APPLICATIONS OF GEOSPATIAL TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

ENLIGHTENMENT TO PERFECTION

D. K. Mandal
Editor

Geospatial Technology for Sustainable Natural Resource Monitoring and Development, A Case Study of Arkasa Nala, Bankura & Puruliya District, West Bengal

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Abstract

Geoinformatics use in Micro Watershed Management can provide the appropriate platform for convergence of multidisciplinary data from various sources for appropriate planning. Remotely sensed data provides valuable and up-to-date spatial information on natural resources and physical terrain parameters. Geographical Information System (GIS) with its capability of integration and analysis of spatial, aspatial, multi-layered information obtained in a wide variety of formats both from remote sensing and other conventional sources has proved to be an effective tool in planning for micro-watershed development. In this study remote sensing and GIS has been applied to identify the natural resources management problems and to generate locale specific micro-watershed development plans. Micro watershed management through the remote Sensing and GIS based methodology is developed for the evaluation of the natural resources for sustainable development in Arkasa nala part of the Dwarkeswar River.

Keywords: Geoinformatics, Micro Watershed, Multidisciplinary, Watershed Management, Multi-layered.

Introduction

Natural resources management is sometimes misunderstood as being as process where planner tells people what to do, i.e typical top down situation. Natural resources means the systematic assessment of physical, social and economic factors in such a way as to assisted and encourage resources users to select resources use options that (i) increase their usability, (ii) sustainability , and (iii) meet the needs of the society.

Natural resources management is requires the individual users and other stakeholders not only realize bio-physical interdependencies of the natural resources system but also to coordinate the planning ideas with that of the users and other stakeholders. So natural resources management is a complex process where the resource use must change to meet new demand, yet changes bring conflicts between competing uses of the resources between the interests of the stakeholders. Therefore the participation of the users in the planning process is essential and this, (i) ensure that good natural resources management plans remain intact over time, (ii) reduce conflict among them, (iii) speed the development process (iv) increase the quality of natural resources assessment and (v) give sense of responsibility to the user for its monitoring and uses.

Aim & Objectives

1. Aim of study is sustainable development through natural resources assessment at micro-watershed level.
2. Physio-graphic setup of study area.
3. Identify Drainage bifurcation system.
4. Delineate micro watershed boundary.
5. Delineated boundaries are coded.

Location of Study Area

The study area consisting watershed namely DEWARAKESWAR watershed situated at the southern slope of Puruliya & Bankura, which is extended over block. This area contains Hura, Kashipur, and Puncha blocks of Puruliya and Indpur, Chatna, Bankura-I blocks of Bankura district of West Bengal state (Figure 1). The latitude & longitudinal extension of the area is 86 °31' 03.68"E to 87° 02' 45.81"E longitude and 23° 31 '38.68" North to 22° 57 ' North latitude. The study area cover by survey of India toposheet numbers 73-I /11; 73-I/12; 73-I/15 and 73-I/16.

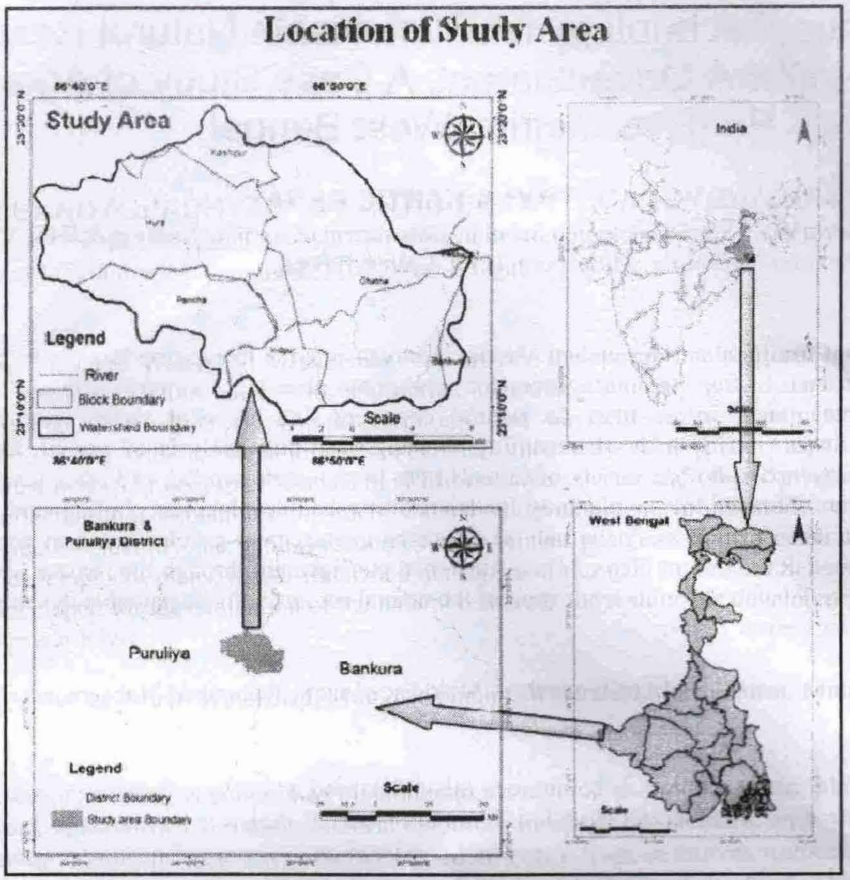


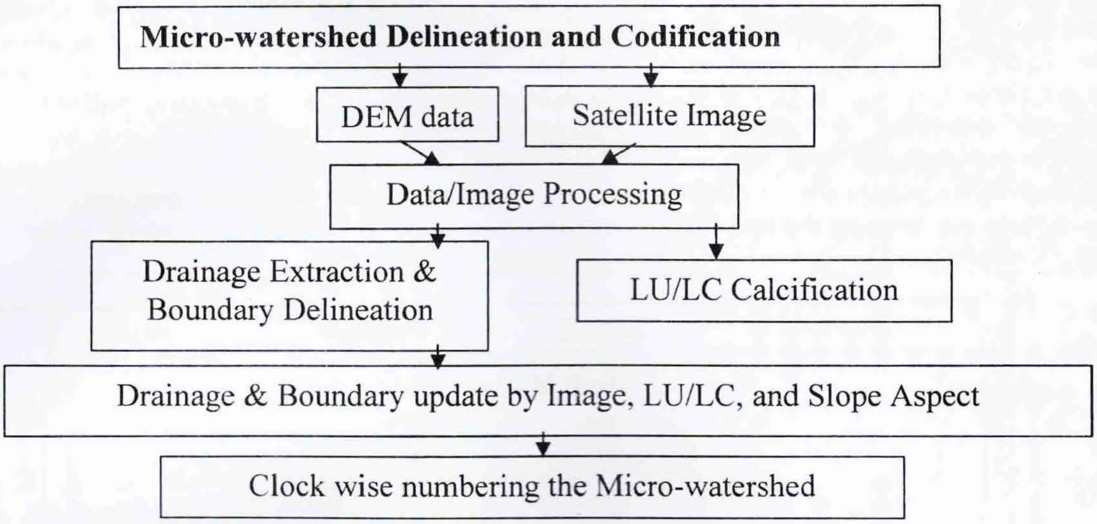
Figure 1 Location of Study area.

Data used and Methodology

Table 1 Data Used and Source.

Data	Source	Year
SOI TOPOSHEET (1:50000)	Survey of India, Kolkata	1975
THEMATIC MAP	NATMO, Kolkata	2001
DPMS	District Planning Office(Purulia, Bankura & Pashim Midnapore)	2001
CIMATE DATA	Metrological Department, Kolkata and Irrigation department of Bankura.	2014
LISS-III	Bhuban website	18th April,2012
SRTM DEM	USGS website	2008

Flow Chart of the Work



Data analysis for evaluation of the study area: The Dwrakeswar river basin is situated mainly in the part of Puruliya & Bankura district of West Bengal state. This area contains Hura, Kashipur, and Puncha blocks of Puruliya and Indpur, Chhatna, Bankura-I blocks of Bankura district. The total geographical area of the study is 341.14 km^2.

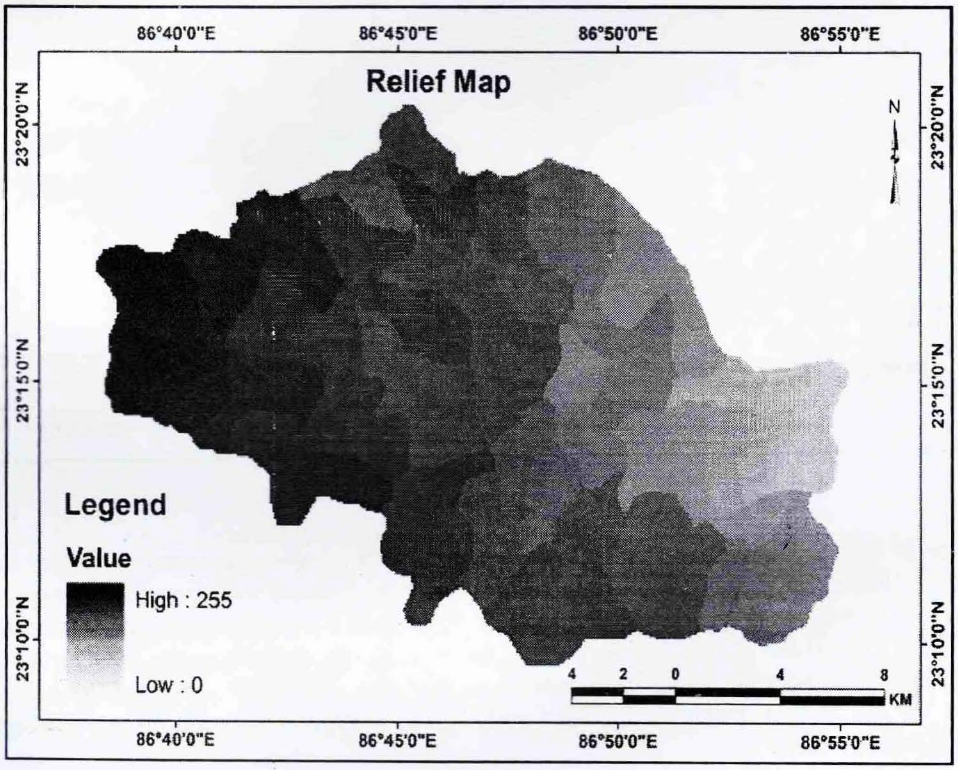


Figure 2

Relief: The relief map of the study area shows that it is a plateau region .In the south western part of the study area elevation is very high (>200m), in the north east part relief is low, with a gentle gradient from west to east (Figure 2). The general elevation of the area ranges from 90m to 400m, with a gentle gradient from west to east. In the high relief area ground water availability is shallow &low relief area ground water availability is near the surface. Mostly the study area is covered by the fallow land and forest area.

Soil: Soil is a natural product formed from weathered rock the action of climate and living organisms. A good understanding of soils with reference to their natural and distribution is essential to formulate any land base production system. Soil is diminishing resources whose loss/degradation is slow and not perceived readily. Spatial distribution and variability of soils are mainly controlled by the geological and geomorphologic factors. In fact, the soils geographic distribution patterns could be identified more reliably from the association of the geomorphic environments (Zinck, et al, 1990). This intimate association between geo-forms and soils along with land cover/ land use offers a good approach for understanding the soil distribution pattern during mapping. In view of that the physiographic soil unit mapping (Figure 3) was carried out covering the study area taking into consideration the local terminology of the landforms 'easy-to-understand' for by the local farmers/villagers.

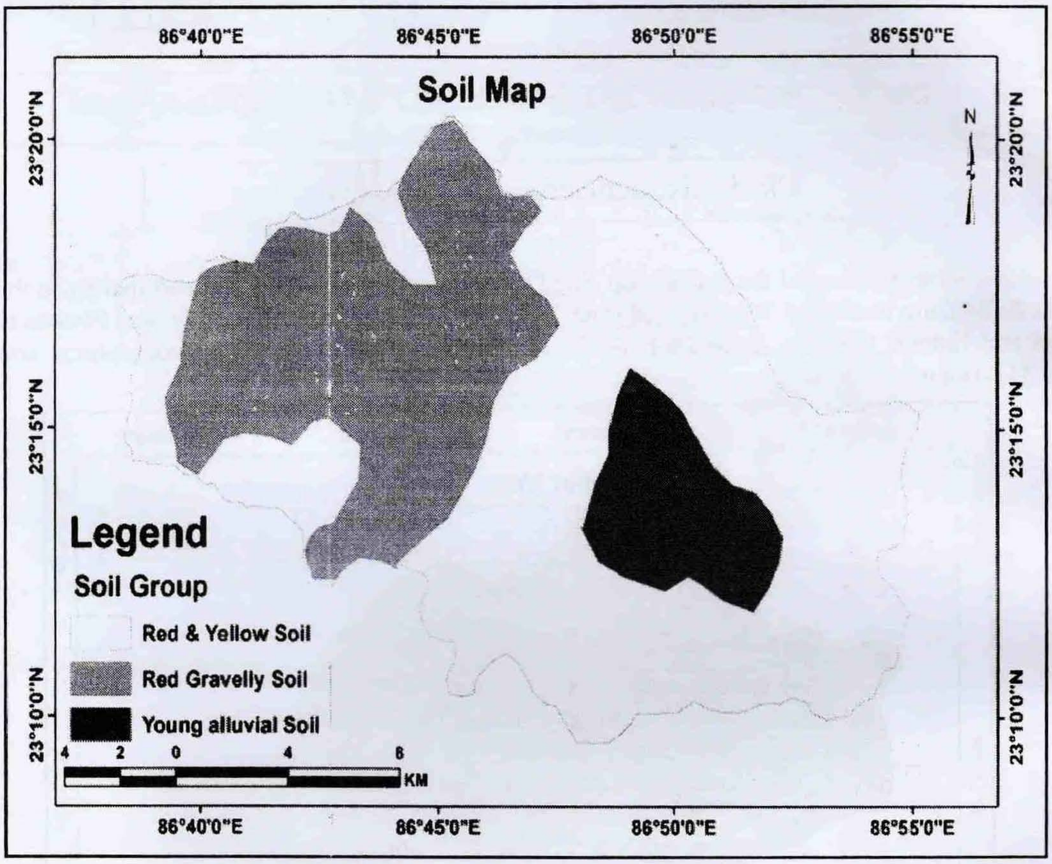


Figure 3

The map of the study area shows that a major portion of the basin is covered with very deep moderate well drained to imperfectly drain. Fine loamy soils which are residual soils developed in-situ mostly from gneiss rocks. It is due to very gently sloping to undulating plain with loamy surface & moderate erosion. The rest part is composed of deep to very deep, imperfectly drained fine soils. It is because of on very gently sloping to undulating plain with loamy surface and moderate erosion. There has been local colluviation in the infield valleys when the soils have developed acquire properties because of low physiographic condition.

Aspect

Derives aspect from SRTM DEM (Figure 4) in Arc GIS software a raster surface option. Aspect identifies the down slope direction of the maximum rate of change in value from each cell to its neighbors. Aspect can be thought of as the slope direction. The values of the output raster will be the compass direction of the aspect.

Conceptually, the Aspect function fits a plane to the z-values of a 3 x 3 cell neighborhood around the processing or center cell. The direction the plane faces is the aspect for the processing cell.

Flat areas in the input raster—areas where the slope is zero—are assigned an aspect of -1.

Aspect identifies the down slope direction of the maximum rate of change in value from each cell to its neighbors. Aspect can be thought of as the slope direction. The values of the compass direction are of the aspect. From the figure it observed that the maximum area of study area aspect 38 to 195 degree.

Slope

For each cell, Slope calculates the maximum rate of change in value from that cell to its neighbors. Basically, the maximum change in elevation over the distance between the cell and its eight neighbors identifies the steepest downhill descent from the cell.

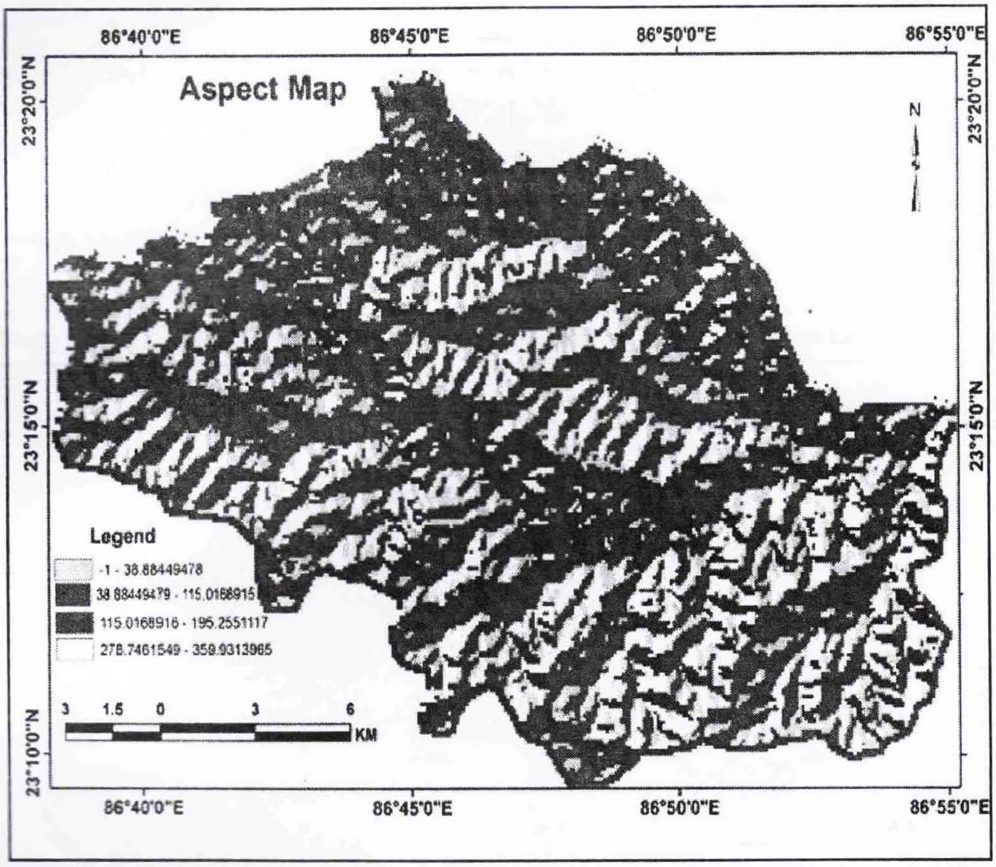


Figure 4

Conceptually, the Slope function fits a plane to the z-values of a 3 x 3 cell neighborhood around the processing or center cell. The slope value of this plane is calculated using the average maximum technique (see References).

The output slope raster can be calculated in two types of units, degrees or percent (called 'percent rise'). The slope map shows that in the few part of the study area slope is high, from upper to lower part slope is moderate & other area slope is low (Figure 5). In the high slope area runoff is high, so ground water availability is low & low slope area ground water availability is near the surface.

Geology

The study area is under the Chhotanagpur granitic gneisses complex, which is mainly constitute of Granite gneisses (cover most part of the study area) Pegmatite vein, quartz vein Lateritic As far as lineament is concern; there is west-east lineament, identified in the imagery through the east of Amdih village. On the ground there is no evidence of related geological signatures of identity the lineaments, as zone of structural disturbance due to the presence of cultivable land only.

The 'semi-circular' warping are very much prominent within the mica-sillimanite-schist zone, in the north-eastern part of the study area, exemplifying in major fold pattern and associated structural parameters (Figure 6).

Lineament
A lineament is a map able linear or curvilinear feature of a surface whose parts align in a straight or slidely curving relationship that may be the expression of a fault or other line of weakness the surface features making up a lineament may be geomorphic (caused by relief) or tonal (caused by contrast differences). Straight stream valleys and align segments of valleys are typically geomorphic expressions of lineaments (Figure 6).

Geomorphology
The study area under reference constitutes the eastern fringe of chotanagpur plateau. The area is gently undulating /rolling surface with enclosures of emotional remnants like pediment, BPS, BPM valley fill/Infill valley.

The jortanr pediment (232 m) in the southern most boundary of the watershed is the highest feature present in the study area. Among others, prominent isolated hill rocks (200 m) are present in the south-west part of the area amount Deuli village. It is worth mentioning that the micro pediment passes are very well developed in Kapaekata as well as in the eastern part Damankiari village.

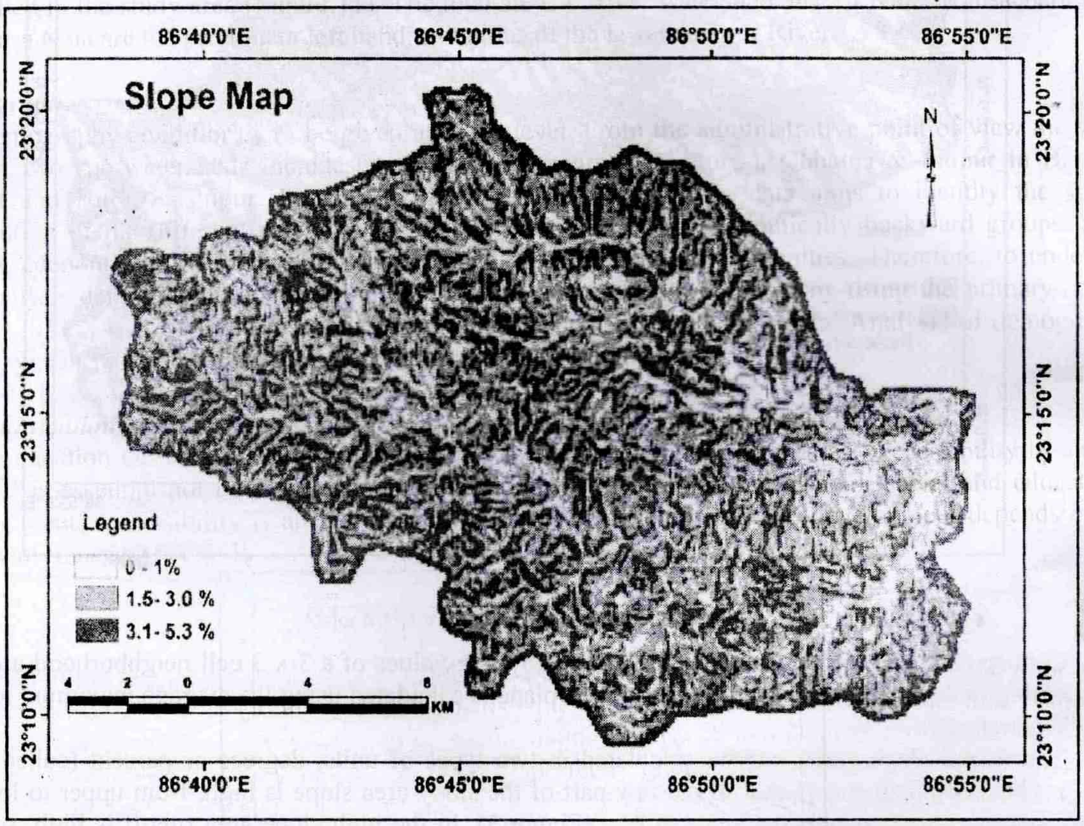


Figure 5

Some geographic anomalies in terms of 'Circular or semi circular or oval features' have been identified in the imagery from the contrasts ring tonal/textural characteristic and specific drainage patterns. Subsequent are the surface expression reflecting the variation in geographical parameters.

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Land use/ land cover

Land use is the surface utilization of all the development and vacant land on a specific point at a given time and space. This leads on back to the village from and the farmer to the field gardens, pastures, fallow and forest and to the isolated farmstead (freeman, 1968).The difference between the land uses and the land utilization is important. Land use is the use actually made of any parcel of land, house, and apartments. And industrial locations are land use categories, where as the term residential, industrial and agricultural refers to a system of land utilization implying roads, neighborhood retail and service activities as well as location of industry and charring of agricultural pursuits. In a rural areas tree crop and corn crop would identify the land use, where as orphaning, truck farming and grazing indicate a system of land utilization.
The land use study should be made in close connection with water resource management, flood protection scheme and irrigation utilities such study should include:

1. Survey of soil and land classification
2. Investigation of surface and underground resource for irrigation.
3. Re-examination of soil after the beginning of irrigation from to time.

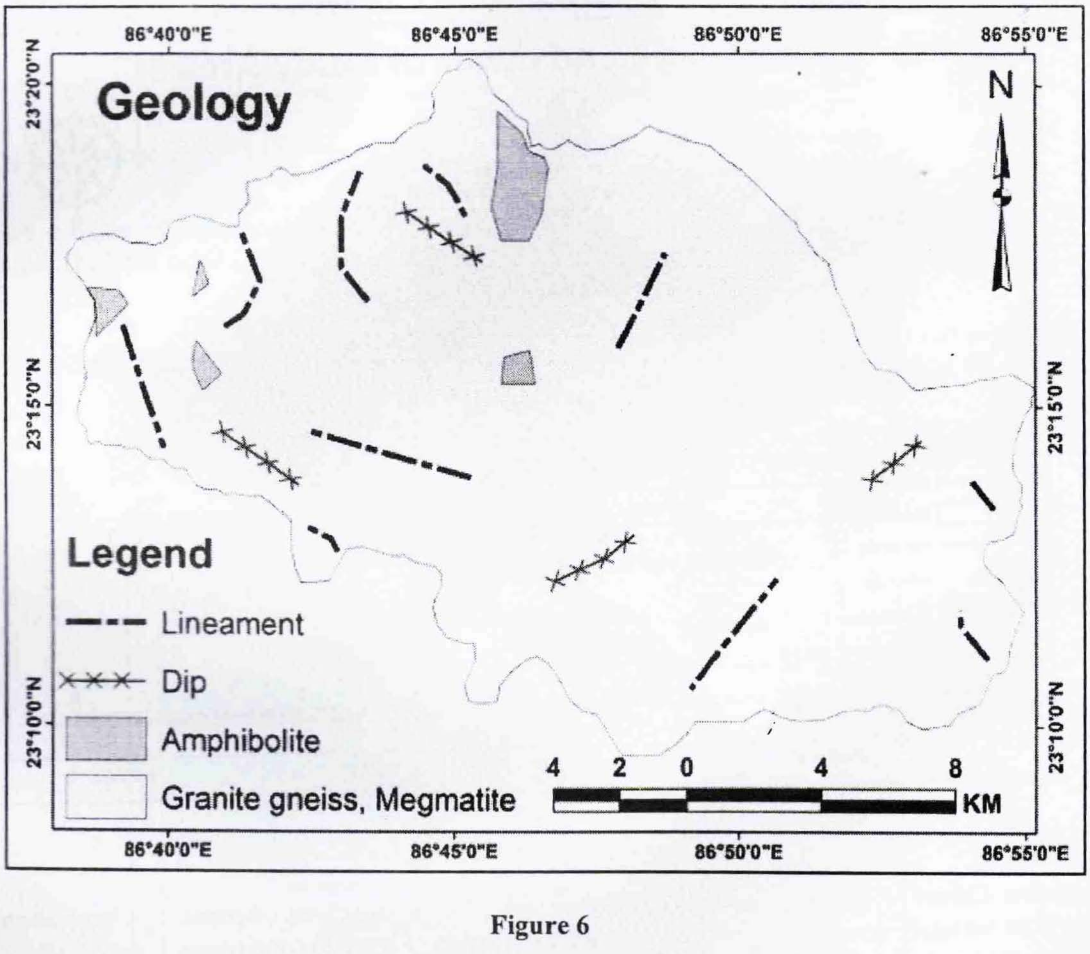

Figure 6

Table 2 Area of Land use/ land cover Class (2013)

Class name	Area in hectors
Existing agriculture	24636.16
Forest	9345.631

Open fallow	17004.12
Water body	1781.778
Agricultural fallow	38114.40
Wet fallow	11450.05
Sand	350.9386
River channel	28240.35
River	4451.588

The most part of land use map we see the agricultural fallow land, here one time of year cultivation is occurred (Table 2). The southwestern, western and southeastern part thin forest are present. Here also shows existing agriculture, open fallow land and also covered wetland, sand few portion of the study area (Figure 7). Here huge amount gully erosion is present. Southeastern rail way pass through the eastern part. Here different type of metalled & unmetalled roads is present.

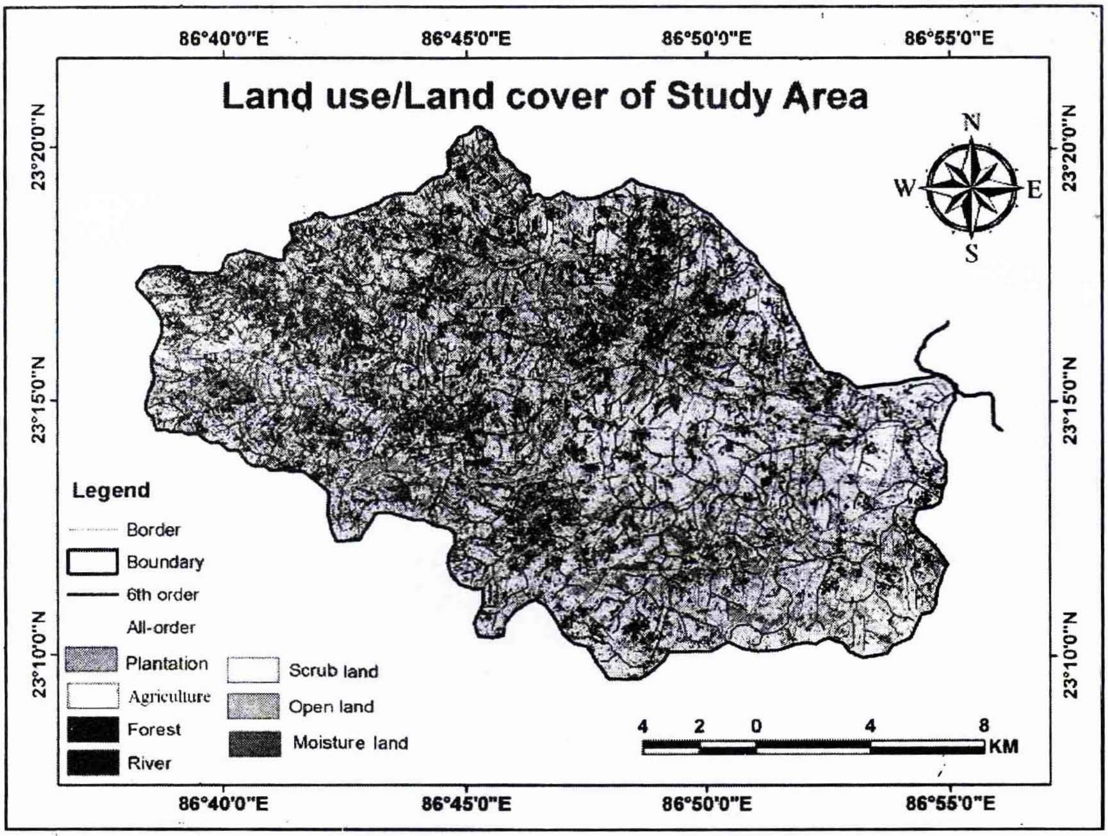

Figure 7

Vegetation Cover: Algorithms used to extract information like leaf area of percent of vegetation ground cover from remotely sensed data referred as vegetation Indies (Figure 8).

Most vegetation indices are based on the fact that these are significant different in the shape of the curve. One of the vegetation indices based on band ratio.

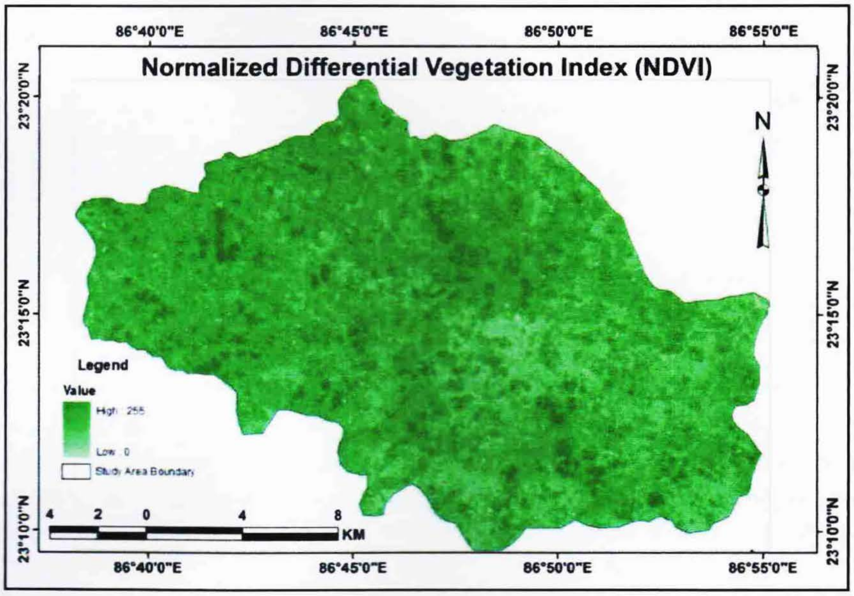

Figure 8

They compute the normalized difference of bright then value from inferred and red band for vegetation. This also called normalized difference vegetation Index (NDVI).

Climate

Rainfall: The normal annual rainfall ranging from 1100 mm in the western part and 1400 mm in the eastern part (Figure 9). More than 70% rainfall is coursed in time of monsoon period (June to September) table no -01 and chart represent them.

Temperature: Temperature of the winter atmosphere ranges between 5^0C to 13^0C (November to February) and summer ranges between 30^0C to 45^0C (March to June). The figure 10 is temperature graph.

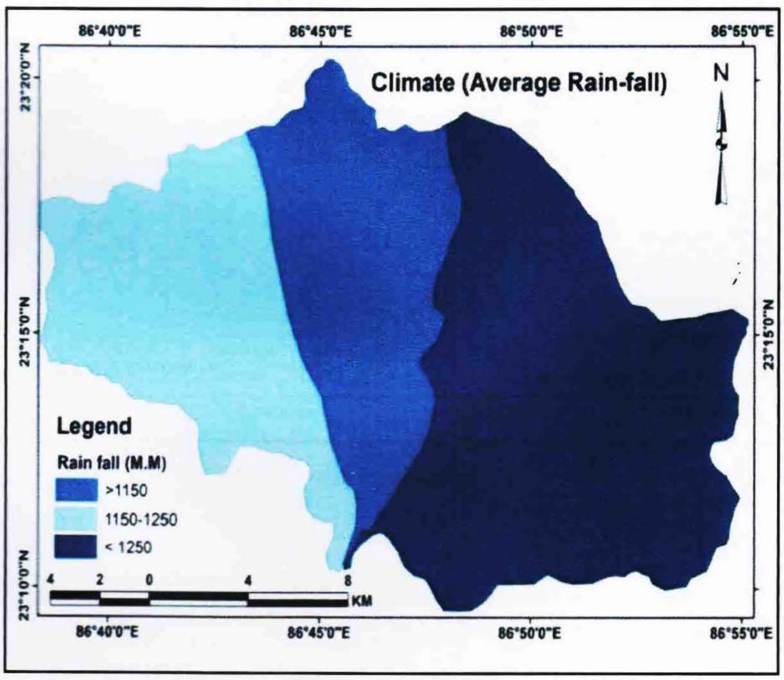

Figure 9

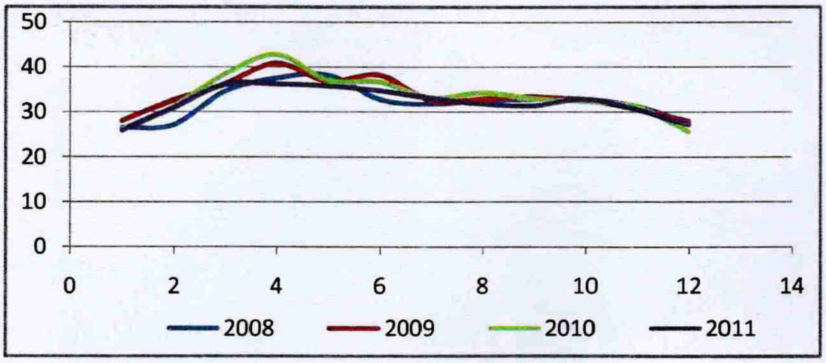

Figure 10

Humidity: In the south west monsoon and the post monsoon season the relative humidity remain high, being above 70% thereafter the humidity decreases and in the summer session it is very high that is around 85%.

The variations in the number of rainy days &soil moisture limitations are common. Severe drought periods lasting for weeks adversely affect the crop growth & yields during main cropping Kharif season.

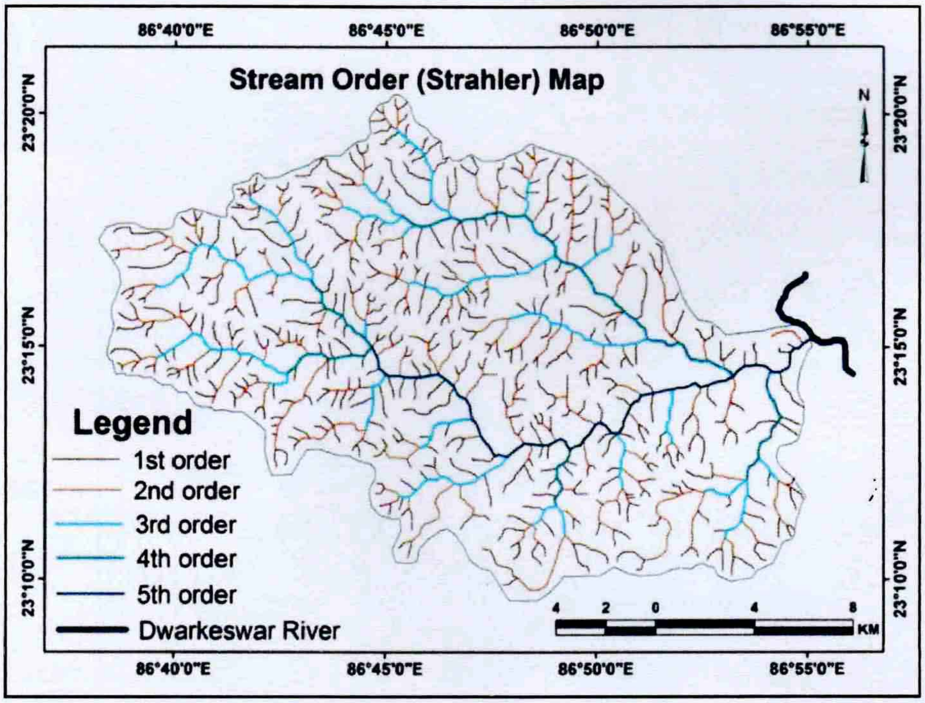

Figure 11

Drainage

The river originates from western upland of chhotonagpur plateau region to and flow almost parallel to each other carrying seasonal flow of water & meets Damodar River.

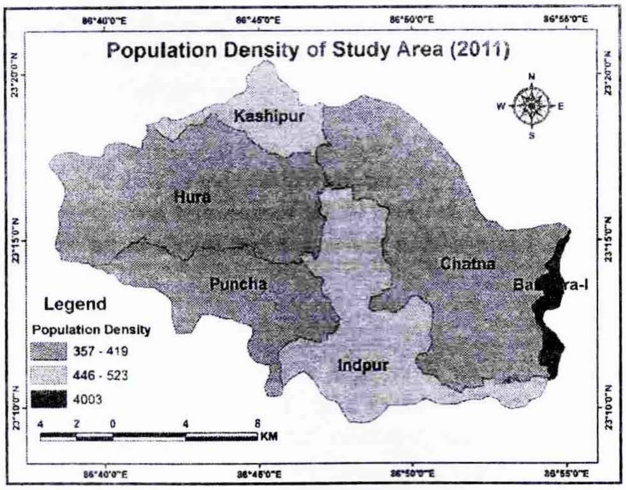

Figure 12

The river Dwarakeswar drain from northwest to southeast of the study area. The study area drainage pattern in dendrite drainage pattern, here sub stream meet with mainstream at right angle. We see 2th sub watershed in the study area (Figure 11). The total areas of river watershed 341.14 Km2. Kansachara Nadi & Arkasa Nala are the prominent left hand tributaries of the Dwarakeswar River.

Demography

The demography condition is to be given at block level. From the administrative point of view the study area of two sub-watersheds includes the partial coverage of Bankura-I, Chhatna & Indpur in Bankura district and Hura, Kashipur, Puncha in Puruliya. The demographic data aims to identity the spatial distribution of the different category i.e socially backward class, economically backward groups, areas lacking economic infrastructure and services and areas lacking basic amenities. Therefore, to undertake this analysis demographic composition map (Figure 12) has been prepared by using the primary census report -2011, Govt. of India in conjugation with other existing collateral data. Analysis of demographic map it reveals that 50% of the total population is under reserved class.

Communication

Communication network plays an important role in the development of an area. Accessibility by broads and rail is essential not only for economic development of a region but also for social and educational development. Accessibility is an indicator of the level of development and development depends on the quality of transport network.

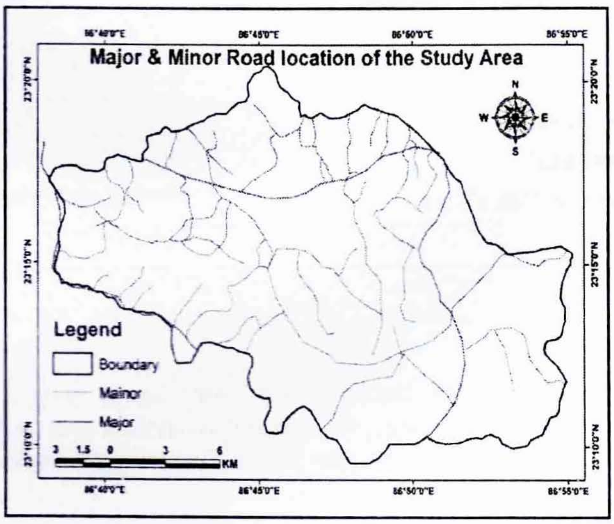

Figure 13

The transport network, settlement location map of study area has been prepared using SOI toposheets on 1:50,000 scale of 1972 edition geo-coded IRS-ID-LISS-III 2011images (Figure 13). The final map is upgraded version incorporation the ground data collection during field checks.

Result and Discussion

During the processes of land use planning, the ultimate objective is watershed management, which aims at efficient use and management soil, water & other biotic systems of a drainage from upper to lower part of the catchments on sustained basis. Land within the watershed needs to be managed as per land capability and suitability class.

Stream Order (Strahler, 1969)

It is a higherarchical position of stream with in a drainage basin, from where we can calculate the Bifurcation ratio & tell about water availability of that area. The output of Stream Order is higher quality if the input stream raster and input flow direction raster are derived from the same surface. If the stream raster is derived from a rasterized streams dataset, the output may not be usable because, on a cell-by-cell basis, the direction will not correspond with the location of stream cells (Kumar, 2010).

In the Strahler order method (Figure 3.3), all links with no tributaries are assigned an order of one and are referred to as first order. When two first-order links intersect, the down slope link is assigned an order of two. When two second-order links intersect, the down slope link is assigned an order of three, and so on (Strahler-1957). When two links of the same order intersect, the order will increase. This is the most common method of ordering.

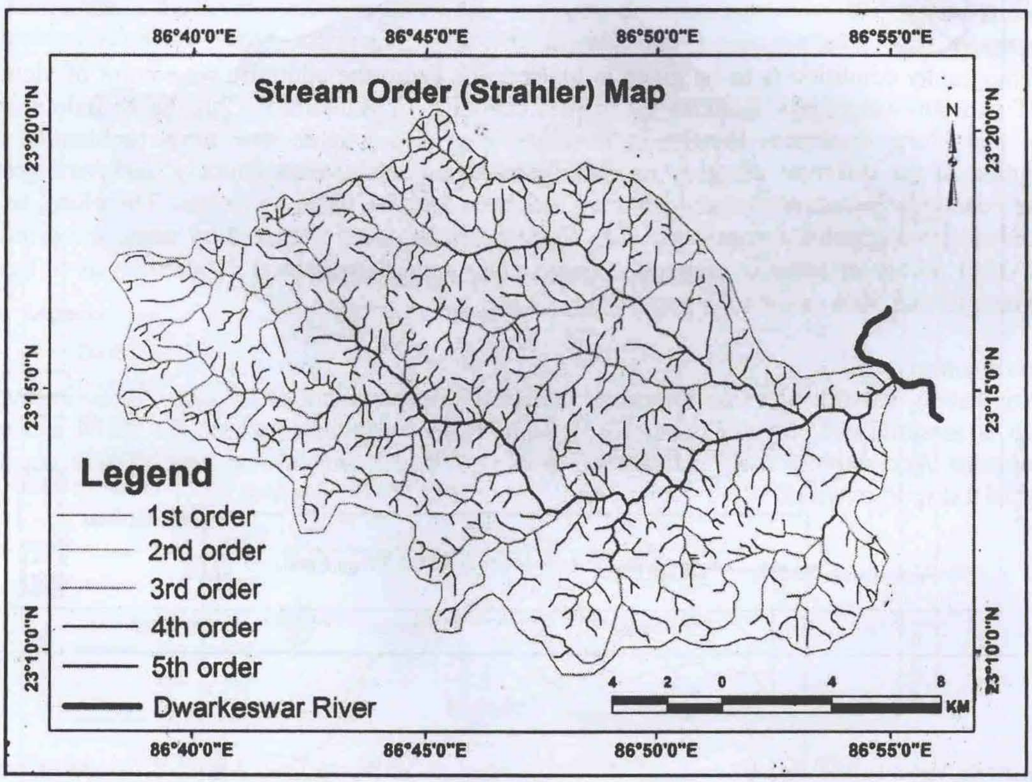

Figure 14

Sub-watershed

The study area (upper catchments of Dwarakeswar river basin) watershed divided with 2th sub watershed.1st sub watershed area is Kansachara 2nd sub watershed area is Arkasa (Figure 17), the two Sub-watersheds is left hand tributary of under upper part of Dwarakeswar watershed.

Watershed Delineation and Codification

The Central Water and Power Commission (CWPC) India in 1949 was made an attempt towards systematic delineation of river basins in the country and identified six (6) water Resources Regions (WRR). These six (6) Water Resources Regions were further divided into 66 major river catchments (Table-1). The above delineations have been extensively used by CWPC in assessment and development of the surface water resources of the country (Sarma and Saraf, 2002).

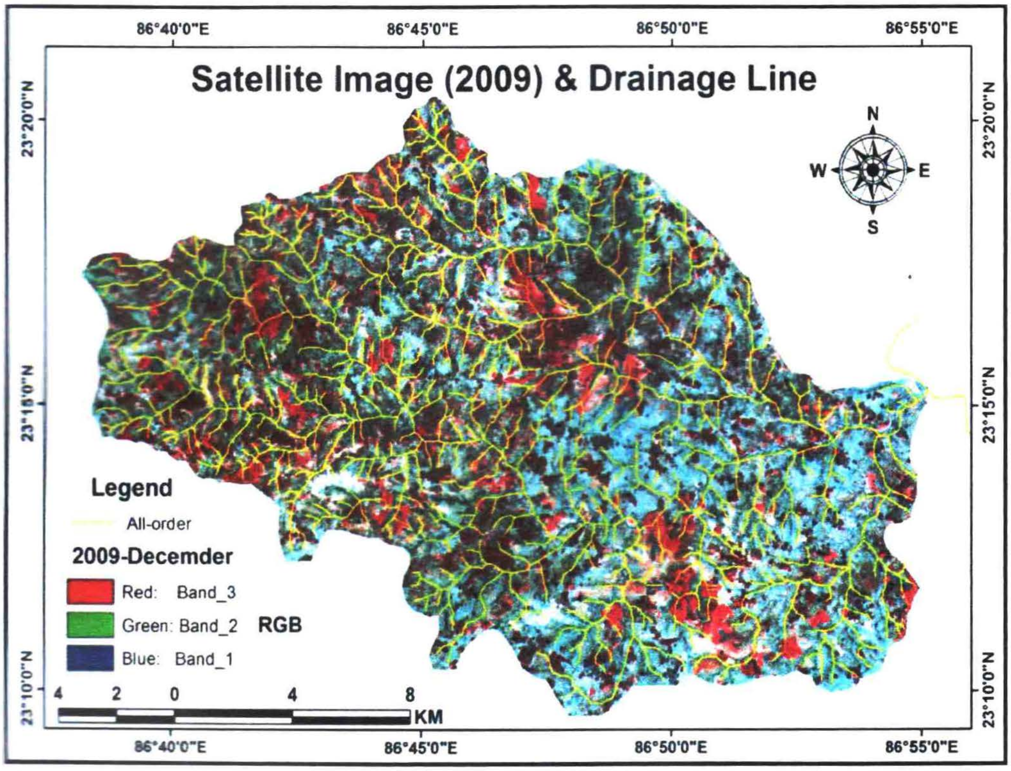

Figure 15

Ultimately, in September, 1990 "Watershed Atlas of India" on Scale 1:1 Million was published by the All India Soil & Land use Survey. During generation of the Atlas, the maps of Irrigation Atlas of India (1922) on scale 1:1 Million/1:2 Million, prepared by the Irrigation Commission were used as the base maps. In the Watershed Atlas, there are seventeen (17) maps which are:

1. Part of Cauvery Basin;
2. Part of Krishna and Cauvery Basin;
3. Part of Godavari and Krishna Basins;
4. Part of Godavari and Krishna and Mahanadi Basins;
5. Part of Sabarmati Basin;
6. Part of Narmada, Tapti, Sabarmati, Mahi, Ganga and Godavari Basins;
7. Part of Mahanadi, Ganga, Narmaba, Godavari and Tapi Basins;
8. Part of Ganga and Mahanadi Basins;
9. Part of Brahmaputra and Meghna Basins;
10. Part of Ganga, Mahi and Sabarmati Basins;
11. Part of Ganga Basin;
12. Part of Ganga and Brahmaputra Basins;
13. Part of Brahmaputra Basins;
14. Part of Indus and Ganga Basin ;

15. Part of Ganga Indus Basin;
16. Part of Indus Basin;
17. Part of Indus.

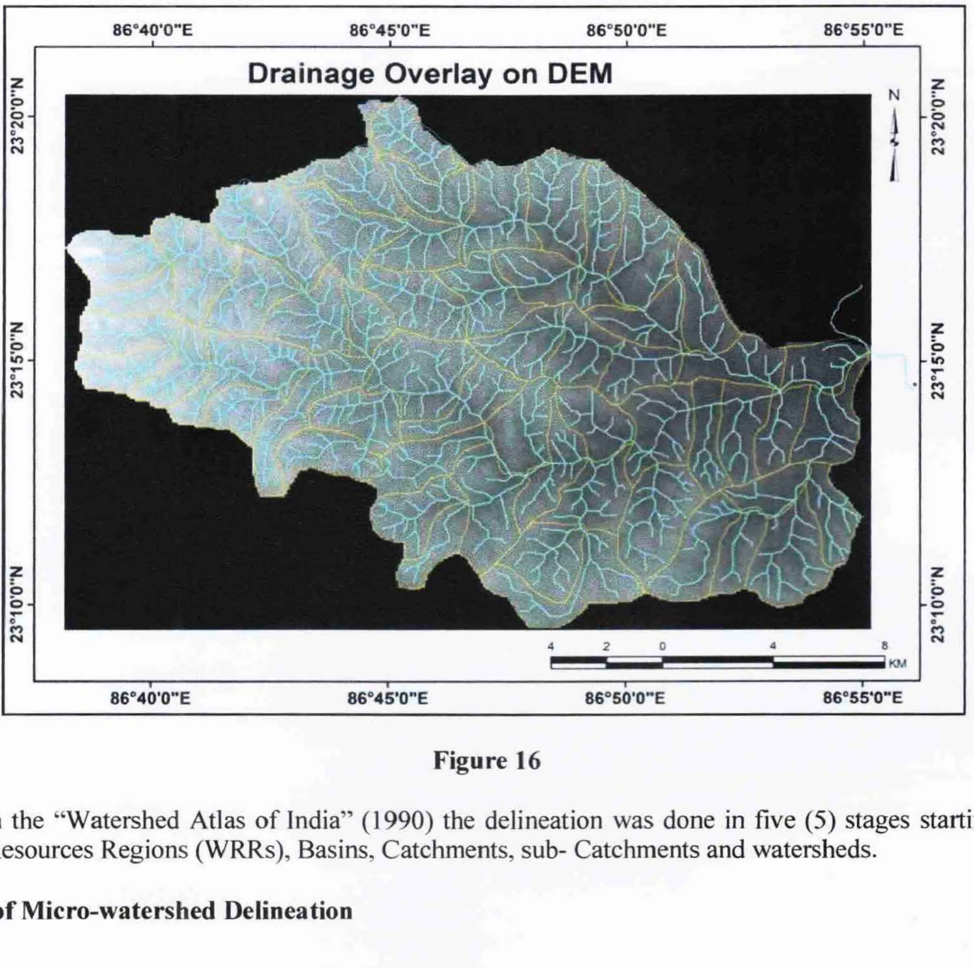

Figure 16

In the "Watershed Atlas of India" (1990) the delineation was done in five (5) stages starting from Water Resources Regions (WRRs), Basins, Catchments, sub- Catchments and watersheds.

Stages of Micro-watershed Delineation

Stage-1

Water Resource Regions (WRR)

In 1949, as conceptualized by CWPC the six (6) WRRs are delineated (Table-1). With slight modification in their numbering system in the watershed Atlas, AIS & LUS a clock –wise numbering system was adopted starting with Indus drainage as No. 1. For example-

Indus Drainage

Ganges drainage

Brahmaputra drainage

All drainage flowing into Bay of Bengal except those at 2 & 3.

All drainage flowing into Arabian Sea except that at 1.

Western Rajasthan mostly ephemeral drainage.

Stage-2

Basins: Each WRR has been divided into basins which constitute individual magnificent rivers like Krishna, Narmada, Chambal, Satluj or a combination of smaller ones which are contiguous to each other, such as basin between Cauvery and Krishna, southern and northern Western Ghats, etc. in some cases very large drainage systems like Ganges have been divided into lower and upper basins or left bank and right bank basins as in the case of Brahmaputra etc.

Stage-3

Catchment: Each basin has been divided into a number of Catchments which pertain mostly to main tributaries or a group of contiguous small tributaries or individual streams.

Stage-4

Sub-catchment: The catchments are further divided into a number or sub- catchments which are mainly smaller tributaries and streams.

Table 3 Micro Watershed Code with area.

Sl. No.	Micro Watershed Code	Area (sq. km)	Sl. No.	Micro Watershed Code	Area (sq. km)
1.	2A2C8F1a	4.59513000000	30	2A2C8G5a	3.51432000000
2.	2A2C8F1b	5.14560000000	31	2A2C8G5b	6.68357000000
3.	2A2C8F1f	5.44939000000	32	2A2C8G5g	9.80114000000
4.	2A2C8F1c	5.29631000000	33	2A2C8G5d	7.83780000000
5.	2A2C8F2a	4.68557000000	34	2A2C8G5c	6.32220000000
6.	2A2C8F2b	5.24783000000	35	2A2C8G5f	5.80060000000
7.	2A2C8F1e	8.20160000000	36	2A2C8G5e	3.66309000000
8.	2A2C8F1d	6.67362000000	37	2A2C8G4f	4.92090000000
9.	2A2C8F3c	4.97091000000	38	2A2C8G4e	4.22096000000
10.	2A2C8F6b	7.74191000000	39	2A2C8G4d	4.57095000000
11.	2A2C8F6a	7.27501000000	40	2A2C8G4c	8.45740000000
12.	2A2C8F3a	6.14099000000	41	2A2C8G4b	4.00224000000
13.	2A2C8F2c	5.52640000000	42	2A2C8G4a	7.74000000000
14.	2A2C8F3b	7.10777000000	43	2A2C8G3f	5.45174000000
15.	2A2C8F4a	5.07699000000	44	2A2C8G3g	5.58393000000
16.	2A2C8F5b	5.09985000000	45	2A2C8G3e	5.73707000000
17.	2A2C8F5a	5.52764000000	46	2A2C8G3d	5.51022000000
18.	2A2C8F4c	6.09441000000	47	2A2C8G3b	8.21788000000
19.	2A2C8F4b	7.69314000000	48	2A2C8G3c	3.59895000000
20.	2A2C8G1f	5.91144000000	49	2A2C8G2g	6.06158000000
21.	2A2C8G2a	4.26589000000	50	2A2C8G2f	6.27106000000
22.	2A2C8G2b	5.45967000000	51	2A2C8G2e	8.70604000000
23.	2A2C8G2c	4.55149000000	52	2A2C8G2d	8.96362000000
24.	2A2C8G2i	7.13044000000	53	2A2C8G1d	6.82212000000
25.	2A2C8G2h	5.06780000000	54	2A2C8G1C	3.94699000000

26.	2A2C8G3a	5.46787000000	55	2A2C8G1e	3.56667000000
27.	2A2C8G3j	6.14139000000	56	2A2C8G1b	8.32734000000
28.	2A2C8G3i	5.58080000000	57	2A2C8G1a	4.34957000000
29.	2A2C8G3h	9.36885000000	**Total Area = 341.14 km²**		

Stage-5

Watersheds: Each sub- catchments has been divided into a number of watersheds which are spatially the smallest hydrologic units in the macro level category and can be cartographically delineated on 1:1 Million scale maps.

In case of stages 2 to 5, the delineation is done from downstream proceeding upstream. Smaller contiguous drainage units that drain directly into the main drainage channel are grouped together at each stage of delineation. With each subsequent stage of delineation they get segregated. Codification System of AIS & LUS.

Alpha–numeric symbolic codes consisting of a combination of alternating Arabic numbers and English capital alphabet letters have been used to designate different stages of delineation as indicated below:

Water Resource Regions are assigned Arabic number 1,2,3---------2
Basins are assigned letters as A,B,C--------- A
Catchments are assigned Arabic number 1,2,3------2
Sub- catchments are assigned letters as A,B,C----- C
Watershed are assigned Arabic number 1,2,3------ 8

Thus, watersheds will have the codes like 1A1A1, 2B2A3, 3A5C4, 4G4D3, 2A2C8 etc.

This system of codification is almost an open chain system and can be extended to the stages of delineations of lower categories as well.

The coding of different stages is carried out starting from downstream upwards serially as the hydrologic unit occurs on right or left side of the main drainage at each stage of delineation. This procedure, incidentally, has the advantage of roughly indicating the likely location of a particular unit with reference to the downstream position of start of delineation.

Further subdivisions of the 'watershed' has been done by the National Remote Sensing Center (formerly National Remote Sensing Agency), Department of Space, Govt. of India in 1995 for the Integrated Mission of Sustainable Development (IMSD) project. The division are-

Sub-watershed (30-50 sq.km) .... F & G *
Mini-watershed (10 – 50 sq.km.)......... 1 & 3
Micro-watershed (5 – 10 sq. km.) .... a & h

However, in delineation of the sub to micro-watershed more emphasis is given on the drainage pattern and network (Figure 15 & 16) rather than spatial extent. The codification systems of sub to micro watershed are exemplified in the Table 3.

N.B: (Study two sub-watershed)

* F Sub-watershed = Kansachara
G Sub-watershed = Arkasa

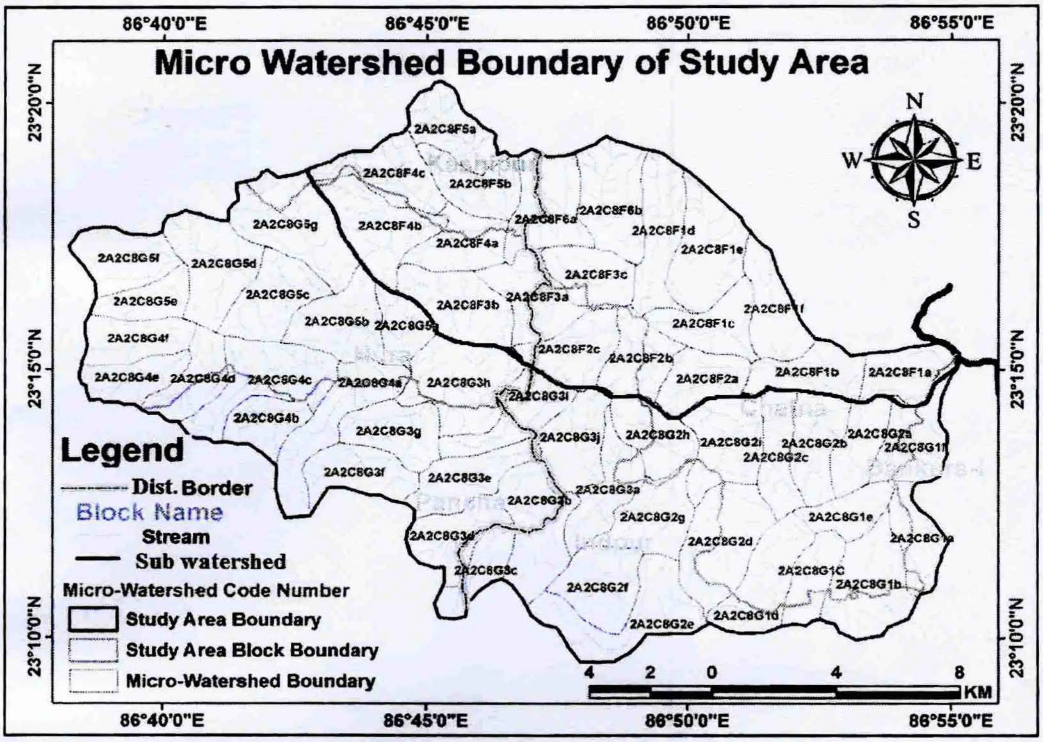

Figure 17

Conclusion

The studies mainly evaluate the natural resources based on theme based physical and societal criteria. The micro-watershed delineation was done using toposheets, DEM, satellite images, Land use/ land cover as well as field verification study following the guidelines of water resources atlas up to sub-watershed level. After that, micro-watershed delineation was proposed using same guidelines.

Therefore the planers and the users hands in hand in the planning process ensure that good natural resources management plans remain intact over time reduce conflict among them, speed the development process.

The purpose of the work was to involve the local micro level stakeholders in the area specific monitoring and management plan of the natural resource for sustainable development.

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ISBN 978-81-921692-7-9

Published by
Registrar
University of North Bengal
Raja Rammohunpur

Printed by
University Press
University of North Bengal