International Journal of Advanced Technology in Civil Engineering

Volume 1 | Issue 2 Article 2

April 2012

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ATAL K. R
Walchand College of Engineering, Sangli, krhatal@yahoo.co.in

Abhijit M. Zende
Pune Institute of Computer Technology, Pune - 411043, India., zenabhi31@gmail.com

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ABHIJIT .M. ZENDE & ATAL K.R

Pune Institute of Computer Technology, Pune - 411043, India.
Walchand College of Engineering, Sangli
Email id: krhatal@yahoo.co.in, zenabhi31@gmail.com

Abstract: Quantitative drainage network analysis & geomorphic evolution of the Sub-basin of Koyna River from Satara District of Maharashtra have been carried out. The various aspects of geomorphometric parameters such as, Drainage Density, Slope, Shape of the Basin, Bifurcation ratio, length ratios etc. along with the 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 geomorphologic features. The generated geo-informatics can be readily used for decision-making. The manual estimation of geomorphic parameters is tedious and cumbersome process. However through this attempt of work, it has been found that integration of RS and GIS allows reliable, most accurate and updated database tool for handling special data, very useful in deriving geomorphometric parameters which are essential for planning of future infrastructural constructions, suggested here, for sustainable water resource development. Quantitative analysis and its interpretation of various drainage parameters enable qualitative evaluation of surface runoff, infiltration and susceptibility to erosion within the basin area. In the present study geomorphometric analysis has been carried out and the RS Data have been interpreted. Also, water availability with the help of flow accumulation study has been carried out. Based on this the locations of various water harvesting structures have been mapped, and also some related developmental activities have been suggested.

Keywords: *Geomorphometric parameters, Water Harvesting structures, Geo-informatics*

I. Introduction

The rapid growth of industrialisation, population explosion and agricultural activities resulted in creating pressure on the fresh water resources leading to over-exploitation, reducing the ground water level and increasing the scarcity of water. Due to rapid urbanization, infiltration of rain water into the sub-soil has decreased drastically and recharging of ground water has diminished. Thus, rain water harvesting becomes imperative to meet the inadequacy of water supply. Deshpande P.K., Assistant Professor 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 geomorphometric parameters easy, less time consuming and more accurate. Integration of Remote Sensing, GIS techniques provide reliable, accurate and updated 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). An attempt was made to examine the geomorphometric characteristics of the malin watershed, a tributary of Ganga River Basin. The various aspect of morphometry such as slope, drainage density, shape of the basin and landforms along with the geological parameters give the precise and objective overview about the watershed. In this analysis they have used the software viz. integrated land and water information

system (ILWIS) of geographical information system (GIS). This software is a powerful tool for watershed management studies, for quantitative analysis and its interpretation of various drainage parameters (Deshpande et.al.2004), for the sustainable development and management of the watershed which is influenced by topography of the area and the geomorphologic features. Their study includes the application of RS & GIS in geomorphometric analysis of Morana River, which right tributary of Koyana River in the part of Western Ghats. The efficiency of RS & GIS over the manual estimation of geomorphic parameters has been experienced through their work.

II. Study Area

The Kera River, fifth order perennial stream has peanut shaped basin which is about 18.07 km. in length, 9 km. in average width. This basin has a maximum elevation of about 1128 m. in its northern part. The basin is developed in the uppermost reaches of the drainage system of the Koyna river, in Satara district of Maharashtra and is included with in the survey of India topographic sheet no. 47 G/15 on the scale 1:50,000. The study area is lying between the latitude 17º 20' N to 17 º 30' N and longitude 73 º 50' E to 73 º 56' E (Fig. 1). The Kera River collects its water from the western part of the Sahyadri ranges and drains an area 103.07 sq. km. appx. The important townships present in the area are Patan, Surul, Tamkane, Katavadi, Mendhoshi, Khivshi, Sakhari, Nivkane, Divshi-Khurd etc. Two water-harvesting projects are ongoing, one near Nivkane and other near Sakhari. The area under study experiences semiarid to subhumid climate. During the period from June to October it receives heavy rainfall, the annual rainfall being 750 mm. The summer is dry with maximum temperature reading up to 38 º C to 40 º C.

III. Methodology

The methodology adopted for the present watershed management study includes geomorphometric analysis and the IRS satellite data interpretation. There is a synchronism between Geographical Information System (GIS) technology and Remote Sensing (RS) techniques. The study is based on this synchronism with the computer aided tools. The remote sensing data has been interpreted by conventional photo recognition elements for decision making.

5.1 Preparation of Thematic Maps

The base map and remote-sensing data have been used to prepare different thematic map layers e.g., drainage map (Fig. 3) , contour map , slope maps (Fig. 5) , map showing proposed water harvesting structures (Fig. 6) etc.

5.2 Digital Data Inputting

Coordinate system for the study area was created using Everest (India, 1956) Ellipsoid and Everest (Indian, Nepal) datum and the latlon related co-ordinates. The contoured topographic maps have been geo-referenced with respect to the above said coordinate system. The watershed boundary contours, drainage have been digitized on the base map and the contour, and drainage maps have been generated. The Satellite data (digital) was geo-referenced and rectified with the help of base map layer.

5.3 Generation of Digital Elevation Model (DEM)

The digitized contour information has been used to obtain the DEM. After interpolating the contours the DEM has been prepared (Fig. 2). DEM was further analyses to create the slope maps and aspect maps, 3D terrain models in the form of stereo pairs and anaglyphs. The generated layers were suitably classified to enhance their applicability. For example the slope degree map was classified as per Youngs classification to extract level, gentle or steep slopes. Aspect map was classified into eight slope directions. DEM was also used to create flow accumulation map, which was found to be very useful in further hydrological application.

IV. Geomorphometric Analysis

From the digitized drainage map, contour map and the DEM various geomorphometric parameters like Bifurgation ratio, length ratio, elongation ratio, circularity ratio, basin shape factor, drainage density etc. have been calculated (Table 1). These morphometric parameters were further interpreted to realize the watershed under investigations. From the contours and stream lengths the profile of the main stream of Kera was extracted, which throws the light on the stages of erosion or the erosive capacity of the main river. The geomorphometric analysis provides a quantitative data base for further hydrological applications.

The generated GIS and RS output layers were studied in the form of different layer combinations for the suitable application in decision making. For example, 3D terrain model draped with satellite image and the drainage map in combination with the map of proposed water harvesting structures was found to be very useful to assess the feasibility of the sites. The flow accumulation map was studied along with the rainfall data and the actual flow accumulation at the proposed sites was found out. In this manner, the final developmental proposals of the present watershed based on the brain storming study of various layer combinations have been made. Thus, the methodology is adopted for the present study.

Study and interpretation of GIS Layer combinations

Total No. of Streams	: 437
Drainage Area	: 103.07 Sq.Km
Watershed Perimeter	: 44.81466 Km
Drainage Density	: 3.24Km/ Sq.Km
Elongation Ratio	: 0.63
Drainage Frequency	: 4.23 / Sq.Km
Form Factor	: 0.31
Basin Length	: 18.07 Km
Total Relief	: 557 m
Ruggedness No.	: 0.30
Circularity Ratio	: 0.8030
Stream Frequency	: 4.23 /Sq.Km
Average outflow	: 6.12 TMC /Year
Constant of Channel Maintenance	: 0.30

V. Watershed Development Plan Based on Interpretation of generated GIS Layers

a) Water Harvesting In the Basin

It becomes most beneficial, for the area like Kera basin with ideal catchments sites, characteristics of ground such as slope, type of soil, and number of streams amount of vegetation etc. to apply the latest technology of RS and GIS for its fast, more accurate and efficient software based methodologies. All the suggested structures are easy to construct for common civil engineering entrepreneur and also very economical as it required the locally available resources. The feasibility of water harvesting structure is governed by factors like Availability of suitable site mainly from topographical., Presence of suitable source to supply water of required quality in requisite quantity, Lithological, composition, thickness, permeability Characteristics of rocks, Availability of property or land, Cost benefits consideration. Considering these aspects, the following water harvesting structures have been suggested in Kera basin based on RS and GIS study followed by groundtruthing field visits. Sites for Conventional type of structures have been located. These structures are Gully plug, Nalla bund, K.T.weir and M.I.Tank.

a) **K.T.Weir** No.1 At ch. 980 m. Near Village Nivkane under Nivkane M.I. Project, Tal: - Patan. (30.28 Sq. Km, 2825 Cumecs, 37.40 Mtr.)
b) **K.T.Weir** No.2 At ch. 1770 m. Near Village Chafoli under Nivkane M.I. Project, Tal: - Patan (32.56 Sq. Km., 856.00 Cumecs, 31.20 Mtr)
c) **K.T.Weir** No.3 At ch. 2290 m. Near Village Mandure under Nivkane M.I. Project, Tal: - Patan. (36.86 Sq. Km, 911.00 Cumecs, 58.40 Mtr)
d) **K.T.Weir** No.4 At ch. 2925 m. Near Village Divashi under Nivkane M.I. Project, Tal: - Patan.(42.35 Sq. Km, 976.00 Cumecs, 34.40 Mtr.)
e) **K.T.Weir** No.5 At ch. 3590 m. Near Village Khivashi under Nivkane M.I. Project, Tal: - Patan.(46.39 Sq. Km, 1022 Cumecs, 32 Mtr.)
f) **K.T.Weir** No.6 At ch.4800 m. Near Village Keral under Nivkane M.I. Project, Tal: - Patan.(47.065 Sq. Km, 1029 Cumecs. 41 Mtr.)
g) **K.T.Weir** No.7 At ch. 5615 m. Near Village Ghanav under Nivkane M.I. Project, Tal:- Patan.(50.775 Sq. Km, 1069 Cumecs, 47 Mtr.)
h) **K.T.Weir** No.8 At ch. 6290 m. Near Village Mendoshi under Nivkane M.I. Project, Tal: - Patan.(63.145 Sq. Km, 1266 Cumecs, 47 Mtr.)
i) **Earthen Dam** - The site near Nivkane in the gorge portion of the main stream is very suitable to construct the earthen dam to create the M.I.Tank. Not only for its geomorphometric reason. But also for geological reasons. The nearby accumulation of the regoliths of lateratic origin provides the Hugh source to form the borrow area. The flow accumulation study is also encouraging near the narrow gorge on the main stream. Similar to all above K.T.Weirs this site for earthen dam is now ongoing and the project is taking its shape. (154.1 Sq. Km, 7.90 MCM.)
j) **Check Dam -** The check dam is suggested in the stream coming towards Divshi-Khurd for its suitability assest according to the GIS layers especially the drainage map, contour map and the RS data interpretation. The check dam will definitely serve the various purposes discussed below.

b) Electricity generation

The suggested check dam will develop the perennial source of water with suitable hydraulic head for the generation of electricity. Mini-hydal power plant has been suggested in association with check dam. The aspect of nearest borrow area is also favorable for this site. The generated electricity can easily be supplied not only to the nearest village but also to the main grid of MSEB since the nearness of the project with preexisting wind-mill site and the major Koyna hydroelectric project. Some features of mini-hydal power plants are highlighted below. **(**Micro hydro power stations: - (MHPS) the term MHPS defines an installation for the production of hydroelectricity at low power levels. In practice the power from such installations can be between 5 to 5000 KW for heads 1.5 m to 400 m, and flows ranging from several hundreds of litter per second to several tens cubic meter per seconds. Common definition is to use micro when the power is less than 100 KW, according to central electricity authority of India (Fig. 4).

C) Other Construction Activities Suggested for Socio-Economic development of Kera Watershed

As this watershed is located very close to Koynanagar, which is a part of Potential tourism area and it bears the typical natural beauty, few more developmental activities have been suggested for overall sustainable development of Kera watershed (Fig. 6).

7.3.1 Developments at Kadka

There is a very beautiful place just west of the village Mendhoshi locally known as "Kadka". Very large pot-holes, waterfall and cascades have been developed on the rocky outcrop in Kera main stream. There is a well marked junction of spectacular cliffs of columnar basalts and ashy and tachylatic bed. Artificially leveled juntle slopes surrounds this place providing sufficient scope for the construction of Children Park, Holiday Resorts, and Information centre, Landscaping and Rock Gardening and Viewing Tower. One hanging bridge will definitely add not only to the beauty but will span the barrier between either sides in the basin near Kadka. From the viewing tower at Kadka, the tourists can view the scenery in the upper part of the basin. There is, in addition, the sufficient open place, gently sloping on the right banks of Kadka where the place for parking of vehicles can be developed. Since this area belongs to the region of one of the twelve places of highest biodiversity characteristics in the world the beautiful garden and Children Park is do advisable near Kadka. Since for tourisms attracting to this site and very close natural things landscape design is essential. The whole landscape design should be made close to the nature.

The resorts, with not the heavy but light constructions, going very close to nature, will definitely attract more number of tourists. Light pre-fabricated constructions should be preferred for resorts or even the temporary hutments from locally available materials will serve the need of tourists. But there stay should be managed by modern hotel management techniques. There is a need of information centre, situated in Mendhoshi near Kadka. This information centre should be well furnished and should contain the communication centre, meeting hall, natural museum, Library, waiting room etc. so that tourists will comfortably get the information and even a guide to roam around in the Kera Basin. From the RS studies, Kadka seems to be located in the central part of the basin. Therefore this is the best suitable place for the tourists to make a camping for the ecotourism in an around Kera basin. The places for development have been indicated on the generated point and segment layers.

7.3.2 Development of Dhareshwar Caves

In the upper part in the basin, from Divshi-Khurd the mountain cliff has, naturally, been carved with beautiful caves. The giant waterfall plunges in the valley from the cave roofs. There is a calm and quiet "Lord Shiva Temple" in the cave. This finds to be the best seat for meditation and mental peace. There is a need to repair or reconstruct the existing hill road to Dhareshwar and similar tourism facilities like resorts, parking of vehicles and information centre is suggested for Dhareshwar caves.

7.3.3 Development of Nivkane Temples

There are two historical temples of Goddess "Janai" and "Dhanai" near the banks of Kera at Nivkane. This beautiful place is surrounded by lofty hill peaks, cliffs, waterfalls and ever green forest. On the west side of these temples the work of earthen dam for M.I. Tank is ongoing. And can be located even on 23m resolution LISS III data. The vicinity of this place with M.I. Tank prompts the judicious and choosy construction manger to propose the garden and sacred grooves along with the modern meditation and Yoga Centre along with the resorts for devotees and tourists.

The M.I.Tank reservoir will definitely serve for a good boat club at Nivkane. And the hilly surroundings will serve a good adventure club. Another advantage of this recreation facility is that of disaster mitigation during the flood of Koyna River. The boats and trained club members will defiantly be helpful in rescue operations.

7.3.4 Cultivation of Medicinal plants

There are already 28 varieties of medicinal plants or aurvedic plants available in this region. But these plants are scattered along the whole region of the hill. These plants cannot be identified easily. Collection of these plants will generate huge revenue to the villages in the basin. However, presently these plants have zero value because of ignorance and unprivileged poor life style.

In order to overcome this problem these plants should be cultivated in such way that they will be identified easily and will be affordable for collection and distribution to pharma industries. By considering these aspects, Ayurvedic plants have been suggested to be cultivated in the form of contour farming at NW slopes of Nivkane, North side slopes of Khivshi, west side slopes near Kadka. The nearest market place being Patan, the distribution of the medicinal plant products will be easier.

7.3.5 Mini-hydal Power Plant

Along with the existing Wind-Mill projects the Mini-hydal power plant has also been proposed in association with the check dam near Divshi-Khurd as already discussed in the chapter of water harvesting structures. Mini-hydal power plants should be the inevitable component of watershed development, as it is helpful to make the watershed self sufficient in electricity, at least in domestic purpose. The proposed developments seems feasible from overall satellite data and GIS layer interpretations. But for more precise and quantified study of feasibility, the detailed constructional planning and designs for the above proposals should take shape. For this, the further detail ground investigations regarding eco-tourism are essential.

VI. Conclusion

The RS and GIS layers generated so far being studied in the software of ILWIS 3.3 have been found to be very effective tool for fast and more accurate analysis of very large watershed of Kera River. From the contour map and imageries it has been observed that the area has got high relief in upper part and moderately sloping grounds in the lower reaches. The main Kera River is found to be in its youthful stage of erosion. Even in the lower reaches of river the change is observed, by little rejuvenation, in the base level of erosion resulted in the development of nick-point of water fall which migrated upstream forming deep potholes as erosion progressed near Mendhoshi.

At the head ward side the river follows a straight and wide path indicating the major tectonic and the structural disturbance. The satellite data indicates that the Kera River emerges out from hilly terrain in the most northern part of the watershed area. The major channel in the middle course and some of the third and fourth order streams are guided by some major lineament. Its basin shows the development of varied geomorphic features such as planer surface, river terraces, residual hills and mainly potholes that are greater in depth and diameter, waterfalls and rapids. The river flows towards S10º E from the origin and confluences with Koyna River near the city of Patan. There are two water-harvesting projects, ongoing near Nivkane and Sakhari. And still the basin has lot of scope for few more developmental schemes as discussed here.

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Figure No. 1 Location Map

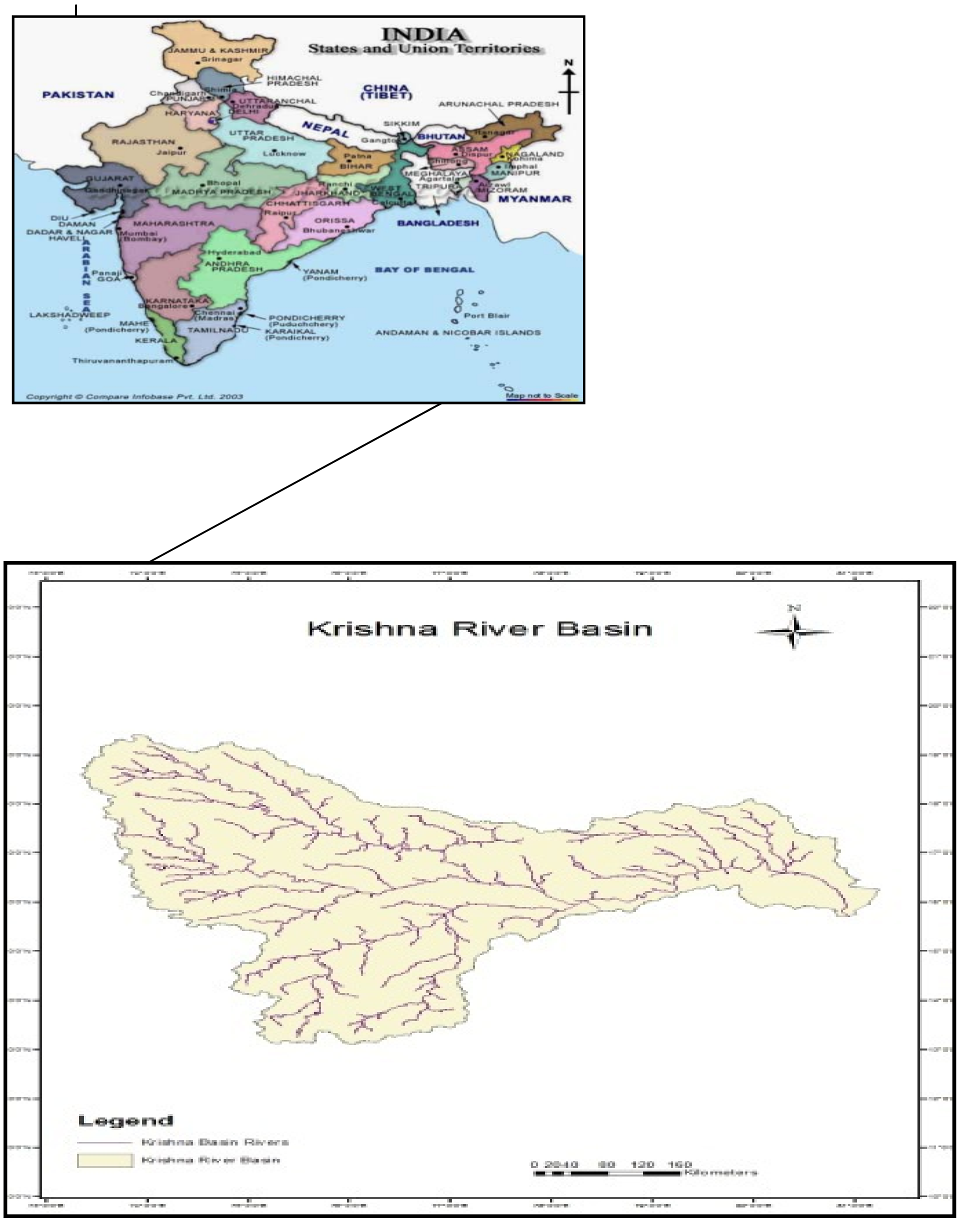

Figure No. 2 Drainage Network

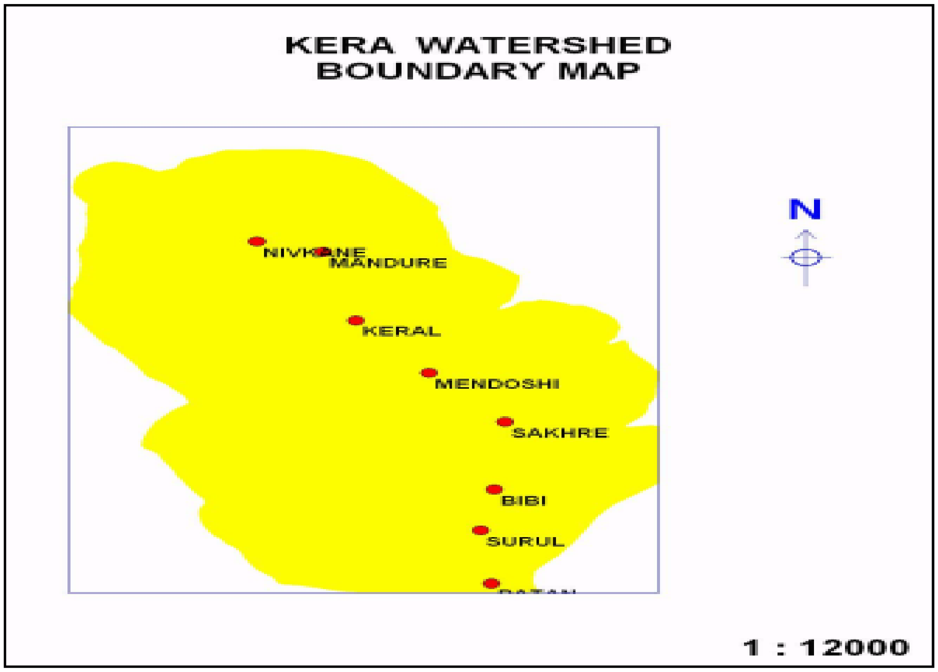

FIG **No. 3** DEM of Study area

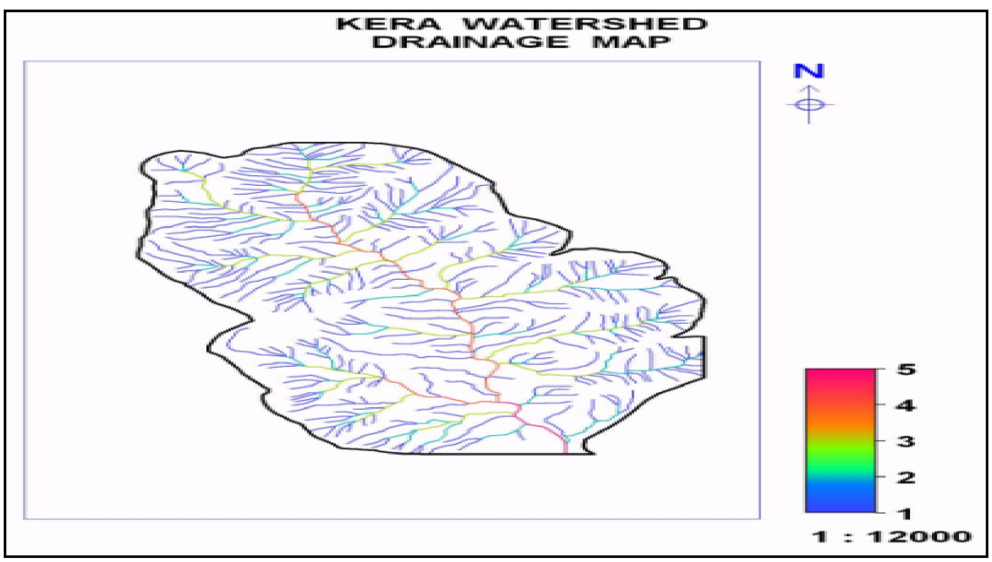

Figure No. 4 ODA of study area

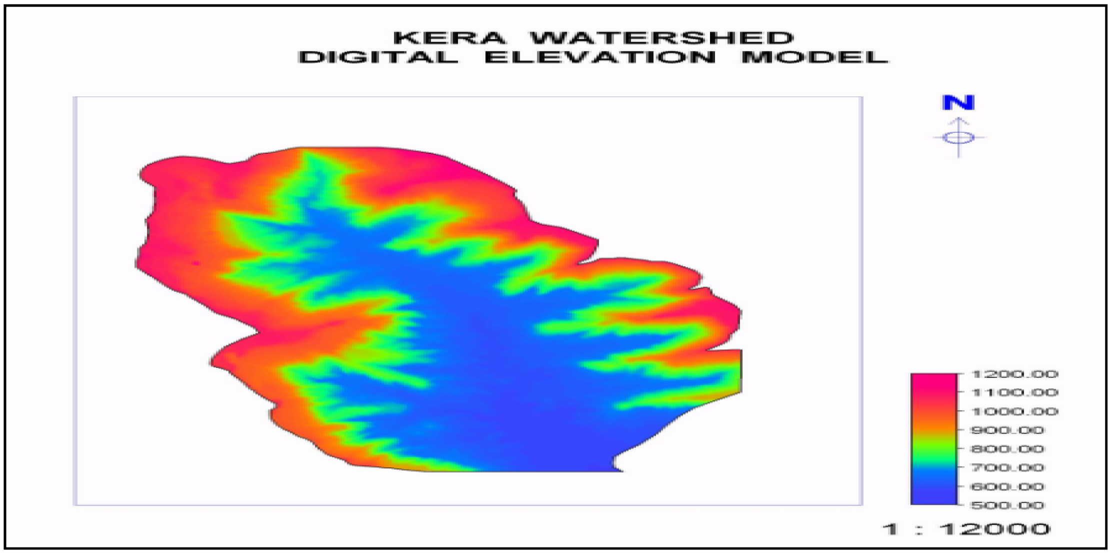

Figure No. 5 Slope Map

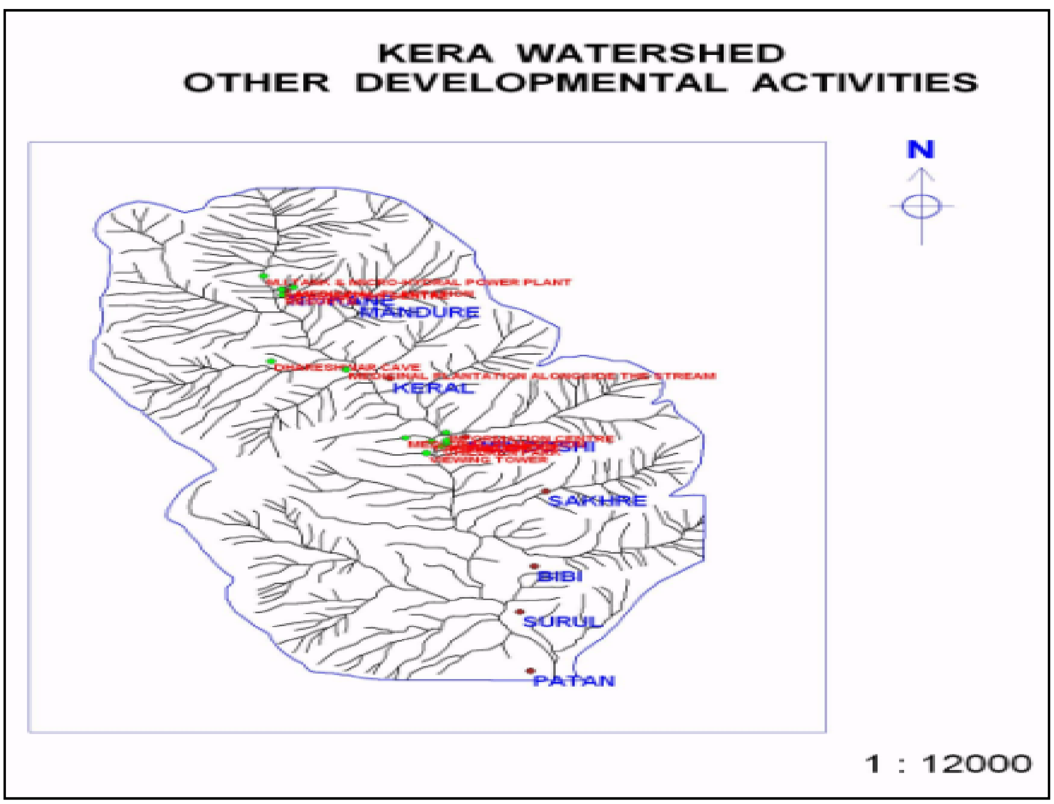

Figure No. 6 kera Watershed Slope

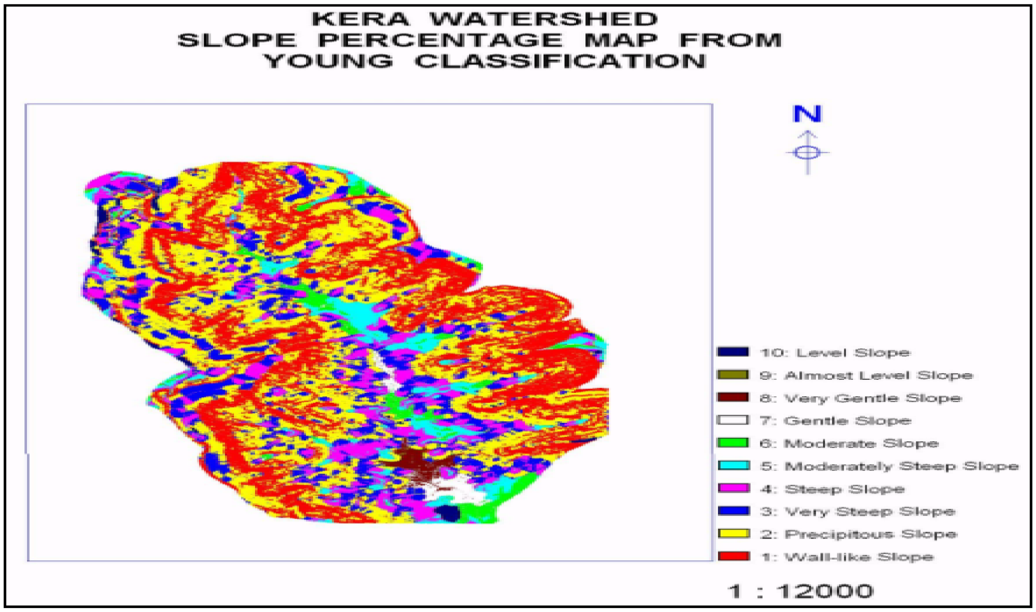

Figure No. 7 Location of WHS like Contour & Drainage Map

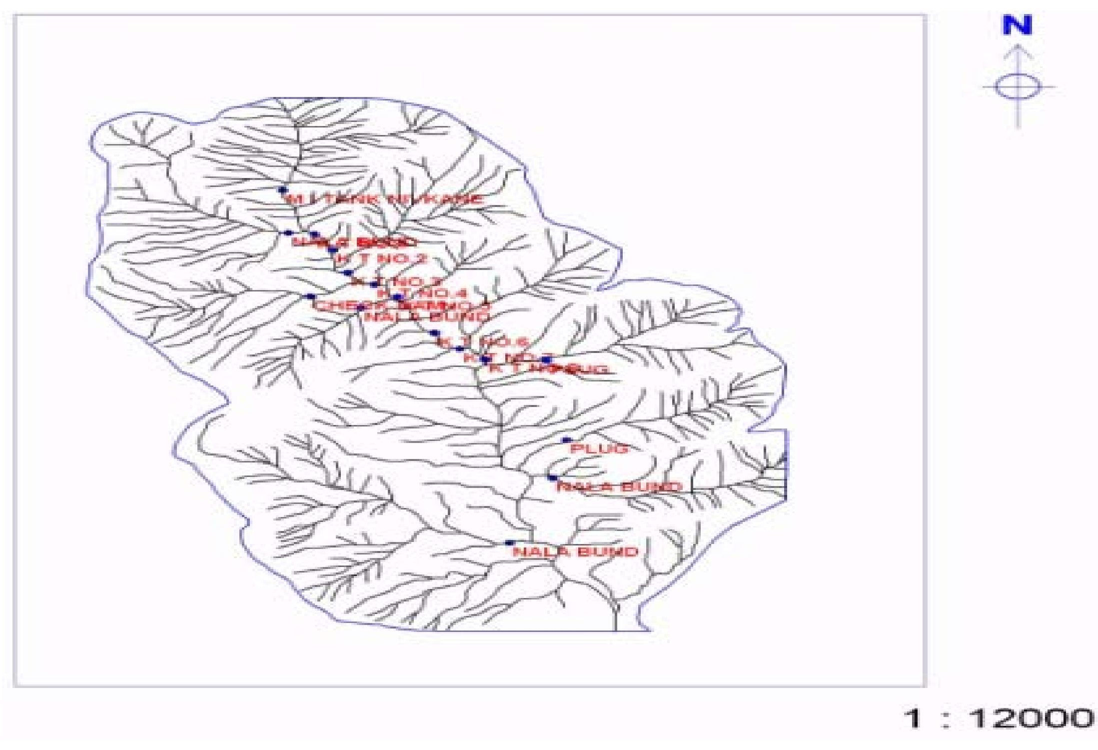

Table 1

Geomorphometric Parameters Calculated from Vector Layers

Strm. Order	Strm. Number	Strm. Number Cumu.	Stream Length (M)	Stream Length Cumu. (M)	Bifurcation Ratio	Length Ratio
1	348	348	238776.99	238776.99	5.04	1.06
2	69	417	44365.73	283142.72	4.05	0.32
3	17	434	33811.72	316954.44	8.5	0.27
4	2	436	14408.80	331363.24	2	2.38
5	1	437	3016.21	334379.45	-	-
Total	437					