1,2 & 3) to 4C2B1h (1,2 & 3). The smallest (4C2B1b1) and the largest (4C2B1e1) macro watersheds measure 11.11 km² and 29.44 km², respectively (Table 2). The macro watersheds have been named according to AIS & LUS classification (Figure 5).

7. Result and Discussion

7.1 Morphometric Analysis

The DEM was obtained with a pixel size of 90 m and the total drainage area of Agaram watershed is 467.82 km². The designation of stream order is the first step in morphometric analysis of a drainage basin, based on the hierarchic making of streams proposed by Strahler [25].

7.1.1 Linear Aspects

Computation of the linear aspects such as stream order, stream number for various orders, stream lengths for various stream orders, stream length ratio and bifurcation ratio are described below.

(a). Stream Order (U)

The streams of the Agaram watershed have been ranked according to the Strahler's [25] stream ordering system and the number of streams of each segment (Nu) of the order (U) is given in Table 2. The smallest permanent streams are called "First order", two first order streams joined to form a larger stream called "Second order", two second order streams joined to form a "Third order", two third order streams joined to form a "Fourth order" and two fourth order streams joined to form "Fifth order". Smaller streams entering a higher ordered stream do not change its order number. The variation in order and size of the tributary basins are largely due to physiographic and structural conditions of the region. Application of this ordering procedure through GIS shows that an entire drainage network of the study area is the sixth order stream. Three sub watersheds 4C2B1 c, e and h were identified under the third order and five sub watersheds 4C2B1 a, b, d, f and g were under fourth order stream.

(b) Stream Number (Nu)

The total numbers of steams gradually decreases as the stream order increases. With the application of GIS, the number of streams in each order and the total number of streams were found out (Table 2). The details of stream number confirm Horton's [12] first law "Law of stream number", which states that the number of streams of different orders in a given drainage basin tends closely to approximate an inverse geometric ratio.

(c) Stream Length (Lu)

The stream lengths for all macro watersheds of various orders have been measured on digitized map using Arc GIS. It also confirms Horton's [11] "Law of stream length", which states that the average length of streams of each of the different orders in a drainage basin tends closely to approximate a direct geometric ratio. The total stream length of the Agaram watershed is 1111.60 km. The stream lengths of first, second, third and fourth order streams are 733.54, 239.19, 112.23 and 26.64 km respectively (Table 2).

(d) Stream Length Ratio (RL)

The stream length ratio is defined as the ratio of mean stream length (Lu) of segment of order u, to mean stream segment length (Lu-1) of the next lower order u-1. The Stream Length Ratio values vary from 0.34 to 7.76 for macro watersheds, while it ranges from 0.09 to 7.87 for the whole watershed. The RL between successive stream orders of the basin vary due to differences in slope and topographic conditions (Rakesh Kumar et al., 2001; Sreedevi et al., 2005). It has an important relationship with the surface flow discharge and erosional stage of the basin. The sub watershed 4C2B1b is prone to high erosion compared to the other sub watersheds. Deep soil erosion noticed in the field. The moderate erosion activities are seen in 4C2B1 g, h and d sub watersheds. The remaining sub watersheds 4C2B1 f, e, a and c indicates low erosion activities.

(e) Bifurcation Ratio (Rb)

The term Bifurcation Ratio was introduced by Horton [11] to express the ratio of the number of streams of any given order to the number in the next lower order. According to Strahler [25], the ratio of number of streams of a given order (Nu) to the number of segments of the higher order (Nu + 1) is termed as the Rb. Lower Rb values are the characteristics of structurally less disturbed watersheds without any distortion in drainage pattern [14]. The mean bifurcation ratio values (Table 3) of Agaram watershed indicate less structural control on the drainage development.

7.1.2 *Areal Aspects*

The Agaram watershed area was computed by converting the map into polygon form. Areal aspects such as drainage density, drainage texture, stream frequency, elongation ratio, circularity ratio, and form factor and infiltration number are presented in Table 4.

(a) Drainage Density (Dd)

Drainage density established by Horton [12], is defined as the total length of channels (Lu) in the macro watershed or catchment divided by the area (A) of the macro watershed or catchment. The Dd for the whole watershed is 2.38 km^{-1}, while those of the 24 macro watersheds are shown in Table 4. In general, low Dd value occurs in the regions of highly weathered and permeable sub soil materials with dense vegetated cover and low relief [7], whereas high Dd value is prevalent in the region of weak impermeable sub surface materials, which are sparsely vegetated and show high relief in the watershed area [9]. The density value of sub-watershed (Table 4) shows that the macro watershed, as a whole is coming under highly permeable characteristics. It indicates that rain water percolation is high in this region. Lower Dd of 4C2B1f, h and c sub-watershed was given better scope for water harvesting structure.

(b) Drainage Texture (T)

The drainage texture is the product of drainage density (Dd) and stream frequency (Fs). The 'T' depends upon a number of natural factors such as climate, rainfall, vegetation, rock and soil type, infiltration capacity, relief and stage of development. Smith (1950) has classified drainage density into 5 classes i.e., Very Coarse (< 2), Coarse (2 - 4), Medium (4 - 6), Fine (6 - 8) and Very Fine (> 8). The texture of a rock is dependent upon vegetation type and climate [8]. The 'T' of the whole watershed is about 7.24 km^{-1}. In general, the drainage texture of the whole basin comes under fine texture, but sub-watershed like 4C2B1a, 4C2B1b, 4C2B1d and 4C2B1g are coming under very fine texture and remaining sub-watershed are showing fine texture.

(c) Stream Frequency (Fs)

The stream frequency of the watershed is defined as the total number of streams per unit area [12]. The Fs of the whole watershed is 3.04 km^{-2}, while the Fs values for all the macro watersheds are given in Table 4. The stream frequency values indicate positive correlation with the drainage density of all the macro watersheds suggesting increase in stream population with respect to increase in drainage density. This is also indicating that the percolation of watershed is high. If stream frequency of one area is higher than other, it depicts that the particular streams increasing lengthwise. It is mostly developed in fissile charnockite and gneissic formation. The structure of rock underlain, intensity of slope, soil condition, distribution of rainfalls and forest cover has aggregate effect on growth of streams. It suggests wider scope for water harvesting in 4C2B1 h, f and c sub-watershed.

(d) Elongation Ratio (Re)

Elongation ratio is defined as the ratio between the diameter of a circle with the same area as that of the watershed (A) and the maximum length (L) of the basin. The values of elongation ratio (Re) generally vary from 0.20 to 0.40 associated with a wide variety of climate and geology and can be grouped into three categories i.e., Circular (>0.9), Oval (0.9 – 0.8) and Elongated (< 0.6) (Schumm, 1956). Elongation ratio for the Agaram watershed is estimated as 0.61 and all of the macro watershed values are shown in Table 4. Those macro watersheds having low Re values are susceptible to high erosion and sedimentation load and the whole of Agaram watershed represent elongated category. The Elongation ratio of sub watershed 4C2B1 g, c and b are low indicating high erosion and sediment load. The elongation ratio of sub watersheds 4C2B1 h, e, f and d are high and hence erosion and sediment load are less. The remaining sub watersheds are subjected to moderate erosion and sediment load.

(e) Circularity Ratio (Rc)

The circularity ratio is the ratio of the area of a basin to the area of a circle having the same circumference as the perimeter of the basin [13]. It is influenced by the length, frequency streams, geological structures, land cover, climate, slope and gradient of various orders. The Rc value of the whole watershed is 0.31 and all of the macro watershed range from 0.21 to 0.63 (Table 4). Maximum value for circulatory ratio is unit 1. Detailed study of 8 sub-watersheds discovered that sub-watershed 4C2B1c is showing a higher value of Rc (1:0.48). The lowest value of Rc (1:0.25) is for sub-watershed 4C2B1h.

Rc parameter is helpful for assessment of flood hazard (Singh 2006). If the value of Rc is high, flood hazard is high at peak time whereas low values denotes low flood hazard.

(f) Form Factor (Ff)

Form factor is defined as the ratio of basin area to the square of the basin length [12]. The value of Ff would be always less than 0.7854 for a perfect circular basin. The form factor of the whole basin is 0.02, while all of the macro watershed values are given in Table 4. A lower form factor value indicates elongated shape of the macro watersheds in the study area.

(g) Infiltration Number

Infiltration number is the multiple functions of the drainage density and drainage frequency. It is controlled by geology, slope, soil and land use. Groundwater occurs in the weathered zones and joints and fractures present in the country rock. The higher value of infiltration for the 4C2B1b, 4C2B1d and 4C2B1g sub-watersheds are probably due to coarse drainage texture, vegetation cover, less aerial coverage and almost homogenous weathered geological formation. Lower value of infiltration number of 4C2B1 f, h and c sub watershed indicates higher filtration and low run off, low value of drainage density and stream frequency. Higher values of drainage density, stream frequency and infiltration number indicate lower infiltration and high run off.

7.1.3 *Relief Aspects*

Evaluation of some of the relief aspects such as relief, relief ratio and slope are discussed below.

(a) Relief

Relief is the maximum vertical distance between the lowest and the highest points of a basin. Basin relief is an important factor in understanding the denudation characteristics of the basin. The maximum height of the whole watershed is 980 m and the lowest height is 260 m. Therefore, the relief of the Agaram watershed is 720 m (Table 5).

(b) Relief Ratio

The relief ratio is the dimensionless height – length ratio equal to the tangent of the angle formed by two planes are intersecting at the mouth of the basin, one is representing the horizontal and the other one is passing through the highest point of the basin [19]. This is an indicator of the intensity of erosion process operating on the slope of the basin. In Agaram watershed, Rh values of sub-watersheds vary from 0.016 to 0.048 (Table 4). The gentle slope of the main watershed indicates low erosion in this basin.

(c) Slope

Slope analysis is an important parameter in geomorphic studies. The slope elements are controlled by the climatomorphogenic processes in the area having the rock of varying resistance. The slope map provides data for planning, settlement, mechanization of agriculture and deforestation, and planning of engineering structures, morphoconservation practices etc [22]. Slope map was prepared using SRTM data and Arc view method. Slope grid is identified as the maximum rate of change in value from each cell to its neighbors, using methodology described by Burrough [5]. The Agaram watershed slope varies from 0º to 30º (Figure 6).

7.1.4 *Gradient Aspects*

Evaluation of the gradient aspects like gradient ratio is discussed below.

(a) Gradient Ratio

Gradient ratio is an indication of channel slope from which the runoff volume could be evaluated. The Agaram watershed has a gradient ratio of 0.02, while those macro watersheds values are shown in Table 6.

8. Conclusions

The Agaram watershed has been classified as sixth order based on the stream orders. The drainage density of Agaram watershed as well as those of the macro watersheds reveals that the subsurface strata are permeable. This characteristic feature of coarse drainage, since the texture values are less than 4. The drainage areas of the macro watersheds are passing through an early mature stage of the fluvial geometric cycle. Lower order streams are mostly dominated in the watershed. The elongated shape of the basin is mainly due to the guiding effect of thrusting and faulting. Relief ratio indicates that the discharge capabilities of these macro watersheds are very high and the groundwater potential is meager. The estimated values of drainage density, drainage texture, stream frequency, circularity ratio, infiltration number and gradient ratio shows that the sub watershed 4C2B1 f, h and c categories forms the first priority for recharging groundwater. The other sub watersheds 4C2B1 e, g and 4C2B1 a, b, d are considered as second and third priority respectively. This is shown Figure 7. Morphometric characteristic like stream length ratio, elongation ratio, infiltration number, relief ratio and gradient ratio are found very much helpful to identify erosion zone (Biswas et al., 1999). The study reveals that sub watersheds 4C2B1 b and d are subjected to high threat for soil erosion. The sub watersheds 4C2B1 g and a, and 4C2B1 c, e, f and h are showing second and third place for soil erosion respectively. Figure 8 shows the soil erosion sub watesheds. This study is the basis for rainwater harvesting; soil erosion and watershed management plans.

References

[1] AIS & LUS, (1990) Watershed Atlas of India, Department of Agriculture and co-operation. All India Soil and Landuse Survey, IARI campus, New Delhi.

[2] Akram, J., Mohd Yousuf, K, and Rizwan, A. (2009) Prioritization of Sub-watersheds based on morphometric and land use analysis using Remote Sensing and GIS Techniques. Journal of the Indian Society of Remote Sensing, 37, 261-274.

[3] Anup Kumar Das and Saumitra Mukherjee, (2005) Drainage morphometry using Satellite Data and GIS in Raigad District, Maharastra, Journal of Geological Society of India, 65 (5), 577-586.

[4] Biswas, S., Sudhakar, S., and Desai, V.R. (1999) Prioritization of sub-watershed based on, morphometric analysis of drainage basin, District Midnapore, West Bengal, Journal of the Indian Society of Remote Sensing, 27 (3), 155-166.

[5] Borrough, P.A. (1986) Principles of geographical information systems for land resources assessment. Oxford University Press, New York, p50.

[6] Chopra, R., Dhiman, R.D. and Sharma, P.K. (2005) Morphometric Analysis of Sub watersheds, District Gurdaspur, Punjab. Journal of the Indian Society Remote Sensing, 33(4), 531-539.

[7] Dietrich, W. E., Wilson, C.J., Montgomery, D.R., McKean, J. and Bauer, R. (1992) Erosion thresholds and land surface morphology, Journal of Geology, 20, 675-679.

[8] Dornkamp, J.C. and King, C.A.M. (1971) Numerical analysis in geomorphology, an introduction. St. Martins Press, New York.

[9] Gardinar, V. (1995) Channel networks: progress in the study of spatial and temporal variations of drainage density. In: A.Gurnell and G.E.Petts (Eds.), Changing Rriver Channels. Wiley New York, 65-85.

[10] GSI (1994) Senior Deputy Director General, Geological Survey of India, Southern Region, Chennai, India.

[11] Horton, R.E. (1932) Drainage basin characteristics. Trans. Americans Geophys. Union, 13, 350-361.

[12] Horton, R.E. (1945) Erosional development of streams and their drainage density: hydrophysical approach to quantitative geomorphology. Geological Society of America, Bull. no.56, 275-370.

[13] Miller, V.C. (1953) A quantitative geomorphic study of drainage basin characteristics on the Clinch Mountain area, Virgina and Tennessee, Project NR 389-402, Tech Rep 3, Columbia University, Department of Geology, ONR, New York.

[14] Nag, SK. (1998) Morphometric analysis using remote sensing techniques in the Chaka sub-basin, Purulia district, West Bengal, Journal of the Indian Society Remote Sensing, 26 (1&2), 69-76.

[15] Nautiyal, M.D. (1994) Morphometric analysis of drainage basin, District Dehradun, Uttar Pradesh. Journal of Indian Society of Remote Sensing, 22(4), 252-262.

[16] Rakesh, K., Lohani, A.K., Sanjay, K., Chatterjee, C. and Nema, R.K. (2001) GIS based morphometric analysis of Ajay River basin up to Sarath gauging site of south Bihar. Journal of Applied Hydrology, 14(4), 45-54.

[17] Rastogi, R.A. and Sharma, T.C. (1976) Quantitative analysis of drainage basin characteristics. Journal Soil and Water Conservation in India, 26 (1&4), 18-25.

[18] Schumm, S.A. (1956) Evolution of drainage systems and slopes in Badlands at Perth Amboy, New Jersey. Bull. Geological Society of America, 67, 597-646.

[19] Schumm, S.A. (1963) Sinuosity of alluvial rivers on the Great Plains. Bull. Geological Society of America, 74, 1089-1100.

[20] Singh, S.R. (2006) A Drainage morphological approach for water resources development of the Sur catchment, Vidarbha Region. Journal of the Indian Society of Remote Sensing, 34 (1), 79-88.

[21] Smith, K.G. (1950) Standards for grading textures of erosional topography. American Journal of Science, 248, 655-668.

[22] Sreedevi, P.D., Subrahmanyam, K. and Shakeel, A. (2005) The significance of morphometric analysis for obtaining groundwater potential zones in a structurally controlled terrain. Environmental Geology, Vol.47 (3), 412-420.

[23] Sreedevi, P.D., Owais, S., Khan, H.H. and Ahmed, S. (2009) Morphometric analysis of a watershed of south India using SRTM data and GIS. Journal of Geological Society of India, 73, 543-552.

[24] Srinivasa Vittala, S., Govindaiah, S. and Honne Gowda, H (2004) Morphometric analysis of sub-watershed in the Pavagada area of of Tumkur District, South India using Remote Sensing and GIS Techniques, Journal of the Indian Society of Remote Sensing, 32 (4), 351 – 362.

[25] Strahler, A.N. (1964) Quantitative geomorphology of drainage basins and channel networks. In: V.T.Chow (Ed.), Handbook of applied Hydrology. McGraw-Hill, New York, 4.39 – 4.76.

[26] Vijith, H. and Satheesh, R. (2006) GIS Based morphometric analysis of two major upland sub-watersheds of Meenachil River in Kerala, Journal of the Indian Society of Remote Sensing, 34 (2), 181 – 186.