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SOIL VULNE*RABI*LITY MODEL IN BIST DOAB: PUNJAB (INDIA)

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Abstract

The present work attempts to interpret the soil vulne*Rabi*lity of Bist Doab in Punjab. Bist Doab is an agrarian region and all productions are depended on the condition of soil. Changing land use pattern like encroachment for agriculture, settlementsand intensification in agriculture has led to soil erosion in the state. Bist Doab is mostly composed by alluvial plains capped by Siwalik Hills and its foot hills. Siwalik Hills one of the youngest mountain range of Great Himalayan mountain ranges and foot hills of Siwalik is well known as Kandi belt has boulder soil frequently dissected by huge networks of small streams, Choes. Siwalik Hills and Kandi areas has experienced severe soil erosion as gully erosion, rill erosion and cut banks erosion. Whereas, sheet erosion has observed in agricultural fields in alluvial plains of the Bist Doab. This paper will focus on accurate assessment of soil erosion areas. A rank sum rule method has been used to generate soil erosion vulne*Rabi*lity model using the six parameters of the region *e.g.* Rainfall, Vegetation, Slope, Soil, Drainage and land Use and land cover change. It is a simple and calculation method for combined analysis of multi class maps. This method does not use the observations but rather the rank of the observations. For study area, all the parameters have been generated through geographical information system and remote sensing data and subsequently integrated with the weighted index overlay method for delineation of soil erosion zones. The weight of the thematic layers corresponding to the susceptibility level has been determined by the rank sum method technique.

Key words: Soil Erosion, Vulne*Rabi*lity and Rank Sum Rule Method.

Introduction

Punjab is an agrarian state and soil is playing the role of a mother for all the farmers. Soil erosion is the detachment and removal of soil material by erosional factors. The process may be natural or accelerated by human activities. The rate of soil erosion may be vary by very slow to very rapid, depending on the soil, slope, vegetation and other physical factors. Soil erosion is known as one form of soil degradation. It is displacement of top soil at a particular site. The main agents of soil erosion are water and wind. Here in the study area water is the prominent cause of soil erosion. Soil erosion can invite many types of risk e.g. weaken of the buildings and even cause them to collapse. It is a serious problem arising by anthropogenic activities in a form of agricultural intensification. It became a central attraction of global crises. Today, it threatens to the natural environment. Asia has the highest soil erosion rate of 74 tons/ acres, year (Swaify, 1997) whereas Asian rivers contribute about 80 percent of the total sediments delivered to the world oceans and amongst these Himalayan, rivers are the major contributors, contribute up to 50 percent of the total world river sediments (Stoddart, 1969). In India, water erosion is the major problem causing loss of top soil representing 62 percent of the total geographical area of the country. Soil erosion consider as a major land degradation problem in Punjab. About 7.4 percent of the total area of Punjab, located in Siwalik foothills, piedmont plains and flood plains is degraded by soil erosion (Sidhu *et al.,* 1995). It is most common by rain water that vary from terrain to terrain and depending upon different land use and land cover categories.

It is the serious menace in the choes of the Siwalik Hills and along River Beas and Satluj in the study area. It is more prevalent in Hoshiarpur and Nawashaher districts of north- eastern side of Punjab where water erosion by various choes and streams is much more and is aggregated by loose structure and softness of rocks, steep slopes, deforestation and enormous manmade activities. Here it is more frequent by rain splash, sheet erosion, rill, gully and stream erosion (Monku, 2002; Litoria, 2013; Rasool *et al.,* 2011; Glover, 1946; Gorrie, 1946). Poor vegetation cover in Siwalik Hills is one of the major cause of soil

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erosion in this region. Roots of the vegetation strongly hold to the soil and pretend it to be eroded. Intensive agricultural activities also play an important role in soil erosion. The use of mechanised equipment allows deep ploughing and breaks up soil into finer particles which severely increases the amount of soil for transport by water, is the primary factor of soil erosion in old alluvial plain in study area.

Study Area

Bist Doab is a triangular shaped region of Punjab. The area bounded by Satluj on the south, Beas on the North West and Siwalik ranges running in the NE-SE (Map 1.1). The area received its name (Bist Doab) at the time of Emperor Akbar. Bist drives by combining the first letters of the name of the Rivers Beas and Satluj. Doab drives its name from the Persian words 'Do' and 'Ab'. 'Do' means 'two' and 'Ab' means rivers- a landmass lying between two rivers. The study area covers an area of 8915 sq, km, 37 towns and has 5580 villages. The region consists of four district and thirty one blocks. It extends from 30p 57' to 32p 7' North latitude and from 75p 4' to 76p 30' East longitude. It is surrounded by Malwa in South after Satluj River and Majha region in the NW after Beas. Himachal Pradesh lies to its eastern side behind the Siwalik ranges. Bist Doab looks like a triangle with its base in south formed by course of river Satluj. Its apex lies in North to the Mukerian block that is the part of Hoshiarpur district. It constitutes 17.8 percent of the total area of Punjab.

Physiography

Whole of the Bist Doab is a flat plain. Physiographically it may be divided into two major regions:

1. The Hills.
2. The Plains.

The Hills

The hills cover only 12.8 percent of the total area of the Bist Doab. They lie in a narrow belt along the eastern boundary of the region. The height ranges from 500 to 750 meters above sea level. This region has scanty natural vegetation and this resulted in the severe erosion by running water. The hills are so badly denuded that they give appearance of bad land topography. Underground water table in this region is very deep. Agriculture depends mostly on rainfall. Due to scarcity of water, agriculture is practiced only on a limited proportion of this area. Agriculturally it is least developed area of the Bist Doab (Map 1.2).

The Plains

The plains cover 87.2 percent of total area of Bist Doab. They range an elevation from 500 m in the north east to 213 m in south west. The alluvial soils of these areas are fertile, easily workable, respond well to irrigation and fertilizers and therefore excellent for raising crops. These areas in general are flat. But on the bases of micro-variations they may be subdivided into three parts:

Flat Upland Plain

Upland plain covers central part of the Bist Doab. It accounts for about 47 percent of the total area of the study region. It covers most of the Jalandhar district and adjoining parts of the Kapurthala district. Slightly higher than the adjoining flood plains; these are the flats and featureless except some local minor irregularities. The area having elevation varying from 216 m in the southwest to 254 m in north and to 277 m in the south east. It is composed of deep alluvium. The depth of sub-soil water in this tract ranges between 5 to 10 m. The aquifers were full of water and thus furnish a rich reservoir for the development of tubewell irrigation but at present due to over exploitation these are in critical condition. There is extremely gentle gradients drainage problem in some of its parts.

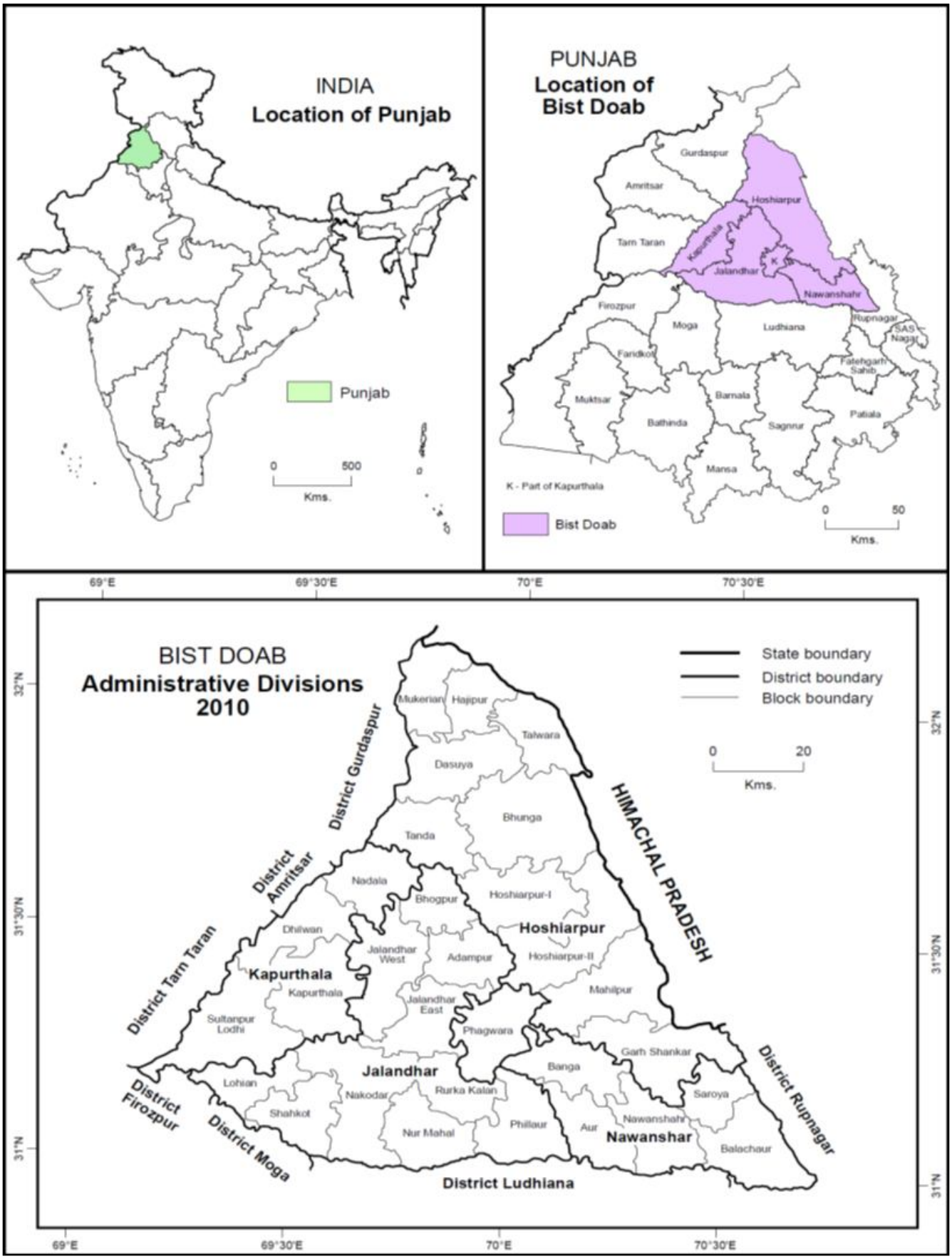
Flood Plains

Flood plains of the Beas and Satluj rivers constitute a unique type of terrain unit. It is known as bet, running along both sides of these rivers. The flood plains form irregular linear strips ranging in width from 4 to 12 miles. It constitutes 14.7 percent of the total geographical area of the Bist Doab. The bet of Beas is more marshy and wider in extend as compare to the bet of Satluj. The area is wider in the east, narrow in the centre and wider in the west. It's loamy and silt loam soils are very fertile, water table is high. The flood plain region is highly suitable for cultivation of rice during *Kharif* season and wheat during *Rabi* season.

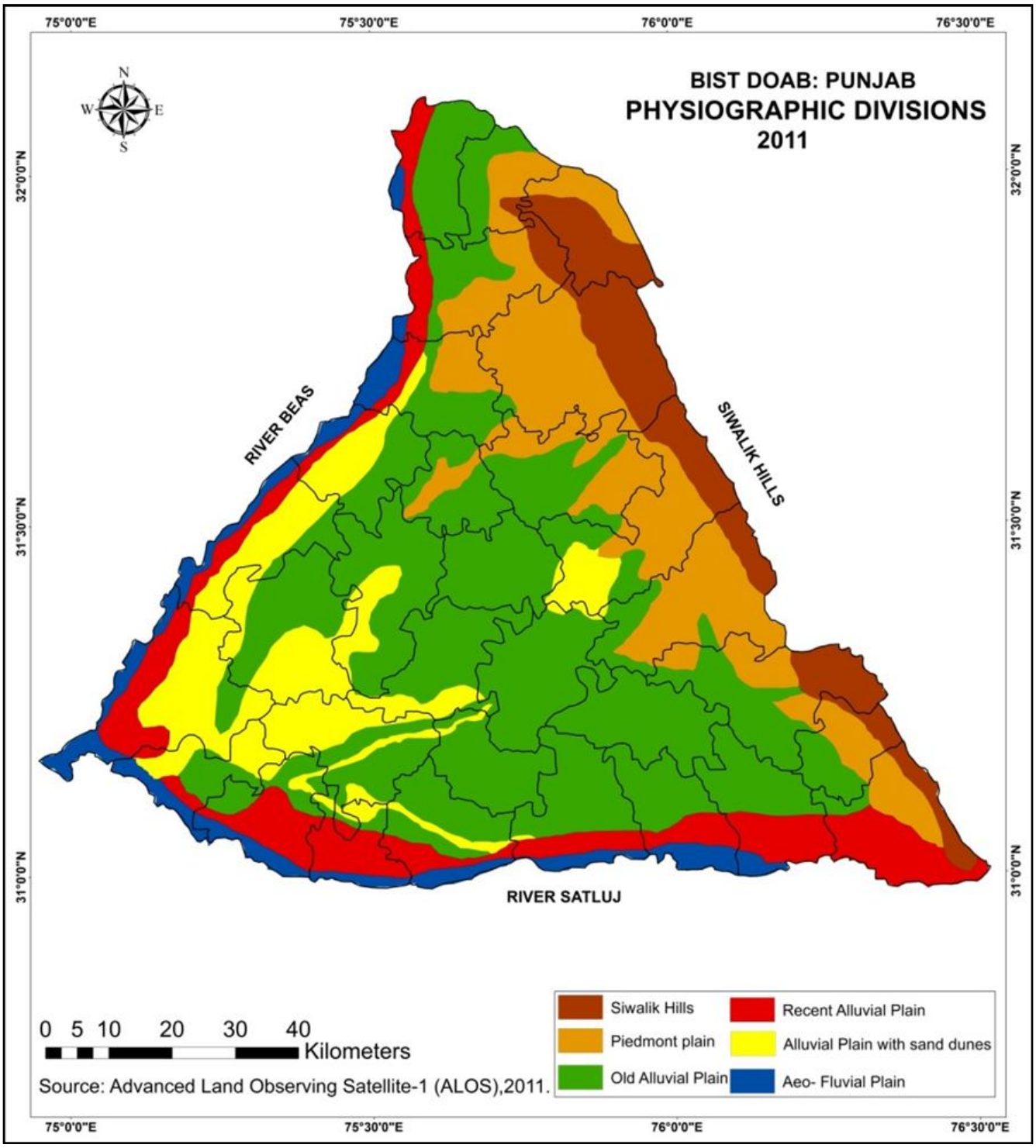
Choes and Plains along the Siwalik Hills

Choes are situated at the foothills of the Siwalik mainly in Hoshiarpur district. As its name indicated this terrain unit is infested with a large numbers of seasonal streams known as choes, sloping in the East West direction. It varies in elevation from 900 to 1500 feet.

Plains are spread immediately next to the Siwalik Hills towards their west and cover parts of Dasuya, Hoshiarpur, Garhshankar and Balachaur tehsils. It slopes from the hills to plain and varies in elevation from 500 m at the foot of the hills to 250 m towards the plains. A large number of seasonal streams emanating from the neighbouring hills traverse this sub region. As a result it suffers from large scale dissection and soil erosion. The sub soil water is deep and inadequate. Degraded soils,


INDIA
Location of Punjab
Punjab
0 500
Kms.
PUNJAB
Location of
Bist Doab
Gurdaspur
Amritsar
Hoshiarpur
Kapurthala
Tarn Taran
Jalandhar
Nawanshahr
Firozpur
Moga
Ludhiana
Rupnagar
SAS Nagar
Faridkot
Fatehgarh Sahib
Muktsar
Barnala
Bathinda
Sagnrur
Patiala
Mansa
K - Part of Kapurthala
Bist Doab
0 50
Kms.
69°E
69°30'E
70°E
70°30'E
32°N
31°30'N
31°N
BIST DOAB
Administrative Divisions
2010
State boundary
District boundary
Block boundary
0 20
Kms.
District Gurdaspur
HIMACHAL PRADESH
District Amritsar
District Tarn Taran
District Firozpur
District Moga
District Ludhiana
District Rupnagar
Mukerian
Hajipur
Tahwara
Dasuya
Bhunga
Tanda
Nadala
Bhogpur
Hoshiarpur-I
Hoshiarpur
Dhilwan
Jalandhar West
Adampur
Hoshiarpur-II
Kapurthala
Kapurthala
Jalandhar East
Mahilpur
Sultanpur Lodhi
Phagwara
Garh Shankar
Jalandhar
Banga
Lohian
Nakodar
Rurka Kalan
Saroya
Shahkot
Nur Mahal
Phillaur
Aur
Nawanshahr
Nawanshar
Balachaur

Map 1.1



Map 1.2

considerable dissection and deep water table have restricted the development of irrigation and agriculture in this part of the Bist Doab.

Climate

The Bist Doab is characterized by a continental semi-arid to sub humid climate, with sharply varying winter and summer temperature. The summer season (April to October) is very hot and June is the hottest month with the average temperature of 34°C. The highest temperature during these months frequently touches 40°C. This hot spell is broken by the onset of monsoon in the first week of the July, thus the temperature comes down. Winters (October- March) are fairly cold with an average temperature of 12°C and January is the coldest month. During this month temperature reaches 0°C.

Vegetation

Except in the Siwalik Hills, natural vegetation has been removed from the face of Punjab due to the extension of settlements and for the purpose of agriculture. The natural vegetation of the region is of dry deciduous type. However intensive cultivation necessitated by population pressure and lack of arable land has resulted in clearance of entire upland plain for agriculture. The forests are found in hilly and foothills parts in the east, while the fertile and flat plains are sparse in vegetation. Vegetation includes *Kikar* (*Acacia aRabica*), *Ber* (*Zizyphus jujuba*), *Sheesham, Tahli* (*Dalbergia sissoo*), *Dhrek* (*Melia azedarach*), Mango, *Amb* (*Mangifera indica*), *Neem* (*Azadirachta indica*), *Pipal* (*Ficus religiosa*). Mango trees are found scattered or in small groves. Man has planted many useful trees along roads, railway lines, canals, around settlements and irrigation wells.

Pipals and *Borhs, Barh* are associated with settlements and wells. These are grown mainly for the purpose of shade. *Safeda* (*Eucalyptus)* and Poplar (*Populus*) are planted along the seasonal streams and on hill slopes to check surface run-off and soil erosion. The wood of *Kikar,* Mango, *Sheesham* and Bamboos is used for making house structure, agricultural implements, furniture and other domestic articles. Apart from trees, rough grasses like *Kans* (*Saccharum spontaneoum*) and *Reeds* (*Phragmites*) are found along Choes of foothill plains. These are used for making paper, ropes, mats and also provide material for thatching roofs, making basket, fuel and for brooms.

Table 2: Bist Doab: Punjab.

Sl. No.	Parameters	Range	Rating	Weight
01	Rainfall (mm)	Very Less (555-644)	1	6
		Less (644-733)	2	
		Moderate (733-822)	3	
		High (822-911)	4	
		Very High (911-1001)	5	
02	Vegetation	Very Less	5	5
		Less	4	
		Moderate	3	
		High	2	
		Very High	1	
03	Slope (Degrees)	Very Gentle (<10)	1	4
		Gentle (10.1-20)	2	
		Moderate (20.1-30)	3	
		High (30.1-40)	4	
		Very High (>40)	5	
04	Soil	NatricUstochrepts	1	3
		FluventicUstochrepts	1	
		TypicHaplustalfs	1	
		TypicUstochrept	1	
		VetricUstochrepts	1	
		Udic Ustochrepts	3	
		Typic Ustifluvents	3	
		TypicUstipsamments	4	
		TypicUstorthents	5	
05	Drainage Density	0-1.5	1	2
		1.5-3.0	2	
		3.0-3.5	3	
		3.5-4.0	4	
		4.0-4.5	5	
06	LULCC	River	5	1
		Sandy Area	5	
		Agricultural Area	4	
		Barren Area	3	
		Current Fallow	3	
		Dense Scrub	2	
		Open Scrub	2	
		Reservoir	1	
		Built-up	1	

Table 3: Bist Doab: Punjab.

Rank Sum Method				
Position Rank (PK)	Criteria Indicator (CI)	Weigh -tage (n-P K+1)	Normalized Weightage (NW)	Criteria Weightage (%)=NW X100
1	RAINFALL	6-1+1 = 6	6/21	28.57
2	VEGETATION	6-2+1 = 5	5/21	23.81
3	SOIL	6-3+1 = 4	4/21	19.05
4	SLOPE	6-4+1 = 3	3/21	14.29
5	DRAINAGE	6-5+1=2	2/21	9.52
6	LULCC	6-6+1=1	1/21	4.76
	n = 6	Σ= 21	Σ = 1.00	100

Material and Methods

Rank sum method model has been used to assess soil erosion of the study area using the six parameters of the region e.g. Rainfall, Vegetation, Slope, Soil, Drainage, and land Use and land cover change. It is a simple and calculation method for combined analysis of multi class

Table 1: Bist Doab: Punjab.

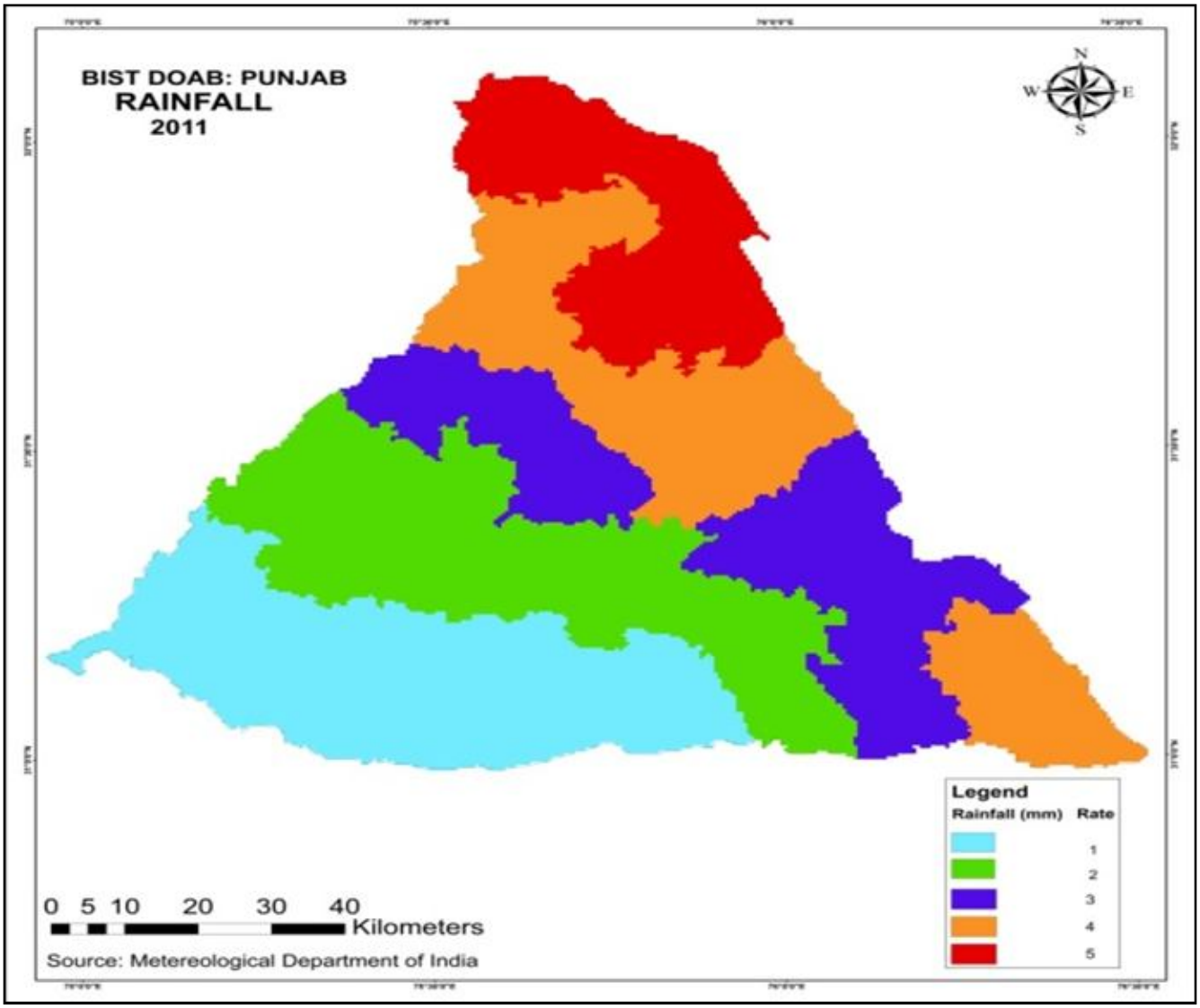
S.No.	Data Type	Source	Format	Output Layer
1	Rainfall	Mdi	Table	Rainfall Map
2	Vegetation	Soi	Map	Vegetation Map
3	Slope	Dem	Map	Slope Map
4	Soil	Nbsslu Nagpur	Map	Soil Map
5	Drainage	Landsat 8	Image	Drainage Map
6	Lulcc	Landsat 8	Image	Lulcc Map

maps. A rank represents the relative importance of the parameters. This method does not use the observations but rather the rank of the observations. For study area, all the parameters have been generated through geographical information system and remote sensing data and subsequently integrated with the weighted index overlay method for delineation of soil erosion zones. The weight of the thematic layers corresponding to the susceptibility level has been determined by the rank sum method technique. The details of data used to soil erosion vulne *Rabi*lity model were given in the table 1.

Data has been collected from various departments and sources. Rainfall data has collected from Metereological Department of India (MDI) in tabulation form that is used for corropleth mapping of rainfall analysis. Data on vegetation cover has been generated (through the NDVI), drainage system and lulcc from Landsat 8, down loaded from usgs.glovis.gov and further classification has been done according to the purpose. For the data preparation of slope aspect SRTM data was used to derive DEM. Slope map was prepared through the 3D analyst tool in Arc GIS. Five slope classes with their rank has explained under table 4.2. Soil map has prepared with digitization process from soil map of Punjab by NBSS&LU, Nagpur.

Explanation and Ranking of Parameters

All the parameters used in this model is ranked on the bases of preference of a decision maker. To generate criteria Weightage of the parameters, each parameter is ranked according to significant influence on soil erosion. The inverse ranking was applied to all the parameters. Each sub-classes are rating to 1-5 in decreasing order of impact, where 5 indicates higher sensitivity and 1 indicates to low sensitivity to soil erosion. The details of ranking



Map 1.3

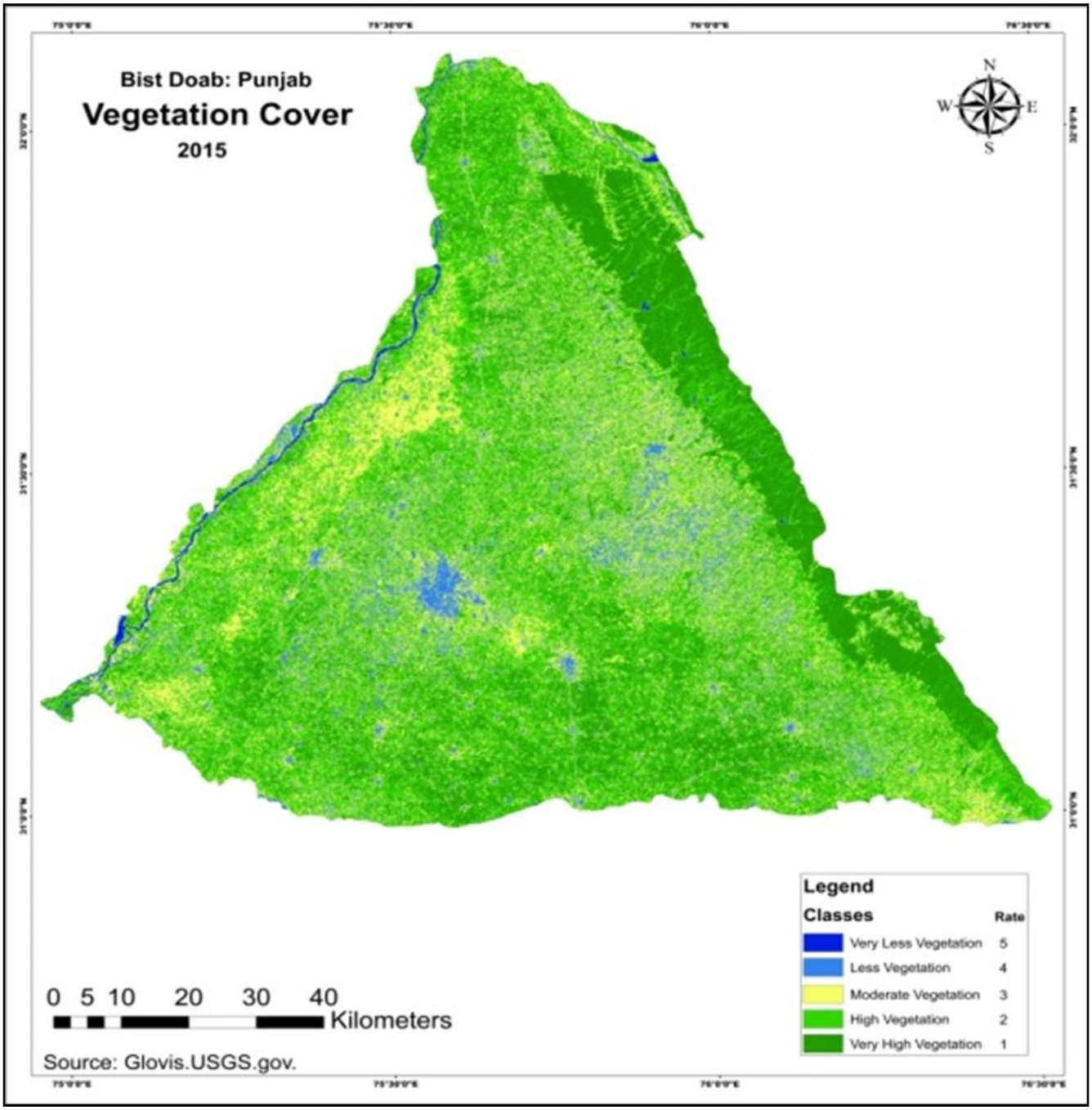
scheme has discussed in table 2.

Weightage of Parameters

Here, position rank (PK) is assigned according to the importance of the parameters e.g. rainfall is the most important parameter to analyse soil erosion vulne *Rabi* lity, so it is located as no. 1 position and land use and land cover change is least important parameter playing a role in soil erosion vulne*Rabi*lity, so it was located as no. 6 position. The position ranks were given to each parameter and criteria weighted was calculated by using mentioned formulas given below:

1. Position Rank (PK)
2. Criteria Indicator (CI)
3. Weightage = (n-Pk+1)
4. Normalized Weighted (NW) = n/Σ
5. Criteria Weightage (CW)= NW*100

Each sub-classes are rating to 1-5 in decreasing order of impact, where 5 indicates higher sensitivity and 1 indicates to low sensitivity to soil erosion. All the six sub-classes are explained below. The details about position rank and Weightage were given in the table 3.



Map 1.4

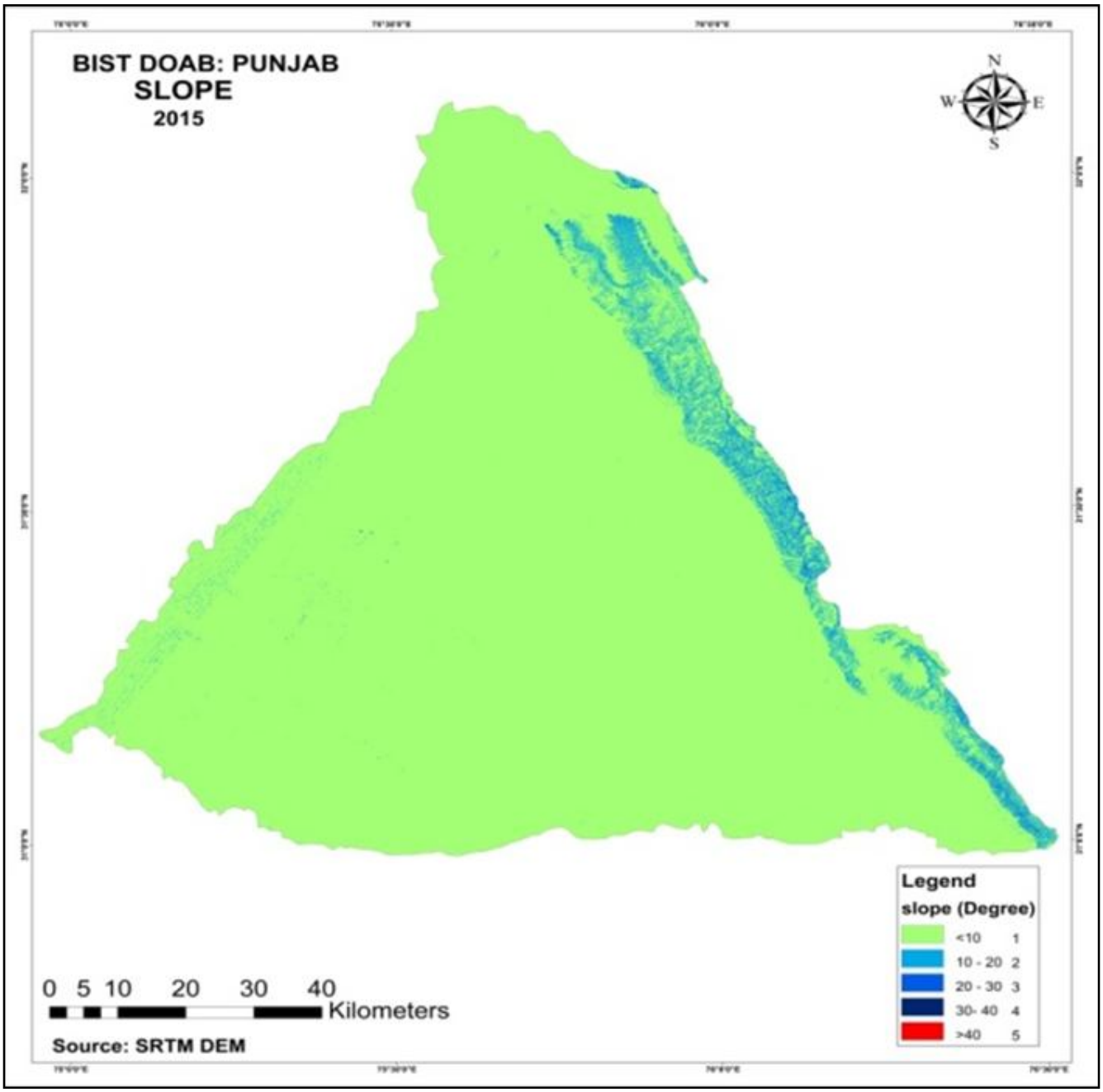
The results have been calculated on the basis of combination of factors. All the rating has been multiplied by their calculated weights for all the raster maps that area equal to 100 percent.

Rainfall

Rainfall intensity is one of the most important factors to construct soil erosion vulne*Rabi*lity model with rank sum rule method. Since, soil erosion generally occurs when the top soil is displaced by rain and soil is transported by rain from highest slope to the flat plains. Probability of soil erosion will be increased where amount of rainfall will be high as it cannot be absorbed into the soil in less duration of time resultant as flash flood with high erosion. Soil erosion is much vary with the intensity of rainfall and the study area is much popular for rainstorm in monsoon (July-September). The high intensity of rainstorm though concentrated for a short period play a big role causing gully erosion in the study area (Lal, 1992). Data has collected from Meteorological Department of India in tabulation form and corropleth map was prepared with 5 classes. Therefore class rating 5 is assigned to high rainfall and 1is assigned to low rainfall (Map 1.3).

Vegetation Cover

Vegetation cover also plays an important role to

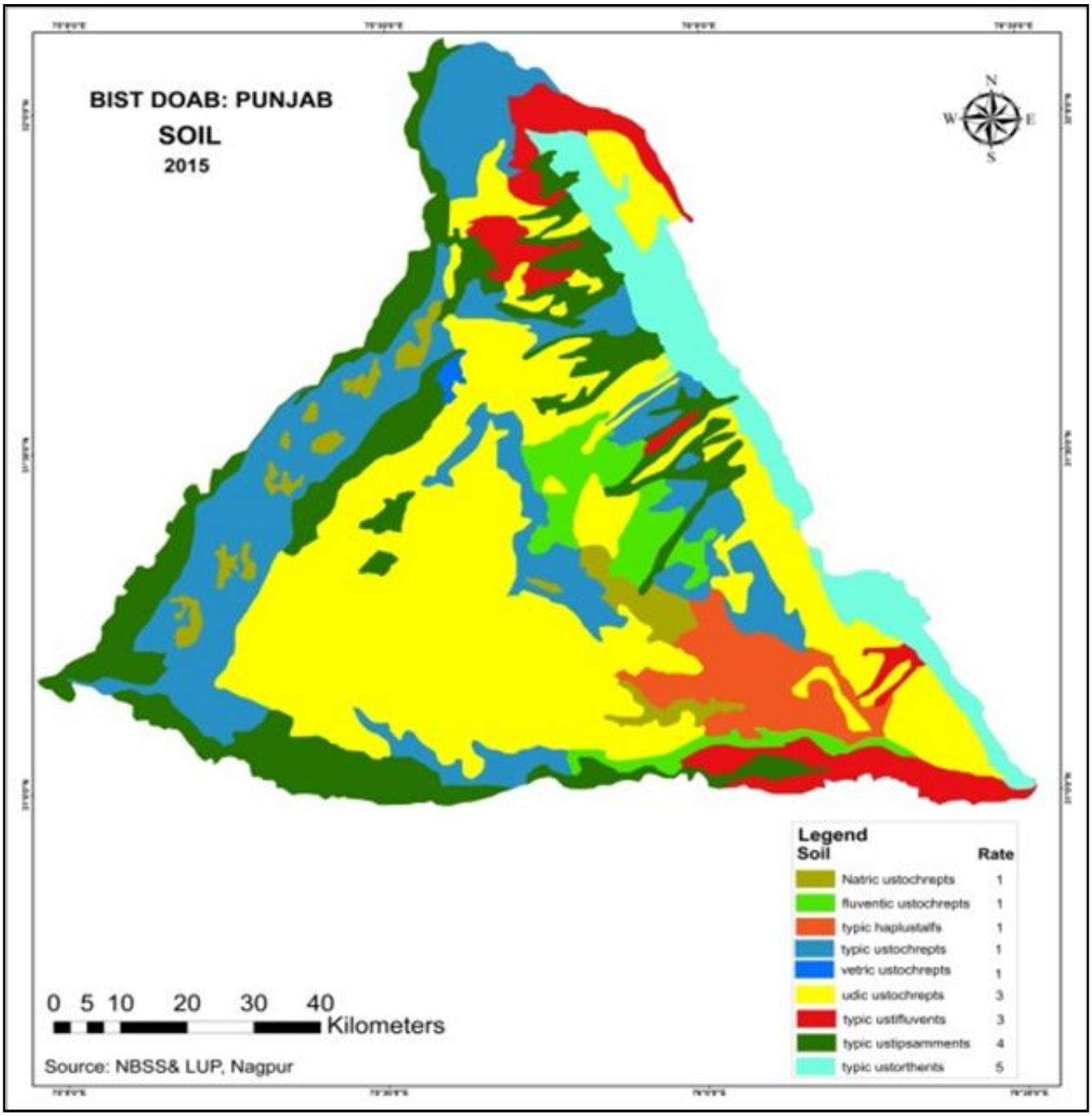


Map 1.5

reduce soil erosion. There is a direct relation between vegetation, rainfall and soil erosion. The area having high intensity of rainfall and having less vegetation cover, the rate of soil erosion will high in these areas. As roots of the vegetation cover holds the soil and reduces the probability of the soil erosion. Nude soil is highly vulnerable in comparison to soil covered by vegetation. Data has been generated through the NDVI image which has classified into 5 classes: very less, less, moderate, high and very high vegetation cover. Maximum weightage 5 has assigned to the very less vegetation whereas 1 has assigned to the very high vegetation cover (Map 1.4).

Slope

Slope refers to the surface of which one end or side is at a higher level than another. Here slope of the surface has also used in the model to know the vulne*Rabi*lity of soil erosion. Very gentle slope has shown less soil erosion and steep slope has shown high level of soil erosion. Here more than 40 has been taken as very steep slope and rating was given to 5 whereas less than 10 has been taken as very gentle slope and assigned to 1 (Map 1.5).



Map 1.6

Details of rating have been given in the table 2.

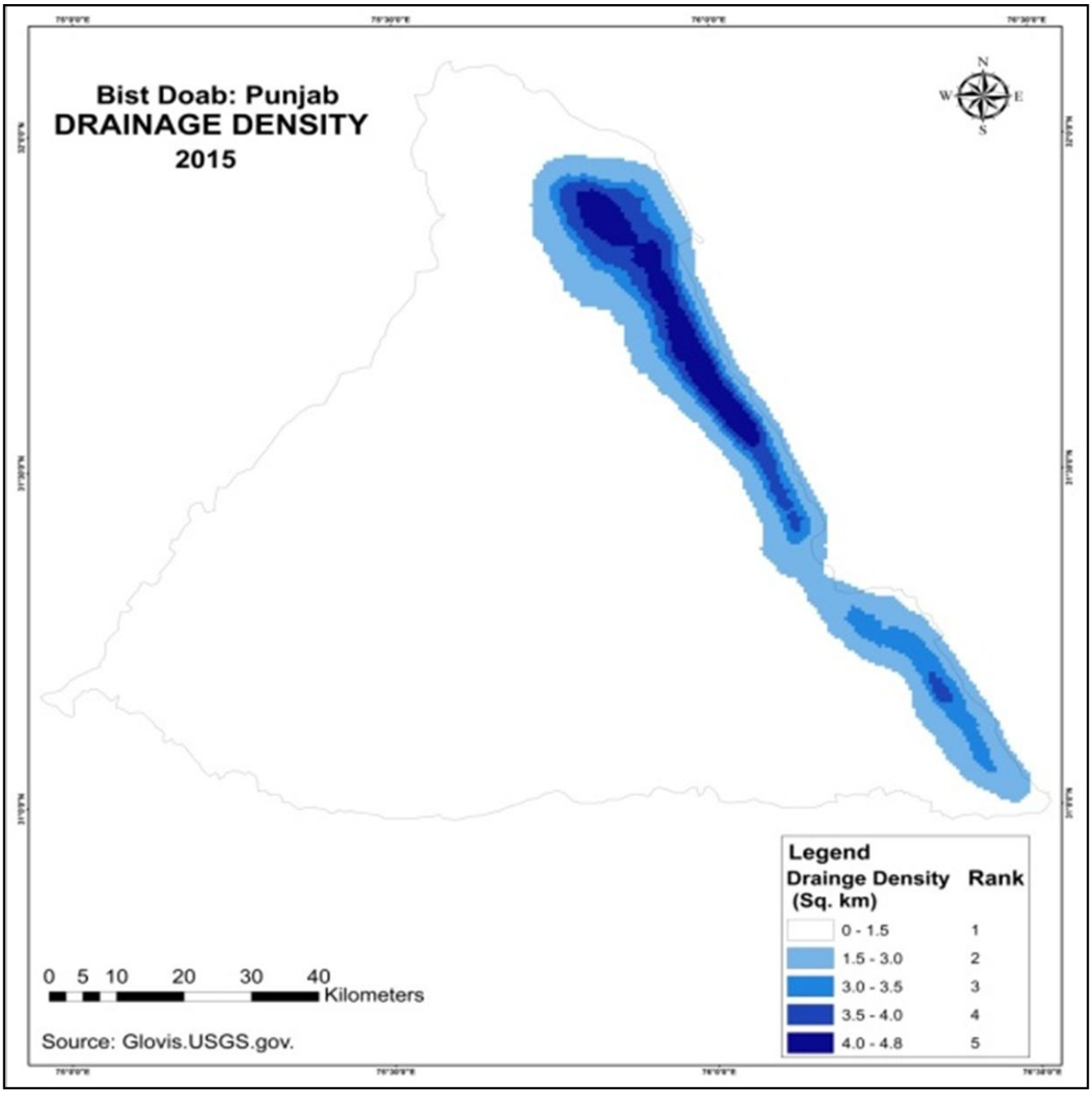
Soil

It refers to the top most soil of the vadose zone. It also plays an important role in the soil erosion. Here soil types have been assigned according to the storage capacity that is explained by NBSSLU Nagpur. In the study area having soil with low storage capacity is the cause of high soil erosion. Because of low storage capacity soil cannot hold water for a long time and produced run-off on the surface whereas high storage capacity soils had less soil erosion. Thus higher rate has been given to the low storage capacity soil (Map 1.6).

Drainage Density

It refers to the total length of all the elements and rivers in a drainage basin divided by the total area of a drainage basin. It is a measure of how well or how poorly a watershed is drained by system channels. Drainage density has also taken as factor to describe soil erodibility. Hence higher drainage density areas are assigned to higher rating whereas lower drainage density assigned as low rating or as 1 (Map 1.7).

Land use and land cover



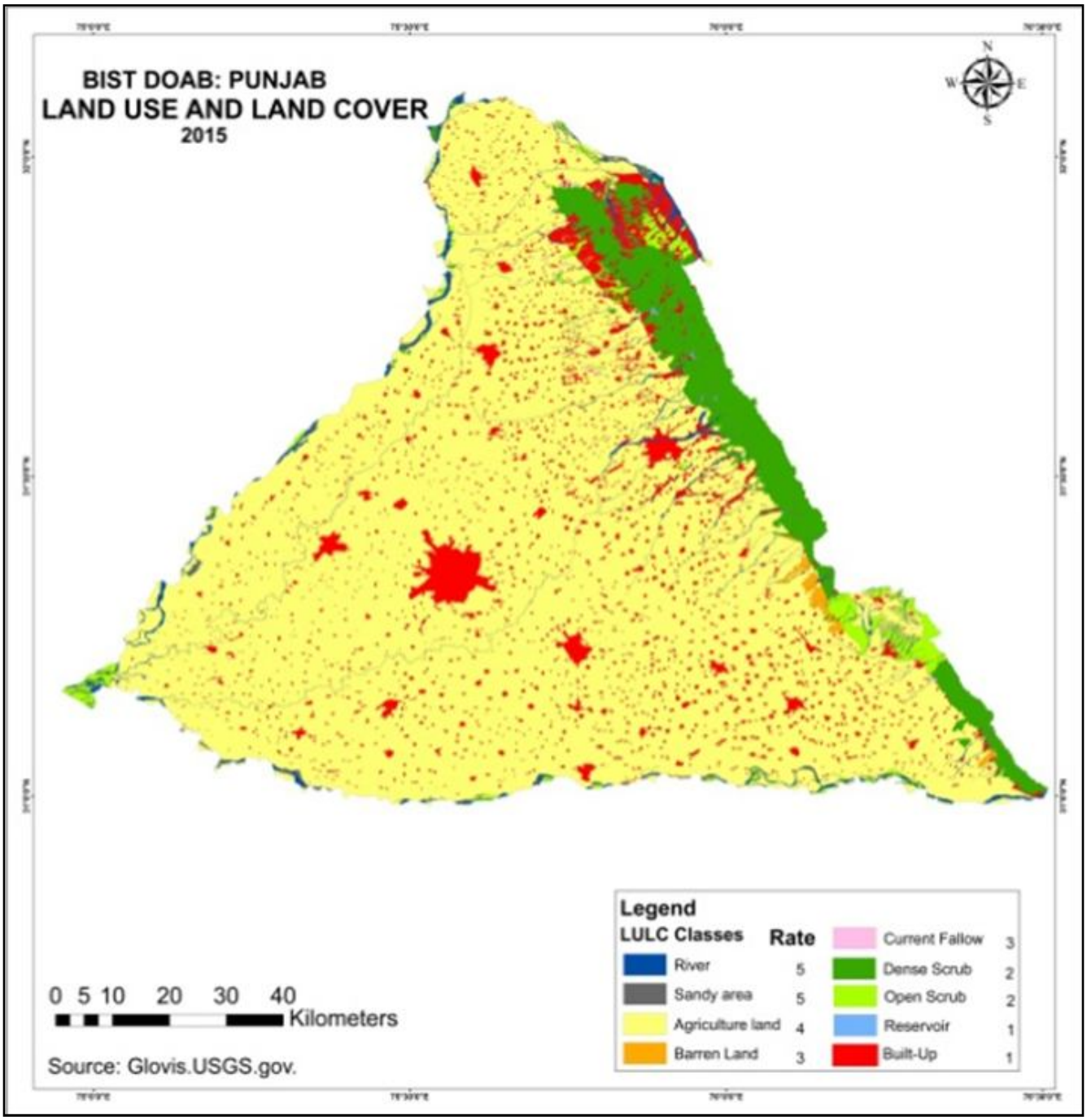
Map 1.7

Land use is directly means to the man-madeactivities. Manmade activities also have great influence on soil erosion. Details of rating for land use and land cover and its vulne*Rabi*lity to soil erosion have given in the table 2. The results has been calculated on the basis of combination of factors. All the rating has been multiplied by their calculated weights for all the raster maps that area equal to 100 percent (Map 1.8).

Results and Discussion

Based on rank sum method, weights are calculated in percent as 28.57,23.81,19.05,14.29.9.52,4.76 respectively for annual rainfall, vegetation cover, soil, slope, drainage density and land use and land cover change to produce soil erosion vulne*Rabi*lity map. After this, grid format of raster layers of each parameter has been multiplied by their own weight and summing them together in Arc GIS 10.2.1 software. The resulted values have been obtained in a range of 100 to 433 (Fig. 1.1).

Less value shows very slight vulne*Rabi*lity whereas high values show very high vulne*Rabi*lity of the soil



Map 1.8

erosion. About 10.86 percent of the total study area lies in very slight vulnerable zone, 31.98 percent has been covered under slight vulnerable zone. 20.45 percent in moderate vulnerable zone, 23.43 percent was covered by high vulne*Rabi*lity of soil erosion and 12.40 percent area was in very high vulnerable zone. Very slight, slight, moderate, high and very high vulne*Rabi*lity ranges has been assigned in category as given in table 4. Soil erosion vulne*Rabi*lity was seen prominently in the Eastern belt of the Bist Doab, which has been covered by Siwalik Hills. It was also seen in the small patches along the River Satluj in the southern direction and few patches have seen along river Beas in western direction. Map depicts that very high soil erosion was seen in Bhunga, Talwara, Hazipur, Hoshiarpur-I and few patches in eastern Garhshankar, eastern Dasuya, Mahilpur, Saroya and Balachaur blocks (Map 1.9). High soil erosion vulne*Rabi*lity area has been well observed in Mukerian, Hazipur (except few patches of its eastern side), Talwara, Bhunga, Dasuya, Tanda, Hoshiarpur-II, Hoshiarpur-I except its eastern belt, Saroya and Balachaur. It was also located in eastern parts of Mahilpur, Garhshankar and Nadala blocks. Moderate soil erosion vulne*Rabi*lity area has been spread mainly in Mahilpur, Bhogpur, western Adampur, Nadala, Jalandhar east, Garhshankar and few parts of Hazipur, Mukerian, Dasuya, Tanda, central Kapurthala, Jalandhar west, Phagwara, Nawashaher, Hoshiarpur-I, Hoshiarpur-II, southern parts

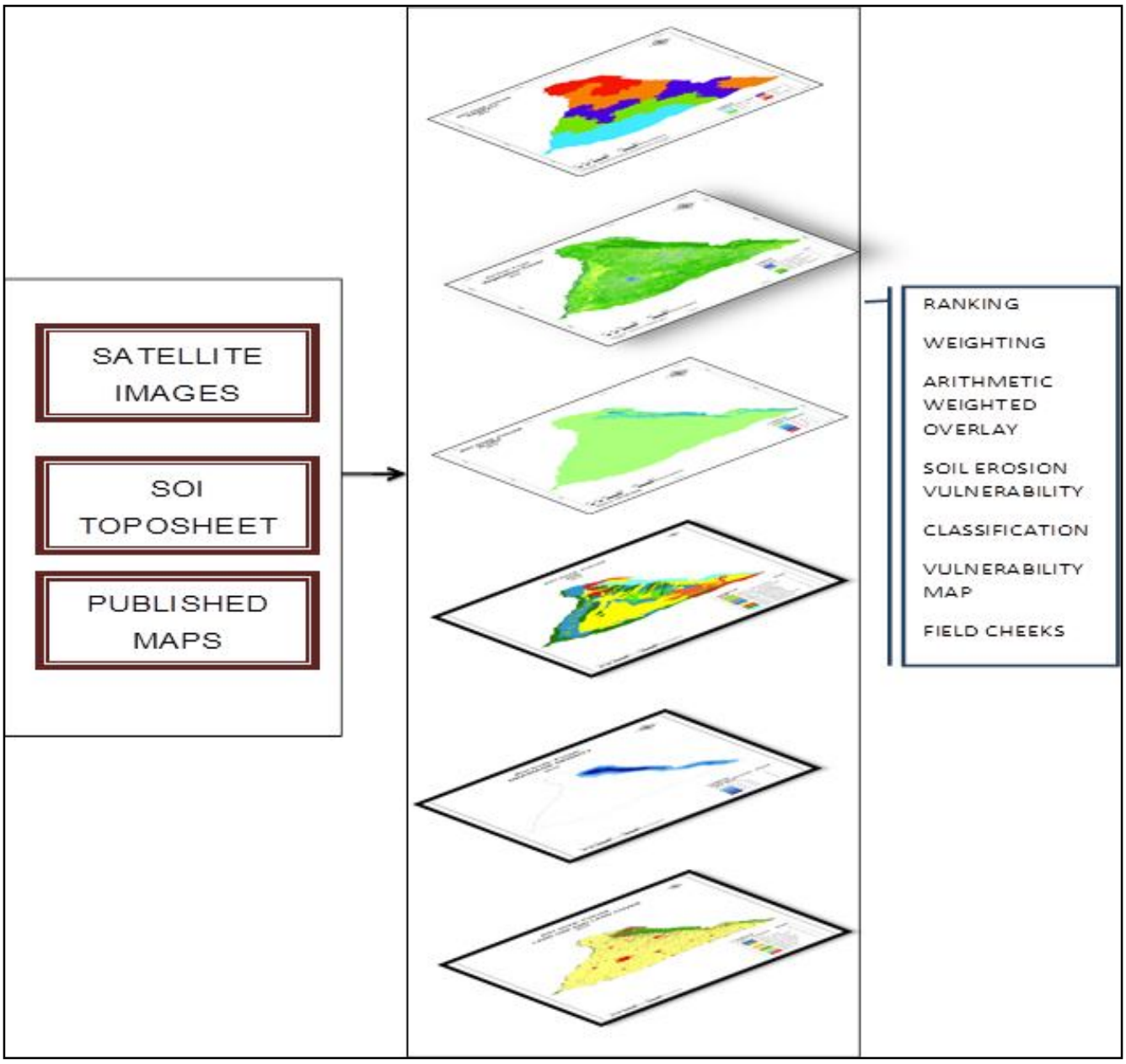
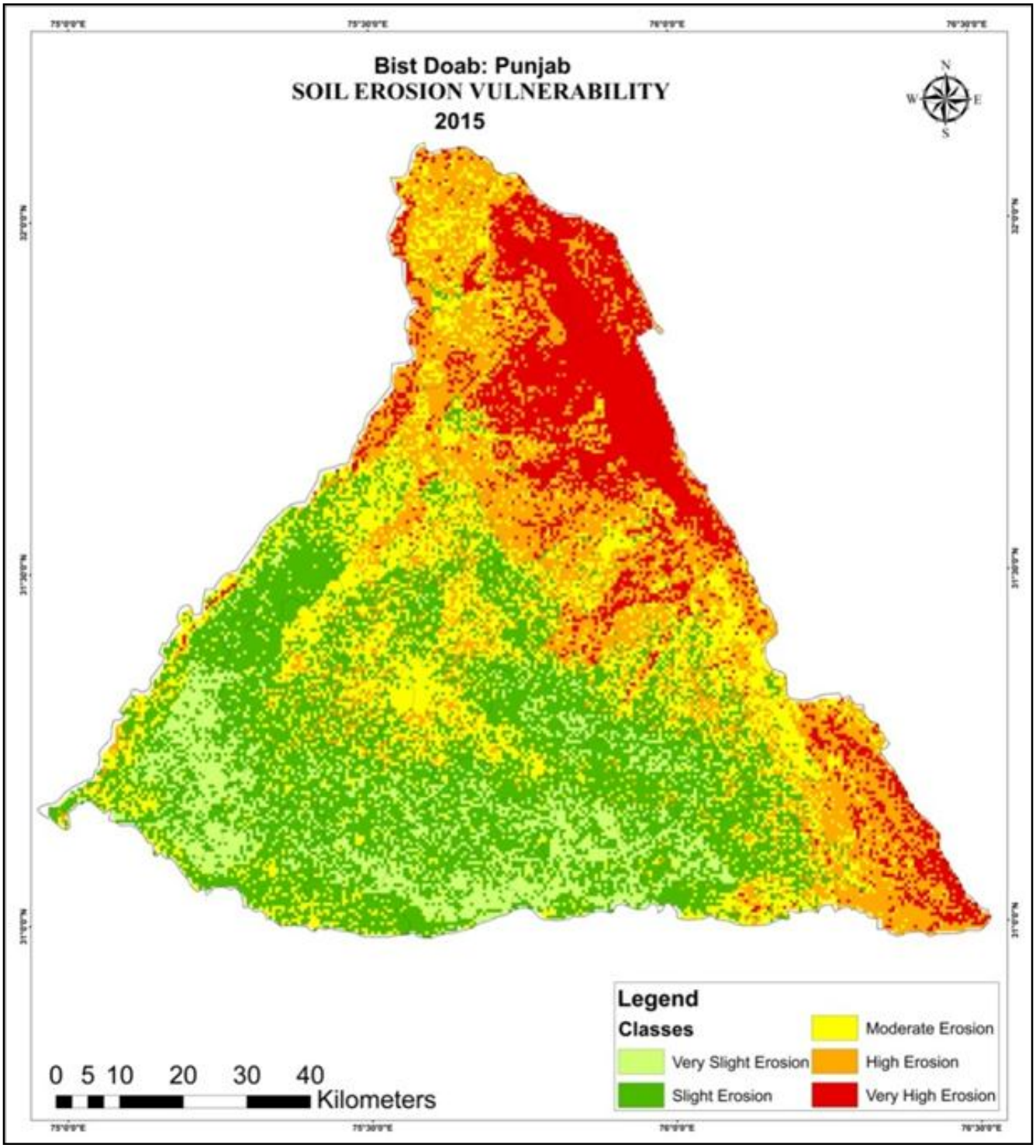


Figure 1.1

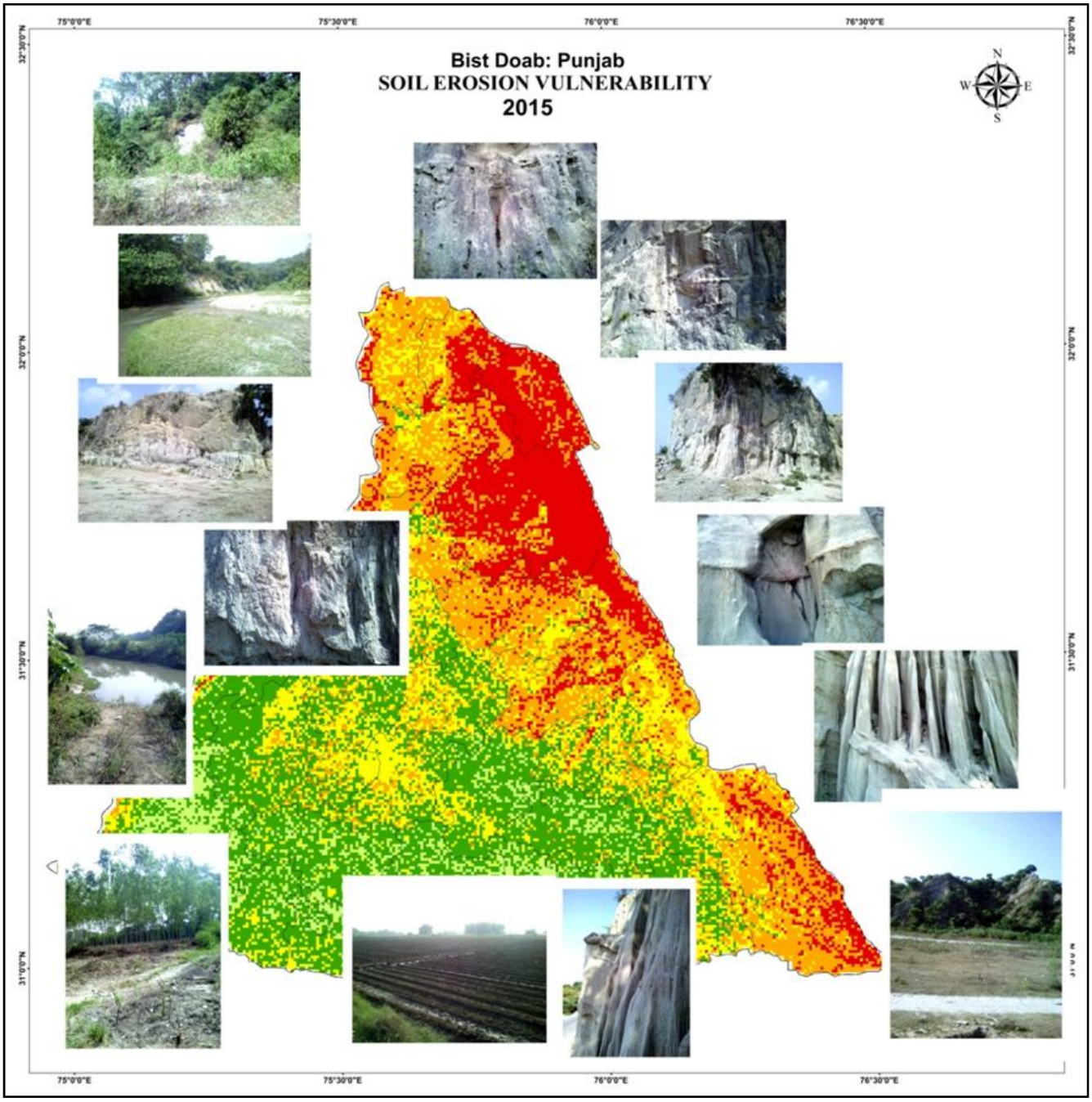
of Nakodar, Shahkot and Lohian. It was also seen in blocks along River Beas like Dhilwan and Sultanpur Lodhi. Slight erosion vulne*Rabi*lity has covered most of the blocks of the Bist Doab and mainly seen in Dhilwan, Kapurthala, Phagwara, Banga, Nawashaher, Nakodar, Shahkot, Aur, Rurka Kalan and Mehatpur. It was also seen partially in Sultanpur Lodhi, Lohian, Jalandhar west, Jalandhar east, Adampur, Bhogpur, Nadala, Mahilpur, Garhshankar, Phillaur and Nurmahal blocks. Very slight erosion vulne*Rabi*lity class has well scattered mainly in Sultanpur Lodhi, Lohian, Nurmahal, Shahkot and Phillaur blocks. It was also seen in parts of Nakodar, Rurka Kalan, Mehatpur, Banga and Phagwara blocks.

Validation of the Model

Field survey has been conducted to check the



Map 1.9



Map 1.10

sensitivity of soil erosion in Bist Doab, Punjab. Total 130 points has been observed with the help of hand held GPS (Map 1.10). The geographic coordinates of each sample has taken and later on imported in GIS and super-imposed on weighted sum map.Ground verification of resulted sites revealed that there are various visual indicators of erosional and depositional geomorphic features like gully erosion, rill erosion,sand point bars, cut bank erosion, abandoned channel and siltation in agriculture fields etc.

Conclusions

Very slight erosion covered an area of 10.86 percent of total geographical area of the study area. This area has well scattered mainly in Sultanpur Lodhi, Lohian, Nurmahal, Shahkot and Phillaur blocks. It was also seen in parts of Nakodar, Rurka Kalan, Mehatpur, Banga and Phagwara blocks.

Slight erosion vulne*Rabi*lity covered an area of 31.98 percent of the total geographical area of the study area. Most of the blocks falls in this category except eastern belt of the Bist Doab e.g. Talwara, Bhunga, Hoshiarpur-I, Hoshiarpur-II, Saroya and Balachaur and blocks of northern Bist Doab like Mukerian, Hazipur, Dasuya and

Nadala.

Moderate soil erosion vulne*Rabi*lity area has been constituted an area of 20.45 percent of the total geographical area of the study area. These areas spread mainly in Mahilpur, Bhogpur, western Adampur, Nadala, Jalandhar east, Garhshankar and few parts of Hazipur, Mukerian, Dasuya, Tanda, central Kapurthala, Jalandhar west, Phagwara, Nawashaher, Hoshiarpur-I, Hoshiarpur-II, southern parts of Nakodar, Shahkot and Lohian. It was also seen in blocks along River Beas like Dhilwan and Sultanpur Lodhi.

High soil erosion vulne*Rabi*lity area has been well observed in Mukerian, Hazipur excepts few patches of its eastern side, Talwara, Bhunga, Dasuya , Tanda, Hoshiarpur-II, Hoshiarpur-I except its eastern belt, Saroya and Balachaur. It was also located in eastern parts of Mahilpur, Garhshankar and Nadala blocks. This category covered an area of 23.43 percent of total geographical area of the study area.

Very High soil erosion vulne*Rabi*lity areas have been spread along Siwalik Hills in the blocks *e.g.* Talwara, Bhunga, eastern side of Hoshiarpur-II, Hazipur and small patches in Mahilpur, Garhshankar, Saroya and Balachaur. It was also seen along the River Beas in blocks *e.g.* western Mukerian, Dasuya and Tanda. This category covered an area of 12.40 percent of total geographical area of the study area.

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