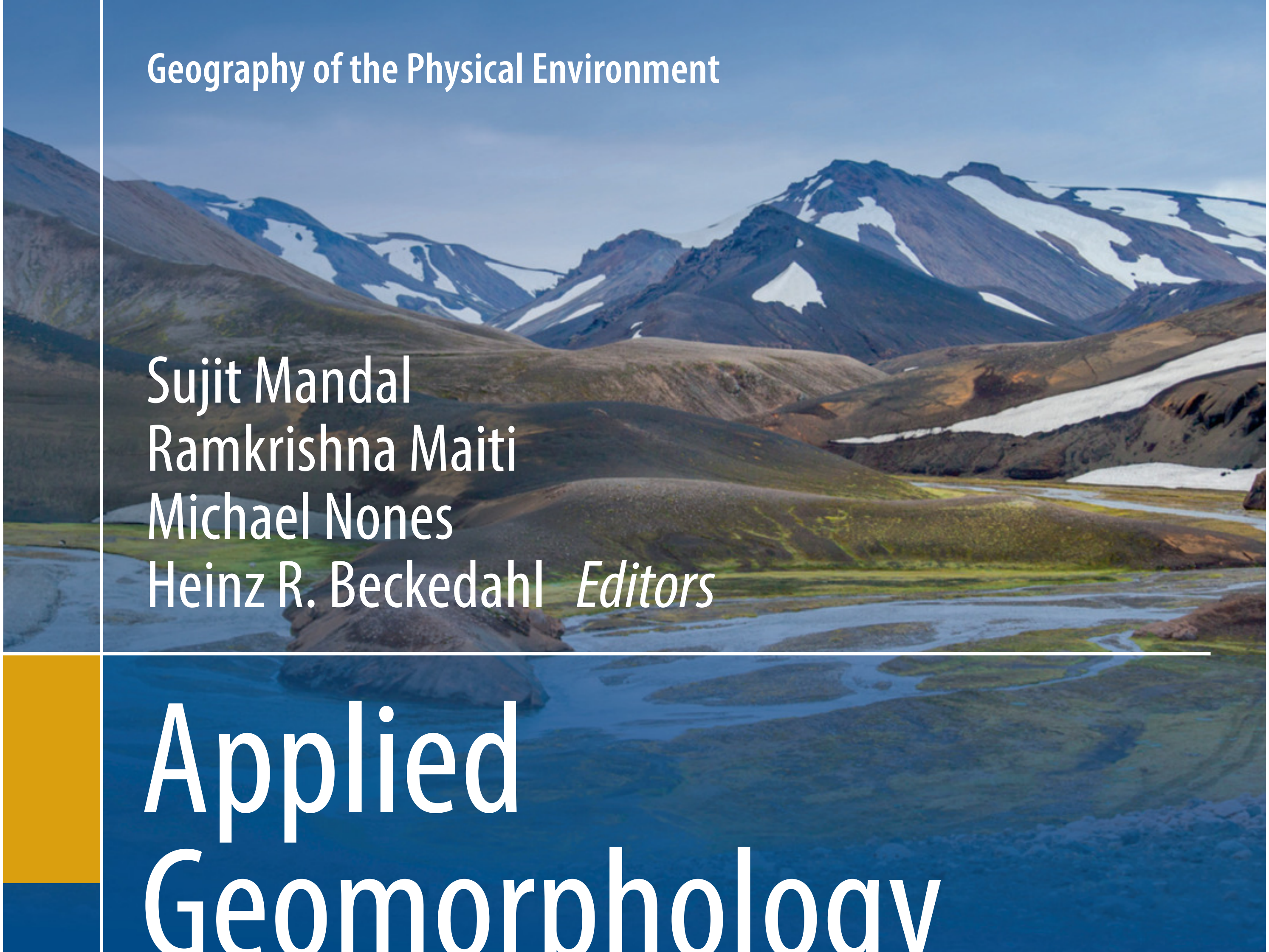

Geography of the Physical Environment

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18 Prioritization of Watershed Developmental Plan by the Identification of Soil Erosion Prone Areas Using USLE and RUSLE Methods for Sahibi Sub-Watershed of Rajasthan and Haryana State, India

Ajoy Das, Jagmohan Singh, Madan Thakur, and Asim Ratan Ghosh

Abstract

Soil erosion is a major cause for land degradation. The process is initiated when soil particles are detached from its original configuration by erosive forces such as rainfall, temperature, wind. Prior research has demonstrated that large sediment loads damages the coral reefs. Current developments in geographic information systems (GIS) make it possible to model complex spatial analysis. A GIS is used in the present work to determine soil erosion potential at watershed scale. Hydrological data has been analyzed to understand the watershed's response to the primary erosive input i.e. rainfall. The aims of the study are to develop a GIS-based soil erosion potential model of the Sahibi Sub-Watershed, located in Alwar district of Rajasthan and Rewari district of Haryana state of India and to develop a correlation between drainage density, LU/LC coverage and slope steepness. The Universal Soil Loss Equation (USLE) was used to assess soil loss in GIS environment, specifically the commercial software package ArcGIS10.0. The USLE calculates long-term average annual soil loss by multiplying six specific factors which describe the watershed characteristics such as rainfall, soil types, slope, and vegetation cover. The GIS is used to store the USLE factors as individual digital layers and multiplied together to create a soil erosion potential map and finally a priority map was made. Recent satellite imagery is used from the Google Earth and IRS LISS-III to determine the extent of vegetation cover and conservation practices. In addition to developing the GIS model, a preliminary hydrological analysis was also conducted.

Keywords

Soil erosion · USLE · Stream flow · Slope · Watershed management

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18.1 Introduction

The surface of the earth is always modified by Endogentic and Exogenetic forces from the ancient eras. Soil erosion mentioned by Wicks

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and Bathurst (1996) is one major type of Exogenetic forces. Soil is one of the three most precious natural resources together with air and water, one of the fabulous products of nature and without this element there would be no imagination of life. Soil is a thin layer of material on Earth's surface which supports vegetation and life. It is a porous natural material which consists of many materials including rocks, weathered minerals, and dead decaying plants and animals. Soil formation process takes a very long time creating a thin layer of soil. About an average soil/topsoil are produced of 1 ton/year and lost 10–40 times faster than it produced. The region was known as densely forested and rich in wildlife at the time of independence. Now the ecosystem of the region has come under severe stress and continuously degrading due to excessive felling of trees to meet the increasing demand for fuel, fodder, and construction industry as well as extensive mining to meet the industrial demand for minerals. This has resulted in extensive soil erosion, loss of topsoil, silting up of river channels and reservoirs, reduced land fertility and lowering of the ground water table. Apart from this fact instead of wind, water plays dominant role in soil erosion in the Aravalli hill range. However, excessive soil erosion is responsible for surface soil loss by Symeonakis and Drake (2004) and a subsequent decrease in soil quality and agricultural production. Soil loss from cultivated and bare land is still very high elsewhere on the globe and soil erosion is the most significant and an ominous threat to food security and development prospects in many developing countries (Bekele and Drake 2003). Soil loss is greater in developing countries where the farmers are totally ignorant of soil conservation practices mentioned by Singh et al. (1992). An escalating population is also indirectly responsible for this soil loss, especially where farmers desperate to grow enough crops destroy forests and other natural areas. The fertility of soil affects the agriculture and as well as population distribution also. Agriculture is a major activity all over the world. As the recent development in technology and mechanization, agriculture has remained the world's primary industry, in which soil plays elementary role. About 66% of the globe population, comprising of farmers derives its living directly from the soil. But soil erosion reduces soil fertility. The objective of the study is to analyze the soil erosion prone areas and how it affects the land use/landcover, using RS and GIS of the Sahibi Sub-Watershed, a small river sub-basin of the Sahibi Basin is in between eastern part of Rajasthan and western part of Haryana. Apart from this study, analyze the extent of drastic impacts of soil erosion affecting the socio-economic activities, toward optimum developmental planning by Hassan and Garg (2007) of the study area with watershed approach. Attempt has also been made for designing various Check Dam parameters of the watershed by Das et al. (2012). In a nut shell, to identify the soil erosion prone areas in semi-arid region of Sahibi (Sabi) Sub Watershed and to increase food security through soil conservation planning by Garg and Sen (1994, 2001). The two goals of the present research are:

I. To develop a GIS-based soil erosion potential model of the Sahibi Sub-Watershed, located in Alwar district of Rajasthan and Rewari district of Haryana state of India.
II. To develop a correlation between drainage density, LU/LC coverage and slope steepness.

According to Morgan (1986), the rate of soil erosion of developing and developed countries is at an alarming level. In some developed countries like the United Kingdom, United States of America, and Belgium have succeeded in minimizing the soil loss to an acceptable level. In the Journal of Environmental Hydrology, Sudhanshu Sekhar Panda et al., 'Application of Geotechnology to Watershed Soil Conservation Planning at the field scale of the Kuniguda watershed of Orissa and Andhra Pradesh' has done this type of soil erosion study. Some work has been done related to this study by the DST, Govt of West Bengal, India. Water & Environmental Research Institute of the Western Pacific, Shahram et al.

(2007), worked on soil erosion and measured the soil loss areas as the name of the thesis 'A GIS based Soil Erosion Potential Model of the Ugum Watershed' also similar work done by Symeonakis and Drake (2004), Wen et al. (2007).

As a branch of earth science, it is concerned with all the elements of the environment. On-site effects are particularly important on agricultural land where the redistribution of soil within a field, the loss of soil from a field, the breakdown of soil structure, and the decline in organic matter and nutrient result in a reduction of cultivable soil depth and a decline in soil fertility. Erosion also reduces available soil moisture, resulting in more drought-prone conditions. "Soil Erosion and Conservation", Morgan (2009). A watershed is essentially a catchment, within the boundaries of which all the soil–water processes are integrated; change in any one parameter influences all the other process parameters. It is a geographical unit draining at a common point (Outlet or pour point: usually the lowest point along the watershed boundary) by a system of streams. All land everywhere is part of some watershed. Other common terms for a watershed classification (Table 18.1) are drainage basin, basin, catchment, or contributing area. The size of watershed may vary from few square kilometers to thousands of square kilometers (Khosla 1949).

Significance of soil erosion in the form of soil loss

The understanding of the soil loss behavior of watersheds is essential to the planning and implementation of integrated watershed management schemes. The major factors to be considered in the soil erosion study of watersheds are Weather records—temperature, Precipitation, Evapotranspiration, Catchment characteristics—size, shape slope, soil type, LU/LC type and Erosion characteristics, Run-off characteristics by Thakkar and Dhiman (2007)—lag time, quantity of flow and spatial and temporal distribution of flow by Das (2012), Nooka Ratnam et al. (2005). It will be difficult to change any physical parameters of a watershed such as the slope, soil, and rainfall characteristics stated by Nag and Ghosh (2012). However it may be possible to change the land use and vegetation patterns, allocation of suitable areas for housing and livestock and introduce some structural measures for soil and water conservation. Adoption of appropriate measures in a spatial framework can create a sustainable watershed ecosystem by increasing ground water recharge, moderating peak flows, enhancing low flows and improving the habitat of the plants, trees, and animals in the watershed.

The rate of erosion is affected by four main factors: Climate, which determines how much rain will occur in an area; Soil characteristics, which determine erodibility and infiltration rates; Topography or slope, which determines the velocity of runoff and the energy water will have to cause erosion; and Vegetation, which will slow runoff and prevent erosion by holding soils in place stated by Wang and Yin (1998). Remote sensing data facilitate identification of existing or potential erosion prone areas which may help in planning, reclamation or preventive measures. Methods of erosion detection and assessment

Table 18.1 Average size and size ranges for each hydrological units (Khosla in 1949)

S. No.	Category of hydrologic units	Example of code	Size range (ha)	Average size (ha)
1	Water resource region	2	27,000,000–113,000,000	55,000,000
2	Basins	A	3,000,000–30,000,000	9,500,000
3	Catchments	1	1,000,000–5,000,000	3,000,000
4	Sub-catchments	A	200,000–1,000,000	700,000
5	Watersheds	2	20,000–300,000	100,000
6	Sub-watersheds	a	5000–9000	7000
7	Micro-watersheds	2	500–1500	1000

using remote sensing techniques are based on tone, texture and physiography recognition features. Factors to be considered in water-induced erosion are drainage, precipitation, vegetation, elevation, and relief. Soil erosion features may occur in a regular sequence of types and intensities along the topographic relief in a certain area. For this study area, the soil erosion is predicted using RUSLE model. Our Indian society is an agriculturally based society where the maximum population lives in rural areas where a sustainable rural development is very much required. Watershed development is best suited here, so Govt. of India, NGOs, and other organizations like NABARD etc. have implemented watershed development in India. In terms of Mahatma Gandhi National Rural Employment Guarantee Act has implemented the watershed-based development. For proper implementation, the application of remote sensing and GIS technique is being used increasingly, for a quick as well as accurate watershed planning mentioned by Samuel (1995).

Application of Remote Sensing and GIS in Hydrological Studies

The success of planning for developmental activities depends on the quality and quantity of information available on both natural and socio-economic resources. It is, therefore, essential to develop the ways and means of organizing computerized information system. These systems must be capable of handling vast amount of data collected by modern techniques and produce up to date information. Remote Sensing technology has already demonstrated its capabilities to provide information on natural resources such as crop, land use, soils, forest etc. on regular basis. Similarly, Geographic Information Systems (GIS) are the latest tools available to store, retrieve, and analyze different types of data for management of natural resources. The space borne multispectral data enable generating timely, reliable, and cost-effective information on various natural resources, namely surface water, ground water, land use/cover, soil, forest cover and environmental hazards, namely waterlogging, salinity and alkalinity, soil erosion by water etc.

Soil Erosion and sediment yield modeling by Rompaey et al. (2005) using RUSLE in ArcGIS Environment

In this study GIS techniques have been utilized for spatial discretization of a catchment into a time-area segments to be used in numerical solutions of the governing differential equations in rainfall-runoff-erosion process. Various thematic layers such as soil, land use, slope, flow direction, DEM were generated for the study area using various tools available in GIS. These thematic layers were further utilized to generate attribute information such as, USLE ‘K’ and ‘C’ parameters for use in rainfall-runoff-soil erosion model by Yitayew et al. (1999). Based on DEM and related attribute information of the catchment, time-area map of the catchment was prepared and used for spatial discretization of the catchment.

18.2 The Study Area

Sahibi River (also known as Sabi) is an ephemeral rain-fed river, locally called SABI Nadi. It rises from Mewat hills near Jitgarh and Manoharpur close to Jaipur district in Rajasthan and after gathering volume from about a hundred tributaries, it reaches voluminous proportions, form in a broad stream around Alwar and Kotputli, it then enters the Rewari district in Haryana near the city of Rewari after which it enters Rajasthan again and then re-enters Haryana near village Jaithal.

The Rewari district, except in its Eastern part is flat and sandy and absorbs all the rainwater. The study area (Fig. 18.1) extending from 28° 03′ 45″ North latitudes to 28° 14′ 45″ North latitudes and 76° 19′ 15″ East longitudes to 76° 29′ 30″ East longitudes. The present Sahibi Sub-Watershed (Fig. 18.1) includes the north eastern portion of Alwar district of Rajasthan and some Southern portion of Rewari district of Haryana (Table 18.2). This area belongs to the river Sahibi, also locally called Sabi Nadi. Total area covered is 182.72 km^2. The major settlement areas under the different micro watersheds are Naodi, Rampura, Khundrot, Dhikwar (SW1);

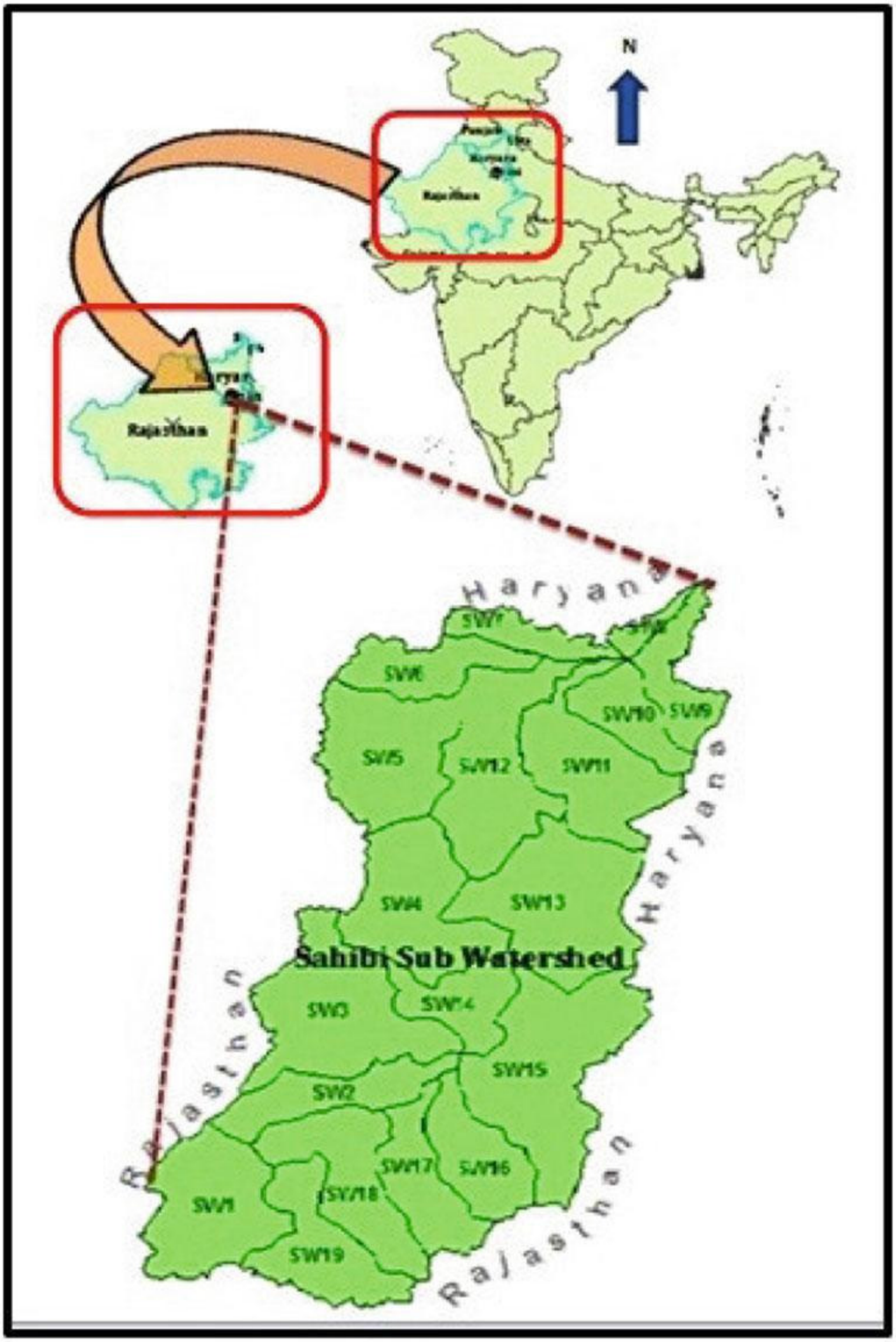

Fig. 18.1 Location map of the study area

Table 18.2 Name and location of the residential area, Sahibi Sub-Watershed

S. No.	Village name	Location in study area	District	State
1	Baturi	North East	Rewari	Haryana
2	Khaleta	North	Rewari	Haryana
3	Mayan	North	Rewari	Haryana
4	Balwari	North	Rewari	Haryana
5	Khol	North West	Rewari	Haryana
6	Nandha	North	Rewari	Haryana
7	Ahrod	North West	Rewari	Haryana
8	Mamaria Asampur	East	Rewari	Haryana
9	Mamaria Ahir	East	Rewari	Haryana
10	Mamaria Thethar	East	Rewari	Haryana
11	Gothra Tappa Khori	East	Rewari	Haryana
12	Bhalki	Central Part	Rewari	Haryana
13	Pali	East	Rewari	Haryana
14	Manethi	West	Rewari	Haryana
15	Parla	West	Rewari	Haryana
16	Kund	West	Rewari	Haryana
17	Nangli	East	Rewari	Haryana
18	Mahtawas	Central Part	Alwar	Rajasthan
19	Arind	Central Part	Alwar	Rajasthan
20	Parula	South East	Alwar	Rajasthan
21	Chela Dungra	South East	Alwar	Rajasthan
22	Giglana	South	Alwar	Rajasthan
23	Chawadi	South	Alwar	Rajasthan
24	Dabarwas	South	Alwar	Rajasthan
25	Birnwas	South	Alwar	Rajasthan
26	Naodi	South	Alwar	Rajasthan
27	Rampura	South	Alwar	Rajasthan
28	Khundrot	South West	Alwar	Rajasthan
29	Dhikwar	South West	Alwar	Rajasthan
30	Anandpur	South	Alwar	Rajasthan
31	Madhan	South	Alwar	Rajasthan
32	Nanagwas	South	Alwar	Rajasthan
33	Manglapur (Nayagaon)	South	Alwar	Rajasthan

Anandpur, Madhan (SW2); Arind, Manglapur (Nayagaon) [SW3]; Manethi, Kund (SW 4); Khol, Ahrad (SW 5); Khaleta, Mayan (SW 7); Bas, Baturi (SW 8); Manmaria Ashpur (SW 9); Manmaria Ahir, Manmaria Thethar, Nagra (SW 10); Gothra Tappa Khori, Pali (SW 11); Balwari, Nandha (SW 12); Bhalki (SW 13); Mahtawas (SW14); Nangli, Chela Dungra, Giglana (SW 15); Chawadi, Nanagwas (SW 16); Dabarwas (SW17); Birnwas (SW 19); SW6 and SW18 has no settlements.

18.2.1 Geomorphology

The district broadly forms part of Indo-Gangetic alluvial plain of Yamuna sub basin. It has vast alluvial and sandy tracts and is interspersed strike ridges which are occasionally covered with blown sand. The hill ranges are part of great Aravalli chain and contain valuable mineral deposits and natural meadows. The elevation of land in the area varies from 232 m in the north to 262 m above mean sea level in south. The master slope of the area is toward the north.

18.2.2 Soil

NBSSLUP (National Bureau of Soil Survey and Land Use Planning) has done the soil classification based on samples where minute details of the soil were studied scientifically. On the basis of soil association, chemical quality, soil series, soil horizon and sub-order association were considered to arrive at scientific soil taxonomical classification.

In this study area four types of soil were found i.e. Older Alluvial soil, Medium Brown Loam, Deep Brown sandy soil, Medium red sandy soil. These different types of soil observed through the satellite imageries and field observation (Fig. 18.2).

18.2.3 Rainfall and Climate

The climate of study area can be classified as semiarid, tropical steppe and dry with very hot summer and cold winter except during monsoon. The region experienced four seasons in a year. The winter season starts after mid of November to last week or first week of March, the hot weather season starts from mid-March to the end of June, July to September the region experienced south west monsoon. The transition period from September to October forms the post-monsoon season. The region received its maximum rainfall in monsoon season. The normal monsoon of the region is 488 mm. and annual rainfall is 550 mm. The south west monsoon contributes about 88% of annual rainfall. July and August are the wettest months. The 12% rainfall received during non-monsoon period was due to the wake of western disturbances and thunderstorms. Generally the rainfall increases from south west to north east. The minimum temperature is experienced in month of January which is about 50 °C. Maximum temperature observed in May and June about 41 °C.

18.3 Data Sources and Methodology

18.3.1 Ancillary Data

To accomplish the study SOI toposheets, hydrological and rainfall data, soil map and Satellite data were being processed properly.

- SOI toposheets, (1:50,000) viz. 54 D/8)
- IRS P6 LISS III data:
- ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) downloaded from Internet from the following source: http://dds.cr.usgs.gov/astr/.
- Soil Resource Map of Rajasthan and Haryana (1:250,000), by NBSS & LUP (ICAR), Dept. of Agriculture, Govt. of India, 1992.
- Available ancillary and proto-type data published information.
- Historical monthly rainfall data for eleven years (1975–1995) has been collected from Investigation and Planning Division, I&WD, Govt. of Rajasthan, for the rain gauge stations located in the watershed and has been used to determine the mean precipitation (Table 18.3).

A software package called ArcGIS version 10.0 is used for this project. Arc Map is the primary application where the data is analyzed and processed. The two spatial data types used in this project these are vector and raster (ASTER) data sets. Vector data contain features defined by a point, line, or polygon. Vector data models are useful for storing and representing discrete features such as settlements and roads, vegetation area, agricultural land, waste land etc. ArcGIS implements vector data as shape files.

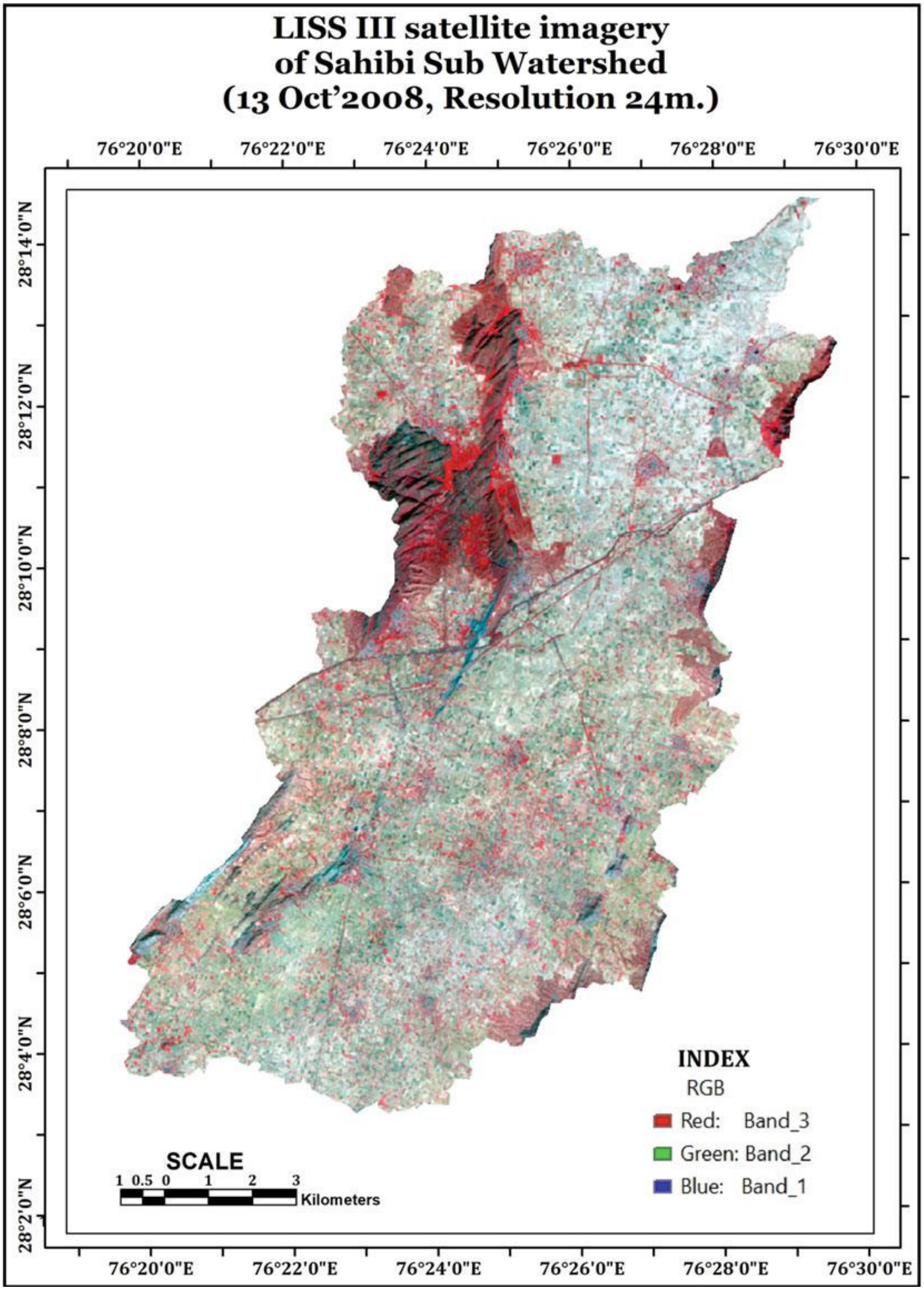

Fig. 18.2 Resource Sat-1 LISS III satellite imagery (13 Oct '2008, Resolution 24 m.) of Sahibi Sub-Watershed

Table 18.3 Satellite data information

Path–Row	Season (Date of pass)	
	Kharif	Ravi
95–051	13th October, 2008	21st January, 2008

18.3.2 Preparation and Discussion on Thematic Maps

Thematic layers help to define each element of the maps separately. We use ARCGIS 10 software for composing thematic layers. Development of Geographic Information Systems (GIS) closely follows advancements in computers. As computers can handle more data intensive operations, the use of GIS has also expanded to handle larger datasets. GIS are primarily used to process and display data having a spatial component. A flow chart is showing the work process for this study (Fig. 18.3).

18.3.2.1 Drainage, Watershed, and Surface Water Bodies

The Drainage map (Fig. 18.4) of the study area, i.e. Part of Sahibi Sub-Watershed, is prepared mainly using the Ravi season data. The streams are digitized, compared, and verified using the Kharif season data. The sub stream channel, main left bank tributaries are digitized, and name is given using the SOI toposheets in ArcGIS environment. Drainage lines are arranged according to order. Surface water bodies, like tanks, ponds are also marked (without zooming more than 1:35,000 scale) and vectorized as

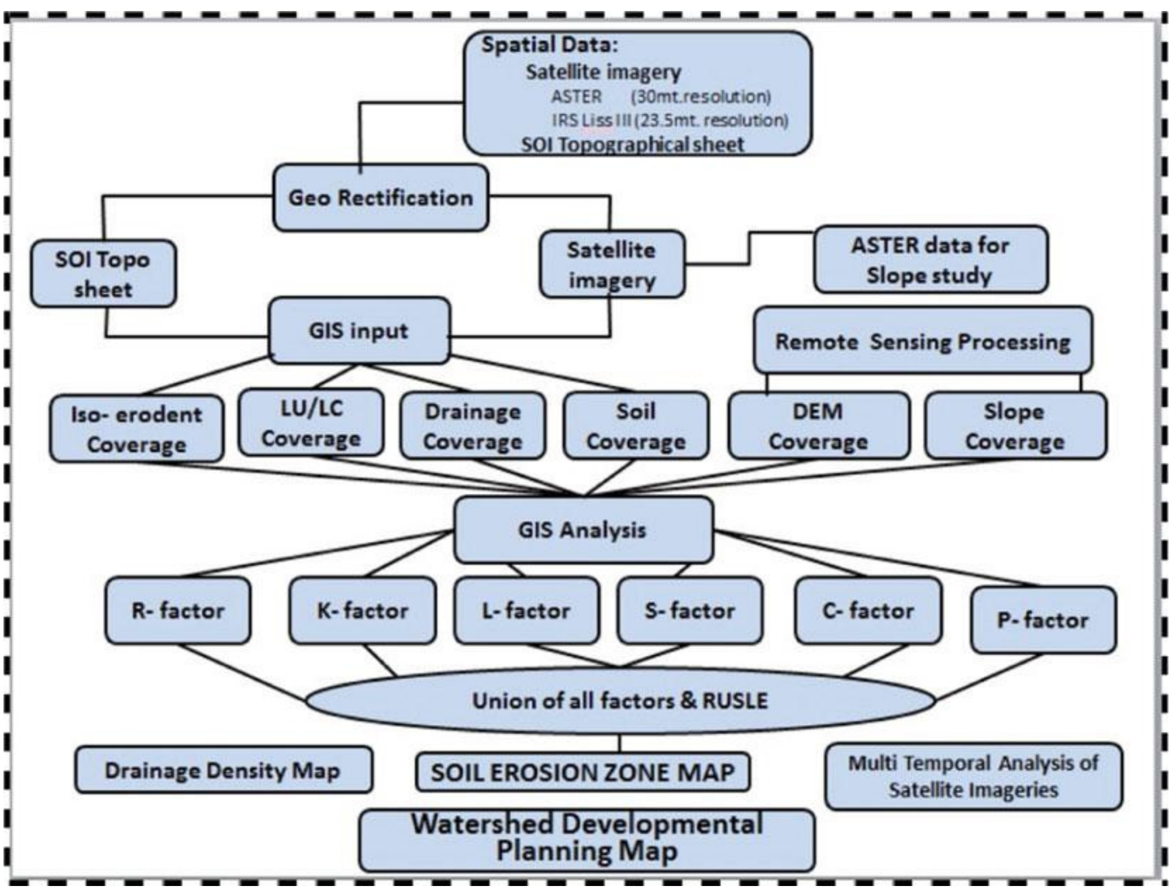

Fig. 18.3 Flow chart showing the methodology

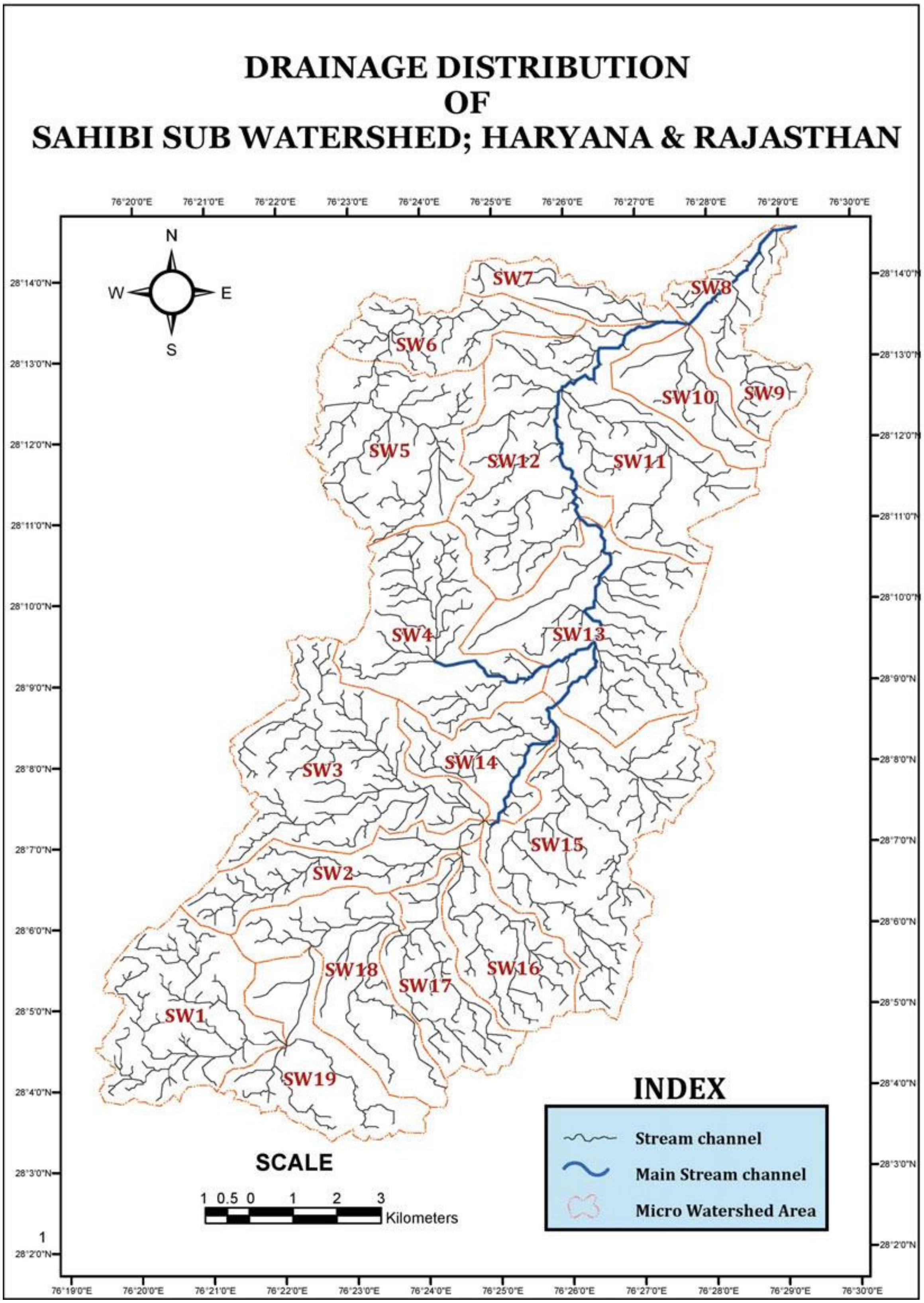

Fig. 18.4 Drainage map of Sahibi Sub-Watershed

polygons. The watershed is delineated. The ASTER data of the study area (in ASCII format) is rasterized. Then with the help of ArcGIS Spatial Analyst tools (Hydrology -fill-Flow Direction-Flow Accumulation) we extracted the drainage. Then with the help of watershed tools watershed boundary has been delineated.

The Sahibi Sub-watershed includes the Sahibi River which is an ephemeral rain-fed river, locally called SABI Nadi. It rises from Mewat hills near Jitgarh and Manoharpur close to Jaipur district in Rajasthan and after gathering volume from about a hundred tributaries, it reaches voluminous proportions, forming a broad stream around Alwar and Kotputli, it then enters the Rewari district in Haryana near the city of Rewari after which it enters Rajasthan again and then re-enters Haryana near village Jaithal. The Rewari district, except in its Eastern part is flat and sandy and absorbs all the rainwater (Dar et al. 2011). Total length of the stream channel is 509.51 km. The catchment area and length of the Sahibi Sub-Watershed have been found as 182.72 km^2. In the micro watersheds i.e. SW1, SW2, SW3, SW5, SW12, SW13, SW15, SW18 has high number of stream channels. Naodi, Rampura, Khundrot, Dhikwar villages are depends on SW1 micro watershed; Anandpur, Madhan villages are depends on SW2 micro watershed; Arind, Manglapur (Nayagaon) villages are depends on SW3 micro watershed; Manethi, Kund villages are depends on SW4 micro watershed; Khol, Ahrad SW5 micro watershed; Khaleta, Mayan SW7 micro watershed; Bas, Baturi villages are depends on SW8 micro watershed; Manmaria Ashpur villages are depends SW9 micro watershed; Manmaria Ahir, Manmaria Thethar, Nagra villages are depends on SW10 micro watershed; Gothra Tappa Khori, Pali villages are depends on SW11 micro watershed; Balwari, Nandha villages are depends on SW12 micro watershed; Bhalki village is depends on SW13; Mahtawas village is depends on SW14. Nangli, Chela Dungra, Giglana villages are depends on SW15 micro watershed; Chawadi, Nanagwas villages are depends on SW16 micro watershed; Dabarwas village is depends on SW17 micro watershed; Birnwas village is depends on SW19 micro watershed. So these settlements are dependent on the agricultural and other water need related activities on the above-mentioned micro watersheds. There are a very minimum number of surface water bodies, both natural and man-made.

18.3.2.2 Land Use/Land Cover

The land use/land cover map of the study area (Fig. 18.5 and Table 18.4) has been prepared with the help of SOI toposheets and Satellite Imageries (Pre and post monsoon data). The forest boundaries and network of roads and railway have been taken from SOI toposheets and incorporated in final map. The open forest area is identified and demarcated using the satellite imageries. Wastelands are also identified and digitized. Settlement with homestead orchards is identified from the Ravi season data. The name of the settlements is taken from SOI toposheets and added to the attribute table.

The land use pattern is a significant determinant of water availability and water use in any basin. The land in a watershed must be used for several purposes—crop and livestock production, housing roads, etc. The land can rarely be put to uses which will provide maximum or most desirable uses for watershed protection. Land use affects rates of runoff, infiltration and types and quality of vegetation cover. In response to that land use/land cover map (Fig. 18.6) is one of the most vital input in 'locale specific' land use planning procedure. The land use/landcover map is the spatial information of the physical and social cover types (i.e. both natural and cultural/anthropogenic) on the existing scenario (Andrade et al. 1988) in relation to hydro geomorphology (including rainfall/temperature), soil and socio-economic conditions of the area under consideration.

18.3.2.3 Soil/Land Capability Class

The study area, falling within eastern part of the Rajasthan and southern part of Haryana, is drawn in eye estimation from the soil map based on overlay method using Arc GIS software. Geo-referencing is done identifying sharp bends in railways, road crossing and place name with the

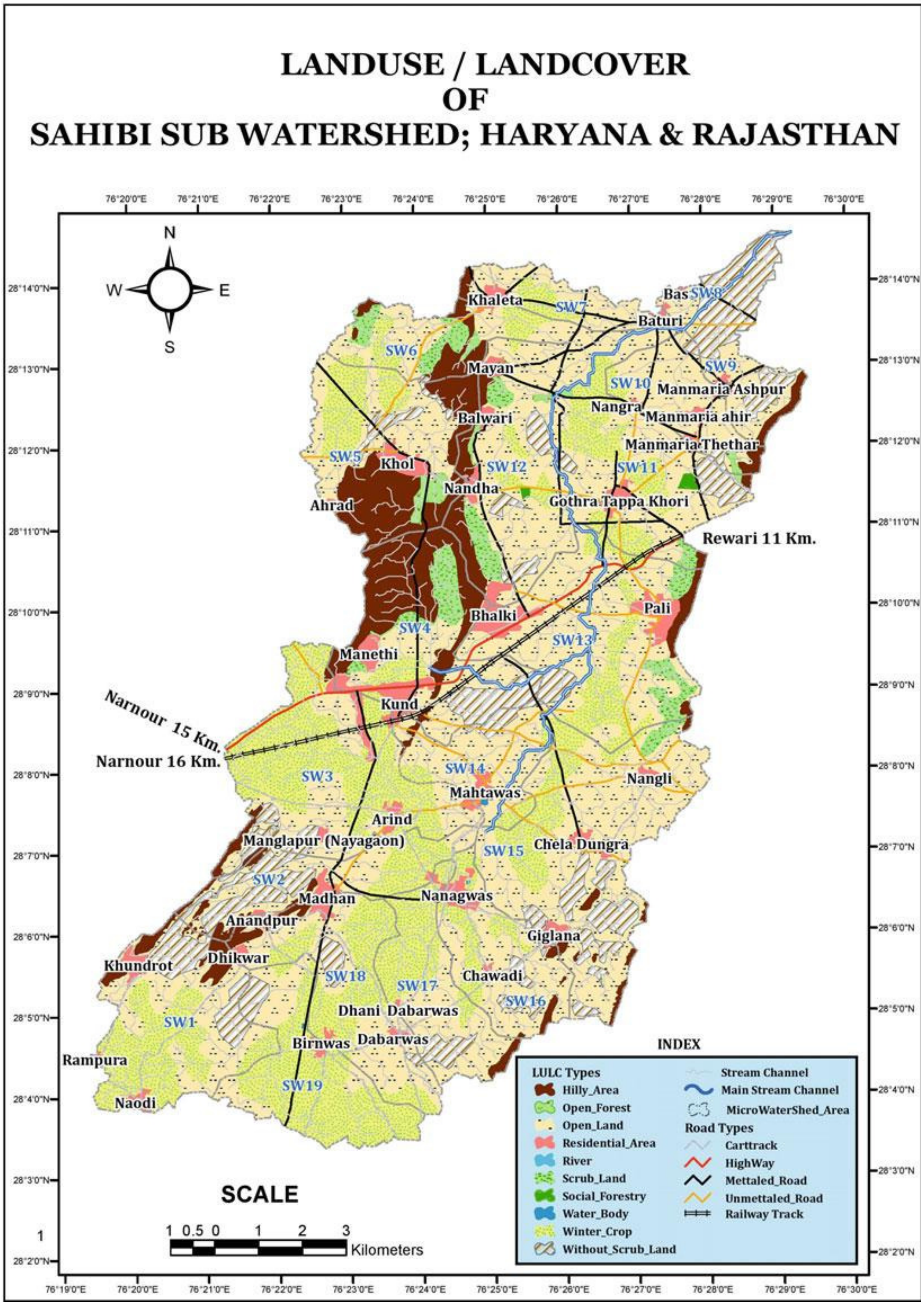

Fig. 18.5 Land use/land cover map of Sahibi Sub-Watershed

Table 18.4 Total area of different thematic layer

S. No.	Thematic layer name	Thematic layer area in km^2
1	Residential area	9.34
2	Land without scrub	16.88
3	Open forest	0.99
4	Agricultural area	48.85
5	Water body	0.06
6	Hilly area	16.36
7	Land with scrub	4.86
8	Open land	85.17
9	Social forestry	0.21
Total area		182.72

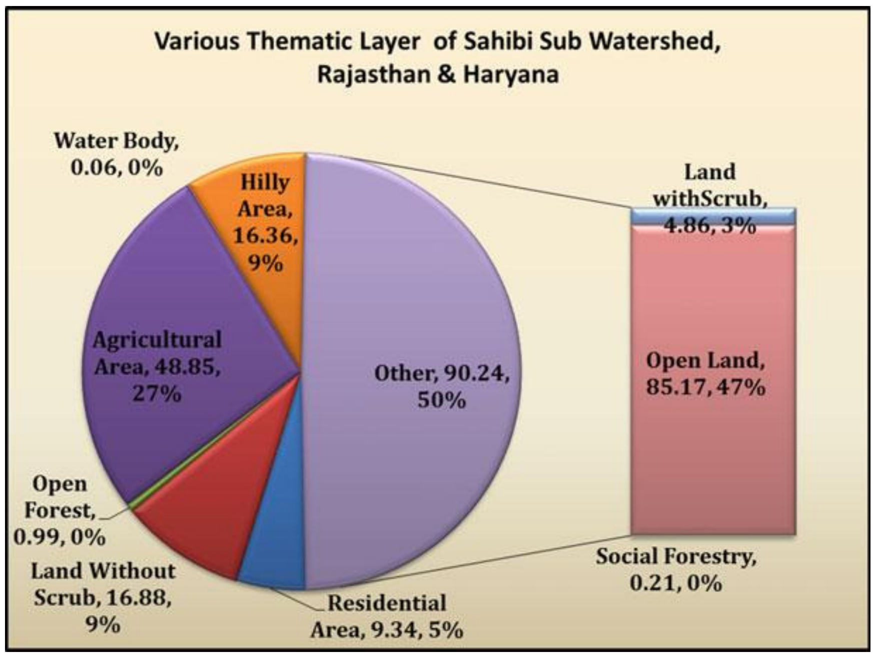

Fig. 18.6 Pie diagram showing the distribution of LU/LC coverage in percentage of Sahibi Sub-Watershed. *Source* The Soil Resource Map of Rajasthan and Haryana (1:250,000), by NBSS &LUP (ICAR)

help of SOI toposheets. Unique soil polygons falling under the study area is digitized, attribute table are filled with their taxonomic name and the soil map is prepared (Fig. 18.7).

Soils of the watershed determine the amount of water which will percolate and corrective measures which will be used. The soil character also determines the amount of silt which will be washed down into water harvesting structures and the valley below. Soils are recognized as 3-dimensional bodies on the landscape whose spatial distribution and variability are mainly controlled, among other features, by the geological and geomorphological factors by Jain and Das (2010). In fact, the soil's geographic distribution patterns could be identified more reliably from the association of geomorphic environments (cf. Zinck et al. 1990). The following categories of soil and corresponding land capability classes are identified within the study area. In these study areas four types of soil are found i.e. Older Alluvial soil, Medium Brown Loam, Deep Brown sandy soil, Medium red sandy soil. Among them the Medium Brown

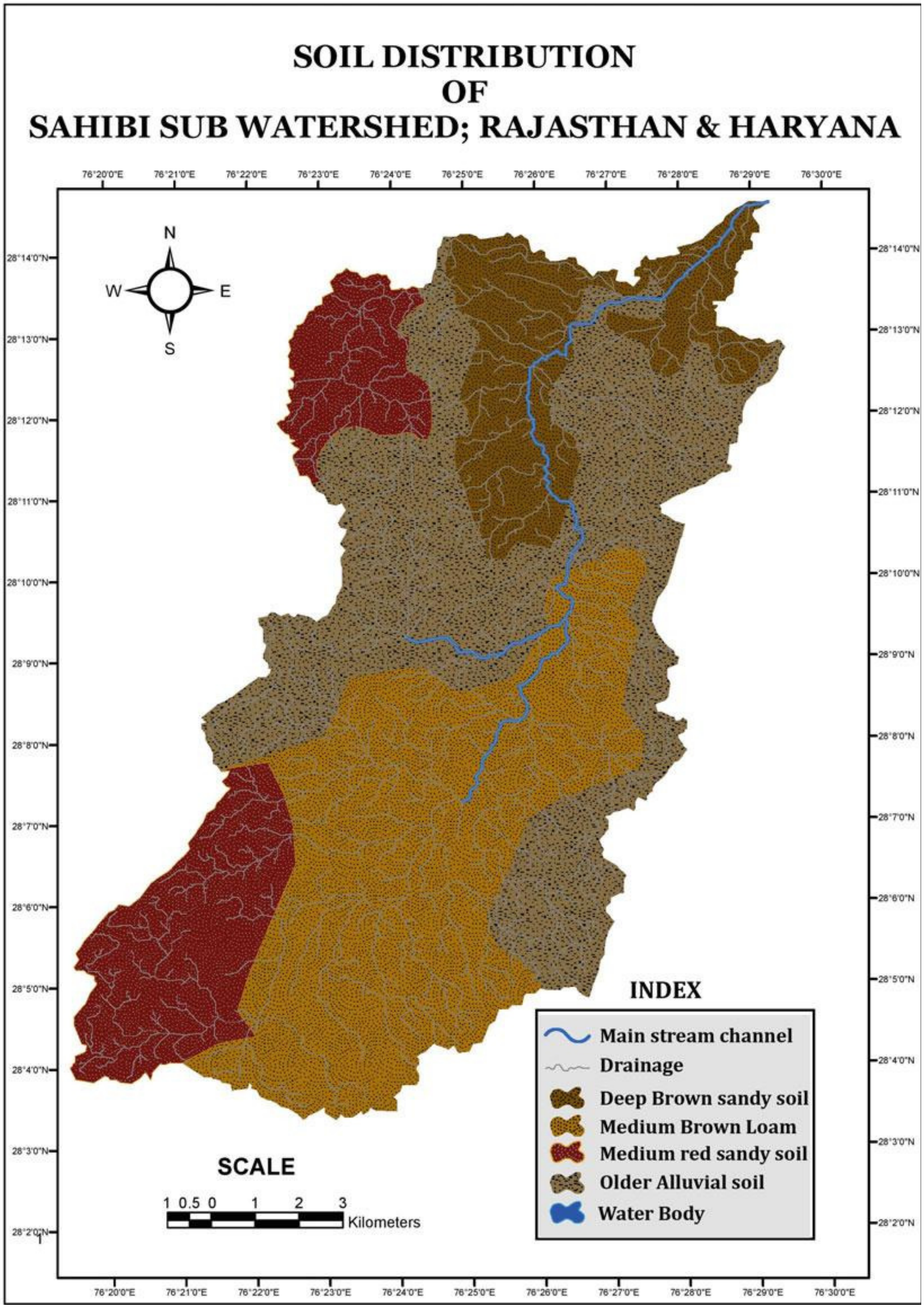

Fig. 18.7 Soil map of Sahibi Sub-Watershed

Table 18.5 Major soil categories define the 'K' value (Zinck et al. 1990)

S. No	Soil type	'K' factor
1	Older alluvial soil	0.2
2	Medium brown loam	0.23
3	Deep brown sandy soil	0.12
4	Medium red sandy soil	0.12

Table 18.6 Slope categories in study area. (NRSC, Hyderabad)

Slope categories	Percent of slope (%)
Uniform or low	0–5
Very gently sloping or moderate	5–20
Steep or high	20–35
Very steep or very high	35

Loam soil is highly fertile (Table 18.5). In this soil the agriculture is highly developed. In Older Alluvial soil, also rich in various fertility parameters as NPK (Nitrogen, Phosphorous, Potassium) and this soil area is less fertile comparatively to Medium Brown Loam soil, as a result some parts are under agriculture.

18.3.2.4 Slope Map

The ASTER (ASCII) data is rasterized. From 3D analyst tool, first we create Slope. The break values for the slope categories are given by NRSC guidelines (Table 18.6).

The slope categories identified in the study area, are:

Based on the slope categories as framed by NRSA (Table No: 5B) the slope (Fig. 18.8) of the study area could be divided into the following major groups:

I. The undulating/rolling topography of the area, characterized by uniform very gentle slope (0.1 and 1–5%) is very clearly depicted in the study area, almost the whole region falls in this category except the north-western and south west part; south-eastern, and north-eastern part of the study area.
II. The dissected hill (472 m) complex, shows the existence of various slope classes varying from very gentle (1–3%) to very steep (> 35%) in accordance with terrain units.
III. Scattered isolated hillocks are present in the western and eastern part of the study area.

18.3.3 Universal Soil Loss Equation (USLE)

The USLE is combined with the ArcGIS to estimate average annual soil loss (A) that is occurring in the Sahibi Watershed. Raster layers corresponding to each of the six USLE factors are created, stored, and analyzed with the ArcGIS. This combination computes the estimated soil erosion potential for the entire watershed and areas of high soil erosion potential were identified. The grid cells in each layer overlap and the USLE computation can be done by multiplying all the USLE factors. The DEM serves as the primary input for calculating the Slope Length and Slope Steepness factors (LS-factors). The R factor map is derived from the USLE standard value (Wischmeier and Smith 1978; Renard et al. 1991) which developed rainfall erosivity factor values for Sahibi Sub-Watershed. The Soil Loss Prediction is also done using Revised Universal Soil Loss Equation (RUSLE) in ArcGIS environment. The slope length and slope steepness factors were interrelated. The LS factors, R factor, K factor, C factor, and P factor were being made for performing RUSLE model (Table 18.7).

18.3.3.1 Modeling Soil Detachment with RUSLE in GIS Environment

The Universal Soil Loss Equation is an empirical equation designed for the computation of average

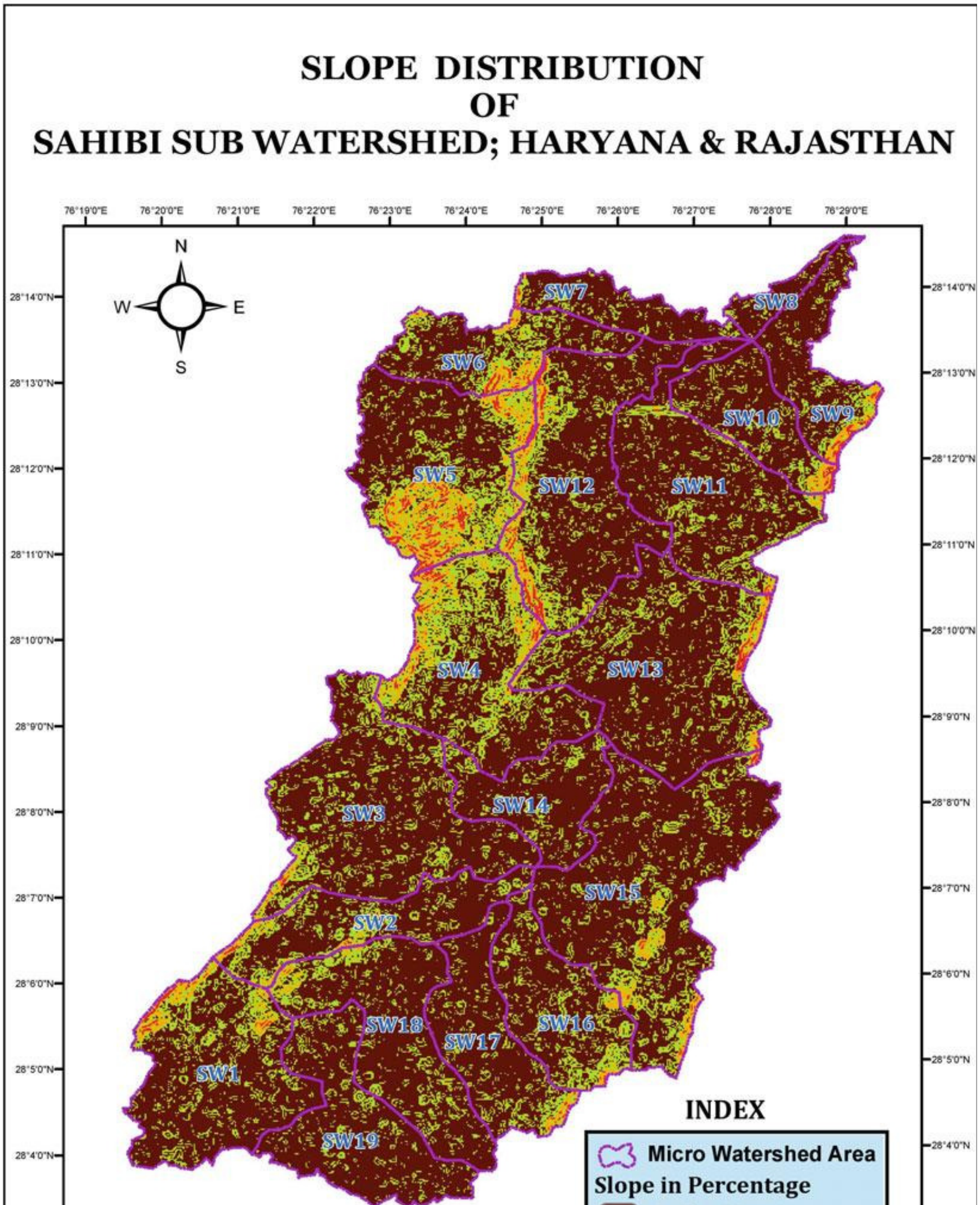

Fig. 18.8 Slope map of Sahibi Sub-Watershed

Table 18.7 USLE factor source description

USLE factor	Derived from	Source description
Slope length (L factor)	30 m Aster DEM* of Sahibi	http://dds.cr.usgs.gov/astr/
Slope steepness (S factor)	30 m DEM* of Sahibi	http://dds.cr.usgs.gov/astr/
Rainfall erosivity (R factor)	Morgan (1986)	https://doi.org/10.4236/as.2020.118043
Soil erodibility (K factor)	NBSS & LUP	http://eusoils.jrc.ec.europa.eu/esdb_archive/eudasm/asia/lists/k7_cin.htm
Vegetation cover (C factor)	Department of Agriculture, Govt. of India	http://agriharyana.nic.in/fert_rewari.htm
Prevention practices (P factor)	Reclassified DEM	NRSC, Dept. of Space, Govt. of India

soil loss in agricultural fields. Five major factors (Table 18.7) were used to calculate the soil loss for a given site. Each factor is the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location. The erosion values reflected by these factors can vary considerably due to varying weather conditions. Therefore, the values obtained from the USLE more accurately represent long-term averages.

18.3.3.2 Factors Used in Erosion Equations in USLE Model

Five major factors are used to calculate the soil loss for a given site. Each factor is the numerical estimate of a specific condition that affects the severity of soil erosion at a particular location. The erosion values reflected by these factors can vary considerably due to varying weather conditions. Therefore, the values obtained from the USLE more accurately represent long-term averages.

$$\text{Universal Soil Loss Equation (USLE)}, A = R \times K \times \text{LS} \times C \times P \tag{18.1}$$

'*A*' represents the potential long-term average annual soil loss in tons per acre per year. This is the amount, which is compared to the 'tolerable soil loss' limits; *K* is the soil erodibility factor. It is the average soil loss in tons/acre per unit area for a particular soil in cultivated, continuous fallow with an arbitrarily selected slope length of 72.6 ft. and slope steepness of 9%. *K* is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. Texture is the principal factor affecting *K*, but structure, organic matter and permeability also contribute.

LS is the slope length-gradient factor. The LS factor represents a ratio of soil loss under given conditions to that at a site with the 'standard' slope steepness of 9% and slope length of 72.6 feet. The steeper and longer the slope, the higher is the risk for erosion. LS factor was used in USLE computation (2).

$$\text{LS} = [0.065 + 0.0456(\text{slope})] + 0.006541(\text{slope})2] \times (\text{slope\_length} \div \text{const})\text{NN} \tag{18.2}$$

where, slope = slope steepness (%); slope length = length of slope (ft.); constant = 72.5 Imperial or 22.1 metric; NN = (as per Morgan 1981).

C is the crop/vegetation and management factor. It is used to determine the relative effectiveness of soil and crop management systems in terms of preventing soil loss. The *C* factor is a ratio comparing the soil loss from land under a specific crop and management system to the corresponding loss from continuously fallow and tilled land. The *C* factor can be determined by selecting the crop type and tillage method that corresponds to the field and then multiplying these factors together. The *C* factor resulting from this calculation is a generalized C factor value for a specific crop that does not account for crop rotations or climate and annual rainfall distribution for the different agricultural regions of the country. This generalized C factor, however, provides relative numbers for the different cropping and tillage systems; thereby helping you weigh the merits of each system. P is the support practice factor. It reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. The P factor represents the ratio of soil loss by a support practice to that of straight row farming up and down the slope. The most commonly used supporting cropland practices are Up and Down slope cultivation, contour farming and strip-cropping.

18.3.3.3 RUSLE

Revised USLE (RUSLE) uses the same empirical principles as USLE, however it includes numerous improvements, such as monthly factors, incorporation of the influence of profile convexity/concavity using segmentation of irregular slopes by Adediji et al. (2010), improved empirical equations for the computation of LS factor (Foster and Wischmeier1974; Renard et al. 1991).

LS factor modified for complex terrain to incorporate the impact of flow convergence, the hillslope length factor was replaced by upslope contributing area 'A' (Moore and Burch 1996; Mitasova et al. 1995, 1996; Desmet and Govers 1996). The modified equation for computation of the LS factor in GIS in finite difference form for erosion in a grid cell representing a hillslope segment was derived by Desmet and Govers (1996). A simpler, continuous form of equation for computation of the LS factor at a point $r = (x, y)$ on a hillslope, (Mitasova et al. 1996) is

$$\mathrm{LS}(r) = (m+1)[A(r)/a0]m[\sin b(r)/b0]n \tag{18.3}$$

where, A[m] is upslope contributing area per unit contour width, b [deg] is the slope, m and n are parameters, and $a0 = 22.1$ m = 72.6ft is the length and b0 = 0.09 = 9% = 5.16 deg is the slope of the standard USLE plot. According to RUSLE modifications, the upslope area better reflects the impact of concentrated flow on increased erosion. It has been shown that the values of $m = 0.6$, $n = 1.3$ give results consistent with the RUSLE LS factor for slope lengths < 100 m and slope angles < 14 deg (Moore and Wilson 1992), for slopes with negligible tangential curvature. Exponent m and n can be calibrated if the data are available for a specific prevailing type of flow and soil conditions. Both the standard and modified equations can be properly applied only to areas experiencing net erosion. Depositional areas should be excluded from the study area because the model assumes that transport capacity exceeds detachment capacity everywhere and erosion and sediment transport is detachment capacity limited. Therefore, direct application of USLE/RUSLE to complex terrain within GIS is rather restricted. The results can also be interpreted as an extreme case with maximum spatial extent of erosion possible. The direction of steepest descent from each cell center to the next closest neighboring cell center is called the FLOWDIRECTION.

18.4 Result and Discussion

18.4.1 Drainage Density

Drainage Density Map (Fig. 18.9), defined as the ratio of the total length of all streams of the catchment divided by its area, indicates the drainage efficiency of the basin. The higher the value, quicker is the runoff and lesser is the infiltration and other losses. Thus, drainage density, $Dd = Ls/A$ [where, Ls = total length of all streams in m; A = Area of the basin in km^2.]. For the study area, Dd = 2807.06. The catchment area and length of the Sahibi Sub-Watershed have been found as 182.72 km^2. The micro watersheds i.e. SW1, SW2, SW3, SW4, SW5, SW6, SW7, SW8, SW9, SW12, SW13, SW15, SW16, and SW17 are attributed with high and very high in drainage density. Naodi, Rampura, Khundrot, Dhikwar villages depend on SW1 micro watershed; Anandpur, Madhan villages depend on SW2 micro watershed; Arind,

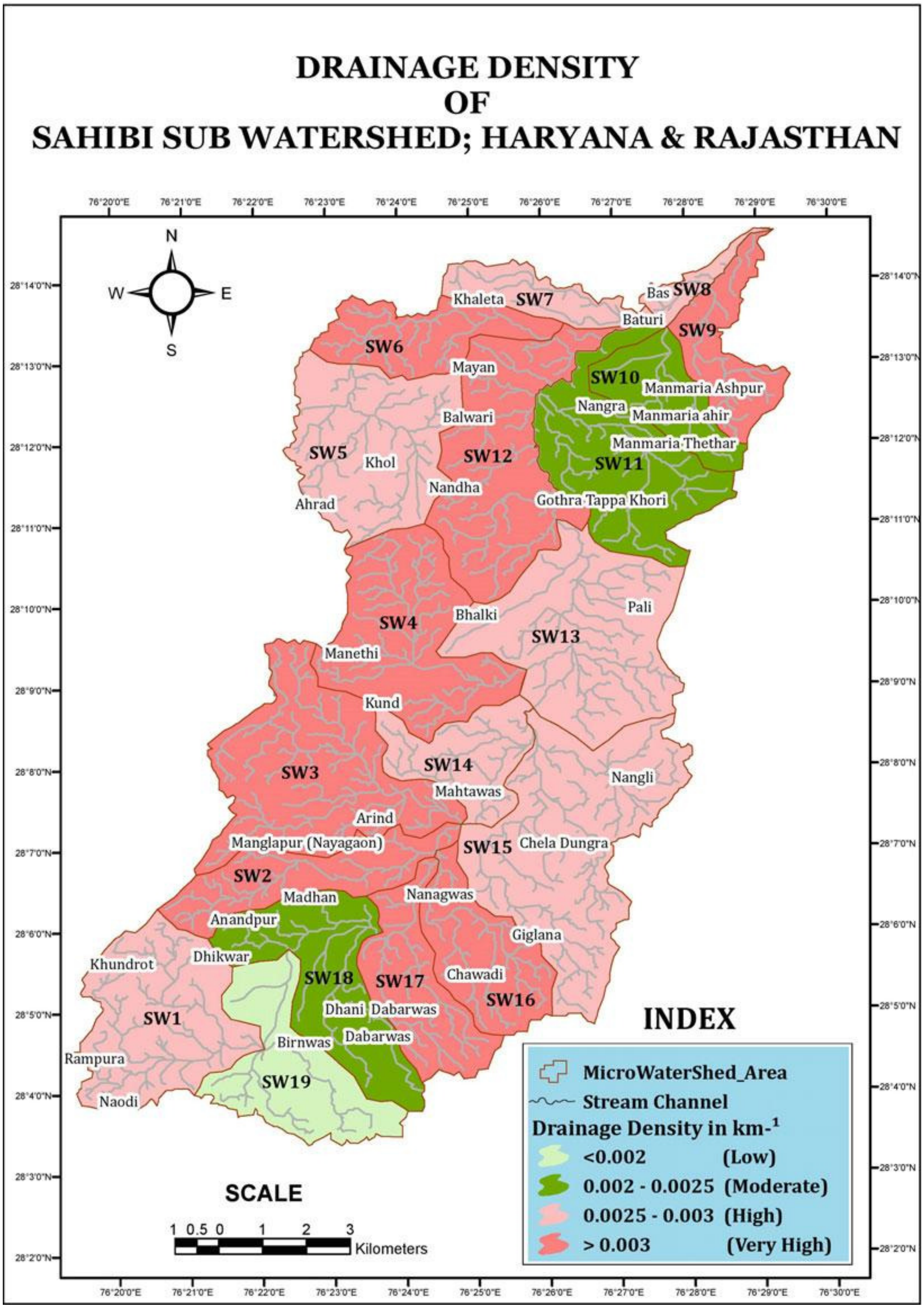

Fig. 18.9 Drainage density map of Sahibi Sub-Watershed

Manglapur (Nayagaon) villages depend on SW3 micro watershed; Manethi, Kund villages depend on SW4 micro watershed; Khol and Ahrad on SW5 micro watershed; Khaleta and Mayan on SW7 micro watershed; Bas, Baturi villages on SW8 micro watershed; Manmaria Ashpur villages depend on SW9 micro watershed; Manmaria Ahir, Manmaria Thethar, Nagra villages depend on SW10 micro watershed; Gothra Tappa Khori, Pali villages depend on SW11 micro watershed; Balwari, Nandha villages on SW12 micro watershed; Bhalki village on SW13; Mahtawas village on SW14. Nangli, Chela Dungra, Giglana villages on SW15 micro watershed; Chawadi, Nanagwas villages on SW16 micro watershed; Dabarwas village on SW17 micro watershed; Birnwas village on SW19 micro watershed. So these settlements are dependent on the agricultural and other water need related activities on the above-mentioned micro watersheds. Soil erosion basically depends on drainage density where the drainage density is high or very high there should be more erosion. Where the drainage density is low there should be less erosion. The areas have been facing more problem regarding soil erosion are Anandpur, Madhan Arind, Manglapur (Nayagaon) Manethi, Kund, Manmaria, Ashpur, Balwari, Nandha, Bhalki, Mahtawas, Dabarwas, Nangli, Chela Dungra, Giglana, Chawadi, and Nanagwas.

18.4.2 Discussion of USLE and RUSLE Method in Respect of Drainage Density

With the help of USLE and RUSLE methods, the maximum and minimum soil loss zones by Kouli et al. (2009), according to the five factor as (*R**[*K*]*[*C*]*[*P*]*[lsfac]) were prioritized. All the elements of USLE model are interlinked with each other. As example increasing drainage density (Ganapuram et al. 2009) define the increasing soil erosion. On the other hand, areas covered with the vegetation experiences less soil loss viz. SW1, SW2 etc. (Table 18.12).

With the help of USLE and RUSLE method derived from the "Soil Erosion and Conservation, 3rd edition 2009" (Morgan), the study estimated soil loss Ton/ hac./year, and results were categorized in four sub classes viz. low, moderate, high, very high of the study area (Fig. 18.10). Naodi, Rampura, Khundrot, Dhikwar villages under SW1 micro watershed, Madhan villages under SW2 micro watershed, Anandpur; Arind, Manglapur (Nayagaon) villages under SW3 micro watershed, Khaleta, Mayan is under SW7 micro watershed; Bas, Baturi villages under SW8 micro watershed; Manmaria Ashpur villages under SW9 micro watershed; Manmaria Ahir, Manmaria Thethar, Nagra villages under SW10 micro watershed; Balwari, Nandha villages under SW12 micro watershed; Mahtawas village under SW14 micro watershed; Birnwas village under SW19 micro watershed falls in low to moderate level soil erosion zones.

Manethi, Kund villages under SW4 micro watershed; Khol, Ahrad under SW5 micro watershed; Gothra, Tappa, Khori, Pali villages under SW11 micro watershed; Bhalki village under SW13; Nangli, Chela Dungra, Giglana villages under SW15 micro watershed; Chawadi, Nanagwas villages under SW16 micro watershed; Dabar was village under SW17 micro watershed falls in the high and very high soil erosion category due to the high drainage density and low land use/landcover cover. Slope steepness is a very prominent factor for the soil loss. So these areas should be provided more attention for the watershed development (Fig. 18.9; Tables 18.8 and 18.9).

The relational micro watershed map has been prepared based on LU/LC categories (%) and Soil Loss Zone categories (Table 18.11; Fig. 18.11). In SW1, there is no open forest, no social forestry, no scrub land whereas agriculture is predominant. In land without scrub (13.76%) effect the upper surface of the land which caused soil erosion. The severe soil effected areas are under the SW1, SW3, SW4, SW5, SW10, SW13, and SW15 (Tables 18.9, 18.10 and 18.11).

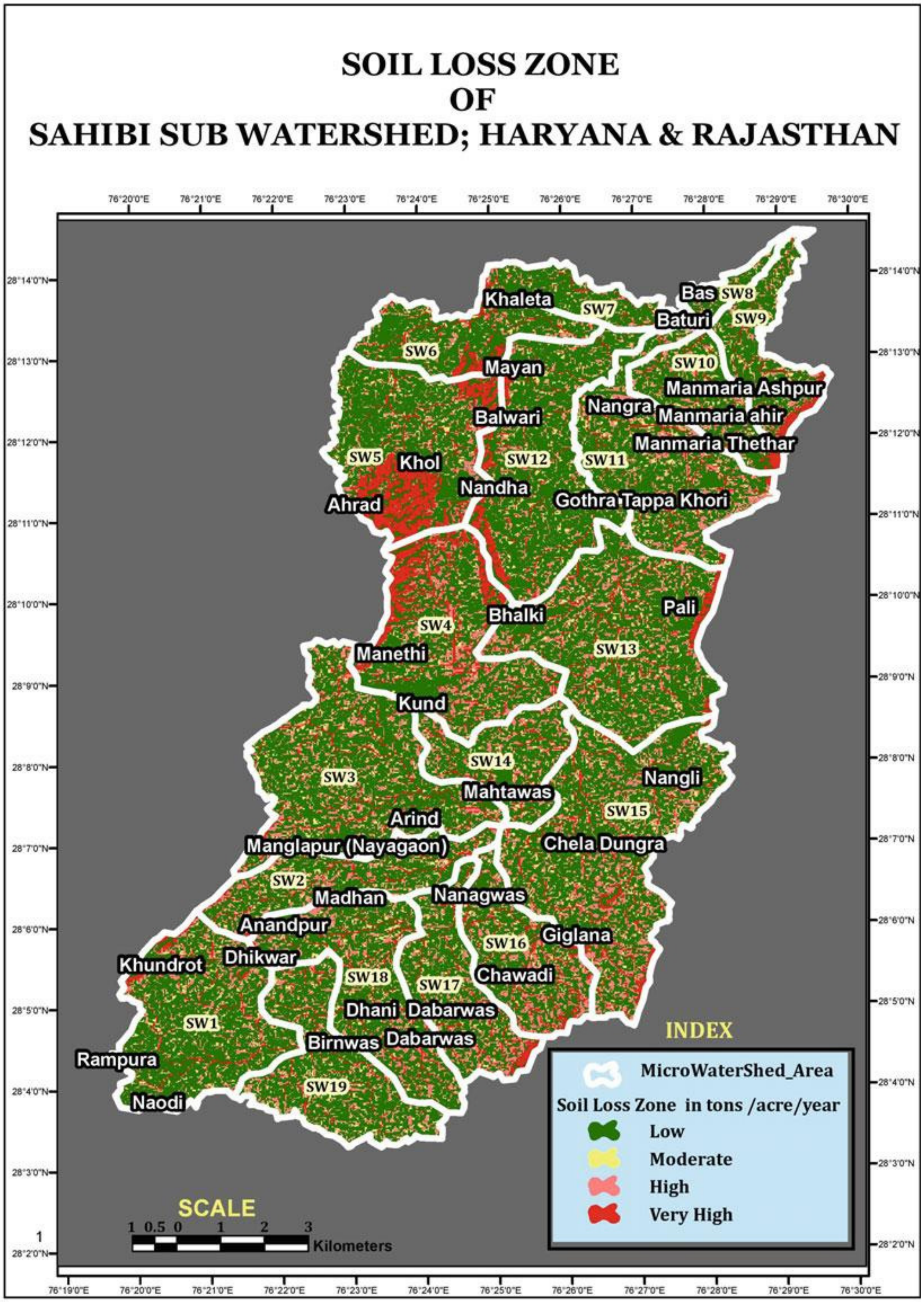

Fig. 18.10 Soil loss zone of Sahibi Sub-Watershed

Table 18.8 Micro watershed wise distribution of different soil loss zone categories related with drainage density

Watershed name	Soil loss types	Area in km^2	Total area affected in km^2	Area affected in SMW (%)	Drainage density
SW1	Low	8.06	12.04	67.0	0.0029
	Moderate	1.21		10.1	
	High	2.00		16.6	
	Very high	0.77		6.4	
SW2	Low	4.30	7.15	60.1	0.0030
	Moderate	0.71		9.9	
	High	1.66		23.2	
	Very high	0.48		6.7	
SW3	Low	9.90	15.78	62.7	0.0032
	Moderate	1.67		10.6	
	High	3.33		21.1	
	Very high	0.88		5.6	
SW4	Low	7.00	12.68	55.2	0.0030
	Moderate	0.79		6.2	
	High	2.68		21.1	
	Very high	2.22		17.5	
SW5	Low	7.24	12.36	58.6	0.0027
	Moderate	0.80		6.4	
	High	1.68		13.6	
	Very high	2.64		21.3	
SW6	Low	4.11	6.25	65.8	0.0030
	Moderate	0.54		8.6	
	High	0.88		14.1	
	Very high	0.72		11.5	
SW7	Low	2.69	3.69	72.8	0.0029
	Moderate	0.34		9.2	
	High	0.49		13.2	
	Very high	0.18		4.8	
SW8	Low	0.94	1.36	69.1	0.0024
	Moderate	0.17		12.4	
	High	0.21		15.3	
	Very high	0.04		3.3	
SW9	Low	3.25	5.18	62.8	0.0033
	Moderate	0.55		10.6	
	High	0.89		17.1	
	Very high	0.49		9.5	
SW10	Low	3.33	5.23	63.6	0.0020
	Moderate	0.51		9.7	
	High	1.03		19.7	

(continued)

Table 18.8 (continued)

Watershed name	Soil loss types	Area in km^2	Total area affected in km^2	Area affected in SMW (%)	Drainage density
	Very high	0.37		7.1	
SW11	Low	7.00	11.48	61.0	0.0023
	Moderate	1.30		11.3	
	High	2.46		21.5	
	Very high	0.71		6.2	
SW12	Low	9.52	14.04	67.8	0.0030
	Moderate	1.30		9.2	
	High	1.92		13.7	
	Very high	1.31		9.3	
SW13	Low	10.07	15.89	63.3	0.0027
	Moderate	1.55		9.7	
	High	3.20		20.1	
	Very high	1.08		6.8	
SW14	Low	3.71	5.99	62.0	0.0029
	Moderate	0.60		10.0	
	High	1.35		22.5	
	Very high	0.34		5.7	
SW15	Low	11.04	19.75	59.4	0.0029
	Moderate	3.30		10.0	
	High	4.35		23.4	
	Very high	1.33		7.2	
SW16	Low	4.22	7.27	58.0	0.0030
	Moderate	0.61		8.4	
	High	1.82		25.1	
	Very high	0.62		8.5	
SW17	Low	4.38	7.22	60.7	0.0031
	Moderate	0.73		10.2	
	High	1.58		21.9	
	Very high	0.53		7.3	
SW18	Low	6.45	10.34	62.3	0.0022
	Moderate	1.08		10.5	
	High	2.15		20.8	
	Very high	0.66		6.4	
SW19	Low	5.74	9.02	63.7	0.0017
	Moderate	1.14		12.6	
	High	1.71		18.9	
	Very high	0.43		4.8	
Total soil loss affected areas (km^2)				182.72	

Table 18.9 Relational analysis table between drainage density, slope and soil loss zone

Micro watershed name	Drainage density in m^2	Soil loss zone in km^2	Slope weightage
SW1	0.0029	12.04	1
SW2	0.0020	7.15	1
SW3	0.0023	15.78	1
SW4	0.0030	12.68	3
SW5	0.0027	12.36	3
SW6	0.0029	6.25	2
SW7	0.0029	3.69	1
SW8	0.0030	1.36	1
SW9	0.0031	5.18	2
SW10	0.0022	5.23	2
SW11	0.0017	11.48	2
SW12	0.0030	14.04	2
SW13	0.0032	15.89	2
SW14	0.0030	5.99	1
SW15	0.0027	18.59	2
SW16	0.0030	7.27	3
SW17	0.0029	7.22	2
SW18	0.0024	10.34	1
SW19	0.0033	9.02	1

Table 18.10 Showing total soil loss zone area in km^2

Soil loss zone category	Total area in km^2
Low	112.93
Moderate	18.62
High	35.37
Very high	15.8
Total area	182.72

18.4.2.1 Prioritization of Watershed Developmental Planning

Prioritization (Biswas et al. 1999) means the evaluation of the whole matter in different categories (Table 18.12) as on priority basis. High priority means, the areas are falling in the category which is highly needed for recovery. In the study, areas having high soil erosion prone have been given more weightage and vice-versa.

Prioritization of Watershed Development planning map has been prepared for identifying the extremely needed treatment areas.

I. Find out the mostly affected villages in the Sahibi Sub-Watershed due to the soil loss.
II. Prepared a map related to LU/LC coverage and soil loss.

A Prioritization Map has been prepared for the Watershed development plan which reveals the areas that require high priority for soil conservation. In Sahibi Sub-Watershed, different weightage is given according to the settlements present in the specific micro watershed. For high density population weightage given as '3', for moderate density it is given '2' and in the low

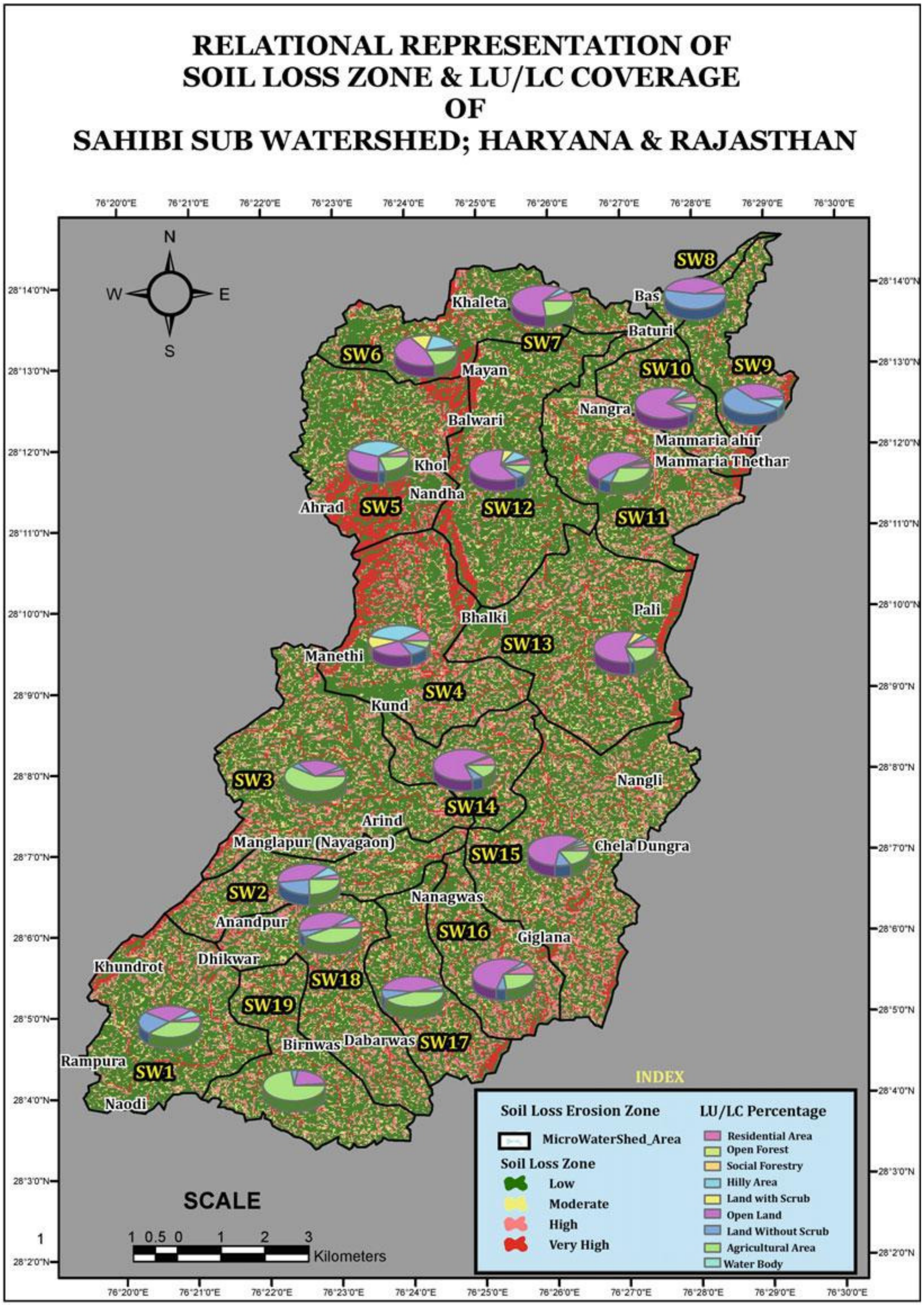

Fig. 18.11 Relation between soil loss zone and LU/LC coverage (%) Map of Sahibi Sub-Watershed

Table 18.11 Micro watershed based LU/LC distribution in percentage (%)

Watershed names	Name of the villages	SW Area in km^2	Residential area	Open forest	Social forest	Hilly area	Scrub land	Open land	Land without scrub	Agriculture	Waterbody
SW 1	Naodi, Rampura, Khundrot, Dhikwar	12.26	4.42	Nil	Nil	6.88	Nil	33.17	13.76	41.69	Nil
SW 2	Anandpur, Madhan,	7.15	3.78	Nil	Nil	8.11	Nil	40.14	23.36	24.48	Nil
SW 3	Arind, Manglapur (Nayagaon)	15.82	5.12	Nil	Nil	2.65	Nil	29.01	4.8	58.41	Nil
SW 4	Manethi, Kund,	12.7	8.98	Nil	Nil	37.32	9.76	27.64	10.55	5.67	Nil
SW 5	Khol, Ahrad	12.47	4.75	4.19	Nil	35.86	Nil	30.54	4.83	19.82	Nil
SW 6	-	6.27	1.75	1.75	Nil	16.19	15.47	45.45	0.32	18.34	Nil
SW 7	Khaleta, Mayan	3.83	8.04	Nil	Nil	4.29	Nil	64.88	Nil	22.79	Nil
SW 8	Bas, Baturi	1.39	5.76	Nil	Nil		Nil	41.01	52.52	Nil	0.72
SW 9	Manmaria Ashpur,	5.44	2.25	Nil	Nil	7.49	Nil	35.77	54.31	Nil	0.19
SW 10	Manmaria ahir, Manmaria Thethar, Nagra	5.35	6.67	2.1	Nil	4.57	Nil	77.33	4.19	5.14	Nil
SW 11	Gothra Tappa Khori, Pali	11.57	3.63	0.69	1.12	1.3	1.99	52.9	7.69	30.68	Nil
SW 12	Balwari, Nandha,	14.04	4.99	1.21	0.57	9.26	7.26	63.03	6.13	7.55	Nil
SW 13	Bhalki	15.47	8.68	Nil	Nil	3.49	6.85	62.18	3.43	18.42	Nil
SW 14	Mahtawas	5.99	6.51	1.5	Nil		Nil	72.62	6.84	12.02	0.33
SW 15	Nangli, Chela Dungra, Giglana	18.84	3.34	Nil	Nil	2.6	2.12	63.69	11.52	16.72	Nil
SW 16	Chawadi, Nanagwas	7.31	8.49	Nil	Nil	3.29	Nil	57.95	7.26	23.01	Nil
SW 17	Dabarwas	7.31	1.78	Nil	Nil	2.87	Nil	43.64	7.39	44.32	Nil
SW 18	-	10.37	6.65	Nil	Nil	4.4	Nil	40.98	5.4	42.43	Nil
SW 19	Birnwas	9.15	1.42	Nil	Nil		Nil	20.77	4.92	72.9	Nil

Table 18.12 Sahibi Sub-Watershed prioritization for management plan by weightage rank method

Micro-watershed names	Name of the villages	Weightage
SW 1	Naodi, Rampura, Khundrot, Dhikwar	3
SW 2	Anandpur, Madhan,	2
SW 3	Arind, Manglapur (Nayagaon)	2
SW 4	Manethi, Kund,	2
SW 5	Khol, Ahrad	2
SW 6	–	0
SW 7	Khaleta, Mayan	2
SW 8	Bas, Baturi	2
SW 9	Manmaria Ashpur,	2
SW 10	Manmaria ahir, Manmaria Thethar, Nagra	3
SW 11	Gothra Tappa Khori, Pali	3
SW 12	Balwari, Nandha,	2
SW 13	Bhalki	1
SW 14	Mahtawas	1
SW 15	Nangli, Chela Dungra, Giglana	2
SW 16	Chawadi, Nanagwas	2
SW 17	Dabarwas	1
SW 18	–	0
SW 19	Birnwas	1

density it is given ‘1’ (Table 18.12). In this way, a relational map of Soil Loss Zone and LU/LC coverages for a better result of the study area i.e. Sahibi Sub-Watershed has been developed (Fig. 18.11).

18.4.2.2 Prioritization of Watershed Developmental

The study found out areas having high population density where priority should be provided for soil conservation in Sahibi Sub-Watershed. Due to surface runoff, the upper surface layer of agricultural field is washed out which affects the fertility of soil and agricultural production.

As a result indirectly this process hit the social development as well as economic growth of the area. According to our study Naodi, Rampura, Khundrot, Dhikwar, Mangalpur, Arind, Manmariya Ashpur, Manmaria Ahir, Nangli, Chela Dungra and Giglana villages will need soil Erosion treatment as soon as possible (Fig. 18.12). We should apply some soil conservation techniques for those areas such as terrace farming, contour bunding farming, rotational crop farming etc.

18.5 Conclusion

Here an attempt has been made to prioritize the Sahibi Sub-watershed for the proper development at watershed level planning using USLE and RUSLE model, RS and GIS. The correlational analysis between drainage density, LU/LC coverage and slope steepness helped to determine the high to low soil loss zones. The USLE calculates long-term average annual soil loss by multiplying six specific factors such as rainfall, soil types, slope, and vegetation cover which describes the watershed characteristics. GIS was used to store the USLE factors as individual digital layers and multiplied together to create a soil erosion potential map of Sahibi Sub-Watershed. At the final stage, the Watershed developmental priority

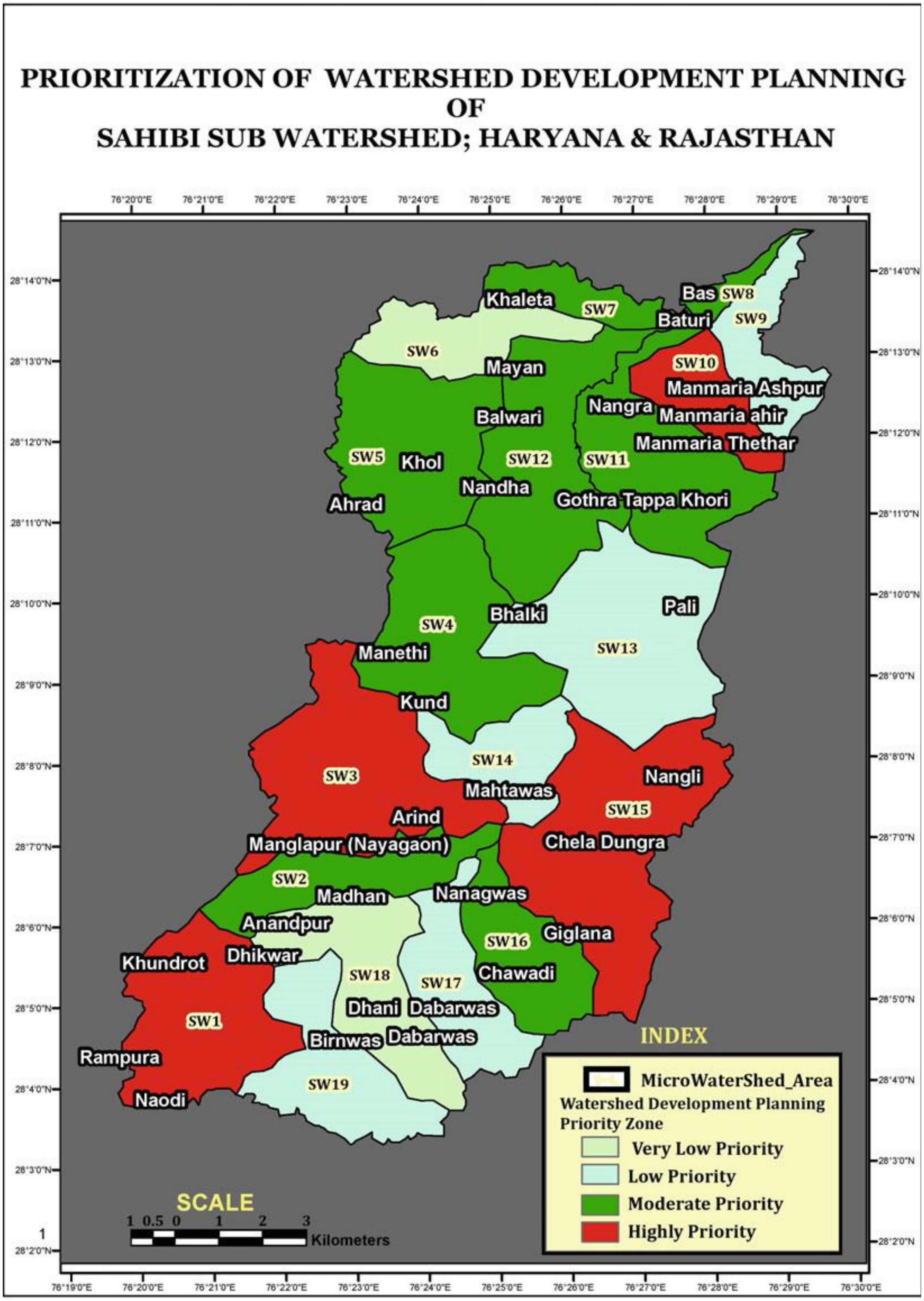

Fig. 18.12 Prioritization of watershed developmental planning map of Sahibi Sub-Watershed

map has been prepared and it revealed the most vulnerable soil erosion prone areas as well. The villages i.e. Naodi, Rampura, Khundrot, Dhikwar, Mangalpur, Arind, Manmariya Ashpur, Manmaria Ahir, Nangli, Chela Dungra and Giglana needs soil erosion treatment immediately. Some soil conservation techniques are to be applied for preserving the land resources i.e. terrace farming, contour bunding farming, rotational crop farming etc.

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