WATERSHED PRIORITIZATION -A CASE STUDY

A DISSERTATION

Submitted in partial fulfillment of the
requirements for the award of the degree
of

MASTER OF TECHNOLOGY
in
IRRIGATION WATER MANAGEMENT

By

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CANDIDATE'S DECLARATION

I hereby declare that the work which is presented in this dissertation entitled "Watershed Prioritization-A Case study" in partial fulfillment of requirement for award of degree of MASTER OF TECHNOLOGY IN IWM, submitted in Water Resources Development and Management, Indian Institute of Technology, Roorkee, is an authentic record of my own work, carried out during the period from July, 2004 to June 2005, under the guidance of Associate Prof. Deepak Khare, WRDM, IIT, Roorkee (India).

I have not submitted the matter embodied in this dissertation for award for any other degree or diploma.

Place: Roorkee

Dated: 29th June, 2005

(TARUN BHATNAGAR)

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

All land based productive activities are dependent on terrain, soil, biomass and water. Therefore, these components call for an integrated management approach, which can be better evolved within a natural domain such as watershed. Thus, it enables planners and managers to consider all inputs, processes and outputs systematically, which something essential for a holistic development approach.

But in most of the cases projects have been predetermined and priorities have not been laid out properly. Looking to the massive investment in watershed development program, it is not possible to treat the complete watershed. Due to financial constrain, watershed is further divided in small sub-watersheds which has to be prioritized so that work in the most sensitive sub-watershed can be taken up.

Hence prioritization facilitates in addressing the problem areas to arrive at suitable solutions and protective measures can be better planned and implemented.

The most common parameter that is widely recommended is sediment yield index. But this parameter is more suitable for river valley projects and for the watersheds where there is major problem is due to sediment yield. For other cases some other factors have to consider for the prioritization.

From the different factors, indicators and prioritization methods which were studied in this dissertation and an effort was made to prioritize the watershed taking consideration into factors that affect the prioritization process such as; slope of the watershed, drainage density, stream order, aspect, land use and land cover, soil, socioeconomic factor and water availability.

Using GIS tools & multi criterion evaluation of these factors, prioritization of the watersheds falling in the study area was conducted for Tendukhera- Tehseel in Damoh district of Madhya Pradesh. Out of 45 sub watersheds, 9 were found as very highly prioritized, 9 were highly prioritized, 16 were moderately prioritized and 11 were lowly prioritized watersheds.

The study will be helpful in comprehending the status of the watersheds of the study area and accordingly watershed planning can be worked out.

CONTENTS:

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1. General

1.1 Watershed

A watershed is all the land and water which contributes runoff to a common point. A small watershed of a few hectares that drains into a small stream forms part of a larger watershed, which in turns form parts of a still larger watershed, until the combined watersheds become a major river basin draining millions of square kilometers of land.

Depletion of forest cover and over use of land and water resources results in deterioration of the watershed. The high velocity runoff causes erosion of the soil, deposition of sediments in the stream and problem of floods down stream. The loss of fertile soil causes reduction in crop production. By adopting soil and water conservation practices the situation of watershed can be improved. In a well managed watershed, most of the storm water infiltrates into the soil which increases the ground water potential, the runoff velocity is reduced which causes less soil erosion and production is enhanced.

One of the most successful watershed projects is of Ralegaon Siddhi, Maharashtra (India). Inspired by the famous NGO worker, Shri Anna Hazare, the people's involvement in the project has made Ralegaon Siddhi self sufficient in all aspect.

Other famous completed project is of Sukkhimajri (Punjab), executed by Central Soil & Water Conservation Research and Training Institute, Dehradun. Through this project not only the problem of siltation of Suhkna lake (in Chandigarh) was solved but also the farmers become self sufficient to full fill their irrigation water requirement.

1.1.1 Watershed approach

Watershed provides a hydrological unit within the natural boundary of area for conservation of natural resources. It allows the planners to focus on all the effects of downhill runoff in a given area and to plan accordingly to control or contain it.

All land based productive activities are dependent on terrain, soil, biomass and water. Therefore, these components call for an integrated management approach, which can be better managed within a natural domain such as watershed.

A watershed is an intricate, dynamic and natural functional unit established primarily by physical relationships and secondarily by social communication and actions. Thus, it enables planners and managers to consider all inputs, processes and outputs systematically. These are essential for a holistic development approach. This approach is also logical from an economic and environment point of view. Not only does the watershed have a definite determining role in shaping basic economic potential, it also determines which activities will be internally compatible as it defines a functional ecosystem.

Drainage basins, catchments and sub-catchments are the fundamental units for the management of land and water resources (Moore *et al.*, 1994). Catchments and watersheds have been identified as planning units for administrative purpose to conserve these precious resources (FAO, 1985; 1987; Honore, 1999; Khan, 1999).

1.2 Watershed Management

Watershed management is the prudent use of soil and water resources within a given geographical area so as to enable sustainable production and to minimize floods.

Watershed management in terms of physical components is very nearly synonymous with soil and water conservation with the emphasis on optimum production rather than on maximizing crop production. These practices are those changes in land use, vegetative cover and other structural or non structural actions that are taken in watershed to achieve specific watershed management objectives. It is a plan of activity geared towards attaining specific goals. The objectives of the plan will decide which factors are to be controlled. Very often if some objectives if realized to extreme will be incompatible with others e.g. a cutting of vegetation will increase the discharge of the streams. Therefore a programme of management will often mean a compromise between objectives.

The objectives of watershed management are to increase infiltration into soil, to control damaging excess runoff, to manage and utilize runoff for useful purpose, to solve the problem of drinking water and to some extent the problem of irrigation water, to increase the agricultural production due to conservation of soil and water, to restore the ecological balance and to prevent premature siltation of the reservoir.

1.3 Objective of prioritization

In most of the cases projects have been predetermined and priorities have not been laid out properly. But looking to the massive investment in watershed development program, it is not possible to treat the complete watershed. Due to financial constraints, watershed is further divided in small sub-watersheds of nearly 500 Ha areas which have to be prioritized so that work in the most sensitive sub-watershed can be taken up.

Hence prioritization will facilitate in addressing the problem areas to arrive at suitable solutions and protective measures can be better planned and implemented.

1.4 Objectives of the study

1. To identify the priority watersheds in the study area.
2. To identify the suitable parameters of the prioritization, pertinent to the problem of the study area.
3. To study the various parameters and indicator of the prioritization.

CHAPTER 2

LITERATURE REVIEW

In India, the concept of priority watershed was developed in 3rd plan period (1966-69) when All India Soil & Land Use Survey (AISLUS) was restructured to include responsibility for integrated watershed programme (Tideman-1996).

Priority classification was based on term called sediment yield index using the empirical formulae. The sediment yield index values can be seen to reflect two derived measures; an erosion intensity and secondly a delivery ratio indicating transportability of sediment to the dam reservoir. The erosion intensity is mapped using four physical factors observed in the field (terrain and slope, soil class and susceptibility to erosion, vegetation cover condition with extent of erosion process).

In this chapter some of the literature on prioritization has been discussed.

A conceptual framework of spatial decision support system (SDSS) for rural land use planning have been developed for supporting decision making on area selection for different watershed management schemes by Adinarayana,(1999). The stepwise approach has been adopted in the study. A topographic base is generated within a Geographic Information System (GIS) from 1:50000 scale survey of India topographic sheets. The boundaries of hydrological watersheds are drawn manually to produce watersheds of the required size and all these boundaries are digitized within the GIS. The SDSS adopts explicit criteria of meeting the minimum goal of a scheme under which it is to be implemented. These criteria include erosion intensity, sediment yield and present land degradation status. Multi-criterion evaluation of each single criterion provides a ranking of sub-watershed. These individual rankings may be combined by various methods. The author used DEFINITE software for ranking. Produced framework has been proposed to be developed as web based SDSS.

Remote sensing is very useful in assessing the land cover of an area at a particular time and monitoring the change over a given period (Lillisand & Kiefer, 1987). Furthermore, the land cover being spatial in nature, GIS can be employed as a powerful tool in monitoring and data processing. With the creation of digital terrain model, it is possible to make digital representation of the topography of the area. This information is very useful in estimating soil erosion and other analyses (Burrough, 1986; Arnof, 1991).

Prasad et al, (1997) has worked on sub watershed prioritization using remote sensing and GIS .The study was carried out in Trijuga sub watersheds of Nepal. These sub-watersheds were prioritized by considering their degradation condition and land sensitivity. Land Sensitivity was defined as locational relationship between forest loss and soil loss. Universal Soil Loss equation (USLE) in conjunction with remote sensing and GIS has been used for estimating soil loss and land cover change. Degradation speed index, sensitivity analysis -sensitivity index and present condition (PC) were considered as indicators of prioritization.

The soil and forest are the two main resources of the watershed. Their amount of change in specified period of time is the indication of the status changing speed. So by assessing the forest and soil loss change between a time period and contribution to the soil loss change, degradation speed index (DSI) can be calculated using the empirical formula given by Sah et al, (1997).

An integrated approach of digital image processing of satellite data and visual interpretation of aerial photograph combined with GIS & USLE was carried out for land cover change and soil loss estimation. Matrix analysis between Degradation speed index & Sensitivity index was done. They were grouped into different classes, which were used for second matrix analysis with present condition of watershed for the prioritization.

Tripathi et al (2001), has worked for identification of watershed project formulation and implementation. Sediment yield index was used as prioritization parameter of River Valley Projects (RVP) and Flood Prone Rivers Project (FPRP). Other parameters were introduced keeping in view of soil and water characterstics in a participatory watershed management programme. These included silt yield index, existing water resources, water quality, fertility of the soil, existing employment opportunity, availability of basic amenities viz; transport, school, hospital, post office, bank, cooperative societies, marketing, communication and adoption of the village by other agencies.

Watershed prioritization for soil conservation planning with Mos-1 Messr Data, GIS applications and socio- economic information through a case study of Tinau watershed, Nepal was done by Shestha. et.al, 1997. They introduced a term called soil erosion status (SES). The sub watershed can be divided into one of the three categories low erosion area (LEA), medium erosion area (MEA), and high erosion area (HEA). In this approach parameters for prioritization of watershed were taken as aspect, slope gradient, drainage density, soil type, land use cover. After drawing thematic maps and classifying the study area into LEA, MEA and HEA for each parameter, a final map of soil erosion status was developed showing the erosion status of different sub watershed within the study area. The study concluded that it is possible to study watershed erosion status by using simple methods. Remote sensing and GIS, with the integration of socio economic data is very useful for watershed planning and management.

Anonymous (2001) has worked in the Cooks Creek Watershed, Pennsylvania for development of an index to prioritize watershed restoration. The objective of the study was to evaluate riparian corridor integrity, identify land parcel with degraded riparian buffers, prioritize degraded riparian land parcels, and engage priority land owners in conservation and restoration efforts. Parameters for prioritization of riparian buffer in watershed were taken as stream order (determined by visual inspection of USGS 7.5 minutes quadrangle maps), land use ranking based on total phosphorous loading rates of different land uses, drainage area and buffer width. Drainage area was determined by delineating the drainage areas from a USGS topographic map in Arc View. Buffer width is a critical factor in determining the need for restoration at each parcel due to the pollutant removal potential.. Wider buffers provide more sediment and nutrient removal capability than narrow buffers, but the marginal value of a buffer decreases with increasing buffer width. Prioritization was carried out using Riparian Restoration Prioritization Index (RRPI).

Khan et al, (2001), studied watershed prioritization using remote sensing and GIS through a case study from Guhiya, India. The watersheds were ranked according to their tendency towards erosion using erosion intensity and delivery ratio to create sediment yield index. Erosion intensity (susceptibility towards erosion) and delivery ratio (indicating the transportability of sediment to the dam reservoir) were considered as the parameters of prioritization. Erosion intensity units were calculated with respect to soil depth and texture, land slope, present land use, vegetation and drainage density. Digitization of each thematic information, superimposition of information was done to calculate sediment yield index. Based on this approach the 68 watersheds in the Guhiya catchment, draining into Sardar Samand reservoir were prioritized. These sub watersheds were classified in four categories viz Very high priority, high Priority, moderate Priority and low priority.

For prioritization of watersheds on regional scale or on state basis it is possible to cluster factors which have the highest priority for influencing non-point source pollution within watershed boundaries (Bartholic and Kang ,1995). Using GIS and digital data, these factors can be grouped within watershed, to develop a prioritization index. The parameters included were animal numbers derived from census data clustered within zip codes provides one index factor. Another was assessment of land slope factor .

Other factors could deal the erodibility characteristics of soils within the watershed and the amount of agricultural land devoted to row crops. The length of the reaches of rivers, streams, and open drains were taken as additional factor. These factors have been clustered for Michigan for a preliminary prioritization. Finally prioritization is done based on erosion intensity and sediment delivery.

Woods and Epp, (2001), identified community support as important factor in small watershed prioritization. Watershed of greatest need, technical and economic practicability of potential solutions were taken as parameters of prioritization. The first step of prioritization was an analysis of watershed data to produce a three tiered ranking of watersheds. The second step of prioritization takes into account the feasibility of launching an effective response, including the technical and economic practicability of potential solutions, level of local interest, and potential to leverage existing resources in each watershed.

CHAPTER 3

FACTORS, INDICATORS & METHODS

3.1 Factors affecting the prioritization of watershed

There are several factors which influence the prioritization process but their significance or relevance is dependent on the objectives of watershed management. For increasing crop production, soil loss, existing water resources, water quality, soil fertility are important factors. To solve the problem of siltation in reservoir, sediment yield is major factor. In land reclamations projects, present land use cover along with drainage density is the prime parameter which influences the soil erosion status. These factors are discussed in detail in section 3.1.1.

3.1.1 Soil loss or erosion intensity which further depends on

Rainfall erosivity (R factor)

Most appropriately called the erosivity index, it is estimated from the annual summation of rainfall energy in every storm (correlates with raindrop size) times its maximum 30 minute intensity.

Soil erodibility (K factor)

This factor quantifies the cohesive or bonding character of a soil and its resistance to dislodging and transport due to splash and overland flow.

Slope length (L)

Slope steepness(S)

Steeper slopes produce higher overland flow velocities. Longer slopes accumulate runoff from larger areas and also result in higher flow velocities. Thus, both result in increased erosion potential, but in a non - linear manner. For convenience L and S are frequently lumped into a single term.

Crop management and vegetation cover (C factor)

This factor is the ratio of soil loss from cropped land under specified conditions to. corresponding loss under tilled, continuous fallow conditions

Erosion control practice factor (P)

Practices like contour bunding, contour farming, strip cropping and terracing are helpful in erosion control. The use of such practices retards the runoff velocity thus less erosion of soil and more in situ soil conservation leads to high production.

The USLE equation 3.1 developed by Wischmeier and Smith (1965), has been the most widely accepted and utilized soil loss equation for over 40 years. Designed as a method to predict average annual soil loss caused by sheet and rill erosion, the USLE is often criticized for its lack of applications. While it can estimate long term annual soil loss and guide conservationists on proper cropping, management, and conservation practices. It can not be applied to a specific year or a specific storm. The average soil loss is given as:

$$A = RKLSCP \qquad ...3.1$$

Where-

A = average annual soil loss in t/a (tons per acre)

R = rainfall erosivity index

K = soil erodibility factor

LS = topographic factor - L is for slope length & S is for slope

C = cropping factor

P = conservation practice factor

3.1.2 Present land degradation status

Sub watersheds can be prioritized according to their proportion of degraded land which can be identified by remote sensing.

The degraded lands are more prone to the soil erosion and require urgent watershed management practices. Land use analysis will reveal the area under crop, forest, habitation or unused land. Watershed which has less forest and crop cover is more affected by the uncontrolled runoff. While high forest area and crop area will reduce the velocity of runoff and there will be less erosion.

3.1.3 Sediment yield

Sub watersheds are prioritized according to the sediment delivery to watercourses or reservoirs. Intervention in the highest priority sub watershed should result in maximum decline in sedimentation.

3.1.4 Extent of social awareness among the watershed community

Watershed development works are to be implemented and managed by watershed community itself, therefore willingness shown by the people in accepting the watershed program is very essential. Hence extent of social awareness among the watershed community must be considered while prioritizing the watershed.

3.1.5 Objective of implementing the watershed work

It should be known before the start of prioritization process, so that factors which affect the attainment of objectives most would be given more weightage in comparison to other factors.

3.1.6 Water quality

If the main objective of the watershed scheme is to provide good quality water for drinking and irrigation purpose Then during prioritization, watersheds which have already good quality of drinking and irrigation water will be given more preference then to the watersheds having water unfit for the drinking and irrigation. So that good quality water resources can be tapped and water can be a available to larger population.

3.1.7 Existing water resources

Watershed programme is based on the need of the community. The information of the existing water resources provides the availability of water in a watershed. The amount of availability of the water in a watershed decides the need of watershed programme.

3.1.8 Fertility of Soil

For watershed projects where the sole aim is to increase the crop production, in such situation watersheds having fertile soil will be treated first in comparison to the watersheds having low fertile soil.

3.1.9 Drainage Density

Drainage density of the watershed influences the soil erosion status. Thus considered as one of the important factor which influences the prioritization.

3.2 Prioritization Indicators

3.2.1 Sediment Yield Index

Equation 3.2 gives the empirical formula for sediment yield index:

$$Syi = \frac{Sum(Aei \times Wei) \times DR \times 100}{AW} \qquad \ldots 3.2$$

Where-

Syi= Soil yield index

Aei= Area of erosion intensity unit

Wei= Weightage of erosion intensity unit

DR= Delivery ratio

AW= Area of watershed

However this approach is primarily recommended to prioritize a watersheds under River Valley project (RVP) and Flood Prone River Projects (FPR) projects.

3.2.2 Soil Erosion Status (SES)

The SES can be calculated by using equation 3.3 as developed by Shrestha (1997):

$$SES = \frac{LEA \times 10 + MEA \times 20 + HEA \times 30}{\text{Total Area}} \qquad \ldots 3.3$$

Where-

SES= Status of the sub watershed

LEA= Low erosion area

MEA= Medium Erosion Area

HEA= High Erosion Area

Low, Medium and High erosion areas are decided as per slope gradient, drainage density, soil type and Land use cover of the sub-watersheds which has to prioritized.

3.2.3 Degradation Speed Index (DSI)

By assessing the forest and soil loss change between a time period and contribution to the soil loss change DSI can be calculated using equation 3.4 (Sah et.al, 1997):-

DSI= 0.3 x forest change (%) + 0.45 x rate of soil loss change (t/ha/yr) + 0.5 x contributions to soil loss change (%) ...3.4

The weightage of the individual factor has been decided on the basis of the importance to the land degradation.

3.2.4 Sensitivity Index (SI)

Impact of forest loss sub-watershed causes various level responses, like soil loss increase. It depends on the characteristics such as steepness of the sub-watersheds. For example forest loss in steep slope is more critical than in flat area. To assess this characteristics, land sensitivity has been proposed and SI is defined (Sah et al, 1997). The land sensitivity analysis shows that some sub-watersheds are more sensitive as slight loss of forest produced tremendous amount of soil loss.

$$SI = \frac{\text{Soil loss increment (t/ha/yr)}}{\text{Forest Loss (\%)}} \quad \ldots 3.5$$

3.2.5 Riparian Restoration Prioritization Index (RRPI)

For buffer land parcel in watershed RRPI can be calculated by using equation 3.6.

$$RRPI = (1 - (BW/(BW+8)) \times (1/(SO \times 10)) \times LUR \times DA \quad \ldots 3.6$$

Where-

BW= Width of the buffer

SO = Stream Order

LUR= Rank Land Use Total Phosphorus Loading

DA= Drainage Area

3.3 Prioritization Methods

3.3.1 Using Sediment yield index as indicator

(i) Preparation of thematic maps namely drainage, land use, geology, geomorphology and soil.

(ii) Development of composite erosion intensity mapping units (EIMU).

(iii) Prioritization

The basic methodology involves a rapid reconnaissance survey on 1:50000 scale for mapping erosion intensity units, consisting of (a) physiography and slope (b) land use/ land cover, (c) soil characteristics depth, colour, texture, (d) stoniness and rockiness, erosion hazards and (f) adopted protection measures. In this technique, catchments are divided into sub catchments, watersheds and sub watersheds. Based on the data collected on various parameters mentioned above composite erosion intensity mapping unit (CEIMU) are developed. Watershed wise area of each CEIMU is measured planimetrically. Each CEIMU is assigned weightage value in accordance with erosion intensity which is estimated from the mapping unit and relevant observations made during the field surveys. Keeping in view of drainage intensity, slope gradient, location with respect to reservoir or active stream, each CEIMU is assigned a delivery ratio, which indicates movement of detached sediments and sediment yield index is calculated using the empirical formulae. Remote sensing technique is used for the preparation of thematic maps. GIS technique can also be used for preparation of erosion intensity units.

3.3.2 Soil Erosion Status(SES)

Low, Medium and High erosion areas are defined for each parameter affecting soil erosion and SES is calculated. Table No 3.1 gives the weightage for each parameter categorically.

Table No 3. 1: SES weightage score for different parameters. (Source?)

Parameter	Categories	Relative erosion	Score for SES
Aspect	North, North-east, North-west	Low	1
	East and West	Medium	2
	South, South-east and South-west	High	3
Slope gradient	<15%	Low	1
	15-30%	Medium	2
	>30%	High	3
Drainage density	No drainage in 500 x 500 m grid	Low	1
	Drainage yes, but no 1^{st} and 2^{nd} order stream	Medium	2
	1^{st} and 2^{nd} order steams in grid	High	3
Soil types	Clay	Low	1
	Loam	Medium	2
	Sandy	High	3
Land use/cover	Forests>40% crown cover, tars, valley cultivation, rocky areas	Low	1
	Forests 10-40% crown cover, level terraces cultivation, shrub lands	Medium	2
	Forests <10% crown cover, sloping terraces cultivation, gully and land slide area, system side 100 meters	High	3

After making thematic maps the area is classified into LEA, MEA and HEA for each parameter, a final map of soil erosion status is developed for showing the erosion status of different sub watershed within the study area.

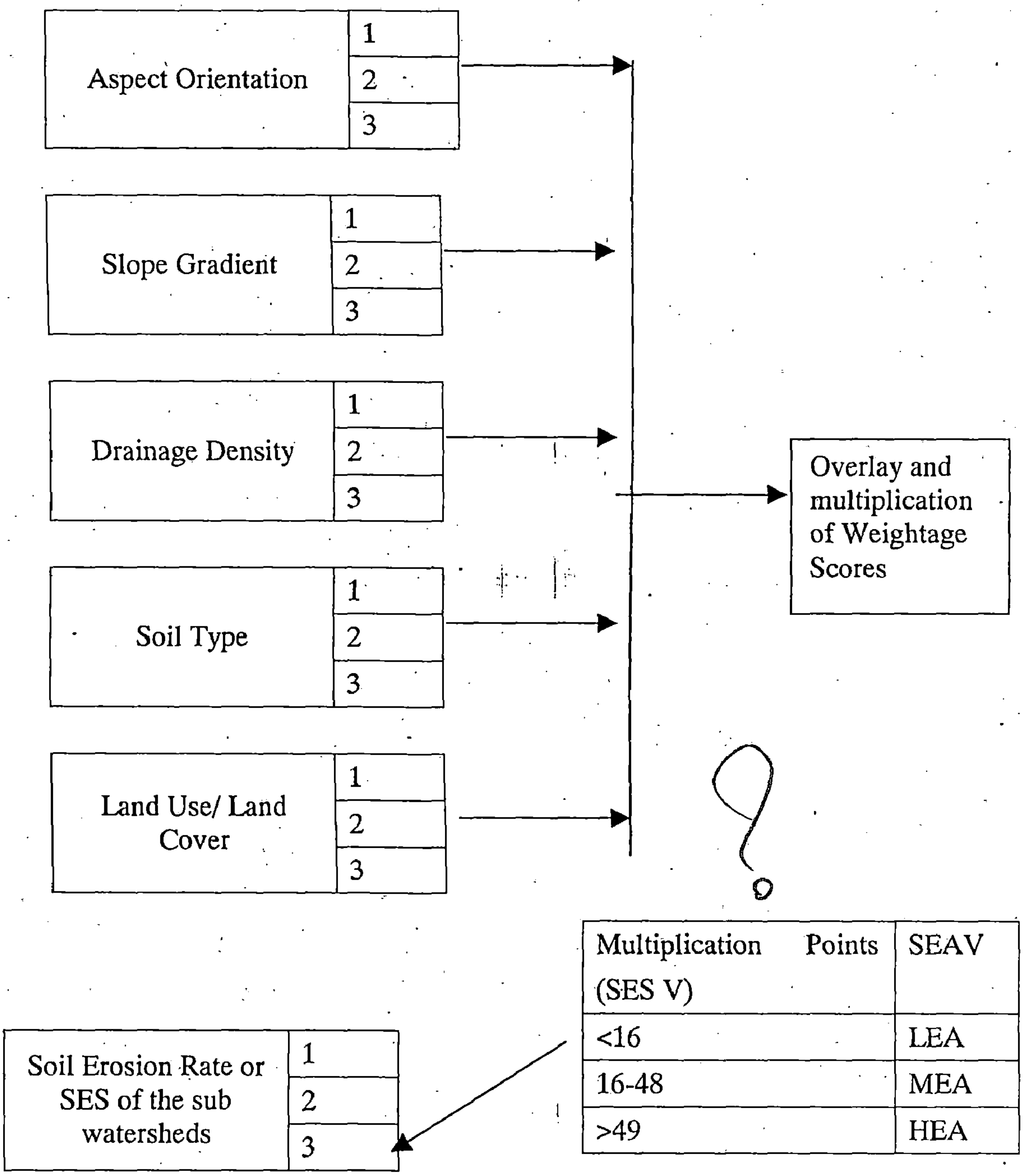

Figure 3.1: Flow chart for generating soil erosion status map

3.3.3 Degradation Speed Index(DSI), Land Sensitivity (SI) and Present condition (PC)

Watersheds are prioritized by considering their degradation condition and land sensitivity. Here land sensitivity is defined as the locational relationship between forest loss and soil loss. USLE in conjunction with remote rensing and GIS has been utilized for estimating soil loss and land cover change. Remote sensing is very useful in assessing the land cover of an area at a particular time and monitoring the change over a given period

The DSI, SI and PC were taken as the condition and used for the prioritization analysis by simple matrix method. From the qualitative rating, the two-dimensional overlay matrix has been created by taking two indicators at a time. The group has been decided on the basis of the logical combination of the indicators. For example, the combination of high DSI and SI were grouped as first priority group.

3.3.4 Riparian Restoration Prioritization Index (RRPI)

This method is useful in United States where a riparian or upstream area or reservoir has to be restored.

Stream order is considered due to its importance to water quality. Stream order was determined by visual inspection of USGS 7.5 minute quadrangle maps. The degradation of stream banks or leaching of pollutants from overland runoff within first order drainages is assumed to be more important to water quality than similar processes occurring along a fourth order stream. Therefore, first order streams were given higher sub index scores than higher order streams. The value of each stream order used in the RRPI is as follows:

First Order = 10.00,

Second Order = 5.00,

Third Order = 3.33 &

Fourth Order = 2.50

The land use ranking is based on total phosphorus loading rates of different land uses. The land use was chosen based on the dominant land use in the drainage area.

These loading rates are chosen from unit area phosphorus loadings summarized by Reckhow et al, (1980). Not in reference list

The ranking are as follows:

Rank	Land Use	Total Phosphorus Loading (Kg/ha/year)
1.	Low-Density Residential	0.19
2.	Pasture	0.25
3.	Industrial	0.75
4.	High-Density Residential	0.83
5.	Commercial	1.18
6.	Crops	2.24

Drainage area is determined by delineating the drainage areas from a USGS topographic map in ArcView. The area of each drainage unit is calculated using MILA Utilities in ArcView. The area was then converted to square miles for the index. This variable is combined in the index with land use rank. This is intended to be a measure of the pollutant load reaching the stream.

Buffer width is a critical factor in determining the need for restoration at each parcel due to the pollutant removal potential of riparian buffers. Wider buffers provide more sediment and nutrient removal capability than narrow buffers, but the marginal value of a buffer decreases with increasing buffer width.

3.3.5 Multi Criterion Evaluation of Parameters :

Statistical multi criteria analysis or decision making based multi criteria can be used for prioritization. Various criterions which can be used for this purpose may be listed as follows:

1. Watershed should meet the minimum criteria of a scheme under which it is to be implemented.

2. Objective of implementing the watershed work.

3. By erosion intensity

4. By sediment yield

5. By present land degradation status.

6. Social awareness shown by the watershed committee.

7. Water Quality

8. Soil Fertility

If a watershed is to be executed under particular scheme, it should first and foremost should fulfill the minimum criterion of selection. For example, National Watershed Program for Rainfed Area (NWDPRA) does not give priority for a area having 30%, irrigation.

If the watershed work is to be implemented for preventing the land degradation, then certainly more weightage is to be given to parameters like present land degradation status, present erosion intensity, fertility of soil etc.

In Western countries, mostly the objective of prioritization of watersheds is for acquiring land parcels and treat that part so that there is reduction in sediment/ pollutant that is affecting the water supply. Hence by prioritization only that part of land of watershed is treated which is affecting the water quality most in form of sediment yield.

Based on the objective of the watershed program each of given parameters are arranged in decreasing order and weightage is given keeping in view of their relevance with respect to objective:-

- Erosion intensity
- Sediment yield
- Present land degradation status.
- Social awareness shown by the watershed committee.
- Water Quality
- Soil Fertility

All the assigned ranks are combined and desired prioritization index is derived.

CHAPTER 4

STUDY AREA

4.1 Study area

Tendukhera tehsil of Damoh district of Madhya Pradesh was considered for this study, the district is located in the northern part of the Madya Pradesh between 23^0 9' and 24^o 27' N and 79^0 3' and 79^o 57' E extending over an area of 7306 km^2. The digitized map of study area is shown in Figure 4.1.The over all profile of the district Damoh is summarized in Table 4.1

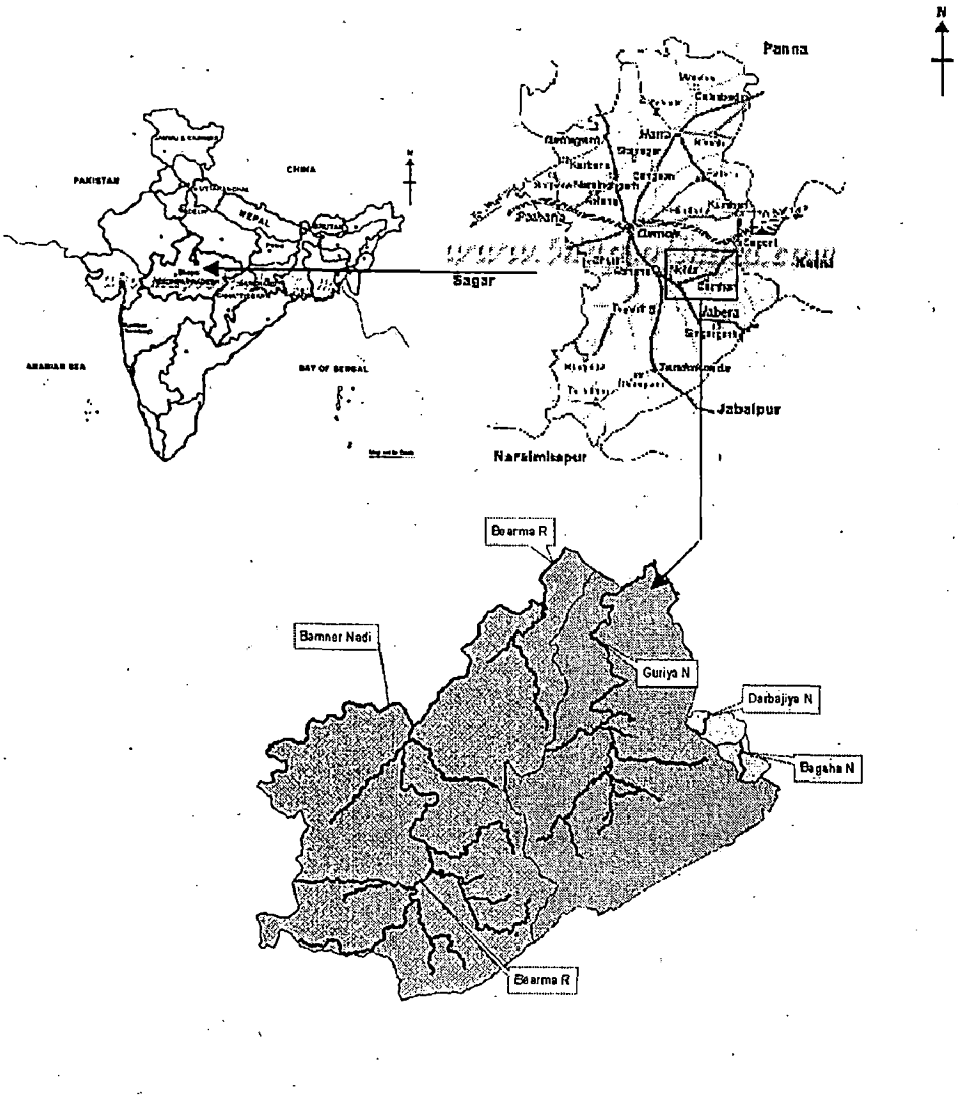

Figure 4.1: Study area

4.2 Brief of Study Area

Block Tendukhera is 55 Km from head quarter district Damoh and located on Damoh Jabalpur state highway. The total geographical area is 163005 Ha, out of which agriculturable land is 29610 Ha. The area wise detail is given in Table No 5.2.

As per 1991 census, the total population of this block is 99447. Out of which Scheduled Class population is 13035 and Scheduled Tribe is 23723.

The block is endowed with two major rivers namely Guriya and Bearma and other small forest and hilly drains which is shown in Figure 4.1.

The major land use is dominated by forest. The water availability for agricultural operations is up to January. The agricultural practices have to bear this constraint of availability. The ground water level is also declining due to absence of water bearing strata in internal geological formations. This leads to unfavorable impact on agriculture and ecosystem

The study area is divided in to 4 macros:

(i) Bearma watershed- 7 milli watersheds which is further divided into 25 sub watersheds as shown in Figure 4.2 to Figure 4.8.

(ii) Guriya watershed-7 milli watersheds which contain 18 sub watersheds which is shown in Figure 4.9 to Figure 4.15

(iii) Darbajiya watershed- 1 milli and 1 sub watershed and

(iv) Bagaha watershed- 1 milli and 1 sub watershed. (Figure 4.16)

All it sums to 45 sub watersheds which are to be prioritized. The area wise details of all sub watersheds is sown in Table No 4.3 to Table No 4.10

Table No 4.1: Profile of District Damoh (Source?)

Area	7306 Km^2	Forest Villages	0
Geographic-Location	23-09-0 N 79-03-0 E	Towns (Urban)	5
<u>Roads</u>		Revenue Sub Divisions	3
State Highway	SH-37(183 Km)	Tehsils	7
Tar Road	1437 Km	Sub Tehsils	0
Other Road	1112 Km	Zila Panchayat	1
<u>Electrification</u>		Janpad Panchayat	7
Electrified Villages	1110	Gram Panchayat	456
Non Electrified Villages	274	Assembly Segments	4
ICDS Centres	7	Post Offices	1
Anganwadi Centres	756	Branch Post Offices	29
Ration Shops	431	Police Stations	17
Urban	46	Police Out posts	
Rural	385	Govt.Degree Colleges	6
Villages	1384	Govt. Higher Sec. Schools	48
Habitiated Villages	1193	Govt. Middle Schools	260
Unhabitiated Villages	191	Govt. Primary Schools	1267
		Central Schools	1

Table No 4.2: Area wise abstract of the Bearma ,Guriya ,Bagaga & Darbajiya drains

SN	Milli watershed	No of sub water sheds	Area (Ha)	No of villages	Village Area (Ha)	Agricultural land (Ha)	Irrigated land	Village Population
1.	Chandana (Bearma)	4	15298	13	4550.17	2267.98	705.69	7199
2	Jamun (Bearma & Guriya)	6	23786	13	10231.2	3250.6	2830.88	11095
3	Narguan (Guriya)	4	18130	11	8282.97	2763.33	107.48	6948
4	Padtho (Guriya, Darbajiya & Bagaha)	6	13579	23	9368.99	3797.11	478.63	8866
5	Tejgarh (Bearma & Guriya)	8	24399	28	10291.5	5860.47	2254.54	23156
6	Beragarh	5	16511	25	1850.93	5845.01	1362.09	17758
7	Sahri (Bearma & Guriya)	5	19955	20	6374.58	4159.7	1905.57	12120
8	Sarra (Bearma)	7	31347	27	8026.87	4247.13	1834.84	12305
	Total	45	163005	160	58977.2	29610	11372.24	99447

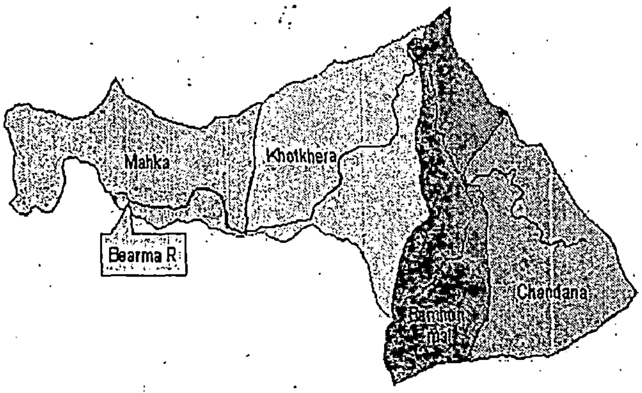

Figure 4.2: Milli watershed Chandana

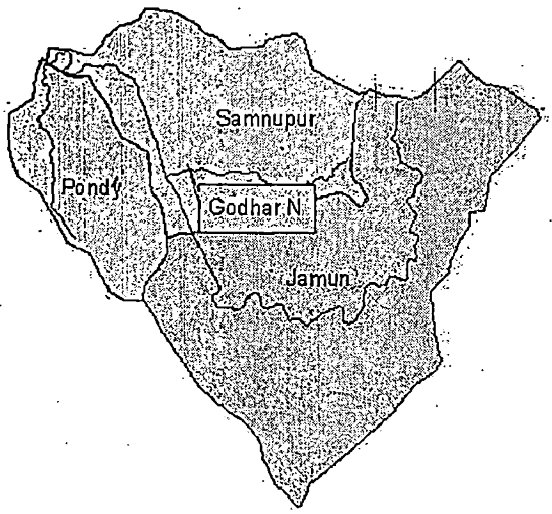

Figure 4.3: Milli watershed Jamun bearma 1

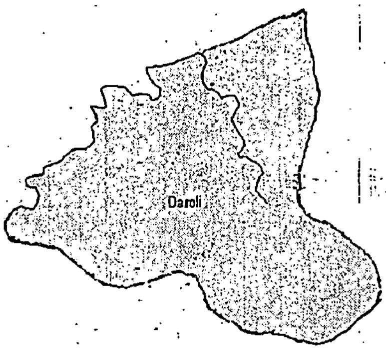

Figure 4.4: Milli watershed Jamun bearma 2

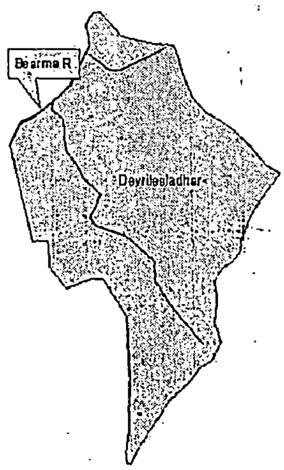

Figure 4.5: Milli watershed Tejgarh bearma

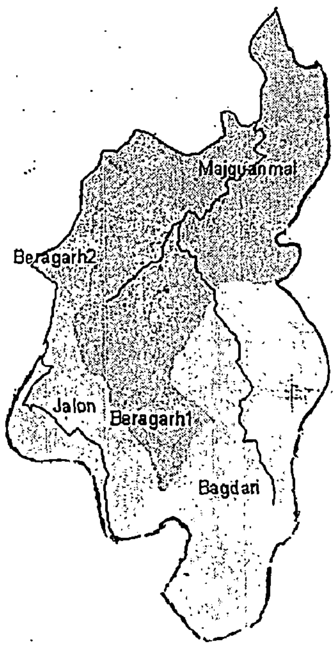

Figure 4.6: Milli watershed Beragarh

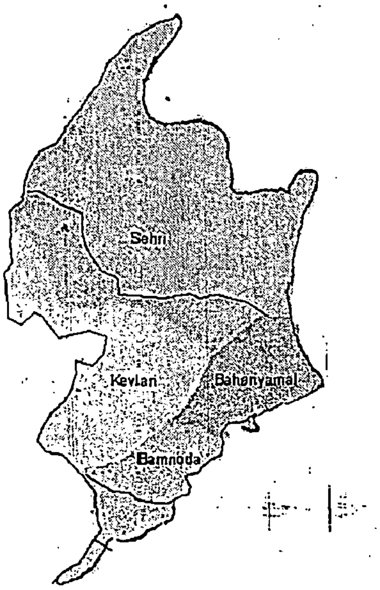

Figure 4.7: Milli watershed Sehri bearma

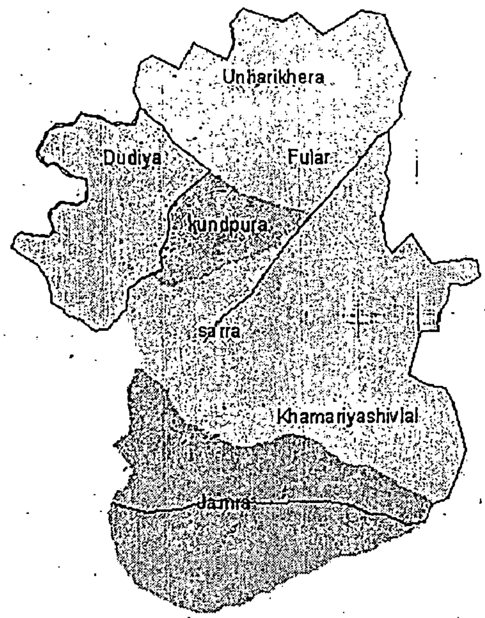

Figure 4.8: Milli watershed Sarra

Figure 4.9: Milli watershed Jamun guriya

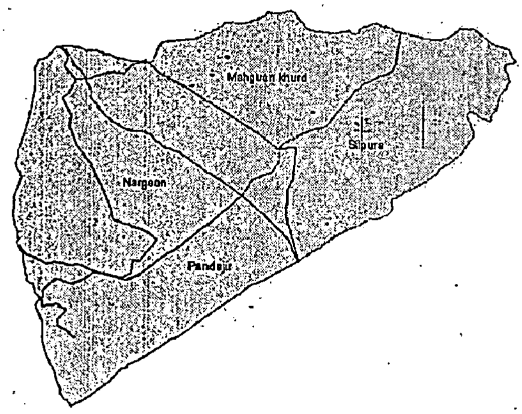

Figure 4.10: Milli watershed Nargaon

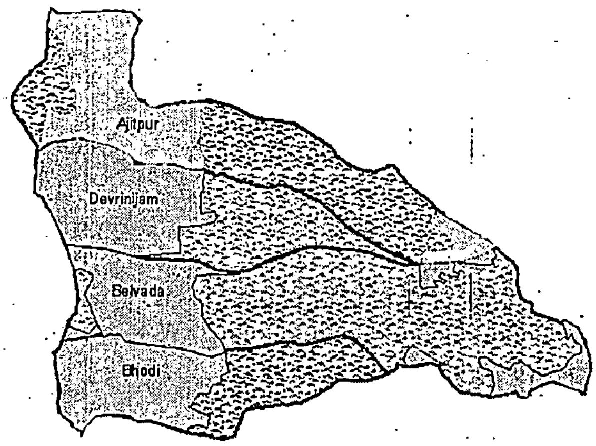

Figure 4.11: Milli watershed Pathado gur

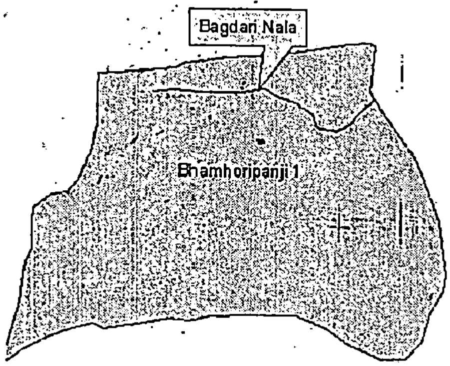

Figure 4.12: Milli watershed Tej guriya 1

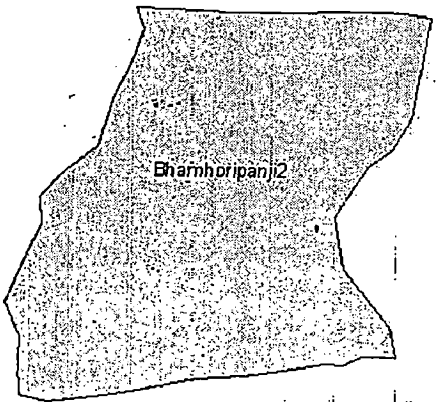

Figure 4.13: Milli watershed Tej guriya 2

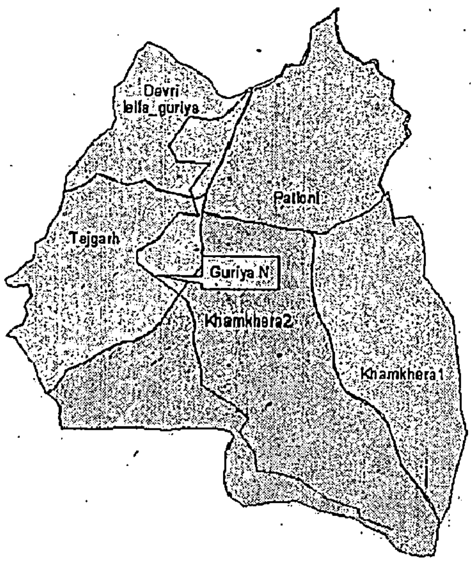

Figure 4.14: Milli watershed Tejgarh guriya 3

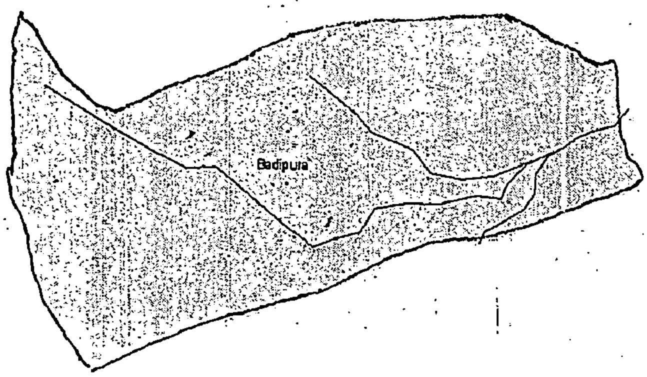

Figure 4.15: Milli watershed Sehri guriya 2

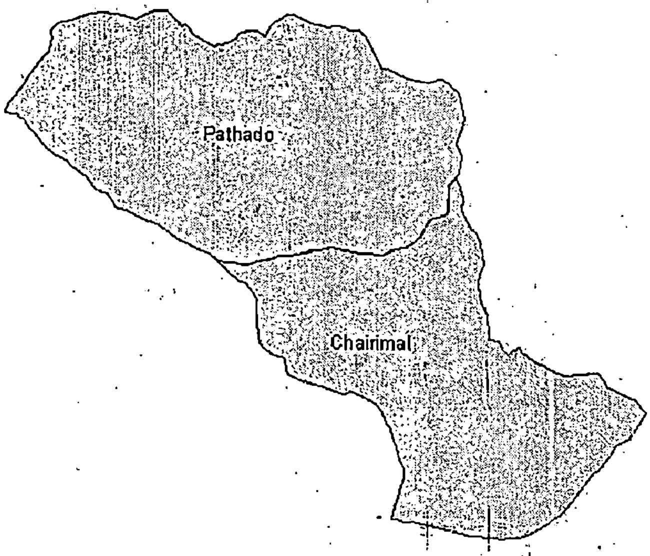

Figure 4.16: Milli watershed Patado darbajiya and Pathado bagaha

Table No 4.3: Area wise abstract of the Chanadana (Bearma drain)

S.No	Mili watershed	Name of sub watersheds	Area (Ha)	No of villages
1	Cahandana	Chandana	3588	3
		Bamhori mall	3676	5
		Kotkhera	4532	4
		Maheka	3502	2
		Total	15298	13

Table No 4.4: Area wise abstract of the Jamun (Beama & Guriya drain)

S.No	Mili watershed	Name of sub watershed	Area (Ha)	No of villages
1	Jamun bearma 1	Pondy	1514	3
		Samnapur	2918	1
		Jamun	5602	2
2	Jamun bearma 2	Daroli	3684	1
3	Jamun Guriya	Imlidol	2788	1
		Khakariya Kalla	7280	5
		Total	23786	13

Table No 4.5: Area wise abstract of the Narguan (Guriya drain)

S.No	Mili watershed	Name of sub watershed	Area (Ha)	No of villages
1	Narguan	Narguan	4624	2
		Panda Jir	3769	1
		Silpura	4638	3
		Mahguan Khurd	5099	5
		Total	**18130**	**11**

Table No 4.6: Area wise abstract of the Pathado

(Guriya ,Darbajiya & Bagaha drain)

S.No	Mili watershed	Name of sub watershed	Area (Ha)	No of villages
1	Pathodo_gur	Bhodi	1680.	2
		Bel Vada4/2	3773	6
		Devri Nizam 4/3	2049	5
		Ajitpur 4/4	2740	5
2	Pathodo_Darbajiya	Pathado 4/5	1857	2
3	Pathodo_Bagaha	Chatrimaal 4/6	1480	3
		Total	13579	**23**

Table No 4.7: Area wise abstract of the Tejgarh (Bearma & Guriya drain)

S.No	Mili watershed	Name of sub watershed	Area (Ha)	No of villages
1	Tejgarh_gur	Bhamhori Panji 1	2702	3
		Bhamhori Panji 2	1619	2
		Devri Leeladhar_gur	1913	3
		Tejgarh	3108	4
		Patnoli	3246	9
		Kham Khera 1	3364	2
		Kham Khera 2	6802	2
2	Tejgarh_bearma	Devri Leeladhar	1645	3
		Total	24399	28

Table No 4.8: Area wise abstract of the Beragarh (Bearma drain)

S.No	Mili watershed	Name of sub watershed	Area (Ha)	No of villages
1	Beragarh	Bhagdari	5919	7
		Beragarh 1	2925	4
		Beragarh 2	713	2
		Jhalon	2270	4
		Majguan mal	4684	8
		Total	16511	25

Table No 4.9: Area wise abstract of the Sehri (Bearma & Guriya drain)

S.No	Mili watershed	Name of sub watershed	Area (Ha)	No of villages
1	Sehri_gur	Badipura	4072	4
	Sehri_bearma	Baheriyamal	1735	2
		Bamnoda	1778	3
		Kevlari	3551	3
		Sehri	8819	8
		Total	**19955**	**20**

Table No 4.10: Area wise abstract of the Sarra (Bearma drain)

S.No	Mili Catch-ment	Name of sub watershed	Area (Ha)	No of villages
1	Sarra	Unharikhera	3956	2
		Dudiya	4129	2
		Kundpura	1699	4
		Sarra	3801	4
		Fular	3403	5
		Khamariya shivlal	6722	7
		Jamra	7637	3
		Total	31347	**27**

CHAPTER 5

METHODOLOGY

5.1 Approach

After reviewing various methods of prioritization critically, multi criterion evaluation technique was used.

The following factors depending on their influence on watershed were used in analysis:

1. Slope of the watershed
2. Drainage Density
3. Stream order
4. Aspect
5. Land use and land cover
6. Soil
7. Socioeconomic factor
8. Water availability

First six factors are significant which take care of susceptibility of the watershed towards soil erosion. With the use of GIS the individual watershed can be classified under severe, normal or moderate categories of the soil erosion. This approach is quite useful for prioritization over the use of cumbersome USLE approach.

The SES as described in equation 3.3 has been used in the evaluation of sub watersheds.

5.2 Data acquisition

o sheets comprising the Tendukhera block of Damoh district were obtained ı Survey of India. Topo sheet no-55 M, 55M/3, 55 M/4, 55 M/6, 55 M/7, 55 , 55 M/10 and 55 M/11 at the scale of 1:50000 were utilized to generate tours and other spatial features. District planning map was used to derive the ırmation related to Tendukhera block. The demographic ans socio economic ırmation was collected from block level officers.

Spelling

. Data Types

:re are three main types of spatial data that can be utilized in watershed essment. The most common spatial data is vector data, which includes points, :s and polygons. Examples of these three types of vector data used in watershed lysis are wells, streams, and soil polygons, respectively. The second form of a in watershed analysis is raster or grid data, a series of grid cells with assigned ues, whether referring to elevation, land use or soil type. The third type of data ful in watershed analysis is image data, which is typically also is a raster type mat. An example of this data would be digital aerial photographs.

Mosaic

nosaic is a composite picture that is made by piecing together two or more aerial otographs or images to provide a continuous view of a large geographical area. osaics portray the relative planimetric positions of spatial features in pictorial m. They can be produced in less time and at a lower cost than topographic maps d have been used in wide range of application.

ing software ERDAS, different topo- sheets of the study area were mosaiced gether.

5.5 Registration of paper map

Before digitization of drainage network, contours etc , the mosaic topo sheet(In img format) need to be registered Registering map involves recording the ground coordinates for the control points identified. These are recorded using the Digitizer tab of the Editing Options dialog box (In Arc Map).

5.6 Digitization

Digitizing is the process of converting features on a paper map into digital format. To digitize a map, we use a digitizing tablet connected to our computer to trace over the features that interest us. The x,y coordinates of these features are automatically recorded and stored as spatial data.

Digitizing with a digitizing tablet offers another way, besides screen digitizing freehand, to create and edit spatial data. One can convert features from almost any paper map into digital features.

5.7 Triangulated Irregular Network (TIN)

Acquisition of terrain data is a sampling process because it is impossible to record each and every point on Earth's surface. There are two approaches to digital terrain data sampling: systematic and adaptive.

In systematic terrain data sampling, elevation points are measured at regularly spaced intervals. The result is a matrix of elevation values that is usually referred to as a digital elevation model (DEM).

When the adaptive sampling method is used, elevation measurements are made at selected points that are assumed to be representative of the terrain. The result is collection of irregularly distributed elevation values that must be properly structured before they can be used for further processing. Since the method of triangulation is used to build the spatial framework for storing the elevation values, the data collected by this approach are referred to as Triangulated Irregular Network (TIN).

In dissertation, TIN is generated from the contour file and later worked out to obtain slope of the watershed.

5.8 Topology Building

This is probably the most important process in graphical data building. As a post digitizing process, however topology building actually serves two interrelated purpose:

- Building the topologic structure and relationship for the graphical elements on a layer. The actual process of topology building is dependent on the type of graphical elements on a layer. In general, this includes the creation of point, line and polygon topology by assigning an internal identifier to each graphical element identified and the creation of attribute tables.
- Error identification and automated corrections. If digitizing errors exist in digital data file, they will be highlighted by the topology building commands.

5.9 Delineation of watersheds

Stream channels depicted in the topographical sheets were extracted to examine drainage information of the basin. For mapping the catchments and their boundary, the information on height provided through contours, spot heights and relative heights were used. The ridge line method was followed. These lines provide site information such as location of lowest elevated points, water divides and the highest elevation. In total 45 watersheds were delineated.

5.10 Analysis

The drainage and the contours of the study area were digitized and later were analyzed for evaluating the TIN of the each individual watershed and finally the slope and aspect were generated. The forest cover of the watershed was also calculated using GIS tool. The factors selected for the prioritization of watersheds were evaluated and given weightage points to finally arrive at the ratings of the individual watersheds thus identifying the most sensitive watersheds.

The topo-sheets of the study area obtained from Survey of India of the study area were utilized by GIS technique to mosaic and then watersheds were delineated. The streams as well as contours were digitized to analyze the slope, drainage density and stream order of the individual watersheds, which are to be prioritized.

5.10.1 Slope

For generation of slope of each individual watershed, the TIN is created from contour shape files in GIS software ArcMap. Then slope of the each individual watershed were generated from the TIN and shown in Figure 5.1-a to Figure 5.8-a.

Then each watershed was divided into three categories low, medium and high erosion area using the following criterion:

Slope< 10^0: LEA

Slope 10^0 to 35^0: MEA

Slope >35^0: HEA

The area of each watershed for all three categories was calculated in GIS. SES for each watershed was calculated by using equation 3.3.Each of the watersheds was ranked as per their SES value. Based on the SES values each individual sub watershed is divided in to three categories: -

SES	Category	Value
13-15	LEA	1
15-17	MEA	2
17-19	HEA	3

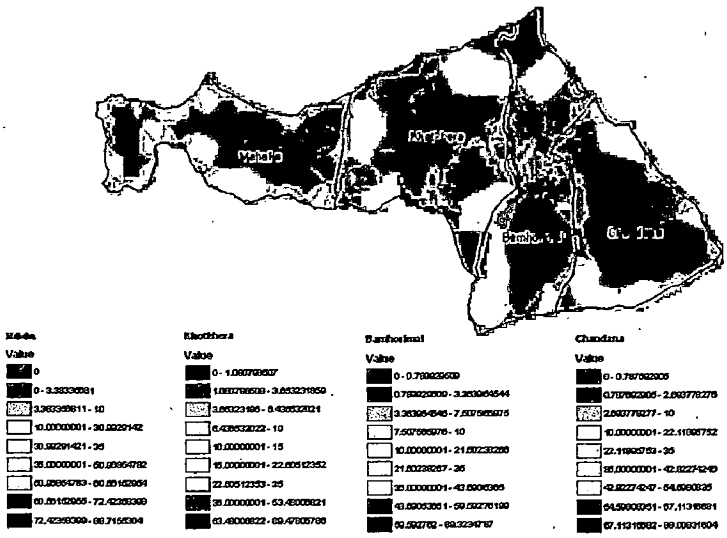

Figure 5.1-a: Slope of milli watershed Chandana

Adopt uniform range for all catchments at least for investigation

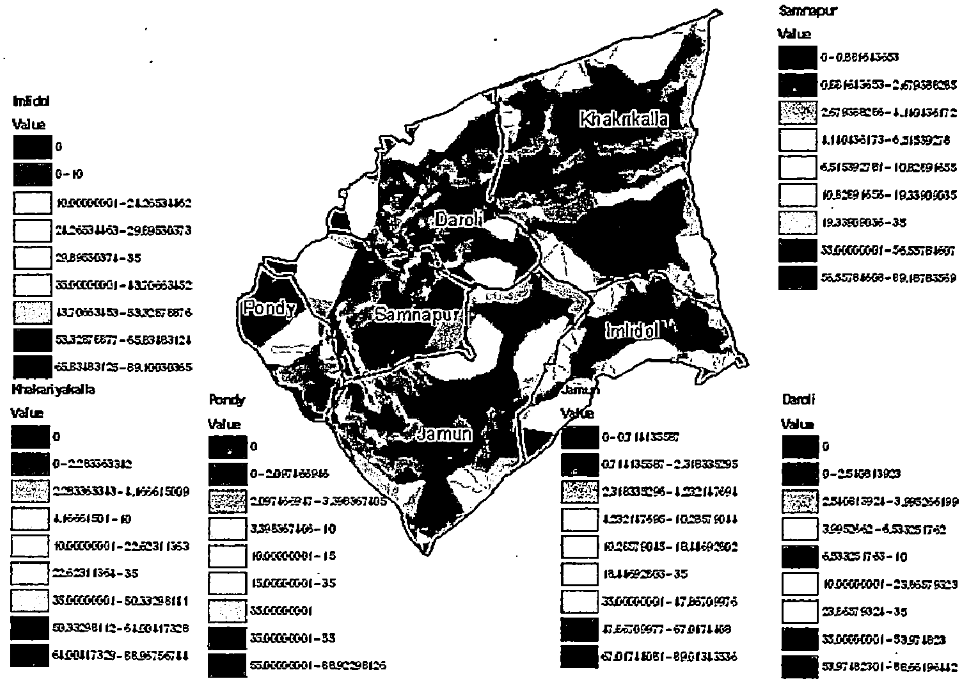

Figure 5.2-a: Slope of milli watershed Jamun bearma1,bearma2 and Jamun guriya

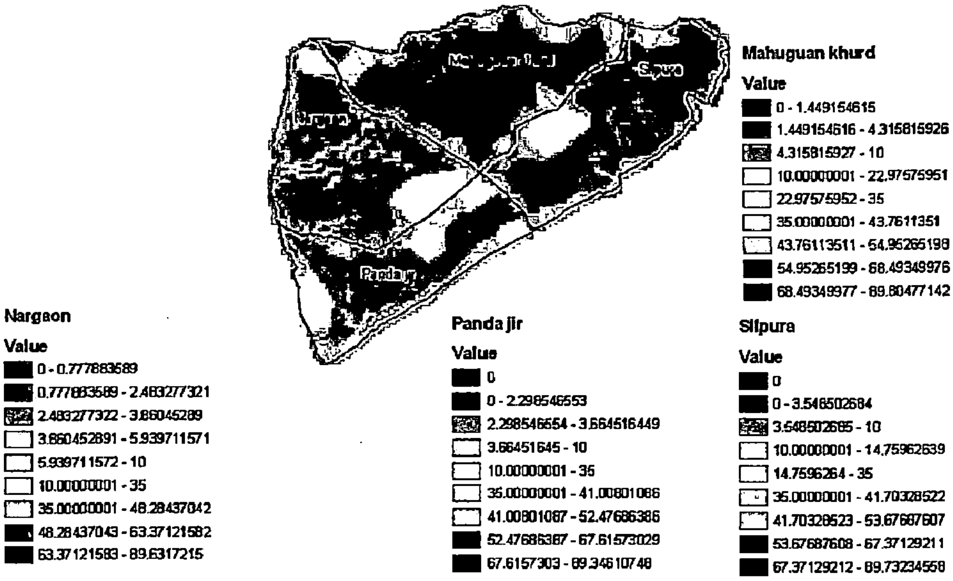

Figure 5.3-a: Slope of milli watershed Nargaon

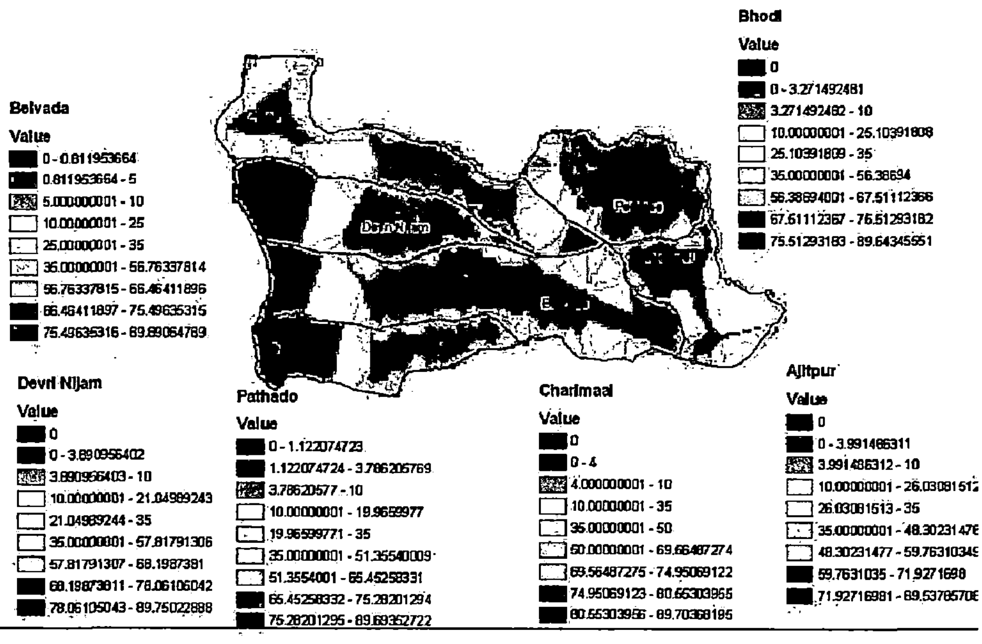

Figure 5.4-a: Slope of milli watershed Pathado

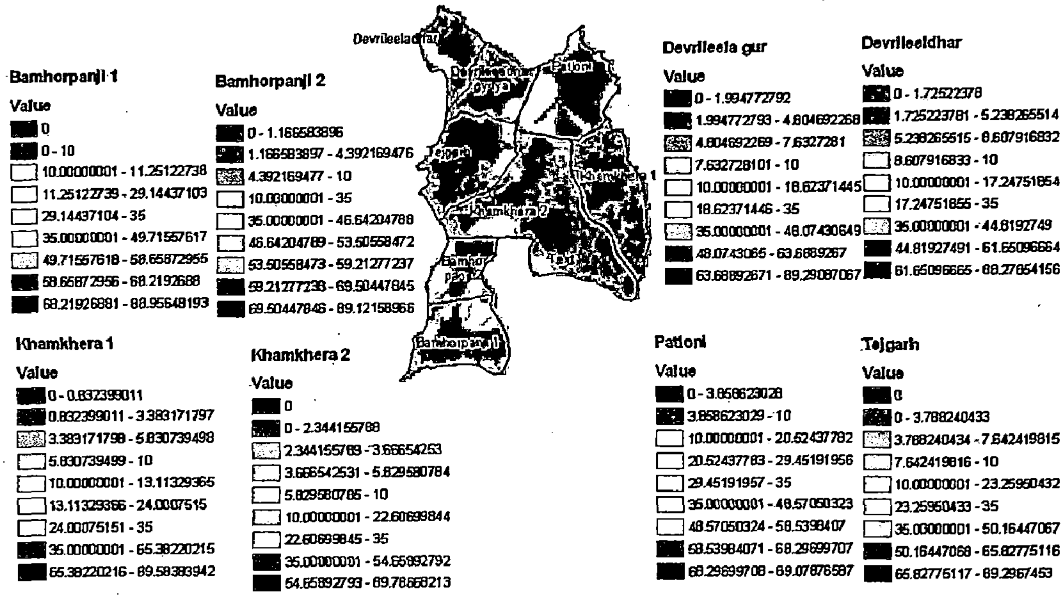

Figure 5.5-a: Slope of milli watershed Tejgarh

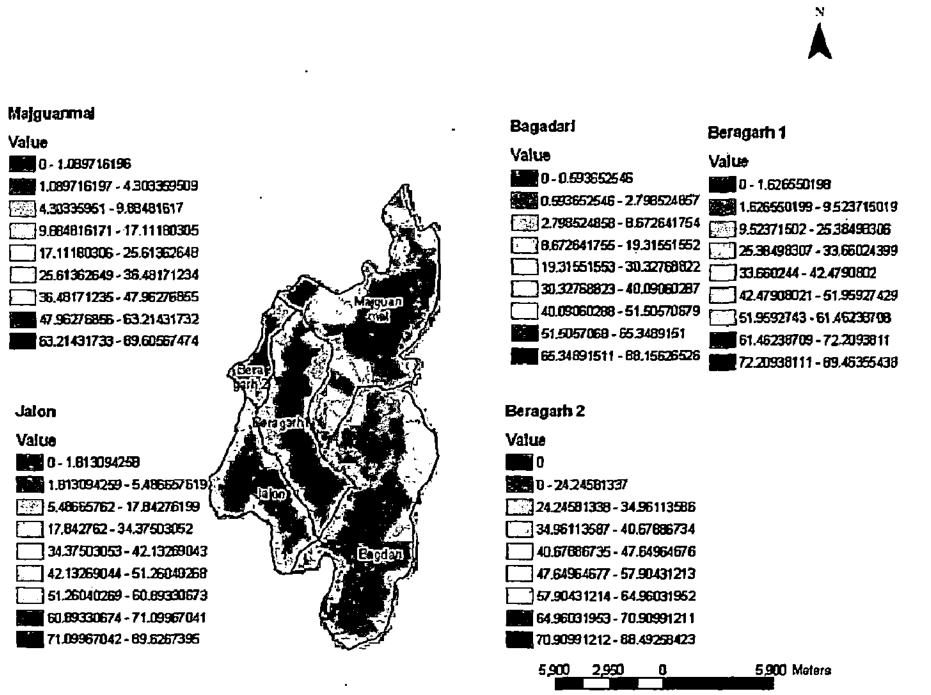

Figure 5.6-a: Slope of milli watershed Beragarh

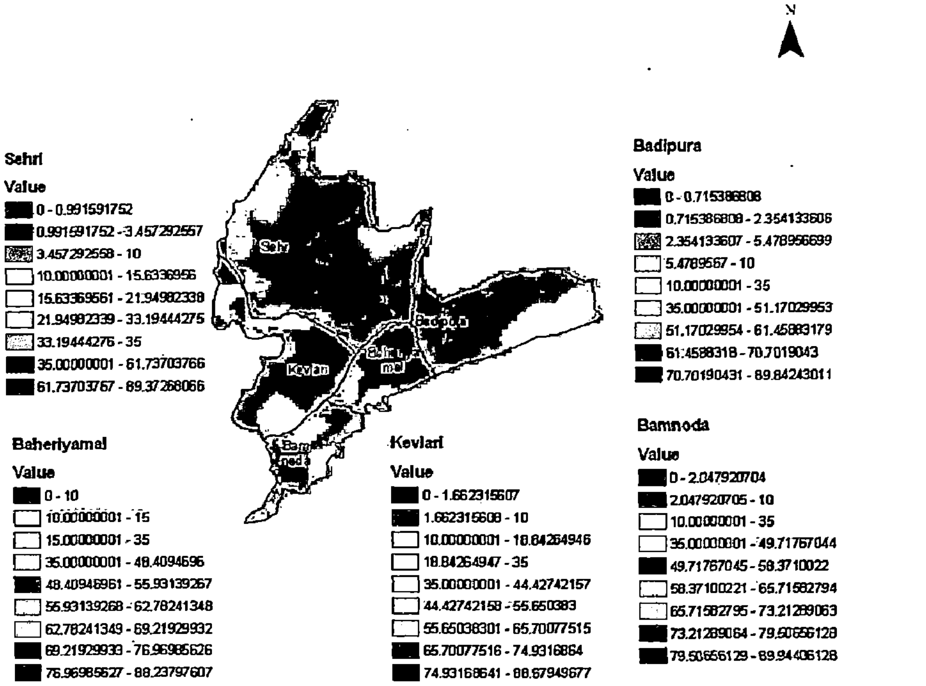

Figure 5.7-a: Slope of milli watershed Sehri

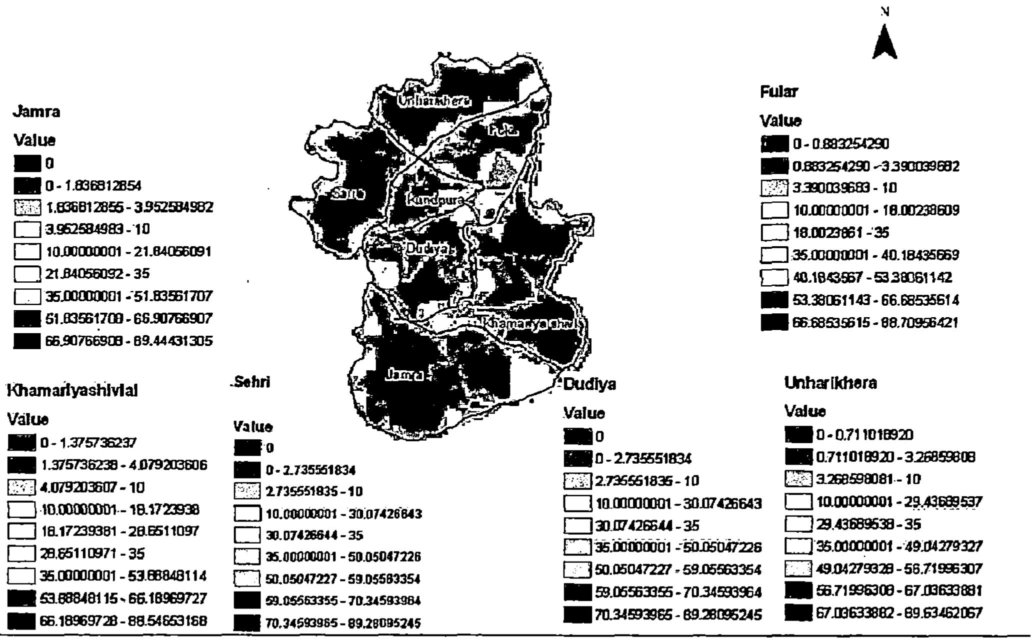

Figure 5.8-a: Slope of milli watershed Sarra

5.10.2 Drainage Density

An important indicator of the linear scale of land-form elements in stream eroded topography is drainage density D_d,

$$D_d = \frac{\text{Total length of particular order}}{\text{Catchment Area}} \quad \ldots 5.1$$

Drainage network of 45 sub watersheds are shown in Figure 5.1-b to Figure 5.8-b.

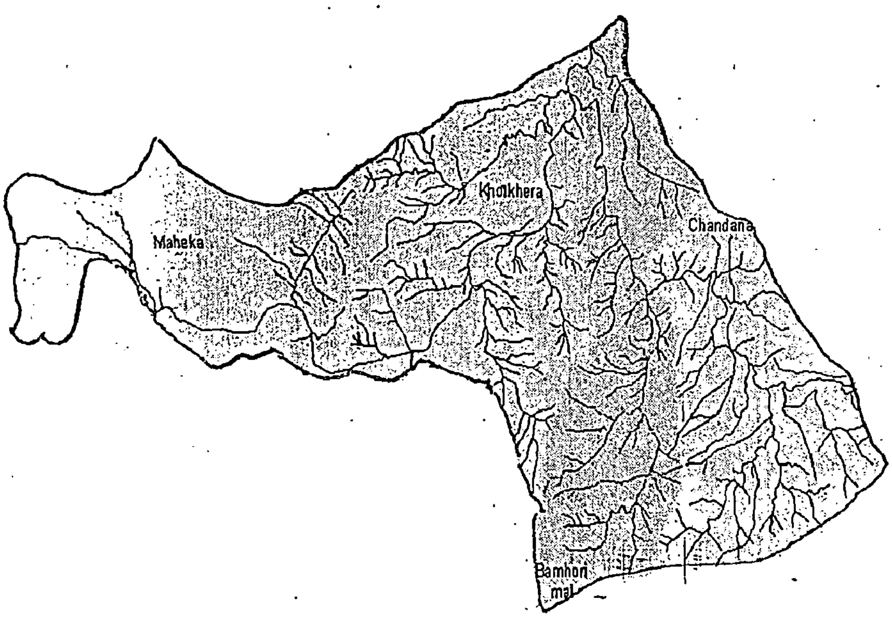

Figure 5.1-b: Drainage of milli watershed Chandana

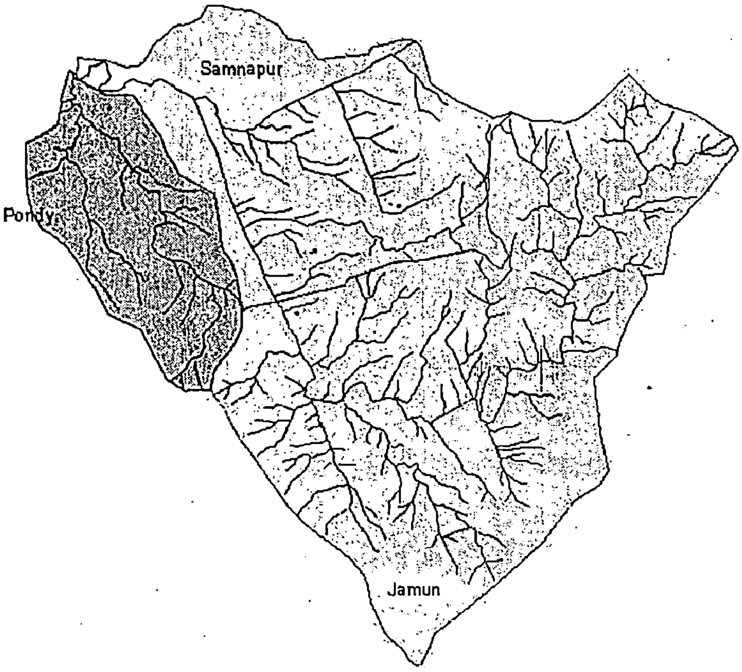

Figure 5.2-Ib: Drainage of milli watershed Jamun Bearma 1

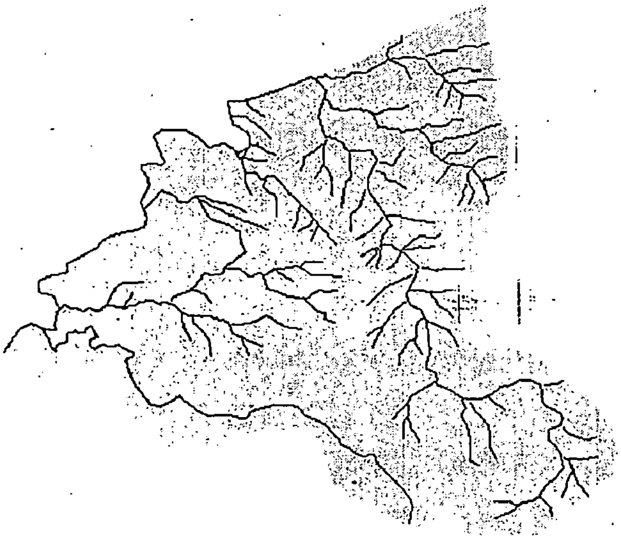

Figure 5.2-IIb: Drainage of milli watershed Jamun Bearma 2

Figure 5.2-III b: Drainage of milli watershed Jamun guriya

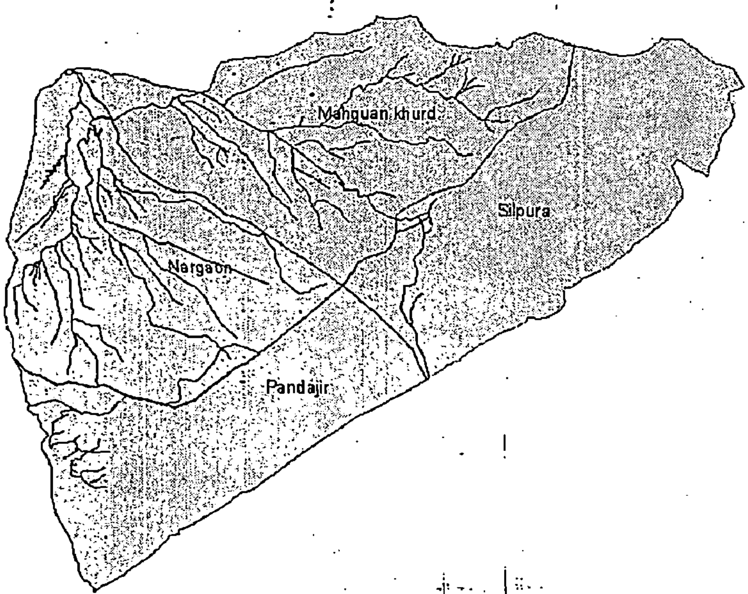

Figure 5.3-b: Drainage of milli watershed Nargaon

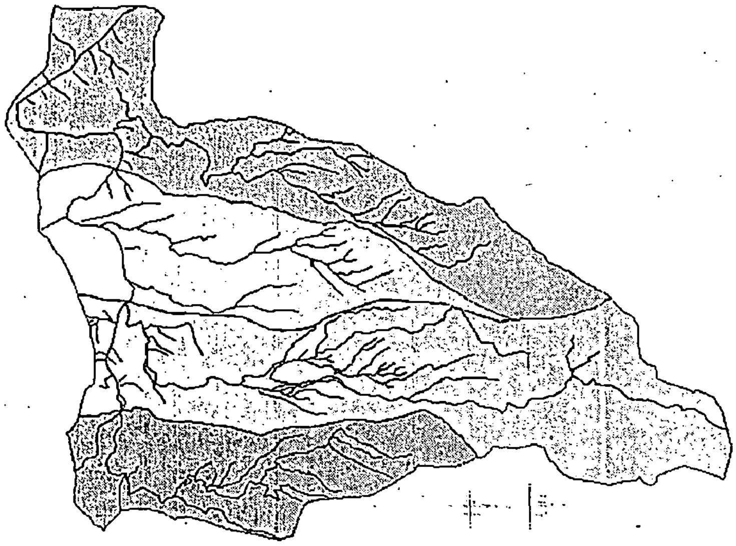

Figure 5.4-Ib: Drainage of milli watershed Pathado guriya

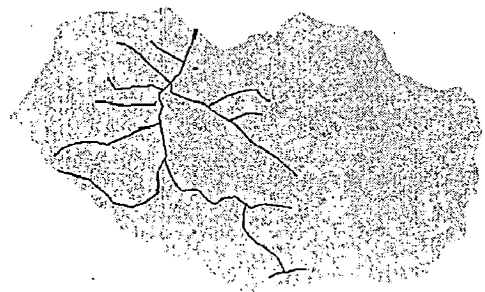

Figure 5.4-IIb: Drainage of milli watershed Pathado darbajiya

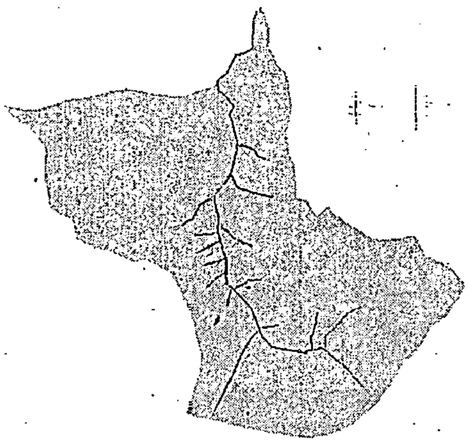

Figure 5.4-IIIb: Drainage of milli watershed Pathado bagaha

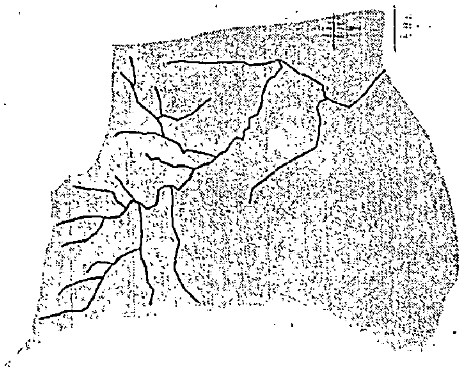

Figure 5.5-I b: Drainage of milli watershed Tejgarh guriya1

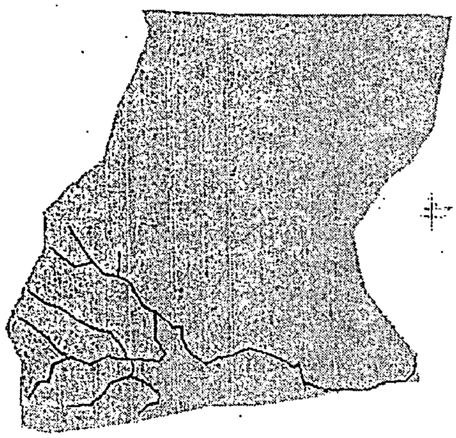

Figure 5.5 II b: Drainage of milli watershed Tejgarh guriya 2

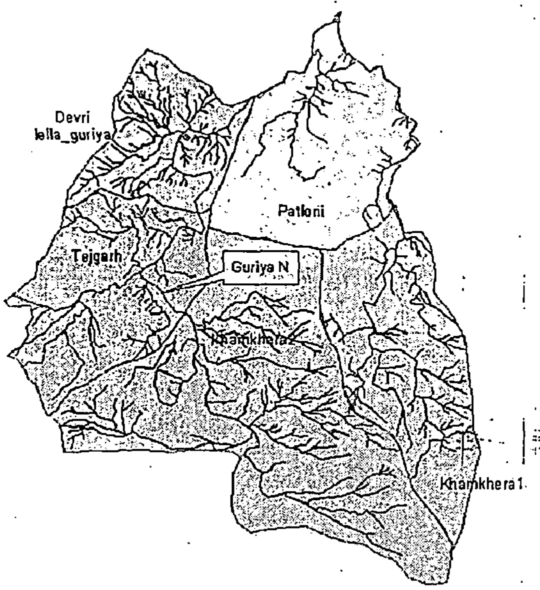

Figure 5.5 III b: Drainage of milli watershed Tejgarh guriya3

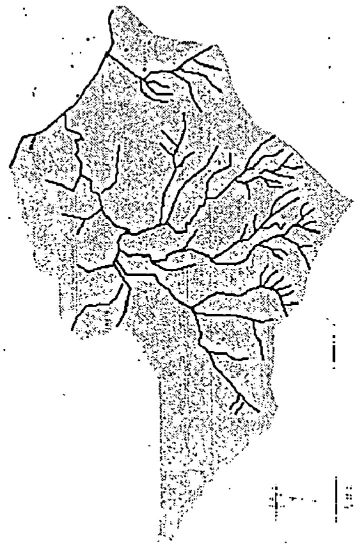

Figure 5.5 IV b: Drainage of milli watershed Tejgarh bearma

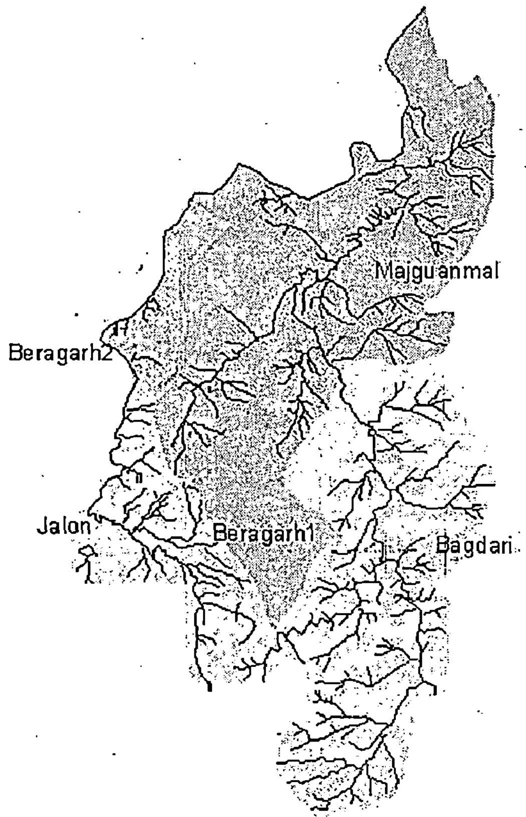

Figure 5.6 b: Drainage of milli watershed Beragarh

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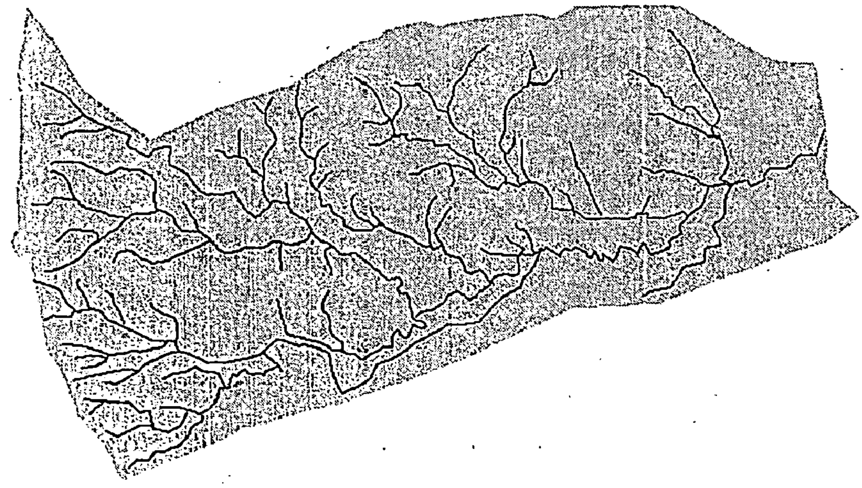

Figure 5.7 I b: Drainage of milli watershed Sehri guriya

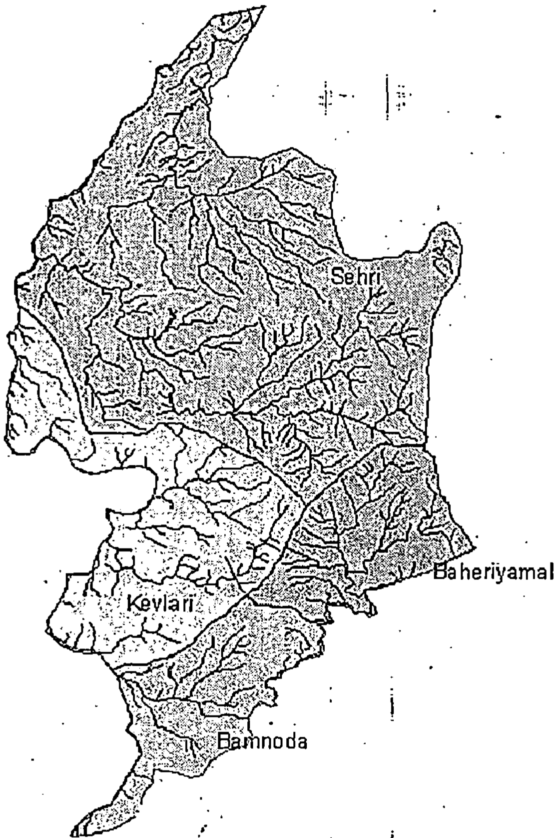

Figure 5.7-II b: Drainage of milli watershed Sehri bearma

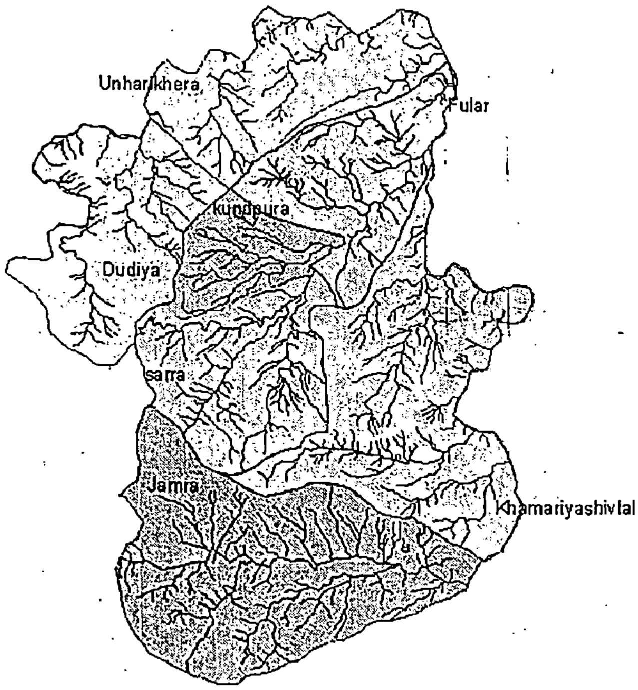

Figure 5.8- b: Drainage of milli watershed Sarra

5.10.3 Stream order

All the streams in the watershed were ordered as given by Strahler, 1957. In this method, the finger-tip tributaries (those, which originate from hilly terrain generally, are in the form of rills and gullies) were designated as order 1. The junction of two such stream segments gave rise to a higher order 2. The junction of two streams of unequal order, for example, U and V (V'U), created a downstream segment having an order equal to that of higher order tributary V. In this way, streams were ordered and designated from order 1 to 5. Morphometrically, the lower order streams are dimensionally shorter, carry less volume of water whereas higher orders (more than 3rd order) are comparatively elongated and carry more water and sediments.Values are given as per Drainage density and Stream Order of the watersheds.

Stream Order	Value
2	1
3	2
4	3
5	4

Additional ½ value (point) was given more than 0.2%.

Based on the combination of stream order and drainage density, all 45 watersheds were given values.

5.10.4 Aspect

The soil erosion is also affected by the aspect of the watershed. Hence each individual micro watershed was analyzed in ArcMap and watershed area is divided in to three categories based on the following criterion as shown in Figure 5.1-c to Figure 5.8-c

Category	Orientation	Score
LEA	North ,North East, North West	0.5
MEA	East & West	1
HEA	South, South East and South West	1.5

Figure 5.1 c: Aspect of milli watershed Chandana

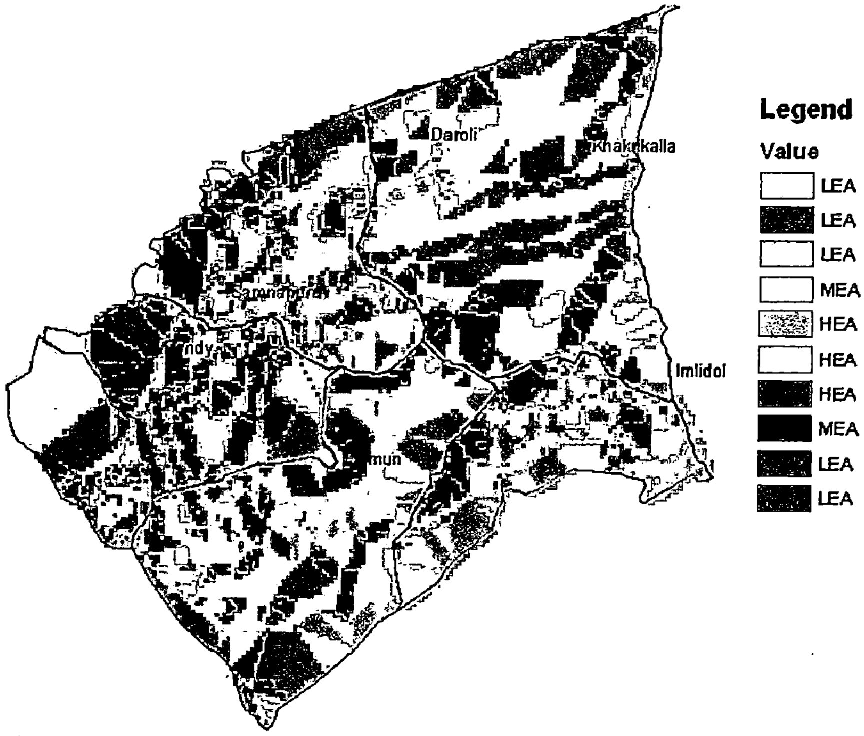

Figure 5.2 c: Aspect of milli watershed Jamunbearma1, bearma2 and Jamun guriya

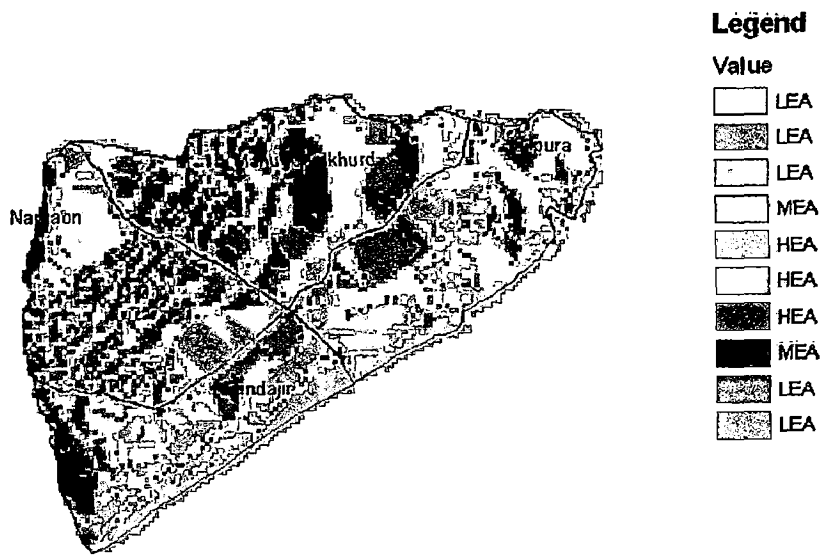

Figure 5.3 c: Aspect of milli watershed Nargaon

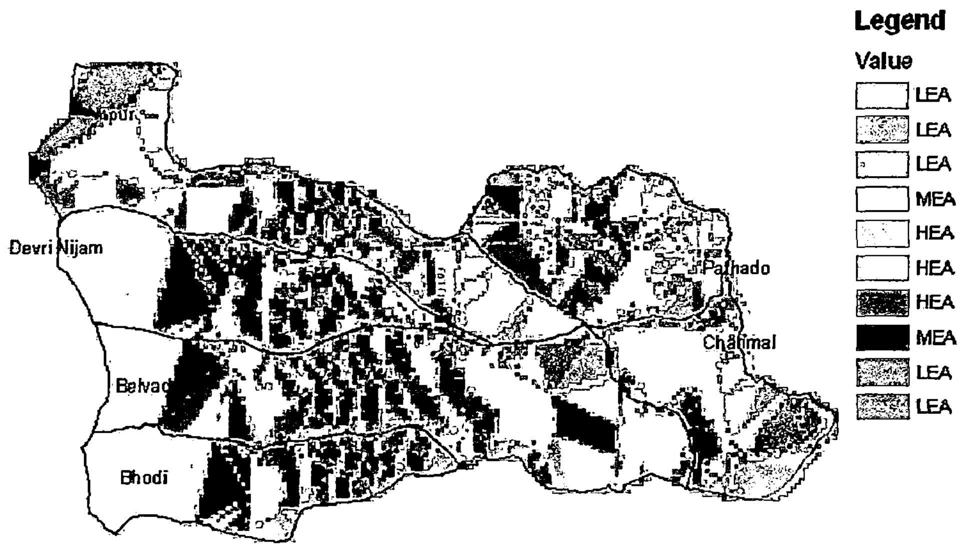

Figure 5.4 c: Aspect of milli watershed Pathado gur,darbajiya & bagaha

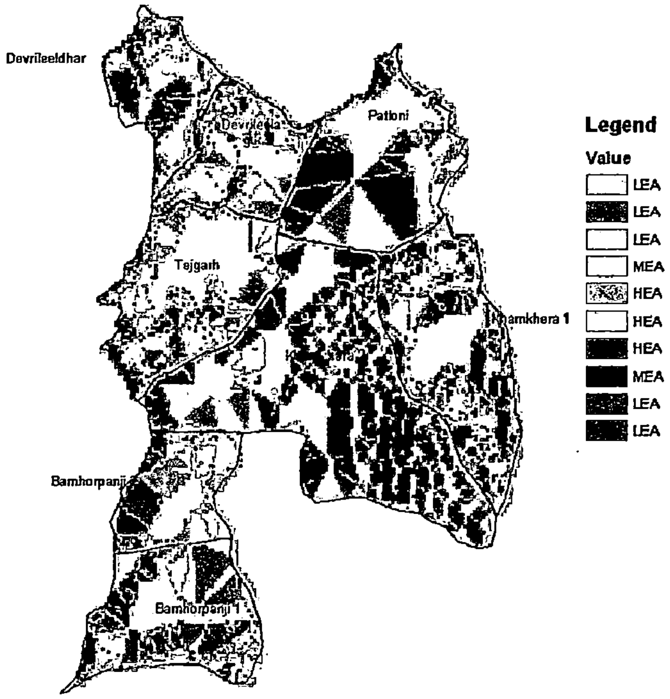

Figure 5.5 c: Aspect of milli watershed Tej gur1,gur2,gur3 and Tej bearma

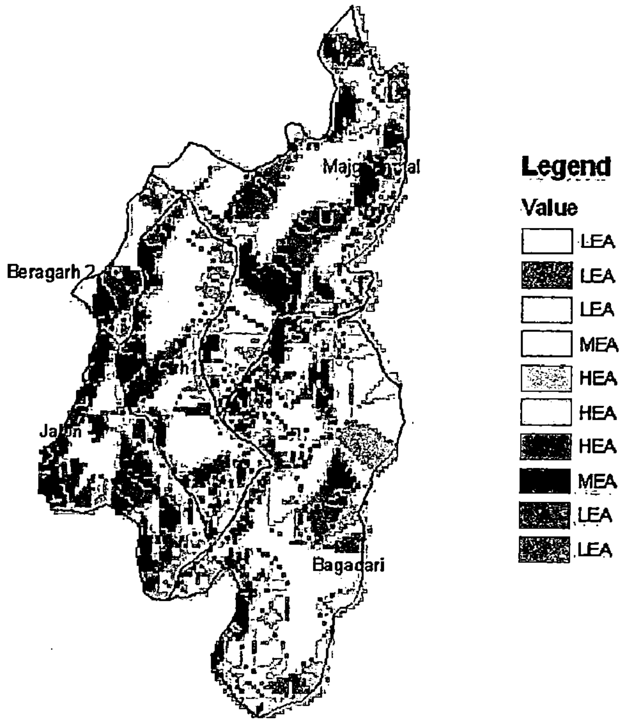

Figure 5.6 c: Aspect of milli watershed Beragarh

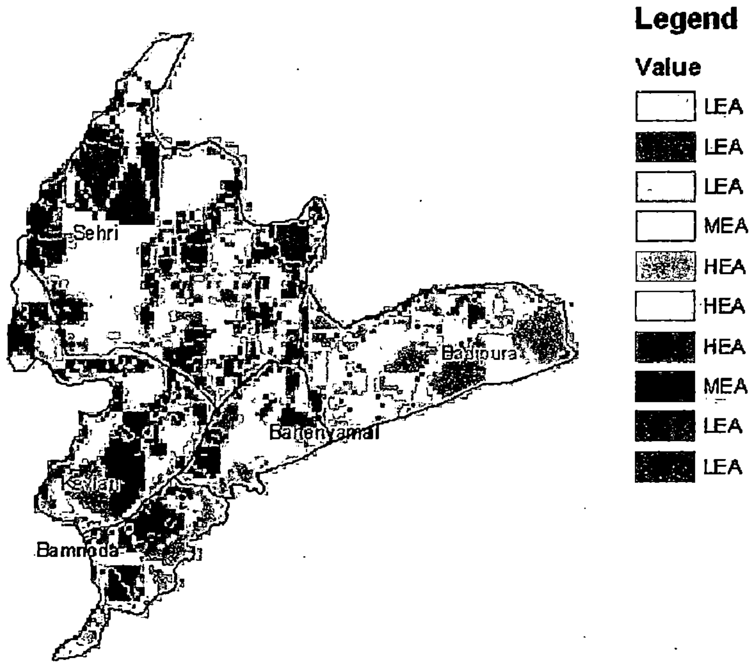

Figure 5.7 c: Aspect of milli watershed Sehri guriya and Sehri bearma

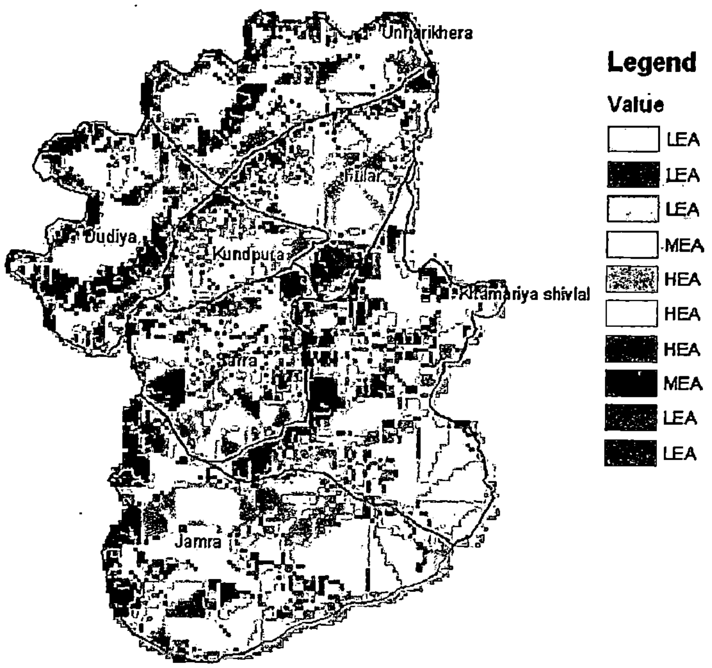

Figure 5.8 c: Aspect of milli watershed Sarra

5.10.5 Land use and land cover

Forest cover affects soil erosion status of the watershed. More the forest area lesser is soil erosion. The forest cover of each watershed is digitized and shown at Figure No 5.1-d to figure 5.8-d and forest area is calculated to allot each micro watershed values based on the following bases:

Forest Cover (%)	Value
>70	0.5
40-70	1
20-40	1.5
<10	2

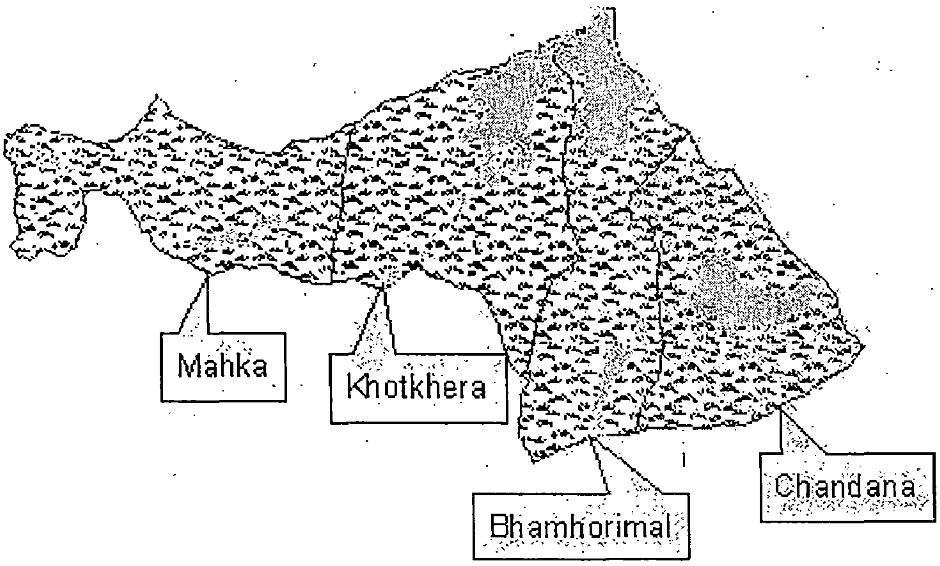

Figure 5.1-d: Forest Cover of milli watershed Chandana

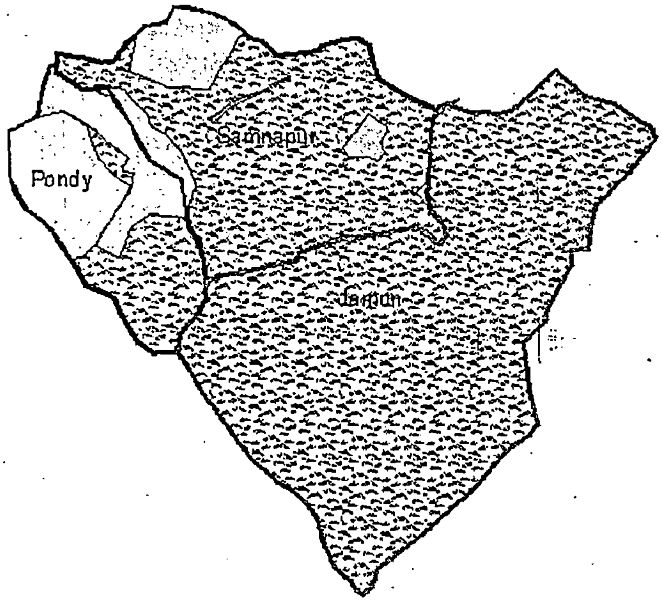

Figure 5.2-I d: Forest Cover of milli watershed Jamun bearma 1

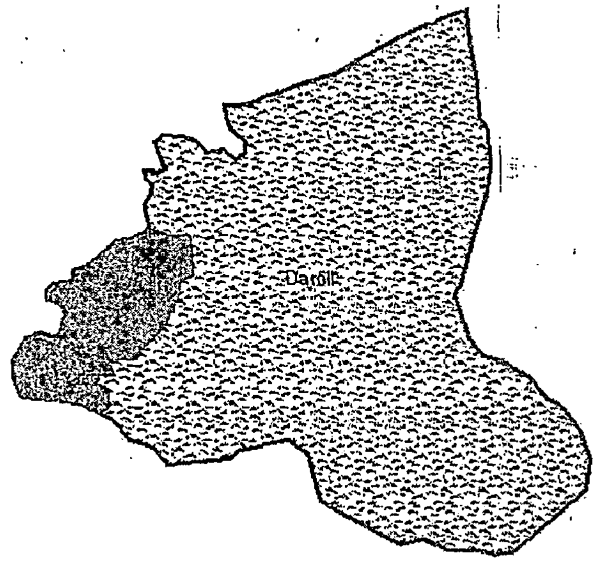

Figure 5.2-II d: Forest Cover of milli watershed Jamun bearma 2

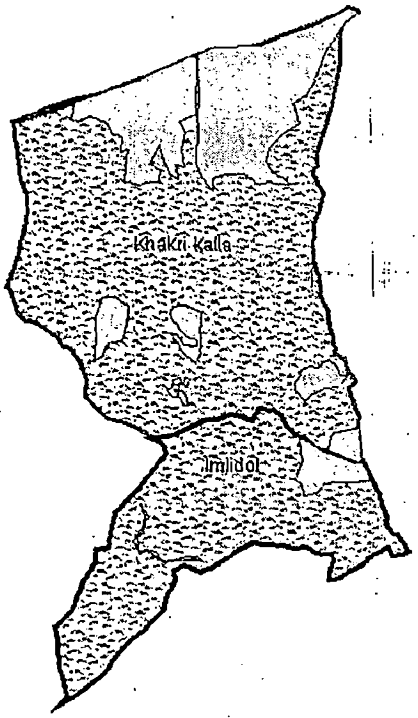

Figure 5.2-III d: Forest Cover of milli watershed Jamun guriya

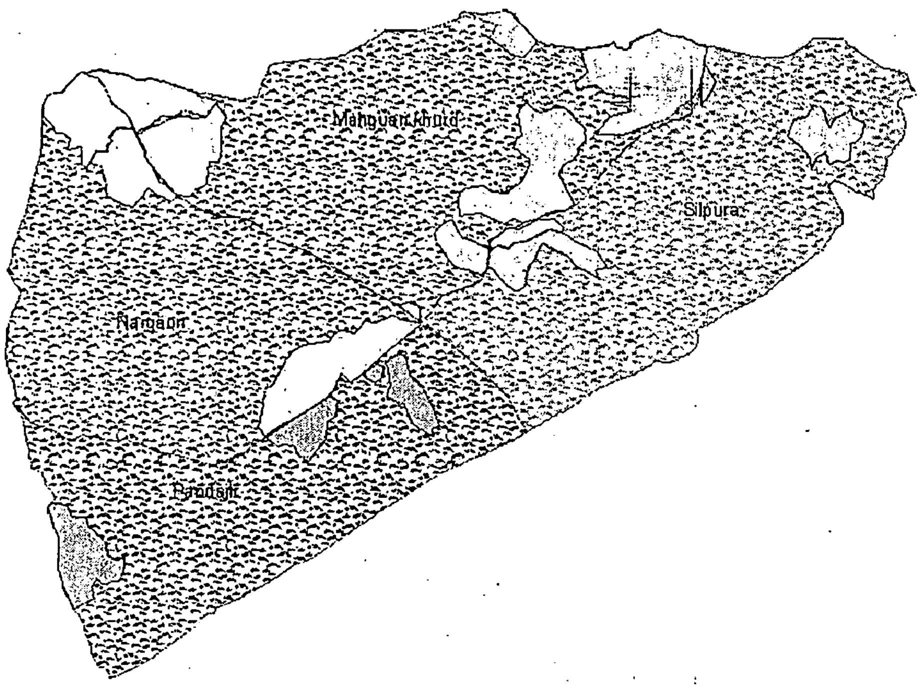

Figure 5.3- d: Forest Cover of milli watershed Nargaon

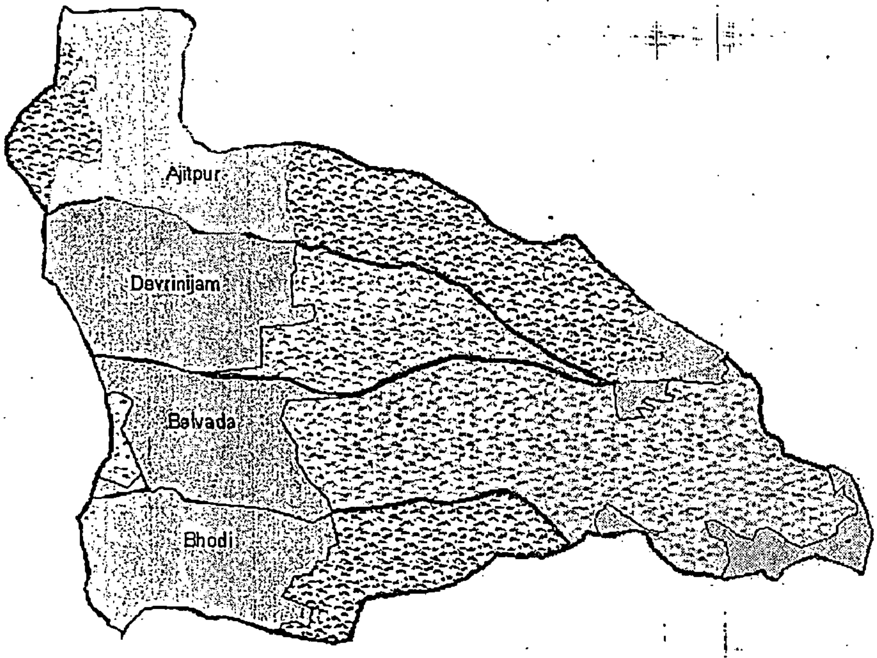

Figure 5.4- I d: Forest Cover of milli watershed Pathado guriya

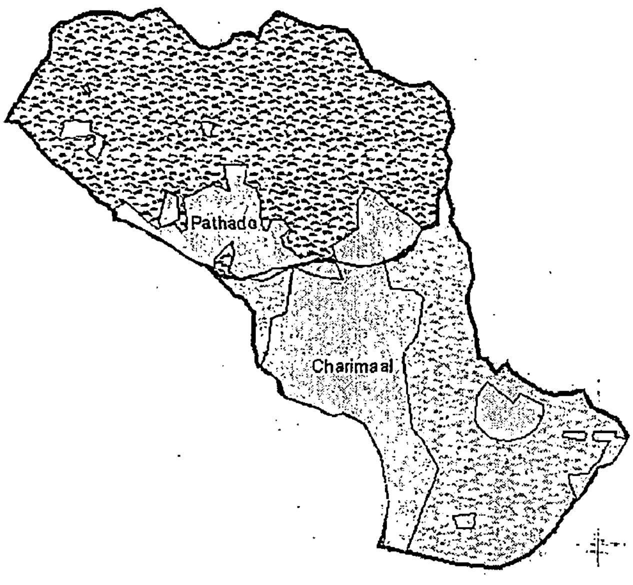

Figure 5.4- II d: Forest Cover of milli watershed Pathado bajaha and Pathado darbajiya

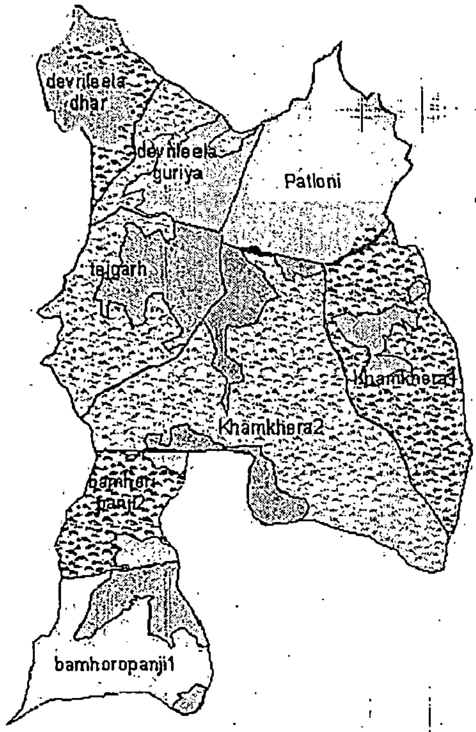

Figure 5.5- d: Forest Cover of milli watershed Tejguri,gur,gur3 & Tejbearma

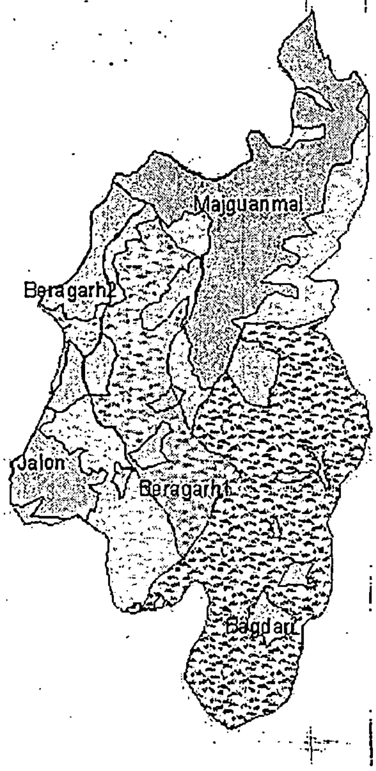

Figure 5.6-d: Forest Cover of milli watershed Beragarh

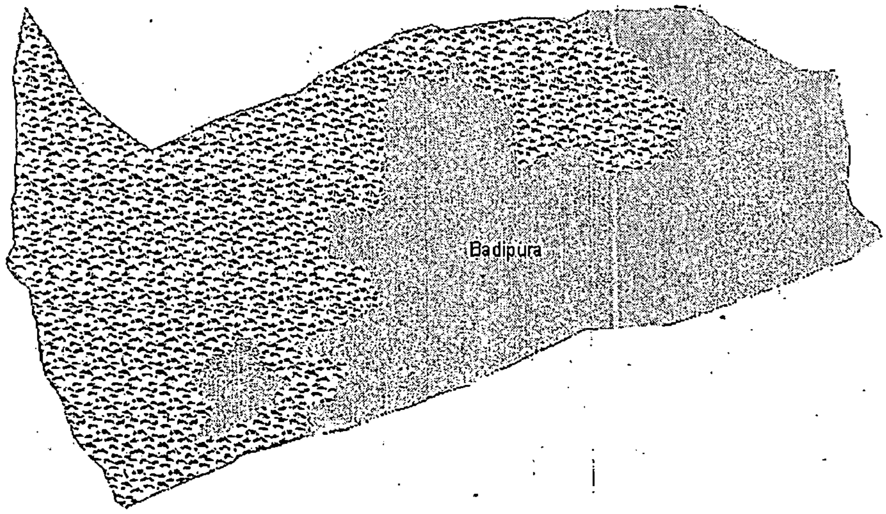

Figure 5.7-I d: Forest Cover of milli watershed Sehri guriya

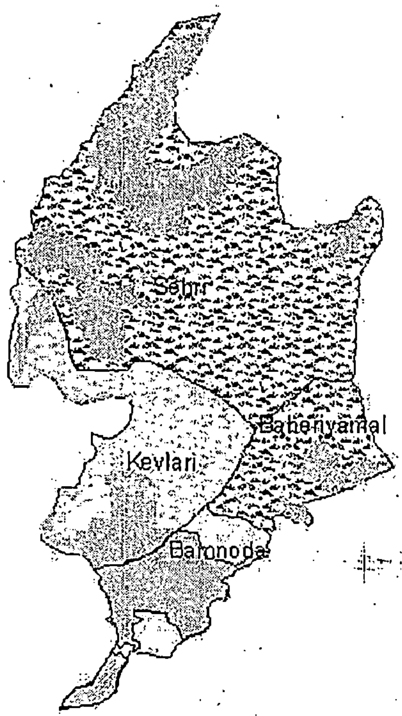

Figure 5.7-II d: Forest Cover of milli watershed Sehri bearma

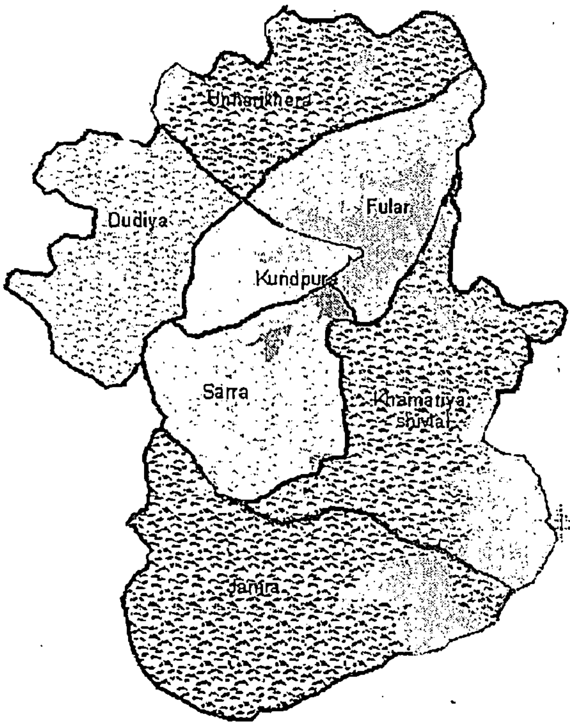

Figure 5.8- d: Forest Cover of milli watershed Sarra

5.10.6 Soil

Observed soil type of the area is of three types deep black soil, shallow black soil and medium black soil. Based on soil type each of the watersheds was assigned scores as follows:

Type of Soil	Score
Deep Black Soil	0.25
Medium Soil	0.5
Deep Black & Shallow Black both	0.75
Medium Black & Shallow both	1
Shallow Soil	1.5

5.10.7 Water availability

On the basis of availability of water for agriculture and drinking purpose, individual watersheds were classified into three classes as low, medium and adequate and assigned weightage scores. The class adequate do not implies that it fulfills the overall water need of the watershed community, but it is a comparative term.

Class	Score
Adequate	0.5
Medium	1
Low	1.5

5.10.8 Socioeconomic factor

On the basis of socio economic data of the study area, it is concluded that watersheds which have been found most serious in terms bio-physical degradation are also the areas where the farmers have felt most serious decline in productivity of agriculture crops and shown the most awareness for launching a watershed project.

CHAPTER 6

RESULTS AND DISCUSSIONS

After the creation of GIS database, analysis and multi criteria evaluation of selected parameters of prioritization. The results of study have been discussed in this chapter.

Morphometrically, lower order streams are dimensionally shorter, carry less water while higher order streams are comparatively elongated and carry more water and sediments. Looking to the problem and requirements of the present study area, in the evaluation procedure more weight-age is given to higher stream order and such watersheds have been allotted score of four, also additional half points is given if the drainage density in the watershed is high.

Slope also has major implication for land use. The velocity and extent of runoff depends on the slope of the land, and in turn affects the soil erosion status of the watershed. Watersheds areas having slope less than 10 degree, were classified under LEA category, slope of the range of 10 to 35 degrees considered as MEA and for slope greater than 35 degrees, area considered under HEA category. On the basis of the identification of the areas of these three categories in a watershed, SES indicator for the slope is calculated, which is represented in Table No 6.1 to Table No 6.3.

The SES value of the watersheds draining into Bearma drain ranges from 14 to 18.4 and of Guriya drain ranges from 13.4 to 17.9. The table reveals that for Bearma catchment, sub watershed Sehri has the lowest SES value of 14 which is due to the fact that 70 percent of its area is under LEA while sub watershed Bamhorimal has highest SES value for slope due to undulation and high slope.

Table No 6.1: Calculation of SES of slope and aspect for Bearma drain

S.No	Name of milli watershed	Name of sub watershed	Calculation of SES for Slope				Calculation of SES for Aspect			
			LEA (%)	MEA (%)	HEA (%)	SES	LEA (%)	MEA (%)	HEA (%)	SES
	Bearma									
1	Chandana	(i) Maheka	71	11	18	14.7	52	11	37	18.5
		(ii) Khotkhera	60	30	10	15	58	16	26	16.8
		(iii) Bamhori mal	54	38	18	18.4	58	25	17	15.9
		(iv) Chandana	67	18	15	14.8	63	11	26	16.3
2	Jamun_bearma 1	(i) Pondy	64	23	13	14.9	80	5	15	13.5
		(ii) Samnapur	63	24	13	15	55	20	25	17
		(iii) Jamun	63	20	17	15.4	54	10	27	15.5
3	Jamun_bearma 2	(iv) Daroli	60	27	13	15.3	71	16	13	14.2
4	Sahri_bearma	(i) Baheriyamal	65	21	14	14.9	47.4	10.6	42	19.46
		(ii) Bamnoda	41	34	25	18.4	48.6	11.7	39.7	19.11
		(iii) Kevlari	57	27	16	15.9	55	19.2	25.8	17.08
		(iv) Sehri	70	20	10	14	70.9	12.4	16.7	14.58
5	Beragarh	(i) Bagdari	63.2	20.2	16.6	15.34	62.2	22.5	15.3	15.31
		(ii) Beragarh1	60.4	18.6	21	16.06	68.7	16.8	14.5	14.58
		(iii) Beragarh2	49.8	40	10.2	16.04	67	16	17	15
		(iv) Majguanmal	58.8	27.7	13.5	15.47	69.8	15.7	14.5	14.47
		(v) Jalon	56.6	15.4	28	17.14	59.2	23.6	17.2	15.8

Table No 6.1: Calculation of SES of slope and aspect for Bearma drain contd ...

			Calculation of SES for Slope				Calculation of SES for Aspect			
S.No	Name of milli watershed	Name of sub watershed	LEA (%)	MEA (%)	HEA (%)	SES	LEA (%)	MEA (%)	HEA (%)	SES
6	Sarra	(i) Unharikhera	69.9	13.4	16.7	14.68	76.6	9	14.4	13.78
		(ii) Dudiya	68.8	16.5	14.7	14.59	72.4	13.8	13.8	14.14
		(iii) Kundpura	57.5	20.5	22	16.45	56.9	13.7	29.4	17.25
		(iv) Sarra	61.2	22.2	16.6	15.54	61	15.6	23.4	16.24
		(v) Fular	58.8	23.2	18	15.92	48.8	15.4	35.8	18.7
		(v) Khamariya shivlal	69.3	15.1	15.6	14.63	65.7	20.3	14	14.83
		(vii) Jamra	68.5	19	12.5	14.4	56.5	13.5	30	17.35
7	Tejgarh_berama	(i) Devrileeladhar	60.5	24	15.5	15.5	53.7	13.3	33	17.93

Table No 6.2: Calculation of SES of slope and aspect for Guriya drain

			Calculation of SES for Slope				Calculation of SES for Aspect			
S.No	Name of milli watershed	Name of sub watershed	LEA (%)	MEA (%)	HEA (%)	SES	LEA (%)	MEA (%)	HEA (%)	SES
	Guriya w/s									
1	Jamun_guriya	(i) Imlidol	51	19	30	17.9	47	9	44	19.7
		(ii) Khakariya kalla	70	16	14	14.4	75	14	11	13.6
2	Nargaon	(I) Narguan	72	13	15	14.3	76	9	15	13.9
		(ii) Panda Jir	54	21	25	17.1	40	18	42	20.2
		(iii) Silpura	68	12	20	15.2	54	8	38	18.4
		(iv) Mahuguan khurd	74	8	18	14.4	68	18	14	14.6
3	Pathado_gur	(i) Bhodi	69	13	18	14.9	66	20	14	14.8
		(ii) Belvada	59	23	18	15.9	55	16	29	17.4
		(iii) Devrinijam	70	18	12	14.2	67	22	11	14.4
		(iv) Ajitpur	43	36	21	17.8	58	15	27	16.9
4	Sahri_gur	(i) Badipura	61	27	12	15.1	38.6	15.4	46	20.74
5	Tejgarh_guriya 1	(i) Bamhoripanji 1	54.4	27	18.6	16.42	76.1	13.4	10.5	13.44
	Tejgarh_guriya 2	(ii) Bamhoripanji 2	52.6	27.6	19.8	16.72	51.9	20.6	27.5	17.56
	Tejgarh_guriya 3	(iii) Tejgarh	71.7	13.1	15.2	14.35	67.4	14.6	18	15.06
		(iv) Patloni	58.2	34	7.8	14.96	52.9	22.6	24.5	17.16
		(v) khamkhera 1	81	4	15	13.4	70.9	19.6	9.5	13.86
		(vi) khamkhera 2	57	15.5	27.5	17.05	51.5	26.3	22.2	17.07
		(vii) Devrileeladhar_guriya	70.6	13.4	16	14.54	50.6	17	32.4	18.18

Table No 6.3.: Calculation of SES of slope and aspect for Darbajiya & Bagaha drains

			Calculation of SES for Slope				Calculation of SES for Aspect			
S.No	Name of milli watershed	Name of sub w/s	LEA (%)	MEA (%)	HEA (%)	SES	LEA (%)	MEA (%)	HEA (%)	SES
	Darbajiya									
1	Pathado	Pathado	68	9	23	15.5	61	20	19	15.8
1	Bagaha									
	Charimal	Charimal	42	26	32	19	67	13	20	15.3

Similarly from the analysis of the SES table of the watersheds of Guriya (Table No 6.2), Khamkhera 1 has been found to get minimum SES value of 13.4. For this watershed 81 percent area is having slope less than ten degree, which justifies its lowest score. While Imlidol sub watershed has been assigned highest SES value for slope of 17.9 because more than 50 percentage of its total area is in moderate to high slope range.

High SES values of slope indicates that watershed is prone to soil erosion hazard while watersheds having low SES value indicates that soil erosion problem is not serious. Therefore for prioritization, higher score is allotted for watersheds having higher SES value of slope.

Aspect of the watershed also has an impact on the soil erosion status. Watershed lying in the North, North East and North West direction is less prone to soil erosion in comparison to the watersheds lying in East and West. While watersheds of South, South East and South West orientation are most prone for the soil erosion, therefore they have been assigned highest value for aspect in ranking procedure. The classification and calculation of the areas of the watershed in three categories of erosion viz, LEA, MEA and HEA are shown in Table No 6.1 to Table 6.3.

Land use also affects the soil erosion status of the watershed. For watersheds having larger area under forest cover, chances for soil erosion are minimal. Hence in ranking procedure more score is given for watersheds which have less percentage area under the forest. In the study area it was found that forest cover ranges from a high of 90 percent to the low as 2 percent, which indicates there is large variation in the forest cover of the study area.

Water availability for crop production and drinking purpose is one of the major problems of the study area. Hence water availability was selected as one of the parameter in the prioritization, on this basis scores were given for the ranking purpose. The study area was divided into three categories.

Soil type has impact on soil erosion. Therefore in the ranking, scores were given to each watershed based on the type of soils.

The 45 sub watersheds were ranked on the basis of their cumulative score of slope, stream order, drainage density, aspect, forest cover and water availability. Ranking is shown in Table 6.4. Watersheds having equal cumulative scores were ranked as per the priority of the score of (1) drainage & stream Order (2) slope (3) soil type (4) forest cover (5) water availability (6) aspect.

On account of cumulative scores of slope, aspect, stream order, drainage density, forest, soil and water availability all 45 sub watersheds are classified into four categories, very highly prioritized, highly prioritized, moderately prioritized and low prioritized. The classification of these sub watersheds is shown in Figure 6.1 and Table 6.5.

It was observed that 9 watersheds are as very highly prioritized, 9 are highly prioritized, 16 were moderately prioritized while 11 are in were low prioritized category

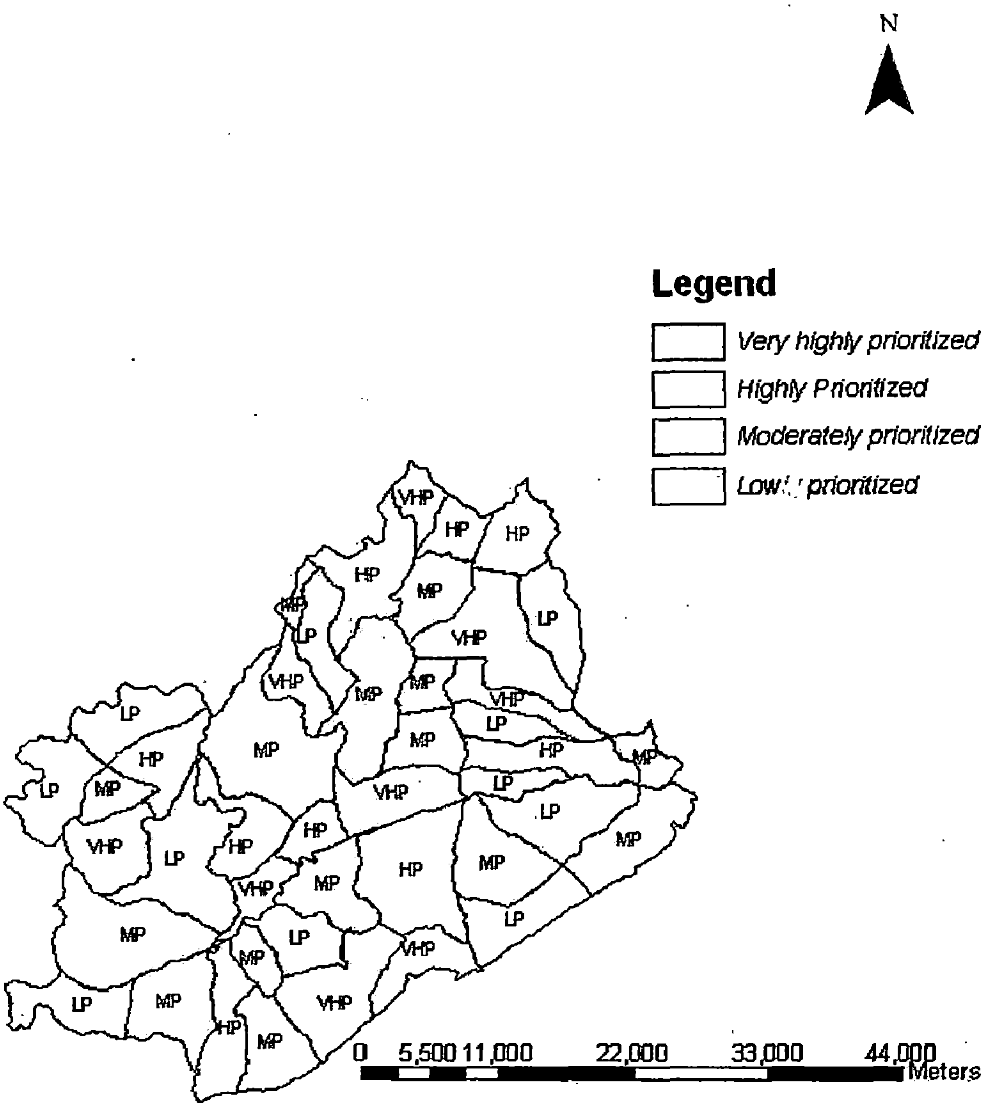

Figure 6.1:Classification of all sub watersheds

Table No 6.4: Ranking of all Sub watersheds

S. No	Name of sub watersheds	Score						Cumulative Score
		Slope	Aspect	Soil	DD & Stream Order	Forest Cover	Water Availa -bility	
1	Ajitpur	3	1	1	3.5	1	1	10.5
2	Bamnoda	3	1.5	1.5	2.5	1.5	0.5	10.5
3	Badipura	2	1.5	0.75	4.5	1	0.5	10.25
4	Jalon	3	1	0.75	3.5	1	1	10.25
5	Imli dol	3	1.5	0.75	3	0.5	1.5	10.25
6	Jamun	2	1	1.5	3.5	0.5	1.5	10
7	Sarra	2	1	0.75	4.5	0.5	1	9.75
8	Khamkhera 2	2	1.5	0.75	4	0.5	1	9.75
9	Devrileeladhar	2	1.5	0.25	3.5	1.5	1	9.75
10	Kevlari	2	1.5	1.5	3.5	0.5	0.5	9.5
11	Belvada	2	1.5	1	3	1	1	9.5
12	Fualr	2	1.5	0.75	3.5	1	0.5	9.25
13	Devrileeladha _gur	1	1.5	0.75	3.5	1.5	1	9.25
14	Patloni	1	1.5	0.75	3	2	1	9.25
15	Khakariya Kalla	1	0.5	1.5	4.5	0.5	1	9
16	Baheriya mal	1	1.5	1.5	3.5	0.5	1	9
17	Majguan mal	2	0.5	0.75	3	1.5	1	8.75
18	Bamhori mal	3	1	0.75	2.5	0.5	1	8.75
19	Bamhori Panji 1	2	0.5	1.5	3	0.5	1	8.5
20	Bamhori Panji2	2	1.5	1.5	2	0.5	1	8.5
21	Sehri	1	0.5	0.75	4.5	1	0.5	8.25
22	Daroli	2	0.5	0.75	3.5	0.5	1	8.25
23	Bagdari	2	1	0.75	3	0.5	1	8.25
24	Silpura	2	1.5	0.75	2	0.5	1.5	8.25

S. No	Name of sub watersheds	Score						Cumulative Score
		Slope	Aspect	Soil	DD & Stream Order	Forest Cover	Water Availa bility	
25	Narguan	1	0.5	1.5	3.5	0.5	1	8
26	Chanadana	1	1	1.5	3.5	0.5	0.5	8
27	Pathado	2	1	1	2	0.5	1.5	8
28	Pondy	1	0.5	1.5	2	1.5	1.5	8
29	Jamra	1	1.5	0.75	4	0.5	0.5	7.75
30	Khotkhera	1	1	0.75	3.5	0.5	1	7.75
31	Tejgarh	1	1	0.75	3	1	1	7.75
32	Kundpura	2	1.5	0.25	2.5	0.5	1	7.75
33	Beragarh 2	2	0.5	0.25	2	1.5	1.5	7.75
34	Charimal	3	1	0.25	1	1	1.5	7.75
35	Samnapur	1	1	1.5	3	0.5	0.5	7.5
36	Beragarh 1	2	0.5	1.5	2	0.5	1	7.5
37	Bhodi	1	0.5	1.5	2	1.5	1	7.5
38	Maheka	1	1.5	1.5	2	0.5	1	7.5
39	Khamkhera 1	1	0.5	0.75	3	0.5	1.5	7.25
40	Dudiya	1	0.5	1.5	3	0.5	0.5	7
41	Devrinijam	1	0.5	1	2	1.5	1	7
42	Panda jir	1	1.5	1.5	1	0.5	1.5	7
43	Khamariya shivlal	1	0.5	0.75	3.5	0.5	0.5	6.75
44	Mahuguan khurd	1	0.5	0.75	3	0.5	1	6.75
45	Unharikhera	1	0.5	0.75	3	0.5	0.5	6.25

Table No 6.5: Classification of sub watersheds

Category	Cumulative	Name of Sub watersheds	Area (Ha)
Very highly Prioritized	> 9.5	Badipura, Jalon, Imlidol,Bamnoda, Ajitpur, Sarra, Khamkhera 2, Jamun, Devrileeladhar	31498 (19.3 %)
Highly Prioritized	8.5-9.5	Bamhorimal, Majguanmal, Baheriyamal, khakrikalla, Belvada, Patloni, Devrileeladhar guriya. Fular and Kevlari.	33261 (20.5 %)
Moderately Prioritized	7.5-8.5	Beragarh 2, Kundpura, Charimal, Pathado,Pondy, Tejgarh, Khotkhera, Narguan, Chandana, Jamra , Silpura,Bamhor Panji1,Bamhorpanji 2,Daroli,Sehri and Baghdari.	58133 (35.6 %)
Low Prioritized	6.5-7.5	Unharikhera, Dudiya, Khamariya Shivlal, Maheka, Beragarh 1, Samnapur, Devrinijam, Panda jir, Mahuguan khurd, Bhodi and Khamkhera 1	40113 (24.6 %)

Very highly prioritized watersheds have cumulative score greater than 9.5 and most of the watersheds have steeper slope and higher stream order. Out of 9 watersheds classified as very highly prioritized, 5 watersheds are part of Bearma catchment and 4 of Guriya drain.

The analysis of slope and forest area in very highly prioritized watersheds shows that Bamnoda, Devrileeadhar and Badipra are more sensitive watersheds on account of their small forest area and steep slope. Because of steep slope any further reduction in forest area of these watersheds will cause more soil erosion in comparison to the watersheds having large forest area and flatter slope.

The study of drainage pattern shows that there are 16 milli watersheds which have 45 sub watersheds. Bearma drain has 7 milli watersheds namely Chandana, Jamun bearma 1, Jamun bearma 2, Tejgarh bearma, Beragar , Sehri bearma and Sarra. Guriya drain have milli watersheds namely Jamun gur, Tejgarh gur, Nargaon, Sehri gur and Patado gur and 2 milli watersheds of Darbajiya and Bagaha namely Patado darbajiya and Patado bagaha.

The 7 milli watershed of Bearma contains 25 sub watersheds, 7 milli watersheds of guriya contains 18 sub watersheds and each milli watershed of Bagaha and Darbajiya contain single sub watershed.

Very highly prioritized watersheds require immediate attention. By adopting suitable watershed treatment practices such as contour bunding, contour cultivation, vegetative bunding and water conservation structures, and crop production can be enhanced and will improve the availability of the water in the area.

Highly prioritized watersheds have the cumulative score in the range of 8.5 to 9.5. Out of 9 watersheds identified as highly prioritized, 5 drains to Bearma drain and 4 to Guriya drain. These watersheds also require urgent attention and suitable watershed management practices.

Moderately prioritized watersheds have cumulative score in the range of 7.5 to 8.5. There are 16 watersheds under this category, out of which 9 are part of Bearma drain , 5 of Guriya and one each of Darbajiya and Bagaha drain. The soil erosion status of these watersheds is not deteriorating at an alarming rate, and such watersheds can be treated at the middle stage of the watershed programme.

Low prioritized watersheds have the cumulative score in the range of 6.5 to 7.5. Out of 11 watersheds identified under this category, 6 drain to Bearma and 5 to Guriya. The watersheds of this category do not require immediate attention. These watersheds can be treated at later stages, because their condition is not deteriorated as of watersheds of other three categories.

The sub watersheds of Bearma and Guriya drains are also ranked separately and shown in table 6.6 and table 6.7 respectively. The study of their ranking table reveals that out of 25 sub watersheds of Bearma catchment, 5 sub watersheds (Jalon, Bamnoda, Sarra, Jamun and Devrileeladhar) are very highly prioritized, 5 sub watersheds (Kevlari, Bamhorimal, Majguanmal, Baheriyamal and Fular) are highly prioritized, 9 sub watersheds (Beragarh 2, Kundpura, Pondy, Khotkhera, Chandana, Jamra, Sehri, Daroili and Bhagdari) are moderately prioritized and 6 (Unhaikhera, Dudiya, Khamariya shivlal, Maheka and Beragarh) are low prioritized.

Table No 6.6: Ranking of sub watersheds of Bearma drain

S. No	Name of sub watersheds	Score						Cumulative Score
		Slope	Aspect	Soil	DD & Stream Order	Forest Cover	Water Availability	
1	Jalon	3	1	1	3.5	1	1	10.5
2	Bamnoda	3	1.5	1.5	2.5	1.5	0.5	10.5
3	Sarra	2	1	1	4.5	0.5	1	10
4	Jamun	2	1	1.5	3.5	0.5	1.5	10
5	Devrileeladhar	2	1.5	0.25	3.5	1.5	1	9.75
6	Kevlari	2	1.5	1.5	3.5	0.5	0.5	9.5
7	Fualr	2	1.5	1	3.5	1	0.5	9.5
8	Baheriya mal	1	1.5	1.5	3.5	0.5	1	9
9	Majguan mal	2	0.5	1	3	1.5	1	9
10	Bamhori mal	3	1	1	2.5	0.5	1	9
11	Sehri	1	0.5	1	4.5	1	0.5	8.5
12	Daroli	2	0.5	1	3.5	0.5	1	8.5
13	Bagdari	2	1	1	3	0.5	1	8.5
14	Jamra	1	1.5	1	4	0.5	0.5	8
15	Chanadana	1	1	1.5	3.5	0.5	0.5	8
16	Khotkhera	1	1	1	3.5	0.5	1	8
17	Pondy	1	0.5	1.5	2	1.5	1.5	8
18	Kundpura	2	1.5	0.25	2.5	0.5	1	7.75
19	Beragarh 2	2	0.5	0.25	2	1.5	1.5	7.75
20	Samnapur	1	1	1.5	3	0.5	0.5	7.5
21	Beragarh 1	2	0.5	1.5	2	0.5	1	7.5
22	Maheka	1	1.5	1.5	2	0.5	1	7.5
23	Khamariya shivlal	1	0.5	1	3.5	0.5	0.5	7
24	Dudiya	1	0.5	1.5	3	0.5	0.5	7
25	Unharikhera	1	0.5	1	3	0.5	0.5	6.5

Similarly out of 18 sub watersheds of Guriya drain, 4 (Badopur, Imlidol, Ajitpur and Khamkhera2) are under very highly prioritized category,(Devrileeladhar_gur,Patloni, Belvada and Khakariya kalla) under highly prioritized category, 5 (Banhorpanji 1,Bamhorpanji 2, Silpura,Nargaon and Tejgarh) are moderately prioritized and 5 (Devrinijam, Panda jir, Mahuguan kurd, Bhodi and khamkhera) are low prioritized watersheds.

Table No 6.15: Ranking of sub watersheds of Guriya drain

S. No	Name of sub watershed	Score						Cumulative Score
		Slope	Aspect	Soil	Drainage & Stream order	Forest Cover	Water Availability	
1	Badipura	2	1.5	1	4.5	1	0.5	10.5
2	Imli dol	3	1.5	1	3	0,5	1.5	10.5
3	Ajitpur	3	1	0.75	3.5	1	1	10.25
4	Khamkhera 2	2	1.5	1	4	0.5	1	10
5	Devrileeladha_gur	1	1.5	1	3.5	1.5	1	9.5
6	Patloni	1	1.5	1	3	2	1	9.5
7	Belvada	2	1.5	0.75	3	1	1	9.25
8	Khakariya Kalla	1	0.5	1.5	4.5	0.5	1	9
9	Bamhori Panji 1	2	0.5	1.5	3	0.5	1	8.5
10	Bamhori Panji2	2	1.5	1.5	2	0.5	1	8.5
11	Silpura	2	1.5	1	2	0.5	1.5	8.5
12	Narguan	1	0.5	1.5	3.5	0.5	1	8
13	Tejgarh	1	1	1	3	1	1	8
14	Khamkhera 1	1	0.5	1	3	0.5	1.5	7.5
15	Bhodi	1	0.5	1.5	2	1.5	1	7.5
16	Mahuguan khurd	1	0.5	1	3	0.5	1	7
17	Panda jir	1	1.5	1.5	1	0.5	1.5	7
18	Devrinijam	1	0.5	0.75	2	1.5	1	6.75

Very highly prioritized watersheds are of 19.3 percent of the total area, highly prioritized watersheds occupy 20.5 percent of the area, moderately prioritized watersheds have 35.6 percent and low prioritized watersheds have 24.6 percent.

Around 40 percent of the area falls under the very highly and highly prioritized watersheds which require urgent attention. While 60 percent of the area is under moderate and low prioritized watersheds.

Out of the total area of 1.63 lacs hectare, watersheds draining to Bearma drain occupies 58 percent area, while watersheds draining to Guriya drain occupies 40 percent and 2 percent area is of watersheds draining to Darbajiya and Bagaha drains.

CHAPTER 7

CONCLUSION AND SUGGESTIONS

7.1 Conclusions

Based on the present study the following conclusions and main features can be out lined.

(i) Land resource development programmes are applied generally on a watershed basis.

(ii) Delineation of watersheds within a large drainage basin and their prioritization is required for proper planning and management of natural resources for sustainable crop production.

(iii) The concept of watershed management recognizes the inter relationships between land use, soil and water and linkage between uplands and downstream areas. Soil and water conservation are key issues in demarcating the priority watersheds.

(iv) There are many factors or parameters, which influence the prioritization, based on the objective of the watershed development work, the method most close to goal can be selected in order to attain the priority watershed.

(v) For integrated and holistic development, watershed prioritization work is essential to identify the priority sites where the limited financial resources can be optimized for the best use of the natural resources with in a watershed and will endow the fruitful results of the development works.

(vi) The use of SES indicator is simple in comparison to the USLE.

(vii) In the beginning of the project, all relevant data may not be available. In such situation, soil erosion status of the watershed can be accessed by indicator such as SES.

(viii) In multi criterion evaluation, factors or parameters that are pertinent to the goal of watershed programme are taken and weightage of the each parameter is assigned as per its importance. In the study slope, drainage, aspect, forest, soil and water availability were considered for prioritization. GIS based analysis of these parameters was carried out for Tendukhera block of Damoh district.

(ix) All 45 sub watersheds were ranked for each parameter taken into consideration, to compute SES, each of the watersheds was classified into one of the four classes viz; very highly, highly, moderate and low prioritized. From the study it was observed that 9 out of 45 sub watersheds namely Badipura, Jalon, Imlidol,Bamnoda, Ajitpur, Sarra, Khamkhera 2, Jamun, Devrileeladhar are very highly prioritized which requires immediate attention.

(x) Nine sub watersheds namely Bamhorimal, Majguanmal, Baheriyama;, khakrikalla, Belvada, Patloni, Devrileeladhar guriya, Fular and Kevlari are highly prioritized class.

(xi) Sixteen sub watersheds namely Beragarh 2, Kundpura, Charimal, Pathado,Pondy, Tejgarh, Khotkhera, Narguan, Chandana, Jamra , Silpura,Bamhor Panji1,Bamhorpanji 2,Daroli,Sehri and Baghdari are moderately prioritized.

(xii) Eleven sub watersheds namely Unharikhera, Dudiya, Khamariya Shivlal, Maheka, Beragarh 1, Samnapur, Devrinijam, Panda jir, Mahuguan khurd, Bhodi and Khamkhera 1 are low prioritized.

(xiii) Very highly prioritized watersheds are of 19.3 percent of the total area of block, highly prioritized watersheds occupy 20.5 percent moderately prioritized watersheds have 35.6 percent while low prioritized watersheds have 24.6 percent.

(xiv) Prioritization facilitates phasing of a watershed programme. Annual planning can be based on the prioritized category of the watershed. Very highly and highly prioritized watersheds can be treated at the early stage, moderately prioritized at the middle phase while low prioritized at the late stage of implementation

7.2 Suggestions

In most of the watershed programmes, prioritization work is neglected, which affects the result of the watershed programme. The most serious or deteriorated watersheds get attention at the later stage of the programme which deteriorates their present status. Hence proper prioritization of the watershed is essential before the commencement of actual programme .

GIS can be used in the studies of prioritization of the watersheds.

For acquiring speedier results from the GIS technique, it is suggested that data base of relevant information of the watershed shall be prepared in advance which will facilitate the prioritization and other planning.

Remote sensing is useful technique to access the land cover in a watershed and to monitor the changes in land cover. The use of GIS along with remote sensing is increasing in the field of prioritization of the watershed. More efforts are needed to integrate the use of both techniques in more simplified manner.

It is not possible to suggest any single method or to identify some fixed number of parameters for the prioritization. As the factors and method chosen depend upon objective of a particular watershed scheme. But for a small study area, the different methods and indicators of prioritization may be worked out and compared. The comparison will be helpful to identify the suitability of a particular method.

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Appendix-1: SES Value of slope of all sub watersheds.

S.No	Name of sub watershed	SES value of Slope	Score of SES
1	Khamkhera 1	13.4	1
2	Sehri	14	1
3	Devrinijam	14.2	1
4	Narguan	14.3	1
5	Panda Jir	14.3	1
6	Tejgarh	14.35	1
7	Jamra	14.4	1
8	Khakariya kalla	14.4	1
9	Mahuguan khurd	14.4	1
10	Devrileeladhar_gur	14.54	1
11	Dudiya	14.59	1
12	Khamariya shivlal	14.63	1
13	Unharikhera	14.68	1
14	Maheka	14.7	1
15	Chandana	14.8	1
16	Pondy	14.9	1
17	Baheriyamal	14.9	1
18	Bhodi	14.9	1
19	Patloni	14.96	1
20	Khotkhera	15	1
21	Samnapur	15	1
22	Badipura	15.1	2
23	Silpura	15.2	2
24	Daroli	15.3	2
25	Bagdari	15.34	2
26	Jamun	15.4	2
27	Majguanmal	15.47	2
28	Devrileeladhar	15.5	2
29	Pathado	15.5	2
30	Sarra	15.54	2
31	Kevlari	15.9	2
32	Belvada	15.9	2
33	Fular	15.92	2
34	Beragarh2	16.04	2
35	Beragarh1	16.06	2
36	Bamhoripanji 1	16.42	2
37	Kundpura	16.45	2
38	Bamhoripanji 2	16.72	2
39	khamkhera 2	17.05	2
40	Jalon	17.14	3
41	Ajitpur	17.8	3
42	Imlidol	17.9	3
43	Bamhori mal	18.4	3
44	Bamnoda	18.4	3
45	Charimal	19	3

Upper case

Appendix-II: SES Value of Aspect of sub watershed

S.No	Name of sub watershed	SES value of Aspect	Score of SES
1	Bamhoripanji 1	13.44	0.5
2	Pondy	13.5	0.5
3	Khakariya kalla	13.6	0.5
4	Unharikhera	13.78	0.5
5	Khamkhera 1	13.86	0.5
6	Narguan	13.9	0.5
7	Dudiya	14.14	0.5
8	Daroli	14.2	0.5
9	Devrinijam	14.4	0.5
10	Majguanmal	14.47	0.5
11	Sehri	14.58	0.5
12	Beragarh1	14.58	0.5
13	Mahuguan khurd	14.6	0.5
14	Bhodi	14.8	0.5
15	Khamariya shivlal	14.83	0.5
16	Beragarh2	15	0.5
17	Tejgarh	15.06	1
18	Charimal	15.3	1
19	Bagdari	15.31	1
20	Jamun	15.5	1
21	Pathado	15.8	1
22	Jalon	15.8	1
23	Bamhori mal	15.9	1
24	Sarra	16.24	1
25	Chandana	16.3	1
26	Khotkhera	16.8	1
27	Ajitpur	16.9	1
28	Samnapur	17	1
29	Khamkhera 2	17.07	1.5
30	Kevlari	17.08	1.5
31	Patloni	17.16	1.5
32	Kundpura	17.25	1.5
33	Jamra	17.35	1.5
34	Belvada	17.4	1.5
35	Bamhoripanji 2	17.56	1.5
36	Devrileeladhar	17.93	1.5
37	Devrileeladhar_gur	18.18	1.5
38	Silpura	18.4	1.5
39	Maheka	18.5	1.5
40	Fular	18.7	1.5
41	Bamnoda	19.11	1.5
42	Baheriyamal	19.46	1.5
43	Imlidol	19.7	1.5
44	Panda Jir	20.2	1.5
45	Badipura	20.74	1.5

Appendix III: Value for Stream Order & Drainage Density

S.No	Name of sub watershed	Stream order	Drainage density (%)	Score
1	Panda Jir	2	0.031	1
2	Charimal	2	0.09	1
3	Beragarh1	3	0.065	2
4	Silpura	3	0.019	2
4	Bamhoripanji 2	3	0.07	2
5	Pathado	3	0.088	2
6	Maheka	3	0.1	2
7	Devrinijam	3	0.152	2
8	Beragarh2	3	0.155	2
9	Bhodi	3	0.17	2
10	Pondy	3	0.18	2
11	Bamnoda	3	0.202	2.5
12	Kundpura	3	0.202	2.5
13	Bamhori mal	3	0.203	2.5
15	Bamhoripanji 1	4	0.101	3
16	Mahuguan khurd	4	0.109	3
17	Imlidol	4	0.119	3
18	Patloni	4	0.133	3
19	Belvada	4	0.16	3
20	Dudiya	4	0.16	3
21	Bagdari	4	0.18	3
22	Samnapur	4	0.184	3
23	Tejgarh	4	0.19	3
24	Unharikhera	4	0.191	3
25	Majguanmal	4	0.192	3
26	Khamkhera 1	4	0.193	3
27	Fular	4	0.204	3.5
28	Khamariya shivlal	4	0.205	3.5
29	Jalon	4	0.21	3.5
30	Khotkhera	4	0.21	3.5
31	Kevlari	4	0.218	3.5
32	Narguan	4	0.22	3.5
33	Chandana	4	0.227	3.5
34	Daroli	4	0.235	3.5
35	Jamun	4	0.247	3.5
36	Baheriyamal	4	0.258	3.5
37	Devrileeladhar	4	0.266	3.5
38	Devrileeladhar_gur	4	0.33	3.5
39	Ajitpur	4	0.582	3.5
40	Jamra	5	0.164	4
41	Khamkhera 2	5	0.178	4
42	Sarra	5	0.204	4.5
43	Badipura	5	0.21	4.5
44	Khakariya kalla	5	0.21	4.5
45	Sehri	5	0.215	4.5

Appendix IV: Value for forest cover

S.No	Name of sub watershed	Forest Area (%)	Score
1	Jamun	96	0.5
2	Dudiya	95.5	0.5
3	Imlidol	94	0.5
4	Maheka	94	0.5
5	Sarra	93	0.5
6	Silpura	92	0.5
7	Unharikhera	91.8	0.5
8	Bagdari	89	0.5
9	Daroli	89	0.5
10	Panda Jir	88.3	0.5
11	Jamra	87	0.5
12	khamkhera 1	86.5	0.5
13	Chandana	86.45	0.5
14	Narguan	83.2	0.5
15	Pathado	83	0.5
16	Baheriyamal	82.6	0.5
17	Khotkhera	82.58	0.5
18	khamkhera 2	82	0.5
19	Bamhoripanji 2	80	0.5
20	Samnapur	80	0.5
21	Bamhori mal	77.2	0.5
22	Beragarh1	76	0.5
23	Kevlari	74	0.5
24	Khakariya kalla	74	0.5
25	Khamariya shivlal	74	0.5
26	Mahuguan khurd	71.4	0.5
27	Kundpura	71.2	0.5
28	Bamhoripanji 1	70	0.5
29	Sehri	69	1
30	Belvada	68	1
31	Fular	63.3	1
32	Jalon	60	1
33	Tejgarh	59.6	1
34	Charimal	58	1
35	Ajitpur	55.6	1
36	Badipura	51	1
37	Bhodi	44.4	1.5
38	Devrileeladhar guriya	43	1.5
39	Devrinijam	43	1.5
40	Pondy	40	1.5
41	Devrileeladhar	39	1.5
42	Bamnoda	32	1.5
43	Majguanmal	31	1.5
44	Beragarh2	25	1.5
45	Patloni	2.24	2

Appendix V: Value for Water Availability

S.No	Name of sub watershed	Water availability	Score
1	Badipura	Adequate	0.5
2	Bamnoda	Adequate	0.5
3	Chandana	Adequate	0.5
4	Dudiya	Adequate	0.5
5	Fular	Adequate	0.5
6	Jamra	Adequate	0.5
7	Kevlari	Adequate	0.5
8	Khamariya shivlal	Adequate	0.5
9	Samnapur	Adequate	0.5
10	Sehri	Adequate	0.5
11	Unharikhera	Adequate	0.5
12	Bamhoripanji 1	Moderate	1
13	Bamhoripanji 2	Moderate	1
14	Ajitpur	Moderate	1
15	Bagdari	Moderate	1
16	Baheriyamal	Moderate	1
17	Bamhori mal	Moderate	1
18	Belvada	Moderate	1
19	Beragarh1	Moderate	1
20	Bhodi	Moderate	1
21	Daroli	Moderate	1
22	Devrileeladhar	Moderate	1
23	Devrileeladhar guriya	Moderate	1
24	Devrinijam	Moderate	1
25	Jalon	Moderate	1
26	Khakariya kalla	Moderate	1
27	khamkhera 2	Moderate	1
28	Khotkhera	Moderate	1
29	Kundpura	Moderate	1
30	Maheka	Moderate	1
31	Mahuguan khurd	Moderate	1
32	Majguanmal	Moderate	1
33	Narguan	Moderate	1
34	Patloni	Adequate	1
35	Sarra	Moderate	1
36	Tejgarh	Adequate	1
37	Beragarh2	Low	1.5
38	Charimal	Low	1.5
39	Imlidol	Low	1.5
40	Jamun	Low	1.5
41	khamkhera 1	Low	1.5
42	Panda Jir	Low	1.5
43	Pathado	Low	1.5
44	Pondy	Low	1.5
45	Silpura	Low	1.5