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Morphological study at micro watershed of Shiwni village, Indore (Madhya Pradesh)

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Abstract

This study is an opportunity to address the natural resource development and management aspects taking shape at Xigloo A living model has started taking shape at Janakpuri area of Shiwni village, Indore (M.P), 36 km away from Indore; M.P. Xigloo is part of a micro watershed on which this study is focused. The total area of the study micro watershed is 101 ha. The Study area is surrounded by hills and having barren land on the periphery of hills followed by agricultural land. Data related to Topography, Climatology, Hydrology, soil and Vegetation were collected and analyzed, which gave the final output in the form of various thematic maps and ways and means to deal with the available natural resources. The drainage map shows that the total length of the stream is 12.54 km and drainage density (12.5 km/km^2) of the watershed which was indicating high runoff potential of the watershed. Bifurcation Ratio of the area was found to be 3.15 which mean greater flooding area effected to soil erosion.

Keywords: Thematic maps, linear aspects, areal aspects and drainage network

1. Introduction

Manav chetna vikas Kendra (MCVK) is a “Center for Research on Human Education” working with motto of “Unified Society Universal System”. A living model has started taking shape at Janakpuri area of Shiwni village, Indore (M.P), 36 km away from Indore, M.P. This model will be a place where 100 families (1000 persons) will live together in harmony with each other and with the nature. Name given to this model village is “Xigloo”. Xigloo is part of a micro watershed on which this study is focused. Micro- watershed having soil of three types such as red soil, black cotton soil, fragmented basaltic (murum). The mean maximum and minimum temperature recorded in the area are 44°C and 50°C . The average annual rainfall of the area is about 1062 mm. The general elevation of the area ranges from 540 to 670 m above mean sea level (MSL). The major crops grown in the area are wheat, mustard, potato, gram, chickpea in rabi and paddy, pigeon pea, maize in *kharif*.

The watershed is the region drained by linking streams in a manner that drains from the prevalent and single outlet all the stream flow produced in the region. Watershed features like slope, shape, size, region, etc. are the variables that separate the different watershed type. Study of morphological features is essential for watershed growth. Watershed management is the watershed planning and management process to achieve the mission linked to the general growth of the watershed, which results in enhancing water quality, enriching the socio-economic situation of individuals residing in the watershed and ecosystem management.

Demand and need for water conservation are growing day by day; GIS together with remote sensing have been shown to be very efficient and effective. The main purpose of the study is to develop the watershed development plan and environmental management for groundwater recharge development using GIS and survey. From the final production of this research, various conservation structures and interventions such as storage tank, and soil and water conservation structures were suggested for groundwater recharge, and reduction of watershed soil erosion.

2. Materials and methods

2.1 Study area

2.1.1 Location of study area

The study area is located near the Janakpuri area of Shiwni village, Indore (M.P) which is a micro-watershed. Village Janakpuri is a micro watershed, which is surrounded by Hills.

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It is located about 36 km away from Indore, Madhya Pradesh. The micro- watershed lies between 76°15'53" E to 76°15'85" E longitude and 22°66'75" N to 22°66'82" N latitude. Location of study area of the watershed is shown in fig. 3.1. The total area of the micro-watershed covers approximately an area of 101 hectares, out of which forest area is about 10 hectares. Area is covered by Toposheet number F43K2 on a scale of 1:25,000. The mean maximum and minimum temperature recorded in the area are 44° C and 5° C. The average annual rainfall of the area is about 1062 mm. The general elevation of the area ranges from 540 to 670 m above mean sea level (MSL). The major crops grown in the area are +wheat, mustard, potato, gram, chickpea in *rabi* and paddy, pigeon pea, maize in *kharif*.

The Total geographical area of the watershed is 101 ha out of which 13 ha land is under Hilly forest area and out of remaining area most of the area is under cultivation *Kharif* crops are mainly dependent on the monsoon. The non-arable land is degraded with poor vegetation cover. The watershed comprises of undulating uplands fields and hills. The slope of

the arable land varies from 20-40 %percent and for non-arable it varies from 80-100 %.

Present land slope map, DEM map, Contour map, Drainage map for analysis and interpretation of required data are generated using Arc GIS10.5 Software and Google earth domain. A global positioning system (GPS) is a computer-based information system that enables the capturing, modeling, manipulation, retrieval, analysis and presentation of geographically referenced data (Ogden *et al.*, 2000).

2.2 Geomorphologic Analysis

Directly or indirectly, the morphological parameters represent the entire causative variables that affect runoff and sediment loss based on the watershed. Before adopting any advanced tool to monitor the watershed reactions in connection with any of the hydrological procedures acting on it, the surface characteristics are the fundamental unit of assessment. The various parameters can be conveniently worked out from the toposheet using the capability of GIS tool. Geomorphological parameters are presented under different groups as shown in Table 3.1.

Table 3.1.

S. No.	Groups	Geomorphological Parameters
1.	Linear Aspects of Drainage Network.	Basin length, stream order, stream length, bifurcation ratio.
2.	Areal Aspects of Watershed	Form factor, circulatory ratio, elongation ratio, stream frequency, Drainage density, constant of channel maintenance
3.	Relief Aspects of Channel Network	Relief ratio, maximum basin relief, maximum relief, Ruggedness Number

2.2.1 Procedure for Determination of Geomorphologic Parameters

1. Fill

Provide *shiwni_dem* as the input surface raster, and save the output raster as *shiwni_fill* in your working directory. The main function of this tool is to remove imperfections in the DEM to enable water flow to the watershed outlet.

2. Flow Direction

This function computes the flow direction for a given grid. The value in any given cell of the flow directions grid indicates the direction of the steepest descent from that cell to one of its neighboring cells using the eight direction pour point (D8) method. Select *shiwni_fill* as the input surface raster, and name the output raster as, *shiwni_fdr*.

3. Flow Accumulation

The function uses the flow direction grid to compute the accumulated number of cells that are draining to any particular cell in the DEM. Select *shiwni_fdr* as the 28 input flow direction raster, and save the output flow accumulation raster as, *shiwni_fac*.

4. Stream Order

This tool creates stream order for the stream network. Provide *shiwni_stream* as the input for stream raster, *shiwni_fdr* as the input for flow direction raster and name the output raster as *stream_order*. Two methods are available for estimating stream order. Choose anyone of them.

5. Stream to Feature

This tool converts stream raster to a polyline feature class. Provide *shiwni_stream* as the input for stream raster, *shiwni_fdr* as input for the flow direction raster and save the output as *stream.shp*. When process completes, a shapefile, named *stream* will be added to the map document. One can

find the value of different morphological parameters by the output file obtained in step 5 (stream.shp).

Steps 1 to 5 are the hydrology tool of the spatial analyst tool and this tools used in Arc Map 10.

2.2.2 Stream Order

The order of the stream is the degree of separation of the stream within a watershed. By order, each branch is appointed. A stream of first order is an unbranched tributary. Two or more streams of first order form a second order stream, a third order stream is a tributary created by two or more streams of second order. Generally an n^{th} order stream is formed by two or more streams of order $(n-1)^{\text{th}}$ and streams of lower order. It is used to calculate the indicators of drainage character of watershed.

2.2.3 Bifurcation Ratio

The bifurcation ratio is defined as the ratio of the number of stream of any order, to the number of stream of the next order.

$$R_b = N_u / N_{u+1}$$

Where,

R_b = bifurcation ratio.

N_u = number of streams of order u .

N_{u+1} = number of streams of order $u+1$.

2.3 Areal Aspects of Watershed

2.3.1 Form Factor

Form factor of a catchment is the ratio of total basin area to the square of basin length. It represents the distribution of area extent of catchment with respect to the centroid of area. It may express as:

$$R_b = A_u / L_b^2$$

Where,

A_u = basin area, m^2

L_b = basin length, m

2.3.2 Elongation Ratio

It is the ratio of diameter of a circle having equal area to the given drainage basin and the maximum basin length. It represents the shape of watershed in terms of comparative length towards the outlet from ridgeline.

$$R_L = D_c / L_{bm}$$

Where,

R_L = elongation ratio.

D_c = diameter of circle having same area as the given drainage basin.

L_{bm} = maximum basin length.

2.3.4 Circulatory Ratio

Circulatory ratio is defined as ratio of basin area (A_u) to the area of circle (A_c) having equal perimeter as perimeter of drainage basin. It represents the shape in extent near to the circle of equivalent characteristics.

$$R_c = \frac{\text{basin area (} A_u \text{)}}{\text{area of circle (} A_c \text{) having equal perimeter as the Perimeter of drainage basin}}$$

2.3.5 Drainage Density

The drainage density (D_d) is described as the proportion of the complete length of all streams within a watershed to the watershed's complete region. In the region of extremely resistant and permeable sub-soil material, low drainage density happens. 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 (D_d) as an expression to indicate the closeness of spacing of channels.

2.4 Relief Aspects of Channel Network

2.4.1 Maximum Relief

It is the difference of elevation between the highest elevated points to the least elevated point in the watershed. It represents the maximum fall in the catchment area.

2.4.2 Relief Ratio

It is the ratio of basin relief to the horizontal projected distance of basin length from ridge to the outlet. It also represents the steepness of the watershed toward outlet.

2.4.3 Ruggedness Number

The product of relief and drainage density is called Ruggedness Number.

$$R_N = H \times D_d$$

Where,

H = Relief

D_d = Drainage density

For morphometric analysis, drainage map, stream length of each order, area, perimeter, maximum length, numbers of stream of each order and watershed relief values were required. These inputs were derived by using GIS software. Once these Inputs were extracted, then by making use of the mathematical formulae as discussed above, all the necessary

parameters for morphometric analysis were computed.

3. Results and discussion

3.1 DEM of study area

DEM is the topographical surface's digital depiction. DEM was prepared using contour lines and extra characteristics observed from GPS. Fig 3.1 shows the DEM of the study area. A DEM is a raster representation of a continuous surface, usually referencing the surface of the earth. Different colors provide varying interpolation areas.

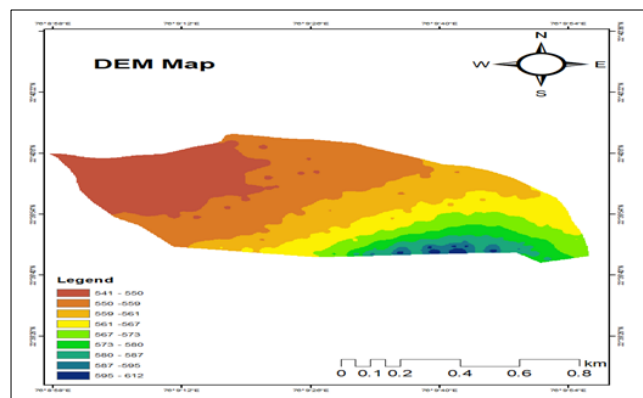


Fig 3.1: DEM map

3.2 Contour Map of study area

The Contour Map was generated through GIS Digital Elevation Model (DEM). Fig 3.2 shows the Contour Map of the study area of 2 m interval. All Points along any one contour line are at the same elevation. The difference in the elevation between two adjacent contours is called the contour interval.

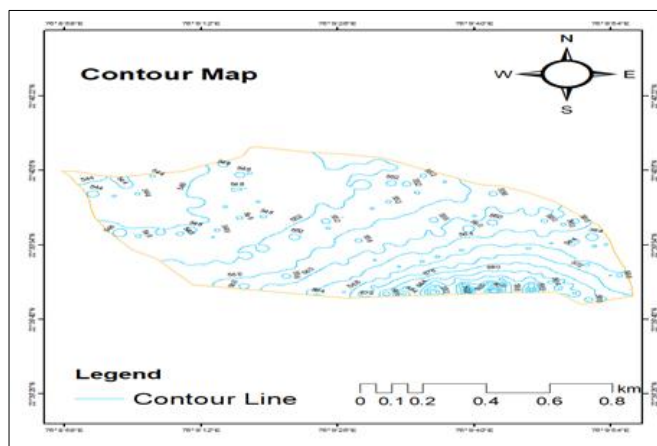


Fig 3.2: Contour map

3.3 Drainage map of study area

All the streams existing in this Small watershed are marked in Fig 3.3. The morphometric analysis has been done for this watershed and is given in Table 3.1. It can be seen that, there was a total of 456 streams found in the entire micro watershed out of which 137 streams are of 1st order, 75 are of 2nd order, 41 are of 3rd order, 9 are of 4th order, and 2 are of 5th order. The total length of the streams was found to be 12.54 km. Bifurcation Ratio of the area was found to be 3.15. Drainage density of the area was found to be 12.5 km/km² which indicate high runoff potential of this watershed.

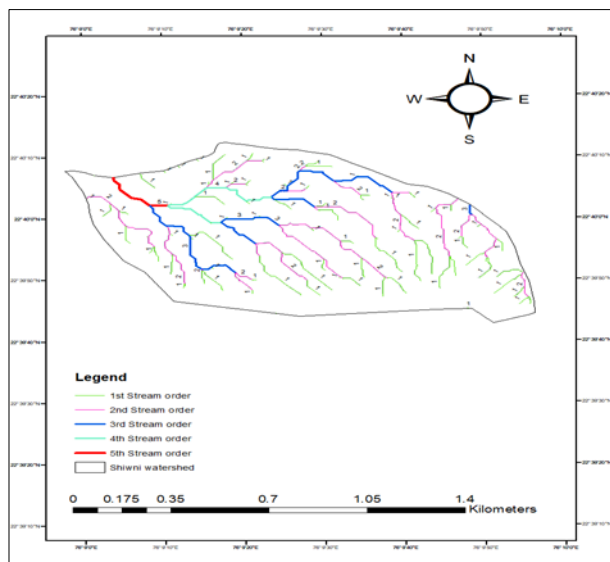


Fig 3.3: Drainage map

3.4 Geomorphological Analysis

3.4.1 Linear Aspects of Drainage Network

It refers to the analysis of stream order, stream number, and bifurcation ratio. After analysis it was found that the watershed is of 5th order type and drainage pattern is dendrite. An elongated basin is likely to have high bifurcation ratio, whereas circular basin is likely to have a low bifurcation ratio. In the present study, the numbers of streams found of 1st, 2nd, 3rd, 4th, 5th order are 137, 75, 41, 9, 2 respectively (Table 3.1). However, in general, the mean length of the stream of the particular order increases with the increase in the order of stream which means the mean length of a stream of a given order is greater than that of immediate lower order but less than that of the next higher order. This confirms the property of the stream order number and their corresponding length. The other important property bifurcation ratio (R_b) reflecting geological and tectonic characteristics of the watershed estimated as 3.15 for the study area.

Table 3.1: Linear Aspects of Drainage Network

S. No.	Characteristics	Values
1.	Basin length	1.6 Km
2.	Maximum basin length	2.1 Km
3.	Stream length (L_u)	
	1 st	5347 m
	2 nd	4417 m
	3 rd	1831 m
	4 th	698 m
	5 th	273 m
4.	Average stream length	
	1 st	39 m
	2 nd	59 m
	3 rd	45 m
	4 th	78 m
	5 th	137 m
5.	Bifurcation Ratio (R_b)	
	B.R.1	1.8
	B.R.2	1.8
	B.R.3	4.5
	B.R.4	4.5
	Average	3.15

3.4.2 Areal Aspects of Watershed

Under this aspect, the study gives the description of arrangement of areal element mainly watershed shape which

affects stream flow hydrographs and peak flow. The key parameters that describe the watershed shape viz. the shape factor, ratio of circulation and elongation were calculated.

It was observed that the value of form factor (R_f) is 0.38 (Table 3.2). Drainage density (D_d) and stream frequency are other important characteristics of watershed. The drainage density of watershed is 12.5 km/km². The drainage density may be described as having coarse texture ($DD < 5$ Km Length per km² /area ;), medium texture ($DD = 5-10$ Km Length per km² /area ;), fine texture ($DD = 10-20$ Km Length per km² /area ;), and ultra fine texture etc., the drainage density in watershed (i.e, 12.5 Km/Km²) is a fine texture.

Table 3.2: Areal Aspects of Watershed

S. No.	Characteristics	Values
1.	Form factor (R_f)	0.38
2.	Drainage density (D_d)	12.5 km/Sq.km

3.4.3 Relief Aspects of Channel Network

The relief was observed 72 m (Table 3.3) and the study area ranges from 540 to 670 m above mean sea level (MSL). The ruggedness number value was observed 0.90 (Table 3.3). This analysis reveals that GIS is an effective tool for analysis of morphometric parameters of the basin. Morphometric analysis employed in this study will assist planner and management of natural resource under changing climate scenario.

Table 3.3: Relief Aspects of Channel Network

S. No.	Characteristics	Values
1.	Relief	72 m
2.	Ruggedness number (N_r)	0.90

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