Geoinformatic studies of Morna watershed

Dr. A.J.Shirke
Dept. of Civil Engineering.
P.D.V.V.P. College of Engineering, Ahemdnagar,
E-mail shirkeaj@gmail.com

A.R.Take
Dept. of Civil Engineering.
P.D.V.V.P. College of Engineering, Ahemdnagar,

Abstract

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 RS &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 Morna River, which is right tributary of Koyana in Patan tahsil of Western Maharashtra. 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 Morna river is flowing through Patan Tahsil of Satara District of Maharashtra state. The study area is lying between the latitudes 17º15'N to 17º21'N and longitude 73º45' E to 73º57'E. The whole area can be obtained in a single toposheet Nos. 47G/15, covering the area of 104.458 sq.km, acquired from Survey of India. The area is approachable through the road link, Sangwad bridge and 25km. away from Karad.

The Morna watershed encircled the village of Gureghar, Ambrag, Nayakwadi, Chougulewadi, Dhangarwadi, Kokisre, Natoshi. Other villages within the watershed are Kordewadi, Kotawade, Kusrud, Kadamwadi, Kalkewadi.

The mouthward side of the basin is dominated by the settlements within the agricultural fields. At the altitude of 760 m the dense mixed reserved forest occupies the basin. Villages and the agricultural fields along with the forest, cover the upper reaches of the basin at the altitude of 680 m to 720 m. The Morna watershed is lying between the Koyna watershed(North) & Warna watershed(South).

General Geology Of the Area:

Geologically, Morna basin belongs to the part of Deccan Volcanic Province constituted mainly of basaltic lava flows of the late cretaceous of Eocene. The flat-topped hills and step-like terraces characterize the terrain. 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. The rock is volcanic, basic, find grained, aphanitic and melanocratic containing the mafic minerals like pyroxenes, ca-plagiodase, olivine, ilmanite etc. volcanic breccias, volcanic ash and tachylite beds are also found.

Alluvium deposits formed during Pleistocene to recent are common in the lower regions providing a good agricultural and land alongside of Morna 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. Morna 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.

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 Morna 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 :

Stream Order (u) :

On the basis of the principles of Strahler's method of steam ordering five order of steams are identified, where the 5^{th} order stream form the main stream.

Stream Number (Nu) :

It is the number of stream segment of various orders. Horton's law of stream numbers states that the number of stream segments of each order is in inverse geometric sequence with order number. There are 423 streams within the basin.

Stream Length (Lu) :

It is the length of each stream segment. Adding length of each stream for a given order, the total stream length of each order (L) is computed. The total stream length divided by the number of stream segments (N) of that order gives the mean stream length for that order.

Length Ratio (R) :
It is the radio of mean stream lengths of any order and that of next lower order.

Relief Ratio (Rh) :
It is the total watershed relief divided by the maximum length of the watershed. It represents the overall steepness of drainage basin and is an indicator of the potential energy of the system to drain off. Large Rh values give rise to quick depletion of water from the basin and hence result in large peaks and steep limbs of hydrographs.

Relative Relief (Rr) :
It is the ratio of the maximum watershed relief to the perimeter of the watershed.

Ruggedness Number (Rn) :
The drainage density determines the maximum basin relief. The value of 4.84 marks the high ruggedness of the basin.

Elongation Ratio (Re) :
It is the ratio of the diameter of circle with the same area as the watershed and the maximum length of the watershed. This ratio may be in the range of 0.6 and 1.0 R and R are measured to depict the influence of basin shape an they represent the time taken for water from the remote parts of the catchment to reach the outlet. The value of elongation reaches one as shape of the basin approaches to a circle. Fan shaped or nearly semicircular catchment give high peak and narrow hydrographs while elongation fern shaped catchments give broad and low hydrographs.

Circularity Ratio (Ro) :
It is the ratio of circumference of a circle of same area as the watershed to the perimeter of the watershed R usually range between 0.6 and 0.7. It decreases for higher order basins because of large crenellations in their perimeter, which affect the denominator.

Basin Shape Factor :
It is the ratio between the squares of the maximum length of the watershed to the area of the watershed.

Confluence (Bifurcation) Ratio (Rb) :
It is the ratio of the number of streams of a particular order to the number of streams of the next higher order. Bifurcation ratio is found to be one of the important geomorphologic characteristics. It has been very widely used in the derivation of geomorphologic instantaneous unit hydrographs for various basins.

Stream Frequency (Sf) :
It is the number of streams per unit area within the basin. It mainly depends on the lithology of the basin and reflects the texture of the drainage network. There are six streams an average per square kilometer of the watershed.

Drainage Density (D) :
It is the average length of stream per unit area within the basin. Drainage gives an idea about the physical properties of the underlying rocks. Low drainage density occurs in the regions of highly resistant and permeable subsoil materials with dense vegetated cover and low relief. The high drainage density marks the regions of weak, impermeable subsurface materials, which are sparsely vegetated and show high relief.(Strahler,1964)

Geomorphometric Parameters Table :

Stream order	Stream Nos	Stream Length	Bifurcation ratio	Length ratio
1	320	66001.89	4.00	-
2	80	16118.06	5.00	1.24
3	16	5514.41	4.00	1.07
4	4	1692.76	4.00	1.02
5	1	5966.93	-	1.07

TOTAL NO. OF STREAMS : 423
DRAINAGE AREA : 104.458 Sq.Km.
DRAINAGE DENSITY : 0.90 Km/Sq. Km.
ELONGATION RATIO : 0.408
DRAINAGE FREQUENCY : 4.049
FORM FACTOR : 0.200
BASIN LENGTH : 28.22 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 24^{th} January 2002 have been selected and procured for study .The standard FCC (Fig 9,10 & 11) has been prepared from band 4,band 3 and band 2,out of four bands of LISS III data .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.12 & 13)and also for the aspect and slope maps (Fig. 14) .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.12,13 & 14.

Result and Discussions **:**

From the contour map and imageries (fig. 1 to 14) it has been observed that the area has got high relief in upper part and moderately sloping ground. The main Morna river is found to be in the youthful stage of its erosion, containing deep gorges, cascades. The contours are ranging from 580 m to 1080m. Some areas are covered with pleistocene deposits.

The satellite data indicates that the main Morna river emerges out from mountains of Sahyadri ranges (Fig. 10) in the most southwest part of the watershed area in between D/s of KOYNA reservoir and in north U/S of CHANDOLI reservoir. The river flows towards north–east and confluence with KOYNA river. There is Minor Irrigation project on Morna river near Gureghar.

With the help of stretched FCC (Fig. 10) of the present LISS-III data the watershed can be classified and the vegetation land use classification map can be produced for the reference .

Agriculture & forests :

It has been observed that the most of the agriculture consist of cane crops and is distributed in the D/S from Gureghar and along both the banks of Morna and in the flat and gently sloping areas. The upper part of the basin especially U/S of Gureghar reservoir is covered by thick forest. Moderate slops contains thickest and scrubs. Rock outcrops and open forests are observed on the gently sloping hill top regions.

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 52 villages in the watershed. The biggest one is Morgiri near the fort of Gunawantgad in the middle north and on the left bank of the Morna river.

Settlement include number of villages like Kohir, ambeghar, Warandewadi, Gokul, Diksi, Kodal, Gureghar, Panchagani, Budhwadi, Dhangarwadi, Panchagani, Bahe, Hambarne, Dhangarwadi, Atoli, Dhawde, Sidrukwadi, Kore\dewadi, Varpewadi, Ambrag, Dhangarwadi, Kokisre, Morgir, Shivapurpeth, Natoshi, Takkalwadi, Kotawde, Donglewadi, Satewadi, Dhoparewadi, KadamWadi, Kusrud, Kalkewadi, Varekarwadi, Sulewadi, Shindewadi, Sonavde, Jangamwadi, Daahamwadi, Umberwadi, Marli, Mongewadi, Nayakwadi, Chougulewadi, Davri, Dudugadewadi, Gavhanwadi, Amrule, Adadev, Adadevwadi, belvde.

Drainage :

The watershed contains the dendraitic drainage (Fig.2). The elongated ratio of 0.408 indicates that the basin in fairly elongated and observed to be so, from SW to NE and opening its month towards north. Out of five orders a stream of 1st order has the total length of 66.6 km, while a stream of IInd order has total length of 16.1km., IIIrd order has a total stream of 5.514 km. the maximum length of IVth order stream has 1.69km. and that Vth is 5.966 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 (5.5966 km). the form factor of the Morna 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 characterisation 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 0.9 km/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 and hard igneous basaltic rocks.

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.4) 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. A gently slopping banks exists only in the D/S north portions where Morna confluences with Koyna river near Sangwad bridge. 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 stream flows in less than 20% slope but overall watershed the slop ranges upto 400% with the exception of small hill topes and gorges.

The slope aspect map (Fig.7) shows that the general slope of evaluated surfaced are either towards NW or towards SE 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 colluvial 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 Morna 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 2nd and 3rd ordered streams is advisable so that run off water may percolate through the columnar and mural joints as well as spheroidal weathering zones and increase the ground water potentials in the low lying areas surrounding main stream.

The ongoing Morna Gureghar minor irrigation project has proved to be the fruitful since the irrigated cane crop areas have found to be increased in the recent past.

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 Guhagar Vijapur in the north of Koyna River. 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 Morna Watershed.

Achnolodgement :

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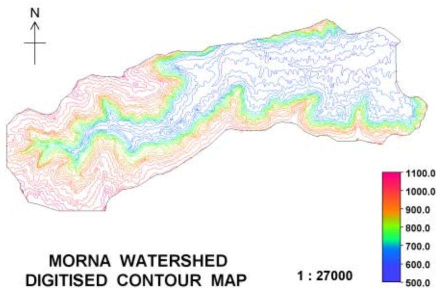
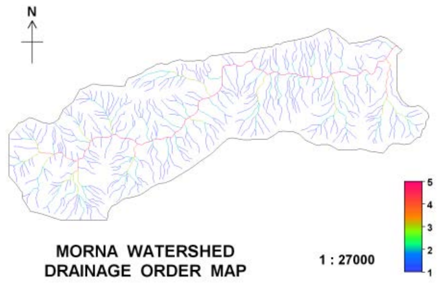


Figure 1.



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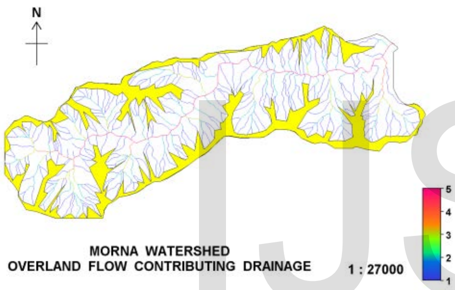

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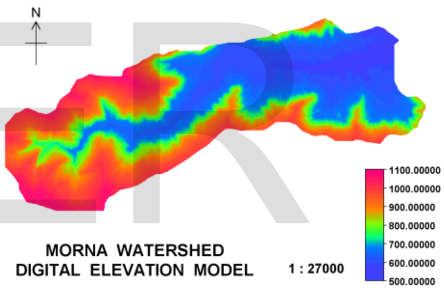

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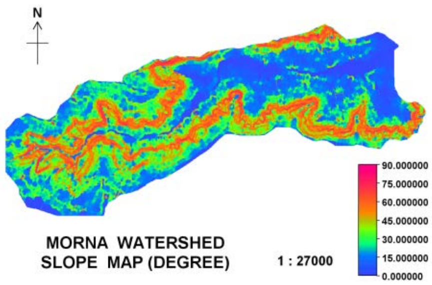

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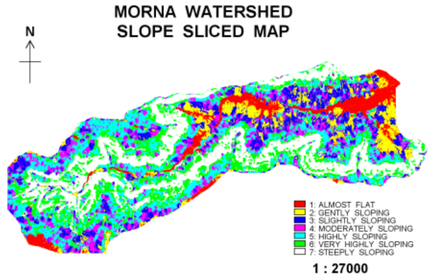

Figure 6.

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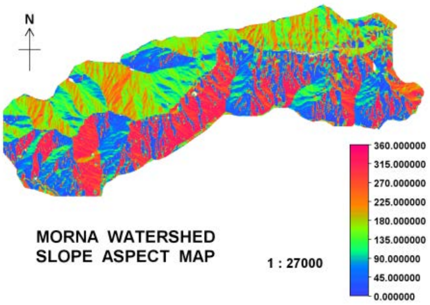

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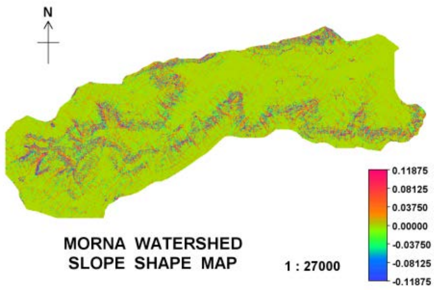

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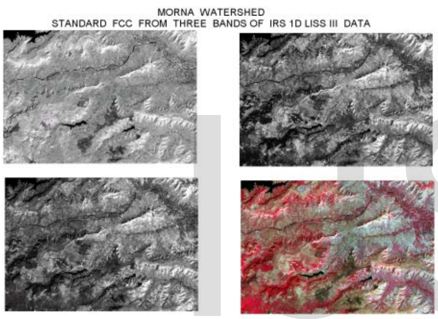

Figure 9.Generation of FCC

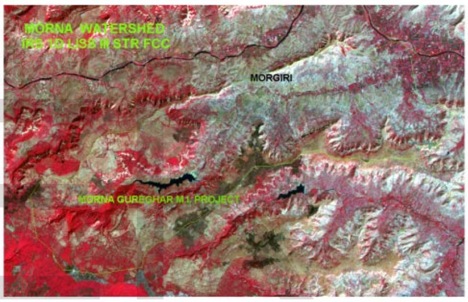

Figure 10.Watershed boundary

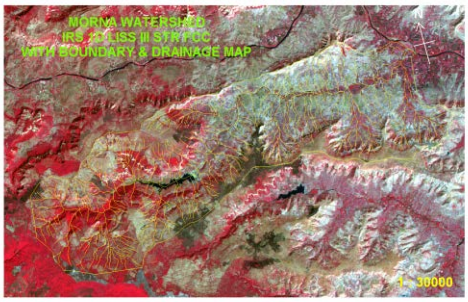

Figure 11.Drainage

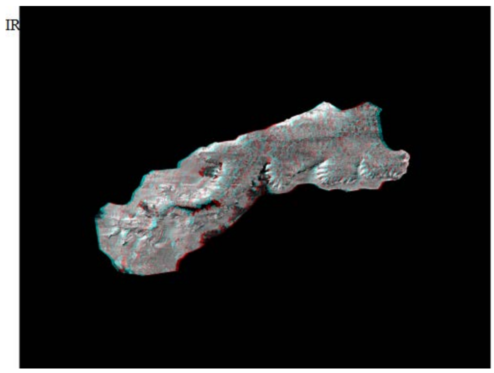

Figure 12.3D Anaglyph. IRS 1D LISS III NIR Band

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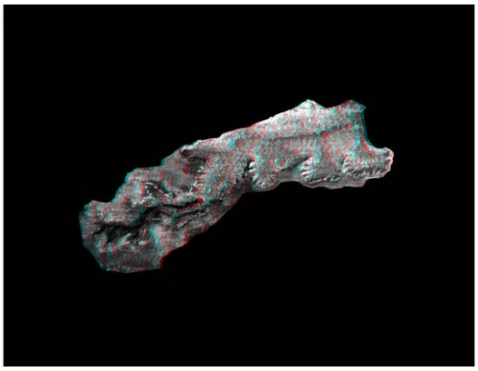

Figure 13.3D Anaglyph IRS 1D LISS III Red Band

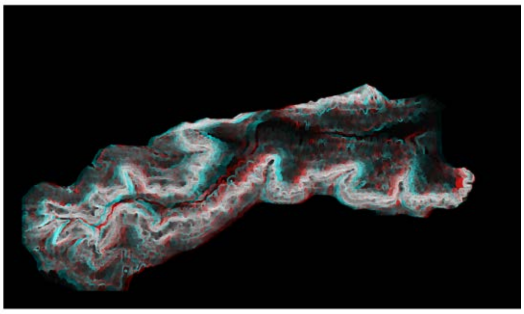

Figure 14.3D Anygliph .Slope Map (Degree)