Water Resource Management of Gadga River Basin, Chikhaldhara Region, Amravati District, Maharashtra with Reference to Remote Sensing Analysis

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Abstract

Detailed hydro geological and hydro-geochemical investigations have been carried out for a part of Gadga river basin exposed around the Chikaldhara region, Amravati District, Maharashtra with an aim to understand the hydro-geochemical, geophysical, geological, geomorphologic and environmental control on the groundwater regime of the region. The study area is characterized by the presence of 825 m thick horizontal sequence of lava flows which can be divided into simple and compound units based on their field characters, textual parameters and geomorphic expression. Detailed study of geomorphic features and the analysis of the remotely sensed data through visual interpretation of the Gadga River basin around Chikhaldhara region, Amravati District were carried out to elucidate the role of various morphometric features, geomorphic processes and structural trends in the evolution of the landscape. The results indicate the presence of seven distinctly different geomorphic units which include alluvial plain, bajada zone, moderately dissected plateau, highly dissected plateau, plateau top, structural ridge and denudational hill. Hill slopes exhibit stepped appearance with parallel retreat during pediplanation due to differential erosion of various litho units exposed in the region. The structural, denudational and alluvial landforms, on the basis of land use and land cover have been sub-divided into agriculture land, built up land, wasteland and water bodies. In addition, remote sensing techniques have been effectively utilized in identifying the potential aquifers so as to enable groundwater exploration in the region. The present investigation based on numerous topographical profiles has shown the presence of marked flat terraces at different levels indicating the present state of the cycle of erosion and landform development. The results confirm the hydrogeological and morpho-tectonic conditions, which have also helped in locating suitable aquifers for the water resource development of the region.

Key words: Hydrogeochemistry, Environmental Management, Groundwater, Deccan Traps, Watershed

Introduction

The Maharashtra state located within the peninsular shield area of the country, with about 94% of its total geographic area underline by rock formation. About 80% of the area of state is covered by basaltic lava flows the overlying alluvium confined to areas in the vicinity to major rivers streams. The heterogeneous nature of these basaltic lava flows is clearly evident through the wide variation in the hydro geomorphological parameters of these basalts, the foremost being their permeability variation which is controlled by the nature and degree of weathering, fracture pattern and jointing the variation in permeability of lava flows exposed in the area is reflected by geometry of drainage network , which provides a reliable index for measuring the permeability of rocks from the drainage basin (Wisler and Brater,1939.Detailed geomorphological and hydrogeological properties will give rise to base flow estimation (Raju and Jha,1990). In this study an attempt has been made by utilizing remote sensing techniques to understand the hydrogeomorphological characteristics of the Chikhaldhara Region with emphasis on water resource management.

Water is one of the main resources essential for the overall socio-economic development of any region and it requires careful planning and appropriate exploration. The study area is characterized by the presence of 800 m thick pile of horizontal lava flows of Deccan Traps. The topography is characterized by the presence of flat terraces of lava plateau, lava hill, mesa, butte, escarpment and linear ridges, which have been resulted from lateral erosion. The heterogeneous nature of the basaltic lava flows exposed in the study area is clearly evident from the wide variation in the hydro-geological parameters of these basalts; mainly their permeability and porosity resulted from the nature and degree of weathering, fracture pattern and jointing. The variation in permeability of lava flows exposed in the area is reflected by geometry of drainage network, which provides a reliable index for measuring the permeability of rocks from the drainage basin (Wisler and Brater, 1959). The Geomorphologic and hydro-geological details aid in base flow estimation (Raju and Jha, 1990). The work done so far in understanding the hydrological conditions of the study area is very limited except some basic data report of exploratory boreholes by Central Ground Water Board. Tiwari et al. (1996) have given primary data on the geomorphology and geology of Purna valley. The basic objective of the present investigation is to delineate various hydro-geomorphic units through remote sensing techniques, understanding the hydrogeological conditions of the Gadge River basin and also to gather information on the occurrence, movement and development of groundwater by examining the open dug wells and tube wells. The study area is located at about 95 km from Amravati, between. 21° 15' to 21° 30' N latitudes and between 77° and 77° 15' E longitudes (Fig.1a and 1b).

Methods and Material

Geological mapping was carried out to understand the nature and aerial extent of the lava flows and detailed morphometric analysis was carried and various statistical parameters like drainage pattern, drainage frequency, drainage density and bifurcation ratio etc. ware computed. Erosional surfaces have been demarcated. Analysis of remotely sensed data through visual interpretation was carried out by utilizing IRS LISS-III Imageries at RRSSC center, Nagpur (Fig.2). In addition hydrogeological studies and hydrogeochemical investigations were carried out to understand the groundwater regime of the region.

Geomorphology

The study area is characterized by erosional and depositional landforms related to the central Deccan Basalt Province with the province of horizontal lava flows where the topography is characterized by lava plateau, lava hill, mesa, butte, escarpment, liner ridges and alluvial plains which might have resulted from the lateral erosion (Table 1)). The Gadga river basin shows sixth order drainage network in the study area (Fig. 3). The results of the geomorphic analysis indicate the predominance of erosional landforms over the depositional landforms (Fig. 4). Soil cover indicating the intensity of weathering process that might have affected the region covers the ridges. In the study area three geomorphic zones are identified on the basis of land form assemblage, nature of its drainage, slope characteristics, sediment generation and deposition. these include (1) zone of high relief, deep dissection and short interfluves, (ii) alluvial plain and iii) zone of moderate relief and gentle slope(Tiwari *et.al.*, 1996). The study area can be divided into low lying plains towards the southern side and abrupt vertical cliffs made up of horizontal basalts flows with multiple scarps towards north. Physiographically, the study area can be grouped into central high land region with a large concentration of lava flows traversed by Gadga River showing mature stage of development (Fig.5). According to Vonengellns classification I, II, III & IV order relief features were computed in this area. The study area is dominated by the presence of Deccan Basalts and Quaternary sediments. The Quaternary sediments are characterized by the presence of alluvial plains (Tiwari and Bhai, 1995).

Geomorphic process

The study area is dominated by the presence of horizontal lava flows of large aerial extent. The dominant geomorphic region includes spheroidal weathering and fluvial erosion, which aids to distinguish various geomorphic landforms. Earlier studies have indicated thermal origin for this but the present study has demonstrated the dominant role of chemical action based on field and petrological investigations. The hill slope analysis indicates the presence of a flat crest, an interim slope with a fairly constant angle off from the plain. Amphitheatrical valley head with narrow entrances and fairly steep sidewalls are common along the edges of the plateau and ridges. The soil profile consists of well defined A, B and C horizons with pH of the soil suspension varies from 6.5 - 8 and moisture content from 10.22%, 24.84% . The study area can be classified into eight groups based on Munsell's colour classification. A blackish clay loam results from the bio chemical weathering of basalts and the thickness of the soil profile varies from 10 cm to 3 m depending upon the existing slope condition. The area of study falls in sub-humid belt showing moderate winter with water being deficient. The hill slopes have a characteristic stepped appearance due to the formation of the short platform on the top of many flows forming flat terraces.

Remote Sensing Data Interpretation

The detailed analysis of remotely sensed data through the visual interpretation indicates the predominance of basaltic terrain in the study area which can grouped into five distinctly different geomorphic units namely highly dissected plateau, moderately dissected plateau, denudational hill, alluvial plain and piedmont zone. The light toned areas in the imagery towards south and north demonstrates the presence of low lying flood plain scattered in various drainage channels indicating change in the stream courses during the geological past. The dark toned area suggests the occurrence of steep scarps. In general, the study area is dominated by the irregular topography due to variations in landscape which might have undergone considerable erosion as evidenced by the presence of elevated plateau surface, elongated linear ridges, mesa, butte and escarpment.

The Result of the remote sensing data interpretation indicate the presence of linear ridges suggesting the dominance of lineaments, which can be recognized by the presence of positive linear ridges . A close observation of IRS imagery suggests two generation of lineaments. Negative linear landform showing low relief features may indicate the possibility of a fault when they are sufficiently large. Smaller lineaments indicate the presence of either fracture shears or at places basic dike which follows a similar trend. The dark toned area suggests the presence of vegetation over thick cover of in situ soil with fresh outcrops of lava flows mostly influenced by NNW- SSE fractures. Geomorphic units from southern side consist of plains drained by Gadga River, which for the most part takes a meandering course indicating its maturity. There is some minor evidence of relict drainage pattern suggesting the possibility of recent or neotectonic activity in the study area. Alluvial flood plain deposits are scattered over the area in and around various palaeo channels of drainage network indicating the possibilities of certain changes in the stream courses during different periods of geological past. It is suggested that temporal satellite data along with aerial photo interpretation would probably throw more light on various changes in the river channel courses and also neo-tectonic activity. Tiwari (1996) has indicated the presence of neotectonic activity in Tapi, Purna valleys and its probable correlations with geothermal activity. Fig. 6 demonstrates the land use and land cover pattern of the study area where as Fig.7 provides information about the lineaments and structural trends identified in the study area based on the remotesensing studies. The geomorphic and morpho-tectonic units can be broadly grouped into structural fluvial and denudation landforms indicating trifacial origin based on the criteria given in the atlas of Amravati district by RRSSC center Nagpur the description of various geomorphic units are as follows.

Structural Origin

The entire basaltic terrain can be broadly grouped as Deccan Trap Plateau, however, on the basis of dissection it can be divided into two units:

1) **Highly dissected basaltic plateau**

The landforms of this type occur in the northwest and central part of the study area with average elevation ranging above 700 m. This plateau is demarcated by the presence of high hills with severe dissections. Steep outcrops with thin soil cover characterize this landform. The forest is the dominant land use of this landform (Table 2).

2) **Moderately dissected basaltic plateau**

Which is seen surrounding the highly dissected basalitic plateau? Moderately high hills with medium dissections are the characteristics features of this landform, which serves as groundwater recharge zone. This landform is characterized by the presence of scrubs.

Fluvial Origin:

This landform can be grouped into two groups.

1) **Older Alluvium:** These landforms seams to occur between the Gadga River and the Satpura hill range. This alluvial plain represents ancient flat surface of large aerial extent and gentle sloping towards Gadga River. It indicates earlier cycle of deposition and the basement rock beneath this plain is Deccan Basalts with uneven basement topography. The alluvial material consists of clay, sand and gravel.
2) **Younger Alluvium**: This unit mainly differs from the older flood plains in the cycle of deposition and occurs at relatively lower level. It is characterized by the scraps of badland topography resulting from severe soil erosion.

Denudational hill

This landform represents low lying isolated hillocks and are seen scattered in different region of the study area.

Drainage Analysis

The study area is a characterized by dendritic and sub-parallel to parallel. Drainage patterns drainage patterns showing sixth order stream however, the presence of sub parallel to trellis pattern can be seen at places where the landform are controlled by structural trends. On the basis of the projection of stream channel system to a horizontal plain various morphometric parameter such as linear and aerial drainage characteristics (length, area and arrangement) have been computed.

1) Stream order relationship: In this study, stream orders were determined following the method given by Horton (1945), which was later, modified by Strahler (1952), the results indicate the presence of sixth order stream. (The total number of streams computed in the study area are 1367 of which 75.11 % falls in first order,16.50% belongs to second order, 3.11% belongs to third order. 0.12% rests with fourth order, and 0.05% lies with fifth order.

2) Stream Length: According to Horton, the mean length of the stream is the ratio of the length of the steam of each order to the number of segments of the same order. In this study, it has been noticed that the length of the stream decreases with stream order indicating the characteristic size of components of drainage network and its contributing basin surface.

3) Bifurcation ratio: It is the ratio of the number of streams of a given order to the number of streams of the next higher order. The results indicate negative correlation of stream order with the total number of streams present. The average bifurcation ratio computed for the study area is 5.02. For Gadga indicating dominance of dendritic pattern showing uniform lithology. However, the presence of sub parallel and trellis drainage are not uncommon indicating the presence of lineaments and faulted horizons reflecting structural control in the region. The alluvial plain is characterized by the presence of sub parallel drainage pattern with high intensity.

4) Drainage density: It is the ratio of the total length of all streams and area of the drainage basin. The results indicate high values in the plains indicating fine drainage texture, low permeability and high relief whereas it is comparatively low in the hilly terrains showing steep scarps reflecting the coarser drainage texture.

5) Drainage Frequency: It is the ratio of total number of stream channels of all orders in a basin to the area of the whole basin. The results show the dominance of drainage frequency in the plateau and plain areas whereas it is low on steep slopes and vertical scarps due to the presence of pinnate drainage pattern. The drainage frequency computed in the study area is 3.16.

6) Circularity ratio: It is the ratio of the area of the basin to the area of the circle having the same perimeter as that of the basin. The results indicate higher values (0.53 reflecting relatively less structural control in the Gadga basin than the Dolar basin.0.23)

7) Length of overland flow: It is the length of flow path projected to the horizontal from a point on the drainage divide to a point on the adjacent stream channel (Horton 1945) it relates inversely to the average slope of the channel and is approximately equal to the half of the drainage density, which determines the length of the flow of water over the ground before it gets concentrate in drainage channels effecting the hydrological development of the drainage basin. The results indicate a range of 0.7. to 1 of which lower values reflecting the short distance covered by the water body on the surface before reaching the channel whereas the higher values indicate a gentler gradient to the channel.

8) From factor: It is the ratio between the basin area and the square of the basin length. The results (0.25-0.22) indicate the nature and shape of the basin.

ISSN 2229-5518

9) Elongation ratio: it is the ratio of the diameter of a circle with same area of the basin to the length of the basin. The results indicate a value of (0.4-0.5) reflecting overall structural control on the topography.

10) Laminscate: It is the ratio of the square length of the basin to the area of the drainage basin. The results show higher value for the Gadga basin (4.67) than the dolar basin (2.11) indicating the dominance of structural control in the region.

11) Basin relief: It is a measure of longest dimension of the basin, which is parallel to principle drainage line. The highest elevation is 1138m. And lowest elevation is 380 m indicating the basin relief of 858 m.

12) Relief Ratio: It is the ratio of horizontal distance along the longest dimension of the basin, which is parallel to the principle drainage line. The relief ratio computed for the study area is 65.02 for Gadga basin and 46.17 for Dolar basin.

13) Ruggedness number: it is the product of the relative relief and drainage density. The ruggedness ratio calculated for the study area is .0.02

14) Constant of channel maintenance: The inverse of the drainage density gives the constant of channel maintenance (Schumm, 1956). Generally, it varies directly with the size of the drainage basin. The larger values in the study area indicate more permeable nature of the region.

Groundwater resource management

The study area is characterized by the presence of shallow unconfined aquifers, which are being tapped by large diameter dug wells and tube wells. The occurrence and distribution of groundwater is mainly controlled by geological, geomorphological structural and climatic condition of the region. Hydrogeologically, the study area can be broadly divided into two hydrogeological zones namely hard rock terrain and alluvial terrain. The hard rock terrain consists of Deccan Basalts which show poor, moderate and good groundwater potential depending on the intensity of weathering and presence of fractures and joints. Whereas, the alluvial zone show very good groundwater potential with brackish to saline water. In general, the groundwater occurs under both water table and semi confined conditions in the basaltic terrain of the study area. Whereas, in the alluvial zones, it occurs in water table and confined conditions with a depth of 70m bgl. In hard and compact basaltic terrain where the availability of groundwater is poor as the storage space is limited and also the joints and fractures are negligible with thin soil cover whereas, highly fractured, jointed basalt with amygdaloidal and vesicular horizons have proved to be potential areas for groundwater development. The phreatic and semi confined acquifers in the area can certainly be utilized as potential water resource for irrigation and water supply. The results of the pumping test data in the study area demonstrates the groundwater regime of the region which is crucial in the water resource management of the Gadga River basin (Table 3)

Based on field, hydrogeomorphological and remote sensing studies the overall groundwater potential of this zone can be classified as moderately productive has resulted in drawdown of the aquifers, which require immediate integrated water conservation and artificial recharge methods for water resource development of the region . The moderately dissected plateau forms midlands with moderate degree of terrain dissection and weathering. In general this unit supports the thin vegetation as noticed in the satellite imageries. Hence

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this must act as a recharge zone with moderate to poor groundwater prospects. The alluvial zone is the most potential horizon of saline groundwater, which needs sustainable water resource development. It is suggested that the controlled pumping of groundwater along with the recharge of rain water and artificial recharge techniques to transform top groundwater layers in brackish water zone into fresh water to overcome the drinking water supply problem in the study area which includes water and soil conservation development of agriculture, horticulture and be use of saline water for prawn forming can be suggested for the socio-economic development of the region.

Results and Discussion

In this study geomorphological and remote sensing techniques have been effectively utilized in locating the potential aquifers so as to unable groundwater exploration in the region. The results will certainly aid in understanding the geomorphological and environmental control on the groundwater regime of the region. The result demonstrates the presence of structural, denudational and alluvial landforms. The morpho tectonic and morphometric analysis hydrogeological conditions of study area, which is suitable for ground water development with high drainage density. In this study, an attempt has been made to understand the sustainable water resource development of the region by identifying the groundwater potential zones which can help in identifying the potential aquifers in the region (Table 4). The results of the hydro-geochemical studies computed in the Gadge River basin provide groundwater quality parameters of the region regarding its suitability for drinking and agricultural purposes. (Table 5). The water quality of the study area is reasonably good for drinking and agricultural purposes as per the existing norms.

Hydro-geological and geomorphologic studies have thrown light on the water level fluctuations in the region with emphasis on water resource and environmental management of water quality. The results of the chemical analysis indicate that both the surface and groundwater are suitable for drinking and irrigation purposes. The results of geophysical resistivity studies have thrown light on the nature of sub surface geology of the region along with groundwater potential zones. The highly fractured, amygdaloidal and weathered basaltic horizons have yielded sufficient amount of water whereas, the compact and massive portions show poor yield in the region. In this study, an attempt has been made to suggest various suitable measures for improving the groundwater potential of the area with due emphasis on water resource management. Detailed environmental analysis was carried out to understand the water level fluctuations and quality of water. In addition, suitable remedial measures were suggested for water resource development and management of the region.

Acknowledgements

The authors are grateful to the director and the staff member of RRSSC, Nagpur for providing necessary remote sensing study facilities. Dr. Khadri is thankful to UGC and DST, New Delhi for the financial assistance in the form of a Major Research Projects.

References

Horton RF (1945) Erosional development of streams and their drainage basins, hydrological approach to quantitative morphology, Geol Soc. Mer.Bull 56:275-370

Krishnan MS (1960). Geology of India and Burma, highinbothams, Madras pp. 604.

Raju TS and Jha BM (1990). Relationship of Base Flow and Geohydrological properties of Bina River basin. *Hydrology Journal of IAH*. 8 (2): 55-72

Schumm SA (1956). Bull Geol Soc. Ame., 67, pp 597-646.

Strahler AN (1952). Dynamic basis of geomorphology: Bulletin Geol Soc Ame. No. 63, pp. 923-938

Tiwari MP (1996). Neotectonism in Gagde valley and its probable correlation with geothermal activity. Pitale Ul and Padhi PK (Eds.) Geothermal energy in india Geol. Survy India Sp., Pub. 45:325-332

Tiwari MP and Bhai HY (1995) Quarternary stratigraphy of Purna Valley, rec. Geol. Surv. India, 128.

Tiwari MP, Bhai HV, Padhi RN and Bandopadhyay KP (1996). Geomorphology and Gology of the Purna Valley; Proc. Vth nat, Symp on Purna Basin pp. 11-20

Wisler CO and Brater FF (1959). Hydrology John Willey and Sons, New york.

Table 1. Hydro-geomorphology of the study area showing various geomorphic units and their characteristics.

	Level 2	Level3	Groundwater potential
PLATEAU (structural origin)	Highly, dissected plateau (HDP)	A: with exposed rocks, negligible soil cover	Poor
	Moderately dissected plateau	A; with exposed rocks, thin soil cover	Poor
		B:-with moderate soil cover & moderately weathered zone	Moderate
		C:-with thick cover and thick weathered zone	Good
	Plateau Top	------	-------
Structural hills	Structural hills (small)	Ridge type, Structural hill	Poor
Denudational hill	Residual hills	Mesa/ butte type residual hills	Poor
Alluvial plain	Alluvial plain	Older/Younger	Very good
Piedmont zone	Bazada	-------	------

Table 2. Hydro-geomorphologic units of the study area.

Origin	Geomorphic unit/ Landform	Description	Groundwater potential
Fluvial	Alluvial plain (A.P.)	Thick unconsolidated alluvial material consisting of sand, silt and clay	**Very Good**
Fluvial	Bazada zone (B.Z.)	Unconsolidated alluvial material consisting of rock boulders, cobbles, pebbles, sand and silt	**Good**
Structural	Moderately dissected plateau - A	Basaltic plateau, moderately dissected, with high drainage density with thin soil cover	**Poor**
Structural	Moderately dissected plateau - B	Basaltic plateau, moderately dissected, with high drainage density and thick soil cover	**Moderate**
Structural	Highly dissected plateau -A	Moderate to steeply sloping basaltic plateau margins with high drainage density and negligible soil cover	**Poor**
Structural	Highly dissected plateau - B	Moderately slopping basaltic plateau margins with high drainage density and thin weathered mantle and soil cover	**Poor**
Structural	Plateau top	Isolated basaltic plateau with steep side slopes with moderate soil cover	**Poor**
Structural	Structural ridge	Narrow aligned ridges	**Poor**
Denudation	Denudation hillock	Basaltic hills with steep sided slopes	**Poor**

Table 3 Pumping test results of the study area.

Well No.	Depth of well	Diameter (M)	Water Level(m)	Q (m3 /d)	DD recorded (in min)	Max DD observed	REC recorded (in min)
1	13.72	1.07	3.40	29.09	120	1.41	180
2	12.19	1.37	6.13	20.07	180	o.54	240
3	13.72	1.07	8.64	13.77	150	0.53	180
4	9.14	1.28	4.57	21.00	210	0.55	240
5	15.85	1.98	2.88	307.13	60	3.19	120
6	16.76	1.12	6.25	21.85	180	0.39	180
7	12.19	1.26	3.03	26.71	150	1.46	240
8	15.24	1.73	8.95	42.39	180	0.33	90
9	22.25	1.14	14.07	12.74	180	0.60	240
10	18.29	1.60	15.15	22.69	180	0.58	300
11	16.76	2.59	6.38	91.76	150	0.49	300
12	9.14	1.52	6.25	24.83	120	0.45	240

Table 4. Ground Water Potential Zones

S.No.	Zones	Ground Water Potential	Area
1.	Valley Fills Younger flood plain	Very good	10%
2.	Composite slopes Bazada Zones	Good	23%
3.	Fragments of Dissected pediment predominantly black cotton soil under degradation	Moderate	35%
4.	Fragments of pediment Ridge and valley complex at the top of Western Ghats	Poor	27%
5.	Residual hill complex	Nil	5%

Table 5. Major ionic concentration in the mq/l in the study area

	Ca	Mg	Na	K	HCO_3	Cl	SO_4	NO_3
Surface water								
Minimum	1.30	2.22	3.44	0.00	1.10	2.79	0.42	0.01
Maximum	45.91	67.93	178.33	1.28	11.70	229.84	60.00	1.52
Mean	8.45	12.56	30.90	0.27	5.52	38.50	8.07	0.29
Std Deviation	15.17	22.47	60.33	0.41	2.93	78.09	20.98	0.54
Dug well								
Minimum	2.00	3.62	1.74	0.03	0.90	2.00	0.27	0.01
Maximum	151.70	134.00	165.28	3.58	13.61	405.90	31.35	1.70
Mean	19.51	19.68	22.62	0.62	5.57	51.81	4.35	0.41
Std Deviation	29.85	25.42	32.46	0.76	3.66	77.75	6.02	0.44
Bore well								
Minimum	0.80	0.33	0.78	0.00	1.00	0.59	0.029	0.01
Maximum	67.86	54.77	130.49	7.42	10.61	164.00	125.00	2.05
Mean	11.50	9.52	12.39	0.80	4.90	26.53	6.94	0.64
Std Deviation	13.01	12.75	26.06	1.40	2.28	35.70	20.33	0.58

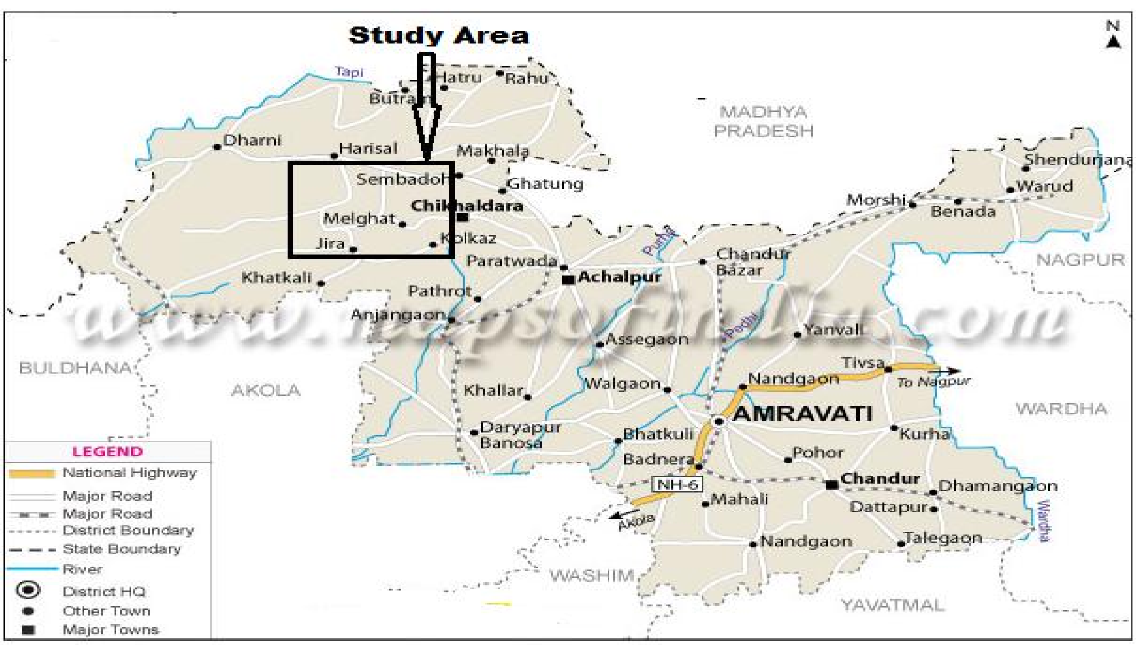

Fig. 1a Location map of the study area

ISSN 2229-5518

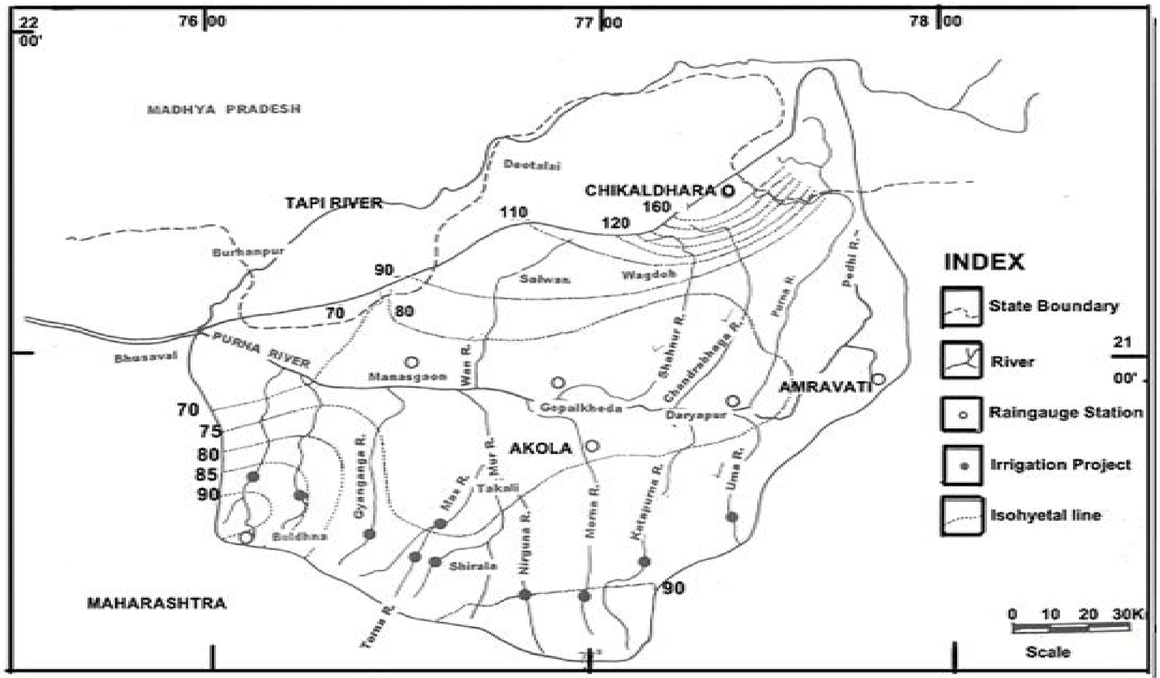

Fig.1b. Purna River basin showing isohyetal map along various tributaries

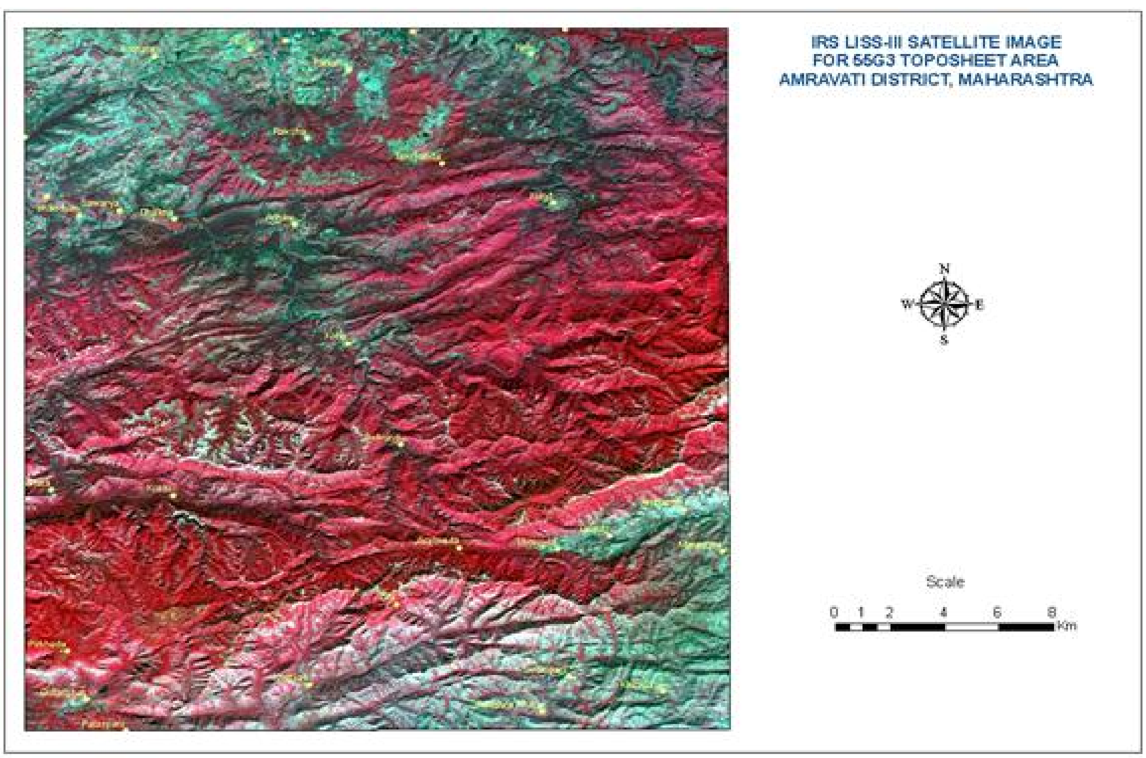

Fig.2 IRS LISS III imagery of the study Area

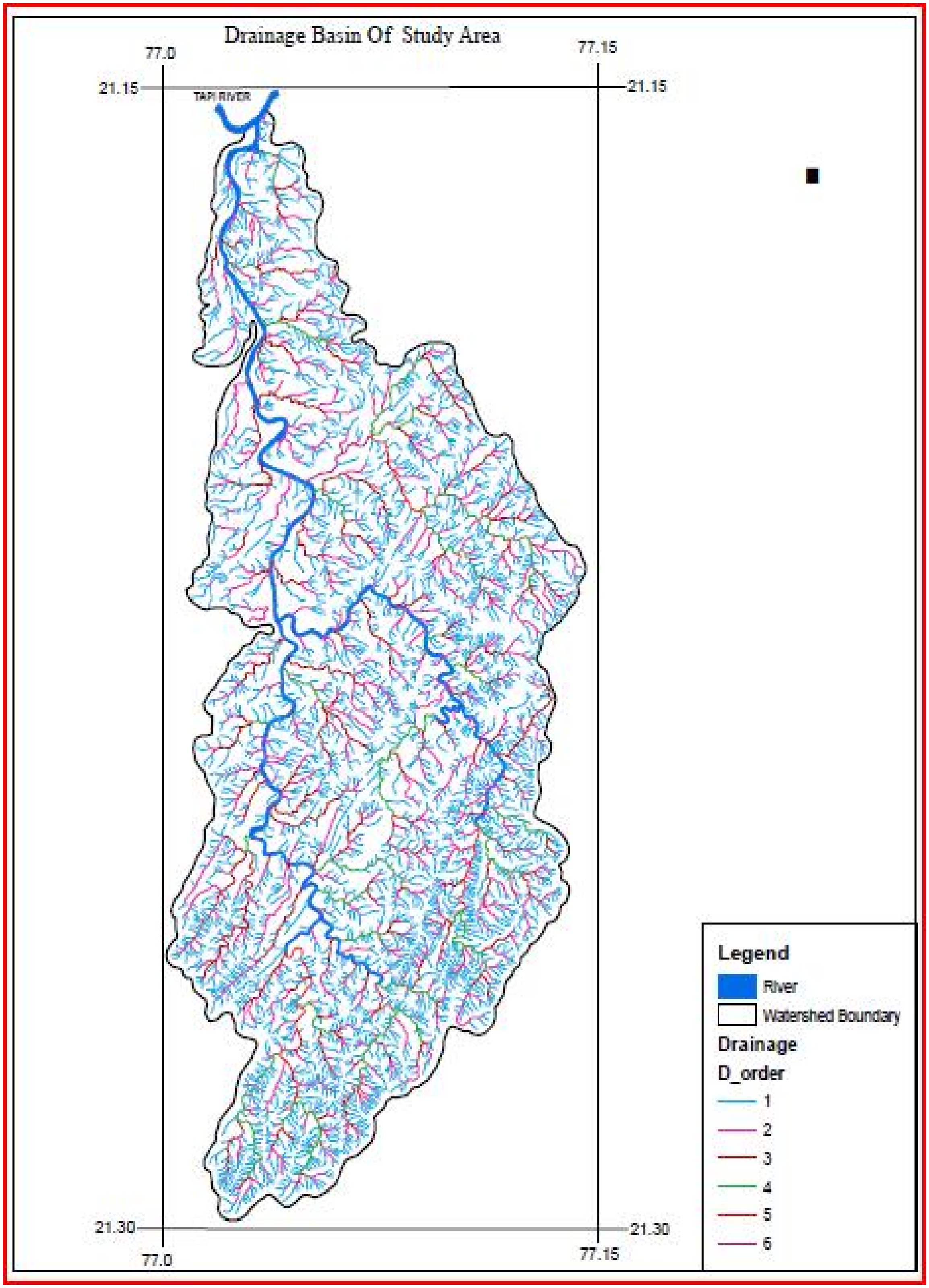

Fig.3 Drainage map of the study area based on topographic data and remote sensing analysis

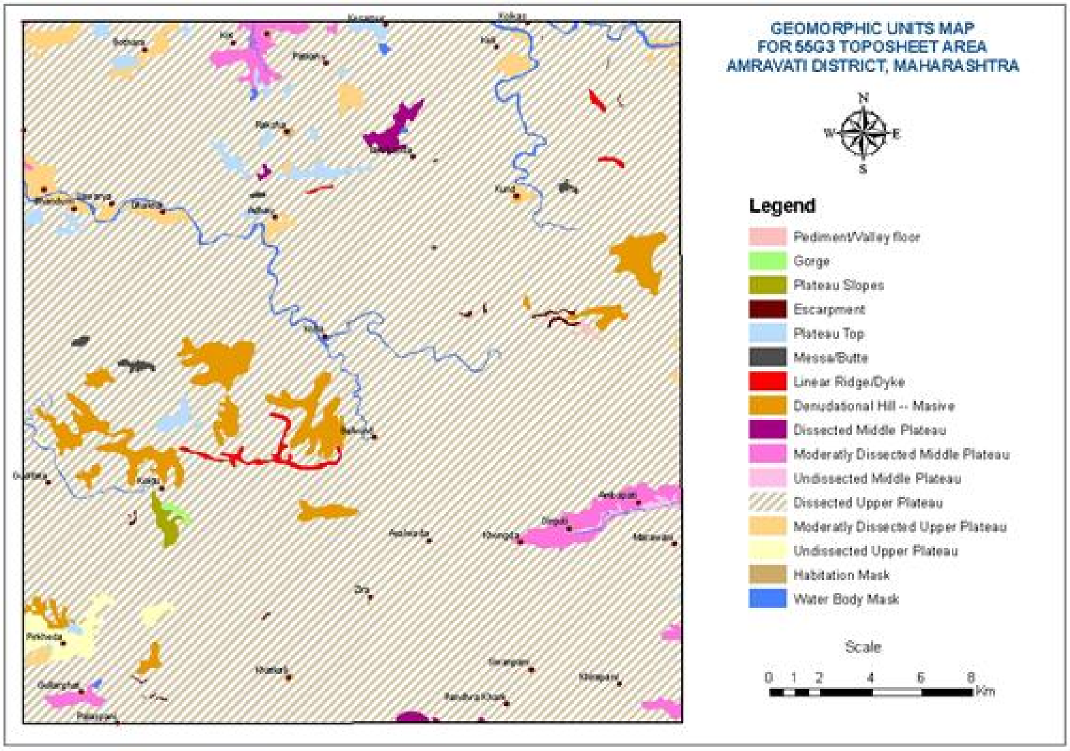

Fig.4 geomorphological map of the study area based on remotesensing data

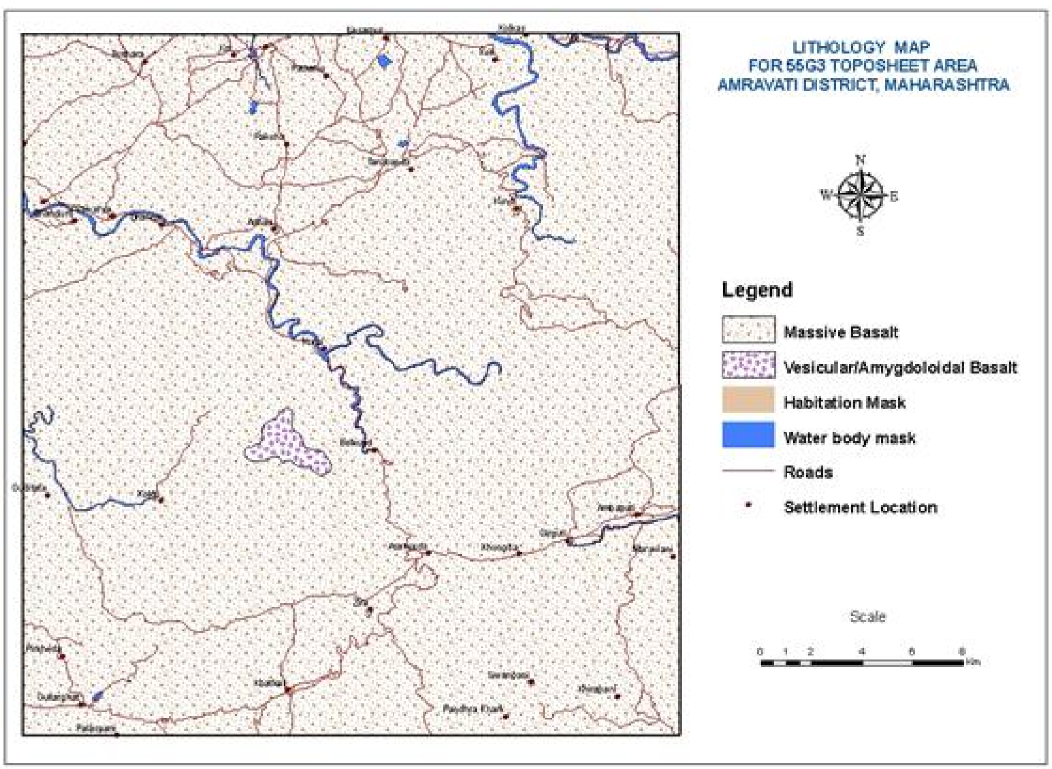

Fig.5 Lithological map of the study area based on remotesensing data

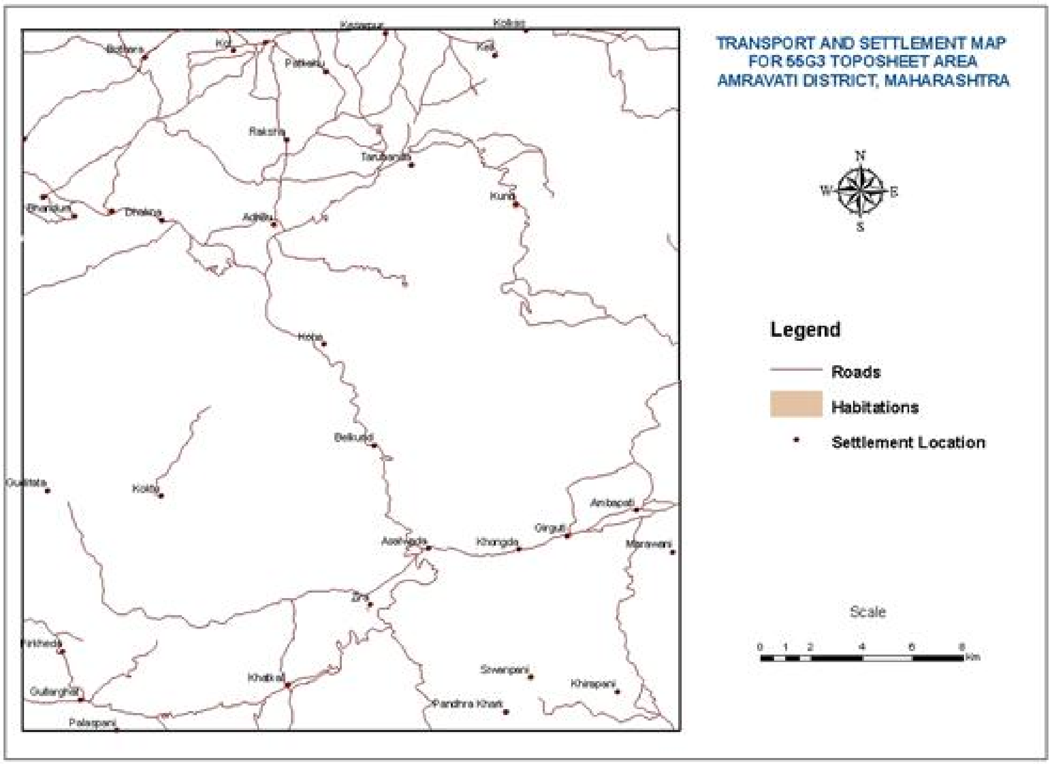

Fig. 6 Land use map of the study area based on remotesensing data

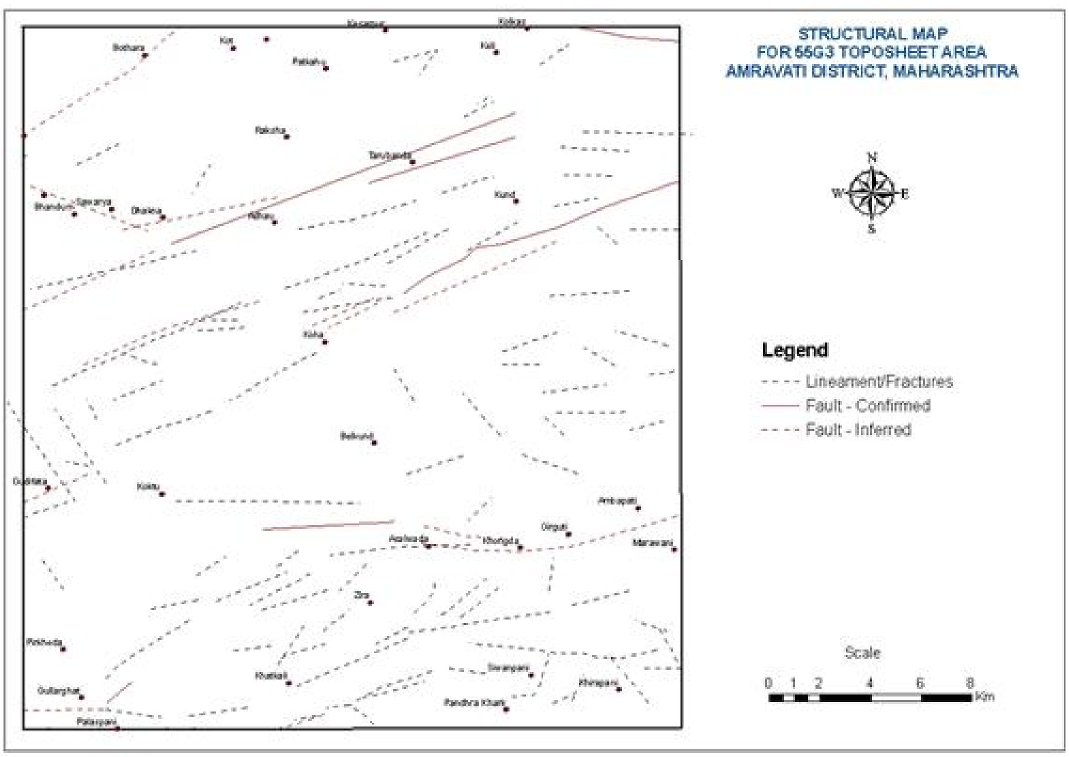

Fig. 7 Structural map of the study area based on remotesensing data