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Landscape Ecology and Water Management

Proceedings of IGU Rohtak Conference, Vol. 2

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Editors

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Preface

Carl Troll, a German geographer, coined the term "landscape ecology" in 1939. It can be viewed as a complex system, representing areas where conflicts for land exist. The analysis of land use is one of the focus areas in landscape ecology. Anthropogenic use of land in the form of agriculture and urban areas has a vital role in the interaction of landscape and ecosystems. The present land use may affect the movement of certain species as well as determining the availability of land for future use. Different organisms display diverse and individual responses to landscape modification depending on the scale on which they normally operate and how they perceive the environment. The modification of landscapes influences ecosystem processes, species richness, and distribution. It also alters physical attributes of the environment, leading to a degraded environment in which all species, including humans, live. Maintaining the integrity of ecosystems is fundamental in order to adapt to climate change, nurturing biodiversity and providing an uninterrupted supply of ecological goods and services on which humans depend for their existence. Classifying the elements and patterns of landscape ecology and understanding the complex biophysical interactions within the context of landscapes enables scientists and land managers to make informed decisions about effective conservation and land management. Thus, landscape ecology is central to effective conservation of ecology and mitigation of adverse environmental effects arising from the degradation caused by human modification of the landscape.

Water is generally considered to be a "free good" resource that is abundantly available and unlimited in supply, given the fact that three fourths of the Earth is covered with water. However, statistics reveal that the long-held view of water being an unlimited resource no longer holds true and that water is an asset that is vulnerable to an increasing population and changing environment. India is having 4 % of World's freshwater which is being exploited for an ever-increasing demand for sanitation, drinking, manufacturing, leisure, and agriculture. As water is the principal medium through which climate change expresses itself, adaptation to climate change and the need to build resilience is increasingly being approached through water management initiatives. Successful management of this precious resource requires accurate knowledge of its availability, uses, measures and processes to evaluate the significance and worth of competing demands, and mechanisms to translate policy decisions into actions on the ground.

This volume incorporates the issues of both landscape ecology and water management. It is divided into two sections, consisting of 24 research papers presented at the IGU Conference, Rohtak, March 14–16, 2013, encompassing the interlinked issues of landscape and water resources in various disciplines such as geoinformatics, geography, hydrology, climatology, forestry, environmental studies, ecology, and biodiversity. The book will be useful for students, researchers, and teachers in these fields as it presents a study of the lithosphere–hydrosphere–atmosphere linked system and its climatic implications, focusing on space and regions, addressing and questioning both short-term and long-term strategies.

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Part I
Landscape Ecology

Chapter 1
Detection of Land Use Change and Future Prediction with Markov Chain Model in a Part of Narmada River Basin, Madhya Pradesh

Arun Mondal, Deepak Khare, Sananda Kundu, and Prabhash Kumar Mishra

Abstract Landuse and land cover change have significant impact on the environment of a river basin and has gained considerable attention. It has a strong effect on the surroundings where increasing agriculture as well as urban areas has led to the rapid deforestation and changes in the ecology. Present study involves detection of landuse and land cover change in a part of Narmada river of Madhya Pradesh where rapid changes such as irrigation planning is leading to changes in the land cover. Hence, change detection in the present landform and probable changes in the near future is required for planning and management. Landsat images of 1990 (TM), 2000 (ETM^+) and 2011 (LISS-III) were used for the classification and future landuse prediction. Supervised Fuzzy C-Mean classification was applied to generate major five classes of water body, built-up area, natural vegetation, agricultural land and fallow land. Overall accuracy for all images was above 85 %. The Markov Chain model was used for prediction. The classified Landsat images of 1990 and 2000 were used to predict the 2011 landuse with Markov Chain which was again validated with the 2011 classified image. The prediction of 2020 and 2030 land use were done to see the future change. The spatial accuracy achieved for the prediction was about 92.5 %. The results illustrate an increase in agricultural land and urban area with the decrease in natural vegetation.

Keywords Change detection • Fuzzy C-Mean • Landuse prediction • Landuse/land cover change • Madhya Pradesh • Markov Chain model

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1.1 Introduction

Changes in land use/land cover are extremely important and must be monitored frequently to assess the impact on the environment. The changes can be natural or may occur due to human interference. Remote Sensing and Geographic Information System (GIS) techniques have an important role to play to estimate the area and rate of changes. Landuse and land cover are often used together but are two different terms. Urban landscape is considered as land use that is the way in which human beings utilize the land whereas land cover is the natural environmental system (Jensen 2007). These changes in the landuse and land cover are significant factors for global environment change (Turner et al. 1995).

Urban processes are extremely dynamic, huge global expansion of urban populations and urbanized areas have an impact on the natural and human systems at different geographic scales and it is further expected to accelerate in the next few decades (Miller and Small 2003). Adverse conditions of over-crowding, inadequate infrastructure, shortages in housing space and rising problems in urban climate and ecology have resulted in the constant supervision of landuse near urban areas. Development in the field of remote sensing with increasing availability of high resolution satellite data have raised the potential to acquire detailed information spatially to identify and monitor number of environmental problems in the urban areas in different spatiotemporal scales (Carlson 2003). Any temporal change in the landuse can have considerable impact on the environment which occurs because of increasing settlements and urbanization. According to Herold et al. (2002) and Maktav et al. (2005) urban environment indicates one of the important areas for remote sensing analysis because of higher diversity both spatially and spectrally of the surface features.

Many studies regarding landuse and land cover are found in the literature. Landuse changes in the Kodaikanal region of Western Ghats in Tamilnadu were studied for 40 years from 1969 to 2008 by using satellite data where reduction in forest areas was found (Prakasam 2010). Samant and Subramanyam (1998) also studied the landuse change of Mumbai resulted in a huge reduction of the forest area. Many works on landuse and land cover change were done by researchers like He et al. (2000) and Zhang et al. (2002). Work on future urban expansion was done by Liu and Zhou (2005). Chen et al. (2009) also studied the Landuse changes in China. Other important works regarding landuse and land cover changes with the satellite images involves works of Lu et al. (2004), Maktav and Erbek (2005), Zhang et al. (2010). All these studies proved the importance of proper identification of an area from the images through the classification process which has significant impact on the further planning and development of a region.

Future prediction of landuse is equally important for the planners as it gives insight for future development of the area. Markov chain helps in future land cover modeling with the preceding state, i.e., a matrix on the basis of observed transition probabilities can be used to project future scenario regarding landscape from the current types (Brown et al. 2000). Many studies have used this model to project future changes in different spatial scales in urban and non-urban areas (Jahan 1986; Muller and Middleton 1994; Zhang et al. 2011).

In the present study landuse changes were studied for three decades of 1990, 2000 and 2011 with the Landsat satellite images. Supervised Fuzzy C-Mean technique was used for the landuse classification. Accuracy assessment was done with all the classified maps. Further the classified maps were used in the Markov model for predicting future scenario of landuse changes.

1.2 Study Area

The study area lies in Madhya Pradesh covering about 20,558 km^2 area in the districts of Burhanpur, Barwani, Sehore, Harda, Dewas, Indore, West Nimar and East Nimar. It is a part of the Narmada river basin as given in Fig. 1.1. The extension of the area is from 21°23′7.7″ N to 22°55′8″ N and 75°21′7″E to 77°21′17″E. The area experiences a subtropical climate with hot dry summer and a cool dry winter. The average rainfall is 1,370 mm and it decreases from east to west.

1.3 Methodology

1.3.1 *Classification and Accuracy*

Supervised Fuzzy C-Mean classification technique was used in the study with the images of 1990, 2000 and 2011. Five classes of water body, built-up area, natural vegetation, agricultural land and fallow lands were identified and validated with the field observation. Accuracy assessment was done with the Kappa coefficient.

This technique is considered as more appropriate than the continuous data. The Khat statistic is given below

$$\hat{k} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{i+}.x_{+i})}{N^2 - \sum_{i=1}^{r}(x_{i+}.x_{+i})} \tag{1.1}$$

where ‘r’ represents the number of rows in the matrix X_{ii} which is the number of observations in row ‘i’ and column ‘i’, and X_{i+} and X_{+i} are considered as the marginal totals for the ‘i’ and column of i respectively and N signifies the total number of observations (Lillesand et al. 2008).

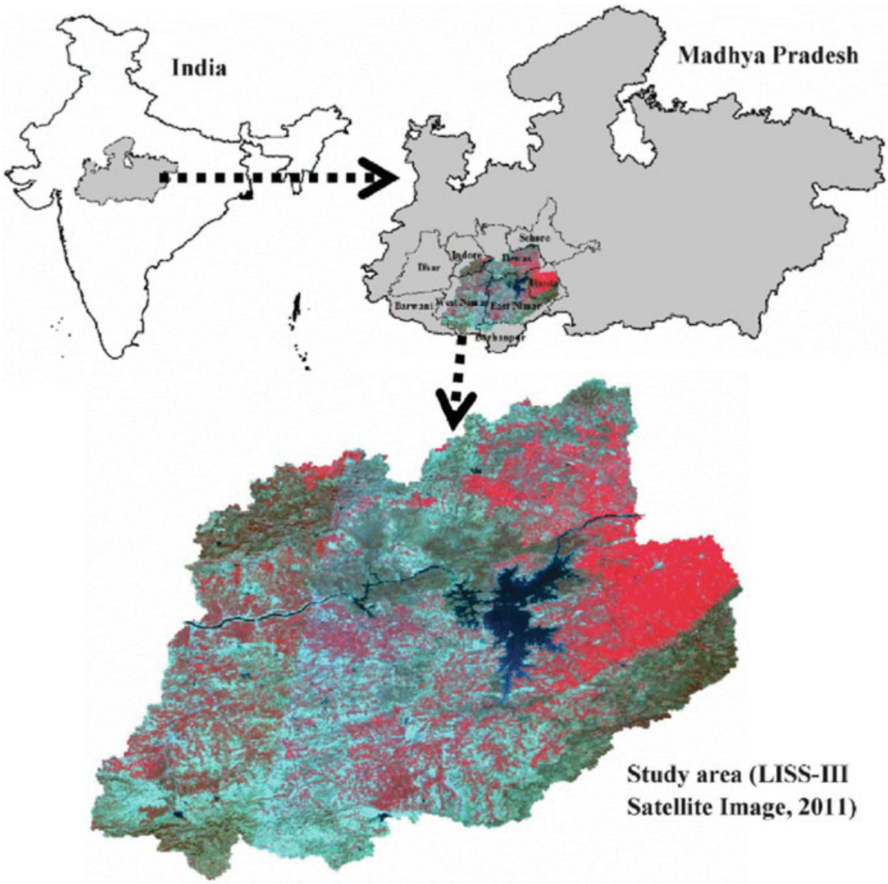

Fig. 1.1 Study area

1.3.2 Supervised Fuzzy C-Mean Method

Classification with supervised fuzzy logic was used by Jain and Dubes (1988). In the fuzzy technique a pixel may have a partial membership value corresponding to many land use categories. This algorithm works on the basis of iterative minimization of the objective function.

$$J_m(U, v) = \sum_{i=1}^{C} \sum_{k=1}^{N} u_{ik}^m \|y_k - v_i\|^2 \tag{1.2}$$

where,

Y = {Y1, Y2 . . . . . YN} ⊂ Rn = the data,
c = number of clusters in Y; 2 ≤ c ≤ n,

m = weighting exponent; $1 \leq m < \infty$
U = fuzzy c-partition of Y; $U \in$ Mfc
v = (v1, v2 . . . . . vc) = vectors of centers,
vi = (vi1, vi2, .., vin) = center of cluster i,
$\| \|_A$ = induced A-norm on R'', and
A = positive-definite (n × n) weight matrix.

The constraints are satisfied by the membership values,

$$0 \leq u_{ik} \leq 1; \text{where} \quad i \in \{1, ...C\}; k \in \{1, ...N\} \tag{1.3}$$

$$\sum_{i=1}^{C} u_{ik} = 1; \quad k \in \{1, ..., N\} \tag{1.4}$$

$$\sum_{k=1}^{N} u_{ik} > 0; \quad i \in \{1, ..., C)\} \tag{1.5}$$

The objective function is considered as the sum of the square of Euclidean distances from each input sample to its corresponding cluster centre where these distances are weighted by the memberships of fuzzy. It is given as:

$$\hat{v}_i = \left[\sum_{k=1}^{N} u_{ik}^m y_k\right] / \sum_{k=1}^{N} u_{ik}^m \tag{1.6}$$

$$\hat{u} = 1 / \sum_{j=1}^{C} \left[\|y_k - v_i\| / \|y_k - v_j\|\right]^{2/(m-1)} \tag{1.7}$$

The membership value of each class depends on the distance to the centre of the corresponding cluster. Samples with small membership values will have little influence values with greater value of m (Bezdek et al. 1984).

1.3.3 Markov Chain Analysis

Markov model is used in the study to give future changes in landuse. The Markov model is given as (Weng 2002),

$$\begin{aligned} P\{X_t = a_j | X_0 = a_0, X_1 = a_1, \ldots, X_{t-1} = a_i\} \\ = P\{X_t = a_j | X_{t-1} = a_i\} \end{aligned} \tag{1.8}$$

Moreover, it is proper to regard the change process as one which is uniquely distinctive with time (t = 0, 1, 2. . . . . .).

$P\{X_t = a_j | X_{t-1} = a_i\}$ gives the probability where the process develops transition from state a_i to state a_j within one time period. When the ℓ steps are required for implementing the transition, then the $P\{X_t = a_j | X_{t-1} = a_i\}$ is called the ℓ step transition probability $P_{ij}{}^{(\ell)}$.

In case $P_{ij}{}^{(\ell)}$ is independent of time and dependent on states a_i, a_j and ℓ, the Markov chain is then called homogeneous. Here,

$$P\left\{X_t = a_j \middle| X_{t-1} = a_i\right\} = P_{ij} \tag{1.9}$$

where P_{ij} value is calculated from the observed data by arranging the number of times the observed data go from state i to j, n_{ij}, and total occurrences of the state a_i, n_i is summed up.

$$P_{ij} = n_{ij}/n_i \tag{1.10}$$

As the Markov chain continues with time, the probability of retaining in state j gets independent of the initial state of the chain after many steps. When this condition occurs, the chain is considered to have reached a steady state. Then P_j, which is the limit probability, is used to determine the value of $P_{ij}{}^{(\ell)}$,

$$\lim_{n} P_{ij}^{(n)} = P_j \tag{1.11}$$

where,

$P_j = P_i P_{ij}^{(n)}$ j = 1, 2, . . ., m (state)
$P_i = 1\ P_j > 0$

In the transition probability matrix, each element comprises a category with the observed and expected number of transition,

$$\chi^2 = \sum \frac{(O-E)^2}{E} \tag{1.12}$$

Here O is the observed number of transitions from one state to another and E represents the expected number of transitions.

1.4 Results and Discussion

Error matrix was prepared with the 120 sample points given in Table 1.1. Producers and Users accuracy for 1990 ranges from 73.5 to 87.5 % for both, for 2000 it ranges from 79.4 to 87.18 % and 81.25 to 87.18 % respectively, for 2011 it ranges from 78.5 to 91.7 % and from 81.5 to 85.4 % respectively (Table 1.1).

Table 1.1 Error matrix

Class name	Reference totals	Classified totals	Number of correct points	Producers accuracy (%)	Users accuracy (%)
1990					
Water body	5	5	4	80	80
Built-up	8	8	7	87.50	87.50
Dense vegetation	34	34	25	73.53	73.53
Grass land	40	39	34	85	87.18
Fallow land	33	34	28	84.85	82.35
Total	120	120	98	.....	.....
2000					
Water body	6	6	5	83.33	83.33
Built-up	11	11	9	81.82	81.82
Dense vegetation	34	32	27	79.41	84.38
Grass land	39	39	34	87.18	87.18
Fallow land	30	32	26	86.67	81.25
Total	120	120	101	.....	.....
2011					
Water body	6	6	5	83.33	83.33
Built-up	12	13	11	91.67	84.62
Dense vegetation	26	27	22	84.62	81.48
Grass land	48	48	41	85.42	85.42
Fallow land	28	26	22	78.57	84.62
Total	120	120	101	.....	.....

Table 1.2 Kappa statistics

Class name	Kappa statistics (1990)	Kappa statistics (2000)	Kappa statistics (2011)
Water body	0.79	0.82	0.82
Built-up	0.87	0.80	0.83
Dense Vegetation	0.63	0.78	0.76
Grass land	0.81	0.81	0.76
Fallow land	0.76	0.75	0.80

Kappa statistic was highest for the built-up in 2011 which was 0.83, for 2,000 maximum Kappa was observed for water body (0.82) and for 1990 it was again built-up (0.87) (Table 1.2).

Overall kappa statistics and overall accuracy for 2011 were 0.78 and 84.17 %, for 2000 they were 0.79 and 84.17 % and 1990 shows 0.75 and 81.67 % respectively (Table 1.3). To assess the landuse change in different decades, Landsat images of the year 1990, 2000 and 2011 were classified with Fuzzy C-Mean. Changes in the area that have occurred in different years are provided in the Table 1.4. The largest increase in the area of water and built-up was observed from 1990 to 2011. Water area increased from 1.01 to 4.56 % in 2011 while built-up increased from 3.62 to

Table 1.3 Overall kappa statistics and overall accuracy

Category	1990	2000	2011
Over all kappa statistics	0.75	0.79	0.78
Over all accuracy (%)	81.67	84.17	84.17

Table 1.4 Distribution of area of different landuse

Classes	1990 (km^2)	1990 (%)	2000 (km^2)	2000 (%)	2011 (km^2)	2011 (%)
Water	207.13	1.01	263.38	1.28	937.35	4.56
Built-up	743.25	3.62	1,307.20	6.36	2,164.64	10.53
Vegetation	6,234.55	30.33	5,879.80	28.60	4,695.65	22.84
Agricultural land	7,167.72	34.87	7,361.18	35.81	8,275.71	40.26
Fallow land	6,205.35	30.18	5,746.44	27.95	4,484.66	21.81
Total	20,558	100	20,558	100	20,558	100

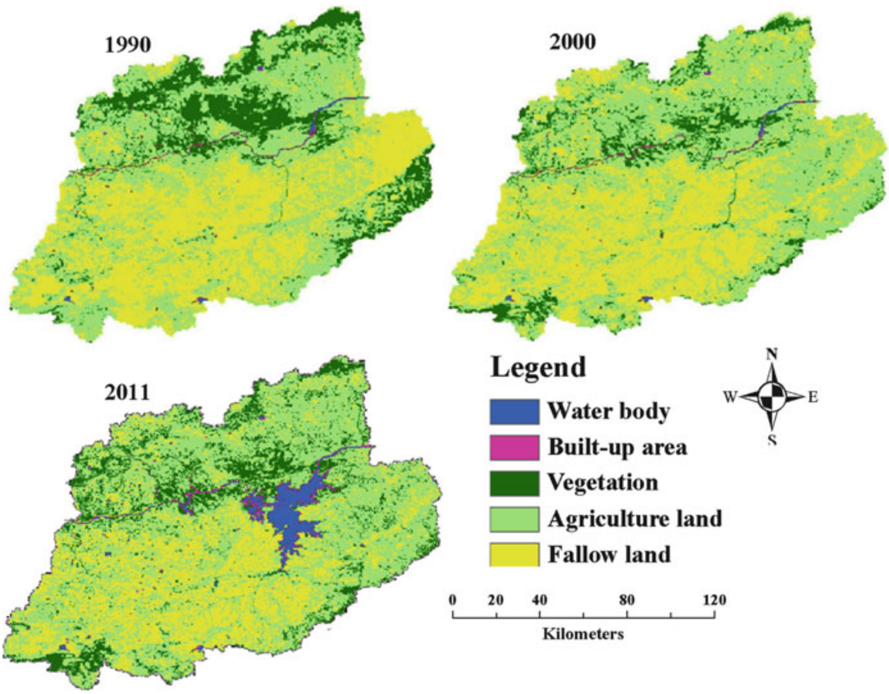

Fig. 1.2 Landuse map of 1990, 2000 and 2011

10.53 % in 2011. Area of light vegetation also increased from 34.87 to 40.26 % in 2011. Increase in water area is mainly because of the construction of the Indira Sagar dam after 2000.

The landuse map of 1990 given in the Fig. 1.2 is showing vegetation in the north and the extreme southwestern part. The water body is found in the eastern part which is a part of Narmada river while agricultural land covers a large area in the

Table 1.5 Predicted 2011 for validation probability matrix

	2011					
	Types	Water	Built-up	Vegetation	Agricultural land	Fallow land
2000	Water	1.00	0.00	0.00	0.00	0.00
	Built-up	0.00	1.00	0.00	0.00	0.00
	Vegetation	0.02	0.02	0.50	0.31	0.15
	Agriculture land	0.06	0.05	0.13	0.56	0.21
	Fallow Land	0.01	0.06	0.14	0.39	0.39

Table 1.6 Predicted 2011 for validation area matrix

	2011					
		Water	Built-up	Vegetation	Agricultural land	Fallow land
2000	Water	262.68	0.00	0.00	0.18	0.52
	Built-up	0.00	1,307.10	0.00	0.00	0.10
	Vegetation	113.58	120.66	2,928.68	1,847.99	868.89
	Agriculture land	450.20	360.78	923.91	4,085.74	1,540.55
	Fallow Land	76.05	364.49	810.33	2,262.98	2,232.59

north and central part of the region. Fallow lands cover major areas in the south central part. Landuse map of 2000 depicts decrease in dense vegetation but increase in agricultural land which is due to increasing settlements. Built-up area increases at the expense of fallow land which has reduced considerably. In 2011, water bodies increases to a great extent due to construction of the Indira Sagar Dam after 2000. Vegetation and fallow land decreased to a great extent with the rise in built-up and agricultural lands.

Table 1.5 indicates the probability matrix generated by using 1990 and 2000 landuse to develop 2011 predicted probability matrix. Table 1.6 illustrates the predicted area of 2011 for validation. The predicted area of water was 902.50 km^2, for built-up it was 2,153.02 km^2, for vegetation it was 4,662.93 km^2, for agricultural land it was 8,196.89 km^2 and for fallow land it was 4,642.65 km^2 in 2011 while the original area of 2011 was 937.35, 2,164.64, 4,695.65, 8,275.71 and 4,484.66 km^2 respectively. Thus the difference between predicted and original landuse was very less. According to the change matrix from 2000 to 2011 (Table 1.6), a shift in the area of built-up to other classes was almost zero while transfer of fallow land to agricultural land was highest (2,262.98 km^2). Again, shift of vegetation to agriculture land was also quite high (1,847.99 km^2) and change from vegetation, fallow land and agricultural lands to built-up contributes to 120.66, 364.49 and 360.78 km^2 respectively. Change in the area of water body to other land classes was also very low. Thus the highest transfer or change of the area was found in cases of built-up, agricultural land, vegetation and fallow land. When change in the area of built-up and agricultural land was positive, it was negative for the vegetation and fallow land.

Table 1.7 Future prediction of landuse from Markov Chain for 2020 and 2030

Classes	2011 (km^2)	2011 (%)	2020 (km^2)	2020 (%)	2030 (km^2)	2030 (%)
Water	937.35	4.56	967.80	4.71	1,009.69	4.91
Built-up	2,164.64	10.53	2,709.80	13.18	3,268.16	15.90
Vegetation	4,695.65	22.84	4,527.05	22.02	4,305.82	20.94
Agricultural land	8,275.71	40.26	8,113.08	39.46	7,945.07	38.65
Fallow land	4,484.66	21.81	4,240.26	20.63	4,029.27	19.60
Total	20,558	100	20,558	100	20,558	100

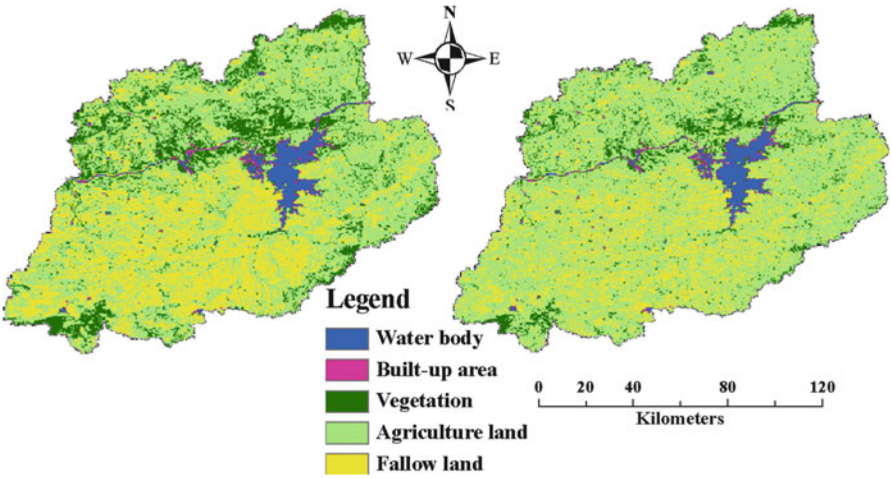

Fig. 1.3 Landuse prediction of 2020 and 2030

The predicted result of 2020 and 2030 indicates an increase in the water body and built-up area in next 19 years while vegetation, agricultural land and fallow land decreases. Settlements have increased at the cost of vegetation and fallow lands which have declined to a great extent. Water area has increased due to construction of dams and other landuse classes have reduced in the next few decades as predicted by the model (Table 1.7). The predicted landuse maps of 2020 and 2030 are shown in Fig. 1.3.

1.5 Conclusion

The study demonstrates the use of the Fuzzy C-Mean for classifying landuse classes of 1990, 2000 and 2011 to detect changes that have occurred within these 21 years. Future prediction was carried out with the Markov Chain model which illustrates huge alteration and changes in the existing landuse. The predicted result was validated with the 2011 landuse. The spatial accuracy for Markov Chain prediction was around 92.5 % and thus has achieved a satisfactory level indicating agreeable similarity between the classified 2011 image of the Fuzzy C-Mean and predicted image of the Markov model. The combined use of both the Fuzzy C-Mean and Markov model was done to see changes in the landuse in three decades due to population growth along with the future prediction of landuse of 2020 and 2030. The study area experienced growth of various irrigation projects, construction of the Indira Sagar dam etc. that has boosted up the agricultural production and encouraged growth of built-up and population in the region. An obvious increase in the built-up area was observed since 1990 which has largely enhanced after 2000. Consequently, agricultural lands have increased due to various planning which has caused a decline in the space of forests and fallow lands. Maximum shift of the area was observed in vegetation and fallow lands from 2000 to 2011. Transfer of fallow land to agricultural land was highest followed by vegetation to agricultural land. Although transfer of vegetation, agriculture and fallow land to built-up area was comparatively much less, but the importance of this change is very high because it is the reason for further growth in agriculture and for the fact that the transfer of built-up to other landuse classes is almost zero. Thus future planning should be done keeping this rapid growth of population in concern as further water resources planning and management will be necessary in near future.

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Chapter 2
Application of Remote Sensing and GIS for Landslide Disaster Management: A Case from Abay Gorge, Gohatsion–Dejen Section, Ethiopia

Shiferaw Ayele, Tarun K. Raghuvanshi, and P.M. Kala

Abstract The Abay Gorge, along Gohatsion–Dejen road, in Ethiopia witness frequent landslides during the rainy season. The natural stability of slopes has been disturbed due to the road construction, the fragile geological conditions, groundwater and uncontrolled surface run-off which favor landsliding during rainy season. Such landslide hazard has resulted into frequent disruption in traffic movement and endangered the people life and their property in the area. Rock fall, toppling, debris slide and rotational failure of colluvial material are some of the common land instability manifestations observed in the area. Mitigating landslide risk disaster is of prime concern and through the present study attempts are made to delineate the landslide hazard prone zones in the study area. For this purpose Landslide Hazard Zonation (LHZ) mapping using integrated Remote Sensing and GIS technique was carried out so as to classify the land surface into zones of varying degree of hazard. Thus, the landslide hazard zonation mapping produced through present study will be useful to the planners and engineers to know the zones which are prone for landslide disaster and they may evolve suitable remedial measures for disaster risk reduction and management.

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For the present study, "Weighted Linear Combination (WLC)" technique was used to prepare the Landslide hazard zonation map. In WMC technique, each factor was multiplied by its derived weight and later the results were added to produce the landslide hazard map.

WLC helps to handle the problem of integration of different data layers with heterogeneity and certain degree of uncertainty. The method used is very useful to integrate single factor maps with each other and thus to produce a multi-thematic map. This model requires multi spatial data on a target area and then can be extrapolated in to a larger area as required. For landslide hazard zonation the major event controlling parameters which were considered are; geology, groundwater conditions, drainage, slope, geologic structure, aspect, and land use/land cover.

For landslide hazard zonation five relative classes, namely Very Low Hazard (VLH), Low Hazard (LH), Moderately Hazard (MH), High Hazard (HH) and Very High Hazard (VHH) were considered. The result has shown that out of 21 past slope failures, seven (33.33 %) occurs in very high, seven (33.33 %) in high, five (23.81 %) in moderate and two (9.52 %) in low hazard zones, respectively. The comparison shows satisfactory results as 67 % of the past landslides lie within the maximum hazard zone, and the remaining within the moderate and low hazards zones. No landslide event was observed in the very low hazard zone. Thus, the satisfactory agreement confirmed the rationality of the considered governing parameters, their influential weight, the adopted methodology, tools and procedures in developing the landslide hazard map of the study area.

Keywords DEM • GIS • Landslide hazard zonation • Multi-criteria evaluation • Remote sensing • Weighted linear combination

2.1 Introduction

The Abay Gorge, along Gohatsion–Dejen road, is one of the common areas in the country where most slope instabilities are frequently observed. It is very common to see slope failure events that hinder traffic movements during the rainy season (Woldegiorgis 2008). Rock fall, toppling, debris slide and rotational failure of colluvial material are some of the common land instability manifestation (Ayalew 2000; Woldegiorgis 2008; Saed 2005; Ayalew and Yamagishi 2003). Huge columnar jointed basalt, groundwater, uncontrolled surface run off, joints of rocks, and the presence of marl and shale within hard rocks are the main causes of slope instability. During the past years, landslides and rock falls had damaged the road sections, bridges and farmlands.

The study area is a part of economically important main Addis Ababa-Debremarkos—Bahardar—Gondar—Metema—Sudan root and Gondar—Tigray road that connects north central and north western part of the country with the capital of Addis Ababa and port of Sudan. The study area is situated in the central

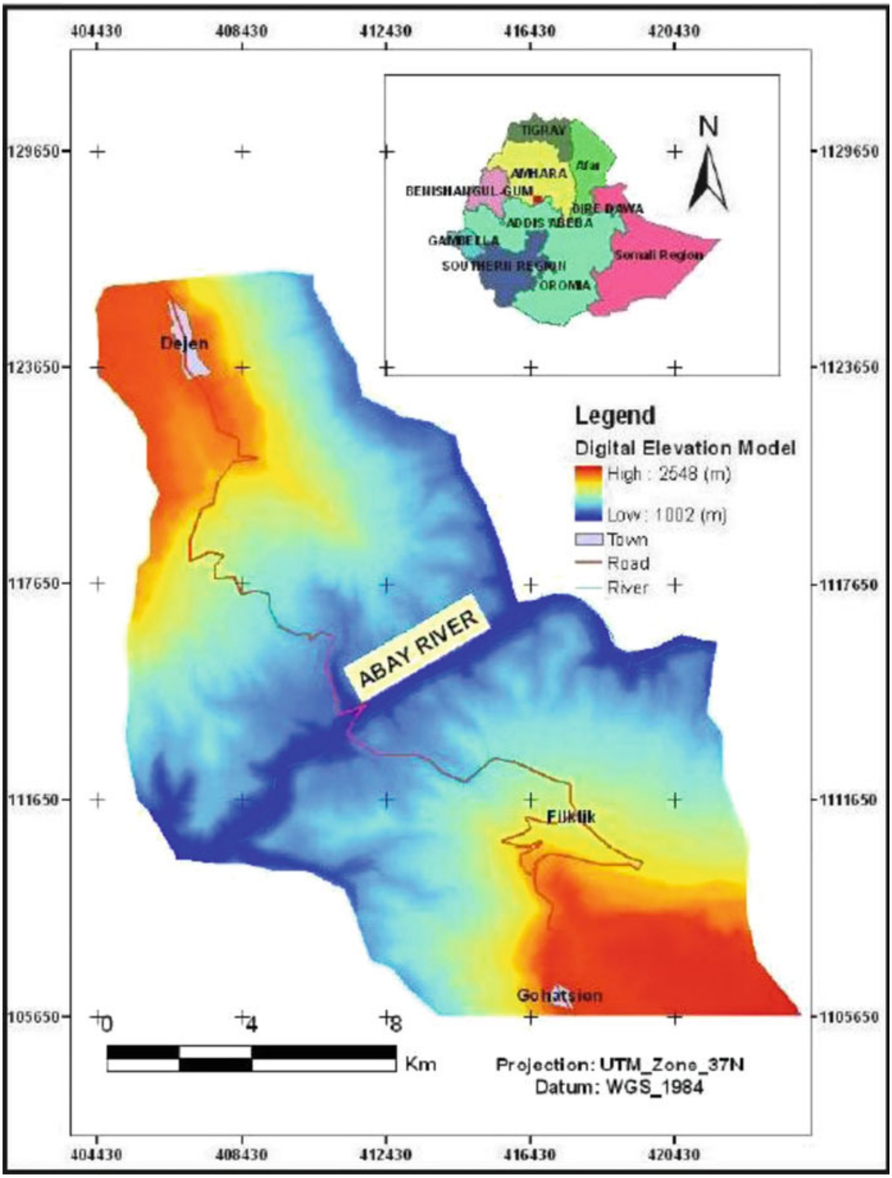


Fig. 2.1 The study area

plateau of Ethiopia and bounded by 38°07′38″ E and 38°18′18″ E longitudes, and 10°00′ N and 10°10′11″ N latitudes (Fig. 2.1), covering an area of about 235.1 km^2.

The present research study was aimed at application of Remote Sensing and GIS for landslide disaster Management—A case from Abay Gorge, Gohatsion–Dejen

Section, Ethiopia. The main objectives of the study were: (1) to examine and demonstrate the usefulness of integrated RS and GIS approaches for landslide hazard mapping in the study area, (2) to produce landslide hazard map of the study area, (3) to delineate the different critical as well as unstable areas in the area in terms of the land hazard risks and (4) to propose possible remedial measures to the problem.

2.2 Geomorphology

The study area is characterized by its 1,400–1,500 m deep gorge, which is made of stratified sedimentary rocks capped by basaltic plateau. The present physiographical setting of the study area is a result of various processes. Uplifting which is believed to be responsible for the formation of the deep canyon, erosional leveling, weathering and mass wasting have played a major role in creating the present landform (Gezahegn and Dessie 1994).

The main landforms of the study area, based on their origin, are Volcanic/Denudational, Denudational, Fluvial/Denudational and Fluvial Land Forms.

2.3 Geology of the Study Area

The sedimentary history of the Mesozoic succession is related to the formation of basins around the borders of the mega continent, especially along the eastern African margin. These basins are the results of the break-up of Gondwanaland during Paleozoic-Jurassic times. The basins is largely fault-controlled and with limited marine access, are filled with a thick succession of Karoo sediments known also as the Gumburo Formation in Ethiopia (Assefa 1991).

The sedimentary rocks in Abay Gorge are formed within Mesozoic time and the volcanic rocks within Cenozoic times, respectively. The nature of lithology fossils dispersion and sedimentary structures are due to a complex of depositional environments, such as coastal fluvial lacustrine, partially arid lagoon. However, the basalt is from fissural flow of Magma (Gezahegn and Dessie 1994).

The Mesozoic sedimentary rocks are exposed in the Abay river valley, between the towns Gohatsion and Dejen, along Addis Ababa to Debre Markos road. A succession about 1,200 m thick is well exposed on the left side of the above mentioned valley, with a nearly horizontal stratification. The major transgression deposit is characterized by restricted marine evaporate sediments lagoonal, Sabkha sediments and continental sandstones in Abay River (Atnafu 2003).

The Geological units of the study area are Paleozoic and Mesozoic Sedimentary Rocks, and Tertiary Volcanic Rocks and Quaternary Superficial Deposits (Fig. 2.2).

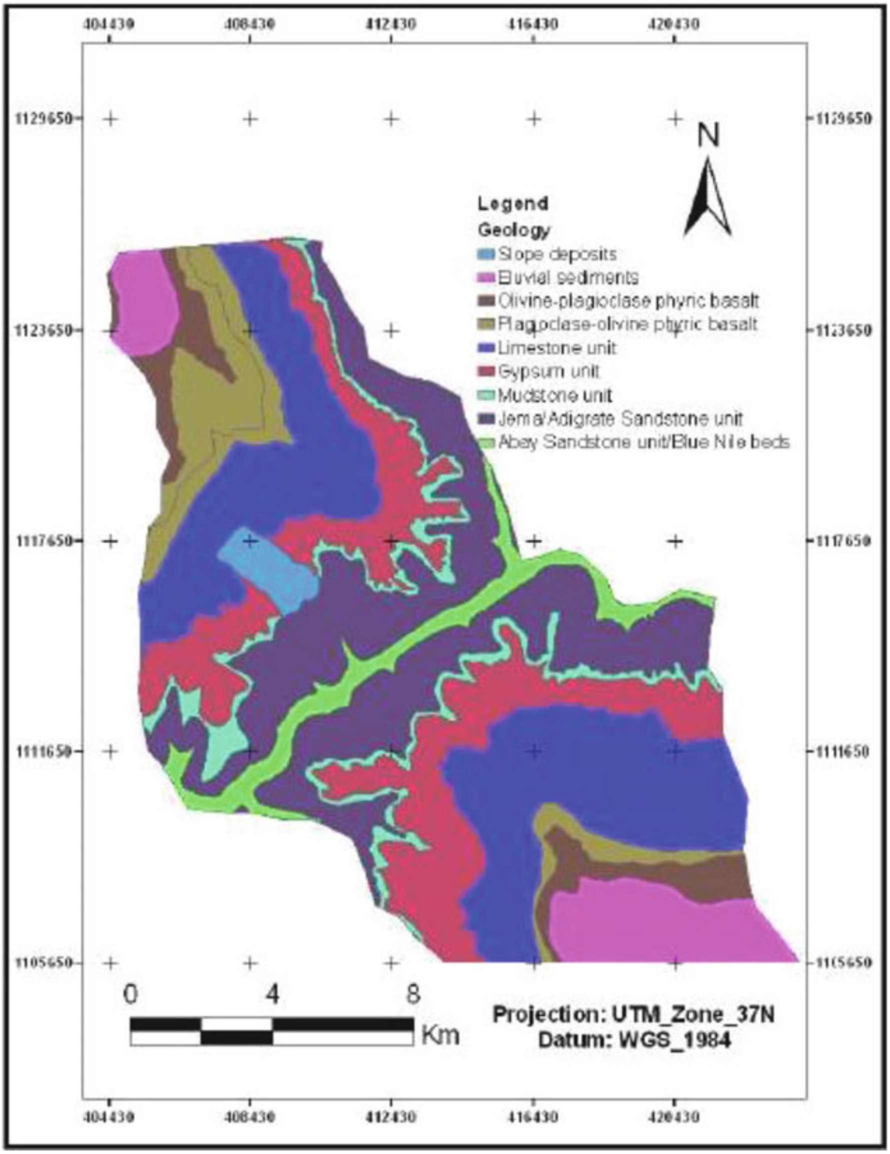


Fig. 2.2 Geological map of the study area

The Paleozoic sedimentary rocks are: Abay Sandstone Unit or Abay Beds (Pssm)—The sandstone at its top part alternates with siltstone and/or shale and mudstone; the siltstone and/or shale and mudstone sediments occupy the top most part while the sandstone occupies the lower part.

The Mesozoic sedimentary rocks from the oldest to the youngest are: Jema Sandstone or Adigrat Sandstone Unit (Mst), Mudstone Unit (Mms), Gypsum Unit

(Mgb) and Limestone Unit (Mls). The Tertiary basalt lava flows from the oldest to the youngest are: Migira basalt (Tv3), Hacho basalt (Tv4), Olivine Plagioclase phyric basalt (Selelkula basalt) and Basalt (Tv6). The Quaternary superficial sediments are Quaternary Eluvial Sediments (Qe) and Quaternary slope sediments (Qs).

2.4 Materials and Methodology

The data that was used for the present study includes; topographic map, geological, structural and engineering geological maps, soil maps, Landsat 7 ETM + Enhanced Thematic (Mapper Plus), Shuttle Radar Topographic Mission (SRTM). ERDAS Imagine 8.6 was used for image processing of landsat ETM + image in lineanament analysis and landuse/landcover classification, MapInfo for digitizing structures and landuse/landcover, respectively, ArcGIS 9.1, IDRISI 32 and Global Mapper were used for data acquisition, analysis and presentation of the final research results.

Several methods have been employed by several authors to assess landslide hazard and to map hazard zone in different parts of the world. These methods can be classified into three groups; expert evaluation, statistical methods and deterministic method (Leroi 1997; Guzzetti et al. 1999; Casagli et al. 2004; Fall et al. 2006; Kanungo et al. 2006).

Expert evaluation method further can be classified into two; landslide inventory mapping and heuristic method (Fall et al. 2006). Landslide inventory mapping is the simple method in which the landslide events are recorded for their location and dimension (Dai and Lee 2001; Dai et al. 2002; Fall et al. 2006).

The heuristic method includes opinion in classifying the landslide hazard which is based on quasi-static variables only (Dai and Lee 2001; Fall et al. 2006). Different maps of causative factors, which may have influence on the landslide occurrence are prepared and combined to prepare the hazard map (Dai and Lee 2002). The numerical ratings are assigned to various causative factors responsible for instability of slope which is based on logical judgments of Geoscientist acquired from experience of studies of causative factors and their relative impact on instability of slopes (Anbalagan 1992). Higher the numerical value of rating, greater will be its influence on the occurrence of landslide (Kanungo et al. 2006). There are several Expert evaluation techniques available these includes techniques proposed by Anbalagan 1992; Pachauri and Pant 1992; Sarkar et al. 1995; Turrini and Visintainer 1998; Guzzetti et al. 1999, etc.

The statistical methods are indirect and landslide hazard assessment is made based on the rules evolved statistically with the relative contribution of instability factors on past landslides. The statistical methods are used to evaluate spatial landslide instability based on relationship in between the past landslide activities and the instability causative factors (Carrara et al. 1992). Statistical analysis approach includes bivariate and multivariate methods. In bivariate method for landslide susceptibility assessments the weights are assigned to various factors based upon statistical relationships between past landslides and various factor (Van Westen 1994). Individual factor maps are overlaid on past landslide map to workout relative contribution for each factor and subclass in inducing landslide. From this data, weights are developed to be applied to each factor subclass so that landslide hazard can be deduced. The multivariate model uses an equation in which independent variables are the geo-environmental factors with coefficients maximizing the predictive capability of the model, and the independent variable is the presence/absence of landslides.

Deterministic approach provides hazard in absolute values in the form of factor of safety, or the probability. In these methods various forces responsible for instability and the forces responsible for stability are evaluated in quantitative terms. The deterministic approach provides the quantitative results for landslide hazard that can be directly used in the engineering design. The deterministic approach requires detailed geotechnical data and can be applied at large scales only (Barredo et al. 2000).

The successful use of one method over other strongly depends on many factors such as; scale of the study area, the accuracy of the expected results, the availability of data, parameters considered etc. (Fall et al. 2006).

In the present study, a "Weighted Linear Combination method" (WLC) to delineate the landslide hazard zones was employed. The method includes three main stages; pre-field work (data preparation), field work (data verification) and post field work (analysis and interpretation) (Ayalew et al. 2004).

The first stage includes data collection from different sources and map preparations. In this stage, lineament/structural and landslide inventory maps were prepared by the interpretation of aerial photographs, satellite image interpretation and digitizing from previous works; bedrock geology of the study was imported; DEM, slope, slope aspect and drainage maps were prepared from SRTM data; land use/land cover map was prepared from Landsat ETM + image interpretation. The study area boundary has been set, (UTM) Zone 37 N & WGS84 datum was chosen.

The second stage of the methodology was ground truthing. It is done with the help of Global positioning System (GPS) and field compass. All other necessary data/information was collected for ground truthing and maps were prepared, verified and modified whenever it was felt necessary.

Finally, the susceptibility maps produced from the weighted linear combination method was produced and subsequently evaluated using field data/ground truthing. Figure 2.3 shows the general methodology followed for the landslide hazard zonation mapping of the study area.

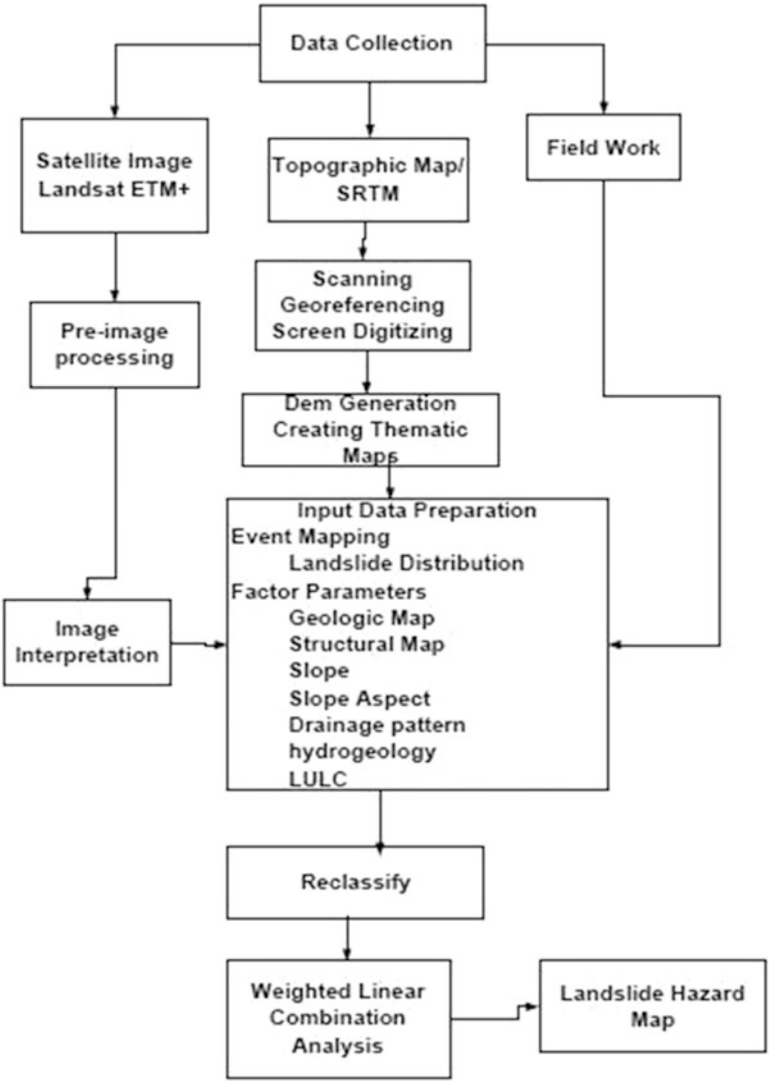


Fig. 2.3 Conceptual workflow the methodology

2.5 Results and Discussion

2.5.1 Factor Maps Preparation

A field survey was carried out to identify and establish priority based on the number of landslide occurrences for the causative factors that might have triggered the mass movement in the area. Accordingly, the location of landslides, type of landuse/

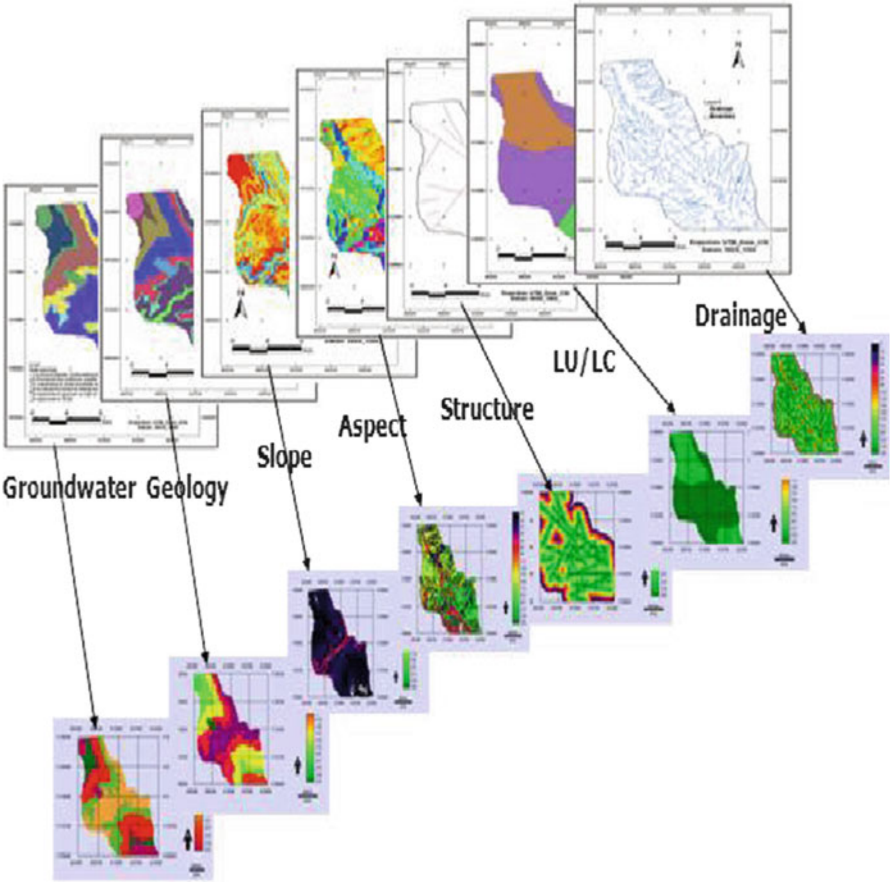


Fig. 2.4 Reclassified factor maps

landcover, slope angle, lithology, geological structures, drainage pattern & hydrogeology/groundwater conditions, degree of weathering and soil types were identified.

Two types of reclassification were applied to reclassify factor maps. The first type is the Fuzzy module in IDRISI 32 software used for the reclassification of different data layers of drainage and geological structures, and slope data layer to avoid distinct boundary where continues scaling values ranging from 0 to 255 was assigned. The second type of reclassification, the STANDARD RECLASS module in IDRISI 32 software, uses each class and has a distinctive rating value that makes it more suitable as compared to the other classes where distinct boundary is assigned.

Based on the landslide event mapping and field observations, each factor was reclassified into different classes (Fig. 2.4 and Table 2.1).

Table 2.1 Input parameters and their relative rating

S.No.	Major factors	Sub factors	Landslide occurrence	Rating
1	Slope angle	As the slope angle increases the impact is also expected to increase	As the slope angle increases the landside occurrences assumed to be increase	0–255 (fuzzy boundary) High value means high impact and vise versa
2	Slope aspect	North (0–22.5, 337.5–360)	9	200
		East (67.5–112.5)	1	20
		South (157.5–202.5)	6	150
		West(247.5–292.5)	7	175
		Northeast (22.5–67.5)	1	20
		Southeast (112.5–157.5)	4	100
		Southwest (202.5–247.5)	2	50
		Northwest (292.5–337.5)	14	255
		Flat (−1)	0	0
3	Landuse/ landcover	Intensively cultivated	14	238
		Bareland/woodland/bush	15	255
		Less dense bush land	14	255
4	Drainage	The drainage impact is expected to decreases further away from the drainage line	Away from the drainages the landslide occurrences assumed to decrease	0–255 (fuzzy boundary) High value means high impact and vise versa
5	Geological structure	The impact of geological structures is expected to decreases further away from the structure lines	Away from the geological structures the landslide occurrence assumed to decrease	0–255(fuzzy boundary) High value means high impact and vise versa
6	Lithology	Colluvial soil	3	255
		Residual soil	1	200
		Basalt overlain by colluvim	14	180
		Limestone with intercalated with friable material	12	50
		Gypsum	4	72
		Shale	1	90
		Fractured Sandstone	9	50

7	Groundwater	Loose materials (colluvial/Residual/basalt) yield up to 1 L/s	15	255
		Fractured discontinuous aquifer in basalt, with Q up to 0.2 L/s	3	200
		Limestone and shale localized aquifer along fracture, Q up to 1 L/s	12	180
		Localized fractured & intergranular aquifer (SST) Q up to 0.4 L/s	9	100
		Aquiclude in gypsum except at some fractures	5	40
		Aquiclude in shale	0	40

Table 2.2 Pair wise comparison matrix

Parameters	Geology	Groundwater	Drainage	Slope	Structure	LULC	Aspect
Geology	1						
Groundwater	1	1					
Drainage	5/7	5/7	1				
Slope	5/7	5/7	1	1			
Structure	3/7	3/7	3/5	3/5	1		
LULC	1/7	1/7	1/5	1/5	1/3	1	
Aspect	1/7	1/7	1/5	1/5	1/3	1	1

Each factor map was reclassified into classes in order to make the same output scaling of 0–255. This Byte (0–255 range) is mainly used with modules such as MCE that require byte data format. This scaling is assigned based on the number of landslides and parameter estimation during field survey. Accordingly, the classes of each factor that had the maximum number of landslide events were given the maximum value of 255 or close to 255, whereas classes in which none or a few number of landslides occurred were assigned with a minimum value of 0 or close to 0.

For slope monotonically increasing module was used because as slope increases landslide effect also increases. This reclassification is applied to avoid distinct boundary where continues scaling values ranging from 0 to 255 is assigned. The second type of reclassification classification is the Standard Reclass module in IDRISI 32 software, in which each class has a distinctive rating value that makes it more suitable as compared to the other classes where distinct boundary is assigned.

2.5.2 Weighting Factor Maps

After the standardization to common scale of each controlling factor, weight is given for each layer based on pair-wise comparison of two data layers at the same time, using pair-wise comparison of 9-point continuous rating scale in IDRISI 32 (Table 2.2). WEIGHT Module is used to develop a set of relative weights for a group of factors in a multi-criteria evaluation.

The weights were developed by providing a series of pairwise comparisons of the relative importance of factors to the suitability of pixels for the activity being evaluated. These pairwise comparisons are then analyzed to produce a set of weights that sum to one. The larger the weight means the more influencing is the factor. The factors and their resulting weights can be used as input for the MCE module for weighted linear combination or for other MCE modules. The weights developed to each factor are given based on the analytical hierarchy process proposed by Saaty (1994) by means of providing a series of pair-wise comparisons of the relative importance of factors.

Table 2.3 The eigenvector of weights

Factors	Weight
Geology	0.2414
Groundwater	0.2414
Drainage	0.1724
Slope	0.1724
Structure	0.1034
LULC	0.0345
Aspect	0.0345

Note: Consistency ratio = 0.00
Consistency is acceptable

The rating assigned during the pair-wise comparison is a subjective term based on the knowledge of the problem with its causing factors obtained during the field. In each cell of the matrix the relative importance of the row variable to its corresponding column variable was considered and the appropriate rating was given (Table 2.2). All the diagonal cells in the matrix contain a one since it represents the comparison of each variable with itself. Only the lower-left triangular half will actually be evaluated since the upper right is symmetrically identical and values are equal to the reciprocal of the lower-left.

After the pair-wise comparison matrix, individual factor weights were calculated (Table 2.3) using the WEIGHT module of IDRISI 32. The resulting consistency ratio of the above pair-wise comparison matrix is 0.00 that indicate acceptable consistency range because the acceptable consistency ratio of the pairwise comparision matrix is below 0:10). This consistency ratio value indicates the probability that the ratings were randomly assigned. The weights calculated indicate the relative significance of the factors in accomplishing the mass movement.

Based on field observations, the geology and groundwater, drainage and slope in the area have a great contribution in aggravating the mass movement. Thus, the highest weight has been given to geology and groundwater. The next highest weight has been given to drainage and slope.

The Dejen–Gohatsion section of the Abay Gorge is not intensively tectonized. However, structural systems in the area can be generalized into three systems of faults and joints of variable magnitude, extent and minor to significant orientation variations. These are the NW system which varies from N20°W to N50°W, the NE system which varies between N60°E to N85°E and the NS system which swings by about 10° in either side. There are some EW fractures at some places although they are not considered as major dislocations in the area. The N42°W faulting and associated jointing system seems the dominant structure in the gorge. The joint sets that affect the rocks especially the top basalt are both structure related and/or cooling joints.

These faults are significant factors in controlling the development of landslides and rock fall. Generally, rock masses near the faults and fractures are highly weathered and severely fractured. Therefore, reasonable weight is assigned for the structure. Finally, less weight has been given to landuse/land cover and aspect as compare to others although they play a reasonable contribution to the existing mass movements in the study area.

Table 2.4 Landslide hazard zonation on the basis of total estimated hazard (TEHD)

Zone	TEHD value	Description of zone
I	<93	Very Low Hazard (VLH) Zone
II	93–118	Low Hazard (LH) Zone
III	118–143	Moderate Hazard (MH) Zone
IV	143–168	High Hazard (HH) Zone
V	>168	Very High Hazard (VHH) Zone

Through a Multi-Criteria Evaluation, these criteria images (the reclassified geology, groundwater, drainage, slope, structure, aspect and landuse image maps) representing are combined to form a single suitability map. To combine the spatial layers to assess landslide hazard, algebraic combination techniques have been used (Wang and Unwin 1992). The integration is done through the application of WLC procedure. Each factor was multiplied by its derived weight and then the results added to produce the landslide hazard map (Fig. 5.15) using the following formula:

$$\mathrm{LHZ} = \mathrm{w1\ X1} + \mathrm{w2\ X2} + \mathrm{w3\ X3} + \mathrm{w4\ X4} + \mathrm{w5\ X5} + \mathrm{w6\ X6} + \mathrm{w7\ X7}$$

Where; LHZ = Landslide Hazard Zonation

w1 . . . w7 = weights for each factor and

X1 . . . X7 = the seven factors used in the analysis based on the degree to which factor weights influence the final result (i.e. X1 is the most influencing factor, where as X7 the least influencing factor the seven factors used in the analysis.

The produced hazard map was reclassified into very low hazard, low hazard, moderate hazard, high hazard and very high landslide hazard zone using ARCGIS Spatial analyst module (Table 2.4 and Fig. 2.5).

Accordingly, the five categories correspond to five relative scales of landslide hazard zones, namely Very Low Hazard (VLH) (1), Low Hazard (LH) (2), Moderately Hazard (MH) (3), High Hazard (HH) (4) and Very High Hazard (VHH) (5). This is depicted in Fig. 2.6.

2.6 Conclusion

Landslides and rock falls are the major frequently occurring problems identified from previous work in the Abay (Blue Nile) Gorge along and near by Gohatsion–Dejen road. Nearly all slope failures occur during rainy season. The frequently occurring landslides have damaged the road sections, bridges and farmlands. The main causes of slope instability identified during the present study were mainly due to the presence of huge columnar jointed basalt, uncontrolled surface run off, preferred orientations of the discontinuities within the rock mass and the presence of soft rocks such as; marl and shale confined within the hard rocks.

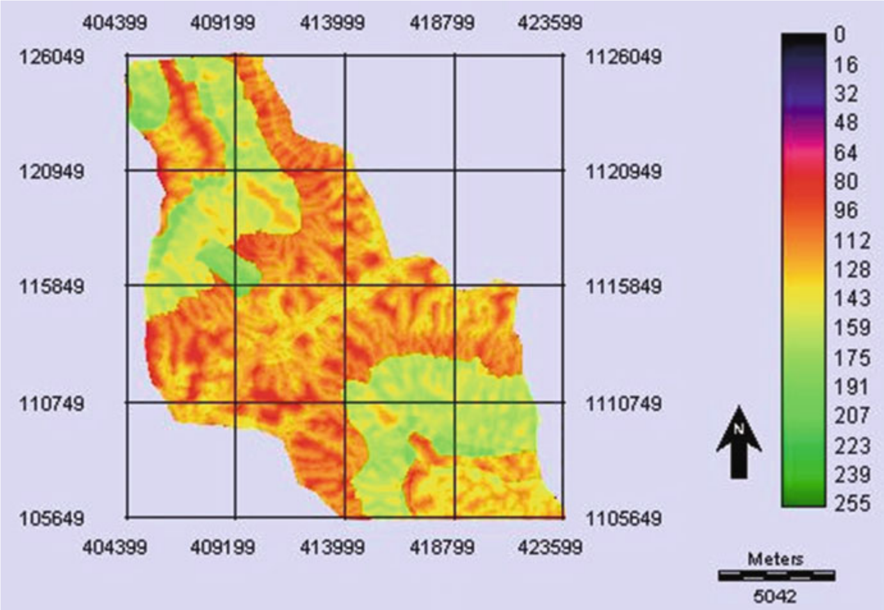
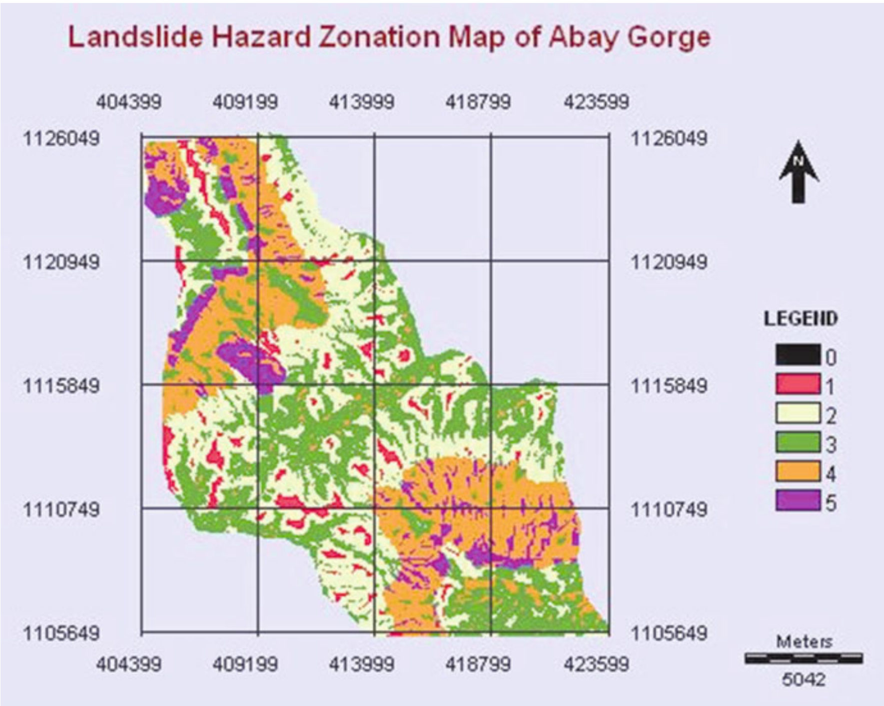


Fig. 2.5 landslide hazard map of Abay Gorge



***Note*: Nos. 1 to 5 marked in the legend indicate: 1, Very Low Hazard (VLH); 2, Low Hazard (LH); 3, Moderately Hazard (MH); 4, High Hazard (HH); 5, Very High Hazard (VHH)**

Fig. 2.6 Landslide hazard zonation map of Abay Gorge

The structural systems of the study area can be generalized into three systems of faults and joints of variable magnitude, extent and minor to significant orientation variations. These are the NW system which varies from N200W to N500W, the NE system which varies between N600E to N850E and the NS system which swings by about 100 in either side. There are some EW fractures at some places although they are not considered as major dislocations in the area. The N420W faulting and associated jointing system seems the dominant structure in the gorge.

Colluvial soils are also the most susceptible soils for the sliding process in the study area. This is because when these colluvial soils are oversaturated during the rainy season, they will be subjected to swelling this ultimately results into landsliding process. Furthermore, when these soils get dried there will be shrinkage which will result into change in the volume of the soil mass, thus the rock fragments of varied dimensions will be subjected to movement.

In this study, seven landslide-controlling parameters, namely lithology, groundwater, drainage, slope geologic structure, aspect and landuse/Landcover were identified. A Weighted Linear combination method to delineate the landslide hazard zones was employed.

The results of the entire analyses and evaluation of MLC method allowed dividing the study area into five zones of susceptibility, namely very low, low, moderate, high and very high using ARCGIS Spatial analyst module. Out of 21 critical slope failures, seven (33.33 %) has occurred in very high, seven (33.33 %) in high, five (23.81 %) in moderate and two (9.52 %) in low hazard zones, respectively.

According to this method landslide hazard was caused by the collective effect of the event controlling parameters. The method used is very useful to integrate single maps with each other and thus produce a multi-thematic map. The comparison of the landslide hazard map with the actual landslide activity distribution map has shown 67 % of the landslides lie within the maximum hazard zone, and the remaining with the moderate and low hazard zones.

Based on the present study following recommendations are forwarded;

The effects of landslides on people and structures can be minimized by total avoidance of landslide hazard areas or by restricting, prohibiting, or imposing conditions on hazard-zone activity.

In area which have intense gully erosions on both down and up slope of the road cut side retaining wall construction is required after clearing the rocks and debris fallen on the road, besides, proper drainage on the upper slope sections must be provided.

Develop appropriate policies in consultation with the local people and encourage their participation is an alternative mitigation strategy.

For the future development and strengthening of this model additional factor such as; characteristics of discontinuity surfaces, interrelationships of discontinuities, pore water pressure in soil mass, water forces acting within the discontinuity surfaces, shape factor of particles in coluvial material may be considered.

Effects of triggering factors such as; rainfall, seismicity, constructional activities and cultivation practices may also be considered.

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Chapter 3
Landslide Disaster Management and Reduction: An Approach Through Remote Sensing and GIS

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Abstract It is fact that, landslide disaster is the most significant hazard in the mountainous regions. These natural phenomena have resulted damage to engineering structures and loss to human life all over the world. Identification of potential instability problems in the initial stage of investigation may not only lead to delineation of landslide disaster zones but will also help to evolve possible remedial measures which may either be adopted to improve the slope stability condition or such problematic zones may be avoided for human settlement and any other developmental activities.

Remote sensing and GIS is a very useful tool in delineating area into various potential instability zones over a wide area. Information and data on all such aspects over a wide area can be abstracted by utilizing remotely sensed data and through GIS application tools. To understand the possible mechanism of landslide and relative contribution of various factors in inducing instability to slopes, it is required to study the past landslide activities. Later, the collected data has to be arranged and prepared into layered spatial GIS database for landslide hazard mapping. Some of the governing parameters; aspect, slope, curvature and elevation can be calculated from the digital elevation model (DEM) of the area, which can be obtained from the ASTER elevation data set. The slope material and land use/cover maps can be processed from Land sat + ETM satellite using different digital image

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processing procedures. Further, GIS based statistical and probability approach can be used to rate the governing parameters and then customized raster calculation can be applied to develop the landslide hazard map. Thus, Remote sensing and GIS application not only facilitate in identifying the potential landslide hazard over the area but it also helps in disaster management and reduction by provided information on possible degree of hazard with spatial distribution. Such information will be vital to mitigate the hazard and to foresee the anticipated adverse conditions which may adversely affect the safety of people and property.

Keywords DEM • GIS • Landslide disaster • Landslide hazard zonation • Remote sensing

3.1 Introduction

In the mountainous region, landslides are the most devastating natural hazards that caused hundreds of millions of dollars and hundreds of thousands of death and injuries each year throughout the world (Pan et al. 2008; Kanungo et al. 2006; Dai et al 2002; Schuster and Fleming 1986; Keefer 2000; Mario and Jibson 2000). These landslides have destroyed and damaged houses, industries, roads and other infrastructure, farm land and forest areas (Turner and Schuster 1996). Identification and delineation of areas having potential to such landslides is not only important to safeguard the existing developed areas but it is also mandatory to identify such areas which may have a potential for landslide before implementing any future developmental activity. Thus, identification of zones with landslide potential may help in evolving proper mitigation measures, on the same time, if required such hazardous zones may be avoided for the developmental activities to minimize the threat of destruction (Pan et al. 2008; Anbalagan 1992).

Assessment of Landslide hazard zones will depend on geologic information and its site characteristics and possible triggering factors. The instability in slopes is induced by natural factors; rainfall/snow, seismicity etc (Keefer 1984, 2000; Dai et al. 2002; Bommer and Rodrı'guez 2002; Malamud et al 2004; Dahal et al. 2006). Besides, in many cases these are initiated by human activities such as improper or poor road construction or inadequate road maintenance in mountainous terrains (Gorsevski et al. 2006). Combination of these triggering factors and inherent causative factors such as; slope material, slope morphometry (slope, aspect and elevation), engineering properties of slope material, groundwater conditions and landuse landcover (Wang and Niu 2009; Ayalew et al. 2004) may result into landslides.

3.2 Delineation of Landslide Hazard

In order to evaluate instability of slopes, landslide hazard zonation (LHZ) techniques can be used over a large area (Anbalagan 1992). LHZ facilitates delineation of area into zones of varying degree of potential or actual landslide hazard. Thus, the degree of potential hazard in an area can be estimated on the basis of qualitative or semi-qualitative measures of various instability inducing factors (Varnes 1984).

For the evaluation and delineation of landslide potential, several techniques has been developed in last few decades. These techniques use qualitative or semi-qualitative measures to assess various landslide inducing parameters. Depending upon method of evaluation these techniques can be placed into three broad groups; expert evaluation, statistical methods and deterministic approach (Leroi 1997; Guzzetti et al. 1999; Casagli et al. 2004; Fall et al. 2006; Kanungo et al. 2006).

The ‘Expert evaluation’ technique is the most straight forward approach and simple in application for landslide hazard zonation. These may further be classified as; landslide inventory mapping and heuristic approaches (Fall et al. 2006). However, Landslide ‘inventory mapping’ includes observations on past landslide activities in the area. The various landslides or related manifestations of instability are recorded for their location, dimension, (Dai and Lee 2001; Dai et al. 2002; Ayenew and Barbieri 2005; Fall et al. 2006) type, material involved and possible triggering mechanism involved. The major drawback with inventory technique is that, it only provides information for past and existing landslides and related instability activities. However, this technique hardly provides any information for possible future landslide activities (Casagli et al. 2004). Even though inventory mapping is not capable of providing information on landslide susceptibility for future activity but still this technique forms the basis for most of the LHZ techniques.

The ‘heuristic technique’ is basically based on the logical judgments of an individual to delineate the landslide hazard based on certain quasi-static variables (Dai and Lee 2001; Fall et al. 2006). The choice or judgment to identify various causative factors responsible in inducing instability entirely depends on geoscientist opinion which may be based on experience of studies of causative factors and their relative impact on inducing instability to the slopes (Anbalagan 1992). The causative factor maps are prepared by assigning numerical ratings to various sub classes of causative factors and later all maps are combined to produce landslide hazard zonation in an given area (Dai and Lee 2002). Higher the numerical value of rating, greater will be its influence on the occurrence of landslide (Kanungo et al. 2006). Over the years several expert evaluation techniques has been developed some of these are proposed by Pachauri and Pant 1992; Sarkar et al. 1995; Turrini and Visintainer 1998; Guzzetti et al. 1999; Raghuvanshi et al. 2013 etc.

The merits of these techniques are simple in application and utilize much more realistic field data well supported by experience of an expert and more practical (Raghuvanshi et al. 2013). Whenever, the major demerit of these techniques is in its subjectivity as it is based on decision of an individual who might be biased in his judgment (Kanungo et al. 2006). According to Fall et al. (2006) expert evaluation techniques are widely used and are most versatile, however these techniques need improvement. In order to integrate the landslide hazard mapping techniques it is necessary to use techniques which involve statistical methods, mechanical methods and geographical data management tools.

The 'statistical techniques' are based on an assumption that "past and present are keys to the future" (Van Den Eeckhaut et al. 2009). It implies that the future instability in a given area will be lead by conditions similar to those which were responsible for the past and present slope instability. Thus, attempts are made to evaluate spatial landslide instability based on relationship in between the past landslide activities and the instability causative factors (Carrara et al. 1992).

The statistical approaches are indirect and landslide hazard assessment is made based on the rules evolved statistically with the relative contribution of instability factors on past landslides. Statistical analysis approach includes bivariate and multivariate methods. In bivariate method for landslide susceptibility assessments the weights are assigned to various factors based upon statistical relationships between past landslides and various factor (Van Westen 1994). Individual factor maps in GIS environment are overlaid on past landslide map to workout relative contribution for each factor and subclass in inducing landslide. From this data, weights are developed to be applied to each factor subclass so that landslide hazard can be deduced. The multivariate model uses an equation in which independent variables are the geo-environmental factors with coefficients maximizing the predictive capability of the model, and the independent variable is the presence/absence of landslides.

Deterministic slope stability analysis techniques are time consuming and require thorough knowledge on geological and geotechnical considerations with a clear understanding on potential mode of slope failure. Besides, such analysis techniques may be suitably applied to small areas, at the scale of a single slope only (Clerici 2002). However, due to constraints of time and financial limitations systematic deterministic slope stability analysis techniques for road projects are often neglected or carried out too quickly without proper geological or geotechnical inputs (Anbalagan 1992). Such inadequate analysis may result into slope failures affecting the safe performance of the engineering structures. The developmental activities in mountainous terrains, particularly road constructions, cover large area of slopes and therefore, require some rapid slope stability analysis techniques.

Intrinsic parameters such as; geologic parameters, elevation, slope factor, aspect, landuse/landcover, curvature and ground water are mainly responsible for slope stability. Besides, external parameters, both natural and manmade, which are responsible for triggering instability of slopes, are also considered. The natural parameters which triggers the instability in slopes are mainly seismicity (Bommer and Rodrı'guez 2002) and rainfall (Dahal et al. 2006). However, there are other natural factors which may trigger slope instability such as; snow/avalanche, wind, permafrost conditions, shoreline processes and volcanic activities which are specific and may also be included for landslide hazard purpose. Manmade activities mainly include construction activities and cultivation practices on slopes (Wang and Niu 2009). Selection of these intrinsic and triggering parameters mainly depends on relative significance of each parameter in inducing slope instability in the given area, the scale at which the LHZ mapping has to be conducted and logical judgment of an evaluator.

3.3 Application of Remote Sensing and GIS

Based on the purpose and analysis techniques, the landslide hazard zonation of an area can be carried out at different scales. The scales at which LHZ mapping, may be classified as; detailed scale (>5,000), large scale: (<1:5,000–1:10,000), Medium scale (1:25,000–1:50,000) and regional scale (>250,000) (Luzi and Floriana 1996, as cited in Lee and Min (2001)). The detailed scale is applied on individual slopes and is generally used for engineering design purposes. Such detailed scale mapping has a restriction on coverage area and requires detailed geotechnical and other field data. Thus, detailed scale mapping on large areas may not be economic and are relatively time consuming. Also, remote sensing and GIS techniques have very limited application for detailed scale LHZ mapping. Generally, detailed and large scale mapping are carried out for planning and infrastructure development projects. Medium scale maps covers large areas and LHZ maps are prepared for the purpose of hazard zonation, land management and planning of developmental activities. For LHZ mapping at medium scale expert evaluation or statistical methods are applied. Much of the LHZ studies are carried out at medium scale. Several methodologies which utilizes integrated Remote sensing and GIS landslide inventory approach with statistical methods has been developed in past (Guzzetti et al. 1999; Kanungo et al. 2006).

The landslide hazard zonation techniques require large volume of data on various intrinsic and triggering parameters. The use of remote sensing and GIS facilitates in data generation, analysis for hazard assessment and zonation.

The past landslide activities can be demarcated for their location and dimension with the help of satellite images and through GPS field observations (Fig. 3.1). The failure mechanisms of each landslide has to be defined and their relation with different governing parameters; slope, aspect, curvature, elevation, land use/cover, lithology and soil material has to be recognized. Most of the techniques of LHZ mapping initiate with inventory mapping. Inventory mapping needs information on past landslide activities and manifestations of slope instability in the area. Thus, based on this past landslide inventory, efforts are made to understand the possible causes of landslides. Which factors were probably responsible in inducing landslide in the area forms the basis to develop general rules based on which LHZ of the area is prepared.

The collected data on various intrinsic parameters has to be processed, arranged and prepared into layered spatial GIS database for landslide hazard mapping. The governing parameters such as; aspect, slope, curvature and elevation can be

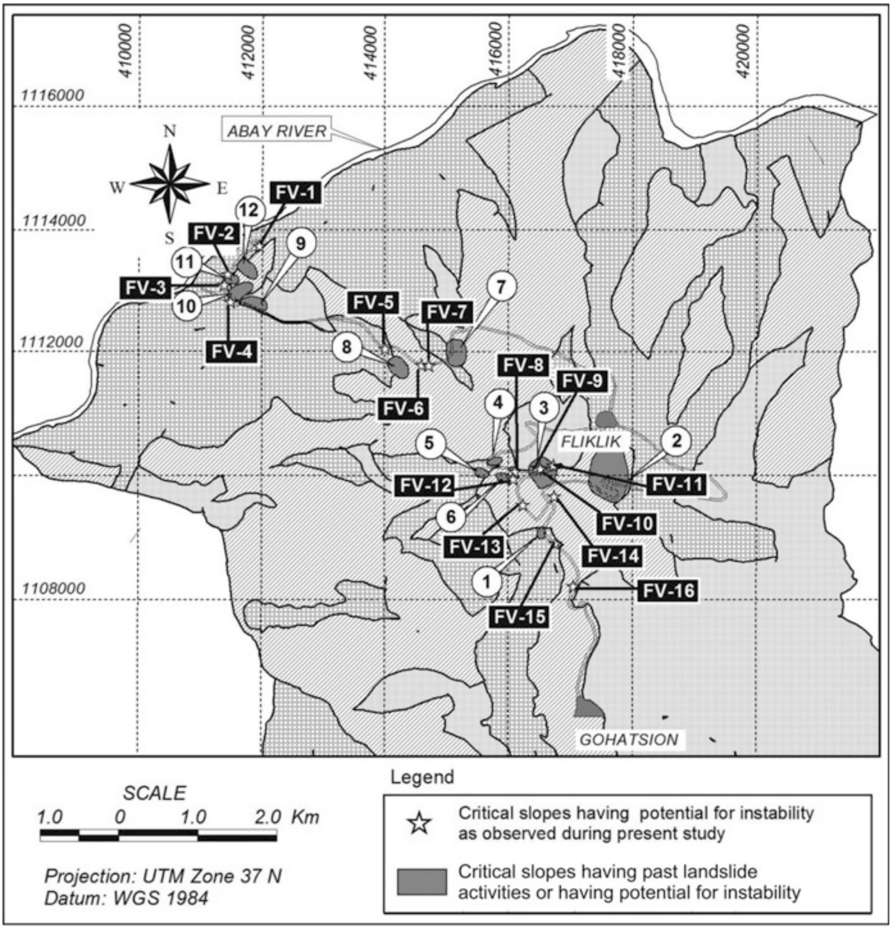

Fig. 3.1 Landslide inventory mapping

calculated from the digital elevation model (DEM) of the area, which can be obtained from the ASTER elevation data set. The slope material and land use/cover maps can be processed from Land sat +ETM satellite using different digital image processing procedures. Further, GIS based statistical and probability approach can be used to rate the governing parameters and then customized raster calculation can be applied to develop the landslide hazard map of the area.

In general, remote sensing and GIS application facilitate in identifying the potential landslide hazard over the area. Besides it also helps in disaster management and reduction by provided information on possible degree of hazard with spatial distribution. Thus, this information will be vital to mitigate the hazard and to foresee the anticipated adverse conditions which may adversely affect the safety of people and property in the area.

3.4 Conclusion

Landslide disaster is significant in mountainous terrain and poses serious problems to people and property. Assessment of instability potential in an area requires proper judgment on contributing factors individually and in combination at the time of investigation and their likely effect during anticipated adverse conditions. Remote sensing and GIS is a very useful tool in delineating area into various potential instability zones over a wide area. It also helps in disaster management and reduction by provided information on possible degree of hazard with spatial distribution.

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Chapter 4
Population-Development-Environment Interface and Flood Risk in Murshidabad, West Bengal

Swati Mollah and Sunando Bandapadhyay

Abstract There is a link between underdevelopment and disasters. Economic dependency increases both the frequency and the impact of natural hazards. Human vulnerability—a feature of the poorest and the most disadvantaged people in the world—became an important concept for understanding the scale of disasters (Wisner et al., at risk: natural hazards, people's vulnerability and disasters, 2004). More recently, vulnerability assessments have explored the social, economic, and political conditions that are likely to affect the capacity of individuals or communities to cope with or adapt to hazard(s) (Cutter, Prog Human Geogr, 20(4):529–539, 1996). Evaluation of different elements of vulnerability is a prerequisite for developing policies for regions affected by climate extremes.

There are numerous social, economic and demographic characteristics available to measure the vulnerability of the community. The creation of a very high spatial resolution GIS database is costly and time-consuming. This paper demonstrates a moderate resolution regional study that would be enough to identify hazard prone and vulnerable zones. Administrative units are selected as the most appropriate unit of investigation for the simple reason that these are the very units demarcating policy and planning authorities and resource allocation crucial to any practical intervention. With the help of Factor Analysis various components of vulnerability have been derived and using a GIS (Geographical Information System) their spatial pattern has been depicted. The paper reveals that there is a difference in spatial pattern of socio-economic vulnerability of the community to flood in the study area.

Keywords Flood hazard • Murshidabad • Socio-economic vulnerability

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4.1 Introduction

Instead of underpinning disasters primarily as physical occurrences, requiring largely technological solutions, disasters would better be viewed as a result of the complex interaction between a potentially damaging physical event (e.g. floods, droughts, fire, earthquakes and storms) and the vulnerability of a society, its infrastructure, economy and environment, which are fixed by human behaviour. Viewed in this light, natural disasters can and should be understood as un-natural disasters (Cardona 1993; van Ginkel 2005). Thus the promotion of district to a disaster-resilient society requires a paradigm shift off the primary focus on natural hazards and their quantification towards the identification, assessment and ranking of various vulnerable societies (Maskrey 1993; Lavell 1996; Bogardi and Birkmann 2004). It is part of UNU-EHS's mission aiming at identification of various vulnerabilities and the development and examining relevant indicators and assessment tools (Birkmann 2005) in order that it can extend the environmental dimension of human security further (Brauch 2005). In the LDCs, the high population densities on river floodplains often reflect the more basic requirements of traditional agriculture and fishing, together with the lack of alternative land for settlement by poor people. These inhabitants are functionally landless and a large part of them live below the poverty line.

Some form of environmental hazard has to be in our surroundings and the severity of the hazard impact is often a function of human vulnerability rather than the physical magnitude of the event. However, the concept of vulnerability remains difficult to assess in practical terms. Several methodologies are available to the humanitarian agencies responsible for determining vulnerability in the field but there is little agreement on their use. In some cases, conflicting findings are obtained at different scales—for example, for macro-scale (regional) assessments as opposed to micro-scale (household) assessments.

Those people lacking capital and other resources, such as land, tools and sources of earning livelihoods are most vulnerable. Access to information and the availability of a social network which enable people to mobilise support from outside the household can be significant too. The poorest people may appear to have little to lose when disaster strikes. Most of the poorest people in the world with fragile existences in rural areas have got few earning skills or opportunities. The combine of social and economic factors can add to risk from environmental hazards. Unsustainable natural resource handling is a major problem. Most of the rural poor are dependent on traditional rain-fed agriculture and are at risk because of climate change. The unregulated use of land and water resources together with widespread illegal practices can result in severe environmental degradation. The collapse of traditional agriculture and irregular slumps in market prices increase the threat of seasonal food shortages. In many countries, most of the land holdings are too small to maintain livelihoods. Consequently, over half of the population is malnourished and has no access to safe water or domestic sanitation. People with chronic undernourished suffer worse from water related diseases after floods, such as dysentery. Many poor remote rural areas are deprived of the public scrutiny and aid monitoring. The people most vulnerable to disaster often live in relatively inaccessible parts, like the small island, remote villages etc.

4.2 Study Area

The district of Murshidabad forms the northernmost part of the Presidency Division of West Bengal and occupies the location forming its north-eastern boundary along the Indo–Bangladesh border. It lies centrally in the Lower Gangetic Plain, having the geographical extension, 24°50′20″ to 23°43′30″N and 88°46′00″ to 87°49′17″E (Fig. 4.1). It covers an area of 5,324 km^2. The Padma flows down the international frontier between India on the east of the district. The river Jalangi demarcates a long stretch of its boundary with Nadia on the south. Occurrence of floods has been an annual phenomenon in the district on account of the domination of the monsoon regime, distinctive physiography and unusual slope of the terrain. Menace of flooding has been prevalent in Murshidabad district since time immemorial. The incessant rainfall inundates large tracts of depressions and lowlands almost

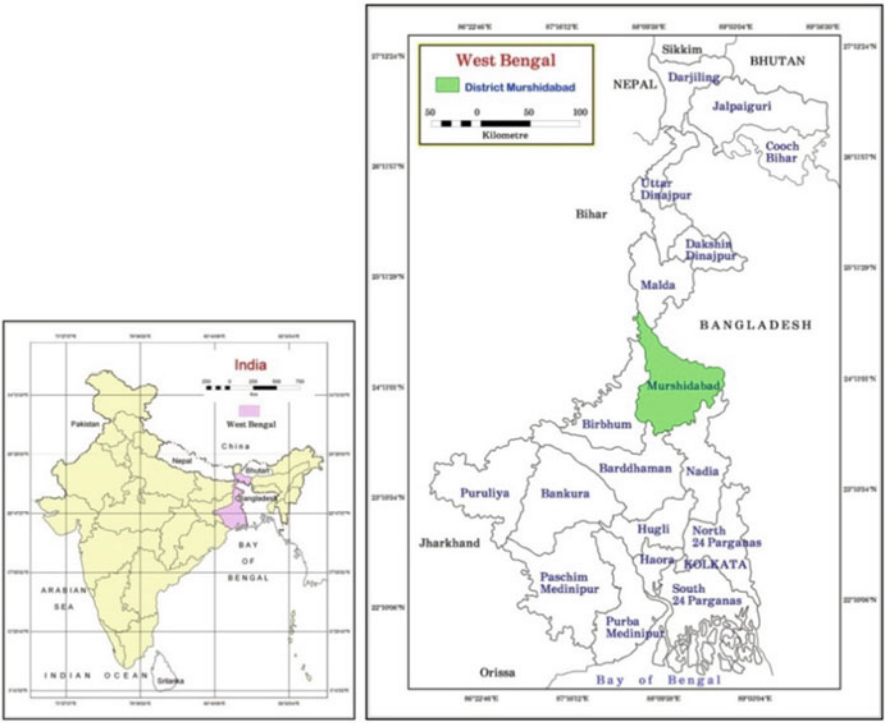

Fig. 4.1 Location of the study area

annually since the rivers, being already full with high water level, cannot pass the surface run-off out of the area. Frequent flooding, channel congestion and river bank erosion inflict scourges upon the district, leaving the area extensively submerged, bringing about loss of lives and property, and wiping out human settlements, crops and communications. Occasionally, floods linger above the danger level for one month or even longer.

With a population of about 7,103,807 (2011), Murshidabad is the fourth most populous district situated in the central part of West Bengal. Accounting for about 5.9 % of West Bengal's area and about 7.8 % of the state's population, the district ranks six in terms of population density of 1,334 per km^2 (2011). About 80.28 % of the people live in rural areas. Murshidabad district recorded the largest population belonging to 0–6 age group (10.27 lacs) and the largest 0–6 rural population (9.16 lacs) (20011). The district recorded the highest proportion of Muslim population to total population of the district. The district is economically a backward district, and also tends to be less advanced in terms of human development. Agriculture remains the mainstay of livelihood of the ill-disposed population in the district across the board. Industrial position of the district has got no industry worth mention, excepting for two thermal power plants, the kind entirely independent of the local resource-based and labour force.

The cottage industry such as handlooms, silk, cotton etc. has fallen sick hardly with any hope of recovery. The bidi industry in the district goes thriving and our poor women folk keep supplying damn cheap labour to the industry exactly at the cost of their life-expectancy. Percentage of households living in good houses (35.08 % is substantially low ranking the district in second position (2001). Annual growth rate of the Gross domestic product and net domestic product of the district (5.86 and 5.79 respectively) is lower than the state's average (6.12 and 6.07 respectively).

4.3 Research Background

The inhabitants living in under developed areas are more reliant on local natural resources and would therefore suffer most. Even small changes in rainfall patterns can have devastating consequences on their crops. They are vulnerable to extreme weather events; have poor access to information and lack resources to cope with and recover from weather-related disasters. Their vulnerability is further compounded by geographic isolation—having poor facility of roads and other infrastructure, often isolated by floods. Studies related to the extreme vulnerabilities should focus on the backward areas because they are the most vulnerable and least able to cope with the adverse impacts. Though theoretically, social and biophysical approaches to vulnerability studies present two divergent schools of thoughts, social vulnerability assessments cannot be complete without taking hazards into considerations since vulnerability is always hazard specific. Some studies have therefore, tried to forge a compromise between the two approaches considering an integrated approach for vulnerability assessments, combining social vulnerability (adaptive capacity) with the biophysical aspects of climate change (exposure and sensitivity) to give a complete picture of vulnerability (Nelson et al. 2010; Cutter 1996). While hazards and disasters researchers have long understood that human decisions have an influence on the outcome of hazard events (Kates 1980: Mileti 1980), it has only been over the past decade that vulnerability as an explicit concept has begun to be broadly recognised (Wisner et al. 2004). Social Vulnerability modelling has been used in a number of published and un-published studies using varying study areas (Boruff et al. 2005; Borden et al. 2006), in different countries (Boruff et al. 2005), at various spatial scales (Cutter and Emrich 2006; Borden et al. 2007), and in different time periods (Finch 2006).

In India, as in many other countries of the southern hemisphere, crucial anti-flood undertakings are handicapped by financial crunch. To optimize the use of precious funds, therefore, it is crucial that planners should be equipped with sufficient accuracy and detailed flood vulnerability maps enabling them to identify the most vulnerable zones requiring urgent attention. To measure vulnerability discretely is increasingly being considered as a key step towards effective risk reduction and conducing to disaster resilience. In the light of increasing frequency of disasters and continuing environmental degradation, measuring vulnerability is a crucial task if we want science and technology to help support the transition to a more sustainable world (Kasperson et al. 2005).

The Gangetic Plain has one of the largest flood plain with highly dense population. Almost every year floods hit the plain. Each time loses get increase instead of decreasing. It poses major developmental problem to the agrarian society of the plain. It is more challenging in the Gangetic plain where mainly agriculture has remained the economic activity. Utilization of recourses and implementation of polices have never occurred at a gainful level. Like other programs, existing flood management measures have been unsustainable, as they adversely affect the river ecology. The priority is given to construction. However, they have failed to meet their target. Frequent incidence of destructive floods poses challenge to economic development. We have failed to draw an integrated plan to minimize loses. The alternative plan requires a proper integration of physical, socio-cultural, economic and demographic data. Although the Irrigation and Waterways Department (IWD) of West Bengal has broadly identified flood prone areas of the state, there have been no attempts to co-ordinate the hydrological facts with socioeconomic or infrastructural data.

4.4 Methodology

The data the study has used for capturing the social vulnerability characteristics at block level in Murshidabad district are from various reports of Census of India (MHA-GoI 2001), District Statistical Handbook (BAES GoWB 2008), Rural Household Survey (PRDD-GoWB 2005), and Flood Preparedness & Management

Plan (IWD-GoWB 2009). This data has been analysed in the method of factor analysis to reduce the number of variables so that compact social vulnerability characteristics can be retained. Further, underlying (latent) structures of variables groups can be elicited to build a social vulnerability profile. Factor analysis is a multivariate analysis technique used to identify information packaging considering the interdependencies between all variables (Bernard 2006: 495). This analysis has been computed in SPSS version 16.0 with a principal component method in order to identify variable groupings. The methodology of the factor analysis follows standard procedure. The principal component analysis aims at finding a linear combination of variables that accounts for as much variation in the original variables as possible. A Varimax rotation with Kaiser Normalisation is applied to the component matrix. This step disposes the respective components as much apart from each other as possible. The extracted communalities are all above 0.5 indicating that the extracted components represent the variables well. For the interpretation, only those eigenvalue greater than one has been considered. The eigenvalue is the standardised variance associated with a particular factor.

Total 17 variables are taken here in the vulnerability analysis. For making the calculation easy and the authentic data being scarce, two parameters of vulnerability- sensitivity and resilience have been taken under consideration. Ten indicators have been used for sensitivity analysis. For calculation of resilience score seven indicator variables have been selected. The variables are entered into a correlation matrix and a Varimax orthogonal rotation with Kaiser Normalisation is applied to the solution. Four components of sensitivity and two components of resilience derived from PCA are combined to calculate the component scores for computation of combined sensitivity and combined resilience scores. Because the scores associated with the retained principal components produced in the PCA are unitless, it becomes possible to combine the resulting vulnerability indices into a single relative vulnerability index using SPSS software. A set of combined vulnerability index are calculated for each block. For each components score and for combined vulnerability scores the mapping is done to trace the spatial pattern.

4.5 Results

Our preliminary analyses regarding sensitivity show that blocks in Murshidabad district demonstrate diversity in terms of environmental and socio-economic conditions. Kandi and Bhagwangola II blocks show the highest frequency of flood over the last decade followed by Bharatpur I and Khargram blocks concerning the exposure indicators. More than 75 % of the total area of the Kandi block is flood prone followed by Beldanga II block and Khargram block. The Kandi block also shows the highest percentage of flood prone population followed by Bharatpur I. In terms of population indicators there is less variation among the different blocks of the study area. Samserganj block has the highest population density and child population followed by Suti II block. Nabagram block has the highest percentage

Table 4.1 Rotated component matrix of the factor analysis for sensitivity showing the computed value loadings

	Components			
Input variables	1	2	3	4
Flood frequency	−0.003	0.892	0.056	−0.040
Flood prone area	0.417	0.773	−0.029	0.149
Flood prone population	−0.334	0.780	−0.129	0.091
BPL households	0.244	0.082	0.904	0.076
Child population	0.887	−0.093	−0.108	0.078
Population dependent on agriculture	0.858	0.265	−0.041	0.103
Population density	0.925	−0.214	0.016	0.026
Houseless households	−0.236	−0.223	0.785	0.055
Villages >10 km away from the main centre	0.206	−0.239	−0.561	0.663
Villages having kuchha road	−0.090	0.233	0.243	0.866
Per cent variance explained	36.95 %	18.62 %	14.96 %	11.59 %
Total = 82 %				
Component name	Population	Exposure	Poverty	Remoteness
Extraction method: principal component analysis				
Rotation method: Varimax with Kaiser normalization				
Rotation converged in six iterations				
Kaiser-Meyer-Olkin measure of sampling adequacy				0.602
Bartlett's Test of Sphericity	Approx. Chi-Square			144.780
	df			55
	Sig.			0.000

Extraction method: principal component analysis

of population dependent on agriculture followed by Bhagwangola II and Kandi. According to the poverty indicators Jalangi block has the highest percentage of population below poverty line and the houseless population. Kandi block ranks highest in case of connectivity of the villages to main centres and Domkal block has the highest percentage of kutchha road.

In terms of resilience Samserganj has the highest number of flood shelter per flood prone population and highest amount of road density followed by Jalangi block and Raghunathganj I block. Naoda block has the highest number of villages having medical facility and in terms of newspaper availability in the villages Bharatpur II block ranks the highest. Khargram, Kandi, Bahrampur, Naoda and Beldanga I blocks have the highest percentages of pucca roads connecting villages.

In both the PCA analysis the Kaiser-Mayer-Olkin (KMO) measures of sampling adequacy are >0.5 and Bartlett's sphericity tests retained $P < 0.05$. This suggests that the variables are suitable for PCA analysis. Table 4.1 presents the PCA results for the indicators of sensitivity of Murshidabad district in terms of flood risk. Four principal components i.e. population, exposure, poverty and remoteness are retained in PCA. Ten variables are used in the analysis. The loading of each variable for the retained principal components are given in the table, with the heaviest loadings highlighted. Total three components have been retained from PCA. Each component

Table 4.2 Rotated component matrix of the factor analysis for Resilience showing the computed value loadings

	Components	
Input variables	1	2
Flood shelter	0.591	0.000
Road density	0.723	0.155
General literacy	0.858	0.049
Female literacy	0.655	0.261
Newspaper availability	−0.187	0.814
Medical facility	0.378	0.733
Bank facility	0.154	0.736
Per cent variance explained	36.52 %	21.68 %
Total = 58 %		
Component name	Evacuation	Infrastructure
Extraction method: principal component analysis		
Rotation method: Varimax with Kaiser normalization		
Rotation converged in six iterations		
Kaiser-Meyer-Olkin measure of sampling adequacy		0.616
Bartlett's Test of Sphericity	Approx. Chi-Square	38.459
	df	21
	Sig.	0.011

Extraction method: principal component analysis

has an eigenvalue >1 and together the three components account for 82 % of the variance in the dataset. The first component in sensitivity analysis is named as 'population' as it captures variables connoted with population like population density, child population, population dependent on agriculture etc. The second component represents the flood proneness of the system, i.e., flood frequency, flood prone area and flood-prone population etc. and named as 'exposure'. The third component depicts poverty and houselessness. This component is named as 'poverty'. The fourth component identifies the backwardness of the areas, thus named as 'remoteness'. Table 4.2 presents the PCA result of all the indicators of resilience. In this case two component i.e. evacuation and infrastructure have been retained from seven indicators. In order to name the resilience components the first component consists of flood shelter, road density, literacy etc. which determine the process of evacuation during flood and this component is named as 'evacuation'. The second component is related to infrastructure of the region such as availability of medical, banking and information facilities and named as 'infrastructure'. All the six components are used separately for computation of sensitivity and resilience scores.

For each component maps have been prepared showing regional pattern of the score of the components—(1) population component; (2) exposure component; (3) poverty component; (4) remoteness component; (5) evacuation component; (6) infrastructure component; Fig. 4.2a, b depicts Sagardighi, Nabagram, Burwan, Khargram, Bahrampur, Hariharpara, Naoda blocks of Murshidabad district having very high population scores and Khargram, Kandi, Bharatpur I, Lalgola,

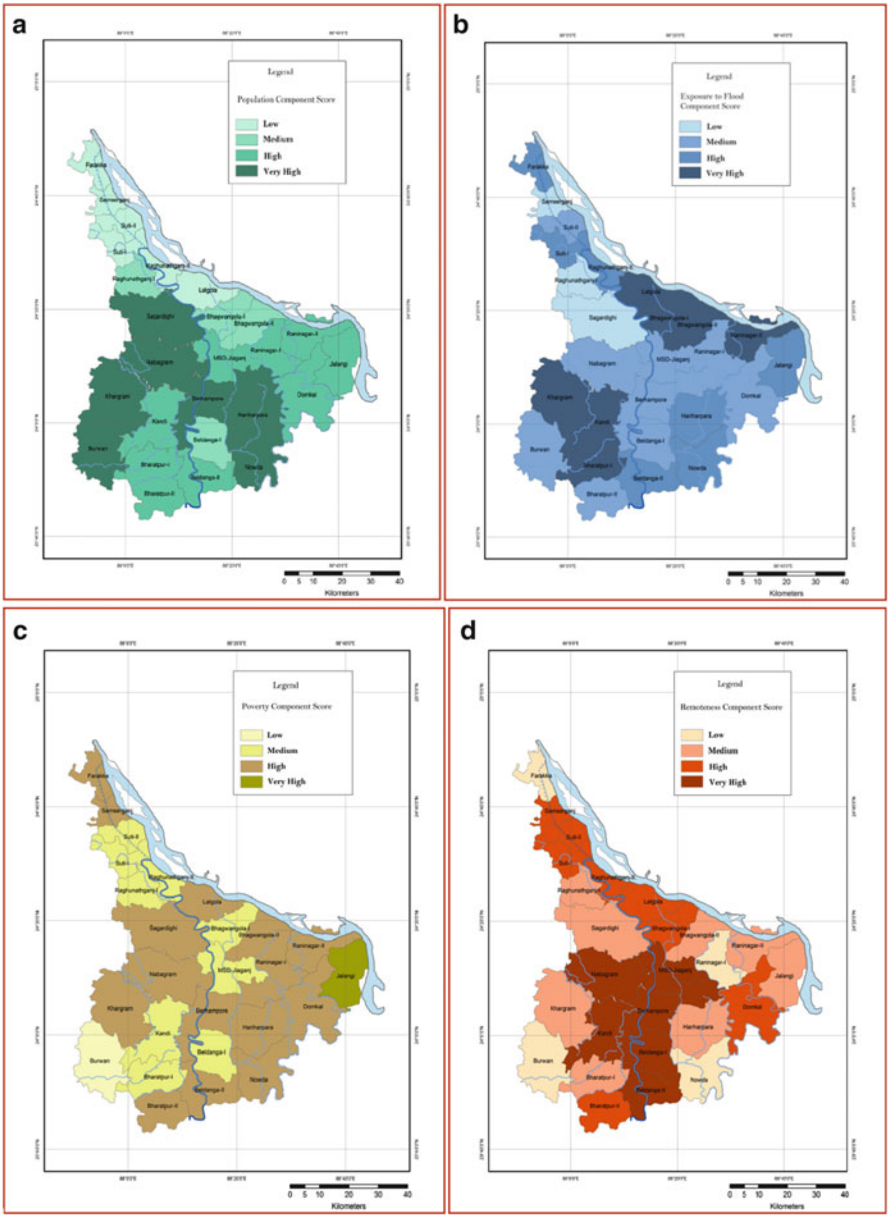

Fig. 4.2 (**a**) Population and (**b**) Exposure Component Scores. *Source*: computed by the author. (**c**) Poverty and (**d**) Remoteness Component Scores; *Source*: computed by the author

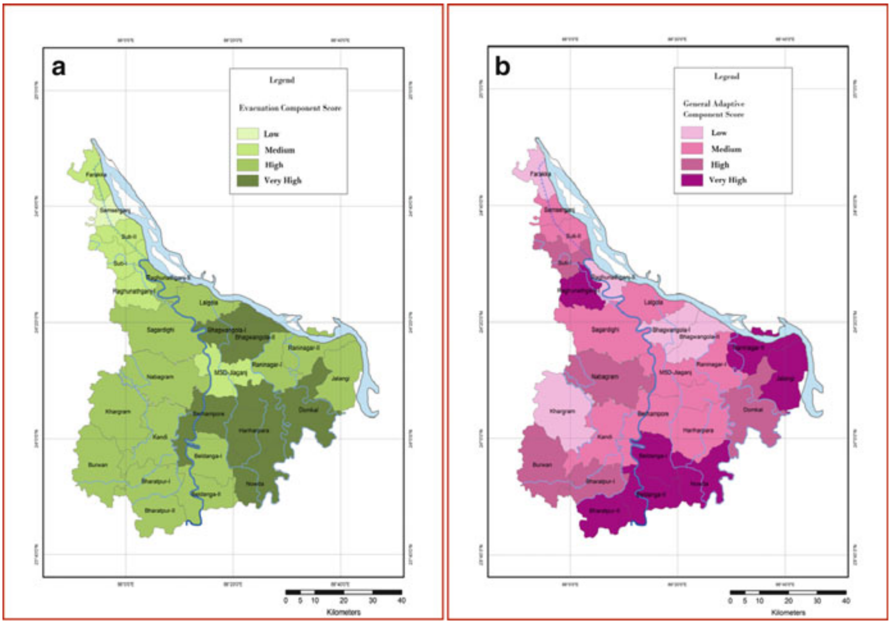

Fig. 4.3 (**a**) Evacuation and (**b**) Infrastructure Component Scores. *Source*: computed by the author

Bhagwangola I and II, Raninagar II blocks having very high exposure scores while Sagardighi and Raghunathganj I blocks having low exposure scores. Population scores for the blocks Farakka, Samserganj, Suti I and II and Lalgola are relatively low. Figure 4.2c, d shows that Jalangi block has the very high poverty score, and above 50 % blocks in Murshidabad district have high poverty index. Regarding degree of regional backwardness Nabagram, Kandi, Bahrampur, Murshidabad-Jiaganj, Beldanga I and II blocks have very high backwardness scores while Farakka, Burwan, Raninagar I and Naoda blocks have less scores in this regard.

Figure 4.3a, b reveals that Bhagwangola I, II, Domkal, Bahrampur, Hariharpara and Naoda blocks have very high evacuation scores and Raghunathganj I, Jalangi, Raninagar II, Hariharpara, Naoda and Bharatpur II have very high Infrastructure scores. The Fig. 4.4a shows the comparison of the different components of vulnerability block-wise and their spatial variation across the district. Khargram, Kandi, Bharatpur I, Bhagwangola II and Beldanga II blocks have positive scores for sensitivity components C1 (population). Raghunathganj II, Kandi, Khargram, Bharatpur I, Bhagwangola I &II and beldanga II blocks score positively in sensitivity component C2 (exposure). Jalangi, Murshidabad-Jiaganj, Bhagwangola II, Raninagar II and Domkal blocks have positive scores for both the components of sensitivity component C1 and C3 (poverty) and Suti-I and II, Bahrampur, MSD-Jiaganj, Nabagram, Kandi, Beldanga I and II and Domkal blocks have positive

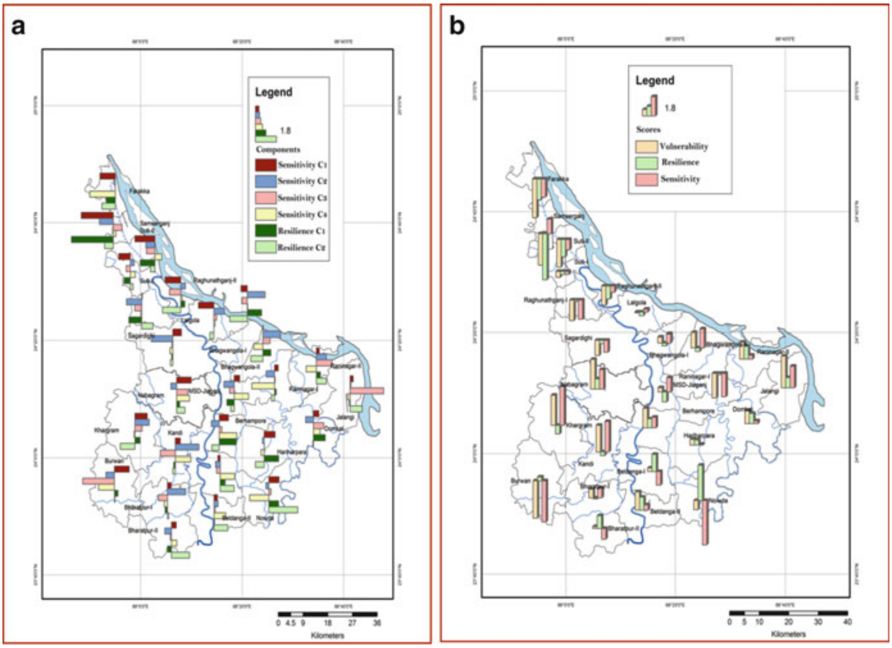

Fig. 4.4 (**a**) Comparison among different components of Vulnerability. (**b**) Block-wise vulnerability. *Source*: computed by the author

scores for sensitivity component C4 (remoteness). In terms of resilience component C1 (evacuation), Lalgola, Bhagwangola I and II, Raninagar I and II, Domkal, Hariharpara, Naoda, Beldanga I, Bahrampur, Khargram, Burwan and Nabagram blocks have the positive scores. Murshidabad-Jiaganj, Beldanga I and II, Naoda, Bharatpur II, Jalangi, Domkal blocks have the positive scores in respect of resilience component C2 (infrastructure).

The regional pattern of vulnerability with its two components- sensitivity and resilience has been depicted in the Fig. 4.4b. Suti I, Lalgola, Bhagwangola II and II, Raninagar II, Jalangi, Domkal, Murshidabad-Jiaganj, Bahrampur, Beldanga II, Kandi, Khargram, Bharatpur I blocks have positive sensitivity index. Raninagar II, Jalangi, Domkal, Harharpara, Bahrampur, Murshidabad-Jiaganj, Beldanga I and II, Bharatpur II and Naoda blocks have positive values for resilience index. Regarding overall vulnerability the combined vulnerability index for the different blocks suggests that environmental vulnerability is relatively low in Burwan and Naoda blocks of Murshidabad and Nabagram, Khargram, Kandi, Jalangi and Bhagwangola II blocks have very high vulnerability scores. The blocks-Samserganj, Suti-I, Lalgola, Raninagar II, Bhagwangola I, Domkal, Hariharpara, Murshidabad-Jiaganj, Beahrampur, Beldanga II and Bharatpur I show high vulnerability.

4.6 Conclusion

Integration of hydrological data with socio-economic information can effectively identify actual areas deserving greatest attention. These socio-economic vulnerability maps would facilitate flood plain zoning and other remedial land use planning measures in sub-regional basis in future. This study will not only help formulating a flood management strategy for Murshidabad but also to show how a flood hazard map can be produced by using available information from local government agencies.

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Chapter 5
Development of Apple Cultivation Vis-a-Vis Other Fruit Crops in Himachal Pradesh, India: A Geographical Analysis

B.R. Thakur, Rakesh Kumar, and Dhan Dev Sharma

Abstract Himachal Pradesh is acknowledged producing excellent quality of apple- a temperate fruit, other temperate fruits like peach, plum, apricot, pear, stone fruits and nuts. It also grows sub-tropical fruits like guava, litchi, papaya, mango and citrus fruits. The present study aims at evaluating and comparing the trends in area, production and yield of apple and fruits other than apple along with total fruits in Himachal Pradesh state of India. The district constitutes basic unit of observation for the present study. The study is based on secondary data collected for three time periods i.e. 1986–1989, 1996–1999 and 2006–2009. The compound annual growth rate has also been computed for assessing the trends in acreage, production and yield of different fruit crops. The development pattern of fruit crops has been shown with the help of choropleth maps. It has been inferred from the study that apple is dominant fruit crop both in terms of production and yield level over the other fruits in Himachal Pradesh. It accounts about 80 % of total fruits production in the state. However, the area under other fruits is more than the apple, so there are vast potentials to develop these fruits in the state.

Keywords Acreage • Apple • Fruits other than apple • Himachal Pradesh • India • Pattern • Production • Trends • Yield

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5.1 Introduction

Himachal Pradesh state located in the northwestern part of India has been endowed with vast natural resources. However, forest and water are considered to be most important and in abundance. It is considered as leading state of India in terms of horticultural development. A large population in the state is engaged in the cultivation of a variety of fruit crops. It is a leading producer of quality fruits especially apple. Horticultural industry has become an integral part of socio economic development of rural masses of state (Thakur and Jaglan 2005). Himachal Pradesh is bestowed with suitable agro-climatic conditions for the development of horticulture. Arable land is, however, very limited and yields of traditional food grains are low due to topographical conditions and lack of irrigation facilities and mechanisation of fields. The net sown area is about 12 % of its total geographical area. The average size of land holding is less than 2 ha which cannot be considered economical by any standard particularly when the fields are terraced, small, sloping, stony and scattered. Under such natural constraints, the majority of farmers cannot hope to improve their level of living by exclusive dependence on field crops. Even the new technology is likely to have little impact in geographically inaccessible areas of the state. This is particularly because here not only the proportion of area suitable for crop farming is limited but also the State's capacity to intensify land use through traditional crop mix is more severely handicapped. The practice of horticulture as a suitable agro-ecological strategy and an afforestation activity is the solution to the problem.

The environmental degradation of the mountain regions of Himalayas due to excessive use of forest resources has made the development of tree plantations, especially plantation of fruit trees, an important measure for the environmental conservation of the hills. Fruit trees provide permanent green cover to tie soil and act as soil binders, preventing soil erosion and retaining nutrients. Fruit trees thus offer productivity, environmental conservation and optimum and economical use of resources, compared with other economic activities in the most ecological acceptable manner (Azad 1993).

During the pre-independence time, there was hardly any attempt to develop horticulture in Himachal Pradesh. The first apple orchards in the state were established at Kullu valley by Captain A. A. Lee an Englishman around 1870. Delicious varieties were introduced by Samuel Nicholas Stoke, a resident of Philadelphia (The United States of America), in 1918 at Kotgarh in Shimla hills. After independence it was realised that horticulture may play a crucial role in development of some parts of the state (Thakur and Jaglan 2005). In 1970, a separate department of horticulture came into existence through public sector efforts. Since then Himachal Pradesh has made significant progress in the production of fruits in general and apple in particular (Teotia 1993). The state is producing excellent quality of apple, which is a temperate fruit, other temperate fruits like peach, plum, apricot, pear, stone fruits and nuts. It also grows sub-tropical fruits like guava, litchi, papaya, mango and citrus fruits. Each fruit requires different types of physiographic and agro-climatic conditions for their growth. Notably, Himachal Pradesh is known for the production of quality apple in the country and sometimes also known as apple state of the country. It raises an academic curiosity among the academicians, planners and policy makers to investigate the relative share and development of apple on the one hand and other fruit crops together on the other hand. It would provide new insights in devising new strategies and techniques suiting to fruit crops other than apple. This study will also bring out new facts which could be taken as a roadmap to relook and revisit the horticultural policy of the state.

5.2 Objectives of the Study

The present chapter aims at investigating the following set of objectives:

1. To study the trends and spatial variations in acreage of apple and fruits other than apple in the study area.
2. To evaluate and compare the spatio-temporal variations in production and yield of apple and fruits other than apple.

5.3 Research Questions

The present study seeks to investigate the following research questions:

1. Has the study area experienced change in the acreage of apple and other fruit crops at the district level?
2. Has there been a noticeable change in production and yield level of apple and fruits other than apple at district level in the state?

5.4 Methods and Materials

The present study is based on secondary data collected for three time periods i.e. 1986–1989, 1996–1999 and 2006–2009. The district-wise data relating to area and production of fruit crops have been collected from Directorate of Horticulture and Directorate of Land Records, Shimla, Himachal Pradesh. In order to examine the temporal and spatial variations in area at district level, the triennium averages of area have been computed for the different periods. Due to discrepancies in area under different fruits in Kinnaur district observed in the triennium area of 1996–1999 area under different fruits of the district has considered as such for the latest triennium i.e. 2006–2009.

Compound growth rate of triennium average for area, production and yield level has been computed with the help of under mentioned formula:

$$R = \left[\left\{Anti\log\left(\frac{Log\,X2 - LogX1}{i}\right)\right\} - 1\right]$$

Where, R is annual compound growth rate, X_1 is the data during earlier period, X_2 is data during later period and I is the interval between two periods.

The present study also evaluates the trends in the production and yield of apple and fruits other than apple along with total fruits in Himachal Pradesh. Tabular method has been used to show the trends in acreage, production and yield level.

5.5 Results and Discussions

5.5.1 Area Under Total Fruits, Apple and Fruits Other Than Apple

Table 5.1 shows percentage of area under fruit crops is increasing year by year in Himachal Pradesh. During 1986–1989 the area under total fruits as a whole was 14.49 % of the total cropped area and reached to 20.71 % during 1996–1999 and further increased to 21.18 % during the last triennium i.e. 2006–2009. At the district level, the table reveals that during 1986–1989, the highest (51.26 %) area under horticultural crops was in Kinnaur district. It was followed by Kullu (30.71 %) and Shimla (25.36 %) districts. These districts offer suitable agro-climatic conditions for raising a variety of fruit crops. Districts like Hamirpur (4.88 %), Lahaul-Spiti (4.80 %) and Una (4.22 %) were having low area under different fruit crops (Fig. 5.1).

The study indicates that during 1996–1999, all the districts of the state experienced increase in area under total fruits and the distribution pattern was almost the same as to the previous decade. Kinnaur district recorded a considerable increase and it had more than three-fourth of total cropped area under fruit cultivation due to high income yielding nature and suitable conditions for the growth of these crops. Table 5.1 reveals that during 2006–2009, certain districts observed increase and decrease in the area under fruits but the concentration pattern of fruit crops continued to be similar to previous two decades. The highest proportion of area under fruits was again found in Kinnaur district (76.75 %) followed by Kullu (43.07 %) and Shimla (42.94 %) districts. Districts in western part of the state like Una and Hamirpur occupied less than one-tenth of total cropped area under fruit cultivation (Fig. 5.2). It may be attributed to more allocation of cultivated land to food grains. The study points out that area under total fruits grew with the average rate of 1.6 % per annum during the study period. Lahaul-Spiti district

Table 5.1 Himachal Pradesh: District-Wise Area under Apple, Fruits other than Apple and Total Fruits (in ha)

	Apple to total cropped area			Compound annual growth rate	Fruits other than apple to total cropped area			Compound annual growth rate	Total fruits to total cropped Area			Compound annual growth rate
District	1986–1989	1996–1999	2006–2009	2006–2009 Over 1986–1989	1986–1989	1996–1999	2006–2009	2006–2009 Over 1986–1989	1986–1989	1996–1999	2006–2009	2006–2009 Over 1986–1989
Bilaspur	0.33 (0.0006 %)	2.33 (0.004 %)	4 (0.006 %)	–	5,533 (9.14 %)	6,870.67 (11.7 %)	5,949 (10.07 %)	0.5	5,533.33 (9.14 %)	6,870.67 (11.77 %)	5,953 (10.08 %)	0.3
Chamba	2,994 (4.70 %)	7,590.3 (11.82 %)	11,446 (16.95 %)	6.9	3,750.3 (5.9 %)	6,008.7 (9.38 %)	4,270 (6.33 %)	0.3	6,745 (10.60 %)	13,599 (21.20 %)	15,716 (23.28 %)	4.3
Hamirpur	NC	NC	NC	–	3,630.7 (4.88 %)	5,657.7 (7.92 %)	5,644.3 (8.16 %)	2.7	3,630.7 (4.88 %)	5,657.7 (7.92 %)	5,644.3 (8.16 %)	2.3
Kangra	525.67 (0.23 %)	450.33 (0.27 %)	3,560 (0.20 %)	−0.9	28,528.33 (12.90 %)	40,897.33 (18.5 %)	37,201.67 (17.17 %)	1.4	29,054 (13.13 %)	37,652 (18.77 %)	41,497 (17.37 %)	1.3
Kinnaur	3,560 (37.77 %)	5,656 (58.94 %)	5,656 (60.13 %)	2.3	1,393 (13.49 %)	1,563.3 (16.29 %)	1,563.3 (16.62 %)	1.00	4,953 (51.26 %)	7,219.3 (75.23 %)	7,219.3 (76.75 %)	3.4
Kullu	12,966 (22.28 %)	18,513 (29.32 %)	22,889 (36.68 %)	2.8	4,906 (8.43 %)	5,135 (8.13 %)	3,989 (6.39 %)	−1.4	17,872 (30.71 %)	23,648 (37.45 %)	26,878 (43.07 %)	2
Lahaul Spiti	95.66 (2.92 %)	418 (12.49 %)	743.67 (21.34 %)	2.9	61.67 (1.88 %)	47.33 (1.4 %)	46.66 (1.33 %)	−1.7	157.33 (4.80 %)	465.33 (13.89 %)	790.33 (22.67 %)	8.4
Mandi	8,384.7 (5.30 %)	12,951 (7.98 %)	15,151 (9.46 %)	3	13,269.3 (8.39 %)	17,208 (10.6 %)	18,018 (11.25 %)	1.5	21,654 (13.69 %)	30,159 (18.58 %)	33,169 (20.71 %)	2.2
Shimla	22,553 (20.77 %)	32,857 (31.13 %)	31,395 (35.77 %)	1.6	4,973 (4.59 %)	6,040 (5.72 %)	6,318 (7.17 %)	2.2	27,526 (25.36 %)	38,897 (36.85 %)	37,713 (42.94 %)	1.6
Sirmaur	3,328 (4.27 %)	3,918.7 (5.01 %)	3,465.3 (4.59 %)	0.2	8,498 (10.9 %)	12,383.3 (15.84 %)	11,296.7 (14.99 %)	1.6	11,826 (15.17 %)	16,302 (20.85 %)	14,762 (19.58 %)	1
Solan	511.67 (0.73 %)	549.33 (% 0.84)	101 (0.15 %)	−8.1	9,467.6 (13.61 %)	11,983.67 (18.4 %)	6,614.7 (10.37 %)	−1.4	9,979.3 (14.34 %)	12,533 (19.24 %)	6,715.7 (10.52 %)	2
Una	NC	NC	NC	–	3,176.3 (4.22 %)	5,087.3 (6.98 %)	5,177.3 (7.06 %)	2.6	3,176.3 (4.22 %)	5,087.3 (6.98 %)	5,177.3 (7.06 %)	2.4
State	54,919.33 (5.60 %)	83,008.33 (8.51 %)	94,656 (9.98 %)	2.7	87,037.37 (8.89 %)	118,929.7 (12.2 %)	106,202.7 (11.2 %)	1.2	141,956.7 (14.49 %)	201,938 (20.71 %)	200,858 (21.18 %)	1.6

Figures in parentheses show the percentage to total cropped area
NC stands for not cultivated

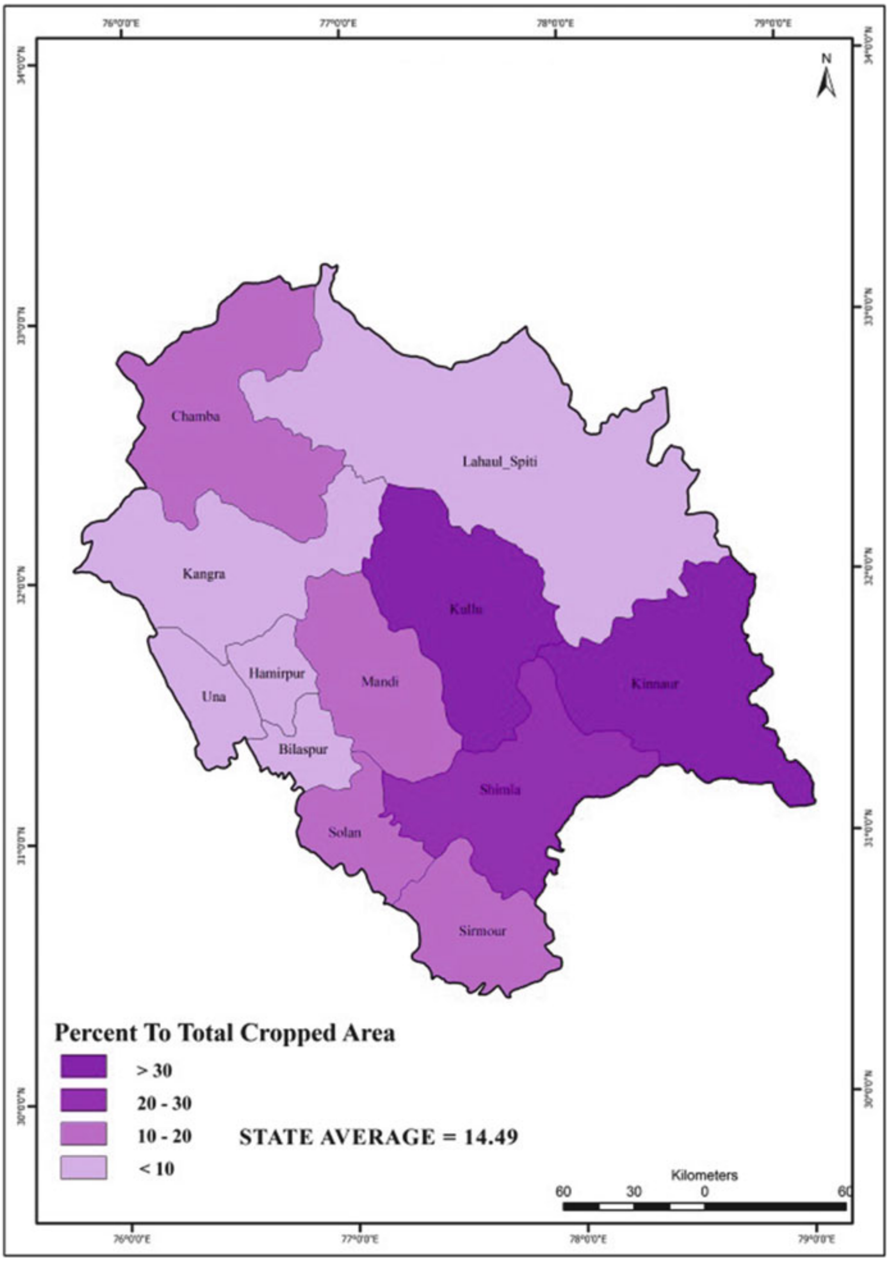

Fig. 5.1 Himachal Pradesh Area under total fruits 1986–89

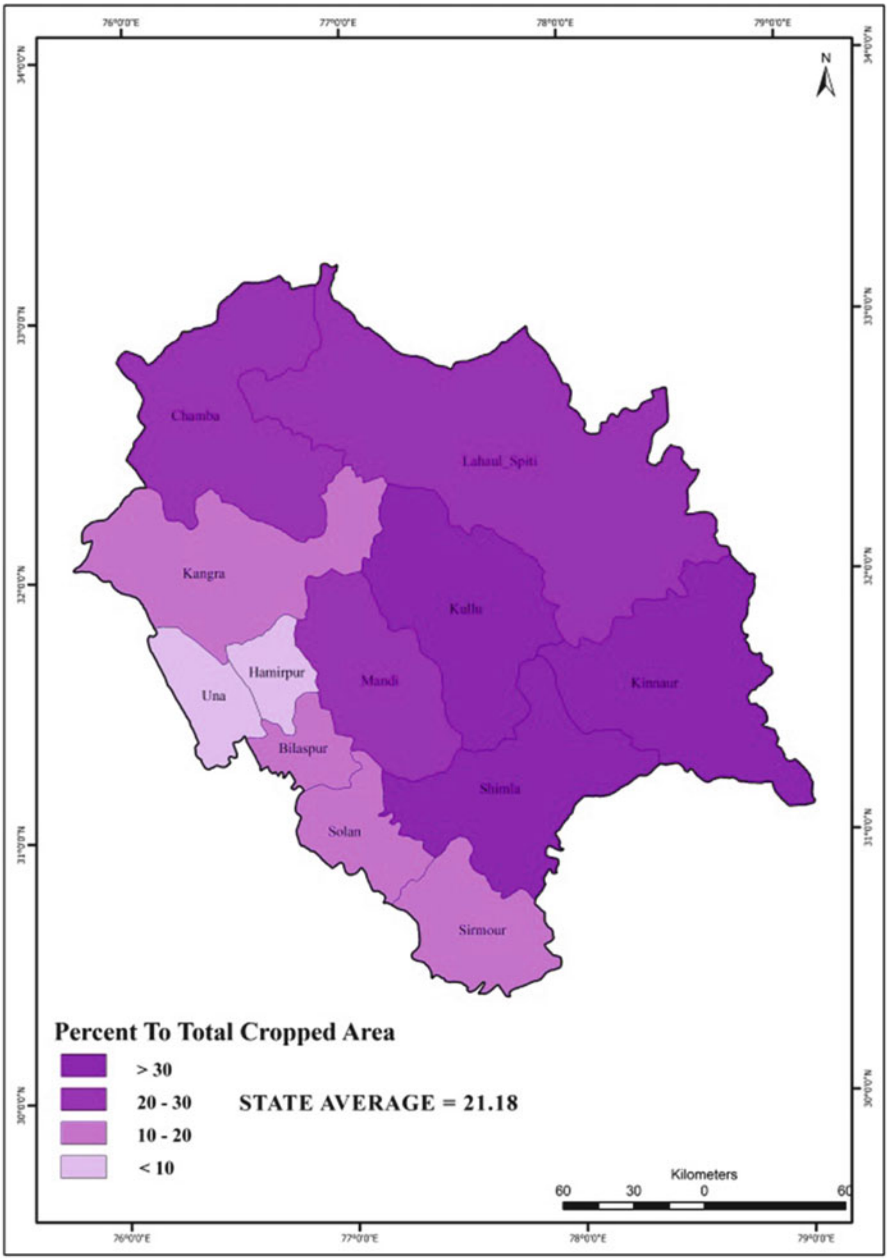

Fig. 5.2 Himachal Pradesh Area under total fruits 2006–09

registered the highest annual compound growth rate (8.4 %) of area followed by Chamba district (4.3 %). Districts like Kangra (1.3 %), Sirmaur (1.00 %) and Bilaspur (0.3 %) experienced low annual compound growth of area under total fruit crops which was less than the state average.

Table 5.1 and Fig. 5.3 reveal that in 1986–1989, only 5.60 % of total cropped area was under apple cultivation for the state as a whole. It increased to 8.51 % in 1996–1999 and 9.98 % during 2006–2009. Thus, the share of area under apple registered a little less than two fold increase during the study period. It can be noticed from the table that during 1986–1989 Kinnaur district occupied the highest i.e. more than one third of the total cropped area (37.77 %) in Kinnaur district. Shimla and Kullu districts devoted about 20–30 % of the total cropped area for apple cultivation (Fig. 5.3). There was almost negligible area under apple in Bilaspur district and apple was not cultivated at all in Una and Hamirpur districts located in Shiwalik Himachal relatively at low altitude.

It is evident from the table that in 1996–1999, every district experienced an increase in percentage of area under apple. But, there was no change in the distribution pattern. Area under apple cultivation in Kinnaur district was more than the half (58.94 %) of the total cropped area and it was followed by Shimla and Kullu districts. Table 5.1 and Fig. 5.4 indicate that during 2006–2009, Kinnaur, Shimla and Kullu continued to be leading districts in terms of higher allocation of area under apple cultivation. This is mainly due to the temperate climatic conditions prevailing in these districts which are required by apple for its best growth. Una and Hamirpur districts continued to be non-apple growing areas. Notably, the area under apple cultivation grew at the rate of 2.7 % annually for the state. Area under apple grew with the highest (6.9 %) annual compound growth rate in Chamba district. It was lowest in Kangra (−0.9 %) and Solan districts as they experienced negative annual compound growth rate. Out of three core apple growing districts, only Kullu district observed annual growth rate (2.8 %) above the state average.

The study points out that percentage of area under fruits other than apple was 8.89 % of the total cropped area in 1986–1989 (Fig. 5.5). It increased to 12.2 % during 1996–1999, while the share of area under other fruits declined to 11.2 % during the last triennium (Fig. 5.6). As far as district wise pattern is concerned, during 1986–1989, the highest percentage (13.61 %) was in Solan district closely followed by Kinnaur and Kangra districts. Districts like Lahaul-Spiti (1.88 %), Una, Shimla and Hamirpur devoted low area for the cultivation of fruits other than apple (Fig. 5.5). During next decade i.e. 1996–1999, Kangra emerged as the district with the highest percentage (18.5 %) of area under fruits other than apple followed by Solan (18.4 %) and Kinnaur districts. Lahaul-Spiti, Shimla, Una and Hamirpur districts again recorded low share of area under these fruits. During the latest triennium (2006–2009) district wise pattern was almost similar to the previous decade. Kangra district again registered highest percentage (17.17 %) of area under these fruits due to suitable climatic conditions for the growth of sub-tropical and citrus fruits. Lahaul-Spiti district (1.33 %) continued to be at the last position because

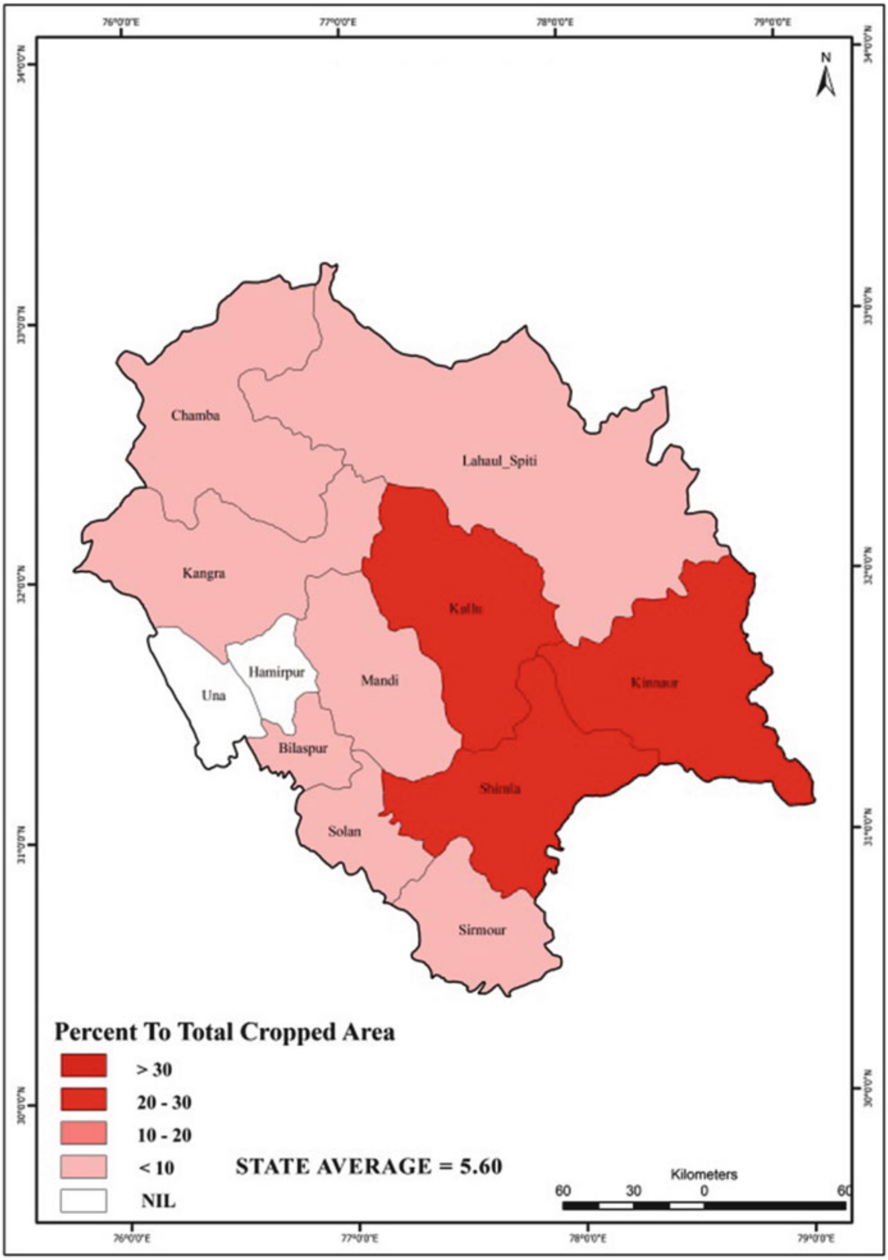

Fig. 5.3 Himachal Pradesh Area under apple 1986–89

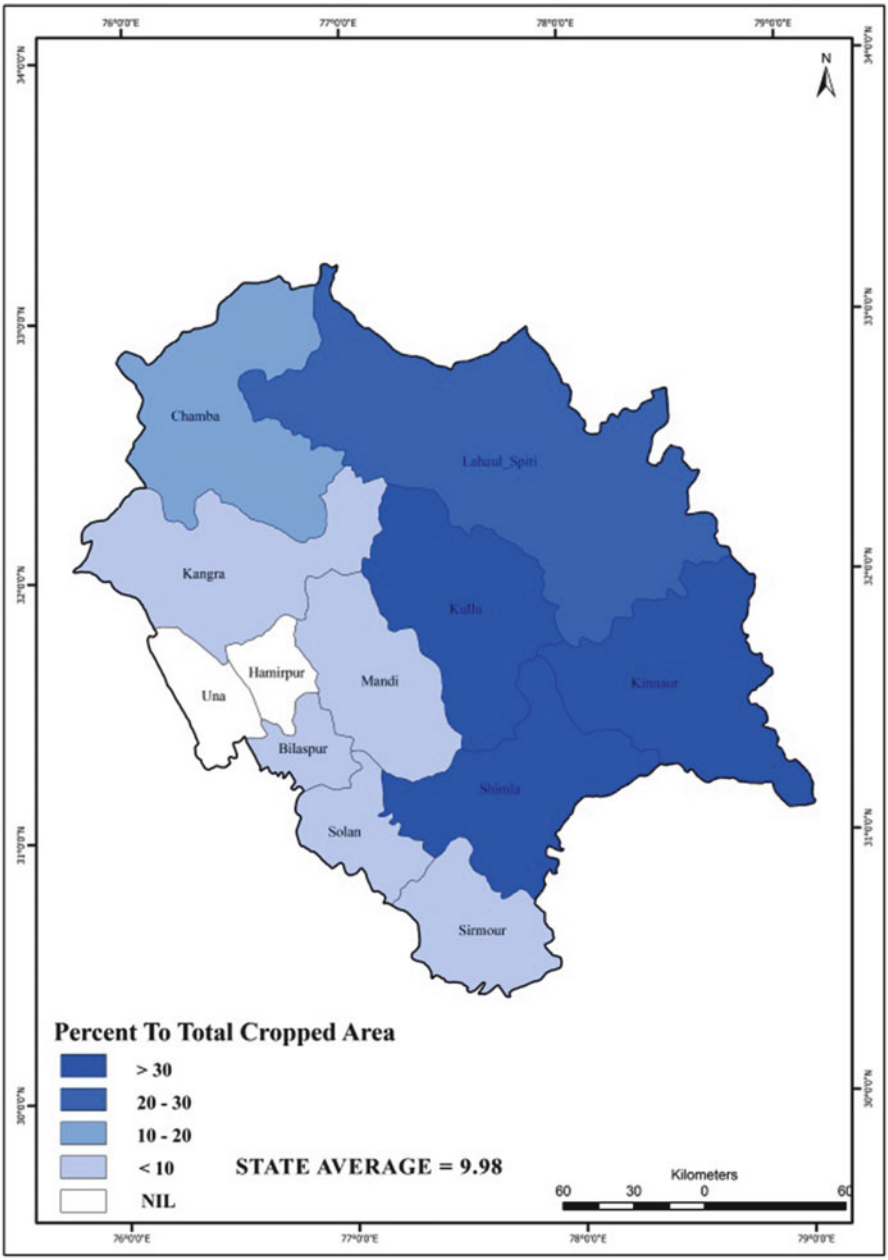

Fig. 5.4 Himachal Pradesh Area under apple 2006–09

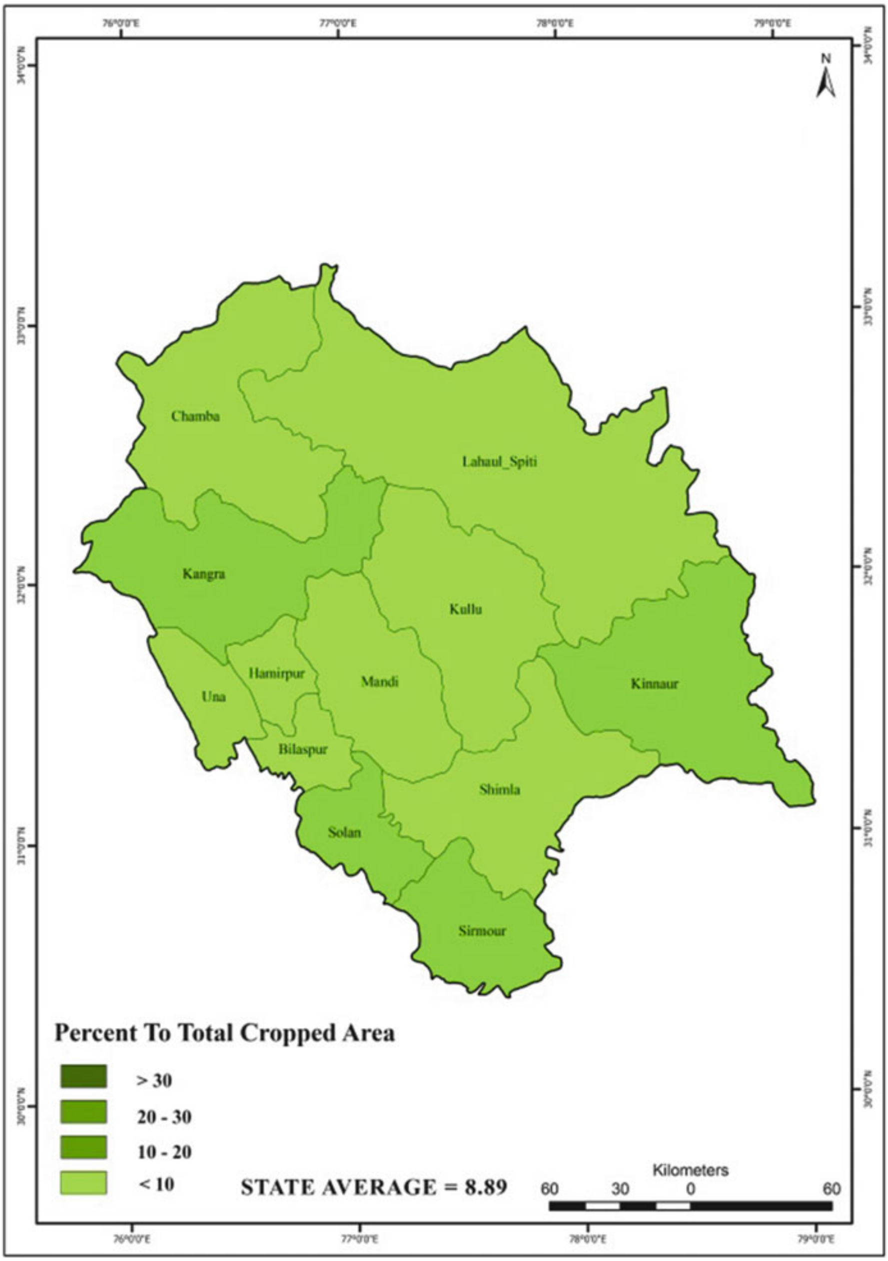

Fig. 5.5 Himachal Pradesh Area under fruits other than apple 1986–89

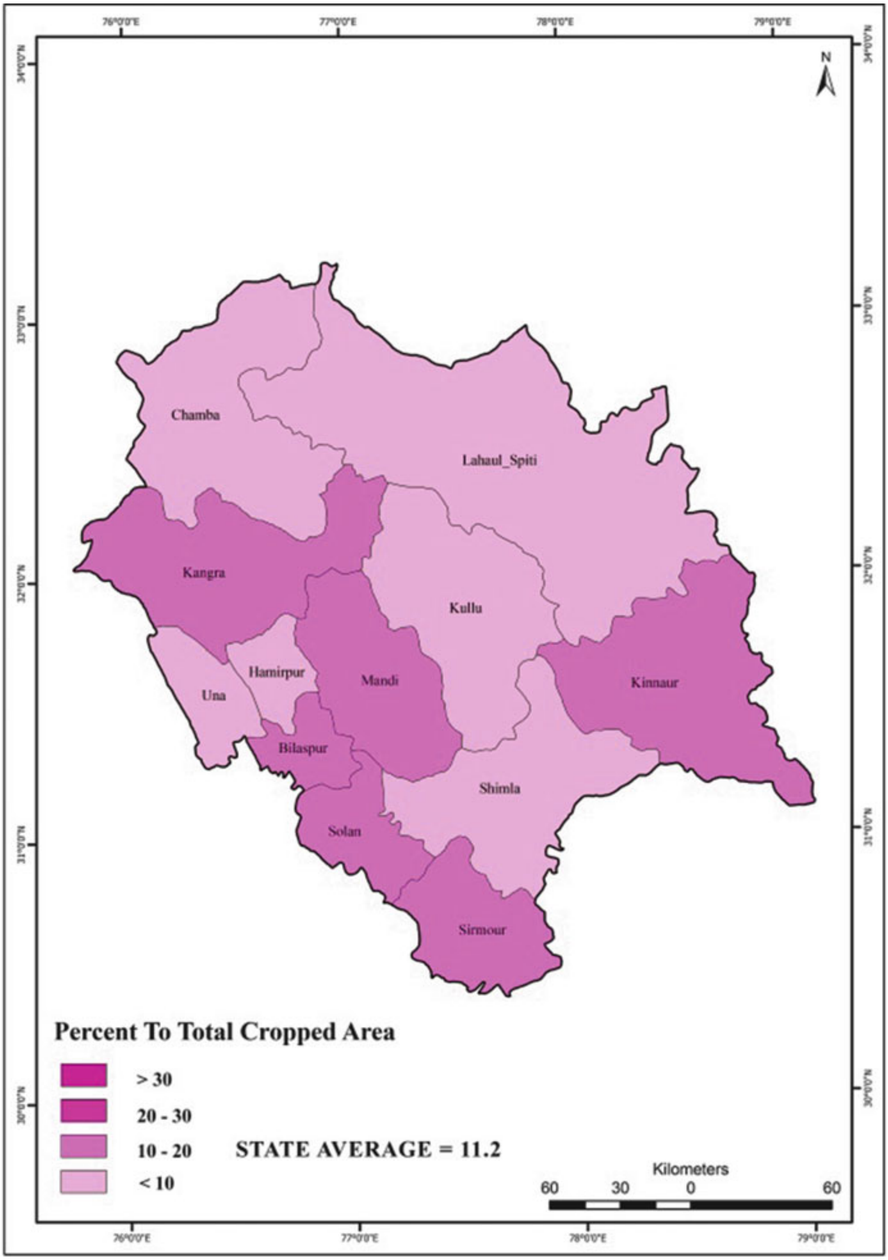

Fig. 5.6 Himachal Pradesh Area under fruits other than apple 2006–09

of its extreme cold climatic conditions which do not favour the cultivation of fruits other than apple. The area under fruits other than apple grew at the rate of 1.2 % annually throughout the study period. The highest growth was registered in Hamirpur (2.7 %) followed by Una district. Districts like Lahaul-Spiti, Kullu and Solan recorded negative annual growth rate in acreage of fruits other than apple.

5.5.2 Trends in Production

Table 5.2 exhibits that the production of total fruits has almost doubled during the reference time periods. The production of total fruits was 302 thousand tonnes in 1986–1989 which slowly increased to 359 thousand tonnes during 1986–1989. However, during the last decade, the production of total fruits increased by 211 thousand tonnes and reached at 570 thousand tonnes. The study reveals that shimla registered the highest production of total fruits followed by Kullu district during the study period.

Kinnaur, Kangra and Mandi districts were other main producers of total fruits. Lahaul-Spiti district has recorded lowest share in the production of total fruits in all the three time periods. It was followed by Bilaspur district. The table also represents that the total fruit production has increased at the rate of 4.43 % per annum in Himachal Pradesh during overall study period (1986–1989 to 2006–2009). The highest growth rate has been witnessed in Lahaul-Spiti (45.51 %) followed by Kinnaur (17.66 %), Kangra and Una districts. Solan, Kullu, Chamba and Shimla were among the districts which registered lowest annual growth rate in the production of total fruit crops.

The production of apple has increased quite rapidly in the state during the last two decades. It is evident from the Table 5.2 that over the period 1986–1989 to 2006–2009, apple production in Himachal Pradesh has almost doubled. It has increased from 261 thousand tonnes in 1986–1989 to 305 thousand tonnes in 1996–1999 and 457 thousand tonnes during 2006–2009. The district wise pattern of apple production has almost been same in all the three triennium periods. Shimla, Kullu and Kinnaur were the districts who contributed most in the production of apple during the study period. This is because of the fact that these three districts fulfil almost all the agro-climatic requirements of apple for its optimum production. Bilaspur district contributed merely 2 ton in the production of apple in 2006–2009. This can be attributed to the fact that Bilaspur along with Hamirpur and Una districts are situated on Shiwalik ranges of lesser altitude. The sub-tropical climatic conditions of these districts are not conducive for apple cultivation. The study indicates that the apple production has increased at the rate of 3.74 % per annum in Himachal Pradesh during the study period. The highest growth rate has been registered in Lahaul-Spiti district (68.00 %). Kangra also registered a very high annual growth rate of 46.43 % followed by Kinnaur district. Shimla and Kullu,

Table 5.2 Himachal Pradesh: District-Wise Production of Apple, Fruits other than Apple and Total Fruits (in tonnes)

District	Apple			Compound annual growth rate	Fruits other than apple			Compound annual growth rate	Total fruits			Compound annual growth rate
	1986–1989	1996–1999	2006–2009	2006–2009 Over 1986–1989	1986–1989	1996–1999	2006–2009	2006–2009 Over 1986–1989	1986–1989	1996–1999	2006–2009	2006–2009 Over 1986–1989
Bilaspur	_	_	2 (0.6 %)	–	1,600 (100 %)	977.33 (100 %)	3,719.66 (99.94 %)	4.3	1,600 (100 %)	977.33 (100 %)	3,721.66 (100 %)	4.3
Chamba	4,169.33 (81.06 %)	5,189.33 (86.69 %)	6,639 (80.43 %)	2.3	974.33 (18.94 %)	797 (13.31 %)	1,615.66 (19.57 %)	2.5	5,143.66 (100 %)	5,986.33 (100 %)	8,254.66 (100 %)	2.3
Hamirpur	NC	NC	NC	–	1,604.66 (100 %)	1,470 (100 %)	5,106 (100 %)	5.9	1,604.66 (100 %)	1,470 (100 %)	5,106 (100 %)	5.9
Kangra	44.33 (0.34 %)	314.66 (1.53 %)	456 (1.01 %)	12.3	12,860.34 (99.66 %)	20,382.34 (98.47 %)	44,723.67 (98.99 %)	6.4	12,904.67 (100 %)	20,697 (100 %)	45,179.67 (100 %)	6.4
Kinnaur	9,479 (93.08 %)	20,349.66 (98.29 %)	45,665.33 (98.92 %)	8.2	705.33 (6.92 %)	356 (1.71 %)	503 (1.08 %)	−1.7	10,184 (100 %)	20,771 (100 %)	46,168.33 (100 %)	7.8
Kullu	63,871 (91.86 %)	75,765.66 (83.57 %)	93,754.33 (85.06 %)	1	5,663.67 (8.14 %)	14,906 (16.43 %)	16,476 (14.94 %)	5.4	69,534.67 (100 %)	90,671.67 (100 %)	110,230.3 (100 %)	2.3
Lahaul Spiti	28.33 (66.41 %)	62.33 (71.65 %)	413.66 (95.98 %)	14.3	14.33 (33.59 %)	24.67 (28.35 %)	17.34 (4.02 %)	1.01	42.66 (100 %)	87 (100 %)	431 (100 %)	12.2
Mandi	10,581 (73.61 %)	7,218.66 (73.41 %)	26,402.66 (80.33 %)	4.7	3,794.33 (26.39 %)	2,615.34 (26.59 %)	6,467.34 (19.67 %)	2.7	14,375.33 (100 %)	9,834 (100 %)	32,870.67 (100 %)	4.2
Shimla	171,687.33 (98.84 %)	195,914.33 (98.47 %)	283,105.33 (98.09 %)	2.5	2,015.67 (1.16 %)	3,058 (1.53 %)	5,516.67 (1.91 %)	5.2	173,703 (100 %)	198,972.3 (100 %)	288,622 (100 %)	2.6
Sirmaur	1,251.66 (21.05 %)	494 (13.86 %)	570 (3.80 %)	−4	4,695.34 (78.95 %)	3,071.33 (86.14 %)	14,466.67 (96.20 %)	5.8	5,947 (100 %)	3,565.33 (100 %)	15,036.67 (100 %)	4.7
Solan	139.33 (3.11 %)	172.66 (12.44 %)	38 (0.69 %)	−6.7	4,352.67 (96.89 %)	1,215.34 (87.56 %)	5,514 (99.31 %)	1.01	4,492 (100 %)	1,388 (100 %)	5,552 (100 %)	0.91
Una	NC	NC	NC	_	2,653.66 (100 %)	5,247.31 (100 %)	8,834.34 (100 %)	6.1	2,653.66 (100 %)	5,247.31 (100 %)	8,834.34 (100 %)	6.1
State	261,251.3 (86.44 %)	305,481.3 (84.94 %)	457,046.3 (80.19 %)	2.8	40,933.7 (13.54 %)	54,186 (15.06 %)	112,961 (19.81 %)	5.2	302,185 (100 %)	359,667.3 (100 %)	570,007.3 (100 %)	3.32

NC stands for not cultivated

the two major apple producing districts observed the annual growth rate less than the state average.

The study reveals that the production of fruits other than apple increased from 40.93 thousand tonnes in 1986–1989 which gradually increased to 54.18 thousand tonnes during next decade in 1996–1999. But the production of other fruits experienced a considerable increase during the next decade i.e. 2006–2009 and became 112.96 thousand tonnes. The study therefore shows that production of fruits other than apple has been about four times less than that of apple in the state. At the district level, Kangra emerged as the leading producer of fruits other than apple throughout the study period. This is because of the fact that Kangra is the major producer of the fruits like sub-tropical and citrus fruits. While, Kullu and Sirmaur districts were next to Kangra district in terms of production of other fruits. Lahaul-Spiti and Kinnaur districts recorded low production of these fruits during the study period due to non-cultivation of sub-tropical and citrus fruits. The annual growth rate of Himachal Pradesh for the production of fruits other than apple was 8.79 % during the study period. At district level, Kangra district registered the highest (12.38 %) annual growth rate followed by Una (11.64 %), Hamirpur and Sirmaur district. Kinnaur district experienced negative annual growth rate (−1.43 %) followed by Lahaul-Spiti (1.04 %) district.

5.5.3 Spatio-Temporal Variations in Yield Level

Table 5.3 shows that in Himachal Pradesh, the yield of total fruits was 2,128 kg/ha in 1986–1989. It decreased to 1,779 kg/ha during the period of 1996–1999. But, it saw a substantial increase during the last decade and reached at 2,887 kg/ha (Fig. 5.7). At the district level, the highest yield was observed in Shimla (6,357 kg/ha), Kullu (3,943 kg/ha) and Kinnaur (2,060 kg/ha) districts. Bilaspur (292 kg/ha) and Lahaul-Spiti (298 kg/ha) districts recorded very low yield. During 1996–1999, Shimla, Kullu and Kinnaur districts again showed higher yield level. Solan and Bilaspur districts had lowest yield level of total fruits. During 2006–2009, the highest yield of total fruits continued to be in Shimla (7,622 kg/ha), Kinnaur (6,380 kg/ha) and Kullu (3,853 kg/ha) districts. The lowest yield level was found in districts like Chamba, Lahaul-Spiti and Bilaspur. It is observed that overall annual growth rate of yield of total fruits was 1.78 %. The highest growth rate was experienced by Kinnaur followed by Kangra district. Kullu and Chamba districts registered negative annual growth rate. Shimla district also had growth rate less than the state average.

The study shows that yield level of apple has been subjected to temporal fluctuations during the study period (Table 5.3). The yield level of apple was 4,757 kg/ha in 1986–1989. It decreased to 3,680 kg/ha in 1996–1999. However,

Table 5.3 Himachal Pradesh: District-Wise Yield Level of Apple, Fruits other than Apple and Total Fruits (kg/ha)

District	Apple			Compound annual growth rate	Fruits other than apple			Compound annual growth rate	Total fruits			Compound annual growth rate
	1986–1989	1996–1999	2006–2009	2006–2009 Over 1986–1989	1986–1989	1996–1999	2006–2009	2006–2009 Over 1986–1989	1986–1989	1996–1999	2006–2009	2006–2009 Over 1986–1989
Bilaspur	–	—	500	–	289	142	625	4	292	143	618	3.8
Chamba	1,392	683	580	−4.5	259	132	378	1.9	778	435	522	−2
Hamirpur	NC	NC	NC	–	441	259	904	3.6	447	256	914	3.6
Kangra	84	524	1,012	13.2	450	498	1,202	5.1	448	499	1,199	5.1
Kinnaur	2,662	3,597	8,073	5.7	506	227	321	−2.3	2,068	2,878	6,380	5.8
Kullu	4,926	4,092	4,096	−0.9	1,154	2,902	4,130	6.5	3,943	3,822	3,853	−0.5
Lahaul-Spiti	296	149	556	3.1	232	261	371	2.3	298	188	534	2.9
Mandi	1,261	557	1,742	1.6	285	151	358	0.92	671	325	988	2
Shimla	7,612	5,962	9,017	0.8	405	506	873	3.9	6,357	5,107	7,622	0.9
Sirmaur	376	126	164	−4.2	552	248	1,280	4.2	504	218	1,023	3.6
Solan	272	314	356	1.4	459	101	834	3	450	110	826	3
Una	NC	NC	NC	–	835	1,031	1,706	3.6	852	1,041	1,711	3.5
State	4,757	3,680	5,005	0.2	470	455	1,064	4.2	2,128	1,779	2,887	1.5

NC stands for not cultivated

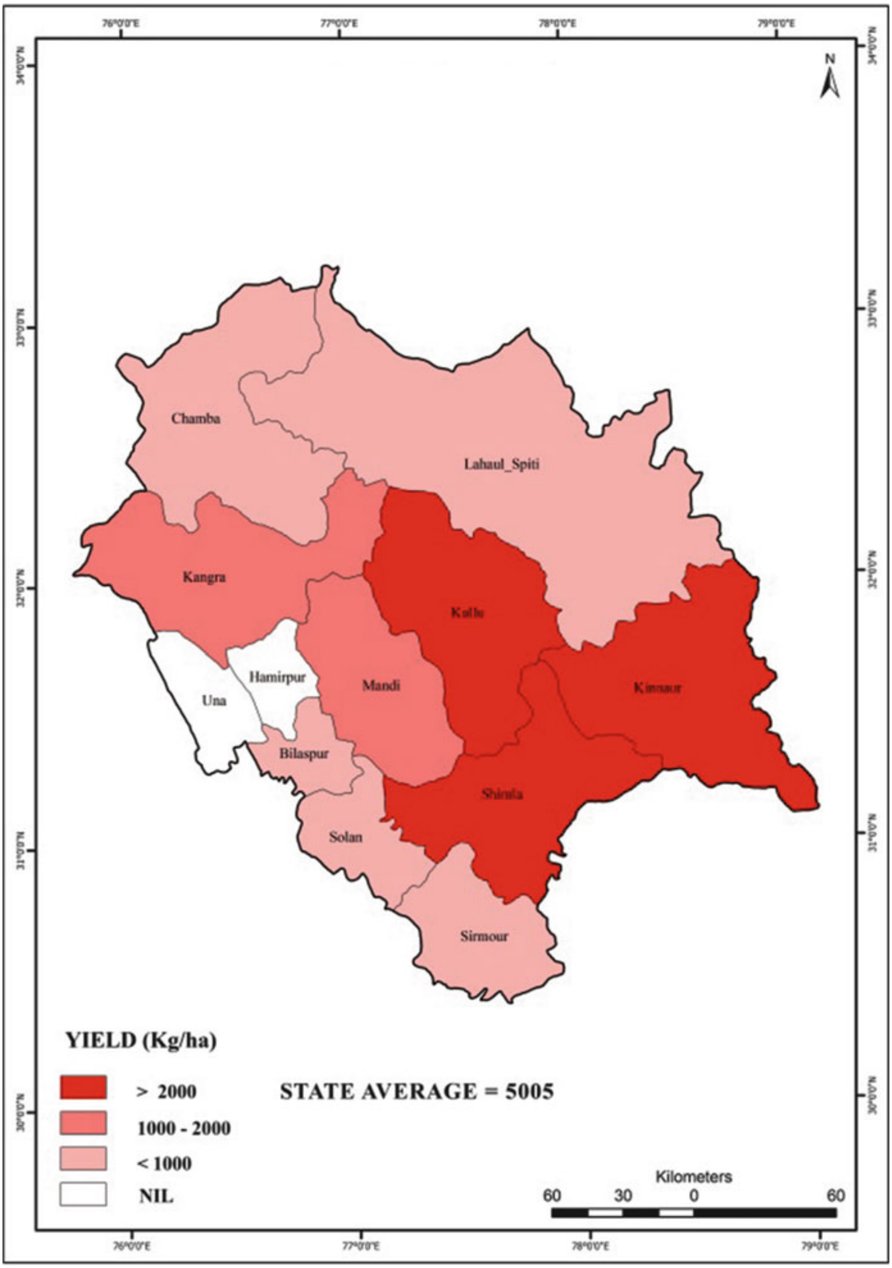

Fig. 5.7 Himachal Pradesh Yield level of apple 2006–09

yield level of apple again increased to 5,005 kg/ha in 2006–2009. The Table 5.3 and Fig. 5.7 exhibit that Shimla district had the highest (7,612 kg/ha) yield level of apple. It was followed by Kullu district (4,926 kg/ha). Kinnaur district (2,662 kg/ha) was at third position. Kangra (84 kg/ha) and Solan (272 kg/ha) districts recorded lowest yield in apple.

During 1996–1999, highest yield of apple was once again recorded by Shimla (5,962 kg/ha) and Kullu (4,092 kg/ha) districts, though their yield level fell during this period. There was a significant rise in the yield level of Kinnaur district, and its yield level increased to 3,597 kg/ha. Sirmaur and Lahaul-Spiti districts registered lowest yield of apple. It has been observed that during 2006–2009, every district recorded increase in yield level of apple. Highest yield was experienced by south-eastern and eastern parts of the state comprising Shimla (9,017 kg/ha) and Kinnaur (8,073 kg/ha) along with the central Kullu district (4096 kg/ha) (Fig. 5.7). The lowest yield (164 kg/ha) was recorded by Sirmaur followed by Solan district. The significant change in the distribution pattern was that Bilaspur district also marked its presence in apple production and registered yield level of 500 kg/ha. Notably, yield of apple in Himachal Pradesh grew with annual compound growth rate of 0.26 %. The highest annual growth rate was seen unexpectedly in Kangra (55.23 %) followed by Kinnaur district (10.16 %). Core of apple producing districts like Shimla (0.92 %) observed very low annual growth rate, while Kullu experienced negative growth rate. Chamba and Sirmaur also registered negative growth rate in yield of apple.

It can be noticed from Table 5.3 that yield level of fruits other than apple during 1986–1989 for the state was 470 kg/ha and witnessed a fall during 1996–1999 up to 455 kg/ha. However, it almost doubled to 1,064 kg/ha during 2006–2009. During 1986–1989, Kullu recorded the highest yield level (1,154 kg/ha) followed by Una and Sirmaur districts. Lahaul-Spiti district had registered lowest yield level (232 kg/ha) followed by Chamba, Mandi and Bilaspur districts. During 1996–1999, the district level pattern of yield of fruits other than apple observed slight change. Kullu (2,902 kg/ha) followed by Una districts (1,031 kg/ha) district had the highest yield. Solan district observed the lowest yield (101 kg/ha) followed by Chamba, Bilaspur and Mandi districts. The study reveals that Kullu (4,130 kg/ha) and Una (1,706 kg/ha) districts continued to be the dominant districts in terms of yield level of fruits other than apple during 2006–2009. Kinnaur district (321 kg/ha) observed the lowest yield level followed by Mandi, Lahaul-Spiti and Chamba districts (Fig. 5.8). Notably, yield level of fruits other than apple for the whole state grew at 6.31 % per annum during the study period. Kullu district observed the highest (12.89 %) annual growth rate while Kangra (8.35 %) and Sirmaur districts were next to it. The annual growth rate was lowest in Kinnaur (−1.82 %) followed by Mandi and Chamba districts.

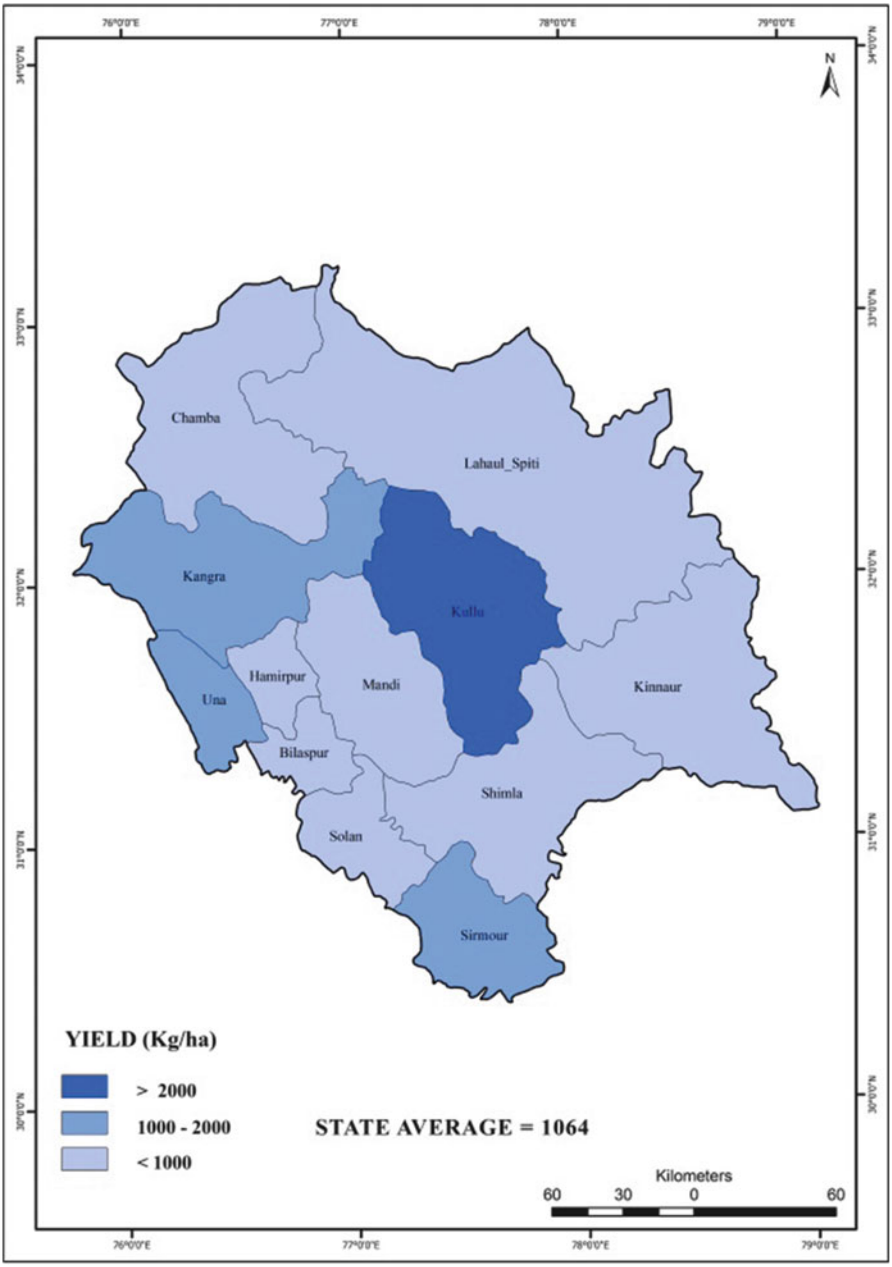

Fig. 5.8 Himachal Pradesh Yield level of fruits other than apple 2006–09

5.6 Concluding Remarks

It is evident from the above discussion that due to mountainous topography and varying favourable agro-ecological conditions the share of area under all fruits has increased from about 15 % in 1986–1989 to about 21 % during 2006–2009. It shows a remarkable increase and significant share of area under horticultural crops in Himachal Pradesh state of India. The study infers that three districts namely Shimla, Kullu and Kinnaur continue to be fruits growing areas due to their geographical conditions suitable for the growth of apple, apricot, nuts, peach, plum, pear and dry fruits. Low lying areas namely Una and Hamirpur districts occupied very less area under different fruits due to higher cultivation of non-fruit crops. The study shows that Lahaul-Spiti registered the highest (8.4 %) and Bilaspur district lowest annual compound growth rate during the study period. Apple accounted for about 5.60 % area in 1986–1989 which increased to about one-tenth of total cropped area during next two decades. Shimla, Kinnaur and Kullu are the major apple producing districts. Apple occupied more than half of total cropped area in Kinnaur followed by Kullu (one-fourth) and Shimla districts. In contrast, percentage of area under fruits other than apple in Himachal Pradesh also increased from about 9 % in 1986–1989 to 11 % in 2006–2009. Kangra district occupied the highest share of area mainly due to the cultivation of sub-tropical and citrus fruits. Lahaul-Spiti district recorded the lowest i.e. merely 1.33 % area under these fruits due to more allocation of land to apple orchards.

It has been inferred from the study that production of total fruits almost doubled during the study period. Shimla has been the leading contributor followed by Kullu district. It has been investigated that apple production almost doubled from 261 thousand tonnes during late 1990s to 457 thousands tones in 2006–2009 at 3.74 % annual growth. Shimla, Kullu and Kinnaur have been observed as leading apple producing districts and experienced increasing trend of production during the study period. In contrast, production of fruits other than apple increased by about three times from 40.93 thousand tonnes in 1986–1989 to 112.96 thousand tonnes in 2006–2009 at growth rate of 5.2 % per annum. Kangra district emerged as the leading producer of fruits other than apple mainly due to cultivation of sub-tropical and citrus fruits.

The study reveals the fact that yield level of total fruits has shown considerable fluctuations during the study period. The study brings out that in Himachal Pradesh, yield level of apple increased slightly from 4,757 kg/ha in 1986–1989 to 5,005 kg/ha in the last triennium period at the rate of 0.26 % per annum. Yield level of apple has been observed highest in Shimla followed by Kullu and Kinnaur districts. However, the yield level of fruits other than apple increased by more than two times from 470 kg/ha in 1986–1989 to 1,064 kg/ha during 2006–2009. Kullu district showed the dominant position in terms of yield of fruits other than apple followed by Una district.

The study reveals that about 22 % of the total cropped area is under different fruit crops in the state. Out of this considerable proportion, apple occupied nearly 10 %

area and other fruits together constituted about 11 % area. However, production wise, apple alone contributes about 80 % of the total fruit production and remaining one-fifth production is shared by fruits other than apple. It has been investigated that the yield level of apple in the state is about five times more to the yield level of other fruits. This shows the dominance of apple in terms of production and yield level over other fruits in Himachal Pradesh. Given the fact that there is more area under fruit crops other than apple, Himachal Pradesh continues to retain its status of apple state due to its higher production and yield. Since, the area under other fruits is more than the apple, so there are vast possibilities to develop these fruits for balanced horticultural development in the state. The need is therefore to develop new techniques, better planting system and other high yielding varieties of fruits to increase the production and yield level of fruits other than apple. So, the growers of these fruits can also avail due economic benefits for their betterment of life.

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Chapter 6
Geospatial Approach for Cropping System Analysis: A Block Level Case Study of Hisar District in Haryana

Saroj Bishnoi, M.P. Sharma, Ravindra Prawasi, and R.S. Hooda

Abstract Agricultural sustainability has the highest priority in all countries, whether developed or developing. Cropping System Analysis is essential for studying the sustainability of agriculture. Crop rotation is stated as growing one crop after another on the same piece of land in different timings (seasons) without impairing the soil fertility. A cropping system can be defined as the cropping patterns and their management to derive maximum benefits from a given resource base under specific environmental conditions. Multiplicity of cropping system has been one of the main feature of Indian agriculture and is attributed to rained agriculture and prevailing socio-economic situations of farming community. Although, it is well known that one of the main advantage of remote sensing satellites is the synoptic and repeated collection of data which facilitate to map multi-year cropping patterns and crop rotations. In the present work, crop rotation and long term changes monitoring in cropping pattern along other spatial and non-spatial collateral data have been done with the help of satellite data at block level of Hisar district of Haryana. Multi-date IRS LISS-III data of different seasons for the year 2007–2008 have been used for the study. Cropping pattern maps of Rabi, Kharif and Summer season have been understood to know the spatial distribution and associations between crops or crops and uncultivated land in the same fields (although not in a particular order of sequence).

Keywords Cropping system • IRS-P6 satellite • Kharif & Zaid • LISS-III • Rabi • Remote sensing

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6.1 Introduction

Agricultural sustainability has the highest priority in all countries, whether developed or developing. Cropping System Analysis is essential for studying the sustainability of Agriculture. Indian society is agriculture based and its economy is dependent on agriculture. Since the scope of increasing area under agriculture is rather limited thus, to increase agriculture productivity. Majority of Indian farmers get the major share of income from crop production. Therefore, it is very much important to select the right crop, in the right season so that maximum profit may be achieved. In selecting a crop for a season, both post and pre season crops should also to be examined (Manjunath 2006). In agricultural applications, remote sensing imagery has been used to identify different crop types, estimate crop area and, predict yield at small scales (Kanemasu 1974). The structure of most crops is identical causing spectral mixes within crops and other types of vegetation. These high spectral overlaps make attempts to understand the relationships between crops and the ecosystems within which they occur in order to classify remote sensing imagery difficult. The spectral signature for vegetation is highly variable in nature since it changes completely during the seasonal cycle of many plants. Therefore, a number of contexts like spatial, spectral and temporal have been used over the years in order to carry out crop identification in remotely sensed data (Byeungwoo and Landgrebe 1992; Wharton 1982).

Agriculture is the backbone of Indian economy, contributing about 90 % towards the Gross National product and providing livelihood to about 70 % of the population. In the country, wheat is the second important food crop being next to rice and contributes to the total food grain production of the country about 25 %. Importance of crop production information was realized in India as early as 1884, when the government initiated a program for wheat. Agriculture is the main occupation of the people of Haryana. Haryana is often called the “Food Mine” of the country. About 80 % of the population of the state is agriculture dependent. Haryana is self sufficient in producing food grains of the country. Wheat, rice, maize and bajra are the major grains produced in the state. The crop production of Haryana can be broadly divided into Rabi and Kharif. The major Kharif crops of Haryana are rice, jowar, bajra, maize, mustard, jute, sugarcane, sesame and groundnut. The major Rabi crops are wheat, tobacco, gram, linseed, rapeseed and mustard. The total area irrigated by canal water is 21.40 lakh hectares. The state of Haryana has a geographical area of 44.20 lakh hectare. About 86 % of the geographical area is cultivable in which 96 % has already been brought under plough. Therefore, there is hardly any scope for bringing additional area under cultivation, except for reclamation of degraded lands affected by water logging, salinity and alkalinity. About 84 % of the cultivated area in the state is irrigated. Irrigation from canals forms the lifeline of agriculture in Haryana. The various canals which are operating in the state include Western Yamuna Canal, Gurgaon Canal, Jui Canal, Jawaharlal Lal Nehru Canal and Bhakra Canal. These canals are the main source of water for cultivation in various districts of the state. Haryana together with Punjab is called the ‘Grain Bowl’ of India.

6.1.1 Objective

This study established the methodology for spatial analysis of cropping systems. It is now envisaged to create remote sensing based Cropping System Analysis for Hisar district and its development Blocks at 24 m cell size.

6.2 Study Area

The district drives its name from its headquarter city, called Hisar which is an abbreviation of Hisar-e-Feroza. The name acquired by the original town is the result of construction of a fort (Hisar) by Feroz Shah Tughlaq about A.D. 1354. Hisar district has rich pre-Harappan sites of Banwali Rakhigarhi (Rakhi Sahpur and Rakhi Khas) and Siswal, which take back to the first half of the third Millennium B.C. And possibly even earlier. The Hisar district a part of Indo-Gangetic alluvial plain occupies an area of 3,983 km^2 (Fig. 6.1). It is bordered on the east by the Rohtak district, on the west by Fatehabad district and Rajasthan state, on the south by Bhiwani district and the north by Jind district.

6.2.1 Development Blocks of Hisar District

6.2.1.1 Hansi I Block

Location 29°06′32″ to 29°17′20″N latitudes and 76°33′18″ to 76°52′28″E longitudes. The total geographical area of the Hansi_I Block is 616.74 km^2.

6.2.1.2 Hansi II Block

Location 28°56′54″ to 29°12′34″N latitudes and 76°39′06″ to 76°51′59″E longitudes. The total geographical area of the Hansi-II Block is 376.05 km^2.

6.2.1.3 Narnaund Block

Location 29°08′24″ to 29°25′09″N latitudes and 76°01′12″ to 76°13′38″E longitudes. The total geographical area of the Narnaund Block is 381.23 km^2.

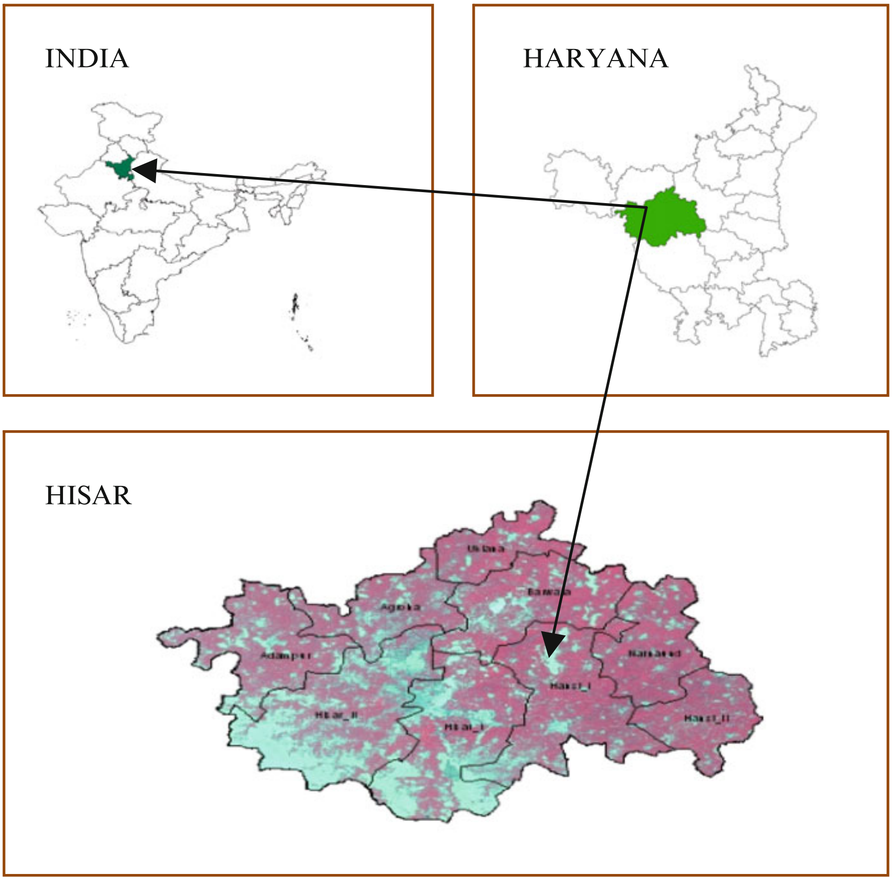

Fig. 6.1 Location map of study area

6.2.1.4 Hisar I Block

Location 28°54′01″ to 29°15′51″N latitudes and 75°37′50″ to 75°55′14″E longitudes. The total geographical area of Hisar -I Block is 650.96 km^2.

6.2.1.5 Hisar II Block

Location 28°58′03″ to 29°19′00″N latitudes and 75°23′34″ to 75°46′01″E longitudes. The total geographical area of the Hisar-II Block is 740.39 km^2.

6.2.1.6 Barwala Block

Location 29°13′43″ to 29°28′18″N latitudes and 75°44′39″ to 76°05′46″E longitudes. The total geographical area of the Barwala Block is 475.83 km^2.

6.2.1.7 Uklana Block

Location- 29°24′10″ to 29°34′48″N latitudes and 75°45′05″ to 76°00′50″E longitudes. The total geographical area of the Ukalna Block is 234.63 km^2.

6.2.1.8 Agroha Block

Location- 29°14′14″ to 29°28′42″N latitudes and 75°29′43″ to 75°47′43″E longitudes. The total geographical area of the Agroha Block is 330.23 km^2.

6.2.1.9 Adampur Block

Location- 29°06′45″ to 29°24′52″N latitudes and 75°16′07″ to 75°37′09″E longitudes. The total geographical area of the Adampur Block is 330.23 km^2.

6.3 Database Requirements

6.3.1 Remote Sensing Data

Remote sensing data is the basic data source for mapping the cropping system of the state region. Indian Remote Sensing Satellite Resourcesat (IRS-P6) LISS III data is the ideal one with optimum spatial and temporal resolution. The sensor provides 23.5 m spatial resolution data in Green, Red, NIR and SWIR bands with 24 days revisit capability. Its repeat cycle can be used for deriving Kharif, Rabi and summer cropping pattern and change analysis between these seasons. Remote sensing data from sensor LISS III on-board Indian Remote Sensing Satellite Resourcesat (IRS-P6) of 2007–2008 were used to analyze the changes in cropping pattern and crop rotation for three seasons Kharif, Rabi and summer. The Multi-date satellite data are used for different seasons which are given in (Table 6.1).

Table 6.1 Satellite data used in digital analysis

S. No.	Season	Satellite	Sensor	Date of Acquision	Path/row
1.	Kharif	IRS-P6	LISS-III	August 08, 2007	94/50
				September 30, 2007	95/50
				October 13, 2008	94/50
				October 18, 2008	95/50
2.	Rabi	IRS-P6	LISS-III	December 30, 2007	94/50
				March 11, 2008	94/50
				March 16, 2008	95/50
3.	Summer	IRS-P6	LISS-III	May 28, 2007	94/50
				May 27, 2008	95/50

6.4 Methodology

Digital image analysis was carried out through study on windows platform using Geomatica and ARC/MAP software packages. In order to analysis cropping pattern and crop rotation of Hisar district and its blocks for the year 2007–2008 complete enumeration approach was used. Basically the methodology for cropping system analysis comprises of the following functional component (Fig. 6.2).

6.5 Results

Analysis by remote sensing techniques reflected that Rice and Sugarcane are two major crops in Kharif season which could be identified using Multi-date RS data. Rice is mostly concentrated throughout the district except in eastern part of the district. Other crops in the Kharif season include Bajra, Maize, Jowar etc. Wheat and Sugarcane are the two major crops during Rabi season followed by other crops.

6.5.1 Cropping System Analysis of Hisar District

In Kharif, Rabi and Summer season, the area under cultivated land is 94.3, 77.48 and 26.80 % respectively of total agricultural land. In Summer season there is very less cultivated area because of harvesting of crops.

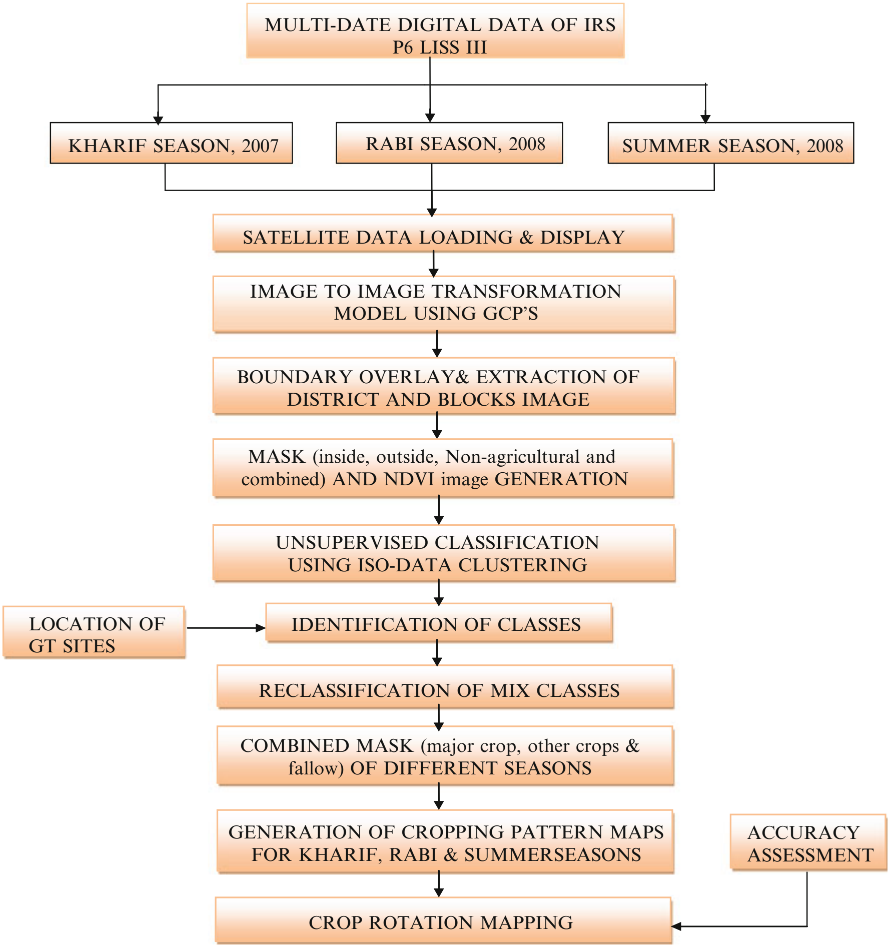

Fig. 6.2 Flow chart of methodology

6.5.1.1 Adampur Block

Adampur Block has the major crop rotations of Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg and Paddy/Other Crops-Fallow/Other Crops-Fallow-Moong Veg. Which occupies 108.79 and 83.23 (00'h) area respectively based on three seasons viz. Kharif, Rabi and Summer. All crop rotation of Adampur Block are shown in Fig. 6.3 (Table 6.2)

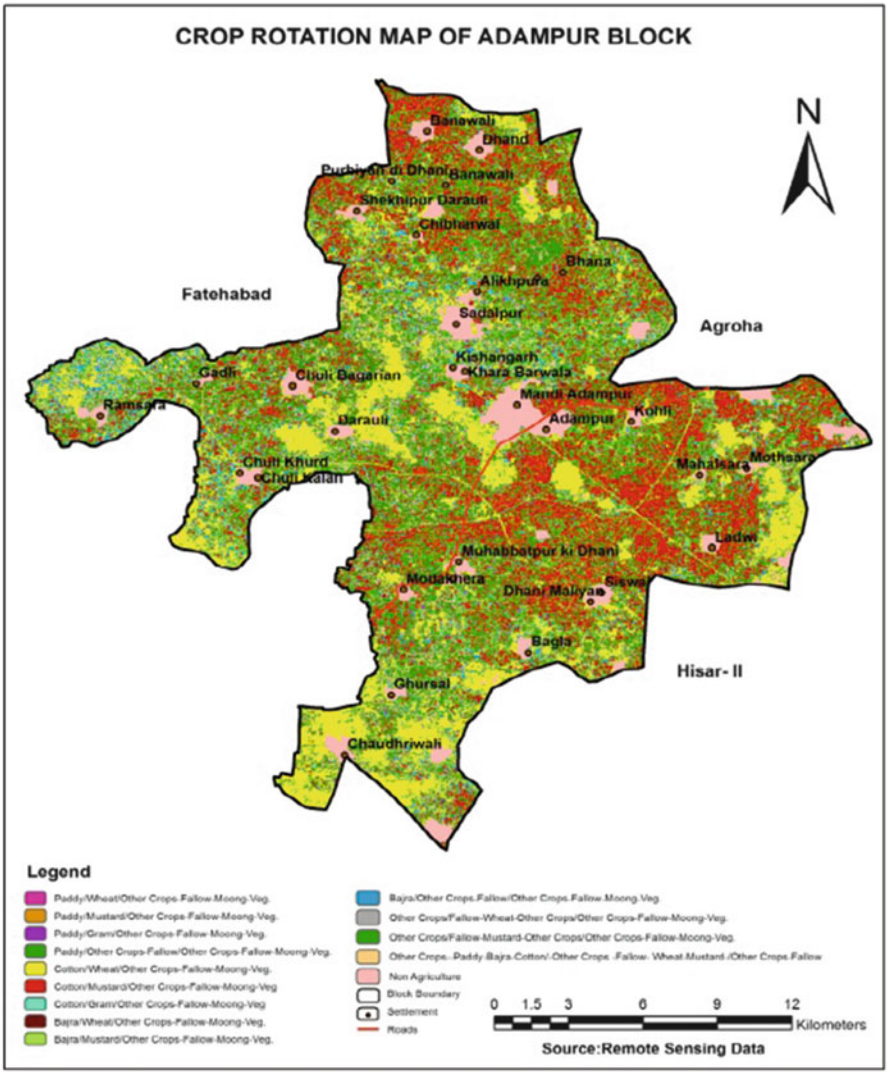

Fig. 6.3 Crop rotation map of Adampur Block

Table 6.2 Crop rotations statistics

S. NO	Rotations	Area (00'h)
1	Paddy/Wheat/Other Crops-Fallow-Moong-Veg.	25.40
2	Paddy/Mustard/Other Crops-Fallow-Moong-Veg.	3.84
3	Paddy/Gram/Other Crops-Fallow-Moong-Veg.	0.89
4	Paddy/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	83.23
5	Cotton/Wheat/Other Crops-Fallow-Moong-Veg.	80.18
6	Cotton/Mustard/Other Crops-Fallow-Moong-Veg	12.52
7	Cotton/Gram/Other Crops-Fallow-Moong-Veg	2.86
8	Bajra/Wheat/Other Crops-Fallow-Moong-Veg.	41.05
9	Bajra/Mustard/Other Crops-Fallow-Moong-Veg.	10.94
10	Bajra/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	3.59
11	Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg.	108.79
12	Other Crops/Fallow-Mustard-Other Crops/Other Crops-Fallow-Moong-Veg.	30.74
13	Other Crops-Paddy-Bajra-Cotton/-Other Crops -Fallow-Wheat-Mustard-/Other Crops-Fallow	14.50
14	Non Agriculture Area	24.54
	Total	443.07

Table 6.3 Crop rotations statistics

S. NO	Rotations	Area (00'h)
1	Paddy/Wheat/Other Crops-Fallow-Moong-Veg.	33.14
2	Paddy/Mustard/Other Crops-Fallow-Moong-Veg.	1.61
3	Paddy/Gram/Other Crops-Fallow-Moong-Veg.	0.45
4	Paddy/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	34.50
5	Cotton/Wheat/Other Crops-Fallow-Moong-Veg.	134.28
6	Cotton/Mustard/Other Crops-Fallow-Moong-Veg	8.07
7	Cotton/Gram/Other Crops-Fallow-Moong-Veg	2.92
8	Bajra/Wheat/Other Crops-Fallow-Moong-Veg.	32.69
9	Bajra/Mustard/Other Crops-Fallow-Moong-Veg.	2.22
10	Bajra/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	1.56
11	Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg.	102.59
12	Other Crops/Fallow-Mustard-Other Crops/Other Crops-Fallow-Moong-Veg.	5.74
13	Other Crops-Paddy-Bajra-Cotton/-Other Crops-Fallow-Wheat-Mustard-/Other Crops-Fallow	4.31
14	Non Agriculture Area	16.41
	Total	380.50

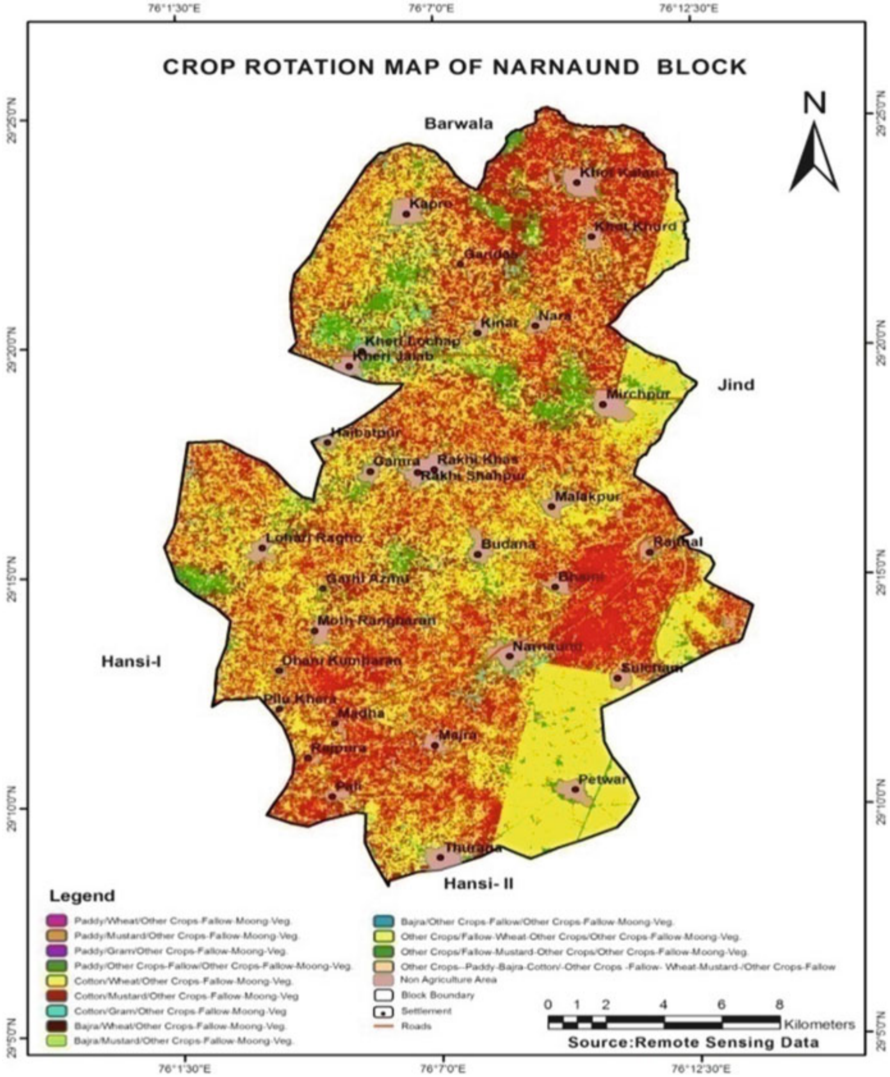

Fig. 6.4 Crop rotation map of Narnaund Block

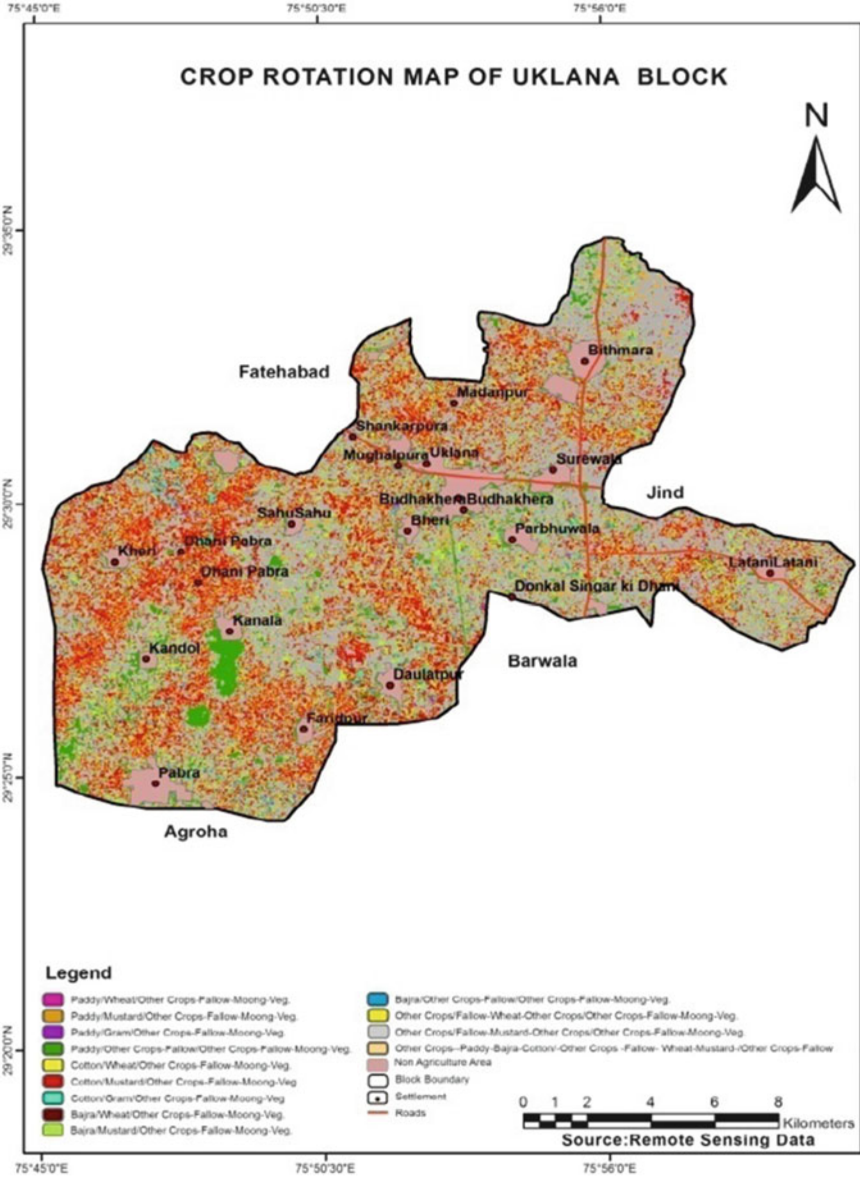

Fig. 6.5 Crop rotation map of Uklana Block

Table 6.4 Crop rotations statistics

S. NO	Rotations	Area (00'h)
1	Paddy/Wheat/Other Crops-Fallow-Moong-Veg.	17.93
2	Paddy/Mustard/Other Crops-Fallow-Moong-Veg.	1.73
3	Paddy/Gram/Other Crops-Fallow-Moong-Veg.	0.18
4	Paddy/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	20.81
5	Cotton/Wheat/Other Crops-Fallow-Moong-Veg.	45.05
6	Cotton/Mustard/Other Crops-Fallow-Moong-Veg	4.64
7	Cotton/Gram/Other Crops-Fallow-Moong-Veg	0.52
8	Bajra/Wheat/Other Crops-Fallow-Moong-Veg.	21.20
9	Bajra/Mustard/Other Crops-Fallow-Moong-Veg.	1.95
10	Bajra/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	0.56
11	Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg.	92.71
12	Other Crops/Fallow-Mustard-Other Crops/Other Crops-Fallow-Moong-Veg.	9.70
13	Other Crops-Paddy-Bajra-Cotton/-Other Crops –Fallow- Wheat-Mustard-/Other Crops-Fallow	3.72
14	Non Agriculture Area	13.85
	Total	234.57

6.5.1.2 Narnaund Block

Narnaund Block has the major crop rotations of Cotton/Wheat/Other Crops-Fallow-Moong-Veg. and Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg (Table 6.3 and Fig. 6.4).

6.5.1.3 Uklana Block

Uklana Block has the major crop rotations of Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg. and Cotton/Wheat/Other Crops-Fallow-Moong-Veg. Crop rotation of Uklana Block is shown in Fig. 6.5 (Table 6.4).

6.5.1.4 Hisar-II

Hisar-II Block has the major crop rotations Paddy/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg. and Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg. These rotations occupy 298.34 and 84.97 (00'h. Crop rotation of Hisar-II Block is shown in Fig. 6.6 (Table 6.5).

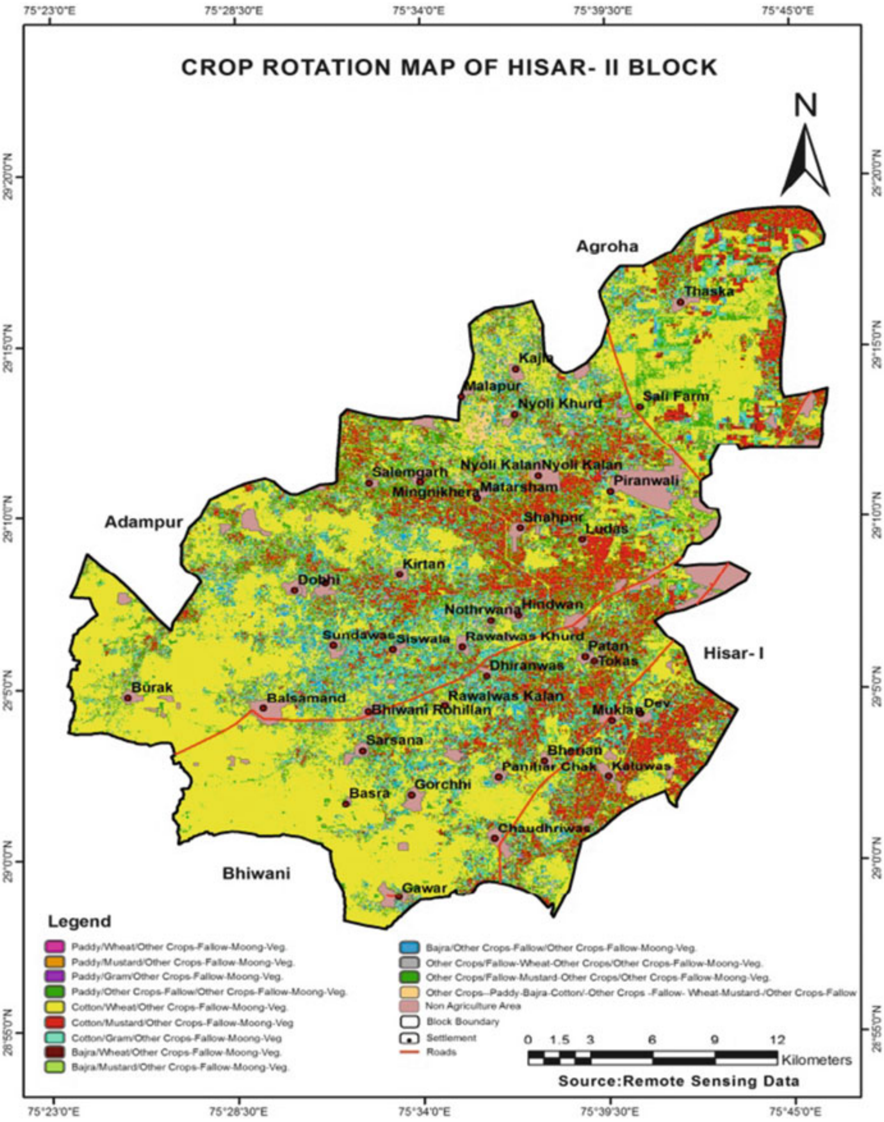

Fig. 6.6 Crop rotation map of Hisar II Block

Table 6.5 Crop rotations statistics

S. NO	Rotations	Area (00'h)
1	Paddy/Wheat/Other Crops-Fallow-Moong-Veg.	17.88
2	Paddy/Mustard/Other Crops-Fallow-Moong-Veg.	7.70
3	Paddy/Gram/Other Crops-Fallow-Moong-Veg.	1.08
4	Paddy/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	298.34
5	Cotton/Wheat/Other Crops-Fallow-Moong-Veg.	84.47
6	Cotton/Mustard/Other Crops-Fallow-Moong-Veg	44.60
7	Cotton/Gram/Other Crops-Fallow-Moong-Veg	6.14
8	Bajra/Wheat/Other Crops-Fallow-Moong-Veg.	37.12
9	Bajra/Mustard/Other Crops-Fallow-Moong-Veg.	34.21
10	Bajra/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	19.13
11	Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg.	84.97
12	Other Crops/Fallow-Mustard-Other Crops/Other Crops-Fallow-Moong-Veg.	48.90
13	Other Crops-Paddy-Bajra-Cotton/-Other Crops -Fallow- Wheat-Mustard-/Other Crops-Fallow	14.21
14	Non Agriculture Area	41.61
15	Total	740.38

6.5.1.5 Hisar-I

Hisar-I Block has the major crop rotations of Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg. and Bajra/Wheat/Other Crops-Fallow-Moong-Veg. These rotations occupy 105.7 and 85.88 (00'h) area respectively based on three seasons viz. Kharif, Rabi and Summer. Crop rotation map of Hisar-I Block is shown in Fig. 6.7 (Table 6.6).

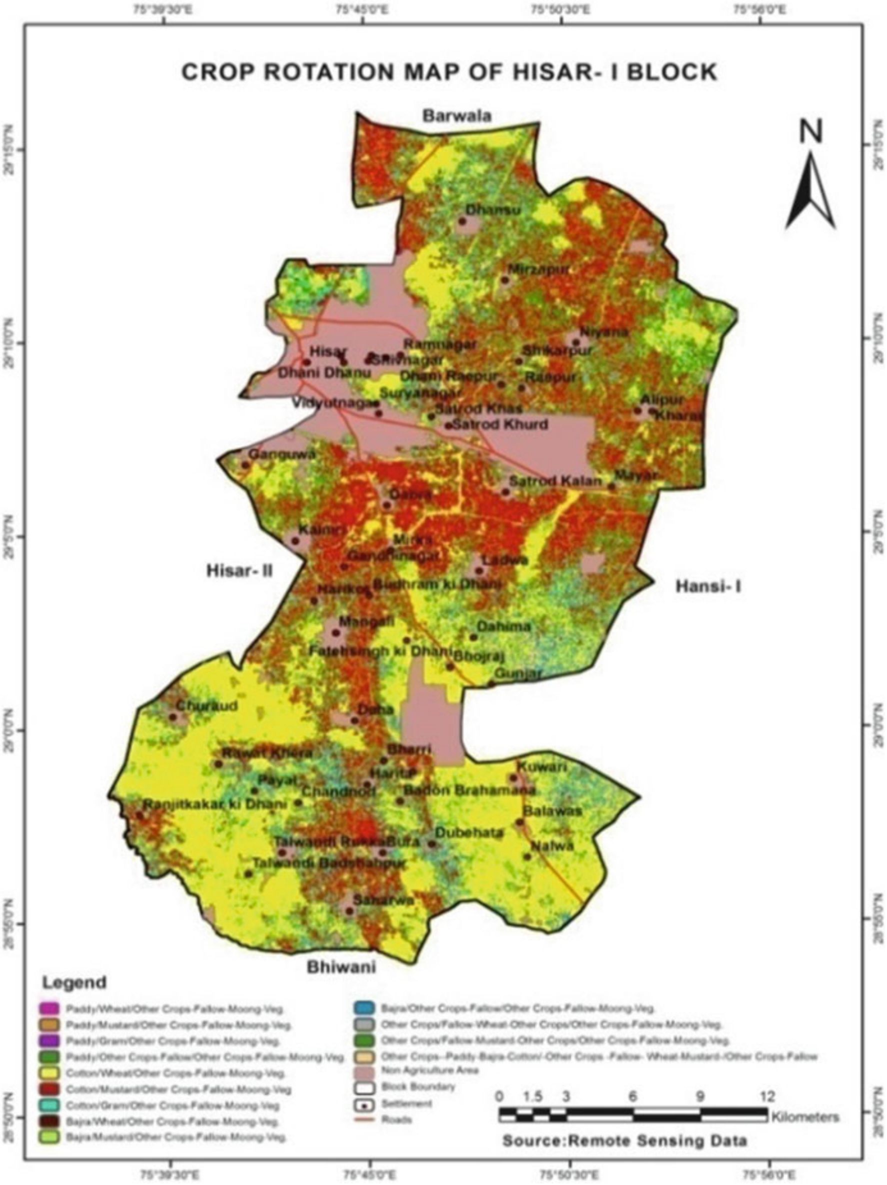

Fig. 6.7 Crop rotation map of Hisar I Block

Table 6.6 Crop rotations statistics

S. NO	Rotations	Area (00'h)
1	Paddy/Wheat/Other Crops-Fallow-Moong-Veg.	9.11
2	Paddy/Mustard/Other Crops-Fallow-Moong-Veg.	14.92
3	Paddy/Gram/Other Crops-Fallow-Moong-Veg.	36.8
4	Paddy/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	70.66
5	Cotton/Wheat/Other Crops-Fallow-Moong-Veg.	30.78
6	Cotton/Mustard/Other Crops-Fallow-Moong-Veg	71.43
7	Cotton/Gram/Other Crops-Fallow-Moong-Veg	16.64
8	Bajra/Wheat/Other Crops-Fallow-Moong-Veg.	85.88
9	Bajra/Mustard/Other Crops-Fallow-Moong-Veg.	38.23
10	Bajra/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	49.98
11	Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg.	105.7
12	Other Crops/Fallow-Mustard-Other Crops/Other Crops-Fallow-Moong-Veg.	54.94
13	Other Crops-Paddy-Bajra-Cotton/-Other Crops -Fallow- Wheat-Mustard-/Other Crops-Fallow	19.2
14	Non Agriculture Area	93.11
	Total	697.38

6.5.1.6 Hansi-I

Hansi-I Block has the major crop rotations of Cotton/Wheat/Other Crops-Fallow-Moong-Veg. and Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg. These rotations occupy 188.55 and 127.72 (00'h) area respectively based on three seasons viz. Kharif, Rabi and Summer. Crop rotations map of Hansi-I Block is shown in Fig. 6.8 (Table 6.7).

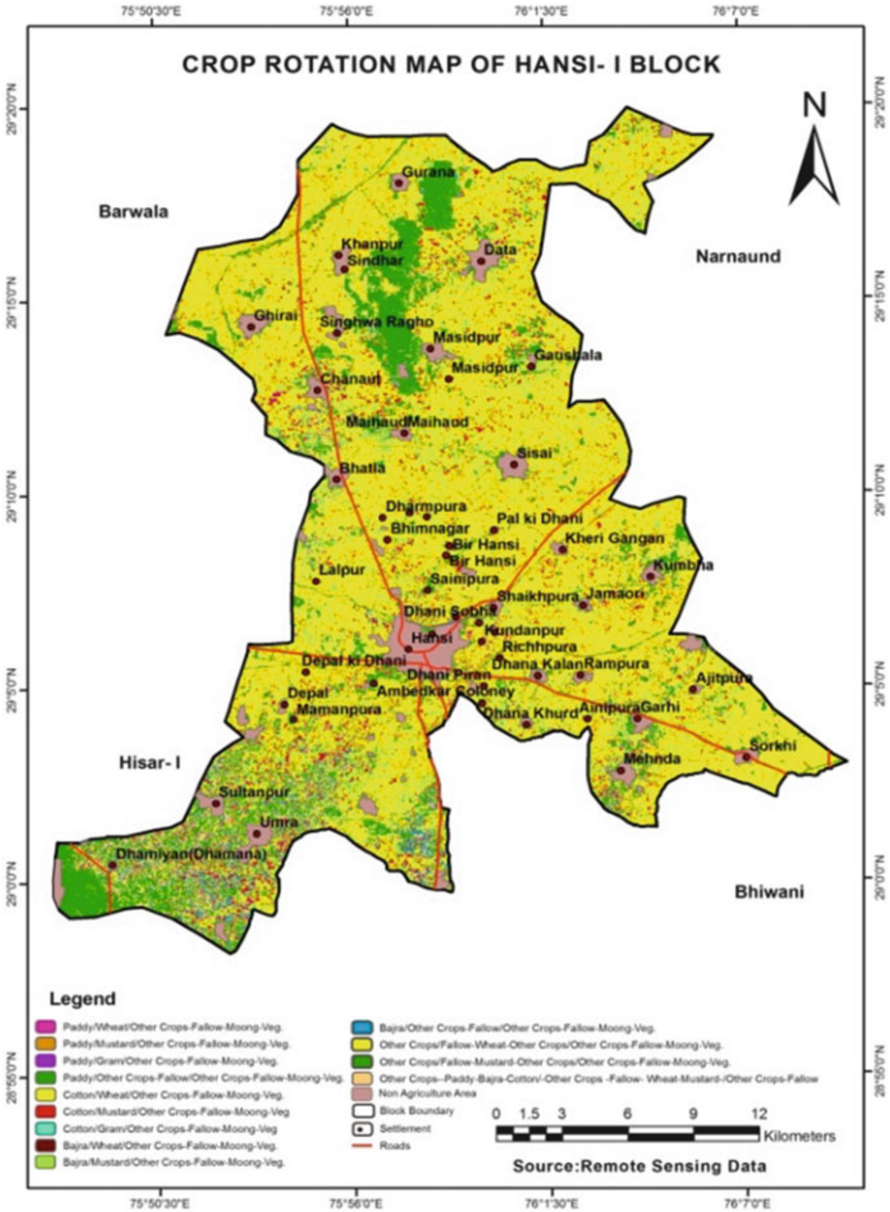

Fig. 6.8 Crop rotation map of Hansi-I Block

Table 6.7 Crop rotations statistics

S. NO	Rotations	Area (00'h)
1	Paddy/Wheat/Other Crops-Fallow-Moong-Veg.	44.26
2	Paddy/Mustard/Other Crops-Fallow-Moong-Veg.	4.89
3	Paddy/Gram/Other Crops-Fallow-Moong-Veg.	1.13
4	Paddy/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	97.51
5	Cotton/Wheat/Other Crops-Fallow-Moong-Veg.	188.55
6	Cotton/Mustard/Other Crops-Fallow-Moong-Veg	21.06
7	Cotton/Gram/Other Crops-Fallow-Moong-Veg	5.12
8	Bajra/Wheat/Other Crops-Fallow-Moong-Veg.	43.38
9	Bajra/Mustard/Other Crops-Fallow-Moong-Veg.	10.55
10	Bajra/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	8.89
11	Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg.	127.72
12	Other Crops/Fallow-Mustard-Other Crops/Other Crops-Fallow-Moong-Veg.	21.48
13	Other Crops-Paddy-Bajra-Cotton/-Other Crops -Fallow- Wheat-Mustard-/Other Crops-Fallow	9.82
14	Non Agriculture Area	32.04
	Total	616.40

6.5.1.7 Hansi-II

Hansi-II Block has the major crop rotations of Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg and Paddy/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg. Crop rotations of Hansi- II Block is shown in Fig. 6.9 (Table 6.8).

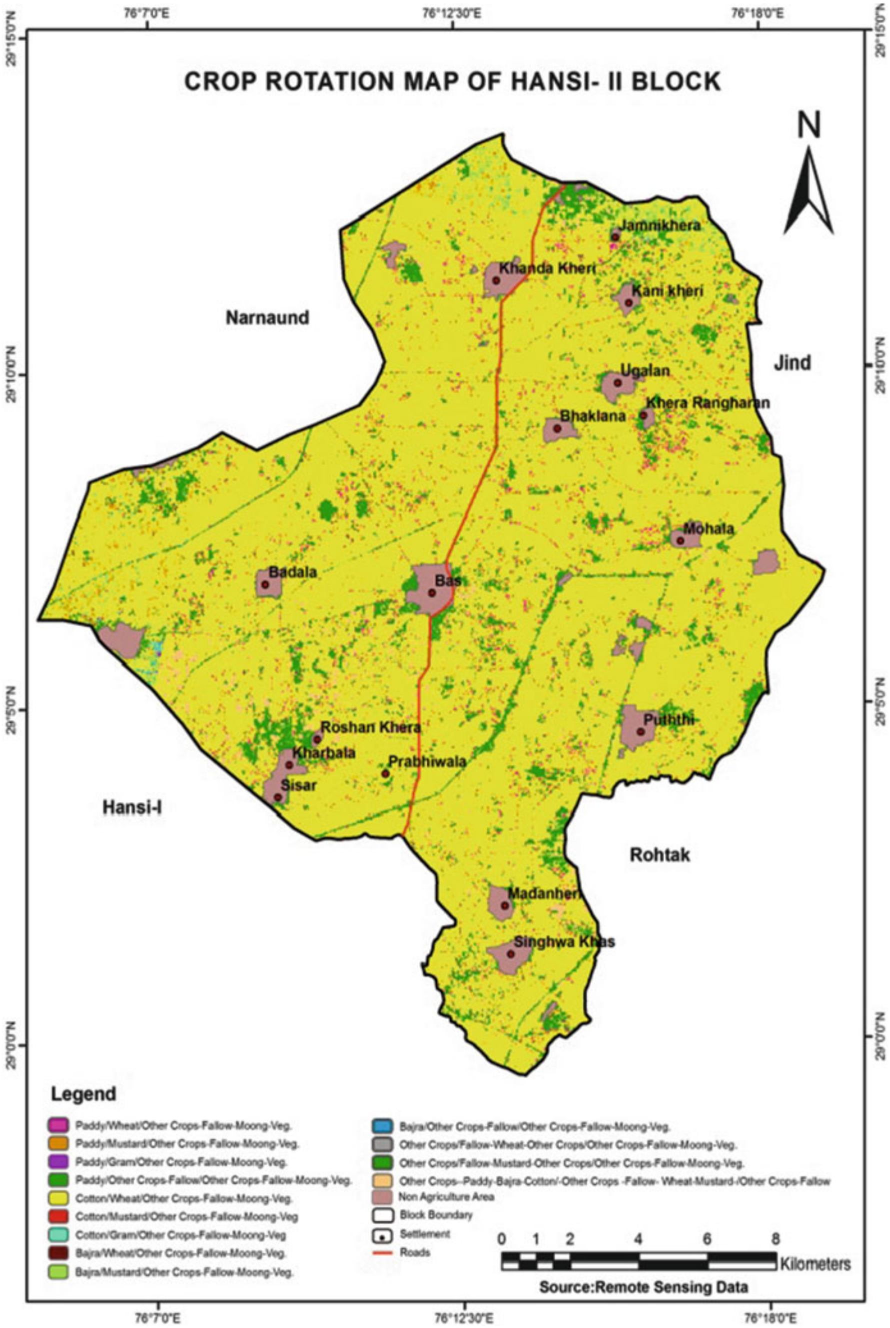

Fig. 6.9 Crop rotation map of Hansi II Block

Table 6.8 Crop rotations statistics

S. NO	Rotations	Area (00'h)
1	Paddy/Wheat/Other Crops-Fallow-Moong-Veg.	1.63
2	Paddy/Mustard/Other Crops-Fallow-Moong-Veg.	0.06
3	Paddy/Gram/Other Crops-Fallow-Moong-Veg.	0.04
4	Paddy/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	32.27
5	Cotton/Wheat/Other Crops-Fallow-Moong-Veg.	11.25
6	Cotton/Mustard/Other Crops-Fallow-Moong-Veg	0.32
7	Cotton/Gram/Other Crops-Fallow-Moong-Veg	0.27
8	Bajra/Wheat/Other Crops-Fallow-Moong-Veg.	1.56
9	Bajra/Mustard/Other Crops-Fallow-Moong-Veg.	0.11
10	Bajra/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	0.08
11	Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg.	219.64
12	Other Crops/Fallow-Mustard-Other Crops/Other Crops-Fallow-Moong-Veg.	11.24
13	Other Crops-Paddy-Bajra-Cotton/-Other Crops -Fallow- Wheat-Mustard-/Other Crops-Fallow	0.65
14	Non Agriculture Area	11.22
	Total	290.32

6.5.1.8 Barwala Block

Barwala Block has the major crop rotations of Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg and Cotton/Wheat/Other Crops-Fallow-Moong-Veg. These rotations occupy 134.08 and 90.25 area respectively based on three seasons viz. Kharif, Rabi and Summer. Crop rotations of Barwala Block is shown in Fig. 6.10 (Table 6.9).

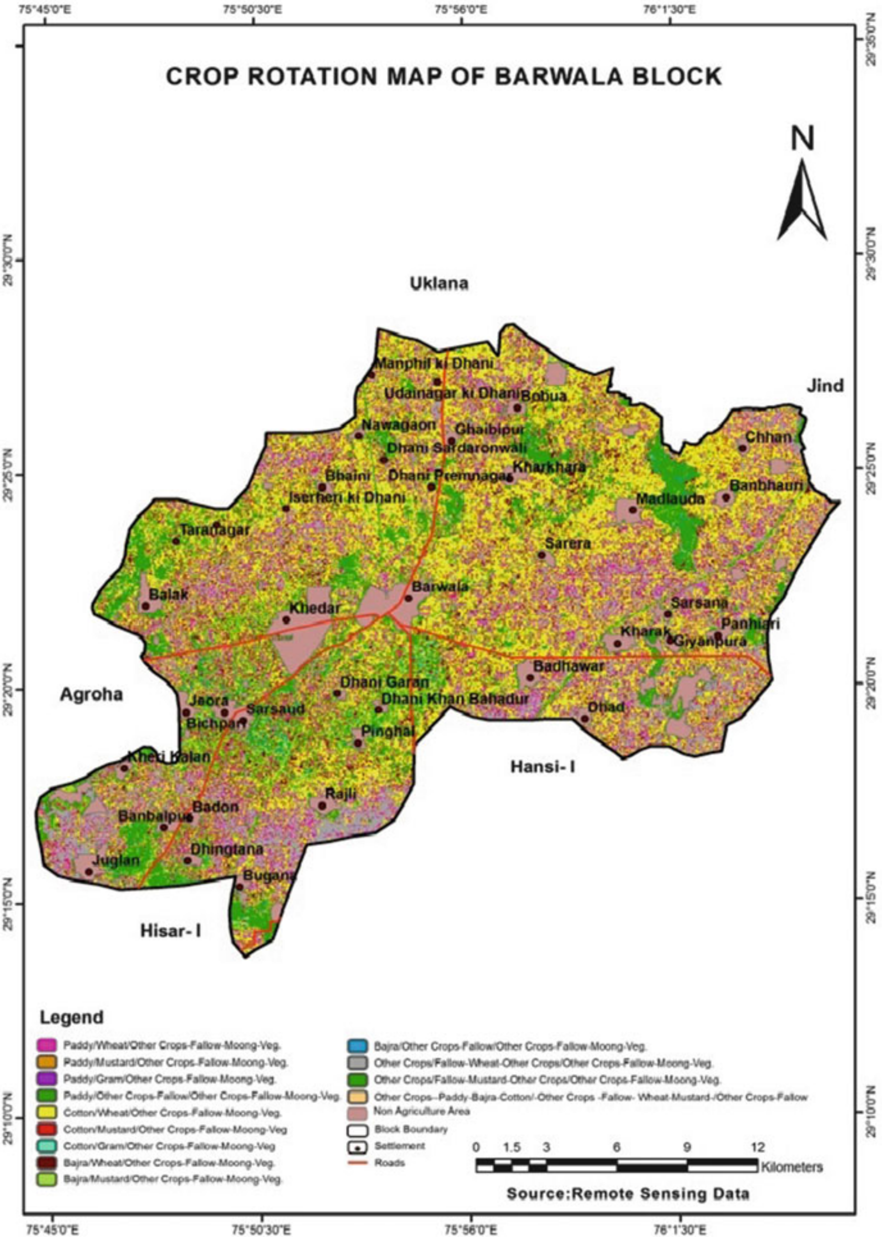

Fig. 6.10 Crop rotation map of Barwala Block

Table 6.9 Crop rotations statistics

S. NO	Rotations	Area (00'h)
1	Paddy/Wheat/Other Crops-Fallow-Moong-Veg.	32.57
2	Paddy/Mustard/Other Crops-Fallow-Moong-Veg.	4.15
3	Paddy/Gram/Other Crops-Fallow-Moong-Veg.	0.39
4	Paddy/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	73.48
5	Cotton/Wheat/Other Crops-Fallow-Moong-Veg.	90.25
6	Cotton/Mustard/Other Crops-Fallow-Moong-Veg	13.64
7	Cotton/Gram/Other Crops-Fallow-Moong-Veg	1.53
8	Bajra/Wheat/Other Crops-Fallow-Moong-Veg.	45.31
9	Bajra/Mustard/Other Crops-Fallow-Moong-Veg.	9.74
10	Bajra/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	5.39
11	Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg.	134.08
12	Other Crops/Fallow-Mustard-Other Crops/Other Crops-Fallow-Moong-Veg.	23.94
13	Other Crops-Paddy-Bajra-Cotton/-Other Crops -Fallow- Wheat-Mustard-/Other Crops-Fallow	7.44
14	Non Agriculture Area	33.91
	Total	475.81

6.5.1.9 Agroha Block

Agroha Block has the major crop rotations of Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg. and Cotton/Wheat/Other Crops-Fallow-Moong-Veg. which occupies 83.10 and 74.70 (00'h) area respectively based on three seasons viz. Kharif, Rabi and Summer. All crop rotation of Agroha Block is shown in Fig. 6.11 (Table 6.10).

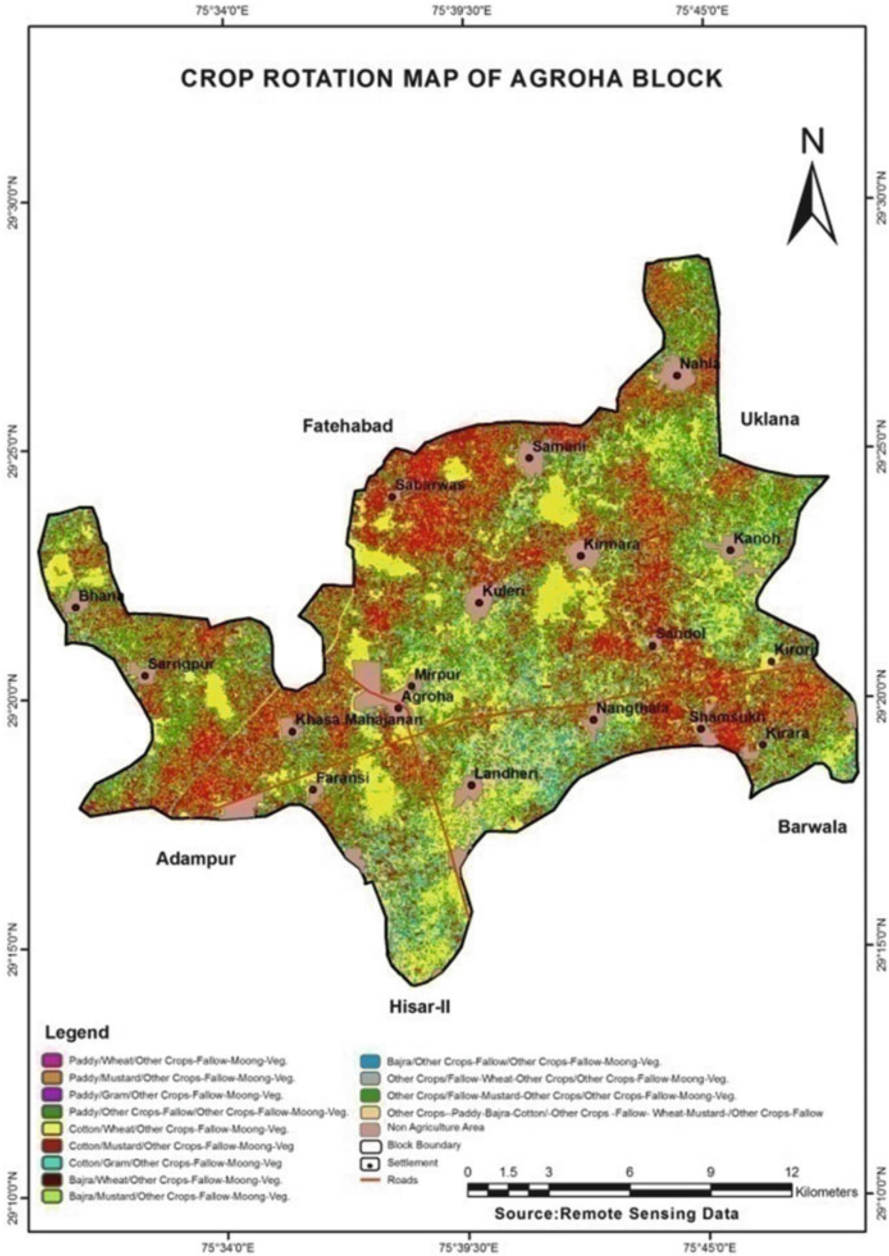

Fig. 6.11 Crop rotation map of Agroha Block

Table 6.10 Crop rotations statistics

S. NO	Rotations	Area (00'h)
1	Paddy/Wheat/Other Crops-Fallow-Moong-Veg.	22.51
2	Paddy/Mustard/Other Crops-Fallow-Moong-Veg.	4.02
3	Paddy/Gram/Other Crops-Fallow-Moong-Veg.	0.78
4	Paddy/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	54.36
5	Cotton/Wheat/Other Crops-Fallow-Moong-Veg.	74.70
6	Cotton/Mustard/Other Crops-Fallow-Moong-Veg	14.09
7	Cotton/Gram/Other Crops-Fallow-Moong-Veg	2.43
8	Bajra/Wheat/Other Crops-Fallow-Moong-Veg.	27.40
9	Bajra/Mustard/Other Crops-Fallow-Moong-Veg.	9.20
10	Bajra/Other Crops-Fallow/Other Crops-Fallow-Moong-Veg.	3.16
11	Other Crops/Fallow-Wheat-Other Crops/Other Crops-Fallow-Moong-Veg.	66.23
12	Other Crops/Fallow-Mustard-Other Crops/Other Crops-Fallow-Moong-Veg.	25.46
13	Other Crops-Paddy-Bajra-Cotton/-Other Crops -Fallow- Wheat-Mustard-/Other Crops-Fallow	8.43
14	Non Agriculture Area	16.87
	Total	329.64

6.6 Conclusion

The present study introduces a method for analysis the cropping system of single year 2007–2008 in study area Hisar district and its development blocks.

Multi-date and multi season remote sensing data was used to generate seasonal cropping patterns and then crop rotation map of Hisar District and its development blocks using Geomatica 10.3 and Arc GIS 9.3 software Package.

The study reveals that Cotton and Bajra are the major crops during *Kharif* season and occupies the 1,167 and 629 ('00 ha.) area respectively. Wheat and Mustard are the major crops in *Rabi* season which occupy 2,378 and 467 ('00 ha) area.

Multi-date, Multi-spectral optical data with spatial resolution of 23.5 m. from Indian Remote Sensing Satellite (IRS P6) is found to be useful for the cropping system analysis of major and contiguous crops at block level. But for cropping system analysis of minor and non-contiguous crops, high resolution multi-date data is required.

An advantage of the proposed method is to identify the spatial relationships between crops. An additional possibility of the multi-year cropping pattern map is its use in future spatial crop distribution prediction, since it contains expert knowledge about spatial relationships between crops in the study area and implicit probabilities of changes. The study of crop rotation map will be very helpful in making good crop rotations planning and by well-designed crop rotation we can creates farm diversity and improves soil conditions and fertility.

With the help of this study we can emphasize on fallow land to utilize with the help of advanced technology.

Crop Rotation technique to identify the specific location of main rotated crops of *Kharif, Rabi* and *summer* season.

Major rotation in Hisar district are Other Crops/Fallow-Wheat-Other Crops/ Other Crops-Fallow-Moong-Veg., Paddy/OtherCrops-Fallow/OtherCrops-Fallow-Moong-Veg., Cotton/Wheat/Other Crops-Fallow-Moong-Veg., which occupy 977.40, 930.10 and 834.63 (00'ha) area respectively.

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Chapter 7
Dynamics of On-Farm Land Use Changes in Terms of Inter-Specific Crop Diversity: A Case Study of Panipat District of Haryana State, India

Seema Rani

Abstract Crop diversity forms a significant component of the Agro-biodiversity. This is believed to be the result of thousands of years of farmer's selection, experimentation and propagation of desirable traits of desirable species in innumerable ways for their subsistence and cultural purposes. But the selection results in detrimental on-farm land use changes that directly contribute to crop diversity loss. Therefore, this study aimed at determining the existing reality of the on-farm land use changes around the inter-specific crop diversity. The Herfindahl–Hirschman and Simpson index have been used to quantify the concentration of crop type and richness and evenness in crops on the farms. The findings indicated the shift from multiple cropping to monoculture system i.e. Rice Wheat Cropping System (RWCS). Other crops (cash crops, fodder crops, vegetables and pulses) are no more farmers' attraction. This has now become the backbone of farming in the Panipat district. It is ultimately led to inter-specific crop diversity loss. It makes the national authority to think about the issues of sustainability. Many national organizations are working towards safeguarding the crop species and cause farmers to diversify towards other species.

Keywords Agro-biodiversity • Crop diversity • Land-use change • Monoculture • Multiple cropping • Sustainability

7.1 Introduction

The land-use pattern, of which the cropping pattern forms a part, has always been a dynamic phenomenon (Singh 1992b). The crop pattern in any region can't remain static due to the fluctuations in the rainfall and nature of inputs and environmental

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instability (Vaidya 1997). This dynamic on-farm land use brings spatial and temporal changes in crop diversity, which is one of the principal elements of the agro biodiversity. According to the Convention on Biological Diversity (2000), agricultural biodiversity includes all elements of biological diversity of relevance to food and agriculture, and constitute the agro-ecosystem: the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro-ecosystem, its structure and processes. Crop Diversity is defined as “the variability in genetic and phenotype characteristics of plants used in agriculture.” Crop diversity on farms has both inter-specific (among crops) and infra-specific (within a crop) components (Bellon 1996). In agricultural system, biodiversity performs ecosystem services beyond production of food, fiber, fuel and income. Biodiversity is necessary in the recycling of nutrients, control of local micro-climate, regulating the local hydrological process, regulation of the abundance of undesirable organisms and detoxification of noxious chemicals (Altieri 1999).

According to Global Crop Diversity Trust, crop diversity is disappearing from the fields as farming systems is changing and farmers are abandoning their traditional varieties. Further, increasing homogenization of agricultural production has led to widespread cultivation and rearing of fewer varieties and breeds for a more uniform, less diverse, but more competitive global market (Kameri and Cullet 1999). Panipat district of Haryana state in India has also shown the similar undesirable changes in inter specific crop diversity that contributes to depletion of crop species. It in turn disturbs the agro-ecosystem balance and put pressure on the available natural resources. The on-farm land use has changed after the advent of green revolution in India. Thus, aim of the study was to highlight the results from the study carried out towards on-farm land-use changes in inter specific crop diversity in the Panipat district of Haryana. The study emphasized on two aspects: the first aspect included the on-farm land-use changes in inter-specific crop diversity using data of share of crop area of all crop species to the total crop area within the territorial dominion in both monsoon (Kharif) and winter (Rabi) season. Focus is given to inter specific crop diversity because of non-availability of data on infra specific diversity in the district. The second aspect was to calculate the Herfindahl–Hirschman to quantify the concentration of crops and Simpson index to take into account richness and evenness in crops on the farms.

7.2 Study Area

Panipat district in northeastern Haryana is flanked by River Yamuna on the eastern edge. It is located between 29°09′15″:29°27′25″ North latitudes and 76°38′30″:77°09′15″ East longitudes, with an average altitude of 220 m. It is surrounded by Karnal district in North, Jind district in West, Sonipat district in the South (Haryana) and the Mujarfarnagar district of Uttar Pradesh in the East (Gulati 2005) (Fig. 7.1)

Fig. 7.1 Location of the study area

It also forms the part of Delhi National Capital Region (NCR). The geographical area of the district is 1,304.372 km^2 including 30.28 km^2 under forests and 240.052 km^2 under non-farm use. Agriculture is the mainstay of the district economy. Approximately 78 % of the total geographical area is cultivable of which 98 % is actually cultivated. The cropped area is 1,928.52 km^2 with a cropping intensity is 194 % (Dahiya et al. 2011). The district has enough drainage facilities. The district is drained by Yamuna River and its tributaries. The discharge of the river is high during the monsoon as it gets water from the southwest monsoon. The water of the river and drains may be harvested for crop production. The annual average rainfall over the area is less than 700 mm in the western part and more than 750 mm in the eastern region. The district has two types of soils via-tropical arid brown and arid brown soils. The tropical arid brown soils are found in the northeastern part of the district, especially in parts of Bapoli and Panipat block and remaining area is covered by the arid brown soils. The district has all desirable agro-climatic conditions for agricultural production. Wheat has traditionally been, and continues to be, the mainstay of food security and is grown in the cool and dry winter season. Over the last 30 years there has been widespread adoption of rice that is mainly grown in the hot and wet monsoon season (Erenstein 2011).

7.3 Data Sources and Method

Cropping pattern data had been taken from the district agricultural department of Haryana. The study was conducted in the Panipat district of Haryana in India. Locational factors were taken into consideration during survey. The simple random sampling technique was employed in the selection of respondents. These included both large and small-scale farmers in the district. Focused group discussion, key informant interview, informal discussion and semi-structured interview were conducted for better understanding. The Herfindahl–Hirschman Index, from the marketing industry index of market concentration has been used to quantify the concentration of crop type (Bradshaw 2004; Rahman 2009a; Rahman 2009b, Table 7.1). Simpson index is also calculated which is also a measure of biodiversity that takes into account richness and evenness. The collected data have been analyzed using simple statistical techniques and various graphical methods.

Table 7.1 Crop diversity index used (Bradshaw 2004 and Rahman 2009a)

Index	Concept	Construction and explanation	Interpretation
Herfindahl–Hirschman	Concentration of crops	$D_h = \sum \alpha^2 j$ $0 \leq D_h \leq 1$ Dh = Herfindahl diversity index aj = area share occupied by the jth crop in A A = total area planted to all crops	A zero value denotes perfect diversification and a value of 1 denotes perfect specialization. Thus, a negative sign of the index indicates a positive relationship with diversity
Simpson	Degree of richness and evenness of crops	$SI = 1 - D_h$ SI = Simpson index	The value of this index also ranges between 0 and 1, but the greater the value, the greater the sample diversity.

7.4 Results and Discussions

7.4.1 On-Farm Land Use Changes and Crop Diversity

The district has two cropping seasons via monsoon (Kharif) and winter season (Rabi). Crops were classified as cereal crops, fodder crops, cash crops, vegetables and pulses to look at the on-farm land use changes in the district. Table 7.2 shows the cropping pattern of monsoon from 1950 to 2012. During monsoon season in 1950–1951, cereal crops (53.25 %) were dominant crops followed by fodder crops (24.70 %) and cash crops (16.49 %). Among cereals crops, Bajra crop (26.70 %) was more concentrated followed by Rice (26.55 %). The remaining cropped area was covered by other crops. In 1960–1961, situation was almost similar. Then, Green revolution technology came around 1965–1966. It was implemented in the green belt region of India includes Haryana, Uttar Pradesh and Punjab. It changed the on-farm land use. It is also visible in both the table. Area under cereal crops drastically changed during 1970–1971. During this period, the area under cereal crops increased to almost 63 %. Rice (51.91 %) became dominant crops followed by Bajra (12 %). But, fodder crops shown a decline. Thereafter, Rice crop had increased in the area in comparison to other crops. In 2011–2012, area under cereal crops increased by 59.57 % followed by cash crops (6.84 %), fodder crops (3.36 %), vegetables (1.78 %) and pulses (0.67 %). Area under rice had increased while remaining crops shown a decline in the area. Cotton, maize and oilseeds had vanished from the farm.

On the other hand, during winter season in 1950–1951, pulses covered major area (54.90 %) of the total cropped area followed by cereal crops (39.54 %), oilseeds (4.65 %) and vegetables (0.91 %). The cropping pattern was almost similar during 1960–1961. Then, during 1970–1971, area under cereal crops increased many folds. Cereal crops covered 73.57 % followed by pulses 18.74 % and remaining crops covered almost 7 % area. The wheat crop was dominant among cereal crops. Since then, the area under wheat has increased. During 2011–1912,

Table 7.2 Per cent of area to total cropped area during monsoon season (Kharif) in the district

Crops	1950–1951	1960–1961	1970–1971	1980–1981	1990–1991	2000–2001	2011–2012	Increased/decreased
	Area to total cropped area (in percent)							
Rice	26.55	30.22	51.91	76.17	80.88	81.30	86.12	59.57
Bajra	26.70	29.70	12.00	3.60	2.10	0.42	1.12	−25.58
Sugarcane	8.65	9.65	10.05	7.72	8.40	6.16	6.84	−0.81
Cotton	7.84	5.84	4.00	2.06	1.05	0.04	0.00	−7.84
Maize	1.01	6.80	15.00	6.18	1.05	0.01	0.00	−1.01
Fodder	24.70	14.20	5.00	1.54	1.05	9.98	3.36	−21.34
Vegetables	1.54	1.00	1.00	1.13	2.31	1.48	1.78	−0.76
Pulses	0.01	0.09	0.58	1.03	2.52	0.31	0.67	0.66
Oilseeds	3.00	2.50	0.46	0.57	0.63	0.30	0.11	−2.89

Table 7.3 Percent of area to total cropped area during winter season (Rabi) in the district

	1950–1951	1960–1961	1970–1971	1980–1981	1990–1991	2000–2001	2011–2012	Increased/decreased
Crops	Area to total cropped area (in percent)							
Wheat	37.6	44.1	70.8	84.2	89.2	91.2	95.5	57.86
Barley	1.90	3.00	2.76	1.21	2.76	0.05	0.00	−1.90
Fodder	0.00	2.00	3.35	6.85	4.42	6.08	2.20	2.20
Oilseeds	4.65	5.00	4.14	1.21	0.63	0.78	1.10	−3.55
Pulses	54.9	44.9	18.7	6.05	2.13	0.13	0.55	−54.35
Vegetables	0.91	1.00	0.20	0.40	0.79	1.68	0.66	−0.25

area under wheat has increased by 57.86 % i.e. 95.50 % and remaining crops cover 4.5 %. Area under pulses has declined by 54.35 %. Barley crop has also shown a decline (Table 7.3).

In both the season, area under rice and wheat crop has changed radically. There are some crops such as sugarcane and mustard that were grown individually but now they are raised with other crops. For instance, Sugarcane is grown in combination with Onion and Mustard is grown in combination with Barseem. The competition between Rice and Sugarcane is more than any other crop in area.

Nevertheless, Rice Wheat Cropping System (RWCS) has emerged in the district because of the new agricultural technologies, including irrigation facilities, improved seed varieties, pesticides, insecticides and new methods of farming (Singh 2000). Increase in irrigation facilities has led to a shift in cropping pattern in favor of those crops that have the highest response to irrigation, such as rice and wheat. Likewise, the availability of high-yielding/improved varieties has also been responsible in bringing change in cropping pattern (Singh 1992a). Therefore, wheat dominates the cropping pattern in winter and rice during the monsoon season (Erenstein 2011). Moreover, introduction of new high-yielding varieties of seeds, irrigation installations and technical know-how is responsible for temporal changes (Vaidya 1997). Besides these factors, value of productivity and profitability of crops have been discovered to be the most important (Singh 1992a) as cultivation of wheat and rice in the rotation gives farmers the best combination for getting the maximum benefit from cultivation (Singh 2000). Thus, monoculture cropping system has developed on the farms.

7.4.2 Diversity Index

The Herfindahl–Hirschman and Simpson Index value indicates the temporal and spatial variations in inter-specific crop diversity from 1950 to 2012 during both the cropping seasons. Figure 7.2 shows Herfindahl–Hirschman and Simpson's Index of monsoon season. Herfindahl–Hirschman index value varies between 0.22 (1950–1951) to 0.75 (2011–2012). It reflects that the concentration of species has increased and moved towards the specialization. Change was drastic after

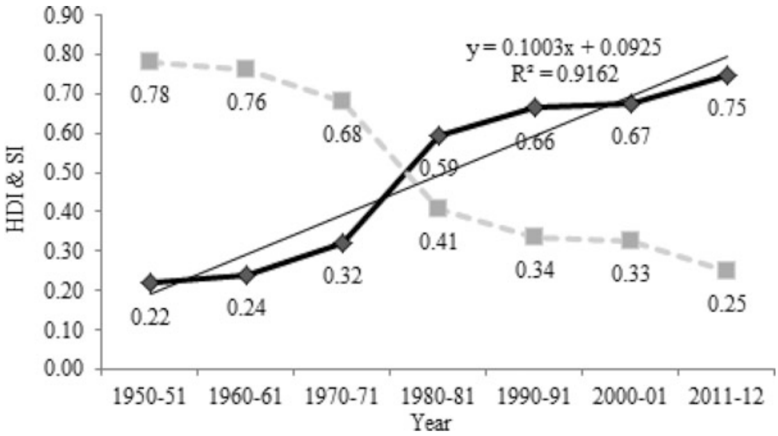

Fig. 7.2 Herfindahl–Hirschman and Simpson's Index of monsoon season in the district. *Black marked line* shows Herfindahl Diversity index (HDI) and *dotted line* shows Simpson Index (SI). *Straight line* without markers shows linear line with equation

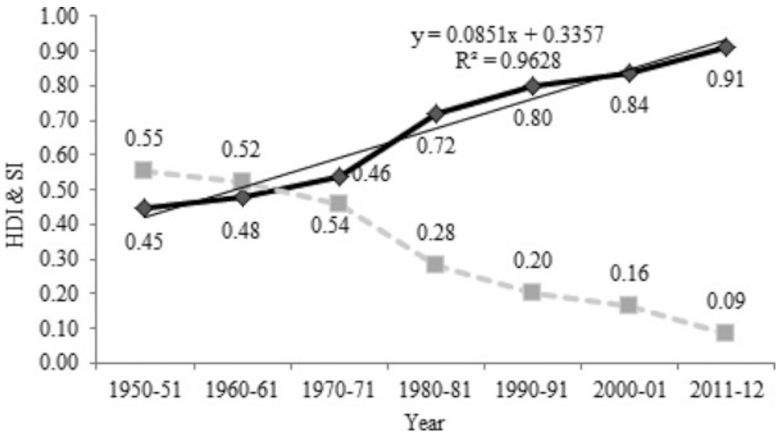

Fig. 7.3 Herfindahl–Hirschman and Simpson's Index of winter season in the district. *Black marked line* shows Herfindahl Diversity index (HDI) and *dotted line* shows Simpson Index (SI). *Straight line* without markers shows linear line with equation

1970–1971. Simpson index is opposite to Herfindahl–Hirschman index. That is why; both curves in the graph intersect each other Simpson index value ranges between 0.78 (1950–1951) to 0.25 (2011–2012). It reflects that the habitat is low in species, so a small change to the environment would have a serious impact.

Data prove that the area is also low in species (Fig. 7.3).value ranges between 0.45 (1950–1951) and 0.91 (2011–2012). Here value is almost near to 1. That means there is homogeneity on the farm. Likewise Simpson's Index value varies between 0.55 (1950–1951) and 0.09 (2011–2012). It shows that the area is also low in species. A high value for Simpson's Index is 'good' and means the area is diverse, species richness, and able to withstand some environmental impact. But a low value is 'poor' and means the area is low in species, so a small change to the environment would have a severe impact. Thus low diversity index value in both the seasons is an issue of concern that requires immediate attention.

The on-farm land use change results in depletion of inter-specific crop diversity. Changes in the number of species grown in the area are shown in Table 7.4. Crop species grown in the district had decreased since 2001 in both the cropping seasons. During monsoon, total numbers of crop species were 39 in 2000–2001. This number decreased to 32 in 2011–2012. Similarly, during winter season, total numbers of crop species decreased from 29 (2000–2001) to 25 (2011–2012). Rice, wheat, sugarcane and forage crops (bar seems and sorghum) are the major crops of the district (Dahiya et al. 2011). Among cash crops, sugarcane is the dominant crop followed by mustard and cotton. Mustard and cotton in the coming years would be completely lost if the trend remains the same. Sunflower has vanished from the farms. Likewise, rapeseeds and Tara Mira are also disappearing from the farms. These two are genetic varieties of mustard. Though pulses can be found out on the farms, but their area had depleted since last decade. Gram, Channa, Moong, Cow-Pea, Mash and Arhar are still grown. Yet, despite this fact, the cropped area has decreased under all these crops. Chana is almost lost from the farms. Among fodder crops, Barseem is widely grown on farms in comparison to others. In fodder crops, Gwar, labia and Javi are also disappearing from the farms. Vegetables stand third in comparison to other crops. These are grown on large area around the urban centers to fulfill their daily need.

7.5 Need for Conservation and Management of Crop Diversity

Conservation agriculture can enhance water productivity, but is unlikely to produce the difference by itself. Alternatively, there is a pressing need to enhance incentives for farmers to use water wisely, although so far the political will has been lacking (Erenstein 2009). Modern agricultural practices strongly favor the reduction of crop diversity by offering the subsidies for cultivating high-yielding varieties and reducing weeds/wild plant diversity by using crop protection measures. This diversity may be preserved by providing positive incentives to local communities (Gadgill et al. 1996). There is scope for reducing the distorted incentives that encouraged the injudicious use of resources-a case in point being the unsustainable water use and lack of crop rotation in rice-wheat systems (Erenstein 2011). Assessment of loss of diversity in farming systems using continued analysis of land-use patterns should be the thrust areas (State of Plant Genetic Resources for Food and Agriculture in India (1996–2006): A Country Report 2007). Diversification of agriculture with alternative land uses can help maintenance of both biological productivity and profitability (Rajput 2006). Diversification involves both enterprise allocation decisions as well

Table 7.4 Changes in number of crop species in the district

	Monsoon Season (Kharif)		Winter Season (Rabi)	
S. No.	2000–2001	2011–2012	2000–2001	2011–2012
1	Rice	Rice	Wheat	Wheat
2	Cauliflower	Cauliflower	Barseem	Barseem
3	Bajra	Bajra	Mustard	Mustard
4	Calabash	Calabash	Brinjal	Brinjal
5	Gwar	Gwar	Carrot	Carrot
6	Carrot	Carrot	Cauliflower	Cauliflower
7	Arhar	Arhar	Tomato	Tomato
8	Spinach	Spinach	Pea	Pea
9	Ladyfinger	Ladyfinger	Potato	Potato
10	Onion	Onion	Spinach	Spinach
11	Brinjal	Brinjal	Coriander	Coriander
12	Chilly	Chilly	Radish	Radish
13	Cucumber	Cucumber	Calash	Calash
14	Tomato	Tomato	Chilly	Chilly
15	Sugarcane	Sugarcane	Cucumber	Cucumber
16	Fenugreek	Fenugreek	Turnip	Turnip
17	Sweet Potato	Sweet Potato	Fenugreek	Fenugreek
18	Coriander	Coriander	Garlic	Garlic
19	Dhaincha	Dhaincha	Mushroom	Mushroom
20	Potato	Potato	Onion	Onion
21	Water chestnut	Water chestnut	Javi	Javi
22	Cotton	Cotton	Barley	Barley
23	Ridge Gourd	Ridge Gourd	Gram	Gram
24	Moong	Moong	Mash	Mash
25	Sesame seed	Sesame seed	Mustard	Mustard
				Lost species
26	Maize	Maize	Mint	Mint
27	Urad	Urad	Pumpkin	Pumpkin
28	Lobiya	Lobiya	Turmeric	Turmeric
29	Radish	Radish	Colocasia roots	Colocasia roots
30	Jowar	Jowar		
31	Turnip	Turnip		
32	Khair	Khair		
		Lost species		
33	Colocasia roots	Colocasia roots		
34	Bitter Gourd	Bitter Gourd		
35	Garlic	Garlic		
36	Turmeric	Turmeric		
37	Gachak Dana	Gachak Dana		
38	Senat seed	Senat seed		
39	Ash Gourd	Ash Gourd		

as marketing decisions (Bryant et al. 1992). The Government took initiatives to diversify the farmers towards other crop species. Training is being given to them, but it did not work up to a desirable level because the farmers' decision is perhaps determined by market forces. These programs failed to bring desirable changes on the farms.

7.6 Conclusions

This paper attempted to look at the land use changes on the farm in inter-specific crop diversity in the Panipat district of Haryana state in India. It is clear from the data that cereal crops has emerged as dominant crops on the farm followed by fodder crops, cash crops, vegetables and pulses. The percent of the cropped area increased under rice and wheat. Thus, rice and wheat are prominent crops of the cropping system during monsoon and winter respectively and other crop species were no longer farmers' attraction. Hence, the agricultural system is being intensified by rice wheat cropping system. Consequently, monoculture cropping system has emerged. Increase in Irrigation facilities, improved seed varieties, pesticides, insecticides and new methods of farming are found responsible for the changes. Value of productivity and profitability of crops have been discovered to be the most important.

The Harfindahl Index during monsoon and winter season indicates the increase in value from 0.22 (1950–1951) to 0.75 (2011–2012) and from 0.45 (1950–1951) and 0.91 (2011–2012) respectively. It showed the highest concentration of fewer crop species on the farms. Likewise a Simpson index value varies between 0.78 (1950–1951) to 0.25 (2011–2012) and between 0.55 (1950–1951) and 0.09 (2011–2012) during the monsoon and winter season respectively. It shows the region is less diverse in species. Number of crops species in monsoon season decreased from 39 (2000–2001) to 32 (2011–2012) and in the winter season from 29 (2000–2001) to 25 (2011–2012). Therefore, it is necessary for sustaining key functions of the agro-ecosystem including structure and processes for and in support of food production and food security. Its utility signifies its importance for the large population. Crop diversity richness and evenness are really the requirement of sustainable agriculture development. Many farmers rely on a variety of crops which help them maintain their livelihood in the face of uncertain rainfall and fluctuation in the price of cash crops, socio political disruption and the unpredictable availability of agro chemicals. Now in the fastest growing population, crop diversity is considered a need for food security. Despite government's initiatives, rice wheat cropping system prevailed on the farms. There is a need of strong measures otherwise serious environmental problems in agro-ecosystem would occur.

Loss of crop diversity in general would perhaps be solved through adopting some of the solutions viz.

1. Farmers should be encouraged towards diversification of crops for increasing the Crop Diversity,
2. There is a need of strong Information Communication System (ICS) between farmers and policy implementations' officers to flow updated information about the availability of new varieties, market, Government schemes, etc.,
3. Initiatives should be taken for on management (in situ conservation) of farm land by improving the soil fertility.
4. There is a need for agricultural innovation to innovate the farmers to move forward to experiment with a new crop variety on their farms.
5. There is a need to offer alternatives for earning livelihood as agriculture is the backbone of the district economy and farmers' choice of crop species is also influenced by profitability.

According to Food and Agricultural Organization (2009), crop diversity is critical for meeting the food challenges we face right away and evermore. The judicious use and management of crop diversity are perhaps one of the best ways to ensure our ability to use agriculture to sustain, and even improve, our lives and those of our children.

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Chapter 8
Cultivable Land and the Nature of Its Distribution in Cold Desert of Lahaul-Spiti District of Himachal Pradesh

Vishal Warpa and Harjit Singh

Abstract Limited availability of cultivable land and its distribution in cold desert regions in general and in Lahaul-Spiti in particular reveal the severity of natural environment. It also affects socio-cultural, political and economic aspects. Cultivable land is limited and it occurs only in a few suitable locations due to rugged topography. Climate shows extremity with very cold, arid to semi-arid conditions. Thin and undeveloped mountain soil and nearly absent natural vegetation further exemplify harsh environment. Role of environmental factors get further accentuated owing to lack of all weather linkages those hinder the proper functioning of many infrastructural facilities. Severity of these natural factors varies attitudinally as well as spatially. Lahaul-Spiti is the largest district of Himachal Pradesh covering an area of 13,835 km^2 accounting for 24.85 % geographical area of the state. It was inhabited by 33,224 persons in 2001 forming density of about two persons per km^2. Only 272 villages out of total 403 villages were inhabited. Altitude ranges from 2,650 to 5,600 m. An attempt has been made in this paper to analyse the spatial variations and temporal changes in the distribution of cultivable land and its per capita availability across altitudinal zones. Data used in the study was acquired from both secondary sources as well as through primary survey. Primary survey covered 300 households selected from 10 villages lying across three altitudinal zones. Per capita availability of agricultural land was found to be 0.12 ha with inter-zonal and inter-personal variations across zones during 1991–2001.

Keywords Altitudinal zones • Land holding size and family size • Per capita availability

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8.1 Introduction

Increasing human population in many hilly and mountainous areas in developing countries is expected to continue to grow for at least in the next couple of decades. This phenomenon has either positive or negative outcomes with changing socio-cultural, religious and economic fabric of society. There is lot of historical evidence to show that intensification of farming is likely to occur as a result of population growth. Population growth results in corresponding increase in pressure on natural resources with a danger of environmental degradation. It raises question about sustainable resource management in relation to contemporary land use and land cover change (Nusser 2000).

Intensive farming appears to ensure increase in agricultural production particularly in areas of “higher-potential” where densities are not yet already very high (Ruthenberg 1971). This fact has rightly and increasingly been recognized by academia, scientists and policy makers that significant increase in agricultural production can be achieved through intensification of farming. It can also be by bringing more area under cultivation which is generally not possible on account of various topographic and other environmental constraints in mountain areas. However, intensification of agriculture poses many direct and indirect threats to the mountain communities in particular and also to those living in lower catchment areas. This may trigger many negative effects such like landslides, deforestation, floods, accelerated soil erosion, diminishing herbal resources and overgrazing etc.

Human population has to primarily focus for their livelihood on available natural resources. These resources are used through primary economic activities in hill and mountain regions as secondary and tertiary activities are generally not much developed in these areas. Hence, dominance of primary activities characteristically symbolises rural landscape of hills and mountainous regions of the developing nations. The relationship between human beings and natural resources, thus, exhibits a remarkable adjustment within the ambit of natural environmental constraints on the one hand while certain specific advantages on the other. The conventional and sustainable mountain agricultural development primarily depends on the effective and sustained utilization of bio-resource base (Pratap 1992). Here, the sustainable, judicious and more productive utilization of natural resources depends upon the triad consisting of traditional knowledge, scientific technology and manpower. Even social life is largely influenced by the pre-dominance of agricultural activities in the economy of such regions. The human population have to adhere to the forces of nature to keep their pressure at the optimal scale so as to maximise the profits accruing from the set of natural resources without compromising on the aspirations of future generations. Traditional societies are generally dependent upon biodiversity for meeting their livelihood concerns (Ramakrishnan 1995). The entire gamut of agricultural economy receives further substantial boost through the aid of subsidized governmental programmes being run in its several dimensions to cover varied components of agriculture and its allied activities. Traditional management of biodiversity in India’s cold desert regions is described in terms of terrain, climate, people, flora and fauna, land use cover, village landscape, traditional farming, livestock and crop depredation, grazing practices, foraging, conventional conservation and interference with traditional grazing systems (Chandrasekhar et al. 2003).

Lahaul-Spiti is one of such areas where nature exhibits tremendous hostility in terms of rugged mountain terrain and cold arid climate. Severity of nature's harshness also varies within the region and people living therein do not have a uniform response in facing this harshness. This region is entirely rural with agro-pastoral activities characterizing the economy of its inhabitants. It is a 'Cold Desert' characterized by low rainfall and low temperature conditions which restrict growing season. These coupled with stony and immature mountain soil act as major constraints in growing crops. People have, thus, traditionally adapted themselves to the requirements of nature by adopting subsistence means of livelihood. Most important factors those have bearing on the climate and ultimately on the people of the region are high altitude, situation in Trans-Pir Panjal Range and Trans-Great Himalayan Range, high amount of local relief and aspect to the sun. The last two factors create a variety of micro-climatic conditions within this region making it extremely cold and arid area (Singh and Warpa 2009). It is a cold desert region designated as a core zone of proposed biosphere Reserve by the Ministry of Environment and Forests (MOEF). It forms a hot spot area from a view point of scanty natural vegetation and biodiversity conservation from low altitude to high altitude (Kuniyal et al. 2009).

8.1.1 Objectives

The above discussion shows that environment in Lahaul-Spiti is harsh and its severity varies in its different parts. Therefore, it is important to see agriculture which is the main source of livelihood in this region of scarce cultivable land. The distribution of land holdings play important role in agriculture and these vary across the altitudinal zones in different river valleys of Lahaul-Spiti. Thus, the main objectives of this study are;

- To see the spatial and temporal variations in the distribution of cultivable land across altitudinal zones in the study area and find out the factors which explain the relative advantages of some zones over others.
- To analyse the per capita availability of agricultural land.

8.1.2 Database and Methodology

Data has been procured using both secondary sources as well as through field survey. Nearly 300 households were selected from ten villages spread across three altitudinal zones for canvassing questionnaire for the primary survey. The main purpose of the survey was to understand the role of environmental factors in the distribution of land holdings. Secondary sources of data used in the study included as given below;

– Census of India, 1991 and 2001, series-9, H.P, Part XII-A & B, District Census Handbook, Lahaul-Spiti, Director of census operations, H. P, Shimla.
– SRTM Digital data (SRTM is an international project spearheaded by the National Geospatial-Intelligence Agency (NGA) and the National Aeronautics and Space Administration (NASA).
– Thematic map 2000, Lahaul-Spiti, NATMO, Department of Science and Technology, Ministry of Science, Govt. of India.

However, the areal variations in the size and distribution of land holdings have been captured through field visits and the survey conducted. Data has been presented by calculating percentages and cross-tabulation, and changes seen over two time periods. Along with these, maps have also been prepared using GIS software.

8.1.3 Study Area

Lahaul-Spiti district is located in an isolated high altitude area of Himachal Pradesh state of India. Before acquiring the status of a border district, it was a unit of Kullu sub-division of Kangra district till 1960s. Kyelong is the administrative headquarter of Lahaul-Spiti district. The district is located between 31°44′57″N and 32°59′57″N latitude and 76°46′29″E and 78°41′34″E longitude. It is largest district of Himachal Pradesh covering an area of 13,835 km^2 constituting 24.85 % geographical area in the state. Its total population was 33,224 persons in 2001 with population density of two persons per km^2. Only 272 villages were inhabited out of total 403 villages in 2001. No urban centre exists in the Lahaul-Spiti district. The district is made up of three administrative sub-divisions those include two tehsils and one sub-tehsil namely Lahaul, Spiti and Udaipur. It is encircled by Kinnaur, Kullu, Kangra and Chamba districts on the south, south-west and north-west. The state of Jammu and Kashmir and Tibet lie on the north and east of the district (Fig. 8.1).

In spite of it being the largest district of Himachal Pradesh, only 0.36 % of its total area is under cultivation. The district of Lahaul-Spiti has two major physiographic divisions, viz: mountain ranges and river valleys. Mountain ranges exhibit the striking intra-area variations from south to north than east to west with altitude varying between 3,500 and 6,000 m above mean sea level (MSI). National Atlas and Thematic Mapping Organization (NATMO), has divided the district into three altitudinal zones:

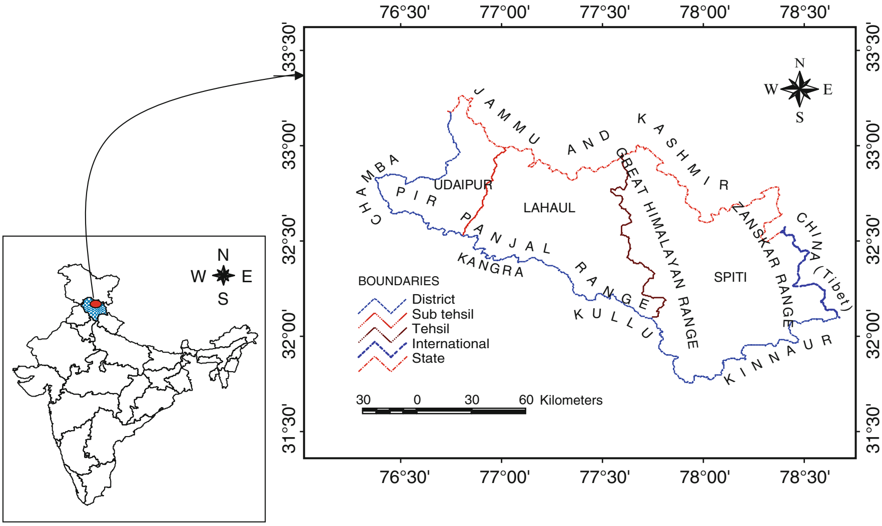

Fig. 8.1 Location map: Lahaul-Spiti, Himachal Pradesh

- Above 4,500 m: Under this zone comes all area excluding the river valleys. This zone comprises mostly the glaciated valleys and is practically unfit for the cultivation.
- 3,000–4,500 m: This zone covers the prominent river valleys of Spiti, Chandra and Bhaga rivers and their associated tributary valleys. These river valleys are mostly inhabited. Most of the arable land is concentrated in this zone.
- Below 3,000 m: This zone has very limited area, which is confined to Chander-Bhaga river valley in the western margin of the district. This area is forested and is inhabited and receives more precipitation compared to other two zones.

Lahaul-Spiti district falls in the rain-shadow area of the Himalayan mountain ranges. Lahaul tehsil and Udaipur sub-tehsil are situated between Pir Panjal and Great Himalayan Ranges while Spiti tehsil lies to the north of Great Himalayan Range. For this reason, meagre amount of annual precipitation i.e. 45.9 cm is received at Keylong in Lahaul. In fact, Spiti tehsil is even more arid. Most of the precipitation falls in the form of snow which is of little direct use. Almost all of the cultivated land is under irrigation. It has very limited forest cover mainly confined to the southern and western parts. The district has historically remained largely isolated due to inhospitable climate and rugged topography. At present, it remains cut off from rest of the country from mid October to April–May due to heavy snowfall on mountain passes linking the district with the outside world. These passes are the main means of transport access. All economic activities except household activities come to standstill during long and severe winters. Living under such harsh environmental conditions, human beings have been trying to modify the nature with available low level technology and at the same time adapt themselves to the needs of nature.

8.2 Results and Discussions

Land suitable for agriculture in high altitude environment is quite scarce as most area is not fit for cultivation. Lahaul-Spiti is characterised by rugged topography with arid and semi-arid cold climate. Most of the land is covered by barren and rocky mountains either covered with glaciers or snowfields or having bare rocky surfaces. However, some geomorphic features like valley floor, river terraces, glacio-fluvial fans and talus cones have relatively thicker soil cover and can support plant life. Climate restricts the length of growing season. Most part of the district grow single crop during short summer months. The only exception is the lower and middle zone villages confined to south-central and south-western portions where some quick maturing crops are also cultivated as second crop. Most villages have small, undulating and fragmented terraced agricultural fields. Agricultural field are smaller in lower and middle zone villages due to population pressure. These become increasingly bigger but steeper with increasing altitude in higher zone villages where population is less and the productivity is low. Likewise, soil cover is thicker with fairly developed soil profile in lower and middle zones as against thin and stony soil in higher zone villages.

Figure 8.2 shows that most of agricultural land is found along major valleys on river terraces, valley floor and on moderately sloping fans and spurs. These have

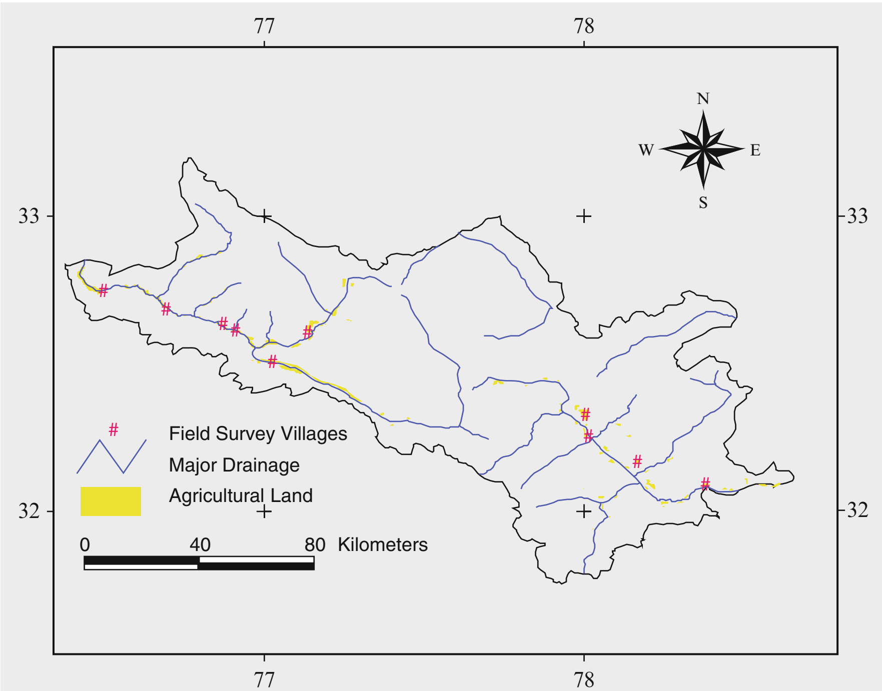

Fig. 8.2 Agricultural land in Lahaul-Spiti, Himachal Pradesh

gentler slope and relatively thicker soil cover. Major agricultural land is on east–west facing slope and in some cases on north–south slope.

Availability of suitable agricultural land is very limited in Lahaul-Spiti district on account of environmental constraints. Table 8.1 shows that only small proportion i.e. 8.71 % of the total area was available for agriculture in 1991 which increased to 9.13 % in 2001 showing a minor increase of 0.42 % in higher zone villages during 1991–2001 period (Singh and Warpa 2009). It shows that villages in the higher zones are located on steeper slope and have limited possibility for bringing additional land under cultivation. As against this, land available for cultivation was notably more at 14.9 % in the middle zone villages of Lahaul-Spiti in 1991 which rose to 17.13 % in 2001. It shows an increase of 2.23 % during 1991–2001 reflecting better topographic conditions for carrying out agricultural pursuits in middle zone villages compared to higher zone villages. The lower zone villages have larger proportion of total geographical area suitable for agriculture accounting for 18.03 % in 1991 and which slightly increased to 18.22 % in 2001. Villages lying in the lower zone have gentler slope and moderately thicker soil cover compared to middle and higher zone villages. Availability of agricultural land was 13.77 % in 1991 and increased to 14.91 % in 2001 across all altitudinal zones. As seen in the table, most expansion in agricultural land was in the middle zone villages. It is mainly due to the fact that some potential land for agriculture is available only in this zone as land is too steep in the higher zone and most of suitable land has already been brought under plough in the lower zone. However, restrictive role of environment becomes clear from the fact that only small area in inhabited villages across the altitudinal zones is under cultivation.

Higher per capita availability of agriculture land was seen in the higher zone villages to the tune of 0.17 ha in 1991 which slightly declined to 0.16 ha in 2001. This decline can be attributed to an increase in population of 250 persons during 1991–2001. More per capita land appears to be due to small population base but agriculture land is less productive in higher areas compared to lower parts. About 0.12 ha per capita agricultural land was available in middle zone villages at both time periods. It was static owing to increase in agricultural land of 265 ha during 1991–2001 which took care of increase in population. On the other hand, lower zone villages had lowest per capita agriculture land of 0.10 ha during both time periods. This was due to decrease in population by 132 persons during 1991–2001. Population seem to have declined mainly due to out-migration which is a common feature in the villages of lower zone. Despite lowest per capita agriculture land in the lower zone, the quality of land here is better in terms of productivity as opposed to higher parts. The phenomenon of out-migration has recently gained momentum on account of better road networks, educational facilities and an increasing willingness to buy property outside the region. Per capita availability of agricultural land remained 0.12 ha both in 1991 and 2001 across all altitudinal zones. This shows that except variations in some villages, the population pressure has not increased in the entire region.

Table 8.1 Agricultural land and its Per Capita availability in Lahaul-Spiti: 1991–2001

Altitudinal zones	Agricultural land (hectares) 1991	2001	Change 1991–2001	Altitudinal zones	Total population 1991	2001	Change 1991–2001
Higher	723 (8,295)	757(8,295)	34 (Nil)	Higher	4,345	4,595	250
Percentage	8.71	9.13	0.42	Per capita agricultural land	0.17	0.16	−0.10
Middle	1,689 (11,334)	1,954 (11,408)	265 (74)	Middle	14,430	16,030	1,600
Percentage	14.9	17.13	2.23	Per capita agricultural land	0.12	0.12	Nil
Lower	1,226 (6,798)	1,242 (6,818)	16 (20)	Lower	12,388	12,256	−132
Percentage	18.03	18.22	0.19	Per capita agricultural land	0.10	0.10	Nil
All Zones	3,638 (26,427)	3,953 (26,521)	315 (94)	All Zones	31,163	32,881	1,718
Percentage	13.77	14.91	1.14	Per capita agricultural land	0.12	0.12	Nil

Source: Computed from Census of India, 2001, series-9, H.P, Part XII-A & B, District Census Handbook, Lahaul-Spiti, Director of Census Operations, H. P, Shimla
Note: Figures in parentheses represent total geographical area in hectares

8.2.1 Distribution of Land Holdings

Availability of land for cultivation is an important aspect in high altitude regions for its agricultural economy. It acquires an additional importance in isolated mountainous regions like Lahaul-Spiti where land available for agriculture is extremely limited. Increasing crop-yield is not easy. Thus, size of land holdings acquires greater importance as most of economy rests upon farming pursuits under harsh environmental conditions. Therefore, size of holdings is closely related to total production.

The surveyed households have been divided into four categories of farmers according to the size of land holdings as given below;

Small farmers	Up to 12.5 bighas*;
Medium farmers	12.5 to 25 bighas;
Large farmers	25 to 50 bighas;
Very large farmers	More than 50 bighas

**Note*: Revenue Department of Lahaul-Spiti measures 20 biswa = 1 bigha, and 12.5 bighas = 1 ha

Along with this, the families have also been divided into four types based on the number of family members. These categories are as;

Small family	Up to 5 members;
Medium family	6–9 members;
Large family	10–13 members;
Very large family	More than 13 members

Table 8.2 reveals that highest proportion of 40 % is constituted by small farmers followed by medium and large farmers having a share of 28.33 and 30 % in the higher zone. On the other hand, the share of very large farmers is only 1.67 %. In middle zone villages, the share for successive categories of farmers is to the tune of 41.33, 37.33, 18.00 and 3.33 %. However, lower zone villages show slightly higher percentage to the order of 42.22% small farmers, 28.89 % medium farmers, 17.78 % large farmers and 11.11 % very large farmers. This reflects that lower zone villages have comparatively large population base and milder environment conditions as opposed to higher zones. These figures also corresponds in all zones showing highest proportion i.e. 41.33 % occupied by small farmers followed by medium and large farmers having a share of 33 and 20.33 % and the share of very large farmers is only 5.33 %. It may be due to sub-division of land with increasing number of nucleated families in recent years. This phenomenon of nucleation gained momentum only after the locals came in contact with people of Kullu district. Earlier, the region used to have large joint families. Due to limited availability of agricultural land, system of polyandry was prevalent wherein only one brother got married and his younger brothers generally not exceeding two in number automatically became co-husbands of the elder brother's wife. Property passed from father to the eldest son with no fragmentation of land. Younger brothers had no claim on property. Now polyandrous marriages have vanished almost completely. This happened in recent decades with the spread of education and better road network.

Correspondingly, almost same pattern can be observed in higher, middle and lower zones regarding distribution of land holdings. In higher zone, all small family households have small sized land holdings. They accounted for 25 % of all small farmers in the higher zone. However, over 70.83 % small farmers had medium size of family. There was only one farmer having large family in this group. There was no small farming household with very large family. As opposed to this, approximately an equal proportion of 49.06 and 49.12 % small farmers had medium family size in the middle and lower zones. Around 50 % larger farmers had medium family and remaining 44.44 % had large and 5.56 % had very large families in the higher zone. None of the medium and above categories of farmers had small family in this group. It may be due to joint families still being prevalent in the more inaccessible villages of higher zone. As against this, there were many large farmers who had medium and large families.

It becomes clear that small and medium farmers had major proportion of land holdings across altitudinal zones. It shows limited availability of cultivated land.

Table 8.2 Distribution of agricultural land

Family size	Units	Farm size				Total
		Small farmer	Medium farmer	Large farmer	Very large farmer	
Higher zone						
Small	No. of farmers	6	0	0	0	6
	% within family size	100.00	0.00	0.00	0.00	100.00
	% within farm size	25.00	0.00	0.00	0.00	10.00
Medium	No. of farmers	17	14	9	0	40
	% within family size	42.50	35.00	22.50	0.00	100.00
	% within farm size	70.83	82.35	50.00	0.00	66.67
Large	No. of farmers	1	3	8	1	13
	% within family size	7.69	23.08	61.54	7.69	100.00
	% within farm size	4.17	17.65	44.44	100.00	21.67
Very large	No. of farmers	0	0	1	0	1
	% within family size	0.00	0.00	100.00	0.00	100.00
	% within farm size	0.00	0.00	5.56	0.00	1.67
Subtotal	No. of farmers	24	17	18	1	60
	% within family size	40.00	28.33	30.00	1.67	100.00
	% within farm size	100.00	100.00	100.00	100.00	100.00
Middle zone						
Small	No. of farmers	10	0	0	0	10
	% within family size	100.00	0.00	0.00	0.00	100.00
	% within farm size	16.13	0.00	0.00	0.00	6.67
Medium	No. of farmers	52	47	7	0	106
	% within family size	49.06	44.34	6.60	0.00	100.00
	% within farm size	83.87	83.93	25.93	0.00	70.67
Large	No. of farmers	0	9	17	2	28
	% within family size	0.00	32.14	60.71	7.14	100.00
	% within farm size	0.00	16.07	62.96	40.00	18.67
Very large	No. of farmers	0	0	3	3	6
	% within family size	0.00	0.00	50.00	50.00	100.00
	% within farm size	0.00	0.00	11.11	60.00	4.00
Subtotal	No. of farmers	62	56	27	5	150
	% within family size	41.33	37.33	18.00	3.33	100.00
	% within farm size	100.00	100.00	100.00	100.00	100.00
Lower zone						
Small	No. of farmers	9	0	0	0	9
	% within family size	100.00	0.00	0.00	0.00	100.00
	% within farm size	23.68	0.00	0.00	0.00	10.00
Medium	No. of farmers	28	19	6	4	57
	% within family size	49.12	33.33	10.53	7.02	100.00
	% within farm size	73.68	73.08	37.50	40.00	63.33
Large	No. of farmers	1	7	8	3	19
	% within family size	5.26	36.84	42.11	15.79	100.00
	% within farm size	2.63	26.92	50.00	30.00	21.11

(continued)

Table 8.2 (continued)

		Farm size				
Family size	Units	Small farmer	Medium farmer	Large farmer	Very large farmer	Total
Very large	No. of farmers	0	0	2	3	5
	% within family size	0.00	0.00	40.00	60.00	100.00
	% within farm size	0.00	0.00	12.50	30.00	5.56
Subtotal	No. of farmers	38	26	16	10	90
	% within family size	42.22	28.89	17.78	11.11	100.00
	% within farm size	100.00	100.00	100.00	100.00	100.00
All zones						
Small	No. of farmers	25	0	0	0	25
	% within family size	100.00	0.00	0.00	0.00	100.00
	% within farm size	20.16	0.00	0.00	0.00	8.33
Medium	No. of farmers	97	80	22	4	203
	% within family size	47.78	39.41	10.84	1.97	100.00
	% within farm size	78.23	80.81	36.07	25.00	67.67
Large	No. of farmers	2	19	33	6	60
	% within family size	3.33	31.67	55.00	10.00	100.00
	% within farm size	1.61	19.19	54.10	37.50	20.00
Very large	No. of farmers	0	0	6	6	12
	% within family size	0.00	0.00	50.00	50.00	100.00
	% within farm size	0.00	0.00	9.84	37.50	4.00
Total	No. of farmers	124	99	61	16	300
	% within family size	41.33	33.00	20.33	5.33	100.00
	% within farm size	100.00	100.00	100.00	100.00	100.00

Source: Field survey, September to November, 2005

Cultivable land also needs to be seen in terms of size of family and the land holding. It has been seen that there exists a co-relationship between family-size and landholding size. Smaller families occupying larger land holdings show the incidence of nucleation on one hand in a few cases and lesser constraining role of environmental factors on the availability of agricultural land on the other hand. As stated above, the phenomenon of nuclear families has started gaining ground in recent times.

Table 8.2 shows that all small families have small land holdings in higher zone. It reflects that small families have low availability of cultivated land. Similarly, 42.5 % medium families have small land holdings followed by 35 % having medium and 22.5 % large land holdings whereas none of the medium size families have very large land holdings. Large families have lowest proportion of 7.69 % having small and also very large land holdings. It may be due to fragmentation of land in the case of some large families with small land holdings. On the contrary, largest proportion of 61.54 % of large families has large land holdings followed by another 23.08 % having medium land holdings. Hundred per cent of very large families have large land holdings. It reflects that very large families have larger cultivable land. Almost similar kind of distributional pattern can be noticed in middle and lower zones with some minor variations. However, none of the large families have small land holdings in middle zone whereas 5.26 % have small land holdings in lower zone. It shows joint family system in some cases.

Almost 100 % small families have small sized land holdings in all zones. Likewise, largest proportion of medium families accounting for 47.78 % owned small land holdings followed by 39.41 % owning medium land holdings and 10.84 % large land holdings whereas only 1.97 % medium sized families owned very large size land holdings. Large families are having lowest proportion i.e. 3.33 % small land holdings followed by 31.67 % with medium land holdings and 55 % having large land holdings. As against this, 10 % large families have large land holdings. An equal proportion of very large families i.e. 50 % are having large and very large land holdings. It shows that very large families have better availability of cultivated land.

Above analysis shows that there is well defined relationship between family-size and farm-size. It reflects that small families have small agricultural land while medium families have comparatively larger cultivable land. On the other hand, large families' have large land holdings showing joint family system.

8.3 Conclusions

It becomes clear that cultivable land and nature of its distribution shows a notable adjustment within the dictates of natural environment. It highlights the restrictive role of environmental factors seen in the form of limited availability of cultivable land with marked variations in its distribution both spatially as well as in terms of altitude. Besides, polyandrous marriages and joint family system earlier played important role in checking fragmentation of already scarce agricultural land under the prevalent harsh environmental conditions. The present study highlights as to how judiciously land resources are being utilized and managed in a rational and inclusive manner by the local inhabitants in this cold desert region. However, the overall analysis suggests that small families have least cultivable land as opposed to their larger counterparts. Their number was found to be lowest in higher zone while higher in the villages of middle and lower zones.

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Chapter 9
Spatio-Temporal Change of Crop Diversification in Kerala: An Economic Review

P.S. Shindu and V. Govindaru

Abstract The significance of analysis of spatio-temporal changes in crop diversity lies in its usefulness for policy makers. It reveals changing pattern of competition among various crops. Diversification is a strategy to optimize the use of land, water and other resources of an area by cultivating more profitable crops. It provides the farmers to decide what to cultivate on their land which provides maximum returns and generally farmer cultivate more than one crop to avoid risk and uncertainty due to climatic and biological vagaries. The concept of diversification implies shift from less profitable and non sustainable crops to more profitable and sustainable crops. It has become an important option to attain natural resource sustainability, ecological balance, employment generation, risk generation: monocropping high risk.

In this paper an attempt has been made to analyze the extent of crop diversification at district level in Kerala state. The study is based on primary and secondary data. Primary data collected from direct field visit. Govt. records, journals and periodicals are used as secondary data. To analyze the crop diversification at district level Herfindahl index and Entropy index were worked out. Toposheets and other maps published by different agencies are used for the study. Arc GIS 9.3 version software is used for the preparation of relevant maps.

The state has an area of 38,863 km^2 with 14 districts. Lying between north latitudes 8°18′ and 12°48′ and east longitudes 74°52′ and 77°22′. Topography, climate, soil, drainage etc… Influences the agriculture land use pattern of the state. The analysis concluded that more diversion of area towards coconut and rubber in Kottayam, Malappuram and Kozhikode districts due to high wages to labours, increased demand of the product, etc. … Such an analysis focuses on the

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identification of crop diversification regions that provide a clean areal differentiation in the case of crop grown and also give avenue to planners to establish more economically sustained agricultural system.

Keywords Areal differentiation • Crop diversification • Entropy index • Herfindahl index

9.1 Introduction

Agriculture practice has been probably changed faster in the past two centuries. Better agriculture techniques have successfully applied in order to get self sufficient in agriculture product. Diversifications analysis is one of the important tools in statistical studies of geography, particularly in agricultural geography presently statistical tools has gained momentum and its importance in agricultural geography.

Diversification is a strategy to optimize the use of land, water and other resources of an area by cultivating more profitable crops. It provides the farmers to decide what to cultivate on their land, which provides maximum returns. Farmer generally cultivates more than one crop to avoid risk due to climatic and biological vagaries. Thus concept of diversification implies shift from less profitable and non sustainable crops to more profitable and sustainable crops. The level of crop diversification is largely depends upon the agro climatic, socio economic condition and technological development of a region. In other words, support from Government, other institutions, and market demands are the determinants of crop diversification. Here, market means both domestics and internationals. Now crop diversification has become an important option among farmers to keep their land in sustainable manner Significance of analysis of spatio-temporal changes in crop diversity lies here.

9.2 Objectives

The main objectives of this paper are:

1. To analyze the nature and extent of area in which multiple crops are cultivated in the state of Kerala and
2. To analyze the changing scenario of crop diversification in the state from 1985–1986 to 2010–2011.

9.3 Study Area

For the purpose of analyzing the economic of crop diversifications, Kerala, state of India was purposively selected. Kerala state located in the southern tip of India is bordered by Arabian Sea and the extensive network of backwaters, rivers and streams, boasts of an agrarian economy. The state has an area of 38,863 km^2 with 14 districts. Lying between north latitudes 8°18′ and 12°48′ and east longitudes 74°52′ and 77°22′. Topography, climate, soil, drainage etc.. . . Influences the agriculture land use pattern of the state. Natural condition of the state is highly suitable for cultivating multiple crops in a field throughout the year. Kerala shares 2.76 % of India's population (31,841,374) with density of 859 persons per km^2, its land is nearly three times as densely settled as the rest of India, which is at a population density of 370 persons per km^2. The growth rate of Kerala's population during last 10 years is 4.9 %, one of the lowest rates among Indian states. Out of the total geographical area 38.86 lakh ha net sown area is about 53 %. The share of total cropped area in the total geographical area is 68 %.

9.4 Data and Methodology

This study is based on secondary data. Time serious data on area under principal crops were collected from Statistics for Planning published by Economics and Statistics Department, Govt. of Kerala during the period 1985–1986 to 2010–2011. Crop diversification index methods seek to identify the behavior of crops over a period of the time and space. It is one of the most important criteria of agricultural regionalization and useful for the identification of cropping pattern of the region. Toposheets, published by survey of India and other maps published by different agencies are used for the study. Arc GIS 9.3 version and MAPINFO 12 software are used for the preparation of relevant maps. Suitable statistical methods are used to analyze the data. Herfindahl and Entropy indices are used for crop diversification analysis.

As the first step, the study analysed the scenario of crop diversification in Kerala using Herfindahl Index. The Herfindahl index (HI) can be defined as follows

9.4.1 Herfindahl Index

Herfindahl index is defined as

$$\mathrm{HI} = \sum_{i=1}^{n} \mathrm{Pi}^2$$

Where, Pi is share of each crop as,

$$Pi = \frac{A_i}{\sum_{i=1}^{n} A_i}$$

Where

Ai = Area under ith crop

$\sum A_i$ = Total cropped area

The value of HI varies between one and zero. It takes the value of one when the field is under monoculture and when it is zero means the field is under highly diversified crops. Hence as HI increases, diversification in a particular region increases and as HI decreases, diversification in that region increases.

9.4.2 Entropy Index

This is a measure widely used by research workers. Unlike Herfindahl Index, the Entropy Index increases with increase in diversification. It defined as

$$EI = \sum_{i=1}^{n} Pi\ \log 1/pi$$

Where Pi = Proportion of ith crop

The value of entropy index varies from zero to log n. When EI takes the value of is zero, the field is under single crop and when it has the value of log n the field is under highly diversified crops

These indices based on crops i.e., Paddy, Sugar cane, Pepper, Cashew nut, Tapioca, Coconut, Rubber, Coffee and Tea were calculated.

9.5 Result and Discussion

9.5.1 Based on Herfindahl Crop Diversification Index

The year and district wise crop diversification indices of Kerala, *based on Herfindahl crop diversification Index*, for the period of last 25 years are given in Table 9.1 According to the table, In Kottayam, Pathanamthitta, Kozhikode,

Table 9.1 District wise Herfindahl crop diversification Index in Kerala from 1985–1986 to 2010–2011

Sl. No.	District	1985–1986	1990–1991	1995–1996	2000–2001	2005–2006	2010–2011
1	Thiruvananthapuram	0.272	0.218	0.241	0.248	0.258	0.256
2	Kollam	0.171	0.176	0.187	0.191	0.182	0.189
3	Pathanamthitta	0.161	0.183	0.231	0.221	0.216	0.264
4	Alapuzha	0.234	0.27	0.268	0.263	0.298	0.249
5	Kottayam	0.192	0.254	0.291	0.285	0.301	0.327
6	Idukki	0.063	0.088	0.084	0.081	0.109	0.107
7	Ernakulam	0.2	0.199	0.196	0.187	0.173	0.189
8	Thrissur	0.265	0.265	0.241	0.249	0.228	0.245
9	Palakkad	0.235	0.203	0.168	0.176	0.16	0.139
10	Malappuram	0.165	0.187	0.192	0.192	0.192	0.223
11	Kozhikode	0.313	0.33	0.316	0.33	0.33	0.374
12	Wayanad	0.202	0.186	0.185	0.163	0.151	0.17
13	Kannur	0.145	0.164	0.166	0.159	0.172	0.162
14	Kasargod	0.138	0.183	0.167	0.182	0.182	0.203
Kerala		0.139	0.144	0.142	0.139	0.168	0.141

Kasargod and Malappuram districts HI has increased from 0.192, 0.161, 0.313, 0.138 and 0.165 to 0.327, 0.264, 0.374, 0.203 and 0.223 respectively during the period of 1985–1986 to 2010–2011. It shows a movement towards less diversification. In Thiruvananthapuram, Ernakulum, Thrissur and Palakkad districts HI values are declining during this period, from 0.272, 0.2, 0.265 and 0.235 to 0.256, 0.189, 0.245 and 0.139 respectively. It indicates that crop cultivations in these districts are more diversified than in other districts with remunerative crops like Coconut, Rubber and Pepper. Figure 9.1a, b illustrates spatio temporal variations in the crop diversification regions of study area.

9.5.2 Based on Entropy Index

Entropy index analysis is another barometer of crop diversification. The value of entropy which was 0.736 in 1985–1986 has declined to 0.688 in 2010–2011 for entire Kerala. Table 9.2 shows entropy index of crop diversification in different districts of Kerala during 1985–1986 to 2010–2011. The results indicated that the value of EI is declining in the state, which means cultivable lands in the state are moving towards less diversification. However in the districts of Palakkad, Pathanamthita, Thiruvananthapuram, Kasargod and Kottayam, the value of Entropy Index is an upward trend. This indicates that farmers in these districts prefer to

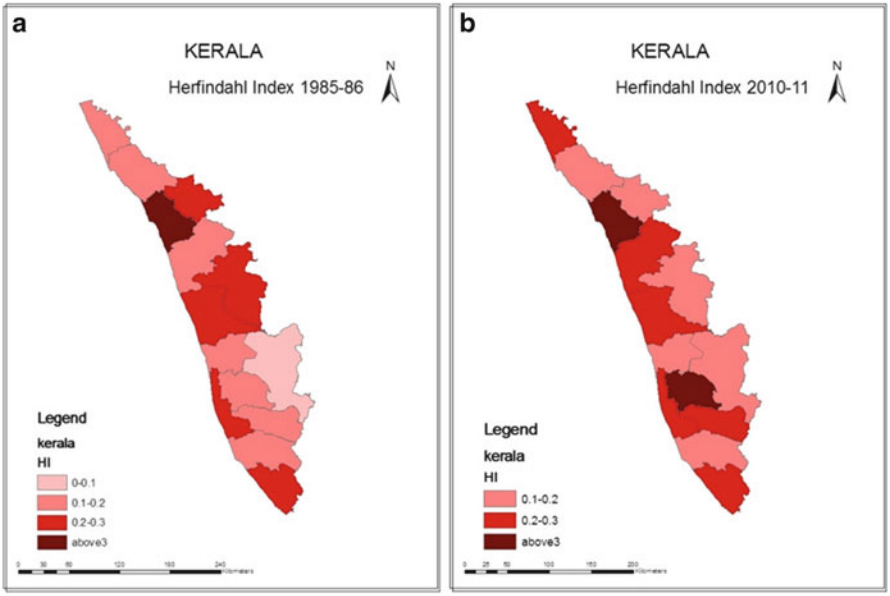

Fig. 9.1 (**a**, **b**) illustrates spatio temporal variations in crop diversification based on Herfindahl Index of study area (1985–1986 and 2010–2011)

Table 9.2 Entropy Index of crop diversification in Kerala state from 1985–1986 to 2010–2011

Sl. No.	District	1985–1986	1990–1991	1995–1996	2000–2001	2005–2006	2010–2011
1	Thiruvananthapuram	0.7449	0.6128	0.5998	0.5955	0.5703	0.5691
2	Kollam	0.6793	0.6606	0.6489	0.6541	0.7087	0.6098
3	Pathanamthitta	0.7003	0.6283	0.6222	0.5597	0.562	0.5078
4	Alapuzha	0.5600	0.5113	0.5322	0.5173	0.5037	0.5139
5	Kottayam	0.6497	0.6013	0.562	0.5586	0.5595	0.5019
6	Idukki	0.6549	0.6770	0.6570	0.6245	0.603	0.5923
7	Ernakulam	0.5950	0.6023	0.5919	0.5958	0.5516	0.5517
8	Thrissur	0.5345	0.5294	0.5405	0.5259	0.4978	0.5134
9	Palakkad	0.4814	0.5180	0.5230	0.5611	0.5559	0.6069
10	Malappuram	0.6435	0.5951	0.5773	0.5587	0.5272	0.5063
11	Kozhikode	0.4923	0.4475	0.4434	0.4469	0.4777	0.3950
12	Wayanad	0.5956	0.6033	0.6142	0.6421	0.6434	0.7214
13	Kannur	0.6701	0.6310	0.6124	0.5740	0.5840	0.5505
14	Kasargod	0.6698	0.6297	0.5903	0.5661	0.5571	0.5079
Kerala		0.710	0.7005	0.640	0.688	0.720	0.688

cultivate more crops on their lands at a time. Another interesting phenomenon noticed in these districts is that declining of paddy fields. Most of paddy fields are converted into mixed crop fields or homesteads. Figure 9.2a, b explains variations in crop diversification regions based on Entropy Index of study area.

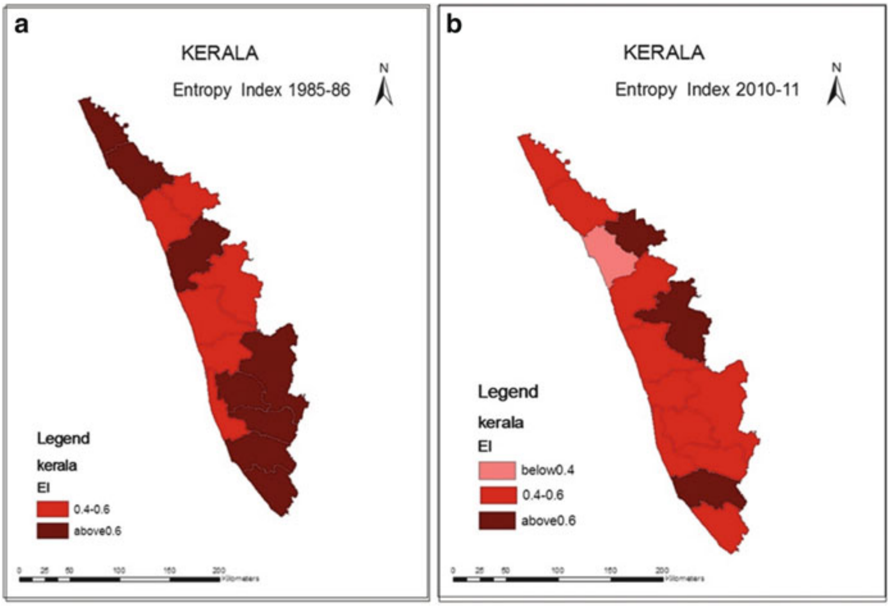

Fig. 9.2 (**a**, **b**) illustrates spatio temporal variations in crop diversification based on Entropy Index of the study area (1985–1986 and 2010–2011)

9.6 Conclusion

The crop diversification analyses reveal that in Kerala, the state as whole farmers prefer to cultivate less number of crops on their fields. Commercialization of cultivation of major crops (like rubber, coconut, pepper, banana etc.,) is one of the major factors for this change. Meantime, in the districts of Palakkad, Pathanamthita, Thiruvananthapuram, Kasargod and Kottayam more fields are adding to mixed-forms category or coming under more diversified farms. This is due to the conversion of paddy fields into mixed crop fields or homesteads. A detailed socio-economic study has to be conducted for diagnosing the reasons behind this type of changing cropping pattern.

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Chapter 10
Cropping System Analysis Using Geo-Informatics Approach: A Case Study of Panipat District, Haryana

Seema Rani, Manoj Yadav, M.P. Sharma, and R.S. Hooda

Abstract A cropping system is defined as the cropping pattern and its management to derive benefits from a given resource base under a specific environmental condition. Crop rotation is a time-honored process of planting annual crops. The paper describes methodology and results of cropping system analysis for Panipat district of Haryana, climatologically characterized by hot summer, cold winter and dry air except during rainy season. Multi-date and Multi-season IRS LISS-III digital satellite data of 2007–2008 was geo-referenced with the already geo-referenced master image by collecting GCP's using second polynomial order and Nearest Neighborhood (NN) resampling approach. District boundary was overplayed on the image and all the data elements (pixels) within this were extracted for further analysis. Multi-layer stacks were prepared for Kharif, Rabi and Summer seasons using multi-date images of each season. The stacked images of different seasons were classified using complete enumeration approach and unsupervised ISO-Data clustering classifier based on some defined conditions such as number of clusters, threshold, standard deviation etc. To improve the accuracy Normalized Difference Vegetation Index (NDVI) of each date and non-agricultural mask was generated and used during the classification. The Kharif, Rabi and Summer cropping pattern maps and statistics were generated using classified images and applying logical combinations. During Kharif season rice is the major crop which occupies 73,700 ha area and in the Rabi season wheat is major crop occupying 82,900 ha area. In the summer season most of the area is lying vacant as fallow and major crops are fodder, vegetables etc. Sugarcane is an annual crop and it is available in all three cropping seasons. Rice-Wheat-Other, and Rice-Wheat-Fallow and the major crop rotations identified in the district.

Keywords Accuracy assessment • Crop rotation • Cropping pattern • Remote sensing

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10.1 Introduction

Substantial increase in crop production is possible by bringing additional land under cultivation and improved crop management technologies (Sivakumaram, M.V.K). Mainly, the crops of Haryana are divided into Kharif and Rabi crops. The main Kharif crops are Paddy, Groundnut, paddy and maize. Minor Kharif crops are chilies, Bajra, Jowar, pulse and vegetables. The main Rabi crops are gram wheat, barley and oil seeds minor Rabi crops are masseur, barsam, mathi, onion and winter vegetables. The study of cropping pattern constitutes significant substantiates population growth during the decade which aspect within the spatial dimensions of agricultural declined to 0.28 ha per capita in the year 2001 (I.M.F. Geography as it provides a good base for regional 1999). Therefore land pressure is high in general. India is one of the fastest growing economies of the world and is currently the focus of a great deal of international attention. It is the seventh largest country in the world in terms of its geographical size. Today it has a population of nearly 1.2 billion which makes it the second most populous nation in the world. Indian agriculture policy is aimed essentially at improving food self sufficient and alleviating hunger through food distribution. Agricultural crops farm input subsidies and preferential credit Schemes.

10.1.1 Objective

The present study aims to generate detailed database on the present cropping system in the spatial domain. It is now envisaged to create the cropping pattern and crop rotation maps and statistics of Panipat district using IRS LISS-III data.

10.2 Study Area

Panipat district first came into existence on November 1, 1989. It was carved out of Karnal district. The district status to Panipat sub division of Karnal was again restored on First of January, 1992. The district has one sub divisions namely Panipat and Five development blocks namely Panipat, Samalkha, Madlauda, Israna and Bapauli. This city has strategic at National Highway No. 1, just 89 km. from the national capital. The city has one of the best rail and road connectivity to the state capital Chandigarh and other important commercial hubs of the adjoining states. Panipat is a historical place and was the gateway of India in medieval times. Three battles were fought here and winner of course occupied the Delhi Throne. Panipat is situated in North Eastern Haryana, flanked by River Yamuna on the eastern ten border. The Panipat district is surrounded by Karnal in North, Panipat in West and Sonipat district in South and Mujarfarnagar district of Uttar Pradesh in the East. It has a total geographical area of 1,267 km^2 (Fig. 10.1).

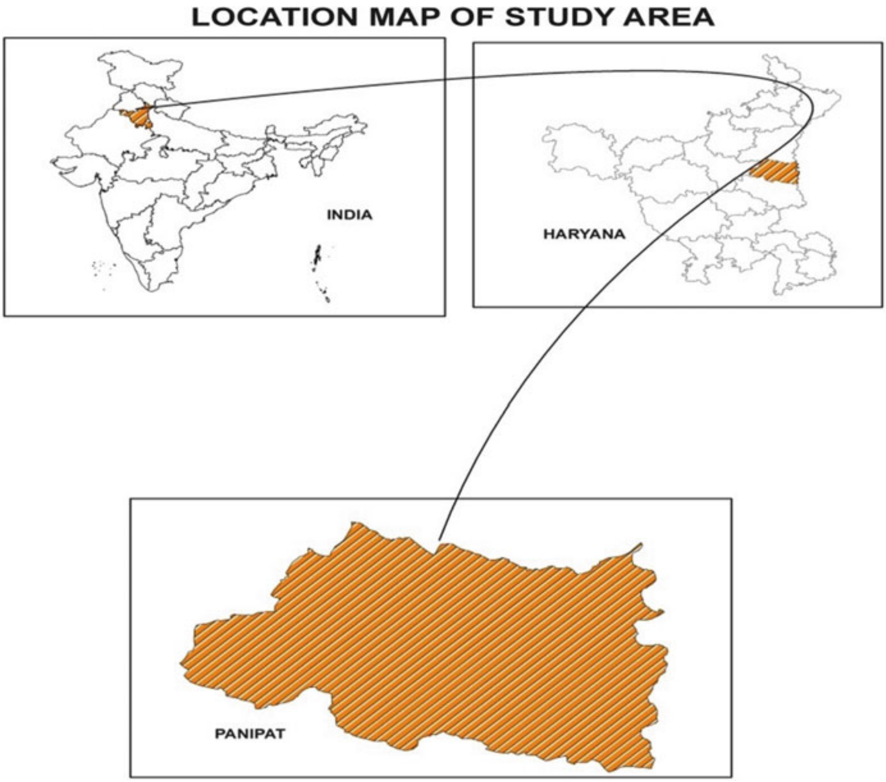

Fig. 10.1 Study map

10.3 Materials and Methdology

10.3.1 Data Used

Remote sensing data is the basic data source for mapping the cropping system of the Panipat district. Indian sensing satellite resource sat (IRS-P6) LISS-III data was used in the present study 23.5 m spatial resolution data in Green, Red, NIR and SWIR bands with 24 days revisit capability (Table 10.1). The data was used in to drive Kharif, Rabi, and Summer cropping patterns. The IRS LISS-III data was the main source of satellite imageries for cretin the spatial maps of cropping pattern, crop rotation map etc.

10.3.2 Methdology

Multi-date and multi-season LISS-III digital satellite data was geo-referenced with the master images by collecting GCP's using second polynomial order and NN Resampling approach. The geo-referenced images were used for further analysis

Table 10.1 Rabi cropping pattern of panipat district

Satellites	Sensor	Season	Date of acquisition	Path/row
IRS-P6	LISS-III	Kharif	24-10-2007	95/50
			29-08-2007	
IRS-P6	LISS-III	Rabi	04-01-2008	95/50
			03-16-2008	
IRS-P6	LISS-III	Summer	27-05-2008	95/50

using complete enumeration approach. In complete enumeration approach the administrative boundary of the districts was digitized, a mask generated and superimposed on the geo-referenced image. All the data elements (pixels) within this were extracted for further classification etc. Unsupervised classification approach Iso-Data Clustering classifier was used and class of interest was using ground truth information provided by HARSAC in the form of GPS location.

The Kharif, Rabi and summer cropping pattern maps were generated using classified images and logical combination. The crop rotation maps were generated using Kharif, Rabi and summer cropping pattern maps.

10.4 Results and Discussion

10.4.1 Cropping System Analysis

10.4.1.1 Kharif Cropping Pattern

Analysis of remote sensing data reflected that Paddy, Sugarcane, Bajra and jowar, are four major crops in Kharif season, which could be identified using Multi-date LISS-III data. Paddy is evenly dominated in the district while Bajra, Jowar and sugarcane crops are in southern, central and eastern part of the district. R.S estimation showed that the Paddy Sugarcane, Bajra, Jowar occupied 73, 8.8, 8.7 and 4 thousand ha. are respectively (Table 10.2, Fig. 10.2) which are very close to with what obtained from department of Agriculture (DOA) estimates for the same year i.e. 2007–2008 Other crops in Kharif season include vegetables, fodder crops etc.

10.4.1.2 Rabi Cropping Pattern

Wheat, Mustard and Sugarcane are the major crops during Rabi season fallowed by other crops. As can be seen from the Fig. 10.3, Table 10.3, which are derived from RS based estimates are close to with what obtained from DOA estimates with the same year i.e. 2007–2008 wheat crop is evenly distributed I whole district while concentration of sugarcane in the Fig. 10.3 and mustard are scattered in other parts of the district.

Table 10.2 Kharif cropping pattern of panipat district

S. No	Crops	
1	Paddy	73
2	Bajra	8.7
3	Jowar	4
4	Sugarcane	8.8
5	Other crops	2.2
6	Fallow	9.5

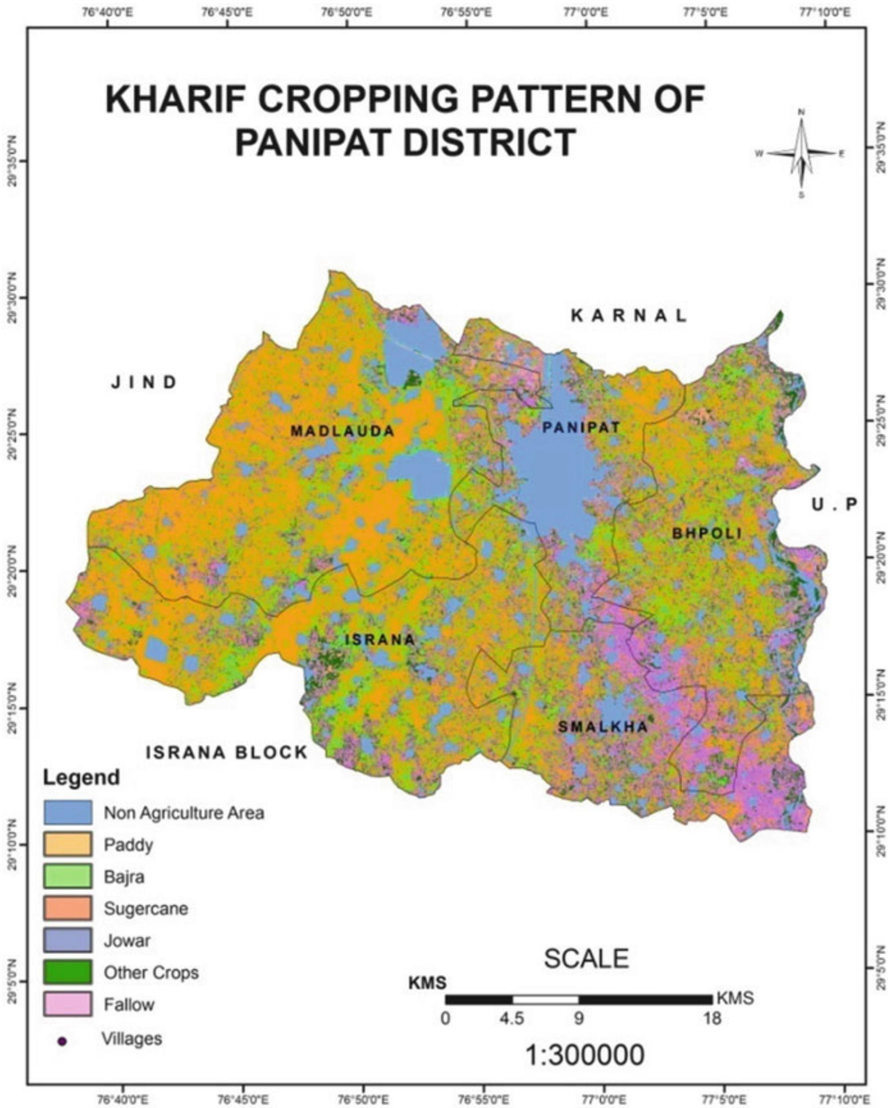

Fig. 10.2 Kharif cropping pattern map of Panipat district derived from RS Data

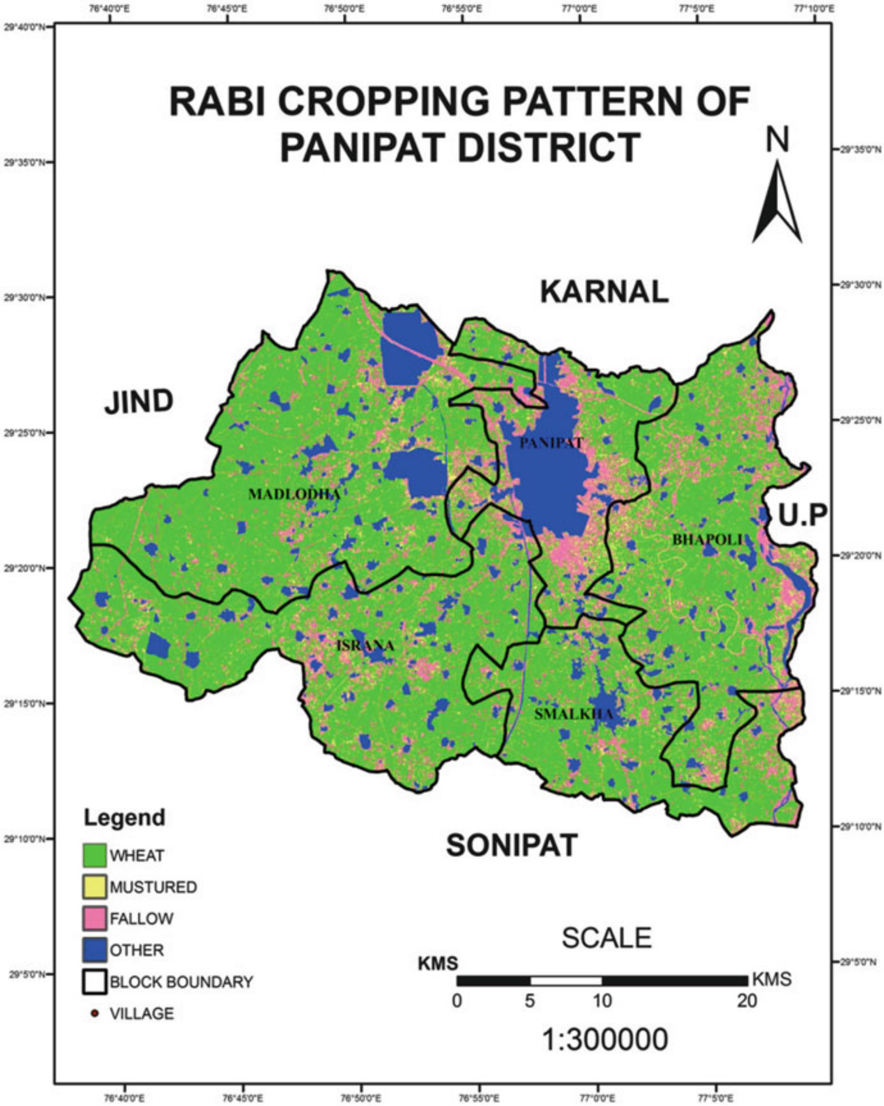

Fig. 10.3 Rabi cropping pattern map of Panipat district derived from RS Data

Table 10.3 Rabi cropping pattern of panipat district

S. No	crops	Area (000' ha.) derived from RS data
1	Wheat	83
2	Mustard	8.48
3	Sugarcane	8.8
4	Fallow	11.70
5	Other crops	8.8

Table 10.4 Summer cropping pattern of panipat district

S. No	Crops	Area (000' ha.) derived from RS data
1	Sugarcane	8.8
2	Other crops	19.4
3	Fallow	80.1

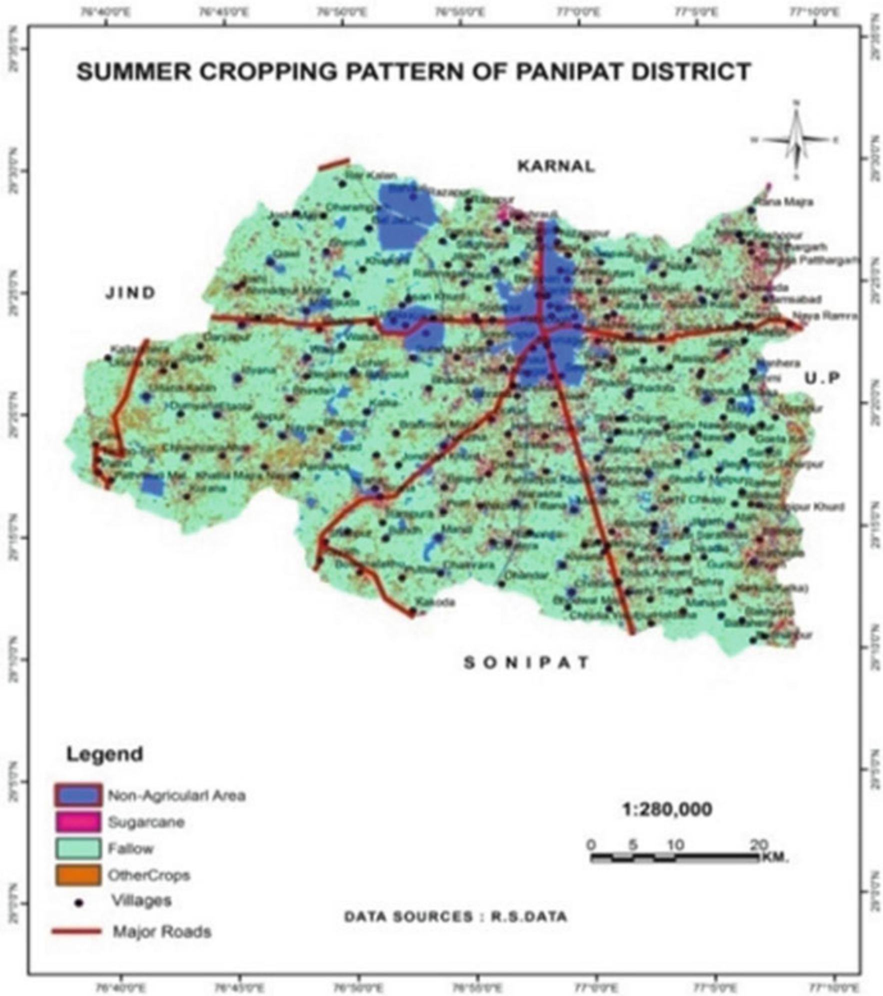

Fig. 10.4 Summer cropping pattern map of Panipat district derived from RS Data

10.4.1.3 Summer Cropping Pattern

During summer season most of the area is lying vacant as fallow. Major crops during summer season is sugarcane followed by other crops derived using RS data given in Table 10.4 and Spatial distribution Depicted in Fig 10.4. Other Crops grown During Summer Season are Vegetables, Fodder etc.

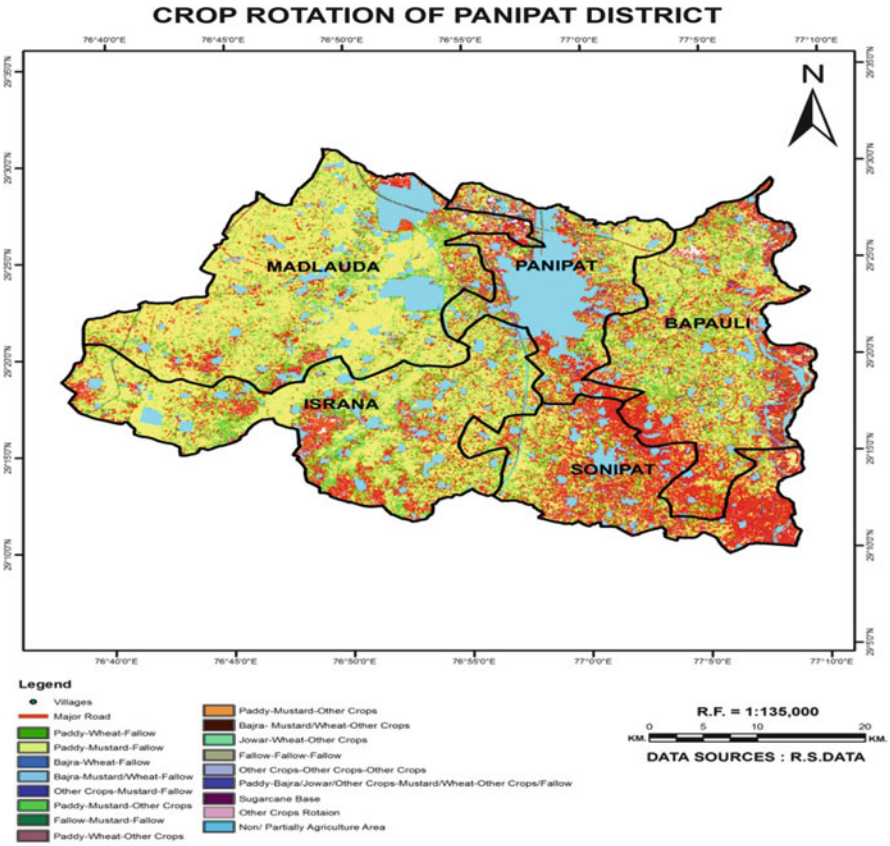

Fig. 10.5 Crop rotation map of Panipat district derived from RS data

10.4.1.4 Crop Rotation

Analysis indicate that Panipat district has the major crop rotations of Paddy-Wheat-Fallow, Paddy-Mustard-Fallow, Fallow-Mustard-Fallow, Bajra-Mustard/Wheat-Other crops and Sugarcane based of three seasons Kharif, Rabi and summer in 2007–2008. The Paddy-Wheat-Fallow rotation dominates the western and southern part of the district while the Sugarcane Based rotation dominates the northern and central part of the district Fig. 10.5 (Table 10.5).

Table 10.5 Crop rotation of panipat district

Sr.no	Crop rotation	Area (000'ha)
1	Paddy-Wheat-Fallow	18.41
2	Paddy-Mustard-Fallow	16.99
3	Bajra-Wheat-Fallow	2.21
4	Bajra-Mustard/Wheat-Fallow	2.21
5	Other crops-Mustard-Fallow	0.07
6	Fallow-Mustard-Fallow	17.20
7	Paddy-Wheat-Other crops	1.57
8	Paddy-Mustard-Other crops	1.53
9	Bajra-Mustard/Wheat-Other crops	18.14
10	Jowar-Wheat-Other crops	0.44
11	Jowar-Mustard-Other crops	0.06
12	Fallow-Fallow-Fallow	14
13	Other crops—Other crops—Other crops	14
14	Paddy/Bajra/Jowar/Other crops-Mustard/Wheat-Othecrops/Fallow	21.50
15	Mustard-Wheat-Other crops	2.4
16	Sugarcane Base	8.8
17	Other crops Rotation	25.58
18	Non/Partially Agriculture Area	178.76

10.5 Conclusion

- Crop production is the result and effect of interaction between natural resources such as soil, water, weather and external inputs like seeds fertilizers management practices etc.
- Multi-date and multi-season optical remote sensed data was used to generate seasonal cropping patterns and then crop rotation map of Panipat District and its using Geomatica 10.3 and Arc GIS software Packages.
- RS data analysis showed that Paddy is major crops followed by Sugarcane, Bajra and Jowar during Kharif Season. Paddy is uniformally distributed in Whole District.
- Wheat is the major crop in Rabi season evenly distributed in the district followed by Sugarcane and Mustard.
- Major area of the district is lying vacant as fallow in Summer Season and the only major crops is sugarcane is a long derived using RS data.

Sugarcane is a long duration crops available in all these cropping seasons.

- Minor non-contiguous crops which are not separable using LISS-III data clubbed in other crops category. It includes Vegetables, Fodder Green manure etc.
- It was observed that Paddy-Wheat-Fallow, Paddy-Mustard-Fallow, Fallow-Mustard-Fallow and Sugarcane based are the major rotation.
- Other rotations are scattered in the district.

- Multi-date and multi-season optical data with spatial resolution of 23.5 m from Indian Remote sensing Satellites is formed to be useful for the cropping system analysis of major and contiguous minor crops at block-level. For cropping system analysis of minor and non-contiguous crops high resolution multi-date multi-spectral data is required.

Reference

I.M.F (1999) Geography as it provides a good base for regional

Chapter 11
Population Environment Interface in Urban India: A Geographical Analysis

Anuradha Banerjee and Joydeep Saha

Abstract The twenty-first century has witnessed rapid urbanization in Asia, particularly for the large population giants like China and India. Such unprecedented urbanization in India has thrown up several issues and challenges in terms of physical and socio-economic environment, infrastructure as well as city management in the next couple of years.

The 'top heavy' nature of urbanization in independent India reflects a maximum concentration of population in largest cities portraying an uneven distribution of population across the various size classes. Also, highly urbanized states often reflect higher urban growth rates as well as higher levels of urbanization. Such imbalances in urbanization have implications on the broader issue of sustainability in terms of infrastructural development, environmental balance and societal progress. This study attempts to portray the interaction of huge population burden with existing physical, social and infrastructural environment in top ten most urbanized states like Goa, Tamil Nadu, Maharashtra, Gujarat, Karnataka, Punjab, Haryana and West Bengal, Kerala and Mizoram.

Keywords Composite-scores • Environment • Infrastructure • Sustainability

11.1 Introduction

The twenty-first century has witnessed rapid urbanization in Asia, particularly for the large population giants like China and India. Such unprecedented urbanization in India has brought to the fore several issues and challenges in terms of physical and socio-economic environment, infrastructure as well as city management for the last couple of decades. Urbanization in India is mainly a product of demographic

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explosion and rural–urban migration dominated by distress. The rural to urban migration is more a result of rural push over the urban pull; since rural areas, due to their stagnation result in higher incidence of poverty, compelling population to move towards urban areas and large cities in particular. This leads to higher concentration of population in a few cities and command of a large proportion of population over limited resources. Of recent, after a policy shift towards global investment accruing higher GDP in post-1990s, India's *large city-centric* urbanization has gained a sheer momentum. The *top-heavy* nature of urbanization in independent India reflects maximum concentration of population in largest cities portraying an uneven distribution of population across the various size-classes. Such imbalances in urbanization have serious implications on the broader issue of sustainability in terms of infrastructural development, environmental balance and societal progress.

11.2 Objective

As Short and Short (2008) have pointed out, city's environment analysis should connect social science and environmental science, simply because both natural and socio-economic environment are equally important. Keeping this notion in mind, this paper attempts to portray the interaction of massive population with existing physical, socio-economic and infrastructural environment in *top ten most urbanized* states (of 2011) like Goa, Mizoram, Tamil Nadu, Kerala, Maharashtra, Gujarat, Karnataka, Punjab, Haryana and West Bengal. Incidentally, these states *consistently* are also the *most urbanized* states of India.

11.3 Data and Methods

The analysis has been attempted at two levels, i.e. the state and the city level and considers important parameters of physical environment (air quality, water quality and solid waste management), socio-economic environment (poverty, slum proliferation and crime) as well as infrastructure and basic amenities related environment (housing, drinking water and sanitation facilities). The data usually pertains to 2000–2001 and 2010–2011. To accomplish this task, latest data has been collected from multiple sources like Planning Commission, Central Pollution Control Board (CPCB), Census of India, Central Ground Water Board (CGWB), National Crime Records Bureau (NCRB), Ministry of Housing and Urban Poverty Alleviation (MoHUPA) and National Sample Survey (NSS). However, certain limitations of data availability has restricted the study of physical environment and crime at city level for representing state, whereas, urban poverty and infrastructural parameters have been dealt at state level. Inferential and quantitative analysis has been attempted based on certain methodologies like-

$$\text{Level of Air Pollution} = (\text{Sum of pollution scores of all stations in a state})/\text{number of stations in a state}$$

where, Pollution levels [of NO_2 (Nitrogen dioxide), SO_2 (Sulphur dioxide), RSPM (Respirable Suspended Particulate Matter), SPM (Suspended Particulate Matter)] at Critical, High, Medium and Low level get weights of 4, 3, 2 and 1 respectively

$$\text{Composite Index (Sum of Z-score values of indicators/number of indicators)}$$

where Z-Score = $X-\mu/\sigma$, where X = Indicator value, μ = Mean and σ = Standard Deviation

11.4 Discussion and Analysis

The first section consists of an overview of urban growth and urbanization in the top ten urbanized states. The second section provides a spatio-temporal variation of various parameters of urban environment for these selected states. The third section presents an aggregate picture of all environmental indicators for the selected urbanized states. Finally, the last or the fourth section focuses on issues related to urban management.

11.4.1 Urban Growth and Urbanization

Data on urban growth rate pertaining to three decades shows considerable spatio-temporal variations in the top ten most urbanized states of India. Though urban growth rate has slowed down in India on the average, being responsive to the Demographic Transition; yet trends in urban growth display that Kerala, Karnataka, Gujarat and West Bengal have shown higher growth particularly during the 1991–2001 to 2001–2011 period. On the other hand, urban growth has slowed down in states like Goa, Mizoram, Tamil Nadu, Maharashtra, Punjab and Haryana. However, the urban growth rates are presumably higher than the rural counterparts as shown by the Urban Rural Growth Differentials. Thus, barring two instances (i.e. Karnataka in 1981–1991 and Kerala in 1991–2001), URGD shows positive values in most cases (Table 11.1).

In contrast to urban growth, the degree or level of urbanization (expressed in terms of ‘Percentage of urban population to total population’), in most of the selected states have been *consistently higher* than national average throughout three decades. Significantly, all the states have reported increasing level of

Table 11.1 Changes in rural and urban growth rates, 1981–2011

State	Rural growth (%)			Urban growth (%)			URGD		
	1981–1991	1991–2001	2001–2011	1981–1991	1991–2001	2001–2011	1981–1991	1991–2001	2001–2011
Goa	0.07	−0.19	−2.05	3.96	3.35	3.02	3.89	3.54	5.07
Mizoram	0.00	1.85	1.60	9.59	3.27	2.60	9.60	1.42	0.99
Tamil Nadu	1.25	−0.52	0.64	1.79	3.65	2.39	0.54	4.17	1.75
Kerala	0.35	0.96	−3.00	4.76	0.74	6.56	4.41	−0.22	9.56
Maharashtra	0.73	2.40	0.99	3.97	2.97	2.12	3.24	0.57	1.14
Karnataka	1.63	1.16	0.71	0.41	2.56	2.74	−1.22	1.40	2.03
Gujarat	1.42	1.59	0.89	2.95	2.84	3.07	1.54	1.25	2.19
Punjab	1.63	1.19	0.75	2.54	3.21	2.30	0.91	2.02	1.55
Haryana	2.06	1.92	0.94	3.61	4.11	3.69	1.54	2.19	2.75
West Bengal	2.07	1.57	0.74	2.58	1.81	2.60	0.51	0.25	1.86
India	2.05	1.76	1.16	3.14	2.82	2.76	1.09	1.06	1.61

Note: URGD = Difference between exponential growth rates of urban population and rural population
Source: Census of India, 1981–2011

urbanization at the end of each decade (Fig. 11.1). During 2001–2011 in particular, most of these states have shown a much higher level of urbanization than the national average. For instance, more than half of the population of Goa and Mizoram is urbanized (62.17 and 51.51 % respectively), followed by Tamil Nadu (48.45 %) Kerala (47.72 %), Maharashtra (45.23 %), Gujarat (42.48 %), Karnataka (38.57 %), Punjab (37.49 %), Haryana (34.79 %) and West Bengal (31.89 %) just slightly above the national figure (31.16 %). Another aspect of urbanization of these states is the rapid increment of the number of towns and cities from 1991 to 2011 Census. The striking cases are Kerala (from 99 to 520), West Bengal (from 375 to 909), Tamil Nadu (from 832 to 1,097) and Maharashtra (from 378 to 535). In many states like Kerala, Goa and West Bengal, this increment has been attributed to the sharp increase in the number of Census Towns.

11.4.2 Urban Environment

11.4.2.1 Physical Environment

For the assessment of various parameters in physical environment, city or town level secondary data has been used for drawing inferences for the entire urban picture of the representative state. This has been due to limitations of aggregate data for all urban centres of the state. Data of few large urban centres have been collected and published, thereby excluding a very large number of medium and small towns leading to a partial picture.

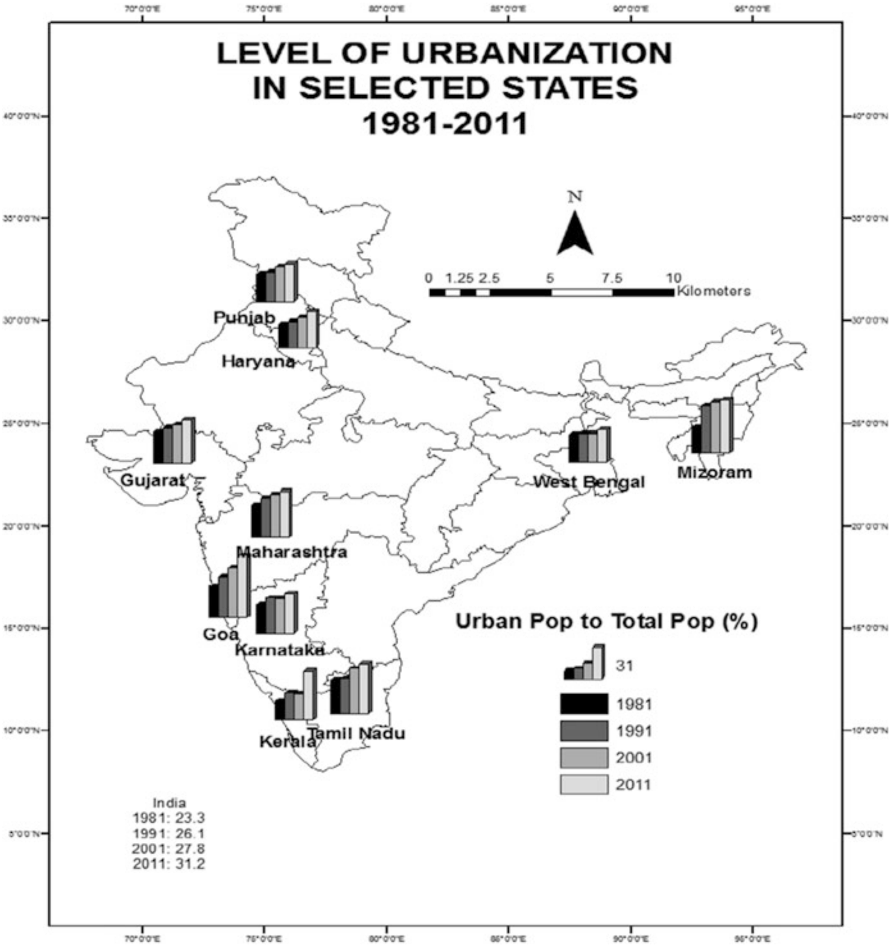

Fig. 11.1 Level of urbanization in study area, 1981–2011

Air Quality

In most of the stations across cities, RSPM and SPM appear as major air pollutants (Fig. 11.2). In almost 18 % stations, SPM is at critical levels, whereas in almost 23 % stations, RSPM level is critical. NO_2 level is quite higher in selected cities like Mumbai, Bangalore, Gulbarga, Pune, Nagpur, Ludhiana and all stations in West Bengal. However, only one station (Victoria Hospital) in Bangalore and one station (PRS Hospital) in Trivandrum exhibit critical level of this pollutant. SO_2 is found at low levels in almost all the cities.

Table 11.2 highlights the problematic cities, where some stations report air pollutants like SPM and RSPM to be at critical levels:

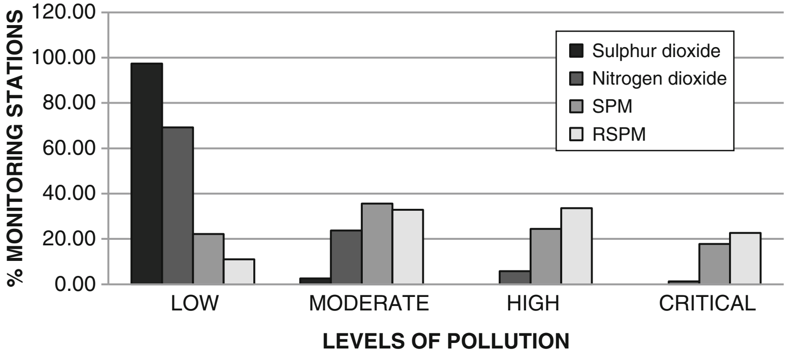

Fig. 11.2 Air pollution levels in selected states (urban), 2008

Table 11.2 Critical pollution level of SPM and RSPM in cities of India, 2008

Pollutant	Problematic cities	Problem states
SPM	Faridabad, Bangalore, Aurangabad, Gulbarga, Hubli-Dharwad, Chandrapur, Nagpur, Navi Mumbai, Govindgarh, Kolkata	Karnataka, Maharashtra, West Bengal and Haryana
RSPM	Jamnagar, Faridabad, Bangalore, Hubli-Dharwad, Chandrapur, Amravati, Kolhapur, Nagpur, Navi Mumbai, Pune, Govindgarh, Jalandhar, Khanna, Ludhiana, Howrah, Kolkata	Karnataka, Maharashtra, Punjab, West Bengal, Haryana and Gujarat

Source: compiled from National Ambient Air Quality Status, CPCB, 2008

Composite scores of weighted air pollutants show that West Bengal is the most polluted state (Fig. 11.3). A large number of monitoring stations have reported critical as well as high levels of SPM and RSPM. On the other hand, smaller states like Haryana, Goa and Mizoram have reported low levels of pollution. One should also note that CPCB report of *National Ambient Air Quality Status* (*2008*) states: "The locations violating the NAAQS requirement for RSPM in industrial area is 78 % and 87 % in residential area. The percent locations violating with respect to NAAQS for SPM in industrial area is 43 % and in residential area it is 84 %. In sensitive areas, the percentage violation is indicated as 23, 62, 92 and 100 for SO_2, NO_2, RSPM and SPM respectively" (CPCB[1] 2009, p. 18).

Water Quality

Available secondary data at river basin level makes it almost impossible for us to quantify water quality at city or state level. However, CPCB data and reports have provided some important observations at the city level. We know that urban centres of India depend either on nearby river or groundwater for water supply purpose.

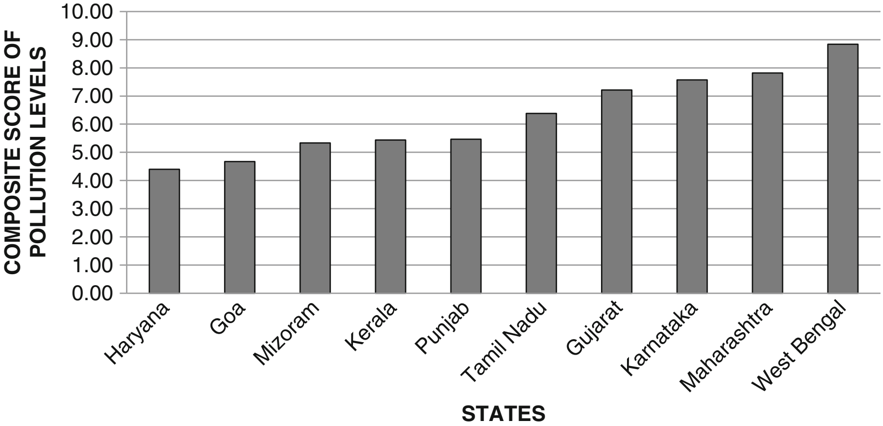

Fig. 11.3 Air pollution status (urban), 2008

It has been found, as CPCB affirms, that industrial wastes and municipal sewages pollute river stretches along these urban centres. CPCB has assessed groundwater quality of some states, in which Mizoram (pH, conductivity), Punjab (pH, conductivity), Kerala (BOD, Total Coliform) and West Bengal (pH, conductivity, total Coliform, BOD) show desired level of ground water quality. But, considerable number of stations in Kerala, Maharashtra and Gujarat do not meet the pH criterion. CPCB has also identified polluted river stretches and stated possible reasons behind this pollution. Some examples of most *polluted* and *risky* river stretches are along Markanda river (due to industrial wastes from Kala Amb and Narayangarh), Western Yamuna canal (due to industrial and municipal wastes of Yamunanagar) in Haryana; Coovum river (due to municipal and industrial wastes of Chennai) in Tamil Nadu etc (CPCB[2] 2009).

CGWB report (2011) has identified that ground water depletion (mainly due to growing use in domestic as well as commercial front) is taking place in all major cities of these selected states. Sea water intrusion and consequent salinization of water is an emerging problem in Chennai and Mumbai. In Bangalore, nitrate pollution is deteriorating the ground water quality. In Chandigarh, rising of shallow aquifer levels has led to waterlogging in some parts. In Thiruvanathapuram, excessive use of ground water for 'water marketing' takes place during summer, thereby creating a pressure on underground water resources.

Solid Waste Generation

Uncontrolled and haphazard urbanization has resulted in generation of huge quantum of solid waste, only part which is properly segregated and scientifically disposed. A recent paper (Kaushal et al. 2012) shows that, according to daily amount of per capita solid waste generated (2000), states like Tamil Nadu, Gujarat, Kerala,

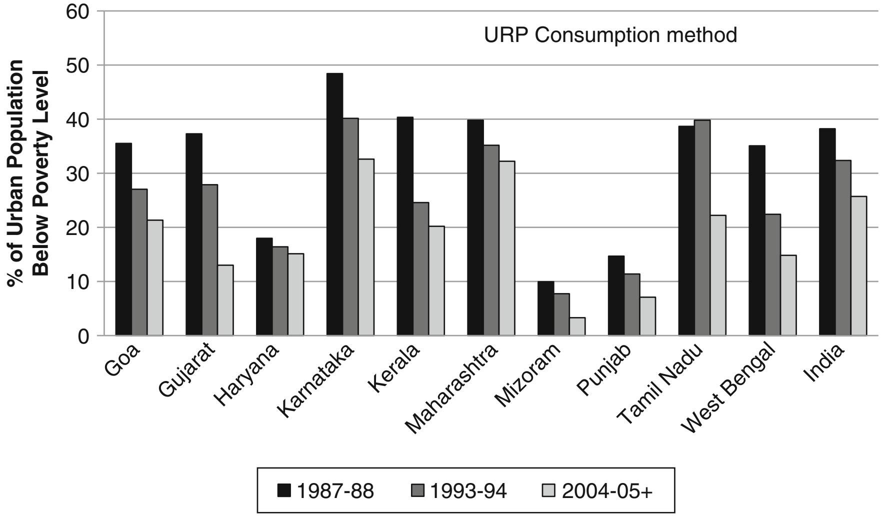

Fig. 11.4 Levels of urban poverty

Maharashtra and Karnataka occupy the highest positions. Haryana, however, reports the lowest amount of solid waste generation. In Mizoram, Punjab and West Bengal, this amount is at moderate level. CPCB data (2004–2005) shows that cities like Mumbai, Chennai and Kolkata generate 5,320, 3,036 and 2,053 tonnes municipal solid waste (MSW), per day, respectively. If we consider physical characteristics of municipal solid wastes in metro cities, compostable matter varies from only 35 % in Coimbatore (Tamil Nadu) to 58 % in Kochi (Kerala). Collection efficiency of MSW also varies spatially, from 82 % in Haryana and Kerala, 80 % in Karnataka to 61 % in Gujarat, and roughly 72–74 % for rest of the states (Sharholy et al. 2008).

11.4.2.2 Socio-Economic Environment

Urban Poverty

Distress in rural India (mainly due to agriculture related problems and inadequate infrastructure) has resulted in migration of large number of poor people to large cities of these states. Therefore, the problem of urban poverty has become one of the critical issues for the city planners. The MoHUPA data on urban poverty, based on estimations of Universal Recall Period method,[1] exhibits that all these states have shown declining percentage of urban poor (Fig. 11.4). Over the decade (1993–1994 to 2004–2005), Tamil Nadu and Gujarat, two economically prosperous states, have

[1] In this method, consumption data is collected (30 days reference period) for all household items.

shown considerable decline in urban poverty. In other states, the decline has been much less than anticipated (MoHUPA Annual Report 2010–11).

Planning Commission estimates (2009–2010) of urban poverty, reveals that Haryana (23 %) and West Bengal (22 %) have substantial proportion of urban poor (Planning Commission 2012). Karnataka (19.6 %) and Maharashtra (18.3 %) are slightly below the national average (20.9 %). Percentage of urban poor is relatively less in Goa (6.9 %), Mizoram (11.5 %) and in socially developed Kerala (12.1 %).

Slums

Perhaps, the best reflection of urban poverty is manifested through presence of slums in urban centres. As Census 2001 data shows, slums in India house a huge chunk of urban residents in all these states except Kerala. Haryana (38.43 %), Maharashtra (34.84 %), West Bengal (33.53 %), Tamil Nadu (26.71 %) and Punjab (26.2 %) had very high percentage of slum population to total urban population. It is also noted that a considerable share of urban poor are engaged in 'low end low paid' informal sector, which hardly fetch them net profits, but just enable to them to make a subsistence livelihood. NSS 66th Round data (2009–2010) on 'Informal Sector and Conditions of Employment' reveals that four states i.e. Gujarat (783 per thousand workers), Tamil Nadu (734), Punjab (711), Kerala (691) and West Bengal (674) have higher proportions of informal sector (Propriety and Partnership) workers among total urban workers (Principal and Subsidiary status) as compared to the national average (669) in non-agricultural sector (NSSO 2012). Recently published slum data of Census (2011) also point out that Maharashtra (22.65 %), West Bengal (21.94 %), Haryana (18.61 %), Tamil Nadu (16.26 %) and Punjab (14.16 %) have higher proportion of slum households to total urban households. The population–environment interface in these dilapidated precarious settlements has several implications on health and well-being, often arising due to lack of basic amenities and service provisioning, indoor air pollution due to increasing use of unclean fuel, overcrowding, improper ventilation and insanitary conditions or be it in the form of fragile social environment that fosters several vices and other urban crime arising out of urban poverty and squalor.

Crime in Cities

The National Crime Records Bureau is the official agency providing crime data at a regular interval of 1 year. Only 13 cities of the selected states are comparable for analyzing temporal changes in cognizable crime rate over the decade. It has been observed that IPC (Indian Penal Code) crime rates have gone up in almost all cities (except Madurai in Tamil Nadu and Nagpur in Maharashtra), whereas SLL (Special and Local Laws) crimes have gone down in most cities (Table 11.3). Kochi has shown exceptionally high increase in rates of both IPC and SLL crimes.

Table 11.3 Crime rates of selected cities, 2000 and 2010

	IPC crime		SLL crime	
City	2000	2010	2000	2010
Ahmedabad	330.5	474.5	270.8	184.2
Bengaluru	476.4	566	57.2	36.9
Chennai	92.1	169.2	1,040.9	794.1
Coimbatore	281.9	289.1	226.3	198.3
Kochi	300.2	1,897.8	88.7	2,263.5
Kolkata	99.4	117.3	7,962.1	6.8
Ludhiana	94	252.5	49.5	71.3
Madurai	299.5	223.6	1,810.5	3,121.4
Mumbai	156.3	207.3	31.3	29.1
Nagpur	457.5	364	173.5	1,202.1
Pune	248.8	362.1	283.8	167
Surat	161	264.2	778.2	636.7
Vadodara	341.2	358.7	486.2	867.7

Note: Crime Rate = Total incidence of crime per lakh population

Source: 'Crime in India', National Crime Records Bureau, 2000 and 2010

11.4.2.3 Amenities and Infrastructure

With growing concern about decent standard of living these days, significance of infrastructure and amenities related environment has increased to a great extent. People can prefer to stay in rural areas, even in smaller towns which have better physical and social environment. But, the trend in India is somewhat different. Large cities, that provide better amenities, economic opportunities and pleasant socio-cultural environment, have become the attractive centres for rural to urban and small town to large city migration streams. Rural people, who come to these cities for earning livelihoods, also expect to access some basic amenities like *housing*, *safe drinking water*, *bathroom*, *latrine facilities* and so on.

Housing

In 2001, majority of good condition houses were found in Tamil Nadu, Goa, Kerala and Punjab (Figs. 11.5 and 11.6). In 2011, Gujarat also reports majority of good condition houses. Over the time period, Mizoram and Karnataka have increased shares of good houses to an appreciable extent. Tamil Nadu, however, has experienced decline of 13 % share of good houses. Kerala and Goa had relatively higher shares of dilapidated houses in 2001. In 2011, even Punjab and Tamil Nadu have seen rise in shares of dilapidated houses. But, both in 2001 and 2011, West Bengal reports higher proportion of dilapidated houses. This is corroborated by the fact that there has been an increase in 'slums reporting majority of unserviceable *kutcha*' households (NSS 65th Round, 2008–2009). Perhaps, this reflects uncontrolled

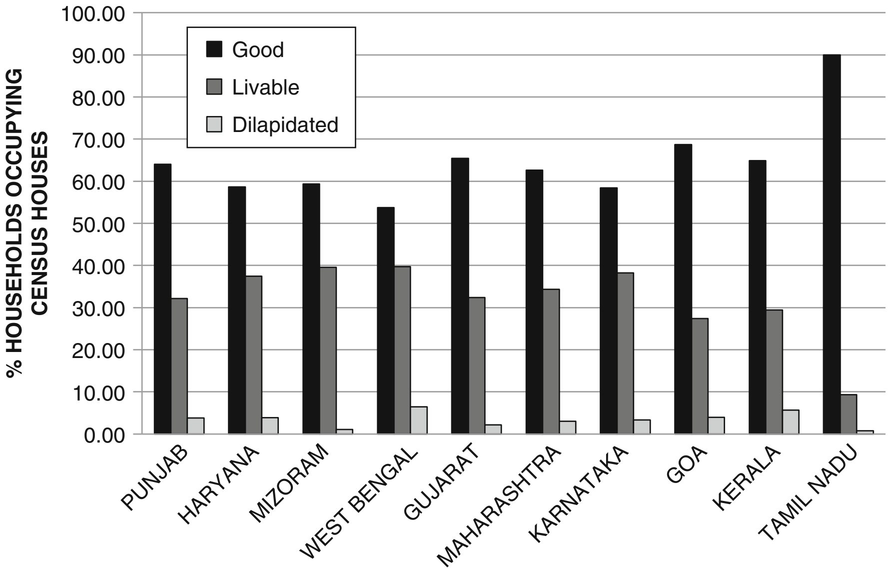

Fig. 11.5 Urban housing conditions, 2001

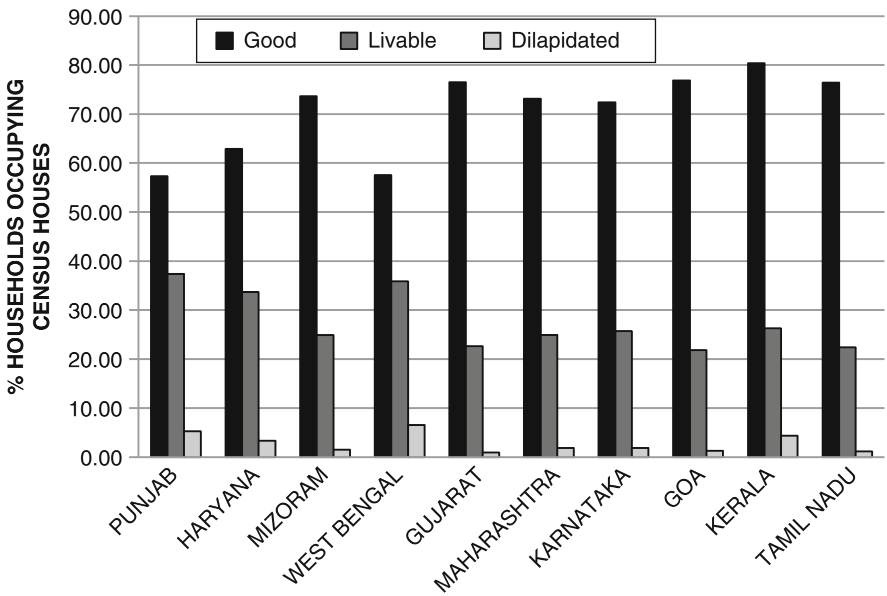

Fig. 11.6 Urban housing conditions, 2011

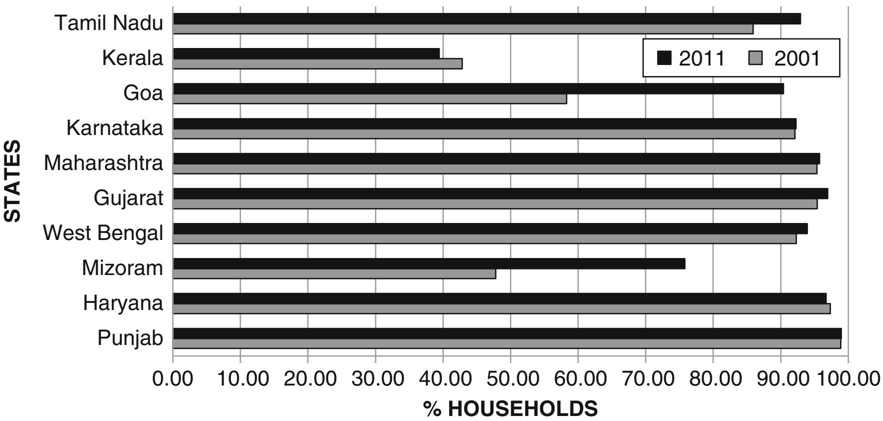

Fig. 11.7 Safe drinking water availability (urban), 2001–2011

proliferation of smaller, non-notified and non-serviceable slums in urban centres, where people just in-migrate, settle down and take up any odd casual job to etch out a subsistence (hand-to-mouth) livelihood.

Drinking Water

In 2001, majority of households used tap water in Maharashtra, Gujarat and Karnataka; hand pump in Punjab, West Bengal and Haryana; other water sources in Mizoram. In 2011, percentage share of households using tap water is higher in Goa, Maharashtra and Gujarat; hand pump water in West Bengal and Punjab; other water sources in Mizoram. Incidentally, Mizoram has remarkably progressed in tap water consumption at household level. A perusal of the conventionally safe water sources like tap, hand pump and tube well together, reflects that performance of Punjab is quite enviable. Apart from this, Gujarat, Tamil Nadu, Karnataka, Haryana and West Bengal have also performed quite well (Fig. 11.7). But, one should also consider that spring, which caters to nearly 12 % households in Mizoram, is generally a safe source of drinking water in such a hilly regional terrain (Kundu et al. 1999).

Bathroom Availability Within Premises

Punjab, Maharashtra and Gujarat had higher shares of such households in 2001. In 2011, Karnataka, Kerala and Goa have higher shares of bathroom availability within premises. In both the years, West Bengal and Tamil Nadu have reported relatively lower share of such households (Table 11.4). In this respect also, Mizoram has shown spectacular progress. The 2011 Census has brought to the fore the data on households with ‘enclosure without roof’, which has concerns on security and privacy. West Bengal, Tamil Nadu, Maharashtra and Punjab have relatively higher share of such households.

Table 11.4 Bathroom and drainage availability at urban household (HH) level, 2001 and 2011

	% HH with connected waste outlet						% HH with bathroom within premises	
	2001			2011				
State	Closed	Open	No	Closed	Open	No	2001	2011
Haryana	35.01	53.39	11.59	49.42	42.82	7.75	75.41	86.13
Punjab	44.97	44.80	10.23	57.63	33.27	9.10	82.76	87.30
Mizoram	8.47	54.52	37.00	20.43	59.05	20.52	64.80	83.66
West Bengal	21.85	45.30	32.86	24.40	42.43	33.17	58.56	59.97
Gujarat	59.26	19.03	21.71	69.44	13.20	17.36	80.62	85.01
Maharashtra	45.07	42.51	22.42	62.70	28.45	8.85	81.60	85.98
Karnataka	41.64	39.33	19.03	56.54	31.06	12.40	79.15	91.70
Goa	38.10	30.93	30.97	54.76	23.19	22.04	77.21	88.69
Kerala	14.85	16.04	69.11	33.54	21.00	45.45	78.91	88.79
Tamil Nadu	34.56	35.46	29.98	44.76	30.18	25.06	66.42	75.50

Source: Household Tables, Census of India, 2001 and 2011

Drainage Facilities

In 2001 and 2011, majority of households with waste water outlet connected to closed drainage are found in Gujarat, Maharashtra and Punjab. Mizoram and West Bengal, on other hand, have lower shares of such households (Table 11.4). Non-availability of drainage was a big concern in states like Kerala, Mizoram and West Bengal (2001). At present, this is a problem in West Bengal and Kerala.

Latrine Facilities

Water closet, is considered to be the best latrine type, was available to majority of the households in Kerala, Gujarat and West Bengal in 2001. In 2011, states like Haryana, Punjab and Mizoram have progressed quite well in this regard. In fact, majority of households in all these ten states have water closets. Non-availability of latrine (Fig. 11.8) has been a grave problem in Maharashtra, Tamil Nadu and Goa. This problem is however minimal in states like Mizoram, Kerala and Punjab. One would appreciate that problem of open defecation has reduced to a certain extent in all the states, especially in the urban areas of Maharashtra, Tamil Nadu and Goa. In fact, *open defecation*, as expressed in Census 2011 data, is relatively higher among urban households of Tamil Nadu, West Bengal, Karnataka, Goa and Haryana.

11.4.3 Fragile Urban Environment

So far as has been analyzed, urban problems are varying in nature, from one state to another as well as over the years. There is no single state, which has performed well in all environmental parameters. Therefore, a composite index, containing all

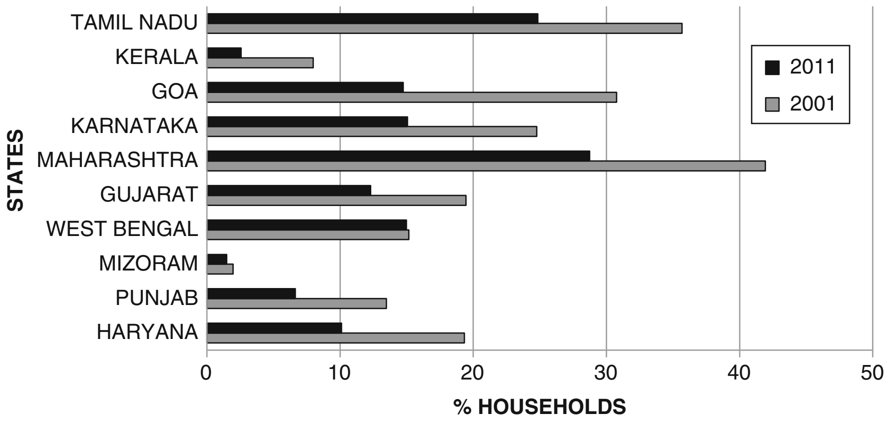

Fig. 11.8 Non-availability of latrines (urban), 2001–2011

Table 11.5 Indicators for composite index of urban underdevelopment/problems

Dimension	Indicators taken
Physical Environment	(1) Air Pollution Level (2008);
Socio-Economic Environment	(2) Percentage Population below Poverty Level (2009–2010); (3) Percentage of slum household to total urban household (2011); (4) Percentage of Informal Workers to Total Non-agricultural Workers (2009–2010)
Infrastructural Environment	(5) Percentage of Dilapidated House; (6) Percentage households availing Conventionally Unsafe Drinking Water; (7) Percentage households having Open Drainage and Percentage households with no access to (8) Bathroom and (9) Latrine (ALL 2011)

Note: Years, for which latest data is obtained, are mentioned in parentheses
Source: (1) CPCB, 2008; (2) Planning Commission, (3) Census of India, 2011; (4) NSS 66th Round; (from 5 to 9) Census of India, 2011

these three dimensions (physical, socio-economic and infrastructural), has been constructed to measure the range of urban environmental problems. This has been done by selecting only the negative indicators of urban environment so as to present a picture of urban underdevelopment in the highly urbanized states. Table 11.5 gives a list of the selected indicators used for this purpose.

The composite index value shows (Table 11.6) that urban environmental problems are relatively less pressurizing in states of Goa, Mizoram, Gujarat, Kerala and Haryana. Except Gujarat, these are the smaller states. On the other hand, larger states like West Bengal, Maharashtra and Tamil Nadu are experiencing more problems or have fragile urban environment. These three states, which boast of popular mega cities of Kolkata, Mumbai and Chennai respectively, may have higher levels of urbanization and associated conveniences, but poor urban environment damages their reputation.

Table 11.6 Composite Index of Urban Environmental Problems

State	Level of air pollution	% urban population below poverty level	% slum HH	% of informal workers to total non-agricultural workers	% Dilapidated households	% HH accessing conventionally unsafe drinking water	% HH with open drainage	% HH without bathroom	% HH without Latrine	Composite index
PUN	5.47	18.1	14.16	71.10	5.24	1.06	42.82	7.37	10.11	0.146
HAR	4.40	23	18.61	64.10	3.38	3.28	33.27	5.18	6.63	−0.082
MIZ	5.33	11.5	13.98	46.90	1.50	24.19	59.05	10.28	1.48	−0.249
WB	8.84	22	21.94	67.40	6.60	6.07	42.43	29.34	14.99	1.045
GUJ	7.21	17.9	6.65	78.30	0.92	3.04	13.20	9.55	12.30	−0.193
MAH	7.82	18.3	22.65	59.50	1.87	4.27	28.45	4.64	28.73	0.240
KAR	7.57	19.6	13.70	64.20	1.93	7.73	31.06	3.61	15.07	0.022
GOA	4.67	6.9	2.45	43.60	1.31	9.60	23.19	5.09	14.75	−0.916
KER	5.44	12.1	1.51	69.10	4.37	60.58	21.00	7.13	2.57	−0.162
TN	6.38	12.8	16.26	73.40	1.18	7.08	30.18	14.83	24.85	0.149
SD	1.48	5.16	7.46	11.10	1.97	18.02	13.02	7.67	8.76	
Mean	6.31	16.22	13.19	63.76	2.83	12.69	32.47	9.70	13.15	

Source: Authors' compilation and calculation from different data sources mentioned beneath Table 11.5

11.4.4 Managing Urban Environment in India

It is being increasingly realized that uncontrolled urbanization in developing nations like India needs a multi-pronged strategy of urban environment management to make cities livable. This is also a pre-requisite or is essential for sustainable cities of future, since the urban tide will continue for years to come. A holistic management of Indian cities calls for disentangling several issues at the city level as well as the intra-city and urban household level. These may be related to provision of shelter/housing and basic amenities and services, urban transport; issues related to water supply, sanitation, drainage, solid waste collection and transport; issues related to pollution and emissions; loss of resources; combating urban crime; hazards and disasters.

In this regard, the Government of India has intervened both at the macro and micro levels by formulating specific and targeted policies. Some of the major initiatives of the GOI have been sector specific pertaining to urban transport, water supply, sanitation, urban environmental infrastructure and solid waste management. On the other hand, certain policies have been specially targeted in managing the economically poorer sections of the urban population groups/subgroups. Some of these include Integrated Housing and Slum Development (IHSDP), Indira Awas Yojana, Urban Infrastructure Development for Small and Medium Towns (UIDSSMT) and Jawaharlal Nehru National Urban Renewal Mission (JNNURM) with its two Sub-Missions of Basic Services for the Urban Poor (BSUP) and Urban Infrastructure and Governance (UIG).

However, in the light of the analysis done in the present study, it is quite inevitable that the urban environment of the consistently highly urbanized states of India had not changed much over the years; rather the urban problems have increased in the face of massive population accretion; particularly with respect to housing, water quality, waste generation and urban crime. Though Census data reveals the increase in basic amenities such as drinking water, availability of bathroom and latrine facilities, the quality/functionality of such provisions need further introspection. Also, the dent created by the above mentioned policies and programmes need further analysis. Moreover, sometimes it has been seen that there are multiple actors in the urban arena which may include the Central and State Government; Urban Local Bodies; Municipal Corporations/Municipal Councils/ Nagar Panchayats under the present decentralized governance. Therefore, earmarking the responsibility of solving any urban problem on any one of them becomes an extremely difficult task. The strength of the urban local bodies as enshrined in the 74th Constitutional Amendment Act lies in peoples participation and peoples desires and strengths. As yet this has not taken off in India, as also local bodies are often found constrained by a gamut of difficulties standing in the way of their smooth functioning.

11.5 Conclusions

The present study therefore brings out the environmental problems of over urbanization in the context of the highly urbanized states of India. Though urban areas portray a plethora of problems, but these have been found to vary widely across the selected states. The trade-off between increased urbanization and deterioration in the environmental quality and pressure on the existing infrastructure is highly marked in the ten selected states of India. However, environmental degradation is not only a manifestation of urban population pressure but also the changing life styles, which often accompany a rise in income levels of a segment of population. On the other hand increasing disparities result in impoverishment of the urban poor/ slum dwellers that also results in deterioration of the urban environment. Combating such problems, therefore, present serious challenge in the twenty-first century not only for the urban managers but also for the researchers and urban analysts in providing ameliorating measures through facts and figures.

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Chapter 12
Temporal Urban Pattern Assessment by Geo-Informatics Technology of Haryana's Town Area

Ritu Sharma and Sultan Singh

Abstract Temporal Urban Pattern Assessment assess that Urban Sprawl is the Major obstacle in urban development. The growth pattern of Haryana's towns is going out of control and the construction land has kept expanding blindly. While doing any type of analysis, we are trying to understand the problem; one has to find and analysis urban social pattern that reflects the social characteristics of urban setting. Urban Pattern Assessment includes status of Haryana's Town in different three periods 1970, 2010 and 2021. The objective of the study is to assess the Urban Sprawl of the City and to check that on which pattern the growth of the city is increasing and it also shows how Remote Sensing and Geographical Information System technology support Temporal Urban Pattern Assessment. The Study follows the Method of Digital Interpretation and finds out the pattern of yearly growth in every town of Haryana. The study finds out Urban Sprawl of the towns from 1970 to till now and future perspectives also. The study is analyzing how much area of Haryana's towns is increasing and encroaching agriculture land and it also find out the growth pattern of the town in which Haryana towns are increasing and its impact for future Proposed Master Plan. The study shows a rapid change in the town's growth which is alarming for the Proposed Plans. Haryana is going to overtake the other states of India in terms of Urbanization.

Keywords Geo-informatics • GIS • Pattern assessment • Remote sensing • Urban sprawl

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12.1 Introduction

Temporal Urban Pattern Assessment assesses that unregulated urban growth and Sprawl is the Major obstacle in the urban development. Land development has been out of control and the construction of land has remains unchecked. In recent years, human activities have been recognized as a major force shaping the Biosphere. This is particularly true in city areas where agricultural land is disappearing each year, converting to urban or related uses. The onset of modern and universal process of urbanization is relatively a recent phenomenon in the process of developing a township in an urban area:

1. Land acquisition.
2. Preparation of developing plan.
3. Site development.
4. Allotment.

12.2 Geo-Informatics

Geo-Informatics is a science which develops and uses infrastructure to address the problems of geo-sciences and related branches of engineering. Geo-informatics combines geospatial analysis and modeling for development of geospatial databases, information system design, human computer interaction and both wired and wireless networking technologies.

12.2.1 Application of Geo-Informatics in Urban Planning

Urban Planning by Geo-Informatics deeply rely on technological and scientific discipline for sensing, modeling, representing, visualizing, monitoring, processing, and communicating in all fields of Urban Planning that are Straightly related to Geo-informatics.

12.3 Hypothesis

Geo-spatial technology may check urban land acquisition and minimizes human interruptions. By studying Temporal Urban Patterns we can identify the Past, Present and Future urban scenario and also give our suggestion about the future perspective of urban sprawl by using the present analytical technique and side by side using the traditional method of land acquisition.

12.4 Objective

The present study has been undertaken with Four major objectives.

- State Urban sprawl assessment.
- Urban Pattern Assessment pattern assessment.
- Urban Pattern Assessment impact assessment.
- How technology support land acquisition system.

12.5 Study Area

Haryana is a situated between 27° 39′ to 30° 56′N latitude and 74° 27′ to 77°36′E longitude. It covers area of about 44,212 km^2. The state is divided into four divisions for administrative purpose—Ambala, Rohtak, Gurgaon and Hisar. The study area of this project includes 76 towns of Haryana.

12.6 Methodology

- Collection of Proposed Master Plan of towns from Department of Town & Country Planning, Haryana.
- Mosaicing of satellite data in ERDAS 9.1 software.
- Scanning and Geo-referencing of the Master Plans with Satellite data.
- The datum and projection system of Toposheet and Satellite data QB were taken as WGS 84 and UTM respectively.
- Visual interpretation and On Screen Digitization of towns from toposheets as well as on satellite data was done in ArcGIS 9.2.
- Changes in the pattern of respective city were identified.
- Final maps were prepared.
- Final report writing was done after completion of the study.

12.6.1 Data Used

1. Cartosat-1 and Resourcesat P-6 LISS III satellite Images.
2. Quick-Bird (QB) Satellite high resolution data.
3. Proposed Master Plan collected from DTPO.

12.7 State Urban Sprawl Assessment

Temporal Urban Pattern Assessment includes status of Haryana's towns in different three periods (From-Toposheet, Quick-Bird Satellite Data and Proposed Master Plan). Its objective is to assess the Urban Sprawl of the City and to check that on which pattern the growth of the city is increasing. As the study includes 76 towns of Haryana, among all Faridabad has been taken as an example to show state Urban Sprawl Assessment.

12.7.1 Faridabad Town

Faridabad is a city in the south-east of Haryana state in northern India. It lies at 28°25′ 16″ N Latitude and 77°18′ 28″ E Longitude. The district shares its boundaries with the National Capital and Union Territory of Delhi to its north, Gurgaon district to the west and Uttar Pradesh to its east and south. Faridabad District came into existence on 15th of August, 1979 as the 12th district of the state.

Urban Pattern Assessment Study includes status of Faridabad City in different three periods 1970 (Toposheet), 2010 (High Resolution Satellite Data) and 2021 (Proposed Master Plan). Its objective is to assess the Urban Sprawl of the City and to check that on which pattern the growth of the city is increasing and it also tells us how Remote Sensing and Geographical Information System technology support Temporal Urban Pattern Assessment. The Study follows the Method of Digital Interpretation for area extraction after that, boundary of the city is demarcated on Toposheet and Quick-Bird Satellite Data. The Proposed Master Plan First of all is scanned and then Geo-referenced with Satellite data (QB). After this, change in the pattern of the city area is identified and then the final map is prepared (Table 12.1) (Figs. 12.1, 12.2 and 12.3).

Urban growth of Faridabad City is increasing 31.51, 99.61 and 401.097 km^2 with growth rate of 3.998, 12.64 and 50.9 % respectively for the year 1970, 2010 and 2021. This increment highlights the forthcoming over-crowded picture of the Faridabad City which results to analyze the proposed plan again and find out the superlative solutions for these impending situations. The above Toposheet description of SOI and DTPO states the path for the proposed plan for year 2021. On the other hand, Geospatial technology reveals the growth rate of the city is faster than what we assume. With the help HRS data i.e. Quick Bird facilitates the real picture of the current city growth for the sustainability of the urban centers with healthy urban environment to sustain the people as well as the existence of city itself.

Table 12.1 Urban habitation area of Faridabad City in km^2 and %

Faridabad	Toposheet (1970)	Quick-Bird (2010)	Proposed plan (2021)
Area in km^2	31.51	99.61	401.097
Area in % (STGA)	3.998	12.64	50.9

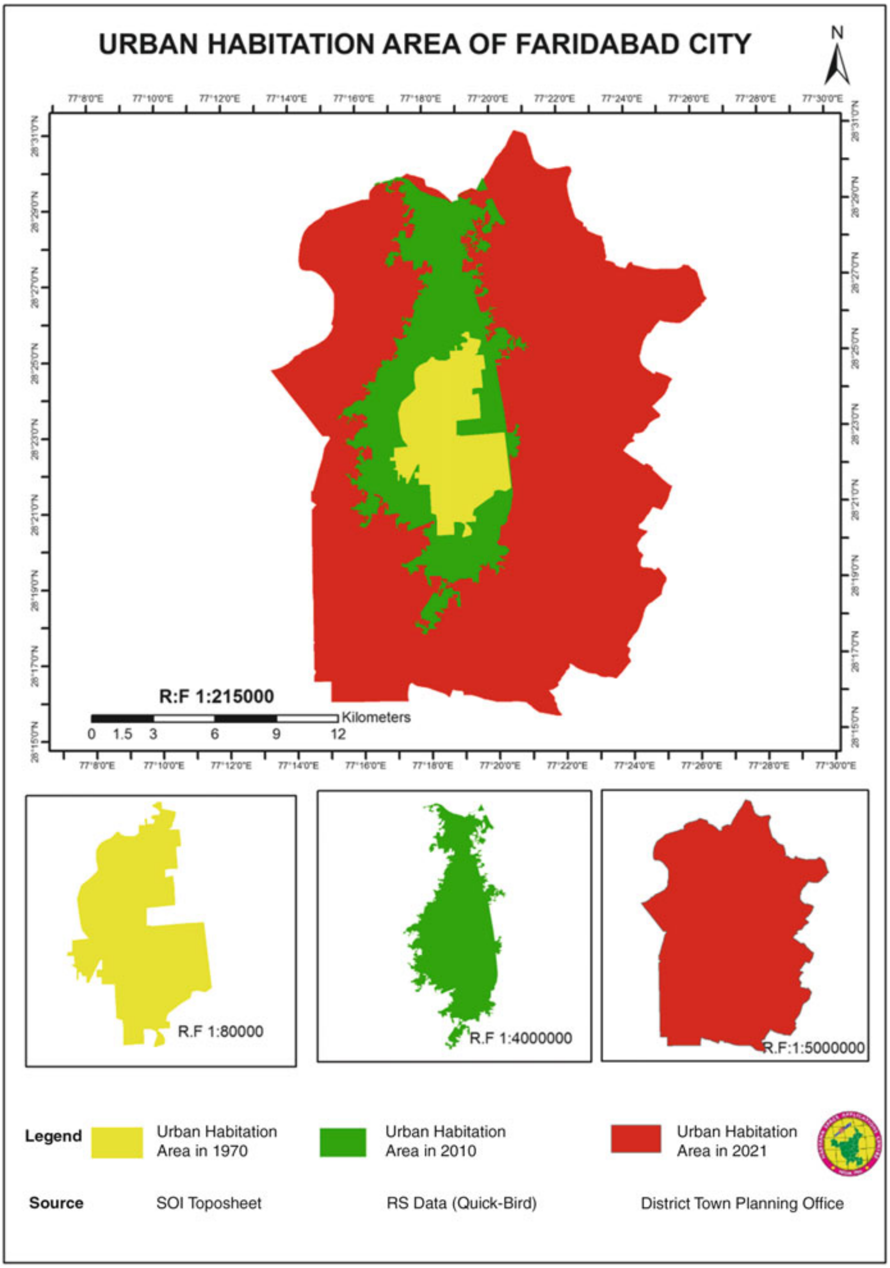

Fig. 12.1 Temporal urban habitation change of Faridabad City

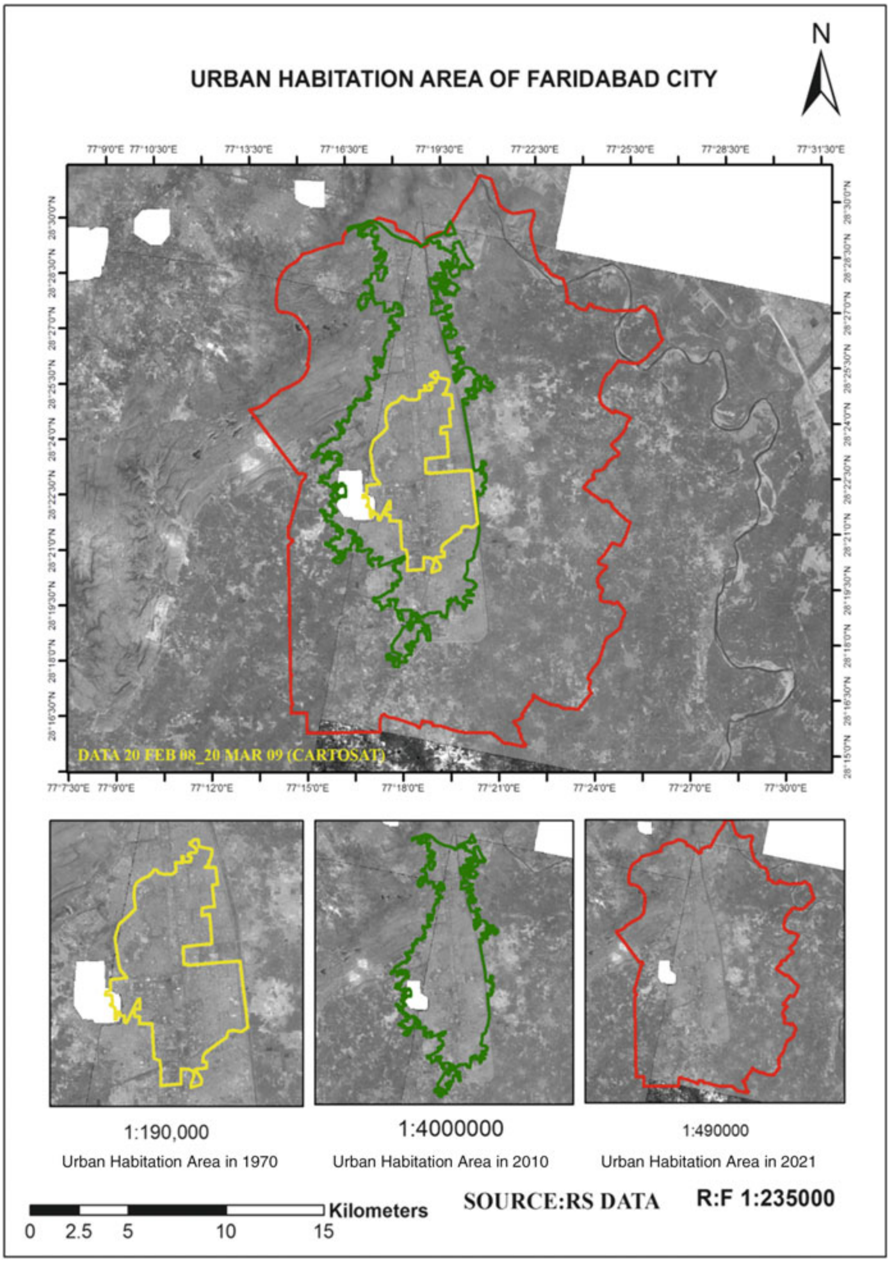

Fig. 12.2 Urban habitation area of Faridabad City on satellite data

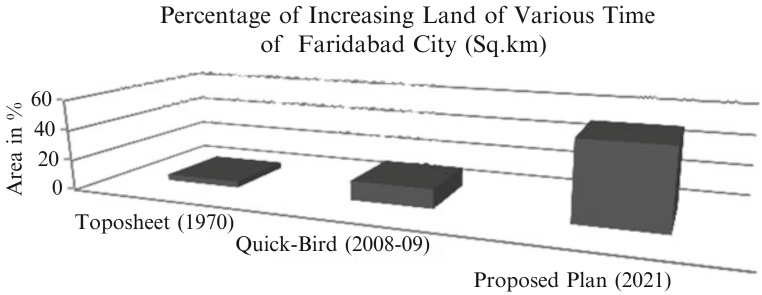

Fig. 12.3 Percentage of increasing urban land of various time of Faridabad City (km^2)

12.8 Result and Discussion

The study of Temporal Urban Patterns for the year 1970, 2010 and 2021 shows a rapid change in the town's growth which is alarming for the Proposed Plans. The pattern at which towns are growing will cause a lot of misbalance and problems in the coming years.

12.8.1 Urban Expause of Haryana Towns in the Year 1970

The Study shows that most of the towns in the year 1970 were very small. Out of the 77 present day towns, 49 towns (64 % of total) had an area less than 1 km^2 in the year 1970. Faridabad was the biggest town with an aerial expause of 31.51 km^2 followed by Ambala with an area of 28.67 km^2.

12.8.2 Urban Expause of Haryana Towns in the Year 2010

The present scenario of the arial expause of the towns shows large increment in the area of all the towns. Most of the Towns are now covering more than 1 % area of total geographical area. Currently Faridabad is the largest town of Haryana that covers 99.61 km^2 of area which is 12.64 % of STGA. The towns those covers more than 50 km^2 area are Ambala, Hisar, Gurgaon, Manesar, Faridabad, Panipat and Karnal. It was observed that most of the headquarters towns are expanding were composed to others as it works as a magnetic power for all the opportunity and infrastructure facilitate for people. Towns of Haryana are scattered all over geographical area and expending towards one another, as for example Kurukshetra and Thanesar have expanded increased so much that their area has merged in

Table 12.2 Change in urban area, population and density of urban population in Haryana

Year	1970	2010
Area (km^2)	166.6	896.1
Population	1,00,36,808	2,53,53,081
Density	60,245	28,293

Table 12.3 Average yearly urban expansion in Haryana State

Year	Area (km^2)	% change	% of STGA	Yearly growth rate in town area (km^2/year)	In terms of %
1970	166.59	–	0.376	–	–
2010	896.10	437.9	2.026	18.24	0.041
2021	5,832.12	550.8		493.60	0.116

one another and there is no clear discrimination now between the two towns. While Analyzing status of Haryana's towns in different three times, Faridabad has been found largest town in 1970, 2010 and 2021.

12.8.3 Urban Expause of Haryana Towns in the Year 2021

The study included future prospects of the towns to indicate what is expected to be the situations of towns in the near future (2021) according to Proposed Master Plan by DTPO. Towns those are covereing more than 100 km^2 are Karnal, Yamunanagar, Sirsa, Bhiwani, Narnaul, Rewari, Bawal, Palwal, Kaithal. Towns those have more than 200 km^2 area are Ambala, Kurukshetra, Thanesar, Hisar, Rohtak, Kharkhoda, Sonipat. Gurgaon, Manesar, Faridabad and Panipat have more than 300 km^2 area in 2021 which are expected to be the largest towns. The analysis shows that the Proposed Master Plans will be not able to serve requirement of expansion in the urban management is going to emerge as a big problem for the urban planners. Towns from 1970 to 2010 have already increased twice or thrice times but in future they will increase at such a rapid rate that many of towns may merge with one another (Table 12.2).

12.8.4 Temporal Change Analysis

Temporal Urban Pattern assessment includes status of Haryana's towns at three different times. From 1970 to till now, towns have increased at such a rapid speed, which is alarming for the Proposed Plans. These towns are covering a significant area of total geographical area of the each district. Almost all towns have increase nearly thrice compared to 1970. These towns are covering geographical area by encroaching the agricultural land. The study analyze the Urban Sprawl of Haryana towns from 1970 to till now and future perspectives also (Table 12.3).

It may be concluded from the above analysis that Haryana, one of the most developing states in India is rapidly going towards Urbanization and in Future a very rapid change is expected in its urban growth pattern. Haryana is going to overtake the other states of India in terms of Urbanization. The study indicates that the Towns expected to increase more than ten times in their area from 1970 to 2010 are: Jind, Gohana, Gurgaon, Manesar, Taoru, Safidon, Hatin. The towns which will expand at a higher rate compared at previous speed are Kurukshetra, Thanesar, Dharuhera, Nuh, Samalkha, Panchkula, Haily Mandi and Taraouri. These Towns will increase more than 20 times as compared to 1970. From 1970 to 2010 Towns of Haryana have expanded at 18.237 km^2/year. Thus in future i.e. by the year 2021 they are going to occupy a very large % of total geographical area of the state. The Towns expected to increase more than ten times from 2010 to 2021 are Pehowa, Charkhi Dadri, Gannaur, Sonipat, Nuh, Safidon, Gharaunda, Sampla and Naraingarh and those which are expected to increase more than 20 times in the same period are Uchana, Maham, Kharkhoda, Bawal, Aasandh, Nilokheri and Indri. In the next 10 years urbanization in Haryana is expected to occur at 493.6 km^2/year, which is very fast. If such a fast urban development is allowed to continue, the entire Haryana will be urbanized in the next 99 years.

12.9 Recommendations

Haryana State is highly influenced by the fast growth of Haryana Towns geographical area. The Growth of Haryana's Towns in km^2 from 1970 to 2010 has increased four Times that is period of four decades. But Temporal Urban Pattern Assessment study includes Proposed Plan also that is of 2021, upcoming one decade. The area of Haryana's Town is increasing five times than the previous growth. The pattern of growth in the size of towns is increasing at an alarming rate which is beyond the expected limit.

No doubt, Urbanization is a developing phenomena for any country but it can't be denied that excess of everything is harmful. This study of different three times of Haryana shows the high increment of town's area due to the massive increase of population, shifting activities from primary to other sectors, along with the advancement of people's lifestyle. The prepared index of town's by town and country planning is going out of range in near future. On the basis of the previous study from 1970 to 2021, Temporal Urban Pattern Assessment study also made future predictions till 2051.

If we follow the pattern of town's growth from 1970 to 2010 and after 2010 to 2021 then in coming 17 years the towns will cover entire Haryana's geographical area. It can be predicted that entire Haryana will be urbanized in the year 2038. Based on this study here are some been recommendations that government should follow.

1. No irrigated multi-cropped land shall be acquired by the Government.
2. Where any person other than a specified person is purchasing land equal to or more than 100 acres, in rural areas and 50 acres in urban areas, through private negotiations he shall file an application with the District Collector notifying him of—
   - Intent to purchase;
   - Purpose for which such purchase is being made;
   - Particulars of lands to be purchased
3. That land in any area is required or likely to be required for any public purpose; a notification to that effect along with details of the land to be acquired in rural and urban areas shall be published in the Official Gazette, in two daily newspapers and on the website of the appropriate Government in public domain.
4. To enter upon and survey and take levels of any land in such locality.
5. To dig or bore into the sub-soil.
6. That no person shall enter into any building or upon any enclosed court or Garden attached to a dwelling-house without previously giving such occupier at least 7 days' notice in writing of his intention to do so.
7. In case of any damage caused, or any case of dispute, the officer shall at once refer the dispute to the decision of the Collector or other chief revenue officer of the district, and such decision shall be final.
8. Any person interested in any land which has been notified as being required or likely to be required for a public purpose, may within 60 days from the date of the publication of the preliminary notification.

Where land proposed to be acquired is equal to or more than 100 acres, the Appropriate Government shall constitute a Committee under the chairmanship of the Collector to be called the Rehabilitation and Resettlement Committee, to monitor and Review the progress of implementation of the Rehabilitation and Resettlement scheme and to carry out post-implementation social audits in consultation with the village Panchayat in rural areas and municipality in urban areas. Whenever multi-crop irrigated land is acquired, an equivalent area of cultivable wasteland shall be developed for agricultural purposes. The acquisition of the land for various projects in a district, in which net sown area is less than 50 per cent of total geographical area, shall in no case exceed 10 % of the total net sown area of that district.

12.10 Limitations

- Unavailability of data, Some area of Sirsa is hidden because that is restricted area, so the study do not contain Toposheet area of Rania, Kalanwali, Ellenabad, as well as some part of satellite data also missing due to security reasons.

- Temporal Urban pattern Assessment study include only Haryana's town area, villages and other categories are not included in this. That why the study gives us information only about Towns.
- Temporal Urban Pattern Assessment covers only the existing habitation of the town area; new habitations are not included in it.
- The results and the Conclusions those are find out in this study are based only on the observations by the Satellite data.

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Chapter 13
Urban Environmental Settings of Dharuhera, Haryana Using Remote Sensing

Suresh Chandra, Devesh Sharma, Sultan Singh, and R.S. Hooda

Abstract The Indian Urban Environment is undergoing a radical change with far reaching implications on society and nature. A rapid impetus and thrust is being given to the development of urban areas on sustainable basis to meet the increasing demand of urban population for housing, infrastructure, and green space without comprising the natural resources, assets and quality of life. The present study demonstrates the present status, scope, need, methodology and outcomes of the thematic mapping for the purpose of urban environment analysis for Dharuhera of Haryana State. Satellite data used of this study is taken from high resolution Quick Bird PAN stereo of 2008–2009 with a scale of 1:4,000. Urban land use map is component of Urban Environment Baseline and thematic mapping in National Urban Information System (NUIS). The urban land use classification has been done with a three tier hierarchy level. Various maps for each class at each level (three level) of urban land use i.e., built-up, industrial, transport, water bodies, etc. were prepared. Ground truth and other field information were incorporated in the final maps. The study shows that urban-land use, comprises-Built-up Urban: 6.80 %, Built-up Rural: 1.91 %, Industrial Area: 8.82 %, Commercial Area: 0.51 % and Vacant Land 9.70 %. These maps are very useful for further urban environment setting and further urban planning and management at town and state level.

Keywords Environment baseline and thematic mapping • Environment setting • Urbanization

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13.1 Introduction

It is the physical growth of urban area as a result of global change. Urbanization is also defined by the United Nations as movement of people from rural to urban areas with population growth equating to urban migration. Urbanization is closely linked to modernization, industrialization, and the sociological process of rationalization. Urban planning. Integrates http://en.wikipedia.org/wiki/Land_use_planning land use planning and http://en.wikipedia.org/wiki/Urban_renewal urban renewal to improve the built and social environments of communities by adapting urban planning methods to existing cities suffering from decay and lack of investment.

13.1.1 Problems in Urbanization in India

In India, there is increasingly growing demands of the basic amenities and services in urban areas. Urban areas continue to contribute to country's economy and employment, but they are also suffering from problems like lack of open space, inadequate infrastructure, overcrowding and congestion, lack of safe drinking water and sanitation, insufficient solid waste disposal sites, inadequate green cover and living environment. Apart from these common problems, some of the major urban centers are facing a variety of environment problems like disasters and social problems for example shifting of industrial activity to outside city areas and so on. All these problems are highly unsustainable and thus leading to poor quality of life and health. Thus, urban areas of toady are posing major challenges which call for urgent efforts for urban planning and management, especially focusing on new investments and economic activities.

We are living in an increasingly urbanized world. At the turn of the twenty-first century, about half of the world's population (roughly three billion people) lives in urban areas. It is estimated that in the next 25 years, almost two billion more people will move to cities (Central and South Asia/Environment/360° analysis). Essentially all of these dramatic changes will occur in developing countries, both in terms of the total global urban population as well as increased percentage of the individual country's population living in urban areas. For many developing countries in the Asia Pacific region, the urban population is already large. Further increases in size and rates of growth will no doubt stress already impacted environments. While urbanization is an important driver to environmental change, it is not the only urban–related influence. The conversion of land to urban uses, the extraction and depletion of natural resources and the disposal of urban wastes cities as well as urbanization in general are having global impacts Urban Ecosystems Analysis Identifying Tools and Methods, UNU/IAS Report

This present study is focused on the urban area of Dharuhera Town of the Haryana state. The study has been done on the basis of Design Standards and

Methodology formulated in "NATIONAL URBAN INFORMATION SYSTEM" (NUIS) (74th Constitution Amendment Act—1992) scheme by "Standing Committee on Urban Management" (SC-U) under the "Ministry of Urban Development" (MoUD), in 2006. The major objective of NUIS scheme is to design, organize and establish a comprehensive information system and the study area, materials and methodology designs standard have been discussed

13.2 Objectives of Study

The objectives of this study are:

1. To investigate factors affecting attitudes and behavior of Dharuhera residents towards environment.
2. To access the present status of urbanization with the help of Geo-spatial data and GIS based information system.
3. To identify the urban environment baseline setting and identify linkage with environment issues.

13.3 Study Area

The study area selected for the present study on "Urban environmental analysis by Geo-Informatics" is Dharuhera town in Rewari District of the Haryana State. Haryana State extends from 27°39′ to 30°35′N latitude and 74°28′ to 77°36′East longitude (Fig. 13.1). The state of Haryana is located in the North–Western part of India. The river Yamuna flows on the eastern boundary of the state. The state of Himachal Pradesh forms its northern boundary. On the western side, it is flanked by the state of Punjab. At the southern side, the state is flanked by Arawali Hills and the desert of Rajasthan. On eastern side U.P. is the neighboring state. The total area of the state is 44,212 km^2. The total population of Haryana is 2.54 Crores as per censes (2001). The Haryana is agriculture based state, although it has 24.79 % of the total population of the state. It has total 106 cities. The level of urbanization in Haryana in comparison to India scenario is increasing much better in terms of population and geographical area (Fig. 13.2) Dharuhera, located at latitude 28°13 N 76°47E/28°22 N and Longitude 76°78 E/28°22, 28°22, 76°78 has and the junction of National Highway No. 8 and at a distance of about 72 km from Delhi (Fig. 13.1). It was a sleepy village before 1975 with the establishment of an Industrial Estate over an area of about 240 and emerged on the industrial map of Haryana sectors.

Fig. 13.1 Location map of study area

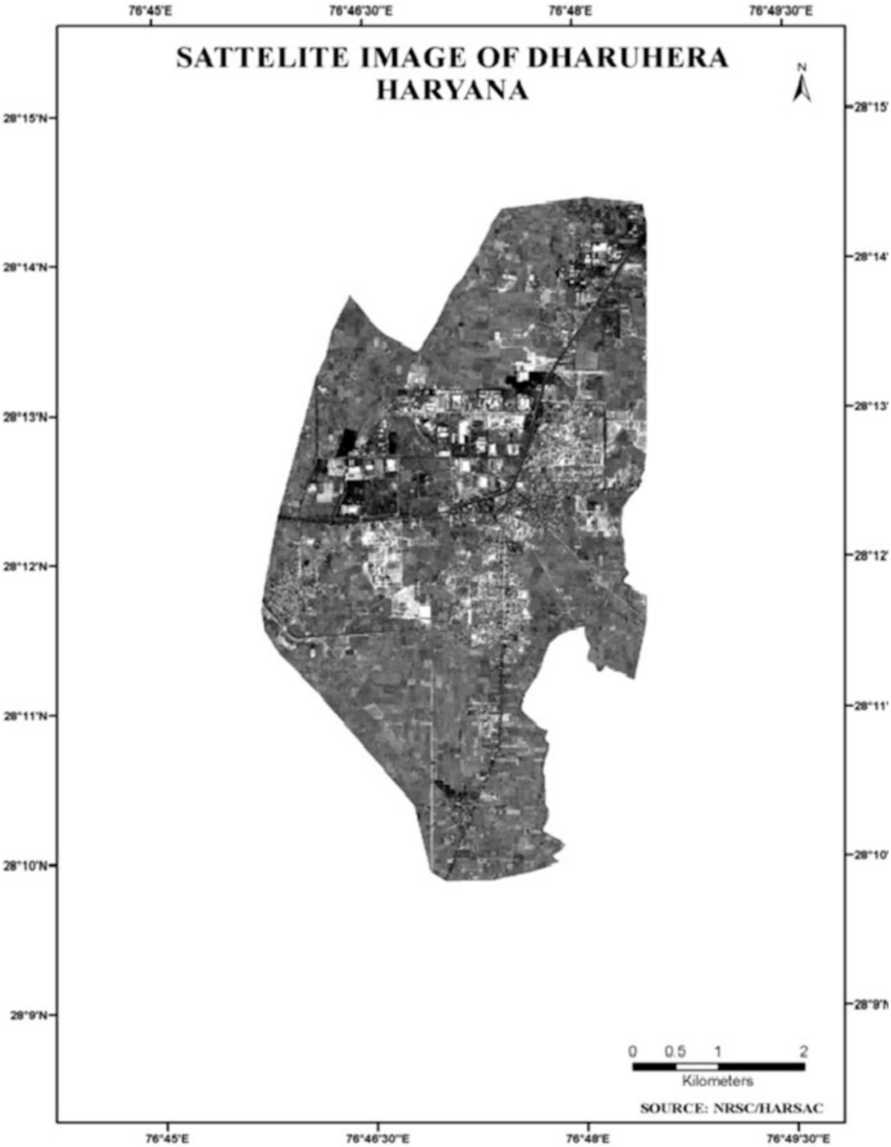

Fig. 13.2 Satellite image (Quick Bird) PAN

13.4 Methods

Quick Bird is a high resolution satellite owned and operated by Digital Globe. Using a state-of-the-art **BGIS 2000 sensor**, Quick Bird collects image data to 0.61 m pixel resolution degree of detail. This satellite is an excellent source of

Table 13.1 About the quick bird satellite sensor

Satellite data and its characteristics					
Satellite	Sensor	Spectral bonds (microns)	Spatial resolution (m)	Swath	Format
Quick Bird	Pan	0.45–0.90	0.61 (nadir) to 0.72 (25° off-nadir)	16.5 × 16.5 km at nadir	TIFF

environmental data useful for analyses of changes in land usage, agricultural and forest climates. Quick Bird's imaging capabilities can be applied to a host of industries, including Oil and Gas Exploration & Production (E&P), **Engineering and Construction** and environmental studies (Table 13.1).

13.4.1 Auxiliary Data

Surveys of India (SOI) Toposheets have been used on the scale of 1:4,000. The number of toposheets used are-53D/16

13.4.2 Ground Truth Data

Ground truth data collected from the field/site from an important source of information for verification, augmentation and accuracy estimation/validation of thematic details mapped from satellite imagery. It is vital for quality assessment and evaluation of the spatial information derived from satellite data.

13.4.3 Secondary Data

The information captured from the imagery would get enhanced in content and quality by use of secondary/ancillary data available both in spatial and non—spatial from published and unpublished sources. The secondary data under this heading broadly confirms to two types:

- Spatial data: Administrative and Town Boundary data is spatial in form. The administrative boundary would consist of different administrative limits such as district, Taluka, village cantonment, wards. Others would consist of forest, sanctuary, national parks and so on…
- Non-spatial data: This data would include as part of the city/town data useful to assist the development of urban indicators. This data would be made available by

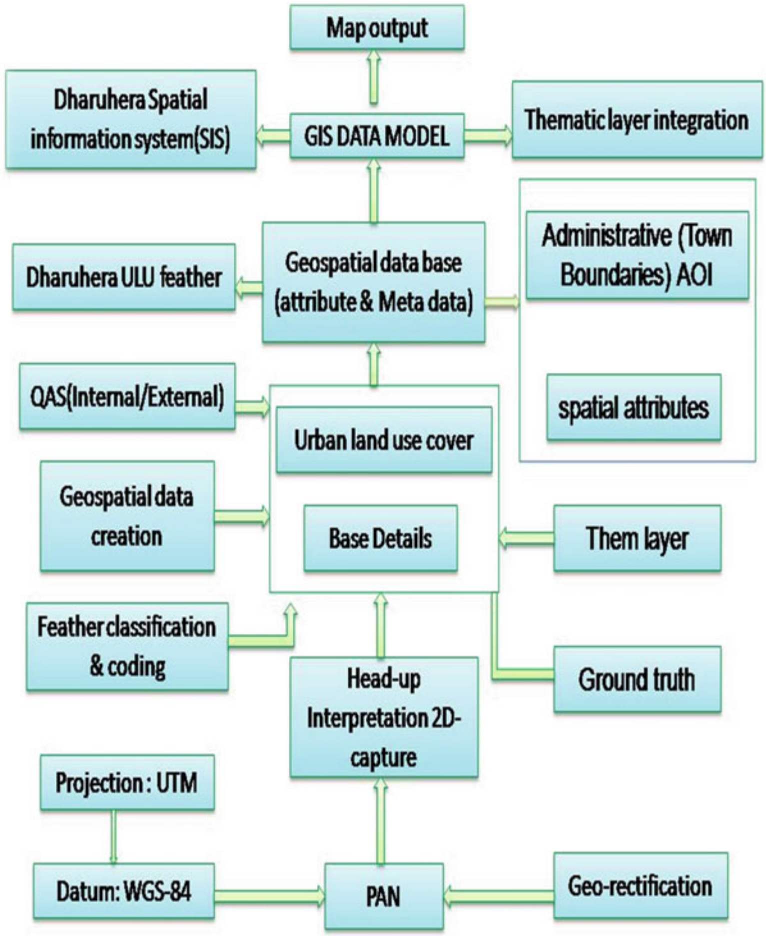

Fig. 13.3 Methodology of thematic mapping

the SNA's/ULB's as an attribute or as a statistical data. The data broadly include urban infrastructure (transportation),

Housing, demography, socio-economic, utilities; environment and land use. The land use includes details of urban land use of residential public/semi-public and so on.

13.4.4 *Thematic Mapping and Data Preparation*

In the present study the whole procedure of Thematic Mapping is done in Personal Geo-database in Arc Gis-9.3 software. The steps involved in the digitization and preparation of Thematic Mapping has been discussed below (Fig. 13.3):

13.4.5 Thematic Mapping and Urban Land Use Feature Extraction

In Geo-database Structure there are two data sets namely;

- Admin boundary/AOI
- Urban_Landuse

13.4.6 Base Layers, Urban LULC Mapping

Feature extraction was done in the Town_Geo-database—Haryana_Dharuhera_Geo-database.

Urban land use was done in Town_ULU_Feature Extraction, as—The raster data has PAN, LISS IV and fused products, while the vector data is organized in a personal Geo-database (PGDB). Out of 37 themes, Physiographic, geomorphology, geology/structures and soils were mapped outside the city core/buildup area whereas urban land use, drainage, surface water bodies, roads, rail, canal, agriculture, wasteland, wetland and transportation nodes were mapped covering the total administrative are of the Dharuhera city. The multiple polygon, line and point Feature Classes can be created within one Feature Database. Each Feature Database is associated with Microsoft Access table in which all the spatial and non-spatial data and its codes are stored. When a particular spatial feature or an attribute data is created, the respective feature code would be automatically attached. In ArcGIS, the interpretation involved the edit mode operation, then the feature class of interest is opened and the delineation of respective thematic classes is completed (Fig. 13.4).

13.4.7 Final Map Preparation and Output Generation

An Arc Map document contained the Geo-database structure. Using the standard ArcGIS interfaces the output was generated based on the design standards and template of NUIS. The area covered by each layer/theme of the total area under study, in percentage, was derived. Finally, thematic map were derived for separately for each layer. The output was generated based on the administrative and planning boundaries of each city/town (Fig. 13.5)

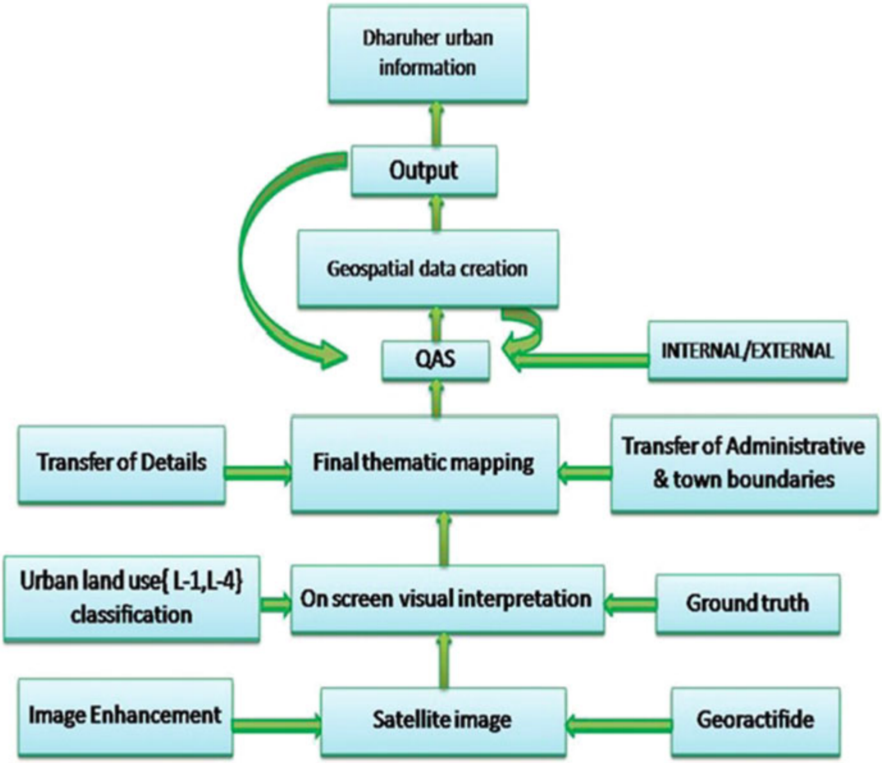

Fig. 13.4 Methodology for urban land use and mapping

13.5 Urban Environment Baseline and Thematic Mapping

13.5.1 Thematic Mapping

The present study "Urban Environment analysis by Geo-Informatics" clearly demonstrates the importance and role of GIS based Information System and potentialities of Satellite Remote Sensing technique for preparation of more updated and reliable information. Here we are going to discuss the results and interpretation of study of Quick Bird (Panchromatic) data mode adhering to guidelines of NUIS Scheme supported by ground truth (secondary and non-spatial data) and quality checks.

13.5.2 Urban Land Use

In the present study, the Thematic Mapping of Urban Land use, which is central to the Master plan/development plan preparation, is the main theme. All other thematic layers' data is used in conjunction with the urban land use thematic data,

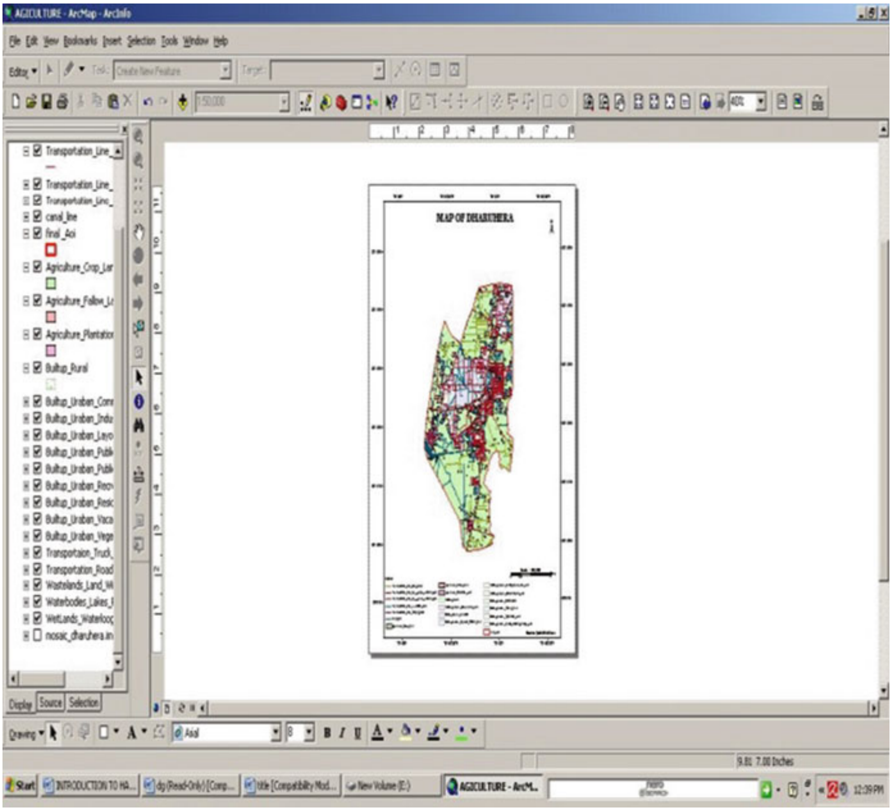

Fig. 13.5 Preparation of final map

while deciding on the future land management, suitability and allocation proposals for Dharuhera town to meet the growing population needs or demands. Under NUIS, the urbanization areas of each town are to be mapped for urban land use using high resolution satellite data. The methodology flowchart for urban land use is shown in Fig. 13.4. The Urban land use classification at 1:4,000 scales has been designed with a three tier hierarchy levels. Each level contains information of increasing content and specificity. The content of land use information in the urbanization areas of city/town is designed to enable subsume with that of land use content of the urban core area. The process of urban land use mapping consist of other important activities like finalization of classification schema and interpretation of urban land use classes and their finalization up to Level-III require detailed collection of information which is provided under NUDBI by SNA and ULB's. During heads up interpretation, the image data is displayed on 1:2,000 scales for area delineation a then compressed to 1:4,000 scales to spatial representations. The urban land use classification at 1:4,000 scale is designed with classes hierarchically arranged with increasing informing content as the levels increase from Level I to

Table 13.2 Distribution of thematic layers in Dharuhera study area

S. No.	Thematic layers (polygon feature)	Area in (% age)
1	Crop land	60.81
2	Fallow land	3.78
3	Agri-plantation	0.08
4	Built-up rural	1.91
5	Commercial area	0.08
6	Industrial area	8.82
7	Layout/plotted land	2.37
8	Public/semipublic area	0.99
9	Public utilities/facilities area	0.19
10	Recreational area	0.33
11	Residential area	6.80
12	Vacant land	9.70
13	Vegetated area	0.41
14	Truck terminus	0.07
15	Road	1.29
16	Land with/without scrub	1.80
17	Lakes/ponds filled	0.09
18	Waterlogged area	0.57
19	Commercial area	0.51

Level-III. The classification also consists of certain land cover classes up to Level II designed to accommodate the rural classes noticed within the urban administrative limits. The description of the classes is given below (Table 13.2) (Fig. 13.6).

13.5.3 Environment Issues

The impact on urban environment are perceived at various levels starting from household level, community level, city level And if unchecked can multiply to issues at regional or national level. This section highlights the environmental that need to address to improve the environmental health of Dharuhera town.

13.5.4 Environment Issues

The impact on urban environment are perceived at various levels starting from household level, community level, city level And if unchecked can multiply to issues at regional or national level. This section highlights the environmental that need to address to improve the environmental health of Dharuhera town.

Data, which is essential for green/open Spaces management. Though technically complex, the remote sensing techniques have revolutionaries the process of data

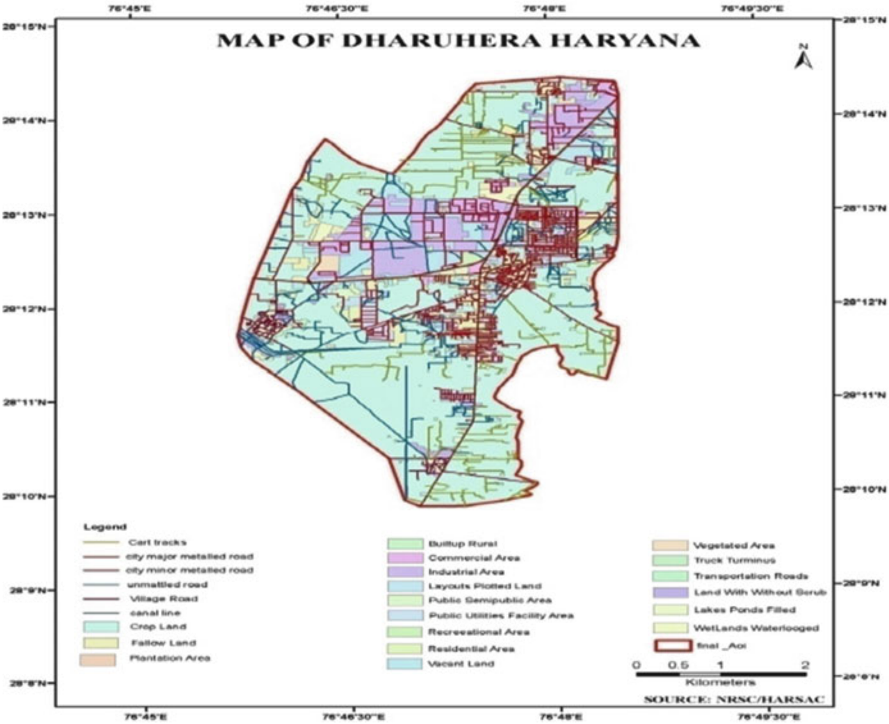

Fig. 13.6 Land use/land cover map of Dharuhera

gathering and map making. About distribution of open spaces in the Dharuhera Town, playgrounds and vacant lands are mainly in the new planned city and covered within 12 wards. Green surfaces are distributed in almost all wards except old city, which are varying in the quantities. These are in the form of garden, agriculture, plantation and natural forest. In Dharuhera town, gardens play an important role to provide natural environment within city. Such types of studies allow monitoring the supply of urban green spaces through time and space against quantitative and qualitative targets and to assess the effects of future policy scenarios.

13.6 Conclusion

The study demonstrates the importance and potentiality Satellite Remote Sensing technique for preparation of more consistent, accurate and up-to-date baseline information on urban land use for future planning, management and development of any area, The present study is derived on the basis of interpretation of Dharuhera Town with the help of satellite data- Quick Bird (Panchromatic) mode. The study together with satellite data incorporated with ground truth data and secondary data revealed that there are total 17 layers in altogether created in 4 Datasets of Geo-database, namely

- Admin boundary/AOI
- Dharuhera_ULU feature

To analysis the rapidly escalating and increasingly complex urban environmental challenges around the world requires the development of comprehensive approaches. Urban ecosystems analysis is the holistic approach that can fulfill this need. However, in order to be truly useful, UEA will have to satisfy the needs of policy makers. The research initiative at UNU/IAS has been undertaken with the goal of developing UEA. This report has outlined the foundations of our approach and identified a number of tools and methods that could be useful in its implementation. Specifically, an urban ecosystems methodology is envisioned as an innovative compilation of guiding principles, methods, and tools selected from a comprehensive array of these entities. This compilation needs take place in light of the environmental challenge being analyses.

13.7 Suggestions

After the image interpretation and data analysis, we come to know that the growth of the Dharuhera town and it's environ is relatively lower than that of the state. Since the city surrounds an agricultural productive land so the expansion of the city urban area will be at the cost of that land. So care must be taken while it's planning. There are some factors responsible for its low urban growth, e.g.

- Lack of industrial share in its economy,
- Slow growth of other social urban infrastructure development

Taking into consideration the above problems following recommendations can be done for the future development planning purpose:

- The agro-industry should be developed in the city so that the potentials of the city environ would be harnessed.
- Some national and state level educational institutes should be set up there that can foster the economy of the city.
- Public infrastructure, e.g. roads, flyovers, planned residential colonies, hotels, restaurants etc. should be developed with combined effort of the city municipality authority and the HUDA.

In the city, the only available land that can be utilized for the purpose of the urban infrastructure development is the vacant land that covers an area of 125 ha. So this available land must be used for the different required purposes.

Part II
Water Management

Chapter 14
Qualitative Assessment of Bank Erosion Hazard in a Part of the Haora River, West Tripura District

Moujuri Bhowmik and Nibedita Das (Pan)

Abstract In West Tripura District Haora is the only major river which is suffering from severe bank erosion due to which it is also gradually shifting. Out of its 46.88 km length, only 19 km stretch has been represented in this paper, within which 4 sites namely, Champaknagar, Rabicharan Thakur Para, Golak Thakur Para and Mekhlipara have been identified as vulnerable to bank erosion through overlay of temporal datasets. This study aims to analyse the temporal change of the bank line of the Haora River and to calculate the Bank Erosion Hazard Index (BEHI) of these vulnerable sites. Overlay of two temporal datasets show the variability of the River Haora during 1932–2009. Then for estimating BEHI intensive field survey has been carried out for qualitative ranking of erosion risk. The variables selected for BEHI are bank height ratio, root depth ratio, weighted root density, bank angle, surface protection, bank material etc. The study shows that the bank erosion hazard rating varies from low to high. The Haora River has shifted about 3–4 km southwards during last 22 years (1.75 m/year) and there is positive correlation between bank erosion hazard rating and shifting.

Keywords Bank material • BEHI • Haora river • Root density

14.1 Introduction

Haora is the only major river in West Tripura District which is suffering from severe bank erosion due to which it is also gradually shifting. Riverbank Erosion is an endemic and recurrent natural hazard. When rivers enter into the mature stage,

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they become sluggish and meander. These oscillations cause massive riverbank erosion. Lateral shifting is a type of change of immense importance which can be detected by its asymmetric position in the river valley and the evidences of its spatio-temporal shift in one direction (Schumm et al. 2000).

Severe bank erosion is going on in several sections of the River Haora, West Tripura District. Out of its 46.88 km length, only 19 km stretch has been represented in this paper, within which 4 sites, namely Champaknagar, Rabicharan Thakur Para, Golak Thakur Para and Mekhlipara have been identified as vulnerable to bank erosion through overlay of temporal datasets.

14.2 Study Area

Study area extends from 23°47′31″N to 23°49′55″N latitude and 91°21′54″E to 91°29′06″E longitude (Fig. 14.1). The region falls under Tipam and Dupitilla group of formation which is characterized by sandy rocks. Tropical monsoon type of climate prevails here. The area is characterized by flood plain, piedmont slopes and uplands where younger alluvial soil and red loam and sandy loam soils are found respectively.

14.3 Aims and Objectives

Aim of this research work is to study the bank erosion problem of the Haora River at Champaknagar, Rabicharan Thakur Para, Golak Thakur Para and Mekhlipara. To fulfill this aim, the main objectives are:

(1) to analyse the temporal change of the bank line of the Haora River.
(2) to calculate the Bank Erosion Hazard Index (BEHI) of these vulnerable sites.

14.4 Materials and Methods

In order to carry out this study Geomatica V 10.1 (for GIS mapping), MS Excel (for statistical analysis), Adobe Photoshop, GPS tool, SOI topographical maps of Ref. No. 79 M/1, 5 and 9 (1:63360 scale), Landsat Imagery (ETM PAN and MSS) have been used.

The present study is mainly based on the intensive field survey and observations. Through overlaying of channels of two temporal datasets, using GIS software, the variability of the River Haora during 1932–2009 in these four sites has been identified. Thus, the rate of change in bank line, loss and gain of land along the river has been calculated. Then for estimating BEHI intensive field survey has been carried out for qualitative ranking of erosion risk. To identify the nature of bank

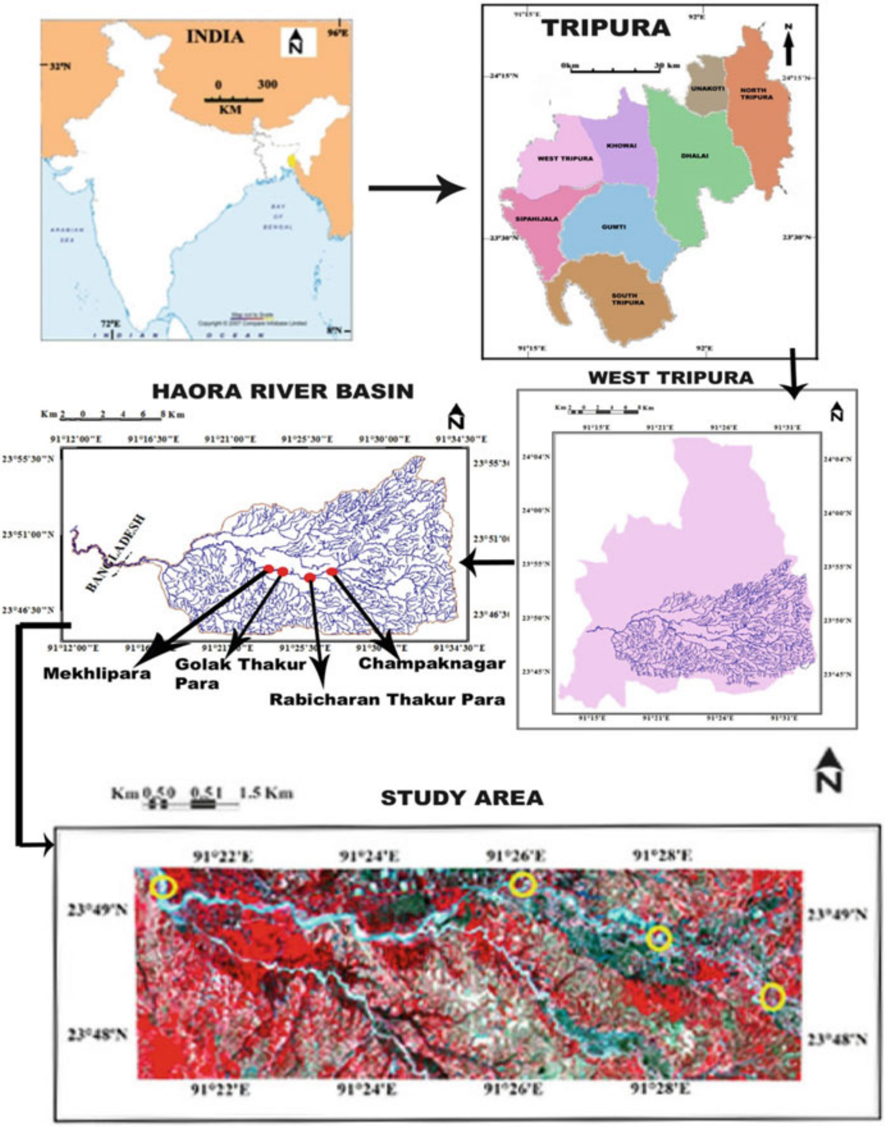

Fig. 14.1 Location map of the study area

material and grain size soil samples have been collected from the bank of the river which indicates the high concentration of sand in the bank material. During field work bank angles at four sites have been measured using Clinometers. Bank height ratio, root depth ratio, weighted root density etc. have been calculated using formulas.

14.5 Results and Discussion

14.5.1 Temporal Change

River bank erosion is the result of a complex set of interactions between hydraulic action of the river and nature of the bank materials. Bank erosion takes place by hydraulic action on the bank materials and mass failure under gravity followed by removal of the failed materials (Laskar and Phukon 2012). Due to continuous erosion of the river bank at Champaknagar, Rabicharan Thakur Para, Golak Thakur Para and Mekhlipara the river is also continuously shifting. In this study a qualitative assessment has been made of the bank line migration of the Haora River for these four sites using two datasets of 77 years, viz. 1932 and 2009 (Fig. 14.2). The bank line migration was measured by overlay analysis of bank lines during these years.

Figure 14.3 indicates that the rate of erosion is higher than deposition. Due to meandering nature of the channel (SI = 1.66) erosion and deposition occur simultaneously. It is observed that some portions are affected by both erosional and depositional activities through which the channel has shifted. Due to bank erosion during 1932–2009 about 7.14 km^2 area (Table 14.1) was lost.

A significant effect of erosion is observed at these four sites between 1932 and 2009, based on overlay analysis of datasets (Fig. 14.4). Bank erosion of the river takes place either simultaneously or intermittently through removal of soil particles from the surface of the bank, sequential failure of the single reach of the bank material due to seepage or undercutting by the river, followed by shear failure of the bank materials (Laskar and Phukon 2012).

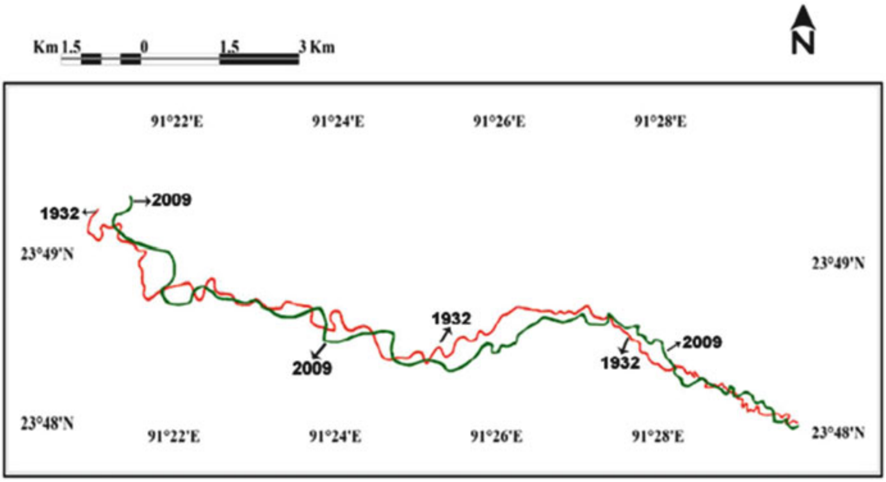

Fig. 14.2 Temporal change of the course of the Haora River at Champaknagar, Rabicharan Thakur Para, Golak Thakur Para and Mekhlipara during the period 1932–2009

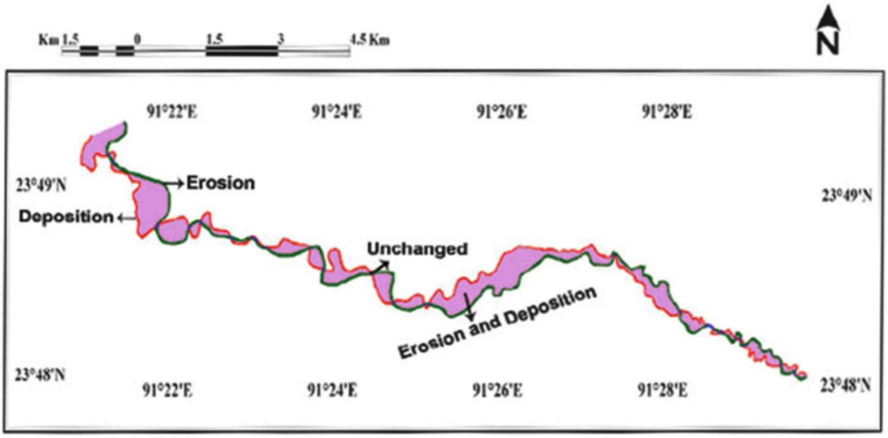

Fig. 14.3 Area of loss and gain due to river bank erosion during 1932–2009

Table 14.1 Area of loss and gain (1932–2009)

Erosion/deposition activity	Area (km^2)
Erosion and deposition	2.91
Erosion	2.07
Deposition	1.85
Unchanged	0.31

Source: Calculated by the researcher

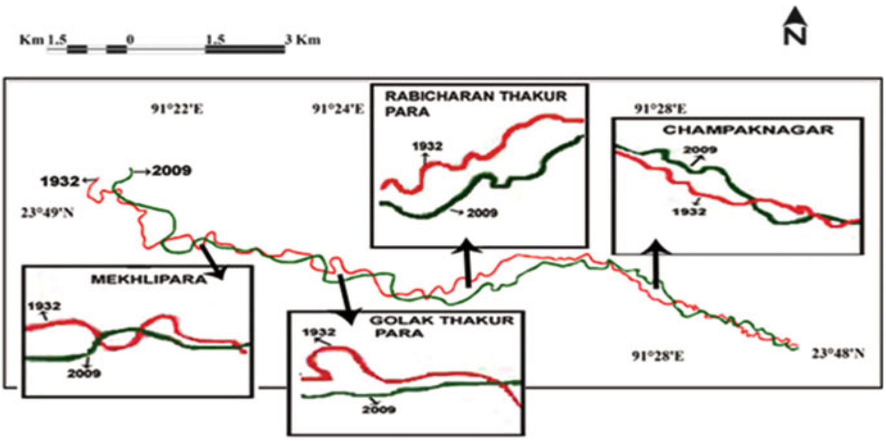

Fig. 14.4 Overlay of two datasets showing variability of the Haora River during 1932–2009. The highlighted segments are the most vulnerable sites for bankline migration

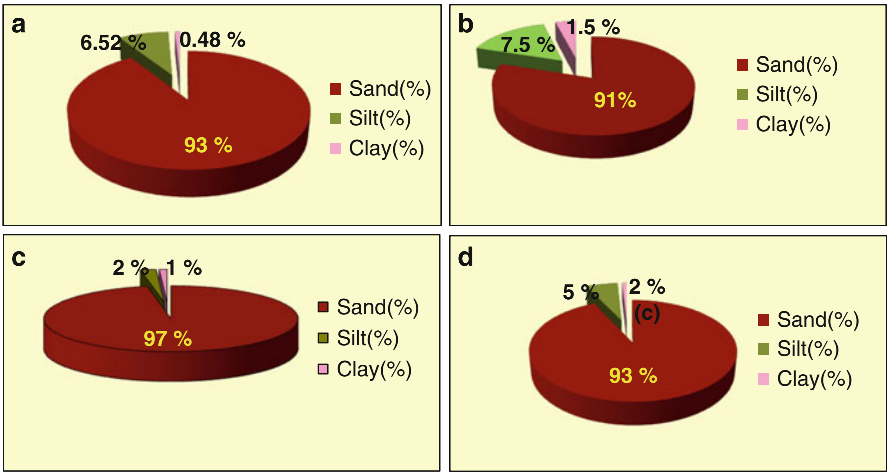

Fig. 14.5 Analytical results of soil samples collected from the bank of the Haora River at (**a**) Champaknagar, (**b**) Rabicharan Thakur Para, (**c**) Golak Thakur Para and (**d**) Mekhlipara

14.5.2 Bank Erosion Hazard

The present study shows a qualitative assessment of the fluvial dynamics of the Haora River. Bank erosion is proportional to erodibility and erosivity. Erodibility is the resisting force which contains nature of bank materials, grain size, vegetation, bank angle and erosivity is the driving force which contains property of the hydraulics, functions of near bank shear stress which are responsible for bank erosion. In this paper only erodibility of the bank has been discussed with the help of Bank Erosion Hazard Index (BEHI) to assess the erosion risk. For estimating Bank Erosion Hazard Index (BEHI) of these four sites intensive field survey has been carried out for ranking of erosion risk.

14.5.2.1 Nature of Bank Material

All sites experience non-cohesive bank material (Fig. 14.5) i.e., sand dominates the bank material with maximum percentage (91–97 %), which lead to maximum erosion and ultimately widening of the channel. Sand and silt particles erode most readily. Cobbles and other large particles are heavier and harder to move. Clay particles stick together and so are also difficult to dislodge (Connecticut River Joint Commissions 1996). At Golak Thakur Para, although the concentration of sand and silt are high, due to high root depth and density the amount of erosion is comparatively less. Figure 14.5 shows the detail result of hygrometer test.

Table 14.2 Grain size distribution at four sites

Grain size (mm)	Champaknagar (%)	Rabicharan Thakur Para (%)	Golak Thakur Para (%)	Mekhlipara (%)
<0.125	21.03	17.55	18.44	29.99
0.125–0.25	32.83	43.76	60.50	24.97
0.25–0.50	24.56	23.90	16.30	30.31
0.50–1	14.22	10.59	4.76	14.73
1–2	5.89	4.20	0	0
>2	1.47	0	0	0

Source: Calculated by the researcher

14.5.2.2 Grain Size Analysis

Non-cohesive bank material is usually detached and entrained grain by grain. Stability depends on the balance of forces acting on surficial grains (Thorne 1991). The samples were tested by sieve analysis method to determine the particle size distribution.

From the grain size analysis (Table 14.2) it is found that the samples are poorly graded fine sand because the diameter size range is 2.0–0.075 mm (as per IS 2720-part 4-1985) and very minimum percent of silt is present in samples. Medium graded sand ranges from 20 to 35 % and fine graded sand ranges from 65 to 80 % overall. As the medium graded sand are more in Champaknagar, Rabicharan Thakur Para and Mekhlipara sites, the shear strength of cohesion less soil is less with respect to Golak Thakur Para site as the fine particle of sand is more. In case of riverbank, the presence of moisture in sand does have some effect in the friction angle. If the friction angle is more than slope of the bank then the stability of the bank fails and erosion takes place. As the sample is medium sand so it is under cohesion less category. Shear strength of cohesion less (sand) soil is less with respect to cohesive soil (clay). Angle of friction (φ) in case of cohesion less soil is more, due to this, inter-granular attraction is less. For these reason erosion takes place in river bank.

14.5.2.3 Vegetal Cover

Vegetation can play an important role in limiting the effectiveness of bank erosion by detachment and entrainment of individual grains or aggregates of bank material. Compared to un-vegetated banks, erosion of well-vegetated banks is reduced by one to two orders of magnitude (Carson and Kirkby 1972; Smith 1976; Kirkby and Morgan 1980).

Large trees and thick woody vegetation tightly bordering stream banks usually prevent erosion. Some bank protection is provided by the tree root system. Shallow rooted vegetation or absence of vegetation provides no protection to banks and therefore indicates probability of higher erosion rates. The banks of fourth order

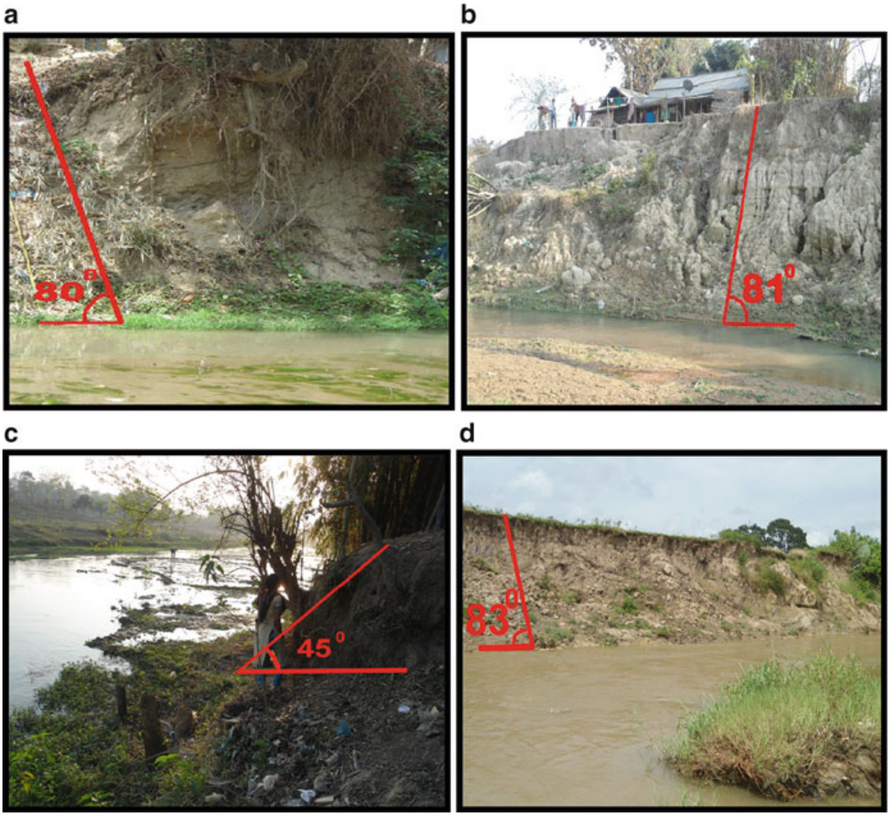

Fig. 14.6 Root-less bank at (**b**) Rabicharan Thakur Para and (**d**) Mekhlipara and deep rooted bank at (**a**) Champaknagar and (**c**) Golak Thakur Para. Presence of steeper bank at (**a**) Champaknagar, (**b**) Rabicharan Thakur Para and (**d**) Mekhlipara indicates high bank erosion. Bank is less steep at (**c**) Golak Thakur Para

stream are covered by large trees providing canopy with deep root system, understory trees and shrubs and ground cover grasses. So, river banks up to fourth order are less pronounced for bank erosion (Shrestha and Tamrakar 2007). Root protects the bank material from erosion. If the roots of the trees enter very deeply and spread widely, it keeps the soil very tight which resist the attack of flow velocity. At Rabicharan Thakur Para and Mekhlipara (Fig. 14.6 b, d) the river bank is vegetation less and so susceptible to more erosion. Again, at Champaknagar and Golak Thakur Para (Fig. 14.6 a, c) root density is 3.84 and 8.63 m/m^2 respectively which indicates the presence of high vegetation cover and thus less erosion occur. Instead of the presence of high vegetal cover, Champaknagar experiences more bank erosion due to the high concentration of sand.

14.5.2.4 Bank Angle

The slope of the eroding bank is an indicator of erosion rate. A vertical slope or undercut bank generally means a high rate of erosion. The lesser the slope of the eroding bank, lower the erosion potential. At most of the areas very steep scarps and undercutting banks are present. In banks with shallow slope angles ($\theta < 60°$), the failure surface is curved and the block tends to rotate back toward the bank as is slides, in a rotational slip. Steep banks characteristically fail along almost planar surfaces, with the detached block of soil sliding downward and outward into the channel in either a planar slip or a toppling failure (Thorne 1982). In nature, many eroding river banks are very steep and near-vertical banks, termed river cliffs, often occur at the outer margin of meander bends and along severely incised channels.

Among the 4 sites, situated along the bank of Haora River, Champaknagar (80°), Rabicharan Thakur Para (81°) and Mekhlipara (83°) (Fig. 14.6 a, b, d) are characterized by steep bank angle which indicates high bank erosion. But comparatively at Golak Thakur Para the bank angle (Fig. 14.6 c) is 45° and it indicates shallow slope due to which less erosion occur here.

14.5.2.5 Bank Erosion Hazard Index (Behi)

Key stream bank variables include bank height ratio (Stream bank height which indicates A and maximum bank full depth which indicates B), Weighted root density, Bank angle, Percent surface area of bank protected, Bank material composition, Root depth ratio. Field experience from direct observations of stream bank instability was used to document stream bank conditions associated with active erosion and various modes of failures. The field measured variables assembled as predictors of erodibility (BEHI), were converted to a risk rating of 1–10 (10 being the highest level of risk).

The risk ratings from 1–10 indicates corresponding adjective values of risk of very low, low, moderate, high, very high and extreme potential erodibility (Fig. 14.7)

The total points obtained as converted from the measured bank variables to risk ratings are shown in Table 14.3. These relationships were established based on a catalog of field observations as opposed to a factor of safety analysis as described by Thorne (1999) and Simon et al. (1999).

Figure 14.7 shows that rank of bank height ratio is more at Champaknagar, Rabicharan Thakur Para and Mekhlipara and less at Golak Thakur Para. Thus, erosion is also more in those places as compare to Golak Thakur Para. The rate of root depth ratio and weighted root density are less at Champaknagar, Rabicharan Thakur Para and Mekhlipara which indicates high amount of erosion. But at Golak Thakur Para the rate is more which indicates less amount of erosion. River banks are very steep at Champaknagar, Rabicharan Thakur Para and Mekhlipara. Thus, the rate of bank angle is also high which indicates high bank erosion. But at Golak Thakur Para the bank is comparatively gentle which indicates low rate and also less erosion. At Champaknagar, Rabicharan Thakur Para and Mekhlipara the value of

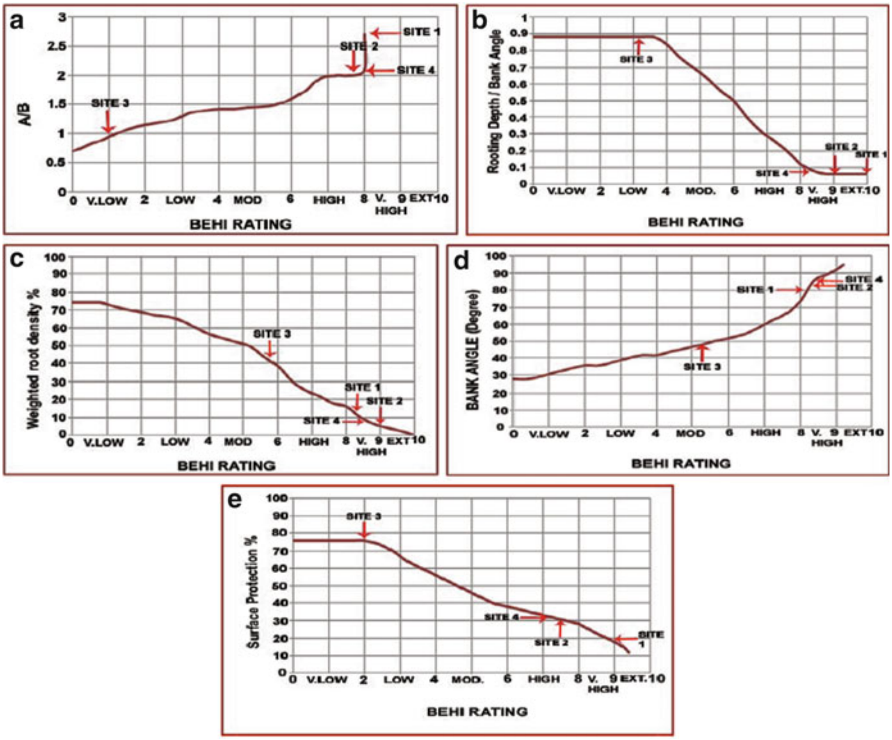

Fig. 14.7 Example of stream bank erodibility variables (**a**) bank height ratio, (**b**) root depth ratio, (**c**) weighted root density, (**d**) bank angle and (**e**) surface protection in relation to the Bank Erosion Hazard Index at Champaknagar (Site 1), Rabicharan Thakur Para (Site 2), Golak Thakur Para (Site 3) and Mekhlipara (Site 4)

Table 14.3 Bank erosion hazard index ranking

BEHI variables	Champaknagar (Site 1)	Rabicharan Thakur Para (Site 2)	Golak Thakur Para (Site 3)	Mekhlipara (Site 4)
Bank height ratio (C)	8.3 (V. High)	7.9 (High)	1.0 (V. Low)	8 (V. High)
Root depth ratio (E)	10 (Ext.)	9 (Ext.)	3.3 (Low)	8.3 (V. High)
Weighted root density (G)	8.6 (V. High)	9(Ext.)	5.9 (Mod.)	8.7 (V. High)
Bank angle (H)	8.5 (V. High)	8.5 (V. High)	5.6 (Mod.)	8.6 (V. High)
Surface protection (I)	9.3 (Ext.)	7.6 (High)	2 (Low)	7.3 (High)
Adjective rating	Very high	Very high	Low	Very high
Total score	44.7	42	17.8	40.9

Source: Calculated by the researcher

surface protection is low as there is no vegetation to protect the soil from erosion which indicates high rate of erosion. Thus, the rate of surface protection of these sites is high. But at Golak Thakur Para the value is more than these three sites. Because there is vegetation cover which protects the soil from erosion. So the rank is less.

14.6 Conclusion

From the above discussion it is clear that within 19 km stretch of the Haora River, three sites namely Champaknagar, Rabicharan Thakur Para and Mekhlipara are vulnerable to severe bank erosion and Golak Thakur Para is comparatively less vulnerable. Because here root depth, root density are higher and the value of surface protection is high. But the presence of sandy soil makes this place erosion prone. But in other three sites, the banks are very steep as well as very sandy. Steeper slopes contribute to sediment transport and erosion. Non-cohesive bank material i.e., sand leads to maximum erosion which ultimately leads to widening of the channel. Beside this, in these three sites, the rank of surface protection is also high which indicates severe bank erosion. From BEHI (Table 14.3) it is clear that Rabicharan Thakur Para (total score 42), Mekhlipara (total score 40.9) and Champaknagar (total score 44.7) are the very high bank erosion hazard zone. Though all the variables at Golak Thakur Para (total score 17.8) show low to moderate rank but the presence of sandy soil (rank 10) in the bank makes it erosion prone area and it falls under low bank erosion hazard zone.

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Chapter 15
Soil Erosion Risk Assessment and Spatial Mapping in Jhagrabaria Watershed, Allahabad, U.P. (India) by Using LANDSAT $7ETM^+$ Remote Sensing Data, Revised Universal Soil Loss Equation (RUSLE) and Geographical Information System (GIS)

K.S. Rawat, A.K. Mishra, V.K. Sehgal, and R. Bhattacharyya

Abstract This article discusses the application of the Revised Universal Soil Loss Equation (RUSLE) in conjunction with LANDSAT $7ETM^+$ remote sensing data, and geographical information system (GIS) to the spatial mapping of soil erosion risk in Jhagrabaria watershed Allahabad, U.P., India. Soil map and topographical data were used to develop the soil erodibility factor (*K*) and a digital elevation model (DEM) image was used to generate the topographic factor (*LS*). The cover-management factor (*C*) was developed based on vegetation, shade, and soil fraction images derived from spectral mixture analysis of a LANDSAT Enhanced Thematic Mapper Plus (LANDSAT $7ETM^+$) image. Support practice factors (*P*) was developed by crossing operation between land use/land cover classification map and slope map. Assuming the same climatic conditions in the study area, the rainfall-runoff erosivity (*R*) factor was not used. The value of *K* for study area lies between 0.25 and 0.485, *LS* values were less than 1.4, *C* and *P* values were less than 1. A soil erosion risk map with five classes (very low, low, medium, medium-high, and high) was produced based on the simplified RUSLE within the GIS environment and was linked to land use/land cover (LULC) image to explore relationships between soil erosion risk and LULC distribution. The results indicate that most succession and mature vegetation are in low erosion risk areas, while Barren and Fallow lands are usually associated with medium to high erosion risk areas. This research implies that remote sensing and GIS provide promising tools for evaluating and mapping soil erosion risk in the Jhagrabaria watershed of India.

Keywords GIS • Remote sensing • RUSLE • Soil erosion risk • Soil loss mapping

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15.1 Introduction

The adverse influences of widespread soil erosion on soil degradation, agricultural production, water quality, hydrological systems, and environments have long been recognized as severe problems for human sustainability (Lal 1998). Analyzing soil erosion risks is an important task, especially in vulnerable areas. Land use and soil conservation planning for large areas requires erosion risk maps, which are typically created using erosion models like USLE, MUSLE and RUSLE (Diana et al. 2011). These models are often developed for different regions than where they are applied (Sang et al. 2011). This paper describes a methodology for mapping soil erosion risks over watershed called ‘Soil Erosion Risk Mapping (SERM)’. The objective of this presented work is to determine the average annual soil loss rate for year 2006, using the RUSLE model for the Jhagrabaria watershed.

15.2 Materials and Methods

15.2.1 Study Area

The Jhagrabaria watershed is situated 45 km to southwest of the Allahabad district of U.P., India (Fig. 15.1). Geologically the area comprises of Upper Vindhayan formations. The minimum and maximum elevations of this area are 90 m (msl) and 180 (msl) respectively.

15.2.2 Remote Sensing Data Acquisition and Database Preparation

LANDSAT 7ETM$^+$ (path/row: 231/67; Table 15.1) was acquired on 27 June 2006. The image was converted to apparent reflectance through an image-based calibration method using the gain, offset and sun elevation angle. This image was geometrically rectified using control points collected from Survey of India (SOI) topographic maps. The nearest-neighborhood resampling technique was used and a root-mean-square error with less than 0.5 pixels was obtained during the geometric rectification of the remote sensing image.

The field data collection and ground-truth work was conducted in August 2006. Different land use/land cover (LULC) types, such as barren land, fallow land, vegetation and water bodies/wetlands etc, were identified and their coordinates were recorded. These data were used as training samples for supervised classification of ETM$^+$ image. About 10 to 15 sample plots for each class were selected. The Maximum likelihood classifier (MLC) was used to classify the ETM$^+$ data into four

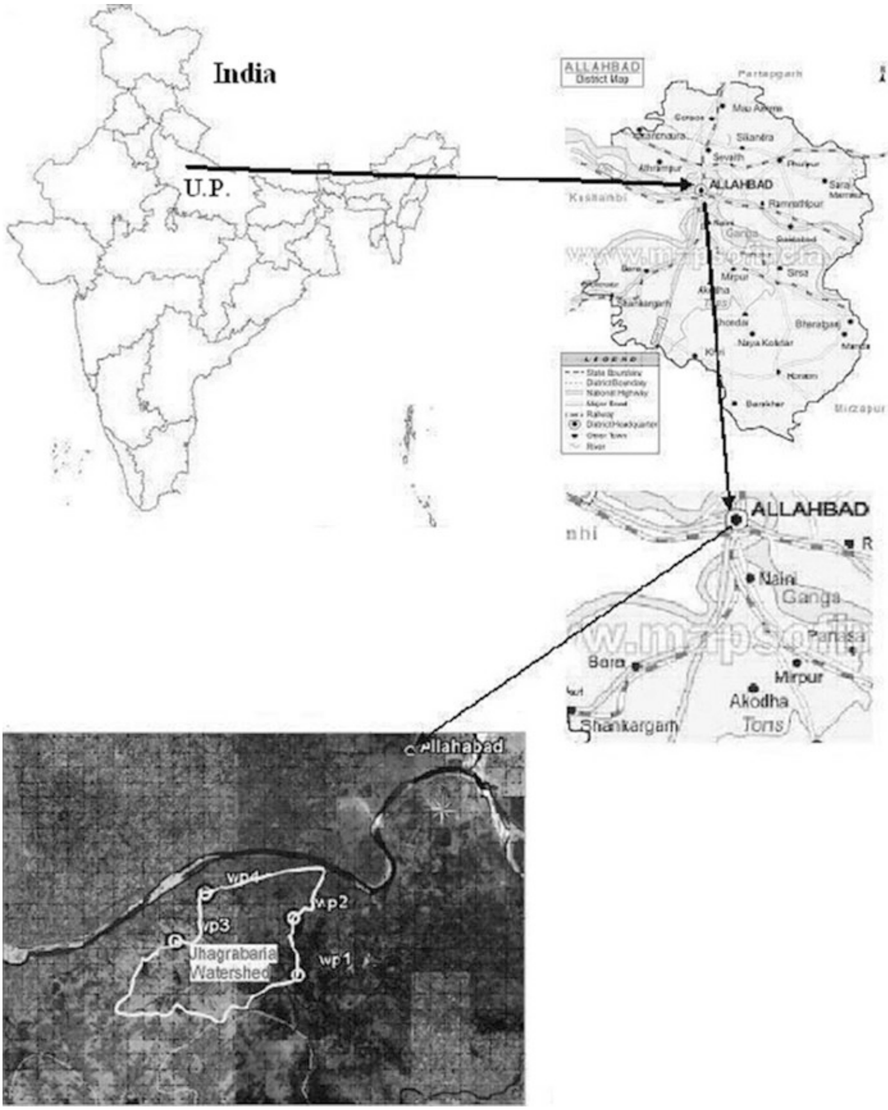

Fig. 15.1 Location of the study area (Jhagrabaria Watershed) in the state of U.P. (India)

LULC viz.; barren land, fallow land, vegetation and water bodies/wetland (Fig. 15.2). Accuracy assessment using field data indicated an overall accuracy of approximately 90 % (Ashwini 2007; Lu et al. 2004).

The LULC map of the study area was recompiled and reclassified into four subgroups namely; barren, fallow, vegetation and water bodies/wet lands. A sizeable area of the watersheds falls into barren land category (24.59 km^2 or 36.91 % of the total geographical area) and almost similar proportion is allocated to fallow land

Table 15.1 Specifications of LANDSAT-7 ETM$^+$ remote sensing data of satellite using in the present study

Spectral bands	Spatial resolution		Spectral resolution	
Band	TM (m)	ETM$^+$ (m)	TM (μm)	ETM$^+$ (μm)
1 (Blue)	30	30	0.45–0.52	0.45–0.52
2 (Green)	30	30	0.52–0.60	0.53–0.61
3 (Red)	30	30	0.63–0.69	0.63–0.69
4 (Near IR)	30	30	0.76–0.90	0.78–0.90
5 (Middle IR)	30	30	1.55–1.75	1.55–1.75
6 (Thermal IR)[a]	120	60	10.4–12.5	10.4–12.5
7 (Middle IR)	30	30	2.08–2.35	2.09–2.35
8 (Panchromatic)[b]	15			0.52–0.90

[a]ETM$^+$ Band 6 (Thermal IR) includes both high and low gain settings
[b]ETM$^+$ Band 8 (Panchromatic) most visible & near-IR data in single band

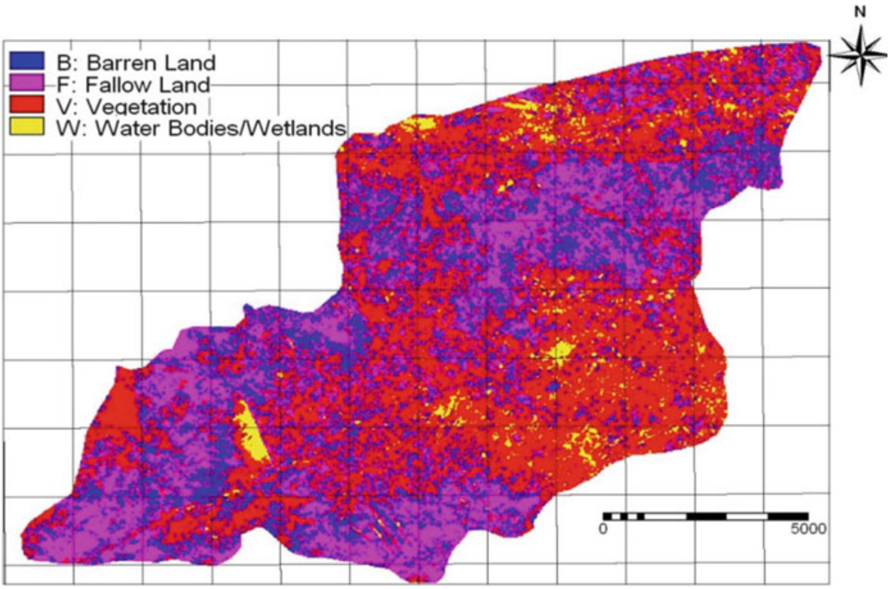

Fig. 15.2 Land use/land cover classification map of the study area based on LANDSAT-7 ETM$^+$ data analysis for June 2006

category (36.62 km^2). These two groups and the water bodies/wetlands mainly consist of the non-productivity land category. Not more than 1/3rd of the geographical area is under vegetation. This is primarily due to recurrent water logging and flooding. The recurring floods take away a chunk of soil along with them which goes on un-noticed. The barren and fallow lands and sole fallow lands, together from the highest area (~49 %) of the entire watershed while nearly almost equal area (47.8 %) is under vegetation. This is a sign of a model setting where the area exposed for erosion offers a very good opportunity to promote water erosion.

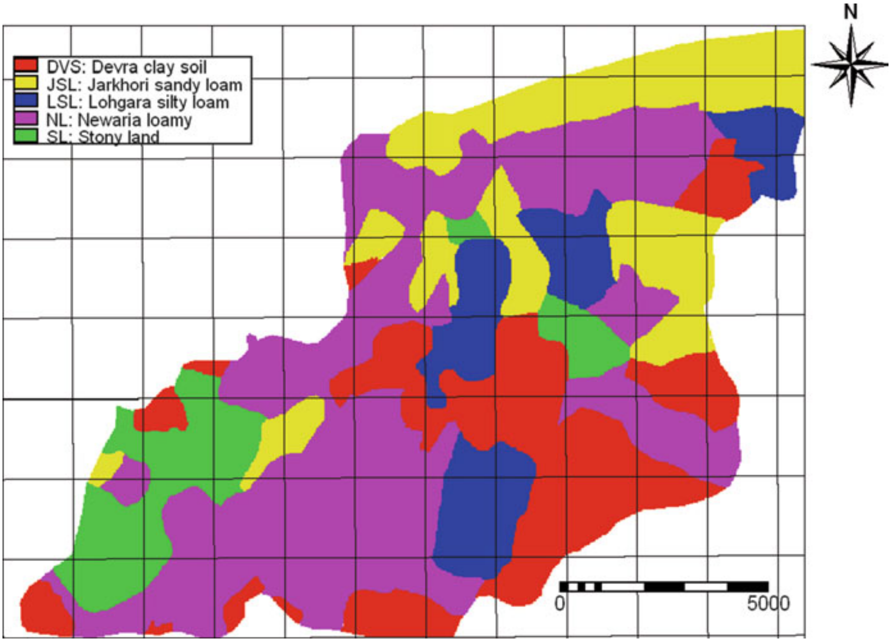

Fig. 15.3 Soil types in the study area and their spatial extent of distribution

The soil map of the Shankargarh block was obtained from Soil Survey Department, Allahabad, U.P., India. The map was scanned and then registered with the help of geo-referenced SOI topographical maps 63G/11 and 63G/12, respectively. The registered soil maps are digitized and different soil attributes were assigned to the different soil groups. The soil taxonomic classes mainly consisted of Devra clay soil, Jarkhori sandy loam, Lohgara silty loam, Newaria loamy and stony land (Fig. 15.3). The soils of the Jhgarbaria watershed are divided into 5 different categories. The watershed is mainly dominated by Newaria loam patties (58.26 km^2 or 38.8 %), Devra clay soils (31.92 km^2 or 21.3 %) and Jarkhori sandy loam soils 27.99 km^2 or 18.7 % of the total geographical area. The entire watershed is vulnerable to soil erosion of a high degree due to presence of sand fraction in large quantities. The stoniness of the land (14.63 km^2 area, ~9.75 %) acts as barrier that generates higher runoff but prevents high soil loss.

15.2.3 Development of Soil Erodibility, Slope Length and Slope Steepness Factors

The value of K is determined either experimentally or theoretically, based on the respective contents of clay and dust particles (<0.10 mm), sandy particles (0.10–2.00 mm), organic matter, soil texture and soil permeability (Table 15.2).

Table 15.2 K-factor (t/acre) as adopted for the analysis in the present investigations

	'*K*' based on per cent organic matter in soil		
Texture class	0.5 %	2 %	4 %
Fine sand	0.36	0.31	0.22
Very fine sand	0.94	0.81	0.63
Loamy sand	0.27	0.22	0.18
Loamy very sandy loam	0.98	0.85	0.67
Silt loam	0.60	0.54	0.42
Very fine sandy loam	1.05	0.92	0.74
Silt loam	1.07	0.94	0.74
Clay loam	0.63	0.56	0.47
Silty clay loam	0.83	0.72	0.58
Silt clay	0.56	0.51	0.43

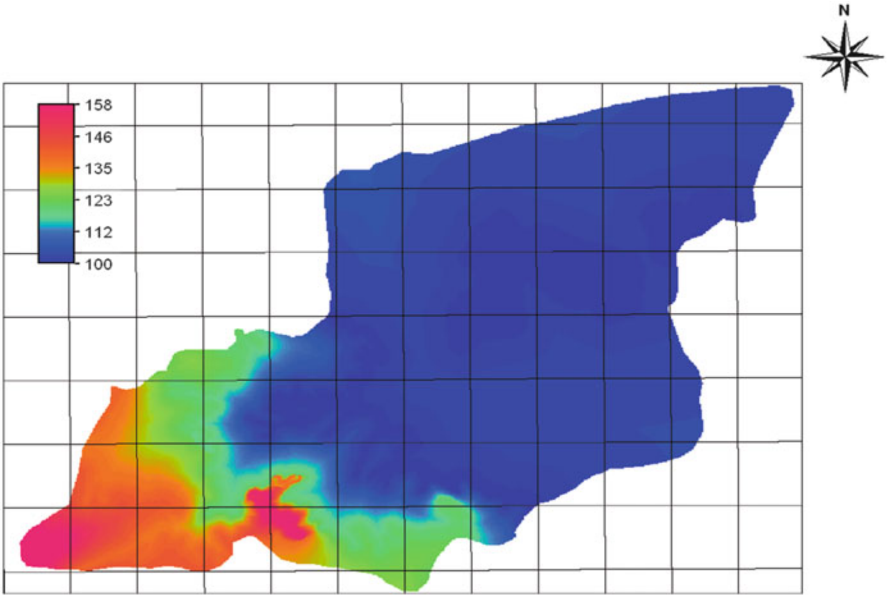

Fig. 15.4 Digital Elevation Model (DEM) showing different elevation classes within the study area

In this study, spatial map of *K* factor was developed based on these data delineated soil map contour lines, rivers, and highest located points were digitized based on 1:50,000 topographic maps 63G/11 and 63G/12, then a 30-meter spatial resolution DEM (Xiea et al. 2002) was generated using the methodology suggested by ILWIS 3.3 in software. Most elevations are between 90 and 180 m above mean sea level and are associated with gentle slopes (Figs. 15.4 and 15.5). The entire watershed has been characterized into four elevation ranges namely 100–115, 115–130, 130–145 and 145–160 m above mean sea level amsl (Fig. 15.4).

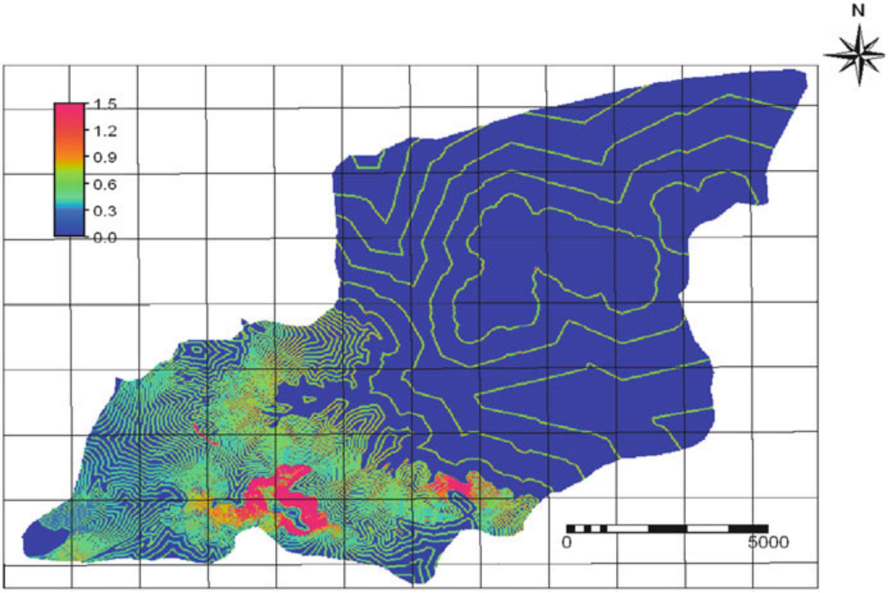

Fig. 15.5 Slope map of the study area superimposed with the contours

15.2.4 Slope Length Factor (L) and Slope Gradient Factor (S)

The common equations used for calculating *LS* are empirical equations (Wischmeier and Smith 1978). The southern-western side of the watershed (Fig. 15.5) is having steeper slope but larger roughness while nearly 2/3rd of the watershed is having moderate slope. Mainly there are two peaks and several mounds in the region while the slope in the entire land is moderate to rolling. Here the following equation for *LS* factor was used with computed programmers and GIS for analytical purposes (ILWIS User Guide 2007).

$$slope = \frac{hyp(Dx, Dy)}{DEM} \times 100 \tag{15.1}$$

where, (Dx) is dfdx and (Dy) is dfdy are two digital gradient filters would be applied to the digital elevation model (DEM).

The relationship between the slope steepness in percentages (S) and slope length in metres (L) in the Cibodas Biosphere Reserve (ILWIS User Guide 2007) has been estimated to be about:

$$L = 0.4 \times S + 40 \tag{15.2}$$

Table 15.3 C-Factors as adopted for analysis in the present investigations

Land use/land cover	C-Factor
Bare soil	1.00
Forest, Dense shrub	0.001
Grassland in good condition	0.01
Grassland in poor condition, overgrazed	0.10
Maize, or millet: high productivity, conventional tillage	0.20–0.55
Maize, or millet : high productivity, conventional tillage	0.02–0.10
Cotton	0.40–0.70
Wheat	0.10–0.40
Rice	0.10–0.20
Sugarcane	0.13–0.40
Plantations after establishment	0.05–0.10

Table 15.4 P-Factor as adopted for analysis in the present investigations

Percent slope	Contouring	Contour strip cropping	Terracing and contouring
1 to 2	0.6	0.30	–
2 to 7	0.5	0.25	0.10
7 to 12	0.6	0.30	0.12
12 to 18	0.8	0.40	0.16
18 to 24	0.9	0.45	–
Level bench terrace			0.14
Reverse slope bench terrace			0.05
Outward sloping bench terrace			0.35

$$LS_1 = \left[\begin{array}{l}(sloplenth/72.6) \times [65.41 \times [\sin\{\deg rad(slop \deg)\}]] + \\ [4.56 \times [\sin\{\deg rad(slop \deg)\}]] + 0.065\end{array}\right] \tag{15.3}$$

$$LS_2 = \left(\frac{sloplenth}{22.1}\right)^{0.7} \times 6.432 \times \sin\left\{\deg rad(slop \deg)^{0.79}\right\} \times \cos\{\deg rad(slop \deg)\} \tag{15.4}$$

By using Eqs. (15.3) and (15.4), LS factor is given as

$$LS = iff(S\langle 21, LS_1, LS_2) \tag{15.5}$$

where, L is the slope length (m), S is the slope steepness (%).

15.2.5 *Conservation Factor (C) and Management Factor (P)*

'*C*' values were calculated using land use/land cover map and ground truth (Table 15.3). Based on Wischmeier and Smith (1965, 1978) and some reported values for India, the values of P for different types of practices are used (Table 15.4).

15.2.6 Soil Erosion Risk Assessment

Because this study focuses on the evaluation of soil erosion risk, instead of estimation of actual soil erosion loss, the *R* factors were not used, assuming that the same climatic conditions exist within the study area. So, the Soil Erosion Risk (SER) was developed based on *K*, *LS*, *C* and *P* factors in a simplified equation:

$$SER = K \times L \times S \times C \times P \tag{15.6}$$

15.2.7 Derivation of the Soil Image Data, K Factor Image, LS Factor Image, C-Factor Image, P-Factor Image and the Soil Erosion Risk Image

The soil map of the Shankargarh block was scanned and then registered with the help of geo-referenced SOI topographical map. The registered soil map was then digitized and different soil attributes were assigned (Fig. 15.3) to the different soil groups following Dan et al. (1976). These classes helped in development of soil erodibility factor (K) map of Jhagrabaria watershed. *The K* factor values for the study area ranged from 0.250 to 0.485 t ha^{-1} (MJ mm ha^{-1} h^{-1} year^{-1}) (Fig. 15.6). Digital Elevation Model (DEM) derived from the contour information was used to develop the slope length and slope steepness factor (*LS*). The *LS* factor was calculated using Eqs. (15.1), (15.2), (15.3) and (15.4). For slopes < 21 %, *LS* factor 1 (LS_1) was applied whereas, for slops > 21 %, *LS* factor 2 (LS_2) was used. The average slope map was calculated in degrees by using equation (5). The LS factor was considerable near the main peak in the watershed while the rest of the area remained very low (0.07) (Fig. 15.7; Table 15.5). The *C*-factors corresponding to each land cover condition were estimated from the USLE guide tables (Wischmeier and Smith 1978). These values were used to reclassify the land cover map to obtain the *C* factor map. *C* values for the present study region ranged from 0.32 for vegetated region to 1.0 for other classes of the watershed (Table 15.3; Fig. 15.8). Management practice factor values were derived by crossing operation between LULC map (Fig. 15.2) and slope map (Fig. 15.5). *P*-factor values for the study region ranged from 0.50 to 1.0 (Fig. 15.9).

The various *P*-factors and the value of conservation practice factor for different classes of land use and slope are given in Table 15.4 and Table 15.6, respectively. After the *K*, *LS*, *C* and *P* factor images were developed, they were overlaid using GIS tools (Lim et al. 2005) to generate the SER image. Eight risk levels i.e., very low, negligible, low, slight, moderate, high, very high and sever, were identified

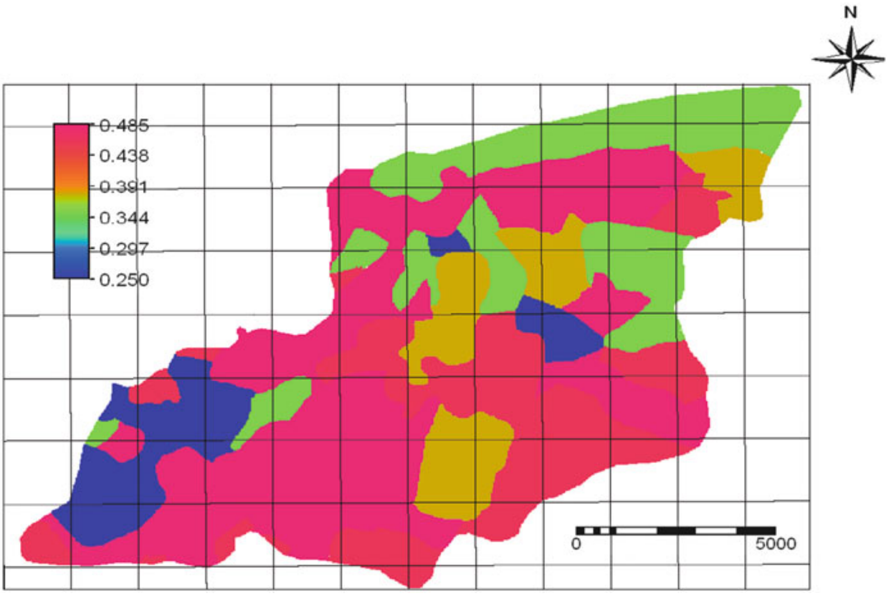

Fig. 15.6 The soil erodibility factor map ('*K*' Factor Map) developed from soil map and corroborated with the measured soil data

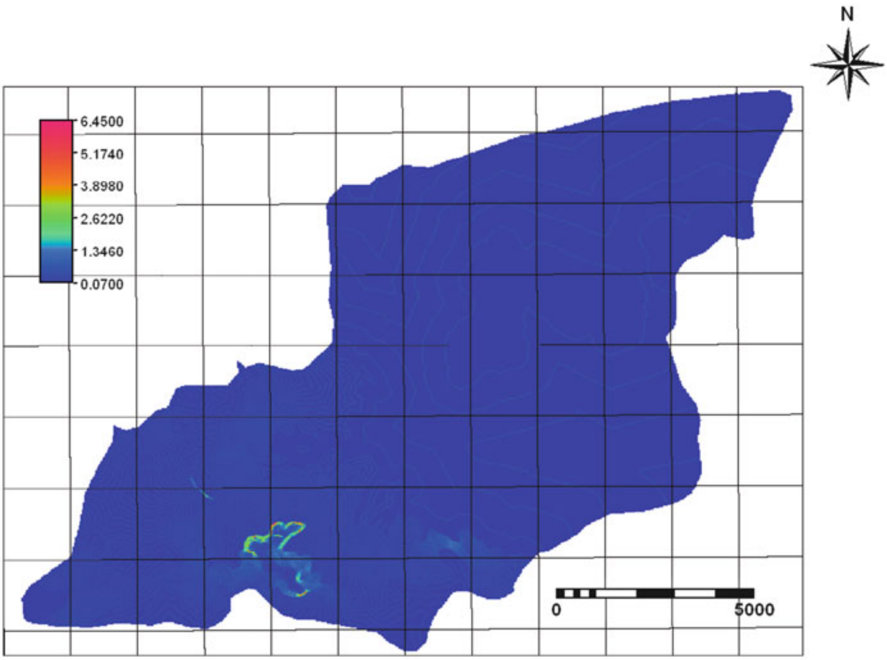

Fig. 15.7 The topographic factor ('*LS*' factor) map as derived from the DEM data

Table 15.5 LS factor ranges in study area and its aerial extent

LS factor (range)	Area (m^2)	Proportion of area (%)
	144,619,488	98.4
0.500–1.00	1,544,087.5	1.05
1.00–2.00	470,293.3	0.30
2.00–6.45	190,880.5	0.14

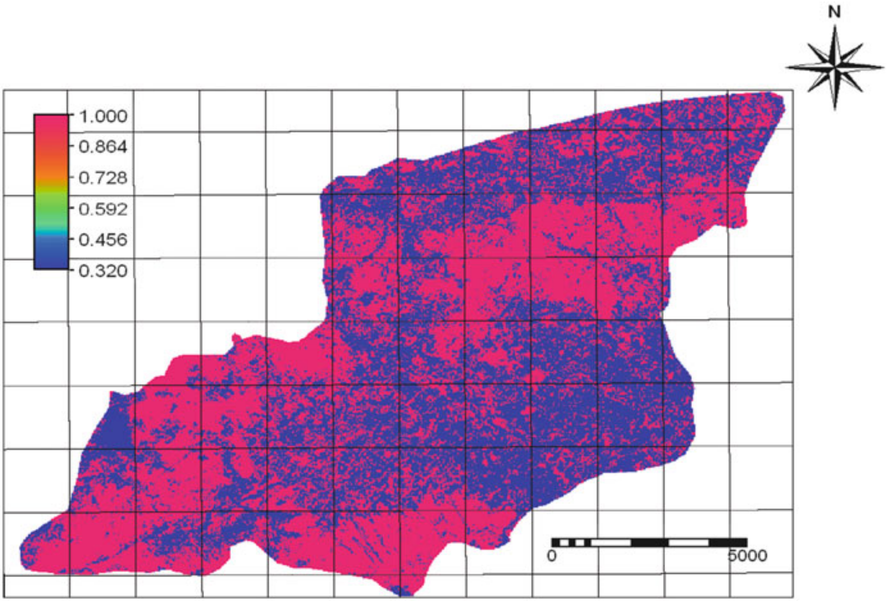

Fig. 15.8 The cover-management factor ('*C*' Factor) map

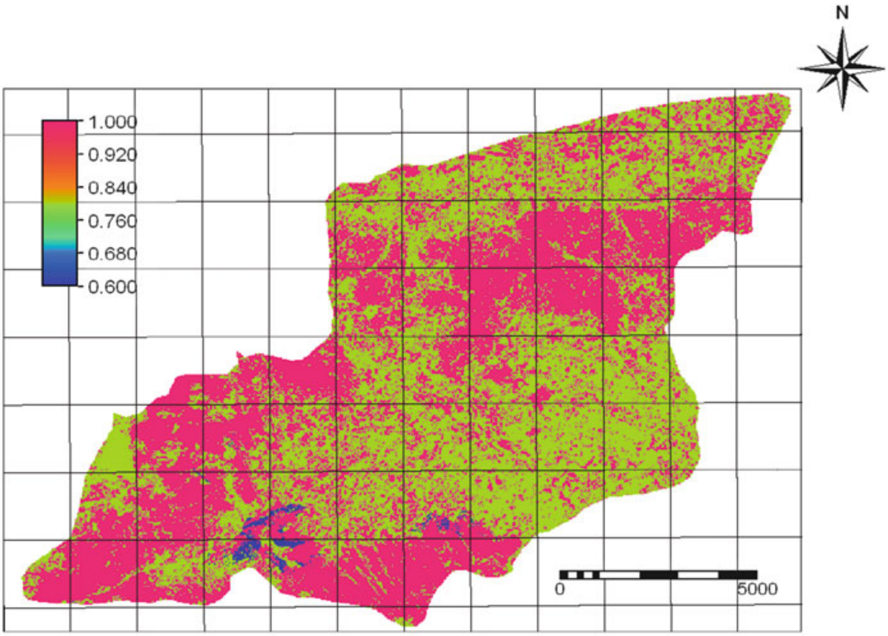

Fig. 15.9 The management practice factor ('*P*' factor) map

Table 15.6 Landuse and slope with their corresponding area coverage

Land use and land cover	Slope range (m)	P-factor	Area (m^2)	Percentage area
Vegetation	0.00–0.10	0.80	69,161,463.0	47.10
Vegetation	1.00–2.0	0.60	17,870	0.012
Vegetation	2.00–7.0	0.50	349,267.5	0.23
Vegetation	7.00–11.0	0.60	644,114	0.43
All other classes (water body, barren, fallow land)	All range	1.00	76,652,032.5	52.20

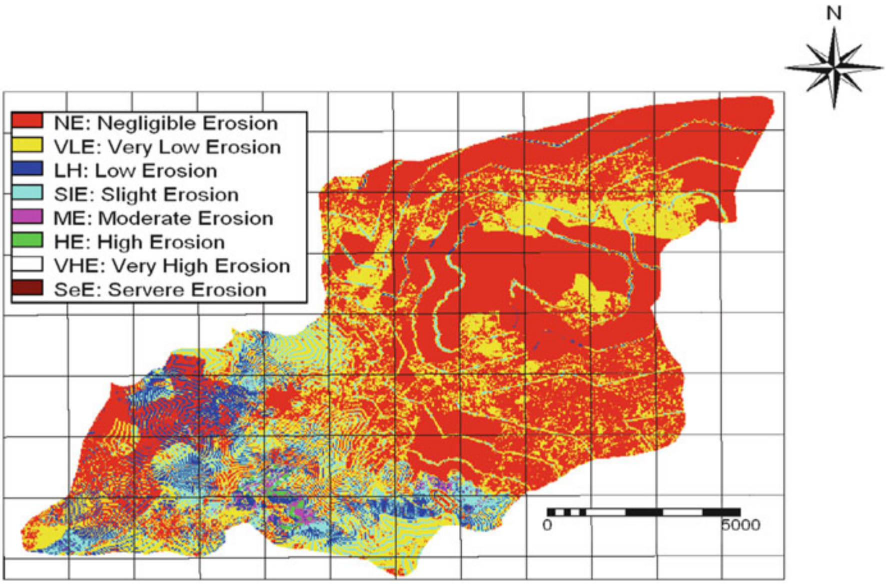

Fig. 15.10 Erosion risk image illustrating the soil erosion conditions within the study area

and mapped (Fig. 15.10). Almost 90 % of the watershed falls into low erosion risk class where soil loss is <4 t ha^{-1} year^{-1}. However, ~57 % of the land comes under negligible erosion class. Form the spatial soil loss risk map (Fig. 15.10), the magnitude of soil erosion and its area coverage in the Jhagrabaria watershed was estimated (Table 15.7). It is evident that ~0.7 % (532,026.3 m^2) area of Jhagrabaria watershed experiences high erosion risk (the soil loss was about 54 t ha^{-1} year^{-1} at a pixel level). The maximum soil loss was 54 t ha^{-1} year^{-1} in the southern part of the basin. The eight classes of erosion (Fig. 15.10), thus, derived would be very useful in planning, management and execution of soil conservation works in the watershed.

Table 15.7 Erosion range with corresponding area coverage and severity nomenclature

Erosion (t ha^{-1} y^{-1})	Area (m^2)	Area (ha)	Percentage of the total area
0.077459–0.503579	82,961,592.5	8,296.16	56.51
0.504627–1.008961	39,158,575.4	3,915.85	26.67
1.029819–2.022402	9,615,417.7	961.54	6.55
2.031575–3.973068	13,739,211.4	1,373.92	9.36
4.011695–7.953621	810,627.1	81.06	0.56
8.083075–20.880267	480,853.2	48.08	0.32
21.299551–30.020627	26,804.9	2.68	0.09
31.194618–54.087443	24,368.2	2.44	0.02

15.3 Results

15.3.1 Result from the RUSLE Model

The mean annual soil loss estimated for the study area using RUSLE was about 27.45 t ha^{-1} $year^{-1}$. Based on the model, the study area was classified into eight erosion classes ranging from 0.0 to 54.09 t ha^{-1} $year^{-1}$ (Fig. 15.10). However, 56.51 % of the total area is within the first class with erosion rates ranged from 0.0 to 0.50 t ha^{-1} $year^{-1}$. This is considered to be within the low range. The most severe eroded area with erosion rates of between 8.08 and 54.09 t ha^{-1} $year^{-1}$ (class 6, 7 and 8) accounts for of the study area. It is evident that SL factor seems to have significant effect on the estimated total soil loss in the area. This is because the areas mostly affected by erosion within the study area coincided with the areas where *SL* factor is high. This study has demonstrated conclusively that Remote Sensing and GIS are highly useful tools for modeling soil erosion using the RUSLE model for evaluating various disturbance alternatives and spatial optimization of conservation measures.

15.3.2 Interrelationships of Land use, Land Cover (LULC) and Soil Erosion Risk (SER)

Eight erosion classes were classified from the LANDSAT 7ETM+image of the area. A linkage between the LULC and the SER images is valuable for understanding how different LULC classes affect soil erosion. The LULC classes were recorded as 1, 2, 3 and 4, corresponding to barren land, fallow land, natural vegetation and water bodies/wetlands, respectively. The SER image was also characterized as 1, 2, 3, 4, 5, 6, 7 and 8 corresponding to negligible, very low, low, slight, moderate, high, very high and severe erosion levels. These two images were compared pixel by pixel to generate the relationship of LULC and SER classes

Table 15.8 Assessment of soil erosion risk (t ha^{-1} y^{-1}) and associated land-cover distribution

Soil erosion risk									
LULC type	NE (%)	VLE (%)	LE (%)	SE (%)	ME (%)	HE (%)	VHE (%)	SE (%)	Total (%)
Barrel land	7.56	8.72	3.34	4.48	0.26	0.180	0.012	0.007	24.56
Fallow land	7.34	9.56	2.64	0.27	4.47	0.139	0.009	0.007	24.44
Vegetation	40.61	6.71	0.39	0.02	0.07	0.001	0.000	0.000	47.79
Waterbodies/ Wetland	0.39	1.64	0.22	0.34	0.003	0.003	0.001	0.002	2.60
Total (%)	55.9	26.62	6.59	5.11	4.80	0.32	0.02	0.02	

NE Negligible erosion, *VLE* Very low erosion, *LE* Low erosion, *SE* Slight erosion, *ME* Moderate erosion, *HE* High erosion, *VHE* Very high erosion, *SVE* Severe erosion

(Table 15.8). Result shows that the barren land, fallow land, vegetation and water bodies/wetland have very low or low erosion risks, but some of the barren land and fallow land areas with limited ground cover have moderate and high erosion risks. Very less area of barren, fallow, vegetation and water bodies/wetland had severe erosion risk (Table 15.8).

15.4 Discussion and Conclusions

Estimation of soil erosion loss in a large area is often difficult, as well as its validation. Although, this paper focuses on the evaluation of soil erosion risk (SER), validation using reference data is also valuable. For example, if reference data are available, the classification of soil erosion risk and the identification of thresholds for each risk level will be more appropriate. The present study highlights the soil erosion prone area and the actual soil loss with references to the rainfall of the year 2006 in Jhagrabaria watershed, India.

The watershed experiences the erosion risks of low to severe category, but by and large the erosion is not severe. Although, the LULC and management practices offers stiff resistances against soil erosion proneness, the affective soil loss is also not profound. Nevertheless, the Jhagrabaria watershed has been placed under slight to moderate erosion prone category. For ease of the study, the change in watershed erosion has been clarified into Negligible Erosion (NE), Very Low Erosion (VLE), Low Erosion (LE), Slight Erosion (SE), Moderate Erosion (ME), High Erosion (HE), Very High Erosion (VHE) and Server Erosion (SE) category (Fig. 15.10). The land use and slope of the area are having greater influences on the soil erosion rate than all other factor. The major portion of the watershed has fallen in negligible or moderate soil erosion rates (56.5 % with erosion rate of 0.077–0.503 Mg ha^{-1} $year^{-1}$). This shows that the condition of watershed is in fairly good condition.

Having said this, when we examined the land use wise area under various erosion categories, results revealed that Barren and Fallow lands were in high soil erosion. However, these lands are nearly 50 % of the total area of the land of the watershed. Therefore, these may possibly be brought under economic cultivation. Alternatively, these lands may be allocated to Agro-forestry or Horticultural or a combined Horticulture-Agro-forestry land use to make them more remunerative with an objective of keeping the soil erosion under check. The results described in this article are valuable for understanding the relationship between soil erosion risk and LULC classes and consequently are quite useful for managing and planning land use. For Jhagrabaria watershed, such studies are very important due to spurt in the land degradation activities involving deforestation of forests.

Based on the results, finalization of a comprehensive watershed development and management plan will be under taken. The algorithms and methodologies developed in this study can be extrapolated to other regions having similar edaphic, topographic and agro-climatic characteristics. Also, the scaling up of the areal extent of the watersheds may be evaluated based on the methodologies developed. The actual rainfall data may be superimposed to quantify the actual quantities of runoff, soil and nutrient losses from the watershed; but with the limitations of cross checking, because hardly a few watersheds in India are gauged and such watersheds lack from the point of monitoring so that intensive management or corrective measures can be taken to restore a degraded watershed or the results are verified.

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Chapter 16
Spatio-Temporal Shift of Right Bank of the Gumti River, Amarpur Town, Tripura and Its Impact

Sima Majumdar and Nibedita Das (Pan)

Abstract Gumti River is the largest river of Tripura which flows for 47 km (35 % of the total length) in a meandering course through the synclinal valley between Baramura and Atharamura hill ranges. The Amarpur town (23°31′ 42.6761″N latitude and 91°39′ 52.1358″ E longitude) is situated to its right bank which has observed the channel's variability of shift in space and time during last 74 years. Fluctuations of different hydrological variables namely, discharge velocity etc. of the Gumti River for both pre and post monsoon seasons have been analysed on the basis of the hydrological dataset from 1995 to 2010. The rate of shift (%) of the right bank of the River Gumti at Amarpur town during both pre and post monsoon seasons have been calculated. The average annual shifting of the meander at Amarpur town is 3.03 m and average eroded area is 767.14 m^2/year. Thus the study aims to quantify different hydrological parameters and river course change using GIS technique. The work has been done on the basis of SOI topographical map of 1932–1933 and 1974–1975 (No. 79M/10) and satellite images for the year (1989, 2006). Overlaying of these four temporal dataset has been carried out to indentify the direction of shift and to mark the amount of area under loss (erosion) and gain (deposition). Due to gradual shift of the channel people lost their valuable property every year and the Amarpur town becomes more and more vulnerable to erosion. So it is highly significant to study the hydrological behaviour, channel characteristics, as well as, the bank material characteristics of the River Gumti to get an idea about propensity to vulnerability of Amarpur town.

Keywords Amarpur town • Bank erosion • Grain size analysis • Gumti river • Hydrological characteristics

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16.1 Introduction

Meanders are usually defined geometrically in terms of their shape, bend, radius of curvature and wave length. A sine generated curve resembles an idealized meandering river. But in reality bendways are asymmetrical. This asymmetry is associated with the fact that the points of deepest bed scour and of maximum attack on the outer bank in bends are usually located downstream of the geometric apex of the bend, so that through time the bends migrate downstream (Leopold and Langbein 1966). Spatio-temporal changes are the most common phenomena in every river. Lateral shifting is of immense importance which can be detected by its asymmetric position and evidence of its spatio-temporal shift in one direction (Schumm et al. 2000). Gumti, the largest river (133 km) of Tripura, flows for 47 km between Baramura and Atharamura Hill Ranges which is only 35 % of its total length and Amarpur town is located along a meander bend in its right bank.

16.2 Study Area

The study area, Amarpur Town, lies between 23°31′12.6802″N to 23°32′11.0102″N latitude and 91°39′25.3277″E to 91°40′13.7777″E longitude. The area is underlined by Surma and Tipam group of geological formation. The average annual rainfall of this area is 2,160.93 mm. It is characterized by older alluvium which is texturally sandy. Total population is 13,004 at Amarpur (2011 Census) and main occupation of the people is agricultural labour (Fig. 16.1).

16.3 Objectives of the Study

In order to carry out in depth study of spatio-temporal shift of the right bank of the Gumti River at Amarpur Town, the following objectives have been selected:

(i) To analyse the hydrological parameters and erodibility variables of the River Gumti.
(ii) To study the spatio- temporal changes of right bank of the Gumti River using GIS technique.
(iii) To analyse the impact of spatio-temporal change.

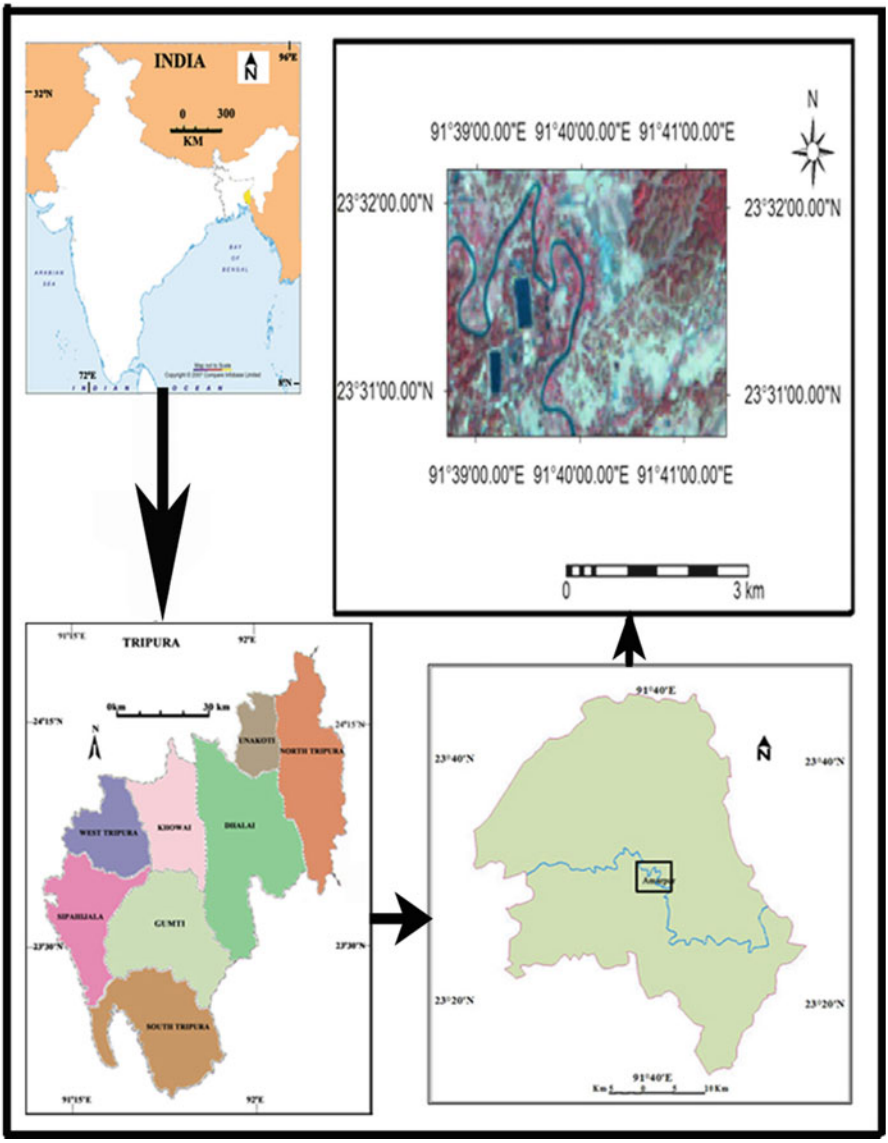

Fig. 16.1 Location map of the study area

16.4 Materials and Methods

To carry out the study SOI topographical sheet No. 79M/10 (1932–1933, scale 1: 63360 and 1974–1975, scale 1: 50000), LISS III Satellite images of 1989 and 2006, Google Image of 2005, Global Positioning System (GPS), Hydrological data from Central Water Commission (CWC) and Geomatica V 10.1, Ms Excel, Adobe Photoshop CS5 etc. data and software have been used.

Temporal change map, plan view map, bank line shifting map have been prepared on the basis of topographical map and imagery using GIS technique. Radii of curvature, Sinuosity index and Meander wave length have been measured depending on temporal change map. Bank angle, root depth and density have been measured during the field survey. Grain size and soil composition have been analysed based on soil samples collected from river bank during field survey. Other primary data have been calculated and cartographically represented.

16.5 Discussion and Analysis of the Results

The channel width at the dominant discharge is used to scale the geometric relationship in meanders. The form of most meanders is influenced by variation in erodibility of the materials encountered in the outer bank (Thorne et al. 2006). Therefore, changes in hydrological parameters and erodibility variables have been considered for this purpose. The Amarpur town has observed the channel's variability of shift in space and time during last 74 years (from 1932 onwards).

16.5.1 Hydrological Parameters

Erosivity depends on the nature and amount of flow. The study area experiences average annual rainfall of 2,108.99 mm, most of which (78 %) falls during the monsoon season (June to September) when southwest monsoon fully establishes. During rainy season, heavy rainfall accelerates water velocity and discharge which again increase the energy of the river to erode its bed and bank. Figure 16.2 shows positive correlation (r = +0.85) between rainfall and discharge.

Discharge and velocity together play important role to bank collapse. Here discharge as well as velocity remains high throughout the year (1995–2010). Figure 16.3 shows positive correlation (r = +0.73) between discharge and velocity. Every year, peak discharge is found during monsoon season which exerts pressure on the bank material and bank materials become weak and collapse.

16.5.2 Erodibility Variables

Bank erosion is related with the erodibility of the bank material. Texture is an important physical characteristic of soil which may be defined as the degree of coarseness or fineness of soil resulting from the relative proportions of the particle size fractions—sand, silt and clay (Goswami et al. 1999)

The river bank consists of high amount of sand (94 %), silt (6 %) but absence of clay (Fig. 16.4) . It means the bank materials are non cohesive and more susceptible

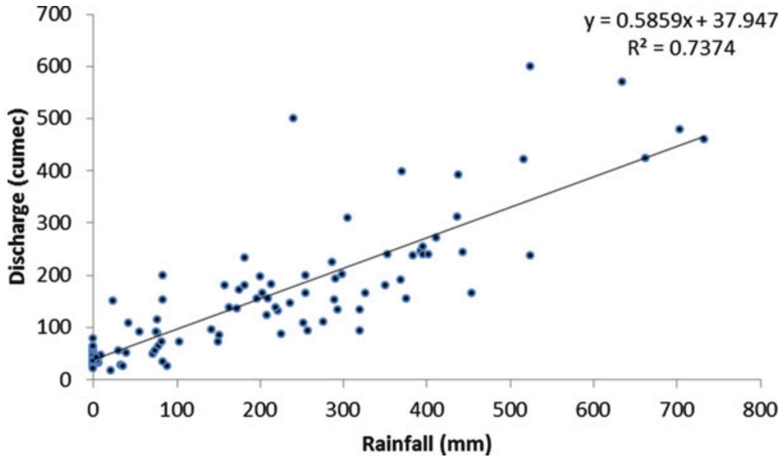

Fig. 16.2 Relation between rainfall and discharge of the Gumti River. *Source*: Based on data provided by Central Water Commission, Meghna Division, Shilong

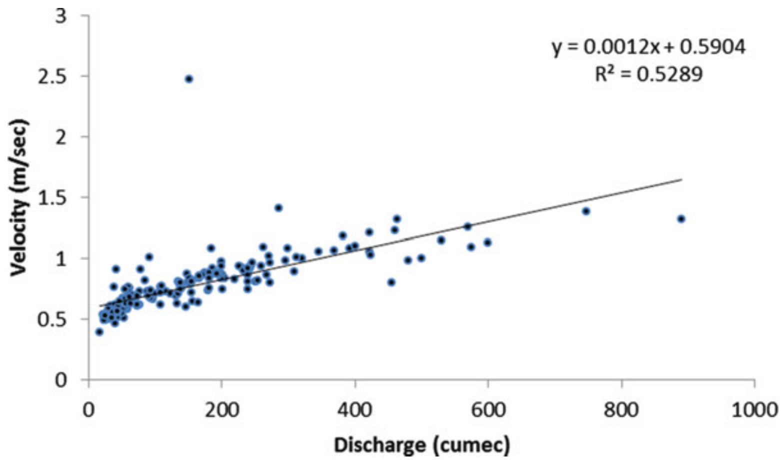

Fig. 16.3 Relation between discharge and velocity of the Gumti River. *Source*: Based on data provided by Central Water Commission, Meghna Division, Shillong

to erosion. From the grain size analysis of soil samples collected from different depths of the study area, it is found that in the study area big sized grains of > 0.25 mm diameter and small sized grains of 0.125 mm diameter are present (Fig. 16.5). During heavy discharge, water penetrates through the interstitial spaces of sandy beds. After recession of high water level, lateral flow of sand and silt into the channel takes place which leads to disequilibrium condition in the bank itself and the bank failure takes place. Again in rainy season when discharge and velocity increase, water flow directly forces on the steep banks, erosion takes place at the

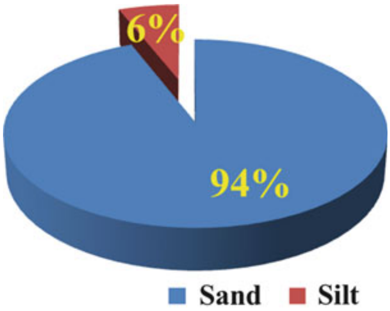

Fig. 16.4 Soil composition of the right bank of Gumti River near Amarpur town

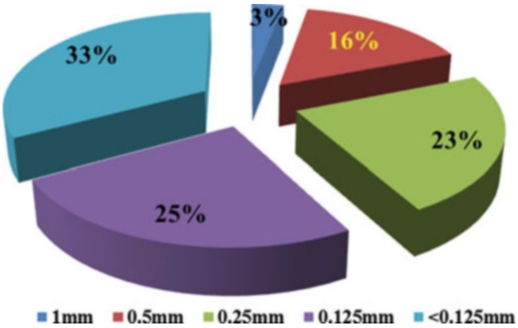

Fig. 16.5 Grain size diameter of the soil at right bank of Gumti River near Amarpur town

maximum sandy portion of the bank (7–9 m height from the bed) leaves the upper portion hanging (maximum height 13.80 m). After some time, due to loss of basal support, the hanging portion collapses.

Bank with steep angle ($\theta > 60°$) is susceptible to erosion. The bank angle at Amarpur town site is 73°. Here the bank does not show any break which indicates that the bank failure is a common phenomenon at this site.

Absence of root depth and density is another causative factor of bank failure. Bank sediment with a root volume of 16–18 % and 5 cm root mat can afford 20,000 times more protection from erosion than comparable sediment without vegetation (Smith 1976). At Amarpur there is short vegetation with shallow root depth along the bank which makes the site more vulnerable.

16.5.3 Spatio-Temporal Change

The rate of bank erosion is related to the above discussed variables of erodibility. During 1932–2006 period channel plan form at Amarpur has been gradually changed. SOI topographical sheet of 1932–1933 shows the River Gumti flowing through an asymmetrical circular-curved meander. Then the thalweg length (T_l) as 1,598.329 m and distance between two sides of the bend (B_d) was 587.041 m. In 1974–1975 the meander became circular in shape, T_l increased to 1,630.659 m and

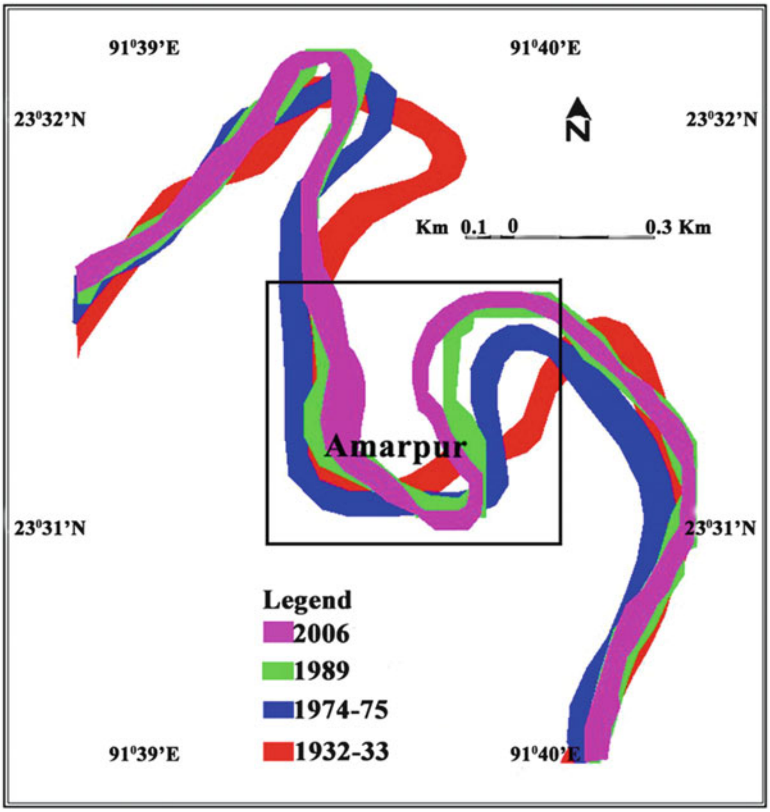

Fig. 16.6 Spatio-temporal change of the Gumti River at Amarpur town

B_d decreased to 480.007 m. Then again in 1989 the meander shape was changed to a sine curve and T_l increased to 1,775.826 m but B_d decreased to 431.34 m. In the year 2006 meander bend shape remained more or less same, T_l increased to 1,863.859 m and B_d decreased to 358.43 m (Figs. 16.6 and 16.7). Therefore, the gradual change in meander shape from semi-circular to sine curve indicates the sharpening of the meander bend. Similarly, continuous decrease in distance among two bends clearly shows the gradual inward movement of the bend sides.

In Amarpur, the Gumti River shows an increase in sinuosity index (SI) by 2.48 and decrease in both meander wave length and radii of curvature by 244.66 and 124.03 m respectively within a span of 74 years (Table 16.1) which also supports the above mentioned findings (Table 16.2).

On the basis of the above measurements it can be predicted that there is very less distance (101.91 m) between two eroded banks. In future (12 year) a cut-off will form and the river will follow a straight course through Amarpur town (Fig. 16.8). Therefore, the settled area within the bend becomes more vulnerable and will suffer a lot from this hazard.

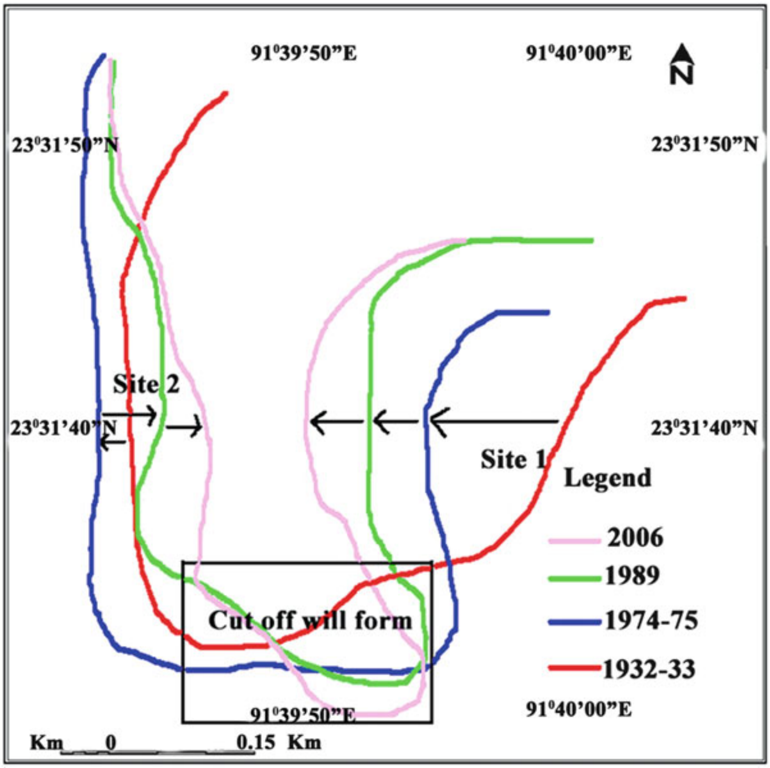

Fig. 16.7 Bank line shifting of the Gumti River at Amarpur town from 1932 to 1975, 1975 to 1989, 1989 to 2006

Table 16.1 Sinuosity index, Meander wave length and radii of curvature of the Gumti River at Amarpur town (1932–2006)

Year	Sinuosity index(SI)	Meander wave length (m)	Radius of curvature (m)
1932–1933	2.72	631.34	282.92
1974–1975	3.12	548.83	231.85
1989	4.12	472.87	195.5
2006	5.20	388.68	158.89

Source: Calculated by the researcher

Table 16.2 Direction of bank line shift

Year	Site	Direction	Bank line shift (m)
1932–1974	1	Westward	138
	2	Westward	36.89
1974–1989	1	Westward	60.15
	2	Eastward	67.51
1989–2006	1	Westward	64.16
	2	Eastward	38.1

Source: Calculated by the researcher

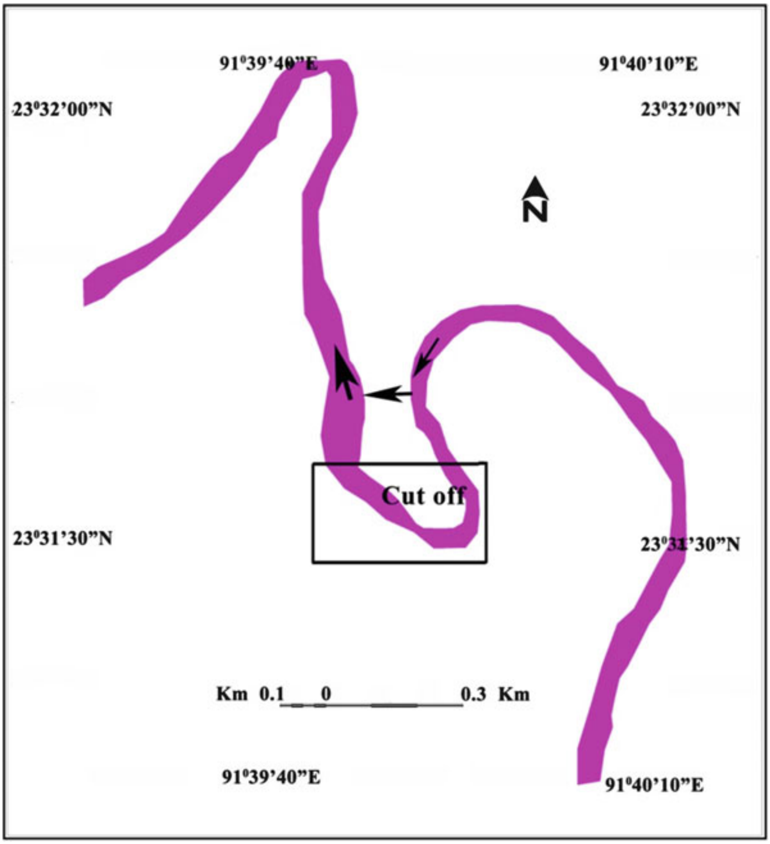

Fig. 16.8 Present and predicted course of the River Gumti near Amarpur town

16.5.4 Impact of Spatio-Temporal Change

The change in position of the river course in the study area over space and time leads to change in land use and life style of the local people. Figures 16.9 and 16.10 shows the changed plan view of the channel and area under loss and gain respectively during 1932 to 1975, 1975 to 1989, 1989 to 2006.

The study area covers 14,31,775.83 m^2 area out of which 18.23 % is occupied by river, 2.65 % by sand bar, 6.55 % by water body, 24.54 % by agricultural land and 48.03 % by settlement and road (Figs. 16.11 and 16.12). The area is thickly populated; large area has come out from the river due to deposition and is used as agricultural land. 12.97 % settled area is situated within this meander bend. Due to shifting of the channel from 2005 to 2006 position, about 72 % of the settled area within the bend has been captured and only 38 % is waiting for this menace.

Among the total affected families of Amarpur, about 50 % have already migrated due to bank line change. Another 10 % families have not yet migrated

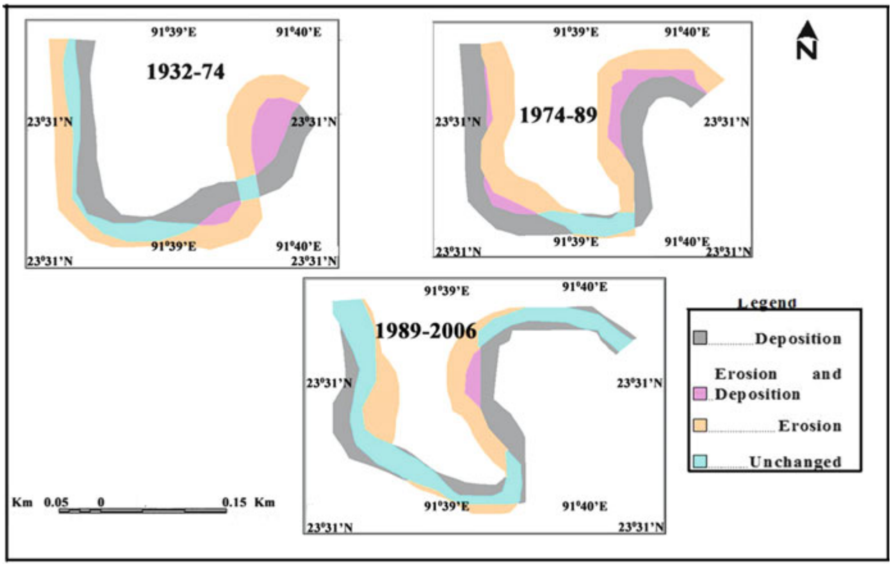

Fig. 16.9 Plan view of the areas under erosion, deposition etc. near Amarpur Town

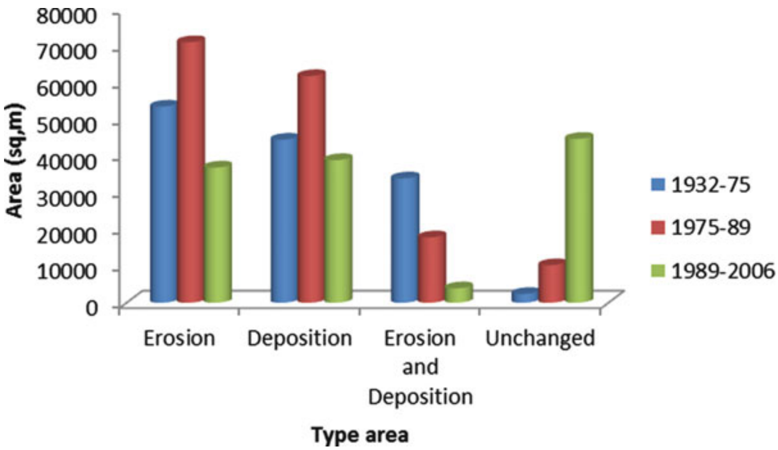

Fig. 16.10 Area under loss and gain due to shifting of the River Gumti along its right bank at Amarpur

but will have to shift in future. Remaining 40 % houses are located within 10 m distance from the river which will have to migrate in near future. In order to shift their houses, people have to spent extra money to build their houses again and again which adversely affect their economic condition. Most of the agricultural lands lost due to bank erosion were double cropped which caused great loss to them. Maximum crop lands with standing crops have lost > Rs. 25,000 which have adverse effect oneconomic condition of the affected people (Fig. 16.13).

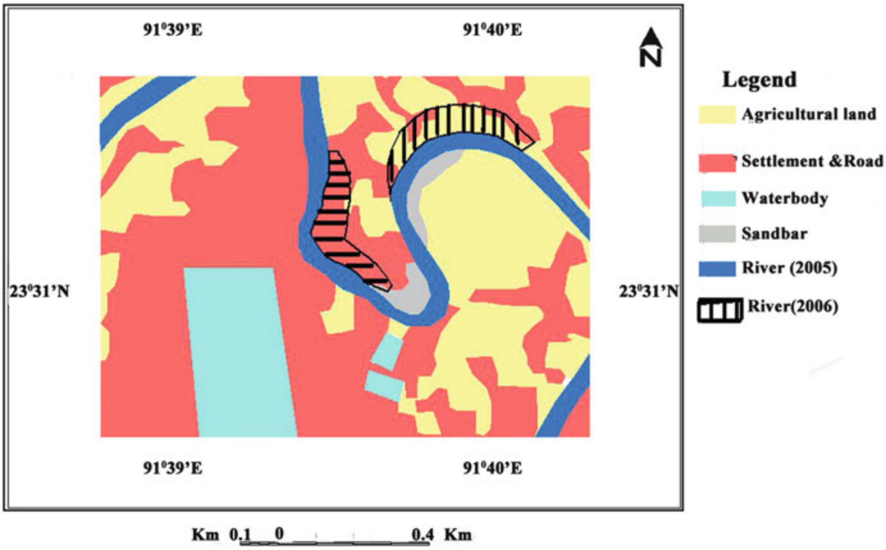

Fig. 16.11 Land use map of the study area in 2005. Area lost due to river shifting from 2005 to 2006 is shown

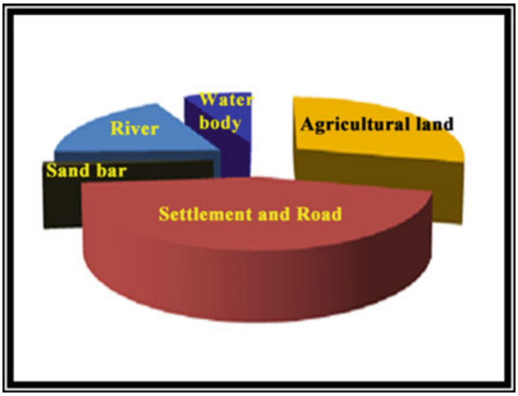

Fig. 16.12 Land use pattern of the study area in 2005

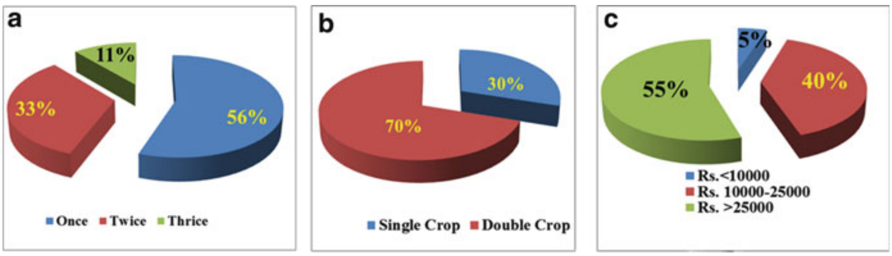

Fig. 16.13 (**a**) Number of migration of the families at Amarpur along the right bank of Gumti River. (**b**) Loss of agricultural land at Amarpur along the right bank of the Gumti River. (**c**) Loss of standing crops at Amarpur along the right bank of Gumti River

16.6 Conclusion

From the above discussion it is found that the River Gumti is characterized by high discharge and velocity which generate great force on the bank materials. On the other hand, the big sized grains (0.25 mm) are more which makes the bank more erodible. Height of the bank at the site is 13.8 m which is mainly composed of sand but 99 % sand is present at the bank height of 7–9 m which level is most susceptible to liquefaction. As a result, upper part of the bank collapses and river has to shift.

In Amarpur, the Gumti River shows an increase in sinuosity index (SI) by 2.48 and decrease in both meander wave length and radii of curvature by 244.66 and 124.03 m respectively within a span of 74 years. Moreover, during 1932–2006 period shape of the meander bend has been transformed from asymmetrical circular curve to sine curve. The average westward and eastward shifting are 3.91 and 3.37 m per year respectively. Due to continuous shifting, there is very less distance between two eroded banks which is 101.91 m only. It means in near future (about 12 years) the river will flow straight leaving a cut- off at this part.

Due to temporal change of right bank of the Gumti River some areas have already been captured by the river and some areas have come out due to sand deposition. Due to river shifting during 2005–2006 32,867.87 m^2 settled area and 25,944.36 m^2 agricultural lands had been captured by the river most of which are double cropped area. Which area firstly captured by river and come out by deposition later are not under the same landlord. So the person, whose land has been captured by river, becomes poorer. The area is thickly populated where the river will flow in a straight channel in near future. it means the area is more vulnerable. Therefore proper protection measures should be taken to protect the Amarpur town from such hazard.

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Chapter 17
Two Indices to Measure the Intensity of Meander

Balai Chandra Das

Abstract Waveform or meandering is obvious for all stream channels. Ideal waveforms, such as a sine or cosine wave, are one line thick, but for a stream, the width must be taken into consideration. The meandering stream follows the down-valley axis, a line fitted to the curve such that the sum of all the amplitudes measured from it is zero. However to determine the intensity of the meander of a stream, several measures such as Wavelength, Amplitude, Curvature, Radius Of Curvature, Sinuosity, Radius: Width Ratio, Wavelength/Width Ratio etc. have been used. The present paper is trying to introduce two other measures—Meander Form Index (F_mI) and Meander Shape Index (S_mI) to the field not only to give a quantitative value to the meander but also to add quality to it.

Keywords Amplitude • Curvature • Meander form index • Meander shape index • Radius of curvature • Radius: width ratio • Sinuosity • Wavelength • Wavelength/width ratio

17.1 Introduction

Potamology, the science of rivers, a branch of physical geography, deals with the (i) physics of running water (ii) volume of water and its fluctuations (iii) action of water on its bed and banks (iv) distribution of running water on the earth and (v) river as a scene of organic life (Penck 1897). Channel plan-form and nature of its morphometric variables depends directly on the action of water on its bed and banks. River channel plan form is classified as straight, meandering and braided (Mueller 1968). Although no natural rivers are straight in plan-form and was

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questioned 'Is there such a thing as a straight river?' (Leopold and Langbein 1966). Sinuosity Index is the best measure of the meander-intensity. Higher the sinuosity index, more is the meander-intensity. But the consideration of radius of curvature, amplitude and wavelength of meander are not valued properly in the index. The present paper will value the ratio of radius of curvature to amplitude that determines the shape of meander and the ratio of amplitude to wavelength that determines the form of meander.

17.2 Meander and Sine Curve

Ideal waveforms, such as sine or cosine waves, are *one line thick*, with uniform bend. Meander wave of a stream have its width which determines the wave length (λ). The sine wave is a mathematical curve that describes a smooth repetitive oscillation about mean. Its basic form is

$$Y = \text{Sin } X^c$$

Stream meander represents nature of both *propagating wave* and *standing wave*. In case of propagating or travelling wave, crests and troughs move along the meander axis (x) towards downstream following the general slope of the region concerned (Fig. 17.1a). Standing waves fulcrum on nodes (middle most point of a limb) and trough and crests are free anti-nodes to take opposite position. Trough becomes crest taking its position and vice versa (Fig. 17.1b).

17.3 Variables and Definitions of Variables of a Meandering Stream

Two reaches of meandering streams are schematized in figure Fig. 17.2 to illustrate principal variables of a meander. Two systems of coordinates are there: rectilinear and curvilinear (Julien 1985).

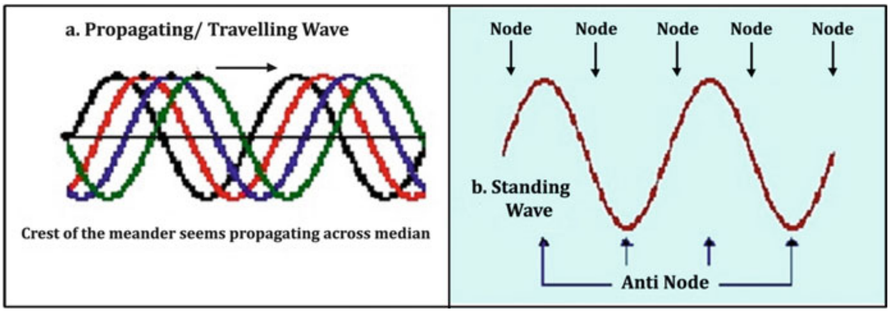


Fig. 17.1 (**a**) Travelling wave of meander (**b**) Standing wave of meander

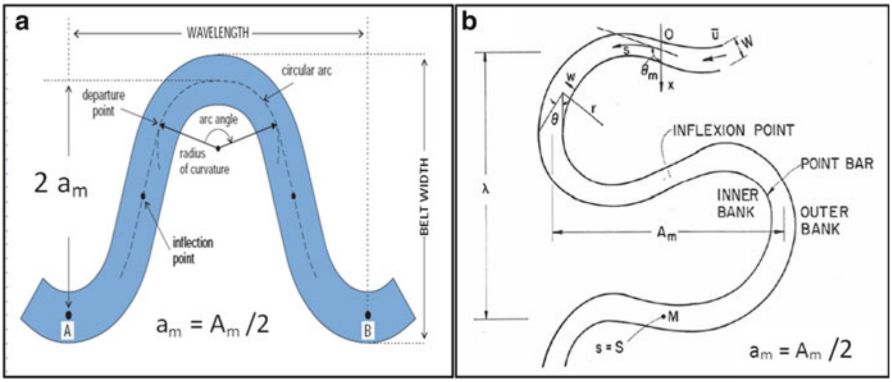


Fig. 17.2 Definition sketch of a meandering alluvial stream (**a**) arc angle, inflection point, departure point and other variables of a meander. (**b**) sinuous axis, orthogonal to principal curvilinear axis, wave length, amplitude and other variables of a meander (*Source*: Fact Sheet No.1, River Course, nc stream restoration institute and Julien 1985)

Here x = principal axis (meander axis) of the meandering pattern downstream the valley slope, s = sinuous axis of the meandering path of the stream in the longitudinal direction, r = radius of curvature, W = width of the stream, w = orthogonal to principal curvilinear axis, $\overline{\upsilon}$ = mean velocity, λ = wave length of meander, Am = amplitude of meander (in physical science what is here named as amplitude, Am, is called *Peak Amplitude* which is the change between peak and trough. The present paper has used the term as per physical science to denote the *maximum deviation from the average or equilibrium value of any repeatedly changing quantity*. Here a_m = Am/2, θ_m = maximum direction angle and θ = direction angle between path and down valley direction.

17.4 Measures of Meander Intensity

17.4.1 Wave Length (λ)

The length between troughs or crests of a meander (Fig. 17.2.). Wave length of a meander alone does not reveal any qualitative or quantitative measure of intensity of a meander (I_m). Only there is a direct relation between wave length and magnitude of volume and width. Longer the wavelength greater is the volume and larger is the river (Cotton 1952). Meanders are proportional to the energy that is, to the volume and velocity of the stream. Channel width (*b*), depth (d), and meander wavelength (*λ*) are directly related to discharge (*Q*) whereas gradient (*S*) is inversely related to discharge. From this, the following generalized relation is obtained: Q ≈ b, d, *λ*/S (Schumm 2005).

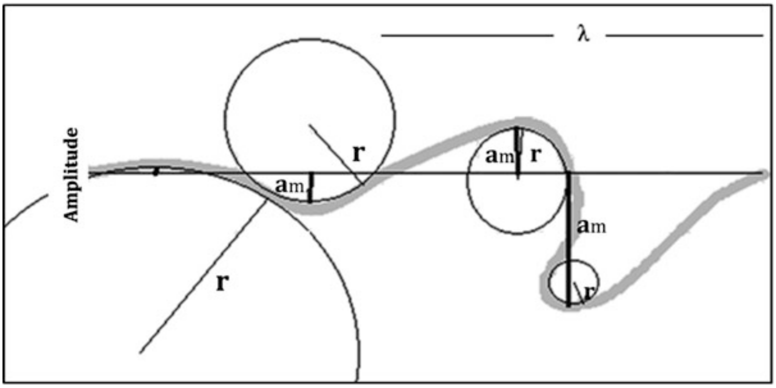


Fig. 17.3 Meander radius and amplitude and intensity of meander

17.4.2 Radius of Curvature (r)

The straight-line distance from arc formed by the mid-channel line of a meandering reach to the imaginary centre of that arc-forming circle. For a sine generated curve, it is equal to half the peak—amplitude (A_m) and equal to amplitude (a_m). It alone does not reveal any qualitative or quantitative measure of intensity of a meander (I_m). Only there is a direct relation between Radius of curvature and magnitude of volume and width. But if wave length (λ) is constant, then smaller the r, more intense is the meander (Fig. 17.3). Nearly constant ratio of radius of curvature to meander length (r/ λ) and of radius of curvature to channel width (r / w) never leads to the idea of size of the river (Leopold and Wolman 1960). The ratio of meander wave length to average radius of curvature is **4 : 7.**

17.4.3 Amplitude of Meander (a_m)

The vertical distance between crest and trough is called the peak-amplitude (A_m). River scientists often use this variable simply as amplitude. But physical scientists use the term 'amplitude' (a_m) to mean half of the peak-amplitude which has been used in this paper. If a_m *increases with constant* λ, intensity of meanders increases (Figs. 17.2 and 17.3).

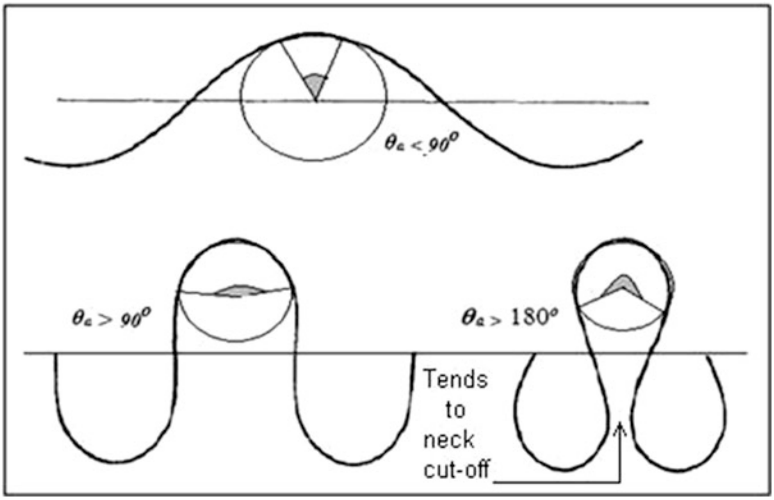


Fig. 17.4 Arc angle and intensity of meander (Based on Langbein and Leopold 1966)

17.4.4 Arc Angle (θ_a)

The angle in between lines radiating from the centre of the meander arc up to the point of deflection of meander-direction. Higher the arc angle, more intense is the meander. Increased arc angle tends towards the point of neck-cut off (Fig. 17.4).

17.4.5 Direction Angle (θ)

Direction angle between path and down valley direction represents the imbalance of relation between slope and volume. Higher the θ, lesser is the slope and more is the volume. Increased direction angle also tends towards the point of neck-cut off (Fig. 17.5).

17.4.6 Radius: Width Ratio (r/w)

It is dimensionless measure of bend tightness. It appears that nature forces certain geometric relations on the features of the river. The geometric relation often found between r and w is so that 10 former variable resembles to 23 later variable. These variables are almost always related in the following way $r \approx 2.3w$.

If such a relationship exists and one of the constants is known, then the other one could be estimated. For example, from $r \approx 2.3w$, in each cycle, a river winds clockwise around one circle of radius $r \approx 2.3w$, then counterclockwise around

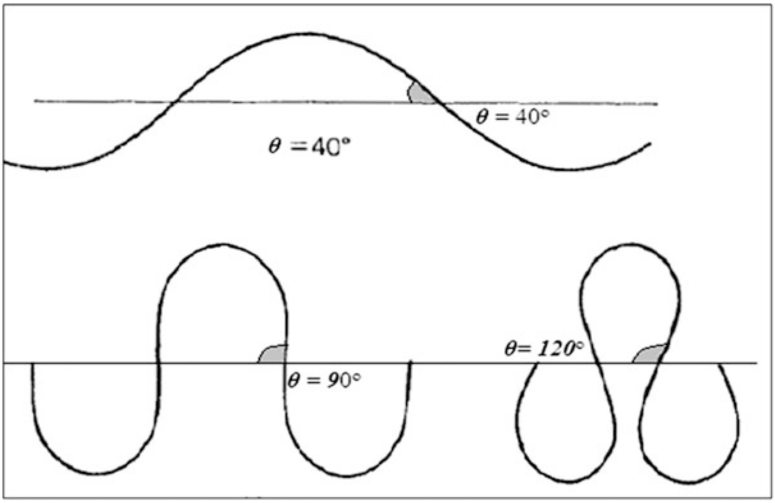


Fig. 17.5 Direction angle and intensity of meander (Based on Langbein and Leopold 1966)

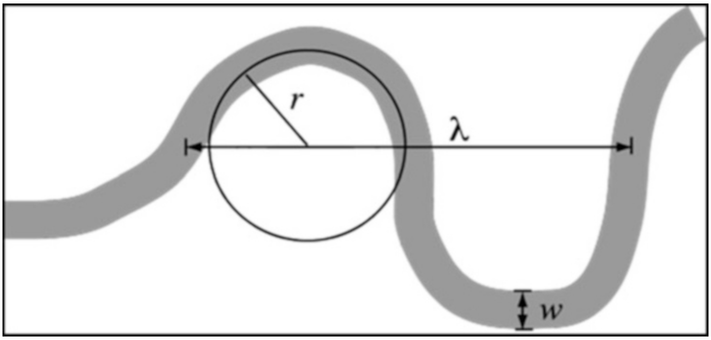


Fig. 17.6 Radius, width and wave-length and intensity of a meander (Richeson 2013)

another circle of radius $r \approx 2.3w$. In doing so, it will produce a wavelength (λ) of roughly $0.5w + 4.6w + w + 4.6w + 0.5w = 11.2w$ (Fig. 17.6). Although this ratio is not the universal truth and wavelength (λ) is usually 10–14 times channel width (w) (Charlton 2008, Chorley et al. 1984). The distance between riffles is about 2 to 7 times the channel width (Leopold et al. 1964; Hogan 1986; Montgomery et al. 1995).

Channel width (w), depth (d), and meander wavelength (λ) are directly related to discharge (Q) whereas gradient (S) is inversely related to discharge. The relation is $Q \approx b, d, \lambda/S$.

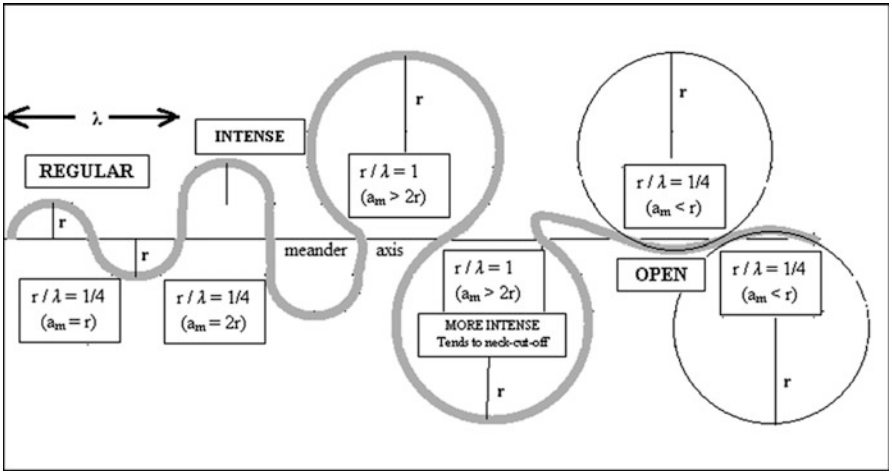


Fig. 17.7 Varying intensity of a meander with varying radius and amplitude but constant wavelength

17.4.7 Radius: Wavelength Ratio (r/λ)

This is the ratio between radius of the meander curvature (*r*) and the wavelength (*λ)* of the meander. The ratio for a perfect sine generated curve of single line is 1:4. This ratio is also a good measure of the intensity of a meander (Fig. 17.7). In general, greater the ratio, more intense is the meander (all other variables are constant).

If amplitude (a_m) varies, then following relations could be found-

a. $(r/\lambda) = 1/4$, meander is regular (where $a_m = r$)
b. $(r/\lambda) = 1/4$, meander is intense (where $a_m = 2r$)
c. $(r/\lambda) = 1$, meander is more intense towards neck cut-off (where $a_m > 2r$)
d. $(r/\lambda) = 1/4$, meander is open (where $a_m < r$)

17.4.8 Sinuosity Index

It is the most common and widely used measure of the intensity of meander of a stream. There are several forms of sinuosity indexes. Such as –

1. Sinuosity Index $(\text{S.I.}) = \frac{\textit{Channel Length}}{\textit{Air Length}}$ (Stolum 2013)
   The ratio varies from river to river with average value slightly greater than 3. The actual ratio is approximately 3:14, which is close to the ratio w/λ (Richeson 2013).
2. Sinuousity ratio $(\text{SR}) = \frac{\textit{Channel Length}(CL)}{\text{Valley length }(VL)}$ (Leopold et al. 1964).

And if the SR < 1.1, the channel is straight; if SR varies from 1.1 to 1.5, the channel is sinuous; and if SR > 1.5, the channel is meandering (Charlton 2008; Leopold et al. 1964).

3. $\text{S.I.} = \frac{\text{Thalweg length}}{\text{Valley length}}$ (Leopold and Wolman 1957, 1960).
4. $\text{S.I.} = \frac{\text{Channel length}}{\text{Wave length}}$ (Leopold and Langbein 1966)
5. $\text{Sinuousity ratio (SR)} = \frac{\text{Channel length}}{\text{Meander Axix Length}}$ (Brice 1964, 1984)
6. $\text{Sinuousity ratio (SR)} = \frac{\text{Stream length}}{\text{Valley Length}}$ (Schumm 1963)

Many authors have set an index range to categorize streams on the basis of sinuosity. Such as less than 1.3 is sinuous and above 1.3 is meandering (Mueller 1968). To refine accepted categories of straight, sinuous and meandering, Schumm used terms straight, transitional, regular, irregular and tortuous (Mueller 1968). Braided and meandering channels have sinuosity indices 1.06 and 1.49 respectively (Schumm 2005). Another scheme of stream classification on the basis of sinuosity index was as follows (Morisawa 1985)-

Straight < 1.05
Sinuous > 1.05
Meandering > 1.5
Braided > 1.3
Anastomosing > 2.0.

Mueller (1968) has redefined the sinuosity index to incorporate hydraulic and topographic sinuosity. As per MuellerC.I. $= \frac{CL}{Air}$ (Fig. 17.8) where

CL is the length of the channel of the stream
Air is the shortest air distance of a reach
CI is Channel Index

$$\text{V.I.} = \frac{VL}{Air}$$

where

VI is the Valley Index

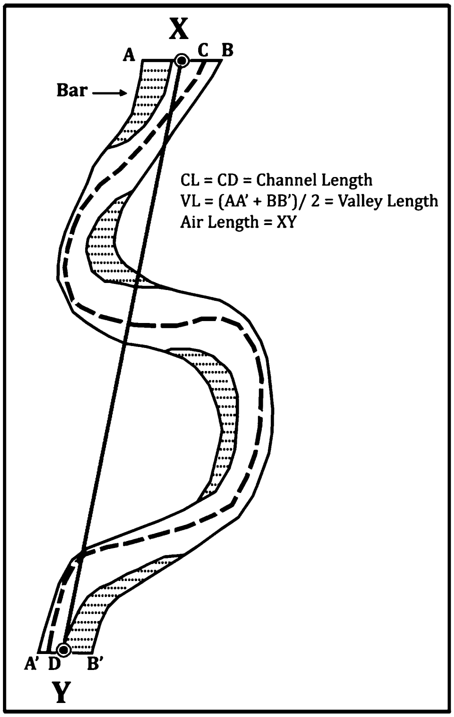
$$\text{H.S.I.} = \left(\frac{\text{CI} - \text{VI}}{\text{CI} - 1}\right)100$$

where

H.S.I. is the Hydraulic Sinuosity Index

$$\text{T.S.I.} = \left(\frac{\text{VI} - 1}{\text{CI} - 1}\right)100$$

Fig. 17.8 Variables needed for sinuosity index



Where

T.S.I. is the Topographic Sinuosity Index

However the sinuosity index determined the intensity of meander of a stream but not the qualitative nature of such intensity of meander. Although attempt has been made to classify streams on the basis of the sinuosity indexes.

17.5 Meander Shape Index (S_mI) and Meander Form Index (F_mI)

17.5.1 Meander Shape Index (S_mI)

It is another dimensionless measure of bend tightness and defined as the ratio between radius of curvature (r) and amplitude (a_m) of meander and expressed as

$$S_mI = r/a_m$$

where r is the meander radius
a_m is the amplitude of meander bend

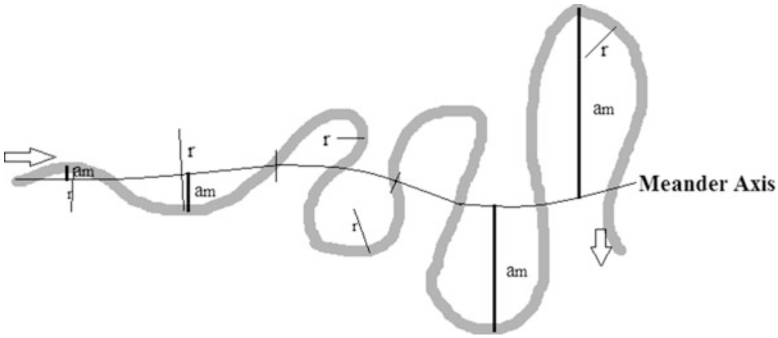


Fig. 17.9 Varying intensity of a meander with varying radius and amplitude

The tightness or intensity of a meander (I_m) is expressed by the value of the index as follows-

When $S_mI > 1$, open meander
$S_mI = 1$, regular meander
$S_mI = 0.5$, intense meander
$S_mI < 0.5$, acute meander

In Fig. 17.9, the intensity of meander is increasing rightwards with increasing value of the ratio. The rightmost bend with amplitude (a_m) manifold greater than the radius of curvature (r), have the lowest ratio and the highest degree of tightness of meander.

When the arc angle (θ_a) is more than 180° and the bend is confined within $\lambda/2$, then if the $r < a_m/2$, the meander is acute towards the tendency of neck-cut off (Fig. 17.9).

17.5.2 *Meander Form Index (f_mI)*

Meander form index is the measure of degree of intensity of curvature of meander. It is defined as meander-amplitude (a_m) divided by wavelength (λ) and expressed as –

$$f_mI = a_m/\lambda$$

If λ is constant and amplitude varies, then (Fig. 17.7 and Fig. 17.10)-

a. *$(a_m/\lambda) = 1/4$, meander is regular (where $a_m = r$)*
b. *$(a_m/\lambda) = 1/2$, meander is intense (where $a_m = 2r$)*
c. *$(a_m/\lambda) \geq 1$, meander is more intense towards neck cut-off (where $a_m \geq 2r$)*
d. *$(a_m/\lambda) < 1/4$, meander is open (where $a_m < r$)*

Guessing about tendency towards neck cut-off is not possible with the knowledge of one of the above mentioned indices or a measure. Arc angle (θ_a) and

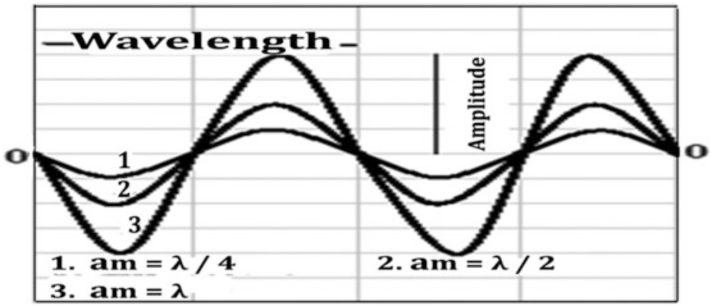


Fig. 17.10 Varying intensity of a meander with varying amplitude

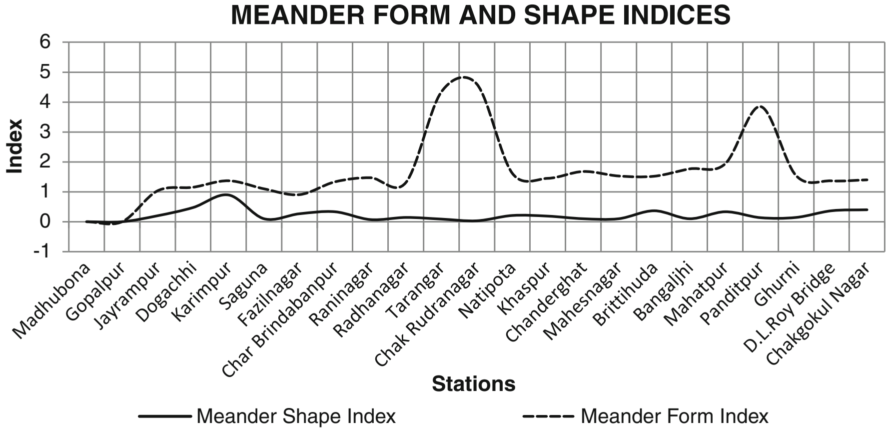


Fig. 17.11 Meander form and shape indices of the river Jalangi at different reaches

Direction angle (θ) are two important considerations along with hydrological parameters and bank materials to comment on the probability on the neck cut-off.

When the value of the index is ≥ 1, the form of meander is acute. If 0.5, meander is regular and if 0.5 to 0.25, it is open. If the value less than 0.25, meander form is wide.

17.6 Case Study

Segment wise details of *Meander Shape Index (S_mI)* of the river Jalangi in the district of Nadia of West Bengal *are* shown in the Fig. 17.11. Average Meander Shape Index *(S_mI)* of the river is only 0.24 which implies the acute shape of meanders with amplitude *(a_m)* more than 4 times the radius *(r)*.

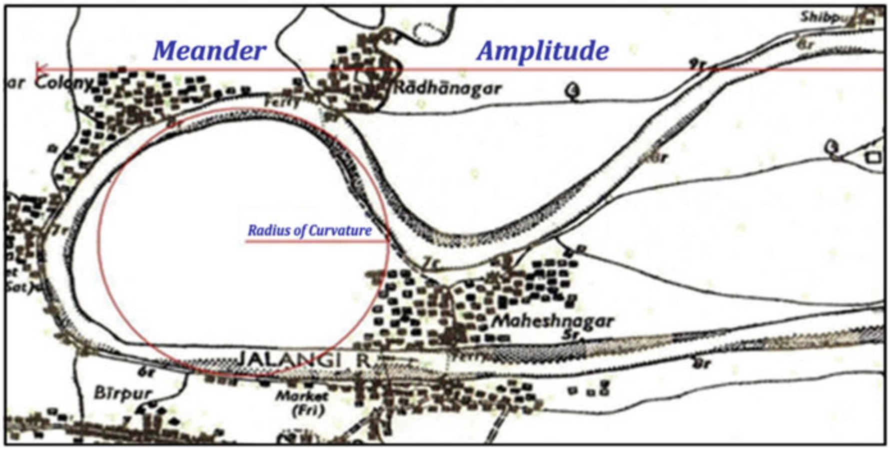


Fig. 17.12 Acutely Intense Meander of Jalangi at Radhanagar Loop (Topographical Map No. 79A/6, scale: 1:50,000)

Meander form index (f_mI) for the river Jalangi is 1.58 which implies that the meander is very acutely developed. Radhanagar loop (Fig. 17.12) has the maximum *meander form index* (f_mI) with amplitude (a_m) nearly twice the length of wave-length(λ).

17.7 Conclusion

Values of meander shape index and meander form index for a given meander goes opposite to each other. If the mender shape index (S_mI), is more, meander form index (f_mI) is less. It is very difficult to add qualitative essence to the intensity of meander. If only one variable of a meander plan-form is known, then it is not possible to mark exactly the other. This is because all the variables of a meander plan-form are ever-changing and affect other variables. Therefore to have the goal further research work with adequate number of case study done on different deltaic meanders tested by more efficient statistical instruments is recommended.

Acknowledgement Who with their kind of spontaneous help made me grateful to them to complete this study are my beloved students; boatmen of different *ferry ghats* and fishermen who live on the river Jalangi making the herculean task of channel measurement possible. I acknowledge my hearty gratitude to them whose names are not uttered here but some information and diagram of them has been collected from internet, the system with which I am not familiar adequately. Listed names under the sub-head 'reference' are also acknowledged. I also acknowledge my gratitude to my beloved student Aznarul Islam who is well acquainted with the *Key Style* of different journals and who set this paper in the structure. I must acknowledge my hearty gratitude to Prof. Mehtab Singh, Prof. R.B. Singh, Prof. Izhar Hassan, editors, who gave me privilege providing space for this paper in this volume. Last but not the least I express my gratitude to Springer.

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Chapter 18
Integrated Approach of Remote Sensing and GIS for Watershed Management: A Case Study of wga-2a Sub-Watershed of Godavari River Basin, Nagpur, Maharashtra

Subrata Chatterjee and Sujay Bandyopadhyay

Abstract A watershed is a fluvial geomorphological unit in which all the precipitation and streams drain into a common outlet such as the mouth of a bay or any point along a stream channel. Stream flow and the water quality of a river are affected by both anthropogenic and natural factors existing within the catchment area, hence it is vital to study watershed and its management. This includes identification of problems and issues impacting the natural resources of the watershed and recommending management solutions that will benefit the community, the economy and the environment and would bring about a sustainable development within the watershed.

The present study seeks to generate various thematic maps in GIS domain like Drainage, Geomorphology, Road, Rail, Canal, Forest, Settlement, Land Use Land Cover etc. using high resolution satellite data (IRS LISS IV and Cartosat-1). The application of Analytical Hierarchy Process (AHP) has been used to give suitable weightage value to various factors in each layer. In this paper, Land Resource Development Plan (LRDP) map has been generated to suggest conservation of forest, Farmbund, Social forestry etc. to protect soil loss, soil erosion and also Water Resource Development Plan (WRDP) map has been generated to suggest to make some structures like Canal, check dam, reservoir for the conservation of water resources. The future implication of the study would be to control damaging runoff and degradation of land and thereby conservation of soil and water.

Keywords Drainage • Remote sensing and GIS • Watershed

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18.1 Introduction

Watershed is defined as "Natural hydrologic entity that covers a specific area expanse of land surface from which the rainfall runoff flows to a defined drains, channel, stream or river at any particular point" (Watershed Atlas of India 1990).

A watershed is an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel (Seshagiri Rao 2000). The word watershed is sometimes used interchangeably with drainage basin or catchment. Ridges and hills that separate two watersheds are called the drainage divide. Larger watersheds contain many smaller watersheds. It all depends on the outflow point, all of the land that drains water to the outflow point is the watershed for that outflow location. Watersheds are important because the stream flow and the water quality of a river are affected by things, human-induced or not, happening in the catchment area "above" the river-outflow point (USGS Portal, n.d).

Remote sensing and GIS techniques are important tool in hydrology and water resources development, this is due to the fact that most of the data required for hydrological analysis can easily be obtained from remotely sensed images (Mustafa et al., 2012). Moreover, remote sensing can provide a measurement of many hydrological variables used in hydrological and environmental model applications, either as direct measurements comparable to traditional forms.

In this study, this tool has been used in determining the watershed geometry, drainage network, and other map-type information and providing input data such as soil moisture or delineated land use classes that are used to define runoff coefficients.

This study has been carried out in a small WGA-2A Sub-Watershed of Godavari River Basin. In this study, various thematic layers like drainage, road network etc. has been generated using high resolutions satellite data (IRS Liss-4 and Cartosat-1). This approach has been assisted to identify the proper locations suitable for various soil and water conservation activities like terracing, bunding, trenching, farm ponds, percolation tanks, check dams, plantations and pasture land development.

18.2 Objectives of the study

The different objectives of watershed management are:

To generate water resource development plan map.
To generate land resources development plan map.

18.3 Study Area

The selected watershed area is located in Umred Taluka of Nagpur District. It is about 22–25 km away from Nagpur city.

The WGA-2A sub-watershed is situated between latitude 20°51′48″ N to 20°58′13″ N and longitude 79°07′83″ E to 79°18′04″ E. It spreads at an area of 127 km^2 and nearly 44 villages bordering NH-7 at West, Nagpur City towards North, Muniya Reserved Forest to Southern and Wainganga River at East (Fig. 18.1).

18.4 Data Used and Methodology

18.4.1 Satellite Data

The following IRS P6 LISS-IV, CARTOSAT-1 data were used for watershed management includes drainage, slope, land use/land cover, geomorphology, geology and soil etc (Table 18.1).

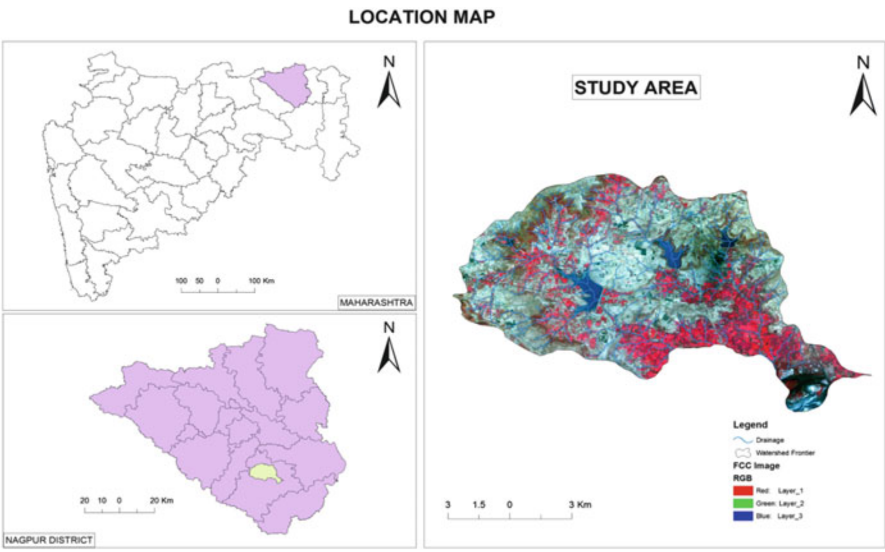


Fig. 18.1 Location map of the study area

Table 18.1 Satellite data

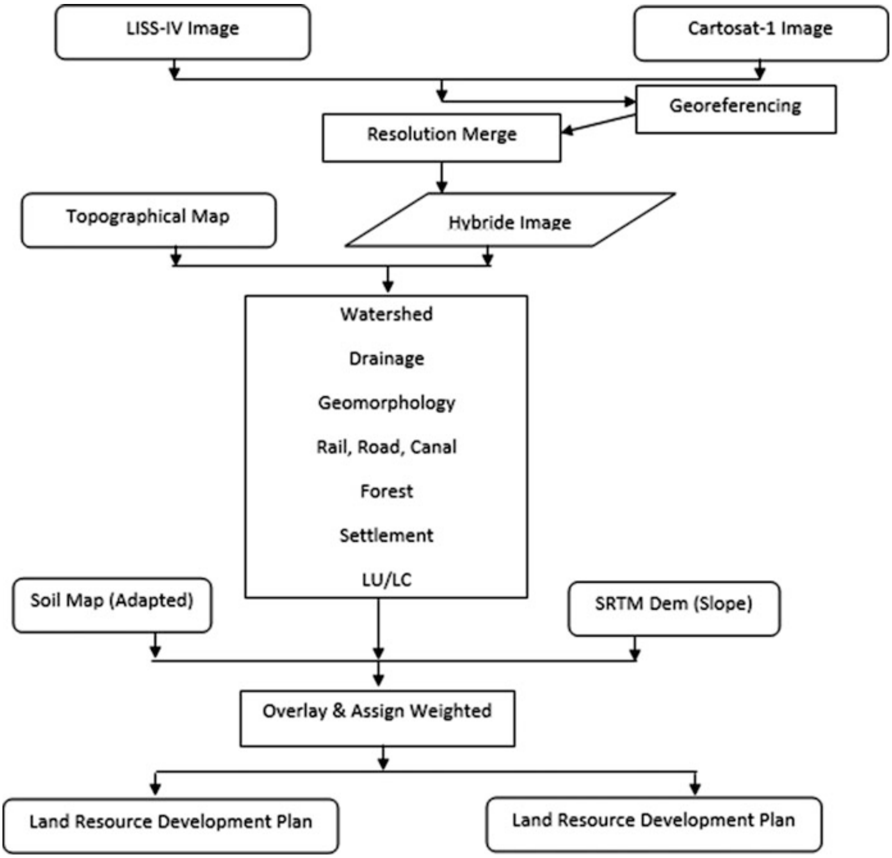
Satellite data	Row	Path
IRS P6 LISS-IV	102	076
CARTOSAT-1	300	544

18.4.2 Collateral Data

The other data used for preparation of different thematic maps include;

Survey of India topographic maps on 1:50 K (55 L/1, 55H/13, 55 K/4).
SRTM data used for digital elevation model preparation.
Digital data base on under Watershed project-2010-2011
Village cadastral maps on 1:10 K scale.

18.4.3 Methodology



18.5 Results and Discussion

18.5.1 Drainage of the Study Area

The drainage is digitized from the SOI toposheet using Digitizing technique and stream ordered has been done using Strahler method. The watershed having stream order up to 5th order. Bifurcation ratio of the watershed could also show which parts of a drainage basin is more likely to flood. The bifurcation ratio is not same from one to another due to irregularities in the topographic feature of the drainage basin. The average bifurcation ratio of sub-watershed is 4.15.

18.5.1.1 Stream Order

It is a measure of the degree of stream branching within a watershed. Each length of stream is indicated by its order (for example, first-order, second-order, etc.). A first-order stream is an un-branched tributary, a second-order stream is a tributary formed by two or more first-order streams. A third-order stream is a tributary formed by two or more second-order streams and so on (Strahler 1957) (Fig. 18.2, Tables 18.2 and 18.3).

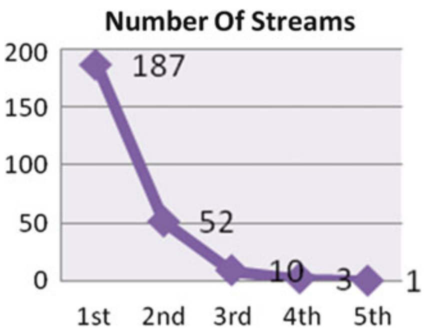


Fig. 18.2 No of streams

Table 18.2 Stream ordering

Stream order	Number of streams
1st	187
2nd	52
3rd	10
4th	3
5th	1

Table 18.3 Bifurcation ratio

Stream order	Bifurcation ratio(Rb)
1st	3.62
2nd	5.30
3rd	3.67
4th	4.00
Mean Bifurcation Ratio of the Study area is = 4.15	

18.5.1.2 Bifurcation Ratio (Rb)

Bifurcation Ratio (Rb) is defined as the ratio of the number of streams of any order to the number of streams of the next highest order (Strahler 1957). Values of Rb typically range from the theoretical minimum of 2 to around 6. Typically, the values range from 3 to 5. The bifurcation ratio is calculated as

$$\mathrm{Rb} = \text{Higher Order} + 1/\text{Next Lower Order}$$

18.5.1.3 Drainage Density

The drainage density (Horton 1932), D is the ratio of the total length of streams within a watershed to the total area of the watershed; thus D has units of the reciprocal of length (1/L). A high value of the drainage density would indicate a relatively high density of streams and thus a rapid storm response. Values typically ranges from 1.5 to 6 mi/mi^2.

$$\mathrm{D} = \mathrm{L_t}$$

Here drainage density is = 1.80 mi/mi^2.

18.5.2 Water Resource Development Plan

Water resource development action plan was developed for the water and soil conservation in the watershed. The weighted overlay method used for the analysis and preparation of the water harvesting using various conservation structures and zonation map was prepared. The weightage and rank are assigned according to the importance of the thematic layer for the zonation of conservation structures (Figs. 18.3 and 18.4, Tables 18.4 and 18.5).

In the action plan water and soil conservation structures suggested were check dam, cement nala bund, earthen nala bund, percolation tank, farm pond, sunkan pond, and loose boulder structure using various thematic layers.

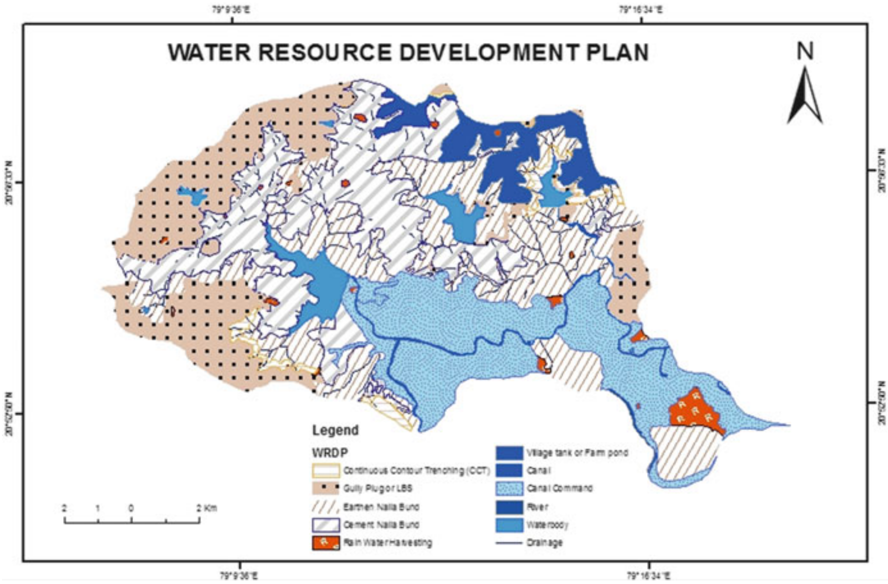


Fig. 18.3 Water resource development map

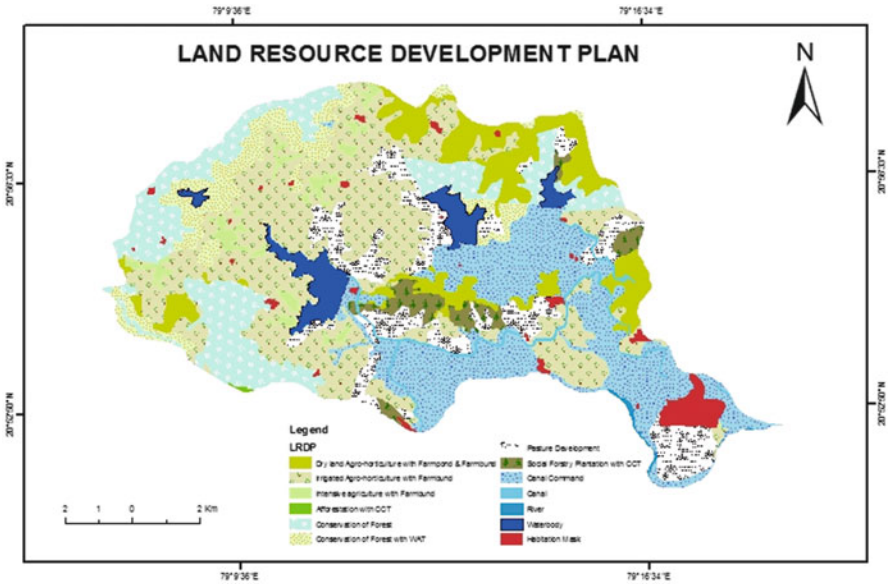


Fig. 18.4 Land resource development map

Table 18.4 Water conservation measures

Region	Recommendations
Hills/mountains	Roof water harvesting, Division of perennial streams into a storage structure, Check dams, Gully plugging, collection from hill slopes
High rainfall areas	Tank/Pond, Check dam, Gully Plugging, Contour bunding
Semi arid and arid areas	Tank/reservoir, Check dam, Percolation tank, Gully plugging, Contour bunding, Gabion in lower reaches
Coastal zones	Tank, Check dam, Gully plugging, Khadin

Table 18.5 Soil conservation structures of the study area

Sl no.	Soil conservation structures
1	Dry land agro-horticulture with farm pond and farm bund
2	Irrigated agro-horticulture with farm bund
3	Intensive agriculture with farm bund
4	Afforestation with CCT
5	Conservation of forest
6	Conservation of forest with WAT
7	Pasture development
8	Social forestry plantation with CCT
9	Canal command
10	Canal

18.5.3 Land Resources Development Plan

Land resource development action plan was developed for the water and soil conservation in the watershed. The weighted overlay method used for the analysis and preparation of the soil conservation using various conservation structures and zonation map is prepared using various thematic layers. Those are

18.6 Conclusion

The study suggests that the impact of watershed is more focused towards physical and biological achievement, but the focus on social aspects is limited. There are certain positive trends towards growth of water level, soil regeneration capacity, land use pattern, cropping pattern, livestock production, etc. For the water conservation structures like check dam, percolation tank, earthen nala bund, form pond, graded bunding, sunkan pond, roof rain water harvesting, and loose boulder structure has been suggested in the study area and for soil conservation activities, continuous contour trenches, check dam, afforestation with continuous contour trenches, canal command, conservation of forest, dry land agro-horticulture with farm pond, horticulture plantation, intensive agriculture with farm bund, irrigated agro-horticulture with farm bund, and pasture development etc. has been suggested in various parts of the study area. The conservation zonation structures were suggested to reduce soil erosion and conserve the water as natural resource for the sustainable watershed management.

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Chapter 19
Evaluation of Drainage Morphometry in Thalisain Area of Lesser Himalaya: (Using Remote Sensing and GIS Techniques)

Tripti Jayal

Abstract The Impact of the Morphological characters on the terrain is reflected by the drainage of the area. Thalisain area of Pauri district consist the upper portion of Nayar Basin (The Eastern and western Dudhatoli Water Divide)+the upper part of Bino Nadi. The upper portion of Nayar Basin, Dudhatoli top from here Eastern and Western Nayar take birth (originates). The study area forms a part of Garhwal Himalaya within in central Himalaya and represents moderate relief of lesser Himalaya. The geometric properties of drainage and network of sub watershed was delineated using remote sensing and are estimated on Topographical Sheet on the scale of 1:50,000. The morphometric analyses of watershed have been carried out using GIS softwares. The study gives a wide description of drainage network analysis, like streams order, drainage density, drainage frequency, length ratio, relief ratio etc. and these are clear evidences for the structural control and also involves the study of drainage pattern. The drainage features of the Thalisain area are dependent on the geology, geomorphology, topography and climate. Therefore in the study a systematic analysis of the pattern in the drainage network as well as the morphometry of the watersheds has been undertaken. The main aim of this paper is to analysis morphometric parameters of this area.

Keywords Drainage • Lesser Himalaya • Morphometry • Remote sensing and GIS techniques • Thalisain

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19.1 Introduction

The physical aspect connects natural combination of landforms, hydrology, soil and biota. Landform is a topographical unit of location ensemble with similar characteristics in Structure, Relief, Pedogenesis and Vegetation types (Fairbridge 1968). Morphometry is the measurement and mathematical analysis of the configuration of the earth's surface, shape and dimension of its landforms (Agarwal 1998; Obi Reddy et al. 2002). Hydrology and Geomorphology are the important measures of drainage parameters which provide the useful numerical measure of landscape dissection and runoff potential. Evaluation of morphometry parameters necessitates the analysis of various drainage parameters such as ordering of the various streams, measurement of basin area and perimeter, length of drainage channels, drainage density (D_d), Stream frequency (F_s), bifurcation ratio (R_b), texture ratio (T), basin relief (B_h), Ruggedness number (R_n) and time of concentration (T_c) (Verstappen 1983; Kumar et al. 2000; Ozdemir and Bird 2009).

Remote Sensing and Geographical Information System techniques have been used for the analyses of the morphometry analysis of the Thalisain area. Identification of drainage networks within basins or sub-basins can be achieved using traditional methods such as field observations and topographic maps or alternatively with advanced methods using remote sensing and DEMs (Verstappen 1983; Mark 1983; O'Callaghan and mark 1984; Rinaldo et al. 1998; Macka 2001; Maidment 2002). Remote sensing and GIS methods are the powerful tools for data analyzing and representing. Remote sensing is capable of obtaining synoptic views of large inaccessible area at a time and can analyze drainage morphometry. The present study is undertaken with objectives to evaluate drainage morphometry based on morphology and geological parameters of the study area (Fig. 19.1).

19.2 Study Area

The study area forms a part of Garhwal Himalaya within Central Himalaya and represents moderate relief of lesser Himalaya. The relief of the area is quite rugged and variable. The whole area is characterized by steep slope, lofty mountains and uneven and difficult topography. The area includes different land feature like horned peaks, serrated crests, cirques, hanging valleys, torrential rapids, waterfall and escarpments. Thalisain area in Pauri district is extended from 29°54′30″ to 30°10′0″ N and 78°54′0″ to 79°13′30″ E, measuring 35 km in length and 49 km in width. The Eastern part is delineated with an alpine pasture locally known as Bugyal is Dudhatoli ridge. The study area is drained by three rivers partially are Eastern 207.91 km^2, Western Nayar 254.75 km^2 and BinoNadi 121.34 km^2. Eastern-Western Nayar and Bino are the sixth order tributaries of Nayar and Ramganga River respectively (Fig. 19.1).

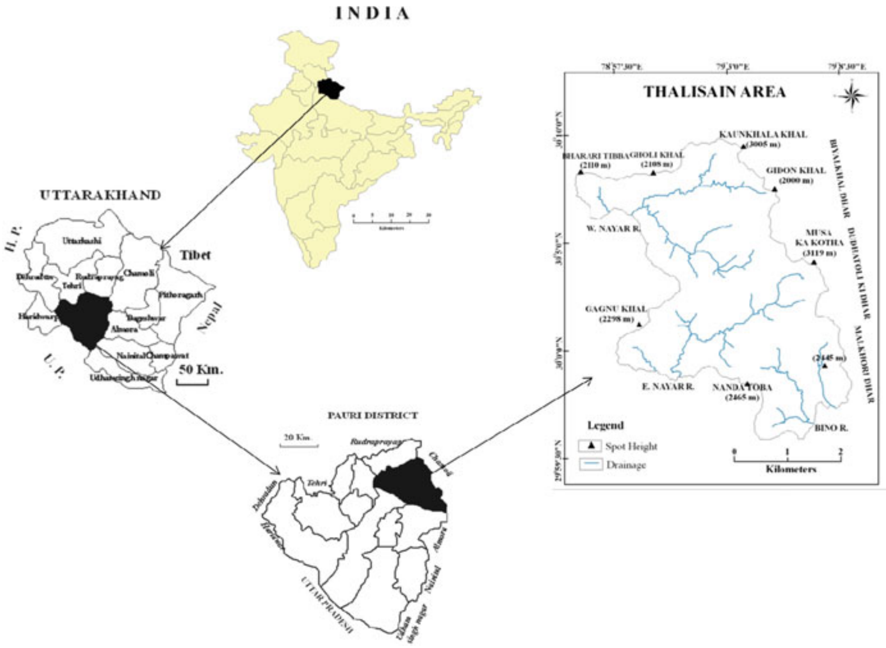


Fig. 19.1 Location map of study area

19.3 Data Used and Methodology

19.3.1 Data Used

In present paper for base map Survey of India Topographic Sheets (53 J/16, 53 K/13, 53 N/4 and 53O/1 at 1:50,000 scales, IRS 1C (LISS III data) satellite imagery and ASTER DEM was used. For interpretation, analysis and map preparation software's used were Arc GIS 9.3, ERDAS Imagine 9.2 and Microsoft Word, Microsoft Excel for calculations and data preparation. For the study of Regional geology K.S. Valdiya geological map was used.

19.3.2 Methodology

The Quantitative analysis has been done based on Survey of India toposheets and used as reference to prepare base map. Drainage network of the sub-watersheds were delineated using IRS 1C (LISS III data)/ASTER (DEM) and different morphometry parameters have been generated in GIS environment. It was verified through limited field check.

The morphometry analysis and interpretation of the watershed has been carried out using ERDAS Imagine 9.2 and ARC GIS-9.3version. GIS techniques are assessing various terrain and morphometry parameters of the drainage basins and watersheds, as they provide a flexible environment and a powerful tool for the manipulation and analysis of spatial information.

19.4 Result and Discussion

19.4.1 Geological Set-Up of Study Area

The Thalisain block is, located in the lesser Garhwal Himalaya south of the Dudhatoli range, which exhibits a variety of meta-sediments that have suffered multiple phases of, deformation and metamorphism (Gairola and Joshi 1978). Auden (1937) described the Dudhatoli crystallines as a thrust sheet. Later (1949) he thought the Dudhatoli granites and schists to be occurring at the base of the KrolNappe unit. The Dudhatoli granite massif is extended in the north-west of Almora Crystalline Thrust sheet (Gansser 1964) (Fig. 19.2).

Structurally, the study area which forms a part of the Dudhatoli-Almora Thrust sheet (Gansser 1964), is very interesting where linear and planer structures and folds are very well developed. The important rocks types present in the study area are Granite, Schists, Quartzites and Gneisses. The area formed by sedimentary, igneous and low to high grade metamorphic rocks. Unweathered are hard, massive and more resistant to weathering viz. gneisses and quartzite form steep slope, whereas those, Phyllites and schist generally are more weathered and close to the surface.

19.4.2 Relief Analysis

Relief analysis is one of the most important and basic device in morphological studies. According to Brusden (1980) relief and slope steepness together have a marked effect on the rate of surface runoff, infiltration and flow through the channel.

19.4.2.1 Absolute Relief

Absolute relief has been prepared by facet map of the study area and collecting the maximum height of each facet with the help of contours and spot heights. These value ranges from a minimum height of 1,180 m at Somaya to a maximum of 3,119 m at Musa ka kotha. After analyzing the different relief feature in relation to

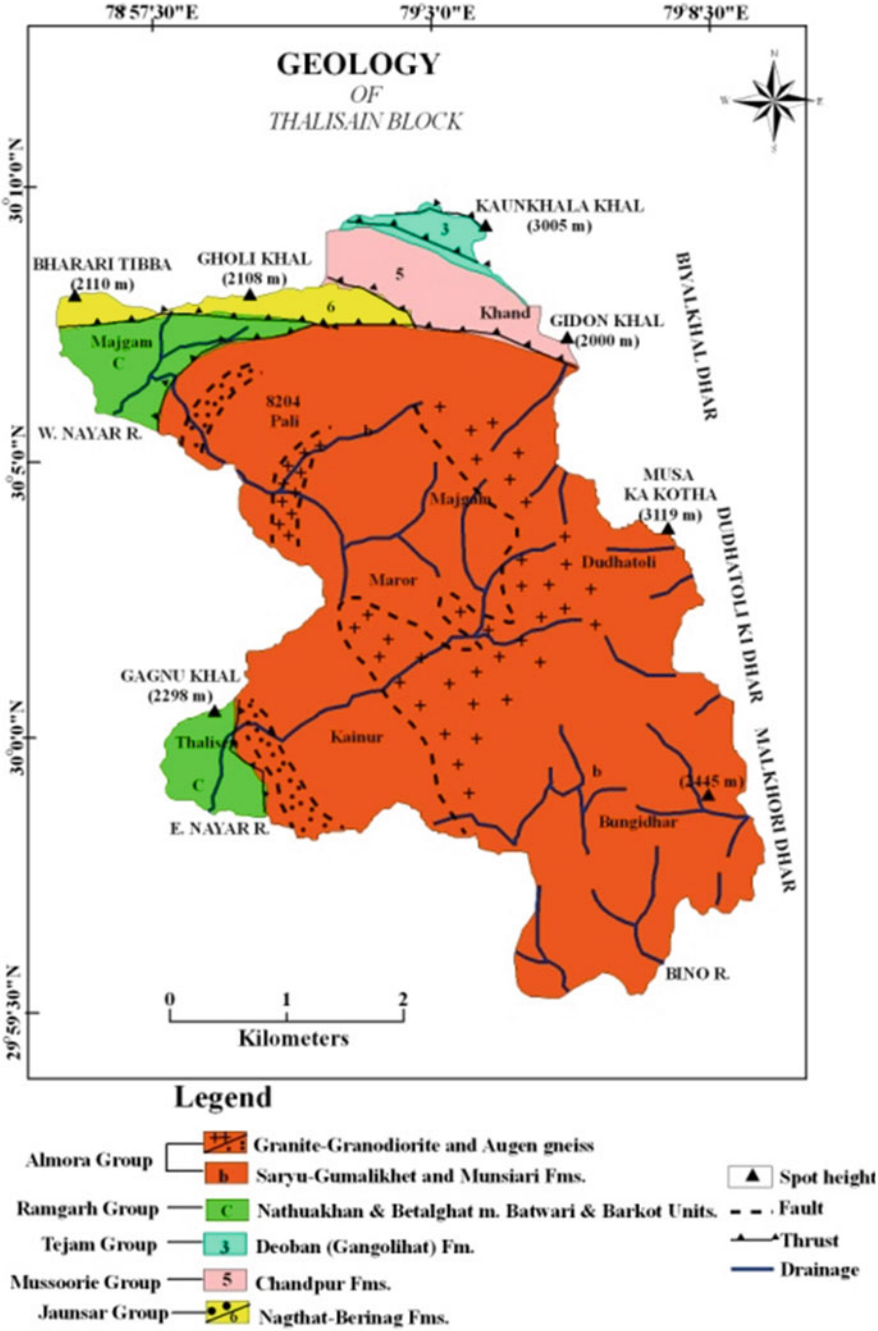


Fig. 19.2 Geological map

altitude, it has been possible to identify and map five categories of absolute relief, ranging from below 2,000 m to above 2,600 m, at regular interval of 200 m.

19.4.2.2 Relative Relief

The term 'relative relief', in general, denotes the actual variation of heights in a unit area with respect to its local. Relative Relief is been classified into five groups: extremely low (below 200 m), Low (200–300 m), Moderate (300–400 m), high (400–500 m) and extremely High (above 500 m). Maximum area 39.56 % of the total area comes under the category of moderate relative relief (400–600 m) (Fig. 19.3).

19.4.2.3 Roughness Index

Roughness Index is basically used to express the roughness or total characteristics of the surface configuration, used also to express the relation with landuse. In the present study area, of Thalisain block the roughness Index has been analyzed by taking the grid of 1 km^2 and the value was computed to portray the distribution of roughness index in the study area. The range of the value has been grouped in five classes which range from less than 6 to above 24.

19.4.2.4 Dissection Index

Dissection Index is the ratio of two variables of morphometry that is relative relief and absolute relief with in a definite area, to express even the dynamic potential of the area as its vertical distance from erosion base.

The dissection index, thus calculated for the study area, varies from (0.71 to 0.86). For the categorical distribution of dissection index, the range of value has been grouped into five categories.

19.4.3 Slope Analysis

Slope defines as angular inclinations of terrain between hilltops (crests) and valley bottoms, resulting from the combination of many causative factors like geological structure, climate, vegetation cover, drainage etc. The area was categorized into five ranges viz. Very Steep slope (above 26°), Steep slope (21–26°), Moderately Steep slope (16–21°), Moderate slope (11–16°) and Gentle slope (below 11°). It is noted that about 20.14 % of the study area has moderate slope and Steep slope characterizes about 22.68 %.

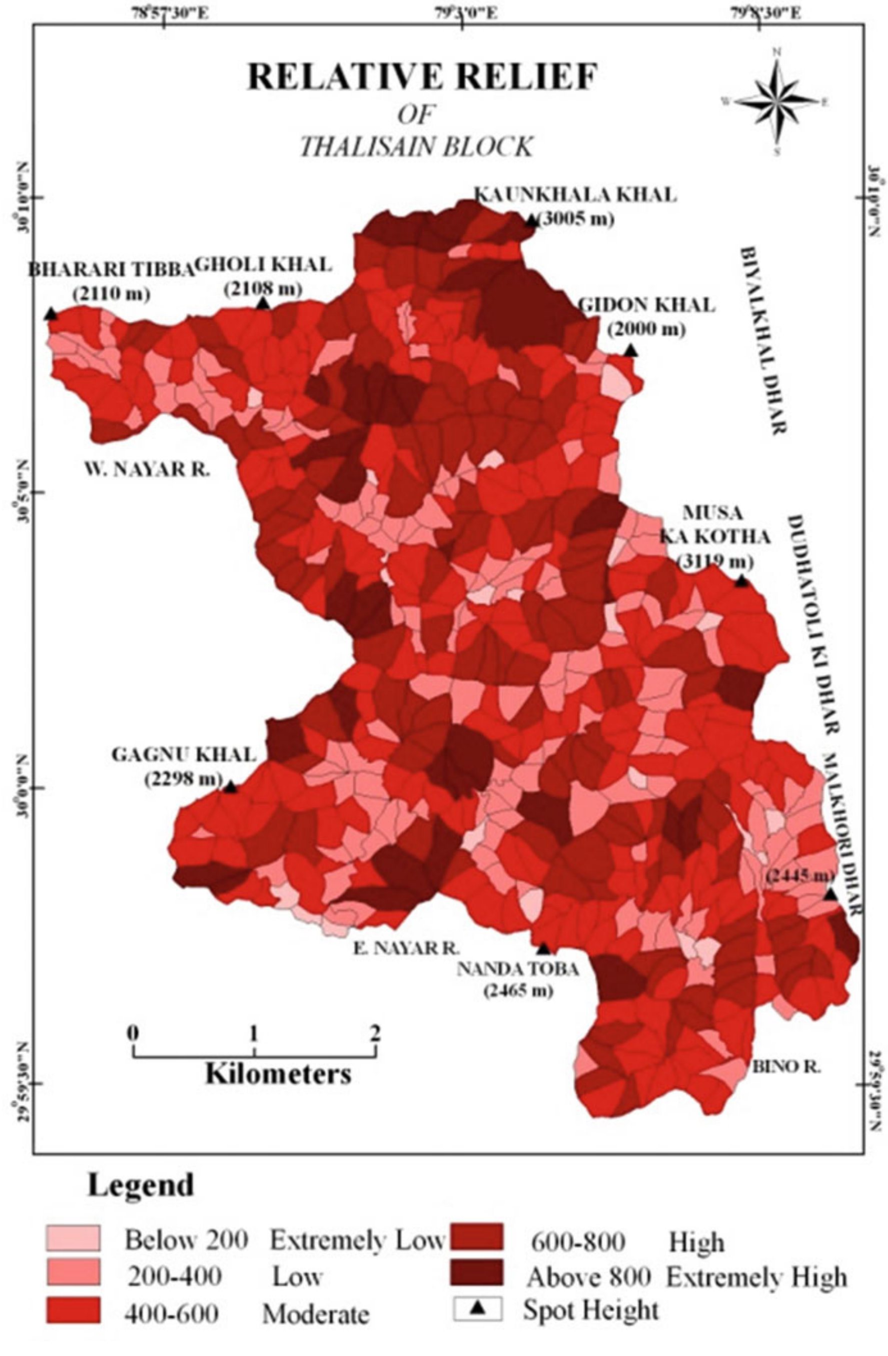


Fig. 19.3 Relative relief map

Table 19.1 Drainage pattern of Thalisain area

Morphometric units	Drainage	Bed rock characteristics
River valley	Trellis	Gentle slope with highly permeable unconsolidated material
Hill slopes		
Valley-side slopes with colluviums	Dendritic	Moderate slope with less pervious bed rocks
Hill side slopes with free face	Sub parallel to Dendritic	Moderately high slope with Impervious bed rocks
Summit surface	Radial	Steep slope with impervious bed rocks

19.4.4 Drainage Analysis

Relevance to morphometry analysis in fluvial terrain, the drainage basin is a fundamental unit. The present study is an attempt to find out the stage in the geomorphic development of the study area, carried out with the help of different morphometry attributes, namely stream order, stream number, stream length, mean stream length, bifurcation ratio, mean bifurcation ratio, stream length ratio, elongation ratio, circulatory ratio, drainage density and drainage frequency etc.

19.4.4.1 Drainage Pattern

Each river system has its own plan or morphology guided by so many factors as initial slope, nature of rocks, structural control, recent diastrophism and recent geological and geomorphic history of the basin (Thornbury 1954) (Table 19.1). Drainage analysis the topographical expression of an area and it is observed that steep slope of the area have developed radial drainage, moderate drainage had parallel to sub parallel or dendritic drainage and gentle slope developed a typical trellis type of drainage (Table 19.1).

19.4.4.2 Drainage Density

Drainage density is defined as the total length of stream segments per unit area. There are many factors affecting the drainage density of the area, these are run off, erosion proportionality factor, relief, density and absolute viscosity of the fluid and its acceleration due to gravity. High density can be observed in high relief, week/ impermeable material, sparse vegetation and low density in low relief, high resistance material and dense vegetation. The drainage density of Thalisain area varies from below 1.5 to above 4.5.

19.4.4.3 Drainage Frequency

The drainage frequency is defined as the total number of stream segments per unit area. In general, the occurrence of stream segments depends on the nature and structure of rocks, vegetation cover, nature and amount of rainfall and infiltration capacity of soil. It is an index of the various stages in landscape evolution. The stream frequency of the area is 0–18 stream/km^2.

19.4.4.4 Drainage Texture

The term drainage texture means closeness in the spacing of stream channels. The concept introduced by Horton (1945) and Strahler (1957). It is defined as the ratio between channel length and the area of the grid in the same planimetric surface (Miller 1953). On the basis of the above model of Savindra Singh the obtained values of drainage texture (after Savindra Singh) range from 0 (Zero) to more than 1. The lower values of drainage texture refer to fine texture whereas higher values designate coarse texture. Drainage texture moderate to fine is highest observed in the basin, whole which consist outer crystalline rock. Covers an area of 54.97 % the drainage lines are moderately developed on the mid slope of the ranges under the soft non-resistance structure.

19.4.4.5 Stream Order

According to Strahler (1964), the first order streams are those which have no attributes. The second-order streams are those which have as tributaries only first-order channels. Where two second order segments or channels join, a channel segment of third-order is formed. Similarly, when two third order channels join, they give rise to a fourth-order channel and so on (Table 19.2). The Eastern/ Western Nayar and Bino River are the trunk stream of the study area and within the study area these three are of sixth order. The plot in (Fig. 19.4) shows relation between stream order and stream length.

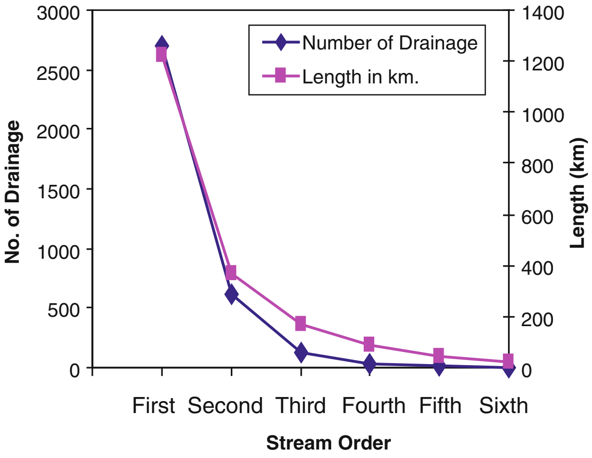
19.4.4.6 Stream Numbers

The number of stream segments in each order is known as stream number Horton's (1945) law of stream numbers status that the number of stream segments of each order forms an inverse geometric series with the order number. (Table 19.2) shows order wise stream frequency in the tributary basin of the study area reveals a maximum frequency in case of first order stream. Further, it is noted that the stream frequency decreases as the stream-order increases. Plots of the number of streams (on log scale along the vertical axis) against the order of streams (on arithmetic

Table 19.2 Morphometric parameters

Stream order (Su)	No. of stream (Nu)	Bifurcation ratio (Rb)	Mean bifurcation ratio (Nu-r)	No. of stream used in the ratio (Rb*Nu-r)	Weighted mean bifurcation ratio (Rbwm)	Stream length (Lu)	(Lu/Su)	Stream length ratio (Lur)	Mean stream length (Lur-r)	Stream length used in the ratio (Lur*Lur-r)	Weighted mean stream (Luwm)
First	2,698					12,221.15	0.45				
Second	613	4.40	3,311	14,572.72		366.65	0.60	3.33	1,587.8	5,288.26	
Third	133	4.61	746	3,438.33		171.35	1.29	2.14	538	1,151.20	
Fourth	33	4.03	166	669.03	3.31	88.25	2.67	1.94	259.6	504.05	2.84
Fifth	8	4.13	41	169.13		46.5	5.81	1.90	134.75	255.74	
Sixth	3	2.67	11	29.33		20	6.67	2.33	66.5	154.61	
Total	3,495	19.83	4,275	18,878.54		1,913.9	17.49	11.63	2,586.65	7,353.86	
		3.31						2.33			

Fig. 19.4 Stream order vs length



scale along the horizontal axis) indicate a linear co-relationship, which means that the number of streams generally decreases in geometric progression as the stream order increases.

19.4.4.7 Stream Lengths

Horton in his law of stream length has stated that the total lengths of stream segments of the successive orders in a basin tends closely to approximate a direct geometric series in which the first terms is the total length of streams of the first order. Here the basin study follows the same trend but in some basins variation is observed. Variation is lithology from hard quartzite to soft soluble limestone may have been the reason (Table 19.2).

19.4.4.8 Mean Stream Length

It is a dimensional property, revealing the characteristic size of components of a drainage network. Plots of cumulative mean stream length (on log–scale) and the order (on arithmetic scale) reveal more or less a straight-line correlation as postulated by Strahler (1945). (Table 19.2).

19.4.4.9 Stream Length Ratio

According to Horton (1945) the length ratio is the ratio of the mean length of streams of one order to that of the next lower order stream segments, which tends to be constant throughout the successive order of watershed. It is noted that the stream length ratio of each of the successive orders of the tributary basins of study area vary due to differences in slope and topographic condition (Table 19.2).

19.4.4.10 Bifurcation Ratio

The ratio between the total numbers of streams of one order to that of the next higher order in a drainage basin is known as the 'Bifurcation Ratio'. It shows the degree of integration prevailing between streams of various orders in a drainage basin. The average bifurcation ratio calculated from the basin is in (Table 19.2) high value of the ratio indicates lower degree of drainage integration and vice. In general, the bifurcation ratio ranges from 2 to 5. Large variations in stream frequency between successively higher order streams result in high bifurcation ratio. The lower number of streams of sixth order may be probably due to development of more mature topography in the lower reaches where these streams meet Western/Eastern Nayar and Bino River.

19.4.4.11 Weighted Mean Bifurcation Ratio

The (Table 19.2) reveals the weighted mean bifurcation ratio for all orders of the study area. It shows that the weighted mean ratio of area is 3.31.

19.4.5 Basin Shape and Size

The shape and size of the basin can conceivably affect the stream discharge and volume of rainwater received and hence, the total run off produced. Large basin has large average discharge (Muller 1968). Basin shape determines how rapidly the runoff will reach in the Main River as well as outlet. Studies by Hack (1957) indicate that as basin enlarges, the stream length increases and basin becomes narrower and longer.

19.4.6 Basin Area (A) and Perimeter

The area of the basin and perimeter P are important parameters in Quantitative morphology. The total area projected upon a horizontal plane contributing to all the channels in the basin along with all interbasinal areas. The author has computed the basin area by using ArcGIS-9.3 software, which is 584 km^2.

19.4.7 Elongation Ratio

The elongation ratio reveals the shape or form of a drainage basin which is the ratio of diameter of a circle of a same area as the basin to the maximum basin length (Schumm 1956).

A circular basin has a maximum efficiency in the movement of the run-off, whereas an elongated basin has the least efficiency, this information is significant in forecasting of drainage discharge, particularly in times of floods. It can be derived as:

$$\mathrm{R} = \frac{\sqrt{A/\pi}}{L}$$

The ratio approaches '1' (one) if the shape of basin approaches a circle. Strahler states that this ratio varies between 0.6 and 1.0 over a wide variety of climate and geologic type's value near 1.0 are found in typical regions of low relief; while value from 0.6 to 0.8 are generally associated with strong relief and step ground slopes (Strahler 1964). The elongation ratio of the area is 0.8.

19.4.8 Circularity Ratio

The circularity ratio may be defined as a basin area to the area of the circle having the same perimeter as the basin (Miller 1953). The circularity ratio of the tributary basin of the study area. The formula for calculation of basin circularity ratio is given below (Miller 1953):

$$Rc = 4\pi A/P^2$$

where Rc is basin circulatory, P is the basin perimeter, 4 is constant value, π 3.14286 and A is the area of basin. A value of '0' (zero) indicates a highly elongated shape and the value '1' (one) a circular shape.

The Circulatory ratio of the area is 0.6

19.5 Conclusion

The study reveals that remote sensing and GIS technique is very much helpful in drainage morphometric analysis. The present paper aims to analyze the quantitative morphometric parameters of the Thalisain area. The dendritic and radial drainage pattern is most common in the basin and varies in some places with moderate drainage texture. Morphology and structure of the basin and the high precipitation in hill ranges controls the initiation and development of drainage network whereas lithology and structure of the basin have great influence on various parameters of the drainage. There is variation in stream length ratio because of change in slope and topography. In the area bifurcation ratio shows normal situation and presence of moderate drainage density. The area shows positive correlation between stream frequency and drainage density. The value of elongation ratio and circularity ratio suggests that area is less elongated.

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Chapter 20
Remote Sensing and GIS Approach for Hazard Vulnerability Assessment of Upper Alaknanda Basin, Garhwal Himalaya (Uttarakhand), India

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Abstract The Upper Alaknanda Basin constitutes a part of greater and Tethys Himalayan zone in Garhwal region. The geology and geomorphology of the area is very complex. The area includes schistose phyllite, schist and granulites intruded by basal large gneissic granite and pegmatite and different land feature like horned peaks, serrated crests, cirques, hanging valleys, torrential rapids, waterfall and escarpments. The main objective of this study is to analyze the geological and morphological parameters for hypothetical hydrological and geological hazard vulnerability assessment like landslides, Soil erosion, flash flood and earthquake using Remote Sensing and GIS techniques. On the basis of geological and morphological parameters, Hypothetical hazards vulnerability assessment of watershed has been done. There are eleven watersheds, out of which 9 are of 4th stream order and rest of 5th. For hydrological hazards, 2 watersheds are highly vulnerable, 7 moderately vulnerable and 2 are having low vulnerability. Geologically, 3 watersheds are low, 3 moderate and 3 watersheds are highly vulnerable for hazards. Remaining 2 watersheds are very high vulnerable for hazards in study area.

Keywords Garhwal Himalaya • GIS • Lithology • Morphometric • Vulnerability • Watershed

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20.1 Introduction

Hazards can be divided into two parts, natural hazards, and anthropogenic hazards. These hazards have caused a great destruction on the surface of the earth everywhere, whether it is plain or mountainous region. In plains the air and water pollution by different mills and factories are the main hazards, while deforestation, road construction, landslides have created problems in the mountains. The man made hazards are those which are caused by man itself, like overgrazing, deforestation, over-population, construction of roads and hydro-power projects. All these hazards have been created by man for the fulfillment of his necessities, like fuel, fodder and timber and for other various developmental programmers.

Himalayas represents a fragile ecosystem, which is often manifested in the recurring natural hazards, like landslides, Earthquake, Cloud-burst-Flashflood, Flood and Soil Erosion. An individual landslide characteristically involves many different processes, operating together, often with different intensity during successive years. These activities are very common in mountainous terrain particularly during an immediate after rainy season (Bartarya 1995; Paul et al. 2000).

Many geological references of the area are cited in the journals but the pioneering workers like Auden (1934, 1937), Heim and Gansser (1939); Gansser (1964), Rupke (1974) Valdiya (1980a, b) and Sinha and Jha (1983) have described the geology of the study area. However Valdiya (1980a, b) has shown a part of this area in the regional geological maps of Kumaoun Lesser Himalaya. Qureshi et al. (1989) described entire Yamuna valley of Himalayan region as Yamuna Tear sinisterly fault. Shandilya and Prasad (1982) described about the geomorphic studies of lineament zones in Garhwal Himalaya. Biyani (1998) emphasis the natural hazards in the Himalayan Yamuna Valley and their impact on hydropower utilization and discussed Natural Hazards in the Himalayan region. Rawat et al. (2011) explains how morphometric parameters responsible for hazards. He has concluded that each third order sub-basin is not equally vulnerable for all three types of natural hazards. In view of that a combined multiple hazard vulnerability map has been carried out through integration and overlaying GIS layers of all these three natural hazards vulnerability i.e. erosion, landslide and flood for each third order sub-basin. Pareta and Pareta (2011) have analysed various morphometric parameters of Yamuna basin through GIS technique using ASTER (DEM) to evaluate the drainage basin morphometry and their influence on landforms, soil and eroded land, particularly in watershed. Guzzetti et al. (1999), Lee et al. (2003), Lu and Rosenbaum (2003), Ermini et al. (2005) have evaluated various factors in the field of natural hazards (landslides) and suggested their management and mitigation. Other factors causing the initiation of landslides were steep slopes and loss of root strength from land clearing are also studied in detailed by Abe and Ziemer (1991), Montgomery et al. (2000), Laird (2001), Chen and Su (2001), Dhakal and Sidle (2002). Anbalgan (1992), Anbalagan and Gupta (1996), Anbalagan and Singh (2006), Anbalgan et al. (2008) has done a landmark work in slope stability and sustainable development of Uttarakhand hilly regions.

Work on Remote Sensing and GIS integrated approach and techniques for susceptibility, zonation, evaluation and validation has been contributed by Ramkrishanan et al. (2005, 2009), Ghosh et al. (2009), Nithya and Rajesh (2010), Ganapathy et al. (2010), Kundu et al. (2011), Kumar et al. (2012), Pareta et al. (2012). GIS based Landslide Inventory is also described by many authors like Singh et al. (2008), Chakraborty and Anbalagan (2008), Dharmaraju et al. (2008), Sharma et al. (2011). They prepared landslide inventory and behaviour and its application in Himalayan region. Saraf et al. (2009), Kumar et al. (2011), emphasized need for mountainous highway for landslide hazards management for sustainable development.

The present study area which includes Alaknanda and Dhauliganga upstream of Vishnuparyag was taken up for intensive investigation including geological and hydrological hazards vulnerability assessment. It is undertaken with objectives like to evaluate lithological, physiographic, morphometric characteristic and Hydrological, Geological hazards Vulnerability assessment based on morphology and geological parameters analysis of the major watershed of Upper Alaknanda Basin.

20.2 Location

The Alaknanda Basin which extends from 30° 15′ N to 31° 05′ N latitude and 79° 15′ E to 80° 15′ E longitude covering an area of 4,569.29 km^2 represents the North-Eastern part of the Garhwal Himalaya, Uttarakhand, with elevation ranging between Vishnuparyag (1,450 m) and Chaukhambha (7,800 m). The study area is drained by two major drainage systems, i.e. Alaknanda and Dhauliganga (Fig. 20.1). The water melting from Satopantbamak and the Bhagirathi Kharak bank jointly gives rise to Alaknandariver at an altitude of approximately 3,600 m below the Balakun ridge.

20.3 Data and Methodology

20.3.1 Data Used

The base map of the study area is been prepared by use of, Survey of India Topographic Sheets (53 M/8, M/12, 62B/1, B/2, B/3, 53 N/6, N/7, N/9, N/10, N/11, N/12, N/13, N/14, and N/15 at 1:50,000 scales, including ASTER DEM and for analysis and map preparation software's used were Arc GIS 9.3, ERDAS Imagine 9.2, Arc Hydro, and Arc HMS.

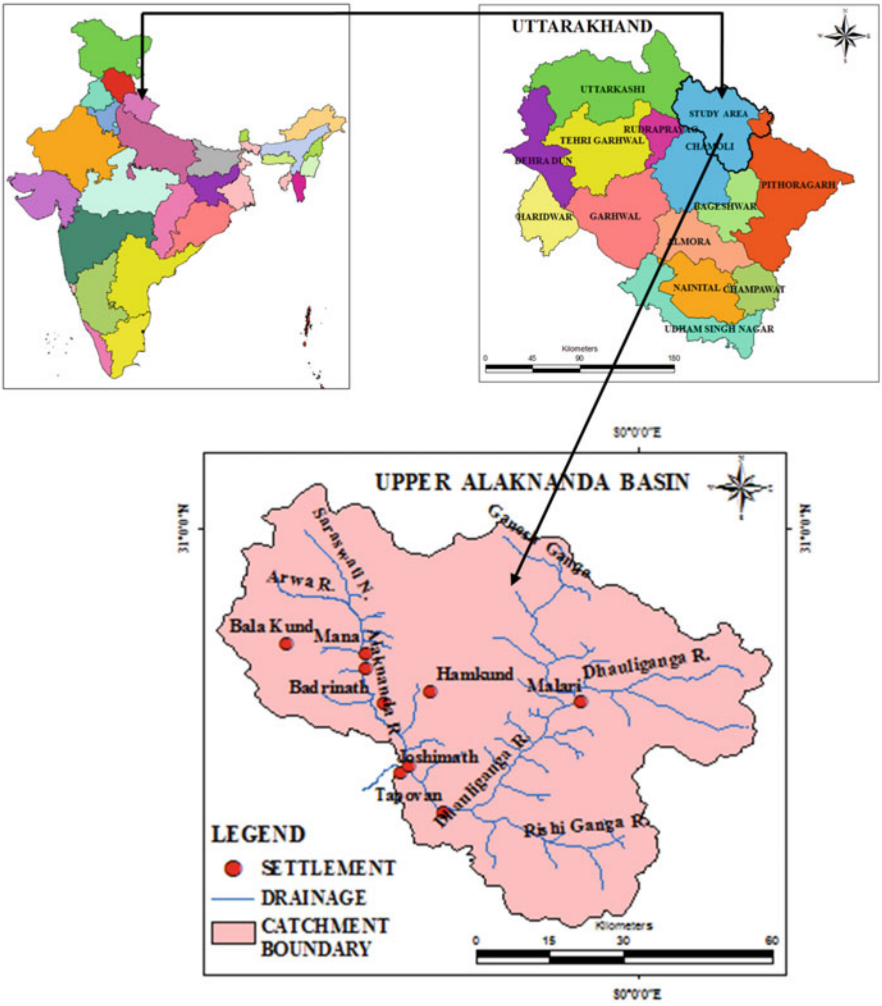

Fig. 20.1 Location map of study area

20.3.2 Methodology

The study has been carried out with the help of Geospatial tools (Remote Sensing and GIS) for geological mapping and morphometric evaluation of the Upper Alaknanda drainage basin in Uttarakhand for assessing hazard vulnerability assessment. Based on Geological and Morphological parameters Hypothetical Hazards Vulnerability Assessment calculated for particular watersheds. There are many parameters in geological and morphometry characteristic according to which study area is been analysed. Amongst the above morphological and geological parameters some selected parameter used in the present study, drainage density,

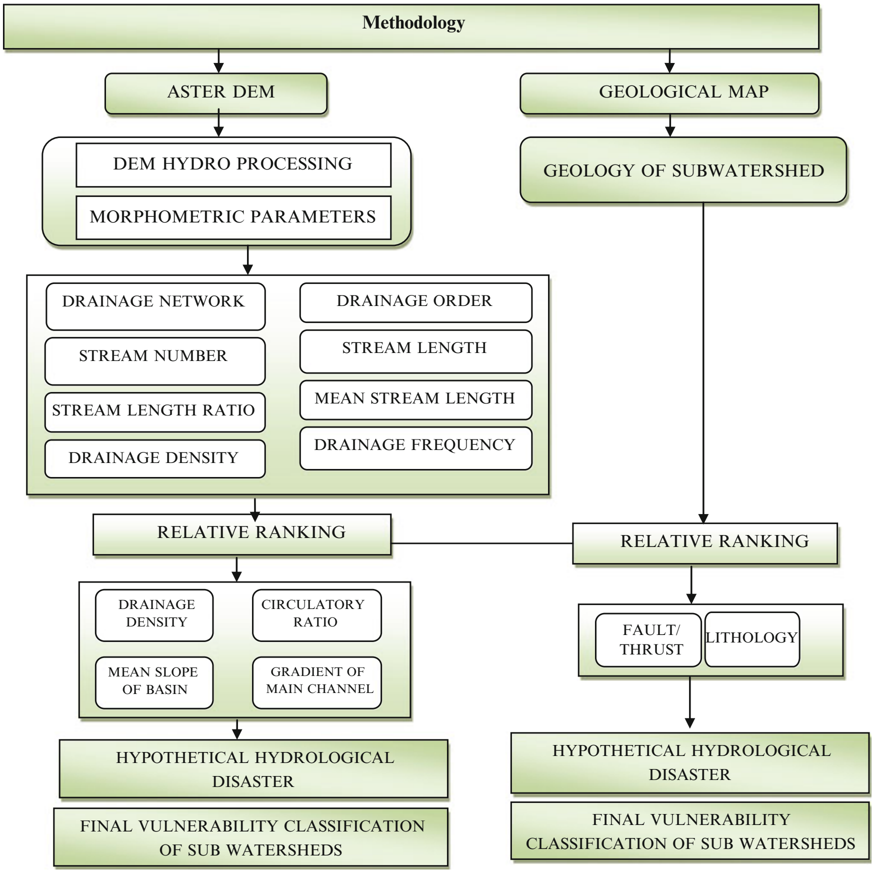

Fig. 20.2 Flow chart of methodology

circulatory ratio, mean slope of basis, mean channel gradient of main channel and lithological characteristics, thrust/fault and lineaments were highly probable for the landslide, soil erosion, earthquake and flash flood. Details of methodology are mentioned in the following flow chart (Fig. 20.2).

20.4 Result of Discussion

20.4.1 Geological Setup of Study Area

The study area comprises of two major tectonic units Namely Higher Himalaya and Tethyan Himalaya. The present study is spread over inters Higher Himalaya i.e. region south of Main Boundary Thrust and Tethyan Thrust part of Tethyan

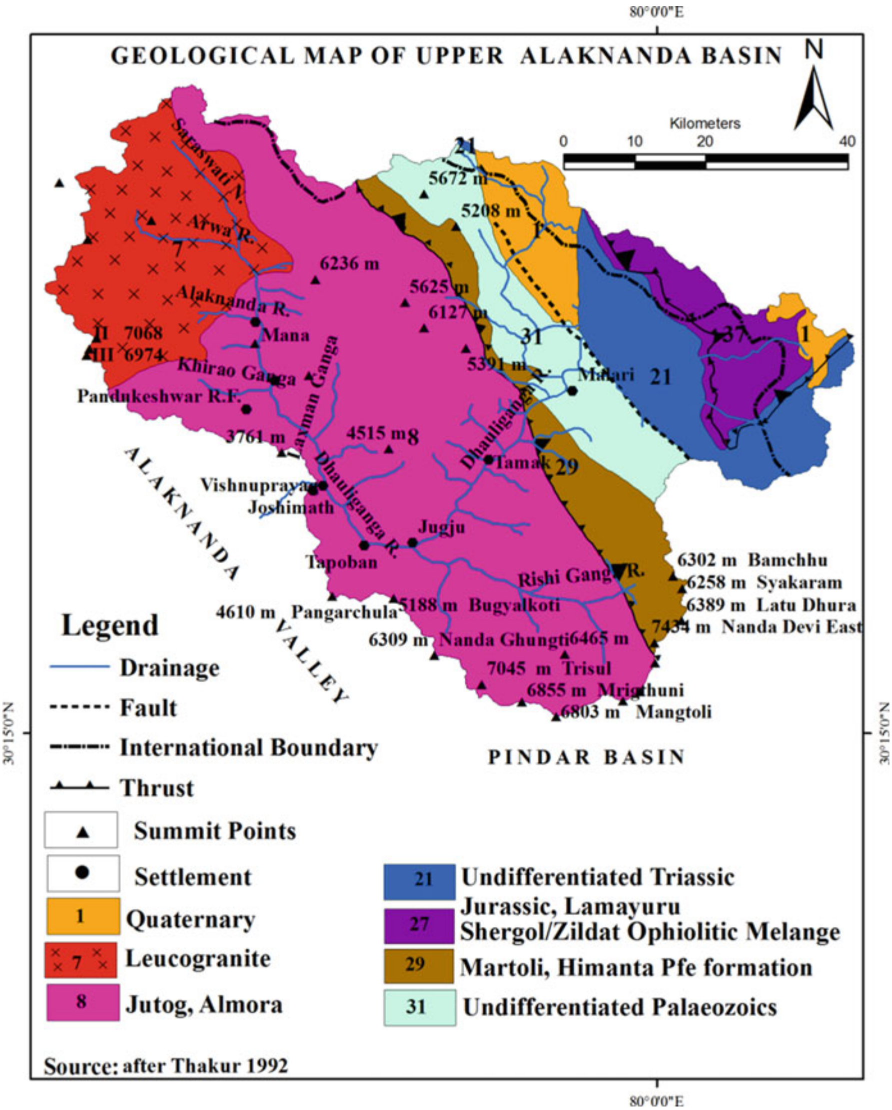

Fig. 20.3 Geological map

Himalaya which starts few km North of Badrinath. These two units are entirely different in their lithology and age (Fig. 20.3) (Thakur 1992).

The present study characterizes of Higher Central Himalayas consisting predominantly of crystallines. Consisting varied assemblages of schistose phyllite, schist and granulites intruded by basal large gneissic granite and pegmatite. At places, a continuous succession of few hundred meters is normal characteristics of the region. One kilometre South from Badrinath the lime silicate, marble interbeded

Table 20.1 Ranking of lithology

S.No	Lithology	Rank
1	Amphibolites, aplite veins, schist, Biotite-muscovite, garnet, gneisses, granite, granite gneisses, granulites, graphitic chist, leucogranite, migmatite	1
2	Dolomite, kyanite, schist's, quartzite, Basalt	2
3	Conglomorat, lime stone, marble, sand stone	3
4	Schists, chart, green Shist, phylit, sillimanitequartzites	4
5	Calcsilicates, clay, mad stone, shale, slete	5

with finely stratified biotite gneiss is found, that may attain over 10 m thickness. At times, fine layers rich in disposed are found within the Biotitic Gneisses (Tangri 1996). Near Helang Thrust and extending from Helang in the Alaknanda valley to Balan in Kali Ganga valley, it shows much lateral lithological variation. The principal rock types are quartzite-biotite schist, kyanite-biotite schist, biotite-muscovite schist, chlorite schist, phyllonite schist etc. The general strike of rock varies from NW-SE to NNW-SSE with 15° to 35° dip towards NE. Highly metamorphosed granite gneisses dipping 60–70° N are dominant rock types beyond North of Hanuman Chatti. The Quaternary sediment of this area unconformably overlies these rock formations. They are exposed in the Alaknanda valley in the form of depositional terraces.

20.4.2 Morphometric Evaluation

Morphometry is defined as the measurement and mathematical analysis of the configuration of earth surface and of the shape and dimensions of its landforms (Clarke 1966). The drainage lines of an area reflect the recent diastrophism and geologic and geomorphic history of the basin concerned and the erosion characteristics such as size, shape pattern and drainage density are controlled by the factors which influence the denudation, i.e. initial slope, structure and stratigraphy of the rocks, climatic and biotic factors (Singh 1977). The selected morphometric parameters of Upper Alaknanda basin such as drainage density, circulatory ratio, mean slope of basis, mean channel gradient of main channel which are gives high response for natural hazards (Table 20.2).

20.4.3 Average Slope

Slope of watershed has been studies and extracted from ASTER DEM with the help of GIS approach and it is an important parameter for hazard assessment. More the percentage of slopes more are its erosion, if all other things are kept constant, the average slope of the watershed is determined. Author has computed the average

Table 20.2 Morphometric parameters

Basin N.	Name of the basin	Average slope	Circularity ratio (Rc)	Drainage density	Gradient of channels
1	Alaknanda river I	40	0.43	0.52	0.06
2	Dhauli ganga I	37	0.36	0.5	0.05
3	Alaknanda river II	36	0.51	0.53	0.1
4	Arwanala	32	0.43	0.55	0.1
5	Sarswati river	30	0.45	0.58	0.06
6	Laxman Ganga	39	0.42	0.41	0.11
7	Dhauli ganga II	33	0.49	0.51	0.08
8	Ghugbag gad	31	0.51	0.49	0.1
9	Keo gad	27	0.47	0.47	0.08
10	Girthi ganga	34	0.46	0.44	0.09
11	Rishi ganga	32	0.57	0.52	0.1

Table 20.3 Range of morphometric parameters

Slope gradient	Range	Mean slope of basin	Range	Circularity index	Range	Drainage density	Range
0.05–0.06	Low	27–31	Low	0.36–0.45	Low	0.40–0.50	Low
0.06–0.09	Medium	31–34	Medium	0.46–0.50	Medium	0.50–0.53	Medium
0.09–0.11	High	36–40	High	0.51–0.57	High	0.53–0.58	High

slope of the all eleven fourth and fifth watershed, which is mentioned in Table 20.2. Maximum slope is calculated of Alaknanda river I 40° (fourth order) and minimum is of Keogad 27° (Table 20.3).

20.4.4 Circularity Ratio

The circularity ratio may be defined as a basin area to the area of the circle having the same perimeter as the basin (Miller 1953). Irregularities in the catchment area; often a function of relief and slope, increase the perimeter which leads to a decrease in the value of the circularity ratio. Table 20.2 shows the circularity ratio of the Upper Alaknanda Basin and its tributary basin. The formula for calculation of basin circularity ratio is given below (Miller 1953):

$$\mathrm{Rc} = 4\pi \mathrm{A}/\mathrm{P}^2$$

where Rc: is basin circulatory, P: is the basin perimeter, 4 is constant value, π 3.14286 and A: is the area of basin. A value of 0 (zero) indicates a highly elongated shape and the value 1 (one) a circular shape. Table 20.2 gives the circularity ratio of the Upper Alaknanda and its tributary basin. The Alaknanda has a circularity ratio of 0.43. This indicates only a moderate circular shape for the basin. The circularity index varies from 0.36 to 0.57. Among the fourth order drainage basin the Alaknanda has a low circulatory ratio and Rishi Ganga has the highest circulatory. The circularity ratio has been basin wise classified into three classes (Table 20.3).

20.4.5 Channel Gradient

The total drops in elevation from the source to the mouth were found out for the fourth and fifth order watersheds and horizontal distances were measured. It is seen from Table 20.2 that the mean channel slope decreases with increasing order number. This testifies to the validity of Horton's Law of Stream Slopes, which states that there is a fairly definite relationship between the slope of the streams and their orders, which can be expressed by an inverse geometric series law. Highest gradient is recorded in Alaknandariver II, Arwanala, Laxman Ganga, Ghugbaggad, Rishi ganga and lowest gradient Dhauli ganga I (Table 20.3).

20.4.6 Drainage Density

Drainage density may also be thought of as an expression of the closeness of spacing of channels (Strahler 1964). The drainage density is obtained by using the following formula:

$$D = \sum Lu/Au$$

where 'D' is the drainage density, 'ΣLu' is the total length cumulated for each stream order with a given basin area 'Au'.

It is noticed that both drainage density and drainage frequency are comparatively less towards the source and more as one proceeds towards the mouth. This is attributed to the fact that towards source there are glaciers and the rocks are quite hard while towards mouth the number of streams and volume of water increases as the glaciers melt to supply water and the rocks which are safe by nature, have undergone lot of erosion (Tables 20.2 and 20.3).

20.5 Vulnerability

20.5.1 Ranking of Morphological and Geological Parameters

Keeping this in mind the dominant morphological and geological parameters governing the hydrological and geological response at the watershed are analyzed to access the vulnerability of all the sub-watersheds in respect of hydrological and geological hazard. Relative ranking is briefly done (1 to 5) with respect to each parameter, where rank '1' indicates high/fast hydrological and geological response of the watershed which in another words termed as high hazard vulnerability. The vulnerability goes on decreasing with increasing relative rank. The final overall vulnerability is analyzed using average rank at the watershed (equal weightage to all the parameters). Using this approach vulnerability of all the 4th and 5th order watershed are done in this study (Table 20.4).

20.5.1.1 Erosion Hazards Vulnerability

Drainage density, circularity ratio, gradient of main channel, mean slope of the basin are the main morphometric parameters for hydrological hazards vulnerability and similarly the active faults, thrusts, lineaments and lithological characteristics are geological parameters for geological hazards vulnerability. Geologically, out of 9 fourth order and 2 fifth order watersheds, 2 watersheds have very high erosion vulnerability, whereas 3 high, 3 medium and 3 are having low hazards. Morphologically 2 basins are high, 7 moderate and 2 basins are low vulnerable for Hydrological Hazards.

20.5.1.2 Land Slide Hazards Vulnerability

Although study area is highly vulnerable for seismic landslide activity due to active lineament such as Main Central Thrust and Tethyan Thrust. It is equally vulnerable for non-seismic landslides during rainy season because of degraded land use pattern whereas morphometric factors are active for landslides vulnerability and some for erosion hazards vulnerability like gully erosion, sheet erosion etc. In present case fault/thrust, lithology, geological parameters were considered as indicator of landslide vulnerability in the study area.

Table 20.4 Ranking of morphological and geological parameters

	Morphological parameters											Geological parameters				
												Structure				
S.N	Name of basin	Order	Drainage density	Rank	Circularity ratio (Rc)	Rank	Mean slop of the basin	Rank	Gradient of main channel	Rank	Rank morphometry	Fault	Thrust	Lithology	Rank (geology)	Final rank
1	Alaknanda river I	Fifth order	0.52	2	0.43	4	40	1	0.06	5	3	5	1	2	3	4
2	Dhauli ganga I		0.50	3	0.36	5	37	2	0.05	5	4	1	1	1	1	4
3	Alaknanda river II	Forth order	0.53	2	0.51	2	36	3	0.10	1	2	5	5	1	4	3
4	Arwanala		0.55	1	0.43	4	32	4	0.10	1	3	5	3	1	3	4
5	Sarswati river		0.58	1	0.45	3	30	4	0.06	4	3	5	3	1	3	4
6	Laxman ganga		0.41	5	0.42	4	39	1	0.11	1	3	5	5	1	4	2
7	Dhauli ganga II		0.51	3	0.49	2	33	3	0.08	3	3	1	1	1	1	3
8	Ghugbag gad		0.49	3	0.51	2	31	4	0.10	1	3	1	1	3	2	3
9	Keo gad		0.47	4	0.47	3	27	5	0.08	3	4	1	1	3	2	3
10	Girthi ganga		0.44	5	0.46	3	34	3	0.09	2	3	1	1	3	2	3
11	Rishi ganga		0.52	2	0.57	1	32	4	0.10	1	2	5	5	2	4	3

20.5.1.3 Flood Hazards Vulnerability

Mainly two types of floods are common throughout the Himalayan region i.e. flash flood and river-line flood which are among the more devastating types of hazard as they occur rapidly with little lead for warning. The morphometric parameters i.e. drainage density, circulatory ratio, mean slope of basin, mean channel gradient, etc. play major role in vulnerability for flood/flash flood and other natural hazards. The distribution of flood hazards vulnerability of fourth and fifth order watershed suggesting that out of total 11 sub-watersheds, 2 are highly vulnerable, 7 is moderately vulnerable, 2 are low vulnerable for flood hazards. In absence of observed flood discharge & depth data it becomes almost impossible to access flood vulnerability in mountain watersheds. Runoff (flood) from any watershed is flood govern by climate factors (Rain amount, intensity, storm movement, etc.) as well as morphological parameters of the watershed.

20.6 Conclusion

The hazards vulnerability has been calculated through geological and morphometrical ranks of watershed for these type of natural hazards vulnerability (i.e. flood, landslide, soil erosion and earthquake), for each 4th and 5th order watershed.

The evaluation of terrain characteristics in the Alaknanda and Dhauliganga river basins up stream of Vishnuparyag have indicated that the relief range from 1,450 to 7,000 m. upstream of Badrinath is from 5,000 to 6,000 m. The slope of the terrain is generally 15° to 45° however some part of the watershed are having steep slope above 60°. The result of this analysis shows that the respect to flash floods, landslides, earthquakes and soil erosion in the river basin. The order of influence is derived from each drainage network within each watershed. Morphometrically, 2 watersheds Alaknanda II and Rishiganga are highly probable for floods on the main channel, 7 watersheds namely Alaknanda, Arwanala, Saraswatiganga, Girthiganga, Laxmanganga, Dhauliganga II and Ghugbag gad are moderately vulnerable to flash floods. Remaining 2 watersheds, Dhauliganga and Keogad has low vulnerability for hydrological hazards. Geologically, 3 basins are low vulnerable for landslide and rock fall, 3 basins are moderate to earthquake rock fall, and 3 basins are highly vulnerable for earthquake and landslide hazards. Remaining 2 basins are very high vulnerable for earthquake landslide and avalanche hazards study area. This study concludes that each order of watershed not equally vulnerable for all four types of natural hazards.

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Chapter 21
Dynamics of Urban Development and Wetland Management in East Kolkata Wetlands

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Abstract Kolkata the seventh largest metropolis in India as per the 2011 census, evolved without a planned sewage disposal system with waste being dumped into the river or into adjacent saltwater and brackish wetlands. The East Kolkata Wetlands which is considered the most biologically diverse of all ecosystems and serve as the natural water purification system for the city is being threatened due to mismanagement of the processes to conserve it. Developmental planning has failed to take into cognizance the role played by these systems. Considered as the low priority areas, solid waste management has never been taken up seriously either by the public or by the Kolkata Municipal Corporation till recently when the large amount of waste is threatening our health, environment and well being. Though crucial, planning has recognized only the provisioning services of the wetland and to a smaller extent its capacity to regulate wastes, at the same time ignoring other services as flood attenuation, and support to biodiversity. Emphasis has been on engineering measures for quick economic gains at the cost of ecological sustainability. The lack of basic understanding of the nature of wetland ecosystem has led to overall loss of benefits accrued from the wetland through natural processes and functions. It is high time to learn from the lessons delivered. The present paper is an attempt to assess the linkages of the city of Kolkata vis-a-vis the management of East Kolkata Wetlands and the role of the Kolkata Municipal Corporation in sustaining and restoring the wetland.

Keywords East Kolkata Wetlands • Ecological sustainability • Solid waste management • Wetland management

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21.1 Dynamics of Urban Development and Wetland Management in East Kolkata Wetlands

The relationship between water and cities is crucial. Unsustainable use of water resources can have significant impacts on wetlands and the biodiversity they support far beyond the peri-urban environment. Wetlands which are considered the most biologically diverse of all ecosystems and serve as natural water purification systems as in Kolkata are being threatened in two principle ways with increasingly rapid urbanization:

1. Through direct conversion of wetlands, whether planned or unplanned, to urban areas, leading to acute problems associated with polluted drainage, direct habitat loss, overexploitation of wetland plants and animals by urban and peri-urban residents and the increased prevalence of non-native invasive species; and
2. Through the watershed-related impacts of urban development, including increased demands for water, increasing diffuse and point source pollution and the need for greater agricultural production to support the burgeoning urban population.

The city of Kolkata is the seventh largest metropolis in India, and had 4.5 million residents in 2011 (Table 21.1).

The city evolved without a planned sewage disposal system with waste being dumped into the river or into adjacent saltwater and brackish wetlands. The East Kolkata Wetlands plays an important role in purifying water by 'locking up' pollutants in their sediments, soils and vegetation and also provides livelihood support to at least 20,000 people. At least one-third of the sewage from the city of Kolkata (population 10 million) is treated effectively by the East Kolkata marshes. Figure 21.1 shows the location of the East Kolkata Wetlands.

The present paper has been attempted with the twin objectives (1) understand the linkages between city development and wetland management—whether they are mutually exclusive? and (2) to assess the role of Kolkata Municipal Corporation (KMC) in wetland management.

The data for the paper has been primarily drawn from secondary sources and substituted by personal references from the field visit undertaken, wherever applicable.

Table 21.1 Urban growth of Kolkata

Year	Kolkata Municipal Corporation (KMC)	KMC share of growth (%)	KMC growth (%)
1981	3,305,006	35.9	5.0
1991	4,400,000	39.9	33.1
2001	4,573,000	34.6	3.9
2011	4,487,000	31.8	−1.9

Source: http://www.newgeography.com/content/002620-the-evolving-urban-form-kolkata-50-mile-city

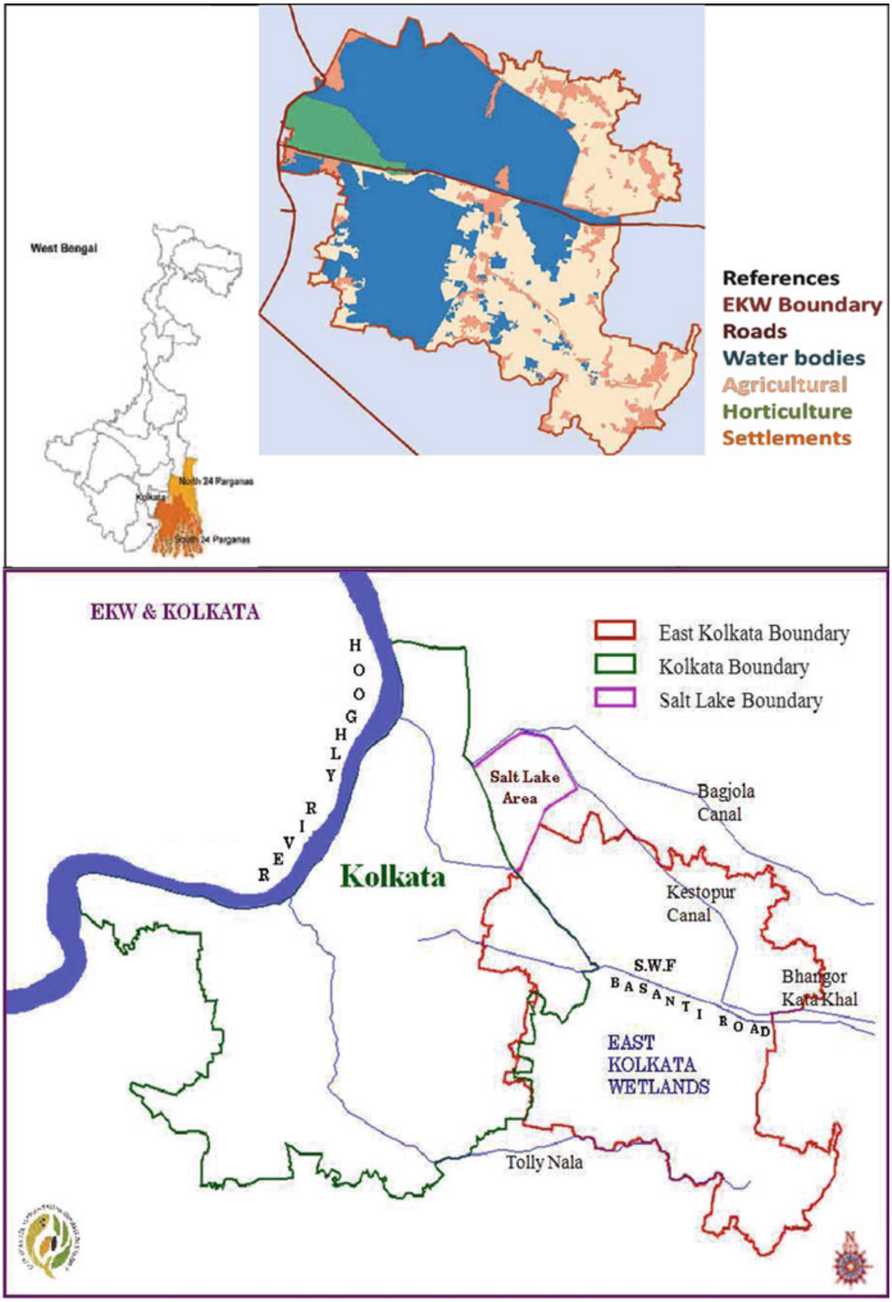

Fig. 21.1 Location of East Kolkata wetlands. *Source*: http://www.ekwma.com/index.php?view=maps&mapname=EKW_Kolkata&MenuID=33

21.2 Linkages Between City Development and Biodiversity Conservation

Chakravorty's (2005)[1] has elaborately discussed the phases of Kolkata's urban growth (Fig. 21.2) and how three small initial nuclei located in three villages (*Sutanuty, Gobindapore* and *Kalikata*) have turned into a single nucleus that is *BurraBazar-BBD Bagh* area where administrative as well as economic activities are still concentrated, though the West Bengal government is carefully trying to shift all important activities towards the city's north-eastern fringe (*Salt Lake/Bidhan Nagar Township area*). But, this change is far from the complete transformation and the city still reveals its old colonial set up. Therefore, Indian planners and policy makers consider Kolkata as a unique case where colonial legacy still burdens the city's urban growth and land use pattern. Though immediately after the independence proper city planning has been introduced in Kolkata like many other Indian cities, but still the city has not yet achieved uniform urban growth and a complete well-planned spatial transformation. Kolkata Metropolitan Development Authority (KMDA) has tried to arrest the unprecedented urban growth in Kolkata by introducing a bi-polar strategy of urban growth in Basic Development Plan (1966–1986)

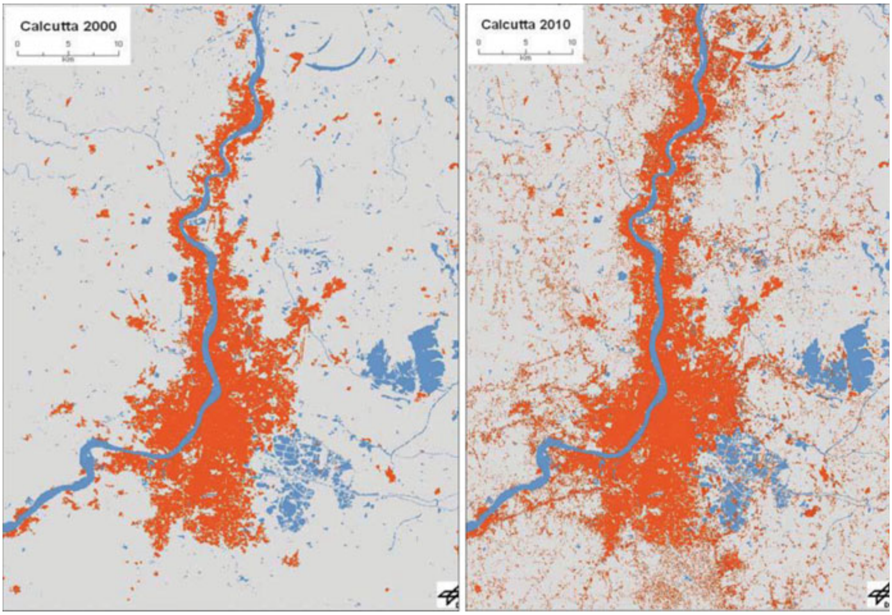

Fig. 21.2 Urban growth of Kolkata, 2000 to 2010. *Source*: Deutsches Zentrum fur Luf-und Raumfahrt, Earth Observation Center (DLR-DFD)

[1] Chakravorty (2005).

Table 21.2 Annual average growth rate of SDP by major sectors

	KMA		West Bengal	
	Avg. annual growth (%)		Avg. annual growth (%)	
Sector	85–86 to 93–94	93–94 to 01–02	85–86 to 93–94	93–94 to 01–02
Primary	1.58	−4.79	5.62	4.18
Secondary	1.81	5.71	4.92	6.36
Tertiary	3.8	11.06	8.42	9.5
Total	2.96	9.04	6.51	7.13

which has tried to motivate the growth of adjoining municipalities and planned to set up '*Kalyani*' as the new growth centre in the north of Kolkata. Unfortunately, this bi-polar strategy has failed to achieve its target of arresting unplanned population growth in the city. Thus the recent perspective plan "Vision 2025" launched by KMDA has adopted a multi-polar growth strategy in which new urban centres near Kolkata have been given impetus.

There have also been signs of structural changes in the economy of the Kolkata Metropolitan Area (KMA) with the share of primary sector falling and those of the secondary and tertiary sectors increasing. The tertiary sector witnessed a phenomenal increase of State Domestic Product (SDP) with the growth of 11.1 % per annum between 1993–1994 and 2001–2002 (Table 21.2). This rate of growth was found to be even higher than that (9.5 % per annum) for West Bengal. This phenomenon can be partly explained by overpowering entry and expansion of banking, insurance and real estate activity into the economy.

The growth in the secondary sector was dominated by basic metal and alloy industries; metal products and parts; machinery and machine tools; rubber and plastic industries; jute textile; cotton textile; and leather and leather products, not only in terms of the number of registered working factories but also employment. The investment in manufacturing industries in KMA-districts has also shown perceptible increase in recent years. This is also corroborated by the data supplied by Commerce & Industries Department, Government of West Bengal, showing that KMA-districts accounted for an investment of Rs.5591 crores in the large and medium industry projects implemented between 1991 and 2002. This constituted 25 % of total investment of Rs.22,101 crores in West Bengal during the same period.

It seems that certain types of industries have been attracted more to KMA than other areas in the state. More than 80 % of units in Drugs & Pharmaceuticals, Electrical & Electronics, Engineering, Leather & Rubber, Metallurgical (without steel), Plastic, Software & Telecom and Textiles (jute, wool, silk, ready garments etc.) industries have been set up in the KMA-districts between 1991 and 2002. In terms of investment, however, the trend is not the same in that the KMA-districts have accounted for as high as 94 % of investments in the state in Service Industries like Hotel, Hospital, Printing, Multi-media, despite the proportion of number of units being less than 80 %.

Table 21.3 Sewerage zones

East bank (14 Nos.)	West bank (6 Nos.)
Kalyani, Bhatpara, Barrackpur, Titarah, Khardah, Barasat, Dum Dum, Manicktala, Salt Lake, Kolkata Tollygunge, Rajpur, Garden Reach, Budge Budge	Bansberia, Chandannagar, Serampur, Konnagar, Howrah, Uluberia

Both demographic and economic growth of the city has exerted tremendous pressure on its water supply, drainage, sewerage and solid waste management over the last few years. In terms of water supply, the vast majority of the city is increasingly becoming dependent on ground water as the water from the Hooghly river is treated and supplied to a very limited area of the KMA. As it has not been possible to extend treated surface water supply to the majority of KMA, inhabitants are forced to depend on ground water. This good quantity of ground water is found to become unpredictable day by day due to over withdrawal by the huge number of haphazardly placed deep tube wells resulting in fall of piezometric level, ground subsidence, trace of arsenic in some places and other adverse effects.

Not only water supply, the existing sewerage system divided into 20 sewerage zones, as mentioned below, has also been affected (Table 21.3).

The existing sewerage zones are dealing with its sewerage network for more than a century and there are instances of sewerage congestion due to weak O&M practices.

The growth of the city has impacted the solid waste management to a great extent, thereby impacting the East Kolkata Wetlands (EKWs) enormously. The East Kolkata Wetlands comprising many water bodies from north and south 24 Parganas is like a lotus in the city of concrete jungle. Sometimes called the "kidneys of Kolkata," the East Kolkata Wetlands are the largest of their kind in the world, covering an area of 12,500 ha. This multiple-use wetland lies east of the city and includes a garbage dump known as Dhapa Square Mile, a mosaic of vegetable fields, a series of 300-odd fishponds connected by major and secondary canals, rice paddies, wholesale markets, a few roads, and 43 villages, with approximately 60,000 people.

However, with the growth in population of the Kolkata city, and industrialisation the municipal solid waste management, like most other infrastructural services has come under great stress. Considered as the low priority areas, solid waste management was never taken up seriously either by the public or by concerned agency or authorities till recently when the large amount of waste is threatening our heath, environment and well being.[2]

The reliance of the city on the EKWs for waste disposal is underscored by the fact that despite the manifold expansions in the city over the decades and the corresponding increase in bio-degradable and non-bio-degradable contents in its sewage water, the city has not constructed a treatment plant for sewage, depending solely on the East Kolkata Wetlands for waste disposal. The Dhapa disposal site has

[2] http://www.ijest.info/docs/IJEST11-03-08-284.pdf.

Table 21.4 Waste composition – Dhapa disposal site[a]

Waste material	Estimated (%)
Food waste	45.5
Garden waste	5.1
Paper	4.0
Textiles	4.0
Wood	1.2
Plastics	3.3
Construction and demolition waste	29.6
Metals	0.5
Glass and ceramics	0.3
Other organics	3.4
Other inorganics	3.4
Total	100.0
Organic fraction (wet basis)	63.0
Organic fraction (dry basis)	25.9

[a]Methane to Markets (2010)

Sources: Data form completed by Arun Sarkar, KMC. A breakdown of reported percentages into specific waste materials was estimated based on information provided in the draft Gorai Landfill Assessment Report

Fig. 21.3 Leachate ponding at Dhapa disposal site

served the city as an uncontrolled dumping ground since 1981. The composition of waste, disposed at Dhapa is reflected in Table 21.4.

Little or no soil cover has been applied historically, and waste is deposited in an uncontrolled manner that has resulted in steep, unstable slopes, leachate accumulation (Fig. 21.3) within the waste mass, and leachate runoff into nearby water bodies. Currently at the Dhapa waste disposal site, none of Landfill Gas (LFG) is managed but left emitted into atmosphere without any treatment. In this regard, it is important to note that a global warming potential (GWP) of methane gas is as 21 times as that of carbon dioxide, and methane gas/LFG generated from the waste disposal site is regarded as one of the causes of global warming. In addition, LFG generated from the waste disposal site becomes risk factors such as bad smell, toxic gases and fires, being a cause of deteriorating local environment.

Based on site volume and waste density estimates, Dhapa is estimated to have received approximately 7 million metric tonnes (Mg) of municipal solid waste (MSW) as on October 2009, and has the capacity to receive another 4 million Mg of waste, for a total of 11 million Mg at closure. Based on 2009 disposal rates (3,500 Mg per day) and an assumed growth rate of 2 %, the site is to be full by late 2012. This implies that either a new landfill site will need to be ready for use, or disposal will need to continue outside of current disposal area boundaries and/or above reported maximum height limits.[3] The disposal site property covers 34.2 ha (ha), of which approximately 21.5 ha consists of waste disposal areas. The site has been divided into an eastern disposal area (Eastern Mound), which receives waste from KMC's waste haulers, and a western disposal area (Western Mound), which receives waste from private haulers. A composting facility is located between the two disposal areas and receives selected waste loads from organics-rich sources such as food markets. The composting facility is privately owned and covers 12.2 ha of the disposal site property. In addition, there are about 200 waste pickers at the site who scavenge through the waste daily.

With the growth of population and the resultant increase in garbage, there has been a progressive shift in the land use within the EKW leading to a gradual dominance of agriculture, which accounts for ~40 % of the wetland area. The area under fish farms has been reduced and with the construction of fish farms bunds and roads within the fish farms the effective areas under water bodies have further reduced. The gradual reduction in waterspread within the wetlands has reduced its capacity to recycle wastes and attenuate floods.

Further, despite having a large direct catchment of 1,625 km^2 including the basins of Kulti, Piyali Vidyadhari, Adiganaga and Kolkata Municipal Corporation, inflows to the wetland are largely governed by the sewage generated from the Kolkata Municipal Corporation. Of the total flows, more than 95 % is siphoned off from the wetland to reduce waterlogging within the Kolkata city. Drastic reduction of freshwater flows and gradual dominance of marine flows has induced rapid siltation within the system. The carrying capacity of various canals within the KMC has been assessed to be reduced in the range of 15–50 % with silt depths ranging between 0.3 and 1.6 m. Of the 2,481 ha of area under fish ponds, 377 ha have been rendered redundant due to siltation. Though the EKW saves the city the cost of construction of Sewage Treatment Plants (STP), and also contributes to flood control in the city and the cause of carbon sequestration,[4] efforts are yet to be taken by the KMC. Failure to effectively manage water regimes integrating hydrological processes has led to adoption of cost intensive and unsustainable solutions for water management.

[3] http://www.globalmethane.org/Data/1128_Dhapa.Assessment.Report.4-27-10.pdf.

[4] http://www.sandeeonline.org/uploads/documents/publication/939_PUB_Working_Paper_62_Gautam_Vivek.pdf.

There has been a rapid change in biodiversity associated with the wetlands due to changes in hydrological regimes and land use. Of the 271 species of birds recorded from the wetlands, only 162 species have been variably noted during the last 30 years. It is assessed that 109 species of birds have become locally extinct, majority being aquatic birds. Similarly, there has been significant loss of vegetational diversity, particularly those of mangroves and other brackish water species.

The sewage fed fisheries (SFF), for which the wetland is known globally, has been constrained due to inadequate management of water regimes, technology integration and weak marketing, post marketing and value addition opportunities.

Despite living within a highly resource rich area, the communities living within EKW have high rates of poverty incidence. The average household income of the wetland communities still stands equivalent to less than 70 % of the state average. More than 70 % of the population is below the poverty line. Regional disparities within poverty incidence have been observed, with the southern region settlements faring lower than the northern region. Less than 35 % of the total population has access to safe drinking water and adequate sanitation facilities leading to high frequency of waterborne diseases. Less than one fourth of the total households have access to formal economic infrastructure for credit and saving needs, thereby limiting opportunities for receiving equitable share of economic enterprise.[5]

As can be seen from the foregoing paragraphs, the role of the EKW in Kolkata's sustenance and development cannot be overemphasized. There are strong linkages between the development of the city and the management of EKW. The answer to the simple question as to whether the increase in toxicity of sewage water negatively impacts on the profitability of the fisheries and agricultural practices in the region is affirmative. If the answer is affirmative it invariably points to reduced livelihood support for people in this region and reduced value addition from the existence of the Wetlands. It also indirectly supports the growing demand to convert the wetlands to real estate and industry. An answer in the negative on the other hand supports the cause of conservation. Appropriate policy interventions are therefore necessary, including the proper treatment of the sewage water flowing into this region, from those who wish to hold at bay the ever-increasing pressure in favour of conversion and to preserve the wetlands for the valuable ecosystem services it provides for the city.[6]

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[5] http://www.wetlands.org/Portals/0/publications/BSO%20publications/East%20Kolkata%20Wetland%20Newsletter%20Volume%201.pdf.

[6] http://www.sandeeonline.org/uploads/documents/publication/939_PUB_Working_Paper_62_Gautam_Vivek.pdf.

21.3 Role of Kolkata Municipal Corporation in Wetland Management

The West Bengal Government as well as the Kolkata Municipal Corporation realises that the EKWs are under severe pressure. Changes in land use, rapid siltation due to changes in hydrological regimes, pollution and stakeholder conflicts have greatly impaired the wetland functioning. Conservation efforts for these wetlands have also been limited in scope. Scientific assessments on the wetland system have largely been restricted to academic exercises and research and no systematic approach to conservation and sustainable development of these wetlands has been adopted.

In terms of encroachment in the eastward of the city, there is speculation that certain areas will succumb to development in the coming years. Some unregulated industries, such as tanneries, have been releasing untreated effluent directly into the wetlands, further threatening the water quality. The build-up of silt through natural processes has considerably reduced the capacity of fish ponds over time. The dredging and transport needed to clean out the larger ponds requires a large investment, even though the silt can be used for landfills planned for new townships north of the city. The presence of the Mafia in the control of fish ponds is a subject no one knew much about or not ready to talk about. The challenge therefore is immense and remains despite the fact that when both the marketed and non-marketed economic benefits of wetlands are included, the total economic value of unconverted wetlands is often far greater than that of converted wetlands.

The entire focus of water management so far has been on protecting the ever expanding needs of Kolkata City, without assessing the implication for downstream ecosystems. Emphasis has been on unsustainable engineering solutions, without considering options which would be beneficial for the ecosystem as well as for the resource use that prevails within the wetland. Balancing water use for human and ecological purposes is a critical issue that needs to be addressed for sustainable management of EKW.[7]

However, to stop further deterioration of the system as also to protect and develop its original character, the East Kolkata Wetlands (Conservation and Management) Act 2006 was enacted by the state Government '*to provide for conservation and management of the EKWs and for matters connected therewith and incidental thereto*'. Under the Act, East Kolkata Wetlands Management Authority was constituted with the following functions and powers:

(a) To demarcate the boundaries of the East Kolkata wetlands on the field as shown in the map in Schedule II;
(b) to take measures or make an order to stop, undo and prevent any unauthorised development project in, or unauthorised use of, or unauthorised act on, the East Kolkata wetlands;

[7] Wetlands International – South Asia.

(c) to make an order directing demolition or alteration of any hoarding, frame, post, kiosk, structure, neon-signed or sky-sign, erected or exhibited illegally for the purpose of advertisement on any land within the East Kolkata wetlands;
(d) to make an order to prevent, prohibit or restrict any mining, quarrying, blasting, or other operation of like nature, for the purpose of protecting or conserving the East Kolkata wetlands;
(e) to take measures to abate pollution in the East Kolkata wetlands and conserve the flora, fauna and biodiversity in general;
(f) to prepare action plans conforming to the resolutions taken and recommendations made, from time to time, under the Ramsar Convention and to update the land use maps of the East Kolkata wetlands;
(g) to implement and monitor the activities specified in the action plans;
(h) to promote research and disseminate findings of such research among the stakeholders;
(i) to raise awareness about the utility of the wetlands in general and the East Kolkata wetlands in particular;
(j) to promote basic conservation principles like sewage fed pisciculture and eco-tourism in the East Kolkata wetlands;
(k) to enforce land use control in the substantially water body oriented areas and other areas in the East Kolkata wetlands;
(l) to detect changes of ecological character and in land use in the East Kolkata wetlands;
(m) to establish network with other Ramsar Sites in India;
(n) to conduct inquiry or scientific study for any purpose of this Act;
(o) to constitute expert committee for any. purpose of this Act;
(p) to enter any land or premises, including to collect samples of air, water, soil and other biological resources, for any purpose of this Act;
(q) to call for relevant records and documents and information from any Department, organisation or local body for any purpose of this Act:
(r) to do such act, or pass such order, which may be necessary and expedient for the purpose of conservation and management of the East Kolkata wetlands.

The main task of the authority is to maintain the existing land use practices (Table 21.5 and Fig. 21.4) along with its unique recycling activities for which EKW has been included in the Ramsar list of Wetlands of international importance.

The East Kolkata Wetlands Management Authority, Department of Environment, Govt. of West Bengal has also prepared a comprehensive and integrated Management Plan in keeping with basic guidelines of the Ramsar Protocol, and started implementing it. It has also been decided by the Environment Department, that reasonable restrictions need to be imposed regarding use of land by different occupiers of East Kolkata Wetlands area in the following manner:-

(a) That the local authority should not issue any licence or building plan for any residential, commercial, or industrial activities without considering the clearance from the EKWMA;

Table 21.5 Land use classification of East Kolkata wetlands

Land use	Area in hectares (%)
Water bodies	5,852.14 (46.81)
Agriculture land	4,959.86 (38.92)
Garbage disposal site	602.78 (4.73)
Settlement Area : (i) Urban	91.53 (0.73)
(ii) Rural	1,234.99 (9.69)
Total area	12,500.00[a]

Source: Natai Kundu, Urban Waste Management through productive activities in East Kolkata Wetlands (2009)
[a]Additionally 241.30 ha are being added to the system for making the system integral

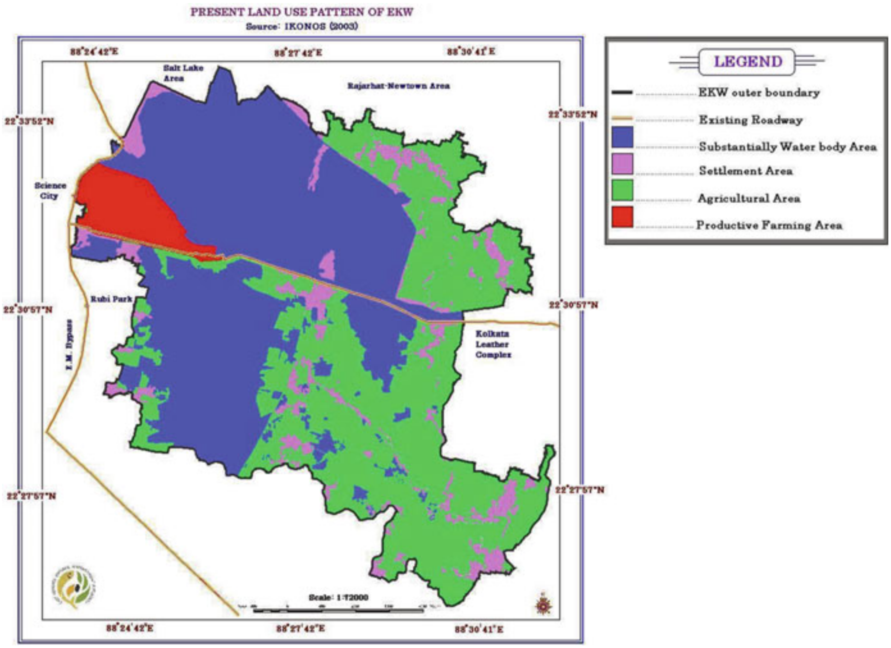

Fig. 21.4 Land use pattern of East Kolkata wetlands

(b) That the Land and Land Reforms Department of the concerned area is also directed not to issue any certificate for change of the character of land under Section 4(c) of the West Bengal Land and Land Reforms, Act 1955, without considering the clearance from the EKWMA;

(c) That the occupiers of the East Kolkata Wetlands area can transfer land to any person or persons in any manner through registered Deed or through providing lease or tenancy right, and such owner may mutate such transferred land in their name. But any construction activities in the said area shall be subject to written permission/prior clearance of the EKWMA.

Provided further that the change of character or mode of use of land by any purchaser shall be subject to and in conformation with the provisions of the said Act, 2006;

(d) Any owner/occupier of land in the EKW area, with prior permission of the EKWMA shall have the right of vegetative fencing their demarcated area utilizing sal, eucalyptus, bamboo made pole and barbed wire, but shall not be permitted to make any permanent construction for fencing their boundary;

Provided that on receipt of any information of violation, EKWMA may take such action as it is necessary for conservation and management of the EKW area in accordance with provisions of the East Kolkata Wetlands (Conservation and Management) Act, 2006.

21.4 Initiatives to Conserve

In line with the powers and functions of the East Kolkata Wetlands Management Authority, certain initiatives have also been taken by the Authority to conserve the wetlands. It has started conserving the 12,500 ha wide East Kolkata wetlands **by planting trees**. It is encouraging corporate houses and NGOs to set up eco-parks and is in the process of shortlisting companies for the purpose.[8]

Efforts by the Kolkata Municipal Corporation (KMC) in order to preserve the EKWs have also been initiated, the important one being the management of solid waste in the area. As is known, the solid waste management system of Kolkata consists of three main components: Collection, Transportation and Disposal.

(a) *Collection:* In terms of collection of waste, the majority (90 %) of collection is done by the KMC and 10 % is contracted out to private contractors. In 2011, 75 % of the KMC area was served by a door-to-door collection system and 25 % by street sweeping. This compares favourably to the national average of 51 % but is still far below the 100 % benchmark target.

Though informal segregation takes place at all stages of waste processing, following a Supreme Court order, in 2011 source segregation has been introduced as a pilot project in 7 wards (33, 47, 64, 103, 110, 115 and 130) of the city covering only 4.4 % of the KMC population. Status baseline as on 2011 is 13 % recycling and 7 % composting making a total of 20 % which compared to the national target benchmark of 80 % is very poor and the KMC still has a long way to go. The privately operated composting plant at Dhapa processes 300 tonnes of biodegradable waste per day, mainly collected from markets.

(b) *Transportation:* From secondary collection sites the waste is transported in trucks to the final disposal site. KMC transports 30 % of waste, while 70 % of solid waste transportation is contracted out to the private sector. Major vat points that accommodate garbage more than 30 MT are serviced from Dhapa

[8] Chakraborti (2011).

garage with pay loaders and 11 m^3 capacity tipper trucks. Other vats are serviced by manual loading vehicles and dumper placers.

(c) *Disposal:* KMC has two waste disposal sites. The Garden Reach dumping ground is a small facility with little remaining capacity. It receives currently about 10 MT/day of waste mainly from borough XV nearby. The main dumping ground is at Dhapa in the east of KMC at approximately 8 km from the city centre. This dump site is nearing its maximum capacity and has been authorized by West Bengal Pollution Control Board to operate for one more year only. It received an average of 4,286 MT/day solid waste in 2011 out of which 300 MT/day was diverted to the privately operated Dhapa composting plant.

The extent of scientific disposal of solid waste is currently zero and should become 100 % in accordance with the national benchmark target. Both the Dhapa and the Garden Reach dump site are not operated as sanitary landfill in accordance with national standards. There is no formal leachate treatment, no proper soil cover and informal, unorganized rag pickers operate at the sites. KMC has an interim permit from WBPCB to operate the Dhapa landfill facility for 1 year.

Because of the critical situation of Dhapa, the KMC in another pilot intervention has taken a step ahead towards becoming a vat-free metropolis and opened the first of the four garbage collection stations at Kalighat Park. The other garbage collection stations that will replace vats along some major thoroughfares, are Northern Avenue (Tallah Park), Shyamaprasad Mukherjee Road, Southern Avenue and Ballygunge Circular Road. With the help of technology from Netherlands, the civic body will place waste compactor machines at these stations. Instead of depositing garbage in the vats, the KMC conservancy labourers will unload the entire garbage of a locality into these compactors. The function of the 4 compactors, placed inside the garbage station, will be to squeeze the garbage and store it inside a container. Water generated from the compacted garbage will be drained out. After collecting garbage for the whole day, a prime mover (fitted with a hook loading system) will lift a compactor filled with garbage. The garbage will then be transported to the Dhapa dumping ground.[9]

Simultaneously, realising the pressing need for an alternative to the existing Dhapa dumping ground a second Dhapa project, has been planned by the Kolkata Municipal Corporation, which have not yet been approved by the National Ganga River Basin Authority (NGRBA) despite being approved by the East Kolkata Wetland Management Authority (EKWMA) and the environment department.[10] Subsequently, the KMC is also planning for an alternate dumping ground in Thakurpukur.

[9] Imagine Kolkata without Garbage Vats (2012).

[10] Pramanik (2012).

21.4.1 Sanitation and Sewerage

In the core city area all properties, except the slums, are directly connected to the underground sewer network, which is equivalent to 75 % of all households in the core city area. The slum areas are in general served by communal toilets connected to septic tanks.

The collection efficiency of sewage is 71 %, which is higher than the percentage of people with direct sewer connections because it also includes sewage collected through the interceptor sewer system. The collection efficiency is around 90 % in the core city area as well as in the KEIP areas. The remaining outer areas have no formal sewer system yet and collection is zero.

The treatment capacity of the existing treatment plants and the East Kolkata Wetlands (EKW) is sufficient to serve the entire central city (100 %) and the KEIP areas (100 %). The total average for KMC is 88 % because the outer areas not yet served by KEIP generate 12 % of the waste water for the entire KMC. The effluent quality at the outlets of the East Kolkata Wetlands and the existing treatment plants fully comply with national norms. The extent of re-use is very high because 90 % of all sewage from KMC ends up in the fisheries of the EKW where it serves as quality food for the fisheries. Effluent from other treatment facilities is partially re-used for agricultural purposes before it finally discharges into the Hooghly River. On average 93 % of waste water generated in KMC is re-used, comparing very favourable to the national target of 20 %.[11]

On the contrary to what KMC has reported, the Centre for Science and Environment in its Citizens' Seventh Report on the State of India's Environment, Excreta Matters, identifies that Kolkata's current sewage system is inadequate to deal with the wastewater production as well as the rainfall that the city receives. The system has been designed for a rainfall of 6 mm/h, but it has been found that 60 % of the trunk sewers in the city's core area are silted up. Most of these are more than 150 years old. The pumping system is in a similarly decrepit state as spares for older pumps are not available.

To handle this sewage and reduce water-logging during monsoons, the Asian Development Bank and the Government of India have signed an agreement. As part of this, the city has prepared a sewage master plan for 2035 with a budget of Rs 9,152.3 crore. This covers a wide range of measures such as release of excess storm run-off load into surrounding water bodies, increase in pumping capacity of the main pumping stations, replacement of sewers etc. The city sewage master plan recognises current limitations as it has used modelling to pinpoint problems and suggest solutions. However, it takes the tried and trusted approach of more pumps and pipes. It would have been beneficial to see much more about wetland conservation in the plan as well as decentralised sewage treatment. This would have ensured that the wetlands are protected for the future and sewage is treated and used locally.[12]

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[11] IND (2012).

[12] http://www.cseindia.org/node/4465.

21.4.2 Threat from Real Estate

To deal with the problem of encroachment problem and address the need for conservation, the East Kolkata Wetlands (Conservation and Management) Act, 2006 provided for stringent measures for preventing illegal encroachments. However, these steps did not end the problem of illegal encroachments. This is partly because of the lack of coordination between the different departments and agencies of the government. Table 21.6 presents the chronology of events regarding court cases in order to conserve the EKWs.

In the name of development, policies that run counter to the declared policy of preservation, through prevention of encroachments, have been initiated. Another important factor that has contributed to the gradual shrinkage is the real estate activity by property developers who are filling up the wetlands. The realtors generally act in cahoots with a section of politicians and the local administration.

The East Kolkata Wetland Management Authority has had to approve projects which were earlier thought to be against the principles laid down for the preservation of the Ramsar Site. In effect, it changed its own decisions. The KMDA's proposal in 2005 to widen the Eastern Metropolitan Bypass for faster movement of traffic was embroiled in controversy because of objections raised by the Pollution Control Board. However, construction work was carried out. Widening of the Bypass from Chingrighata to the Park Circus connector has reduced the size of the "Captain bheri", in violation of the government's policy. In 2006, the KEIP sought the permission of the East Kolkata Wetlands Management Authority to set up a 'land-fill site' for KMC on 113 ha of land adjacent to Dhapa where the KMC deposits solid waste. The PCB had serious reservations about the project as it would damage the Ramsar Site. However, the project was cleared by the East Kolkata Wetland Management Authority. It was to be executed by the KMC, instead of the KEIP, and directly from its own resources.

The illegal encroachment on "Collector bheri" by first draining out its water and then constructing a boundary wall were first highlighted by the media in December 2011. Three stop-work notices—two by the East Kolkata Wetlands Management Authority and one by the KMC, were issued and two FIRs filed, one by the Authority and the other by the KMC. But the illegal construction of the boundary wall couldn't be stopped thanks to the nexus between the powerful land mafia, a section of politicians and the police. However, ultimately it was the pressure mounted by the media and the environmental activists that led to coordinated action by the East Kolkata Wetlands Management Authority, the KMC and the Kolkata police.[13] The entire illegal wall around the 43-bigha Collector Bheri waterbody in Chowbagha mouja of Ward No. 108 in South 24-Parganas, off EM Bypass had been demolished.

[13] Banerji (2012).

Table 21.6 Highlights of court verdicts, government and people actions related to EKWs

1992	PUBLIC filed PIL in the SC.
1995	PUBLIC had accused leading government officials of contempt of court, A criminal offence, for not having adequately safeguarded the wetlands, particularly with respect to the leather complex and several other minor encroachments
	A report was prepared by the National Environmental Engineering Research Institute that detected that presence of chrome-based tanning among Kolkata tanners, with inappropriate wastewater drainage and collection systems, was causing serious environmental, health and hygiene problems
1996	Supreme Court order directed these and other inner city tanners from Tiljala, Topsia and Pagla Danga districts to shut shop and relocate to the Bantala Leather Complex, 15 km away from Kolkata as a judgement of M.C. Mehta Vs Union of India
2001	The judges expressed their dissatisfaction over the inability of the Ministry of Urban Development to specify the time frame for amending the buildings by laws. DJB was fined Rs 2,500 for not submitting the report on the leaking water pipes.
	The HC took up the issue of protecting the natural lakes of Delhi during this hearing. The bench observed, "We understand that natural water bodies that exist in Vasant Kunj and Prasad Nagar areas would vanish if not taken care." The MCD was directed to submit an affidavit with regard to steps taken to protect these water bodies. As a prelude the court directed the DJB, MCD and the NDMC to collect information on the water bodies in Delhi
2002	East Kolkata Wetlands was designated as a Ramsar Site
2004	The tanning association formed. The association of the tanners approached the state government to manage and operate the common effluent treatment plant
2005	East Kolkata Wetland Management Act was formed. The act has the power to demarcate the boundaries of the wetlands as well as to take measures to stop, undo or prevent any unauthorized development project or illegal use of the wetlands
2006	East Kolkata Wetlands Conservation and Management Bill, 2006, which aimed at including 12, 571 ha of land into the East Kolkata Wetlands, was passed. Any illegal construction will be penalized up to 1 lakh according to the bill. The state government decided not to dislocate 50,000 villagers who were already living in the five moujas that had been included in the wetlands. According to the bill all the pre existing constructions within the wetland had to be demolished
	PUBLIC filed another petition in the HC alleging that KMC had selected an area for its water supply project at Bointala in Dhapa which fell under the purview of the East Calcutta Wetland Management Act (2006)
	The tannery association emphasized that Dalmiya had failed to construct the common effluent treatment plant, as promised. WWF, other environmental groups and MoEF protested the action
2007	433 of the 550 tanners have been allocated land at the Bantala Leather Complex and 125 tanners have already started operations
2008	The state environment department was "in principle" against the Kolkata Municipal Corporation's (KMC) plan to set up a water treatment park on the East Kolkata Wetlands, where the high court has banned construction activities
	An order was issued barring local authorities (municipal corporations, Panchayat, etc.) from issuing licenses or sanctioning building plans for commercial activity without a clearance from the East Kolkata Wetland Management Authority (EKWMA)
	Calcutta High Court granted conditional approval to Kolkata Municipal Corporation (KMC) to set up a water treatment plant in the east Kolkata wetlands. While giving the nod, the division Bench imposed strict conditions, including compensatory greening, creation of water bodies, minimization of ecological damage and specifying the quality

(continued)

Table 21.6 (continued)

	and nature of materials to be used. The court also appointed a three-member committee (comprising two former university vice-chancellors and a professor) to monitor and report on the KMC's compliance with the restrictions
2009	The Supreme Court admitted the matter filed by Kolkata's non-government action group PUBLIC, objecting to Kolkata Municipal Corporation's plan to locate the facility of Rs 100-crore water treatment plant at Dhapa inside East Kolkata Wetlands, a Ramsar site
2011	In March, scooping out silt from the canals of EKW, that carry 1,300 million litres of wastewater into the *bheris (*small ponds*)* everyday has made them deeper, changing the natural gradient and obstructing the flow into some parts. Fish production had dropped in these areas
	In March it was found that about 33 water bodies in the Ramsar-protected East Kolkata Wetlands were filled illegally for the construction of the Newtown-Rajarhat Township. A letter (No. Hidco/planning 13/99) dated 19 November, 1999, written by the erstwhile managing director of Hidco, West Bengal, Mr Sanjay Mitra, to the secretary of the fisheries department, sought permission for relaxation of the provision of Inland Fisheries Act, 1984 and West Bengal Inland Fisheries (Amendment) Act, 1993 for filling up of water bodies for the implementation of the New Town Calcutta Project. The 33 water bodies that were filled by the Hidco without permission from the fisheries department ranged from 6.05 cottahs to 114.95 cottahs
	The government prepared a draft management plan to conserve East Kolkata Wetlands (EKW). The state government has been forced to prepare the draft plan after the Centre recently imposed a ban on discharging sewerage into any kind of water body by framing a new Wetland rule. The new rule has left the state in real trouble as the EKW serves as the natural sewerage treatment plant for the city

21.4.3 Court Cases on Protection of EKW at a Glance[14]

In 1992, a Kolkata based NGO, People United for Better Living (PUBLIC) in Calcutta filed a petition in the HC against the changes of land use in the Waste Recycling Region of the wetland area.

21.4.4 Chronology of Action

This case is still under the consideration of SC of India. The followings are some of the highlights of court verdicts, government and people actions.

East Kolkata Wetlands through their natural functioning form the basis of various developmental activities. However, developmental planning has failed to take into cognizance the role played by these systems. Emphasis has been on engineering measures for quick economic gains at the cost of ecological sustainability. Planning has recognized only the provisioning services of the wetland and

[14] East Kolkata Wetlands.

to a smaller extent its capacity to regulate wastes, at the same time ignoring other services as flood attenuation, and support to biodiversity. The lack of basic understanding of the nature of wetland ecosystem has led to overall loss of benefits accrued from the wetland through natural processes and functions. Involvement of multiple agencies with sectoral approaches limits adoption of a holistic management approach and strategy. Absence of appropriate monitoring and evaluation mechanisms limits assessment of impacts of implementation of action plans. An innovative approach needs to be adopted for developmental planning integrating ecosystem services of the wetland. Such an approach would help to mitigate floods, regenerate water quality, enhance resource base and improve overall quality of the life of the marginalized community. A demonstration project is therefore recommended to map and analyse various factors contributing to the ecological footprint of the city and provide policy guidelines for specific sectors and to the Kolkata Municipal Corporation for reducing the footprints. Such a study would indicate the advantages of considering these issues in planning urban programmes and in suggesting solutions for making the city more sustainable.

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Chapter 22
A Geospatial Analysis of Flood Risks and Vulnerability in Ogun-Osun River Basin, Nigeria

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Abstract The frequency and intensity of flood disasters have become serious issues in the development process as flood disasters have caused serious environmental damage, loss of human lives and wanton destruction of economic assets globally. Loss of human lives and development assets, rising costs of reconstruction efforts and associated hardship are putting the issue of disaster reduction and risk management higher on the policy agenda of affected governments, multilateral agencies and NGOs. The starting point of concrete flood disaster mitigation efforts is to identify the areas with higher risk levels and fashion out appropriate preventive and response mechanisms.

This paper proposes a GIS-based model for identifying flood-prone areas for the purpose of planning for disaster mitigation and preparedness, using a river basin as a unit of analysis. This model uses a number of physical, demographic and landuse data to identify areas and settlements that are vulnerable to flooding. Based on this multi-criteria model, areas, settlements and populations with varying degrees of vulnerability to flooding were identified and mapped. The model results showed that over 1,200 settlements harbouring over 13 million people are at grave risk of flooding. These vulnerable settlements and populations are mostly located within

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the coastal stretch, river valleys and urbanized parts of the study area. While the model proves to be usable for planning purposes, inclusion of population data at a finer level (Enumeration Areas) would improve the performance of this model by providing a near accurate estimation of population at risk as well as their spatial spread.

Keywords Flood • Multi-criteria • Risk • River basin • Vulnerability

22.1 Introduction

Increased fluxes in the global climatic regime have led to a concomitant increase in the frequency and severity of hydro-climatic events, of which flood accounts for more than a half. The rising frequency and severity of flood events and related disasters which are linked to hydro-meteorological changes on one hand and the consequences of human activities on the other hand have put man and the current civilization on the brink. Although, flooding has occurred throughout human history, available statistics shows that the frequency, severity, spatial coverage and level of destruction remain staggering and are on the increase. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) predicts that 'heavy precipitation events, which are very likely to increase in frequency, will augment flood risk' which will affect life and livelihoods in human settlements in all areas, especially in coastal zones, river deltas and mountains (Nicholls et al. 2007).

In spite of the increase in activities targeted at natural disaster reduction in the past decade, losses in assets and human lives resulting from flooding have been on the increase in tandem with increased incidence of flooding. Between 1901 and 2012, a total of 806 major flood events was recorded in Africa with fatality in 24,393 settlements while 56,840,203 people were affected (EM-DAT). These figures exclude a large number of unreported events mostly in remote areas of the continent which were no less devastating as many people were rendered homeless, infrastructure damaged and farmland washed away by floods caused by excessive rainfall and associated dam breaks. Nigeria has had more than her fair share of losses in material and human lives as flooding has become a single most recurrent disaster in the country. In 2012, pervasive flooding of major rivers stemming from concentrated rainfall and persistent release of water from dams claimed over 150 lives, destroyed property worth billions of Naira, disrupted inter- and intra-regional movements, and caused disruptions in the lives of tens of millions of people. The prevalence of poverty and illiteracy and lack of institutional framework have combined to weaken the capacity of people in Sub-Saharan Africa to respond and cope with flood disasters.

The devastation that attends flood events has remained a serious concern to policy makers and the academia alike. Research efforts focusing on different aspects of flood disaster are quite enormous, with many digging into the root, the impact and various ways of mitigating the occurrence and severity of damage that result from such disasters (Ojo 1991; Ologunorisa 2006). In Nigeria, much research energy has been dissipated on the study of causes and effects of floods within the context of cities (Olaniran 1983; Gobo 1988), since in the view of the researchers, the impact of flooding together with its associated damage is felt more in the urban areas being centres of population and human civilization (Adelekan 2009). However, flood disaster impact is even more severe in the countryside and vulnerabilities are higher among the rural dwellers than their urban counterparts. A dissection of flood related literature in Nigeria shows that majority of the works treated specific flood events (Babatolu 1996; Abams 1995; Ojo 1991; Omuta 1988), their nature and perception (Okechukwu 1983); while others focused on the causal factors such as rainfall fluctuation (Olaniran 1983; Ojo 1991; Ologunorisa 2000), climate change (Adefolalu 2000) as well as risk and vulnerability assessment of different spatial units (Adelekan 2009; Ologunorisa 2006). Despite the copious coverage of the range of issues addressed in these studies and the diverse methodologies applied, there exists a clear lacuna in the methodologies and focus as many of the previous works adopted purely descriptive risk perception techniques often combined with rainfall data to identify places at risk and vulnerable populations. Few (if any) of these studies have tapped into the geospatial capabilities of modern GIS to carry out multi-criteria flood risk and vulnerability assessment.

A number of methods ranging from descriptive to quantitative exist for assessing the level of risk exposure of population to a specific disaster. Previous studies have focused on flooding and its impact on urban dwellers (Adelekan 2009; Maantay and Maroko 2009; Orok 2011). Studies adopting regional approach to flood risk modelling using a GIS-based multi-criteria analysis are scant. Ologunorisa (Ologunorisa 2006) attempted a flood risk assessment using a hydro-climatic method in parts of Niger Delta region of Nigeria. In a similar study, Adelekan (Adelekan 2009) examined the vulnerabilities of urban poor to flood disaster in the coastal city of Lagos employing the integrated assessment framework that includes both natural and human sub-systems interactions. A recent perception study of flood incidence in Lagos using questionnaire survey methods (Aderogba 2012) reported a progressive increase in volume and areas of coverage. (Kolawole et al. 2011) have examined various options available for flood risk mitigation in Ilorin, Nigeria, concluding that assessment of the risk impact of flood will facilitate countries to plan adaptation measures and adapt effectively to flood events. None of these studies employed GIS methods in their estimation of the vulnerability and risk assessments. This study is designed to plug these identified lacunae by attempting a multi-criteria analysis of flood risk and vulnerability, using river basin as a unit of analysis.

The current effort is aimed at bringing conceptual as well as methodological improvement on the existing body of knowledge in the area by expanding the variable that form input to the flood risk model within a regional framework.

22.2 Flood Risk and Vulnerability: Some Conceptual Clarifications

A major challenge in the analysis of risk and vulnerability to disasters is the clarification of concepts which are often used by a wide range of academics, professionals and practitioners. The concepts of hazard, risk exposure and vulnerability are critical to the understanding of regional pattern of vulnerability to flooding in Nigeria and globally.

The concept of hazard in disaster management is used to describe an extreme event with potentially damaging effects if and while it occurs. In other words, hazard can be seen as stressors or perturbations (Turner et al. 2003; Maantay and Maroko 2009). In this wise, a higher than normal rainfall, proximity to a river channel may constitute a flood hazard. According to Jeb and Aggarwal (2008), "Flooding is a general temporary condition of partial or complete inundation of normally dry areas from overflow of inland or tidal waters or from unusual and rapid accumulation or runoff". Natural hazards may produce significantly different impacts on people and places, often depending not only on the severity of the hazards, but also on their biophysical attributes and the socioeconomic characteristics of a locale (Huang et al. 2011).

Vulnerability is conceived as a measure of the degree to which an entity (a population, city, ecosystem etc.) can anticipate, cope with, resist, and recover from the impact of a natural hazard (Maantay and Maroko 2009; Blaikie et al. 1994), or a social response to a biophysical danger within a specific geographic domain (Huang et al. 2011), or within the context of specific human groupings or animal kingdom. But since the geographical domain is made up of both biotic and abiotic components, it may well be apt to focus on the spatial unit in the analysis of risk and vulnerability to flooding which itself is a geographic phenomenon. A regional view of vulnerability therefore focuses not only on the people but also on other elements of the environment such as critical infrastructure, plant and animal species and other elements of the bio-physical environment. Vulnerability is a function of a wide range of factors paramount among which are the frequency and intensity of the stressor (hazard), physical, structural and socio-economic capacity of the people to resist and or cope with the resultant devastation. Of course, the level of vulnerability will vary from one individual or group to another due to variations in the socio-spatial characteristics and the available institutional support system.

Risk is a concept usually defined in relation to disaster to describe future or potential condition which is a function of exposure to natural hazard and the vulnerability of exposed entities in a particular location. It is often interpreted in terms of the total loss and damage in terms of lives, injuries and property incurred in the event of a disaster occurring at any given place and time period (Dolan and Walker 2004). It is important to note the spatio-temporal component of the risk definition. Also, risk perception on the part of individual and communities varies based on their locations and socio-economic conditions and circumstances.

Flood risk assessment is usually carried out by considering the nature, extent and the probability of occurrence of hazard together with factors that predispose a particular individual or community to the hazard. In the context of flood hazard, hazard factors are conceived in terms of the physical characteristics of the stressor (flood) like flood depth, frequency, duration damage, and velocity (Ologunorisa 2006) and vulnerability factors like socioeconomic variables (income, level of education), land use type, proximity to hazard source, building type and material quality, and adequacy of flood damage. Often times, risk perception of the exposed population may form part of the input into risk assessment and analysis. However, risk perception is usually fraught with value judgment and may not reflect actual levels of exposure. Flood risk assessment incorporates meteorological parameters (spatio-temporal distribution of rainfall) that regulate water supply to the earth's surface, hydrological parameters that directly cause inundation and cultural parameters that capture the effect of human activities.

22.3 Material and Methods

This section highlights the type of data used in this study and their sources. It also discusses the various methods employed in data processing and analysis.

22.3.1 Data Types and Processing

The study relies on spatial data obtained from different sources. Elevation data for the region was derived from the STRM data which was downloaded from their website. Digitized drainage, and administrative boundary maps, land use maps alongside the Digital Elevation Model form input into the flood risk analysis. These data are complemented by attribute data like rainfall and population data, obtained mostly from archival sources. Figure 22.1 presents the cartographic model of the data input, analysis and output of the flood risk analysis.

Spatial data from satellite images were georeferenced and existing digital data transformed to the WGS_1984 Projection System. This was done to allow for consistency and avoid representation errors that may arise from differing spatial extent of these data. The attribute were joined to spatial data based on common fields to further improve the usefulness of the spatial data. Specifically, the population and rainfall data which came as tabular data were joined to the administrative boundary data.

The SRTM Digital Elevation Model (DEM) for the study area was downloaded from SRTM website. Rainfall data were obtained for selected stations within the study area and used to produce precipitation map of the study area. The rainfall data were obtained from Nigerian Meteorological Agency. Drainage map of the area was produced from vectorization of the scanned topographical maps of the area and

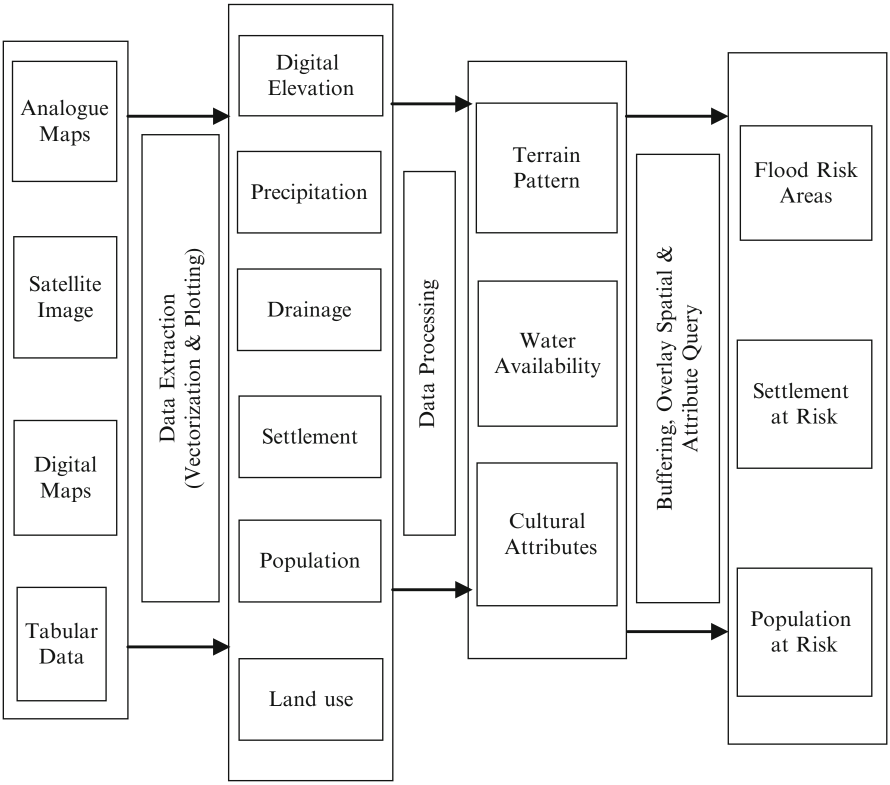

Fig. 22.1 Cartographic model of flood risk analysis

re-projecting the data to WGS_1984. Settlement data were obtained from the Settlement delineation study conducted by the Nigeria Communications Commission conducted in 2005 which remains the most comprehensive settlement data in the country till date. Absence of population figures on a locality basis presented a problem. However, GRUMP population figures raster data were downloaded and used in the study to estimate population under varying degrees of flood risk. Population data were downloaded from Global Rural-Urban Mapping Project, Version 1 (GRUMPv1) (Center for International Earth Science Information Network (CIESIN) 2012). The population raster data have a resolution of 4 km (each cell is a $4 \times 4\ km^2$). Since this size in the most urbanized area is bigger than the size of an Enumeration Area (EA) in Census data, the accuracy of this data may be slightly lower than what could obtain if EA were used as spatial units for population sampling. Land use data were obtained from digital vector data from FORMECU, a Federal Government Department in charge of forest management. Due to the numerous land uses types used in the original data, the land use types were reclassified into three major types for the purpose of flood risk analysis. These three major classes are urban, agriculture and undisturbed forest.

Table 22.1 Decision variables for flood risk analysis

Variables	High risk	Score	Medium risk	Score	Low risk	Score	Total score
Relief (meters)	≤ 50	3	50.1–400	2	>400	1	6
Drainage (buffer in meters)	≤ 100	3	101–1,000	2	$>1{,}000$	1	6
Land use types	Urban	3	Agriculture	2	Undisturbed forest	1	6

22.3.2 *Data Analysis*

The data analysis for this study was essentially carried out within GIS framework, using ESRI's ArcGIS 10.0™. Three major variables were used to determine the risk exposure to flooding in the areas. From literature, it is apparent that relief, hydrology and human activities are risk factors in flooding (Ologunorisa 2006). Each of the three variables was categorized into three major categories—high, medium and low risk factors.

The study area is for the most part a lowland area made up of coastal and flood plain of major rivers. This informed the choice of the decision variables for delineating the area into high-, medium- and low- flood risk areas (Table 22.1). Since the rainfall regime is essentially the same for most parts of the study area, it was excluded from the decision variables. Generally, areas with height less than 50 m were designated as high risk areas; areas with height between 50.1 and 400 m were described as medium risk areas while areas above 400 m are designated as low risk areas. Proximity to river channels is an important variable in this analysis. Distance from rivers and their tributaries were reckoned at 100, 1,000 and 2,000 m, with areas within 100 m of river channels were categorized as high risk areas; areas within 101–1,000 m as medium risk areas and areas located at over 1,000 m to the river channels were described as low risk areas. Based on land use, urbanized areas were designated as high risk land use; cultivated land as medium risk and forested areas as low risk area.

22.3.3 *The Study Area: The Ogun-Osun River Basin*

The Ogun-Osun River Basin is one of the twelve river basin authorities created as part of the Nigeria's Third National Development Plan in 1977 (Federal Government of Nigeria (FGN) 1975). Located between longitudes $2^{\circ}\ 38^{1}$ and $7^{\circ}\ 32^{1}$ E and latitudes $6^{\circ}\ 14^{1}$ and $9^{\circ}\ 25^{1}$ N, the Ogun-Osun River Basin has an area of 49,580 km^2 (Fig. 22.2). The area is bounded in the north, east, south and west by Niger River Basin, Benin-Owena River Basin, the Atlantic Ocean and Benin Republic respectively. The drainage is characterized by rivers and streams that mostly flow in a north-south direction, taking their sources from the Western Uplands in the North

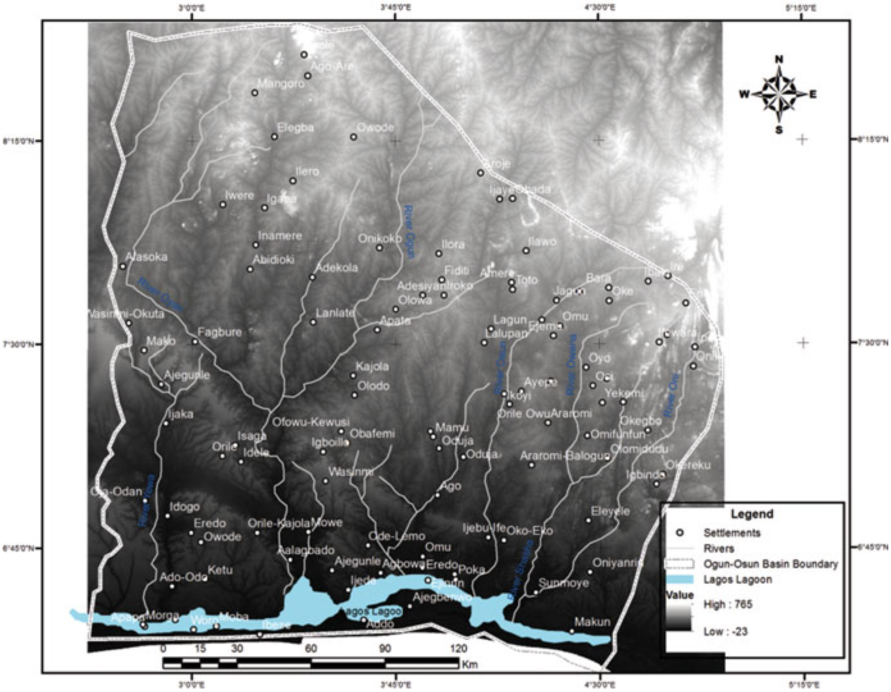

Fig. 22.2 The physiography of Ogun-Osun river basin

and emptying their waters into the Gulf of Guinea in the south via Lagos lagoon. Important rivers include Osun, Ogun, Shasha and Yewa. The climate is wet equatorial climate with annual rainfall ranging between 1,016 mm in the northern part and 2,540 mm per annum in the southern coastal fringe. The concentration of rainfall, mostly from cyclonic sources is responsible for constant inundations of the entire areas during heavy rainfall. This is not helped by the generally low relief which is less than 500 m above the mean sea level. The coastal plain is particularly low in relief with some parts less than 10 m above the mean seal level.

This region has a population of over 20 million people, concentrated in about 26 urban centres and over 9,000 appendage semi-urban and rural enclaves. Invariably, the region is the most urbanized area in Nigeria, with Lagos (largest city) having more than 10 million inhabitants. The significance of the region is also underscored by the concentration of economic activities and infrastructures. The Western Industrial Complex that extends from the coastal areas of Lagos and Ogun to Ibadan accounts for more the 70 % of Nigeria's industrial output. The region also houses the busiest air and sea ports in the West Africa sub-region. In the hinterland, various agricultural activities ranging from plantation agriculture to arable farming are carried on. In fact, the region is the heart of cocoa and kola nut production in the country. Pastoral nomadism and poultry farming are also part of important agricultural activities in the region. The region is well served by road and rail transportation.

The presence of thick population, concentration of important national infrastructure and the climatic, topographic and drainage systems that predispose the entire region to flood hazard accord the region a high point on the vulnerability index. Previous flooding events in the area had resulted in significant loss in human lives, extensive damage to national infrastructure and private property while crops and livestock were washed away. Hitherto, there has not been any systematic assessment of the pattern of risk exposure of settlements and populations in this region to the flood hazard.

22.4 Results and Discussions

The purpose of the flood risk analysis conducted was to among other things categorize the areas flood risk into different risk zones and produce classified risk maps based on some selected predefined criteria. Based on this, areas, settlements and population were classified as high risk, medium risk and low risk, depending on their risk ratings. A number of spatial queries were used to generate the areas, settlements and population at varying levels of risk of flood in the study area.

Categorization of areas was achieved by combining all the three parameters used in this study namely height (above mean seal level), proximity to drainage channel and land use type to generate a risk variability surface. Each of these areas were ranked on scale of 1–3 as shown in Table 22.1. The highest score (3) denotes high risk and the lowest (1) indicates low risk. These scores were added together and areas that scored more than 10 on the scale were designated as high risk zones while areas that scored between 8 and 10 were categorized as medium risk area. Any area with less than 8 as the score was categorized as low risk area. Following this procedure, the settlement and population at varying level of flood risk were delineated. The summary of result of land area, settlement and population at risk are shown in Table 22.2.

It is apparent from Table 22.2 that 50,126 km^2 (79.3 %) of land area is moderately at risk of flooding while a considerable 12,574 km^2 or 19.9 % of the land area is at high risk of flooding. Only 548 km^2 of land has a low risk of flooding. Figure 22.3 shows that the areas at high risk of flooding are mostly located in the vast lowland area bordering the Atlantic Ocean. These areas are also the most densely populated areas of the Ogun-Osun River Basin. Areas with medium

Table 22.2 Risk properties of selected phenomena

Parameters at risk	High risk (%)	Medium risk (%)	Lower risk (%)	Total (%)
Land area (km^2)	12,574 (19.8)	50,126 (79.3)	548 (0.9)	63,248 (100)
Settlements	1,256 (12.3)	8,449 (82.6)	518 (5.1)	10,223 (100)
Population	13,233,010 (55.1)	10,773,693 (44.8)	13,219 (0.1)	24,019,922 (100%)

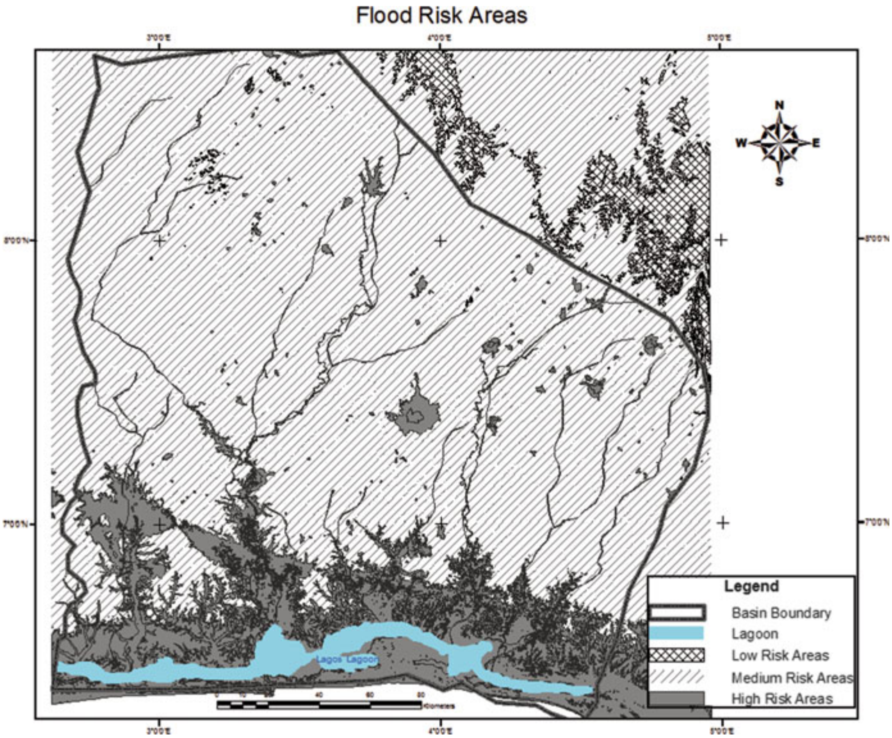

Fig. 22.3 Areas at varying risk of flooding

likelihood of flooding are located in the moderately high ground of the interior. The proportion of settlements at high risk of flooding (1,256 or 12.3 %) is also relatively high compared with 8,449 or 82.6 % of the 10, 223 settlements in the entire area. However, the distribution of land areas and settlements at risk of flooding contrasts with the population. It is evident from the table that the largest proportion of the population in the study area (55.1 %) is located in areas that are considered high risk areas, while 44.8 % is in medium risk zone. Only 13,219 people representing a paltry 0.1 % of the total population are located at the low risk zone.

Figures 22.3, 22.4, and 22.5 show areas, settlements and population at varying levels of risk of flooding respectively. The entire area has a moderate to low relief but the southern part being close to the ocean has lower relief than the northern part. Also, the digital terrain model depicts a wide, gently sloping river valley in the southern end of the basin area [Fig. 22.2] while urban land use is also more widespread and intense along the coastline. These factors combined with high annual rainfall predispose the entire basin area to flood disaster. However, the level of exposure to flood risk is highest along the coastal and flood plains in the extreme southern part with the upper part of the basin having moderate exposure. The coastal plain is exposed to flash flooding due to its low relief, river flooding as a

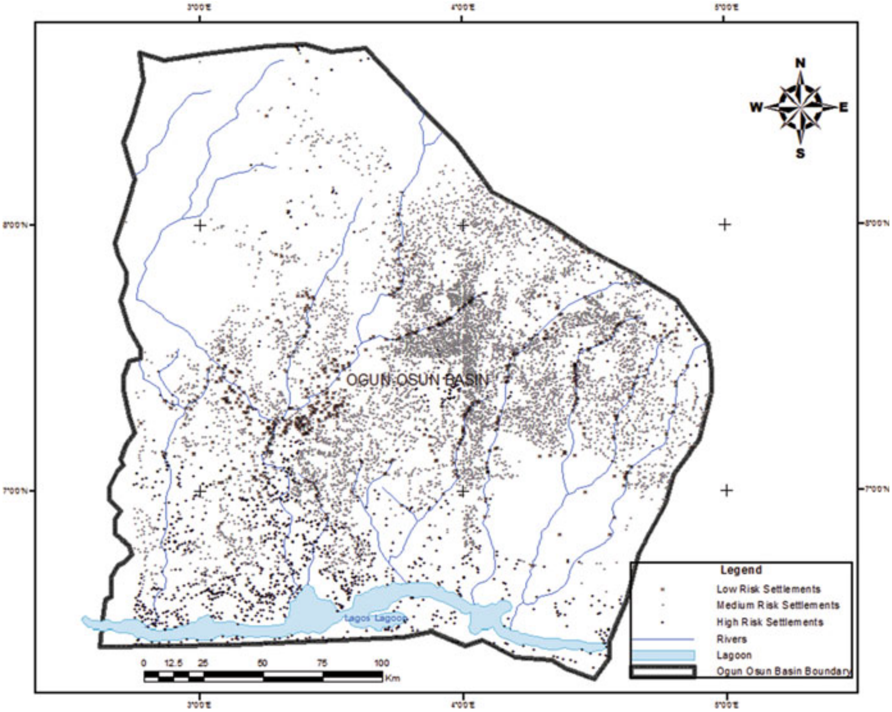

Fig. 22.4 Settlements at risk of flooding

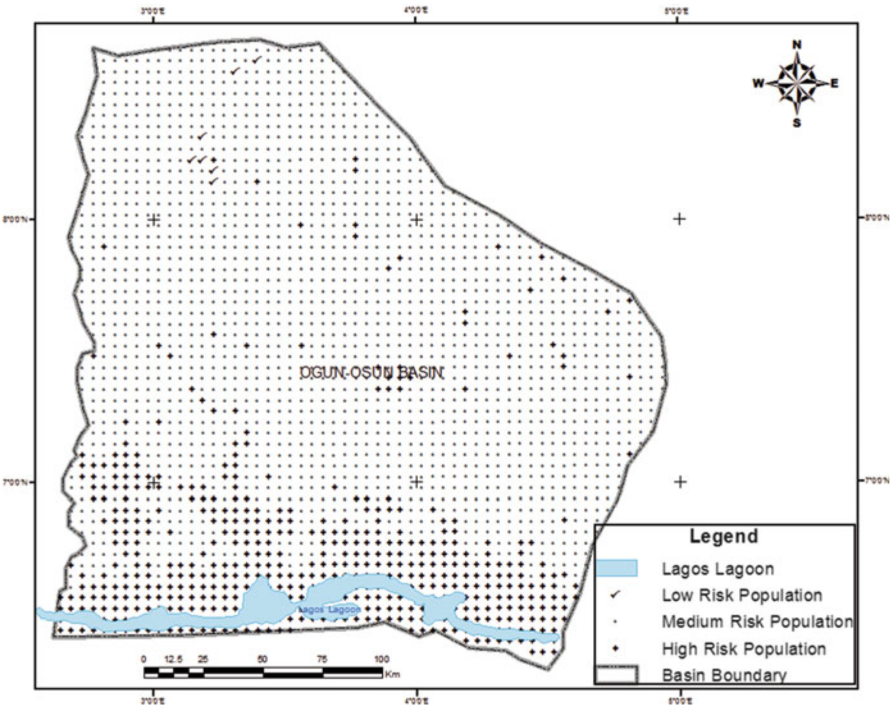

Fig. 22.5 Population at risk of flooding

result of several rivers entering their flood plains and ocean surge from occasional rise in the volume of ocean water. The relief in this upper part is fairly high with narrow river valleys and large expanse of undisturbed forest and cultivated land. As evident in Fig. 22.3, only some small patches of urban land use exhibit a high risk to flood hazard in the study area. Except for some isolated high grounds in the northwestern part of the study area, no part of the study area has a low exposure to the risk of flooding.

The situation is almost the same with settlements at risk of flooding. Most settlements in the basin area have moderate exposure to flood risk. Figure 22.4 shows clearly that virtually all of these settlements are located outside of the coastal area where diverse forces of consistently heavy precipitation and intense human activities combine to increase risk of flooding. In terms of population, the population with high risk of exposure to flooding is more than half of the population. Out of over 24 million inhabitants, over 13 million inhabitants face a high risk of flooding (Table 22.2). These populations are located in the low-lying coastal areas (see Fig. 22.4). The effect of the mega city of Lagos with a population of over ten million people is apparent in this case. Even when the land area and settlement numbers in the high risk zones are smaller than what obtains in the medium risk zones, the population with high risk of flooding is far more than in the medium risk zone. This indeed underscores the need for urgent flood mitigation efforts in the high risk zones since the area is home to some 15 million people, and several billion dollars of critical infrastructure and personal property.

22.5 Conclusion

This study has attempted an assessment of flood risk in Ogun Osun River Basin, which unarguably is the economic nerve centre of the country. The study reveals that low-lying coastal areas are in grave danger of perennial flooding due to its hydro-climatic as well as topographic configurations and human interference. The study estimates that over 1,200 settlements harbouring over 13 million people, mostly in coastal areas, are at grave risk of flooding. Incidentally, this high risk coastal stretch is the most urbanised in the basin area and is home to about two thirds of the population and more than 80 % of the economic wealth. It is therefore imperative that policies aimed at mitigating the effect of flooding be strictly implemented in order to forestall losses in human lives and material possession.

Acknowledgments Authors are grateful to the Federal Ministry of Environment for their support for this research.

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Chapter 23
Recurring Impact of North Indian Flood Disasters on Agri-Masses: Benchmarking Remedial Strategies for Sustainable Development

G.S. Chauhan and R.N. Dubey

Abstract Floods are the most devastating hazards that occur frequently almost every year in most parts of the Northern India. In the present research paper an attempt has been made to analyse and highlight the impact of recurring floods on various anthropogenic activities mainly on agri-masses and their livelihood security. Apart, from that such types of natural calamities reflect their impacts on various other important phenomena as well, like agriculture, human and live stock wealth including the local existing environment. Almost all parts of northern India are intensively affected by severe floods with high to moderate intensity, i.e. Punjab, Haryana, Himachal Pradesh, Uttar Pradesh, Uttaranchal, Jammu & Kashmir followed by Delhi the capital city of India. The estimated area affected by the floods is 40 million hectares. The estimated annual loss due to the most destructive floods is Rs. 2,104 million, while the average affected area by floods during 1953–1996 was about 7.52 million hectares. In the same duration nearly 32.35 million people were affected. The mitigation of the flood hazards would require identification and mapping of flood-prone areas, advance warning system through satellite, planning and action, as well as integration of local and traditional knowledge with existing scientific knowledge system, to save the precious lives of millions of people including the cattle wealth

Keywords Anthropogenic • Calamities • Catastrophes • Disaster • Livelihood

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23.1 Introduction

Flood is a global phenomenon and severe floods frequently occur almost every year in various isolated parts of the world including India, causing gigantic loss of life, large scale damage to property and untold miseries to millions of people. Hence, it may be rightly stated that such types of natural calamities leave behind a story of death, hunger, epidemic and mass destruction. Floods are considered to be the most devastating hazards among all the natural calamities. In case of India, it has been observed that most parts of the northern India are frequently hit by severe to moderate floods, mainly the states of Uttar Pradesh, Punjab, Haryana, Himachal Pradesh, Jammu and Kashmir and Uttaranchal States including national capital Delhi because the entire region is ecologically fragile and dominated by the flood prone river systems

These frequent floods disasters which occur every year undoubtedly cause sudden disruption to normal life and colossal damage to the natural resources, and hit various pertinent developmental activities particularly the biotic and a biotic activities. Literally such vagaries of nature have far reaching adverse impact not only on environment and natural resources but also on the agri-masses dwelling in the affected areas and their livelihood security and livestock wealth. Eventually such types of natural calamities destabilize the national and regional economy (Aggarwal 1991).

23.1.1 Geo-Physiographical Profile of Study Region

Geographically north India is a vast region comprising of six states and one union territory i.e. Jammu and Kashmir, Himachal Pradesh, Haryana, Utter Pradesh, Punjab, Uttaranchal and Delhi (Fig. 23.1). The northern part of India is endowed with immense geographical diversity, different cultures, rivers and diversified climatic conditions. The entire region under study i.e. North-India shares its borders with the neighbouring countries of India like Pakistan in the West, China and Nepal in the North. It is surrounded by Rajasthan state in the South-West, Madhya Pradesh in the South, Chhattisgarh in the South-East and Bihar in the East. It covers a total geographical area of 6,24,166 km^2 which constitutes near about 18.98 % of the total geographical area of the country. The lion share part of this region is famous for its green revolution and agricultural prosperity. The majority of population consists of the rural agri-masses and possesses agrarian type of economy. Almost all rivers which have their origin in the Himalaya pass through this region predominantly the Ganga, Yamuna, Indus, Ravi, Beas, Chenab, Sutlej, Jhelum, Ghaghara, Gomati and Rapti etc.

Fig. 23.1 Location of study region

23.2 Aims and Objectives

The main aims and objectives of this research study are as under:

- To trace out the flood prone areas.
- To know the Spatial Extent and Magnitude of the flood problem.
- To assess the flood loss due to recurring floods.
- To highlight the major causal factors of flood disasters.
- To suggest the Benchmarking remedial strategies to mitigate flood disasters.

23.3 Material and Methodology

The research study is primarily based on secondary data sources only. The major data and information pertaining to the research investigation have been collected from various secondary sources. The main sources of secondary data are Ministry of Water Resources, Govt. of India and Disaster Management Departments, Central Water Commission (CWC), Ministry of Agriculture, Govt. of India and Rastriya Barh Ayog (RBA). Apart from these sources extensive flood literature has also been collected from concerned States Government Departments. Similarly, various latest flood reports related to flood management and water resource department of Govt. of north Indian states of study region have also been consulted to get the latest relevant information regarding the recurring floods. Precisely, all the data has been analysed by applying various statistical methods and techniques including some maps, figures and tables to depict the Spatio-temporal view of recurring floods.

23.4 Major Causal Factors of Recurring Floods

However, there are several causal factors of recurring floods, depending upon the local physiographic and climatic conditions and drainage system of a particular region. Out of them, the most pertinent and dominant factors which are also interrelated to each other, have been mentioned below and highlighted with the help of the given Fig. 23.2:

- Incessant and excessive rainfall within a short period
- Overflow in major rivers and their tributaries, canals, drains due to high discharge of rain water in the catchment areas
- Over-exploitation of natural resources and unskilled agricultural practices on marginal hills slopes
- Inadequate sewerage system in cities, towns and flood prone areas
- Increase in Human population and Livestock numbers
- Deposition/accumulation of debris and silt in the courses of major rivers and drains
- Defective and Poor drainage systems, especially in densely populated cities and towns
- Occasional breaches in various rivers, canals and drains
- Uncertain extreme events of cloud burst and torrential rainfall
- Heavy rainfall in upper reaches of mountainous hill-states and adjacent areas
- Increase in developmental activities (Road, Bridges, Buildings, Tunnels and Construction of Reservoirs)
- Expansion of urbanization and industrialisation in and around major cities and towns
- Indiscriminate deforestation, overgrazing and slow pace of afforestation

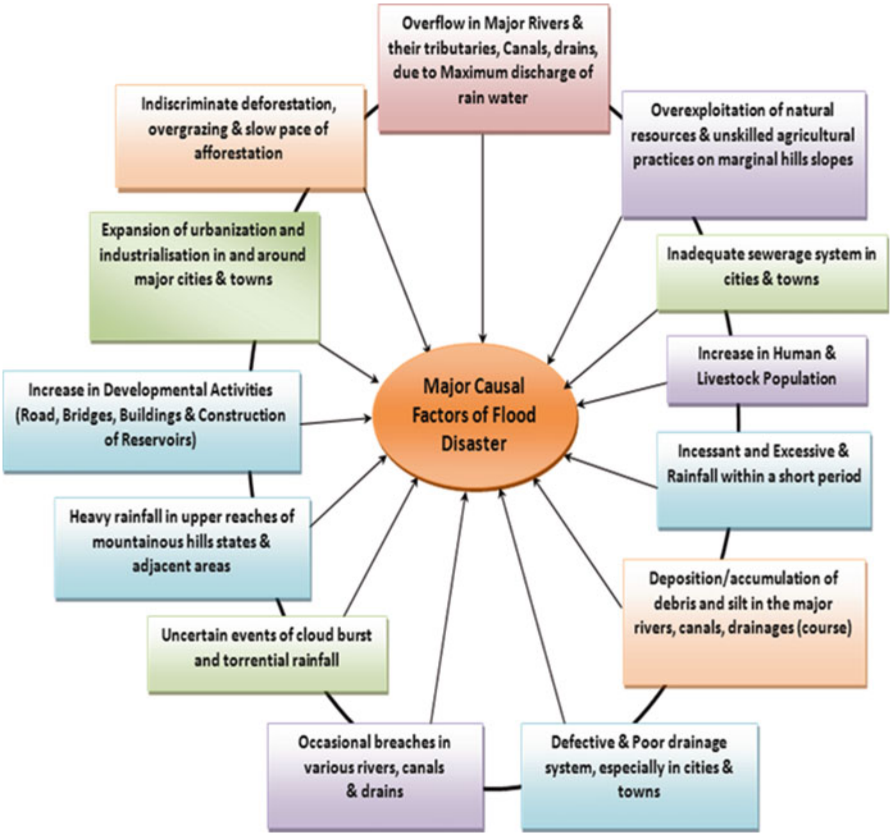

Fig. 23.2 Major causal factors for floods disasters in North India

23.5 Flood Scenario in India

India being one of the richest countries with regard to its water resources, is continuously suffering from the menace of floods since centuries due to poor management of this rich natural resource. Unplanned development has been another cause of floods. Because of large geographical area (32,87,263 km^2) India has often faced severe flood hazards occurring frequently in its different parts throughout its history of civilization. The country receives an annual precipitation of 400 million ha meters out of which 75 % is received through four months of monsoon (June to September), and as a result almost all the rivers carry heavy load of discharge during this period. The problems of sediment deposition, drainage congestion and synchronization of the river beds compound the flood hazard in various parts of the country.

It has been estimated that over 90 % of the total damage to the property and crops in India is done in the plains of north India especially in UP, Uttaranchal, Punjab,

Table 23.1 Flood affected area and flood damages in India (1953–1996)

S. no.	Item	Unit	Average (1953–1996)	Maximum damage (with year)	Damage during 1996 (tentative)
1	Area affected	Million ha.	7.52	17.50 (1978)	7.36
2	Population affected	Millions	32.35	70.45 (1978)	39.02
3	Human lives lost	Nos.	1,514	11,316 (1977)	1,271
4	Cattle lost	Nos.	95,270	618,248 (1979)	60,171
5	Cropped area affected	Million ha.	3.45	10.15 (1988)	3.35
6	Value of damage to crops	Rs. Millions	4,558.70	25,109.00 (1988)	3,838.80
7	Houses damaged	Millions	1.15	3.51 (1978)	0.36
8	Value of damage to houses	Rs. Millions	1,359.30	7,416.00 (1988)	903.20
9	Value of damage to public utilities	Rs. Millions	3,812.00	20,500.40 (1985)	8,605.90
10	Value of damage to houses, crops and public utilities	Rs. Millions	9,999.80	46,303.00 (1988)	21,780.60

Source: Central Water commission (FM and DP Directorate)
Note: Figures from 1991 onward are tentative and are being finalized in consultation with State Govt. *: Includes Rs. 8,432.70, Millions for which breakup is not available

Haryana, Delhi including several parts of Himachal Pradesh. The total area affected annually on an average is 3.5 million ha and it was as high as 10 mha in 1988, the worst year. The average annual damage to crops, house and public utilities during the period 1953–1996 was about Rs. 46,303 million in the floods of 1988 (Table 23.1).

It has been already mentioned that in India since time immemorial recurring floods frequently hit the study region. There is hardly a year when some or other part of the related states does not face the spectre of furious floods. With regard to recurring floods the trends are quite significant. In spite of the state and central govt. flood policy and several flood control schemes, the loss and damage due to flood clearly appears to be increasing. A large part of rural and agriculture oriented population being subjected to distress is rising in flood prone areas. Sharp ups and downs in the flood trends have been observed during 1953–2004 (Table 23.2 and Fig. 23.3). Almost all designated states have been affected by floods between '1953–2004' (Table 23.2**).** India had experienced heavy flood damages during the monsoon of 1955, 1971, 1973, 1977, 1978, 1980, 1984, 1985, 1988, 1998, 2001 and 2004 (Fig. 23.3**).**

Moreover almost all states of north India have also been severely affected by floods since 1953 as per the data available, and flood-damages loss has also been assessed during 1953–1996 (Table 23.1) in India including the flood prone area of study region (1953–2004), which has been shown with the help of given Table 23.2.

Table 23.2 Flood affected area in India from 1953 to 2004

Year	Flood affected area (million ha.)	Year	Flood affected area (million ha.)
1953	2.290	1979	3.990
1954	7.490	1980	11.460
1955	9.440	1981	6.120
1956	9.240	1982	8.870
1957	4.860	1983	9.020
1958	6.260	1984	10.710
1959	5.770	1985	8.380
1960	7.530	1986	8.810
1961	6.560	1987	8.890
1962	6.120	1988	16.290
1963	3.490	1989	8.060
1964	4.900	1990	9.303
1965	1.460	1991	6.357
1966	4.740	1992	2.645
1967	7.150	1993	11.439
1968	7.150	1994	4.805
1969	6.200	1995	5.245
1970	8.460	1996	8.049
1971	13.250	1997	4.569
1972	4.100	1998	9.133
1973	11.790	1999	3.978
1974	6.700	2000	5.166
1975	6.170	2001	3.008
1976	11.910	2002	7.090
1977	11.460	2003	6.503
1978	17.500	2004	8.031

Source: Ministry of Water Resources, Govt. of India

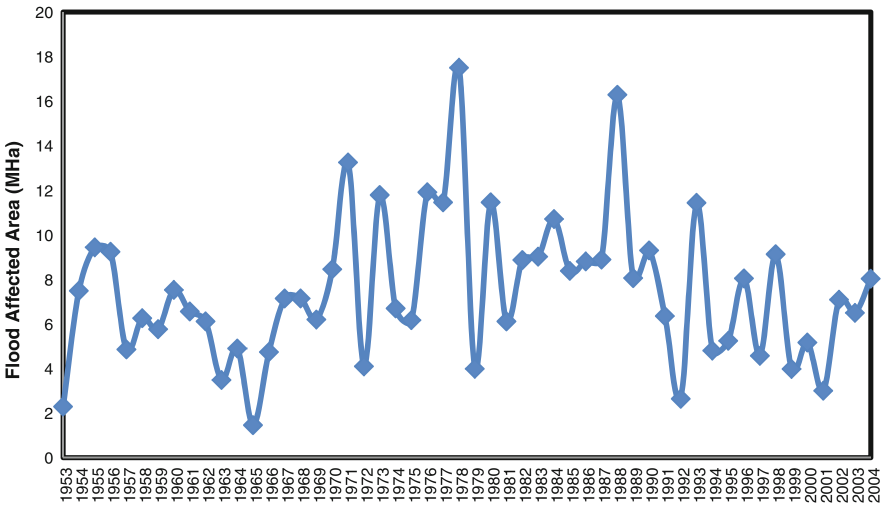

Fig. 23.3 Flood affected area in India from 1953–2004

23.6 Flood Scenario in Study Region

The entire belt of north India and most of its surrounding fertile areas are very fragile from disaster flood point of view and often remained in the grip of furious floods in every monsoon season (Chauhan 2002). This part of the country is probably the first to suffer by floods in the very beginning of the monsoon in comparison to the other parts of the country (Chauhan 2004b). Almost all the states of study region are flood-prone but out of them Uttar Pradesh, Uttaranchal, Punjab, Haryana are worst flood prone (Table 23.3), whereas Himachal Pradesh, Jammu & Kashmir and Delhi are the least affected (Fig. 23.4). Heavy rainfall amounting to 200–250 cm during the rainy season (beginning of June to end of September) is the chief cause of floods in North India. The average rainfall in study region was relatively very high during 1993, 1995 and 2008. As a result, there was a mass destruction of agricultural crops, life and property (Table 23.3). Floods and their impact on various states of study region have also been highlighted and shown with the help of Fig. 23.4 in 2008. The floods have harmed and their impact visibly reflects on various developmental activities and population including crops, houses and human lives (Figs. 23.5, 23.6, 23.7, 23.8, 23.9, 23.10, and 23.11).

23.6.1 Uttar Pradesh

Almost the entire area of state is affected and hit by the flood havoc. Considerably large area of eastern U.P. remains in the grip of furious floods which is known as a platform of various major rivers and their tributaries particularly the Ganga and its tributaries, both left and right banks. During rainy season, all these rivers receive heavy rains and consequently inundate a large area of the state. The Ganga itself is flooded when the water level rises in its tributaries, causing immense devastation in the vicinity areas too. The recurring floods in India particularly in the upper reaches

Table 23.3 Flood prone areas of North India (area in million ha)

S.no.	State	Area liable to floods
1	Jammu and Kashmir	0.08
2	Himachal Pradesh	0.23
3	Punjab	3.70
4	Haryana	2.35
5	Uttar Pradesh+Uttaranchal	7.336
6	Delhi	0.05
Total (study region)		13.746
Total : (rest of Indian states)		19.77
Grand total (all India)		33.516

Source: Ministry of Water Resources, Govt. of India

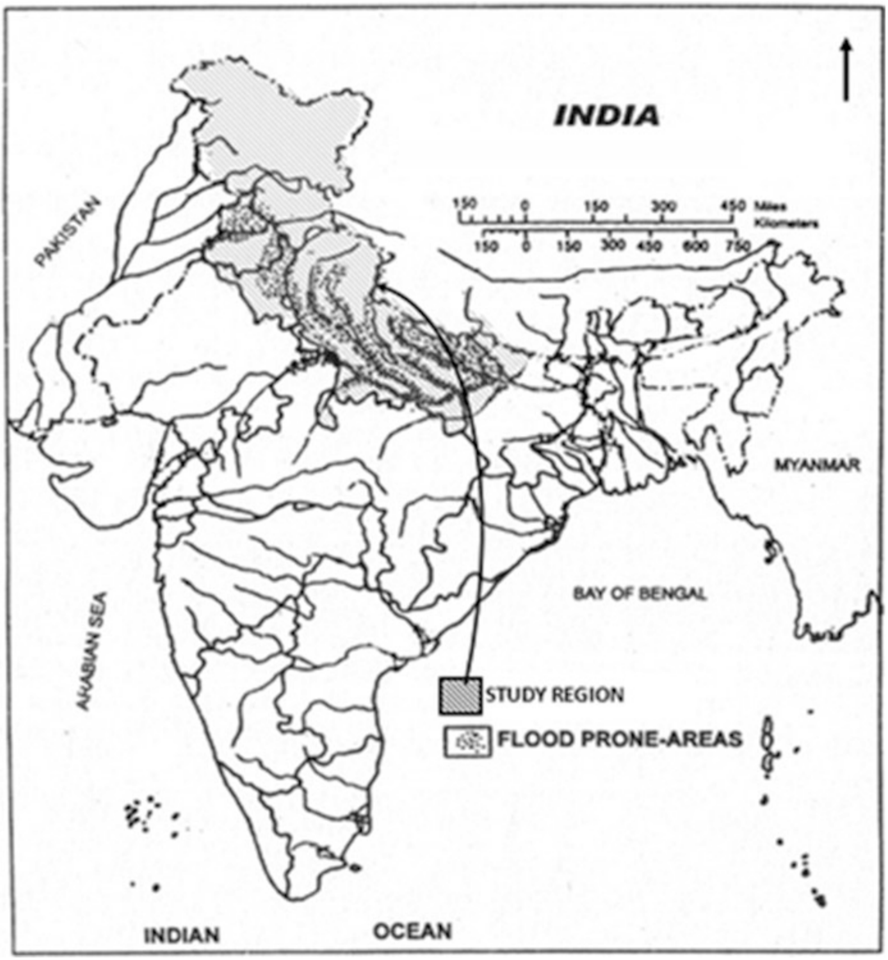

Fig. 23.4 Flood prone areas of North India

of hill states like Uttaranchal, Himachal Pradesh certain parts of Jammu and Kashmir, including U.P. are in grip of floods due to the result of man's over-exploitation of nature. Indiscriminate deforestation, overgrazing by cattle and unskilled agricultural practices on the marginal hill slopes are other significant contributory factors.

According to the latest figures (1998) as many as 46 out of 83 districts in the whole state were flood-prone. Gorakhpur is the worst affected district in the whole state, whereas the other worst affected districts of eastern UP are **Ballia, Basti, Sidharthnagar, Mau, Azamgarh, Gonda, Balrampur, Maharajganj, Sant Kabir Nagar, Kushi Nagar and Faizabad including the higher reaches of Garwal and Kumaon hills** in the north-west (presently in Uttaranchal state). Apart from these, the other moderately hit districts are **Allahabad, Varanasi,**

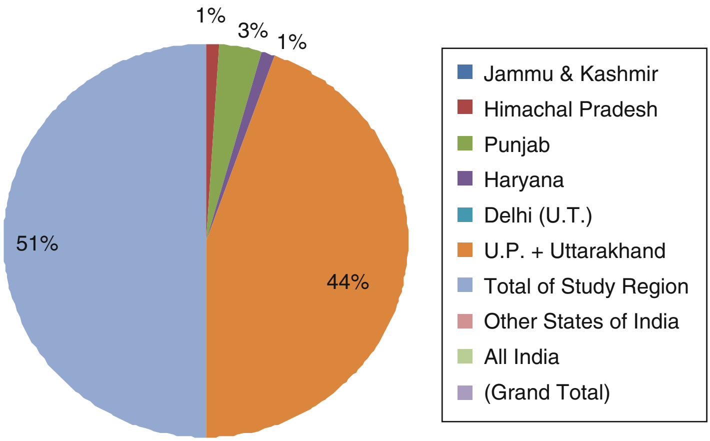

Fig. 23.5 Population affected by flood (in millions)

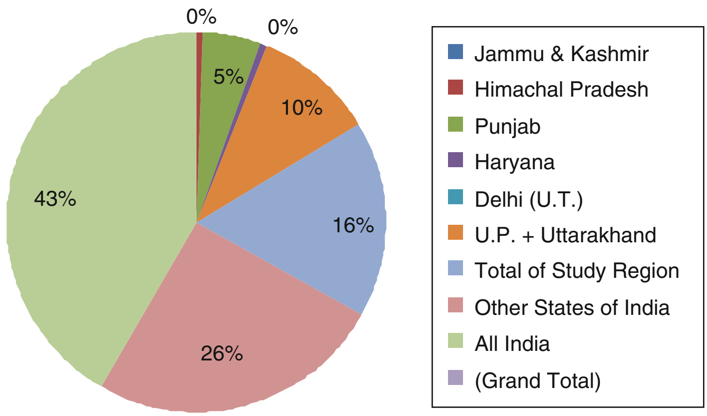

Fig. 23.6 Flood damages to crops (in Mha)

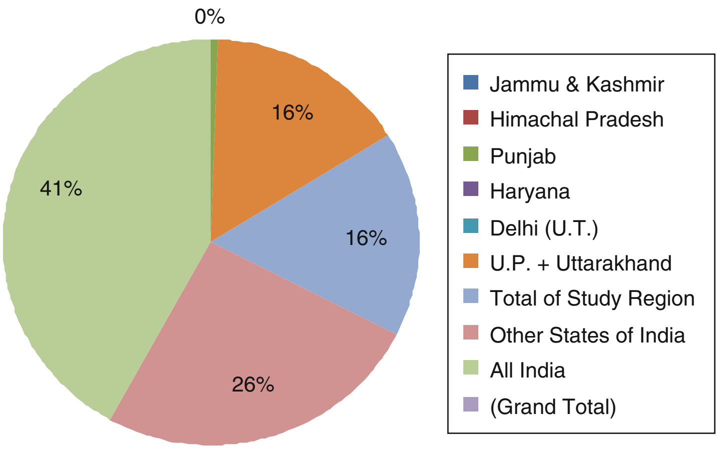

Fig. 23.7 Flood damage to houses

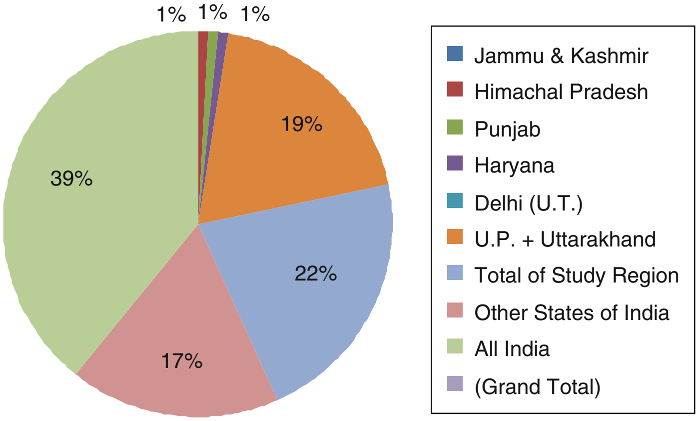

Fig. 23.8 Human lives lost due to floods (in Nos.)

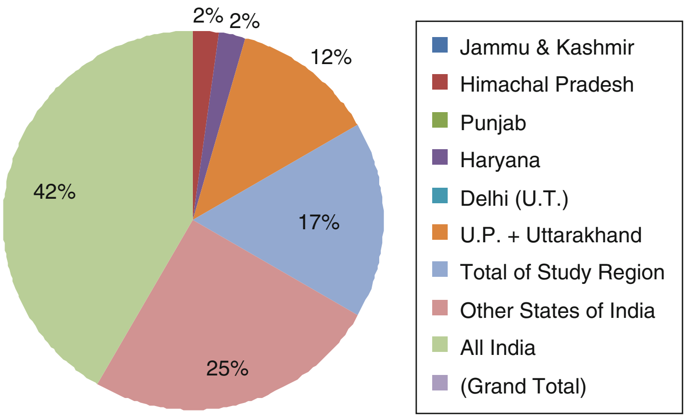

Fig. 23.9 Damage to public utilise (Rs. crores)

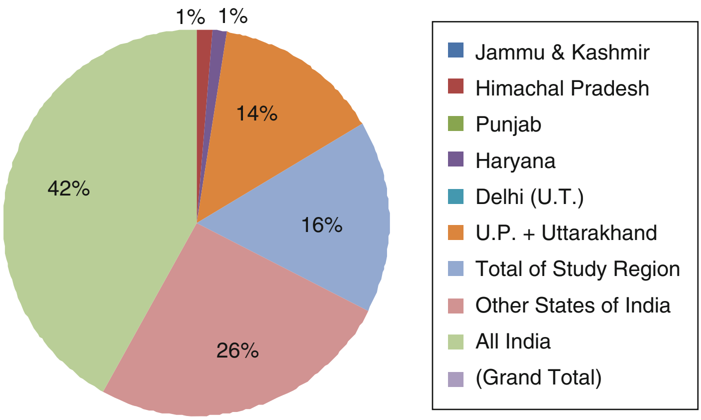

Fig. 23.10 Total damages to crops, houses and public utilities (Rs. crores)

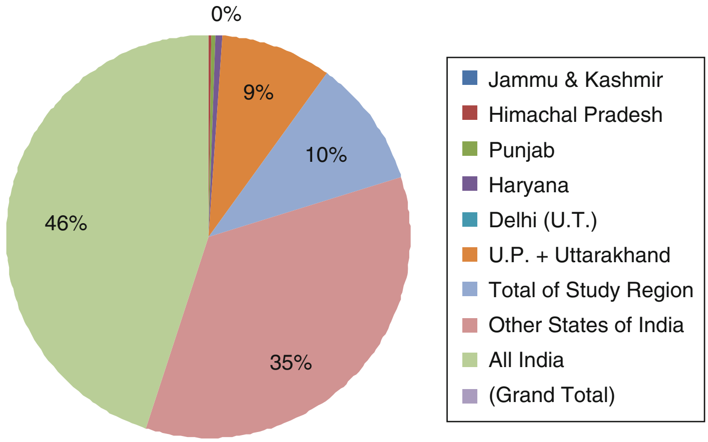

Fig. 23.11 Cattle loss due to floods (in Nos.)

Sant Ravidas Nagar, Lucknow, Muradabad, Rampur, Ghaziabad and Rae-Barely. The Ganga, Gomati, Rapti, Ghaghra and Kunao are some of the most important rivers responsible for floods fury in huge geographical area of UP and its neighbouring areas.

23.6.2 Punjab

The plains of both Punjab and Haryana are well known as one of the badly affected plains and this account for nearly 15 % of the total losses incurred by floods in India. The main causes of floods occurrence in Punjab state is the heavy rainfall in the upper reaches of Himachal Himalaya and adjacent hills and ultimately sudden floods occur. The 1960 floods of Punjab are famous in the state which made about half a million hectares of agricultural land drastically insolvent. The total damage done to the crops and property was estimated around Rs. 150 million. Similarly, the July, 1993 floods also extensively damaged and destroyed property worth about Rs. 570 million in at least 13 districts of the Punjab state. The major flood-prone districts were **Hoshiarpur, Ropar, Amritsar, Monga, Kapurthala, Phillaur, Fatehgarh Sahib, Patiala** and so on.

23.6.3 Haryana

This tiny but agriculturally advanced state is not spared by the recurring floods. Many times, it has also become the victim of flood fury. In the state, usually choked courses of Ghaggar and Markanda which are seasonal rivers inundate large areas in the rainy season. The defective and poor drainage system in the various parts particularly in Rohtak, Jind, Hisar and Gurgaon districts of the state are the main causes of floodsThe furious floods of 1995 have been considered the worst floods of the century in the state history (Chauhan 2004b). It has been estimated that about 1.8 million people in 13 cities and about 2043 villages in at least 15 districts were devastated and had to be shifted to safer places. More than 72,000 houses and at least 1,558 roads in different parts of the state were extensively damaged. About Rs. 20,000 million properties was damaged and 2.2 million ha agriculture area was affected. Out of 17 districts, 10 districts namely **Rohtak, Bhiwani, Hisar, Jind, Sirsa, Kaithal, Sonepat, Faridabad, Rewari and Gurgaon** were noticed to be in the grip of fierce floods. Rohtak, Bhiwani, followed by Hisar were identified as the worst-flood affected districts.

23.6.4 Himachal Pradesh

Since many decades, the hilly state of Himachal Pradesh is reported to be in the clutches of disastrous floods. The main causes of severe and devastating floods in the state are cruel and uncertain events of cloud bursts and torrential rainfall. Kullu valley and its adjacent areas have been frequently hit by flash floods in the monsoon season and the river Beas claims to have destroyed and had a great impact on several hundred acres of marginal land of the surrounding villages on its banks. The major flood hit districts are **Kullu, Solan, Chamba, Rampur, Kangra and Sundernager** including **Mandi, Hamirpur and Una**.

23.6.5 Jammu and Kashmir

Jammu & Kashmir state is relatively a less flood-prone state. However, sometimes the floods hit only those areas which are located either near the perennial rivers or along the hill slopes. As per the Statistical figures, no area has been reported to be flood affected Table 23.4. Therefore the state is least affected by recurring floods.

23.6.6 Delhi

The Union Territory and capital city of India is hit by floods almost every year. Because the river Yamuna passes through Delhi and during rainy season due to continuous rainfall in the upper hill areas of Himalaya and surrounding parts, the Yamuna becomes furious during rainy season. However, the damage done by flood disasters in this state is probable very less in comparison to other states.

Table 23.4 Damages due to flood/heavy rains in North Indian states during 2008

Sr. no	Name of the state/Uts	Area affected (Mha)	Population affected (million)	Damage to crops: Area (Mha)	Damage to crops: Value (Rs. Crores)	Damage to houses: Nos	Damage to houses: Value (Rs. Crores)	Cattle lost nos.	Human lives lost in nos.	Damage to public utilise (Rs. Crores)	Total damages to crops, houses and public utilities (Rs Crores)
1	Jammu and Kashmir	–	0.00	0.00	0.00	0	0.00	0	0	0.00	0.00
2	Himachal Pradesh	–	0.06	0.02	8.10	1	2.16	147	46	57.99	68.24
3	Punjab	–	0.20	0.21	0.00	13,161	0.00	90	38	0.00	0.00
4	Haryana	–	0.06	0.02	8.10	1	2.16	147	46	57.99	68.24
5	Delhi (U.T.)	–	0.00	0.00	0.00	0	0.00	0	0	0.00	0.00
6	U.P. + Uttaranchal	–	2.58	0.42	189.02	340,761	213.05	3,490	1,056	322.49	724.56
7	Total of study region	–	2.9	0.67	205.22	353,924	217.37	3,874	1,186	438.47	861.04
8	Other states of India	–	–	1.03	474.06	560,327	223.74	13,340	957	655.55	1,353.37
	All India (grand total)	–	–	1.70	679.28	914,251	441.11	17,214	2,143	1,094.02	2,214.41

Source: Central Water commission (FMP Directorate) (As per the report received from State Revenue Authorities and MHA)

23.7 Impact of North Indian Recurring Floods

- In fact, natural calamities like floods are complex and stern events of nature which pose severe menace to the various types of anthropogenic activities of society and their impact reflects on human life, especially on agri-masses is multi-dimensional. Almost all aspects of social life i.e. domestic, social, economic and cultural are severe affected by such type of hazard UNICEF Report. However, it is very difficult to assess the indirect environmental damage since plant - animal - human chain is intensively affected by such calamities. The direct impact of flood hazards is indeed tremendous, especially on the local economy. The damage done by such hazards to infrastructure, crops and productive assets of local agriculture-based population and selected masses are massive especially on its poor strata, in addition to imposing a huge financial burden of relief and rescue operations (UNDP 2009).
- Indirectly these natural calamities often lead to decline in agriculture production, loss of income, unemployment, indebtedness of the poor, threat to livelihood security and increased cost of goods and services etc. The large scale damage caused by flood run into worth thousands of million rupees. But worst of all are the precious lives of human-beings including their cattle wealth, a loss of hundreds and thousands of cattle. What is most surprising is that despite thousand millions of rupees spent on flood control measures every year, the losses keep mounting, although, the figures may fluctuate from year to year depending upon the severity of floods. No doubt, floods that occurred in the past also damaged the life and property of the society, but their overall colossal impact was not felt in the past because of low population pressure, and relatively less industrial development followed by other developmental activities in the plain areas. Apart from that countless trees especially on the road, canal, river and railway line sides got up-rooted due to the devastation caused by floods and this has had a reverse impact on the ecology and the biodiversity wealth of the region.

In Brief, the flood disasters have the following impacts on the various anthropogenic activities including two major sectors i.e. agriculture and socio-economic conditions of society:

- Every year millions of people are rendered homeless and wander for shelter for many days and in most of the cases they are forced to stay under the open sky.
- Thousands to millions of houses and settlements have been badly damaged and a large number of them collapsed.
- Similarly thousands to millions hectares of agricultural land come under deep flood water and is rendered useless for further cultivation.
- Millions of tons of fertile top soil has been eroded by several major rivers and their tributaries of the country and ultimately deposited in the seas/oceans.
- Hundreds of people are washed away in the flood water and equal numbers have died either due to lack of food availability or epidemics.

- Thousands hectares of land has been converted into wasteland/barren land and resultantly problems of salinity and alkalinity including water logging originate.
- Due to stay of large quantity of flood water at certain places for a long time, there is a threat to spread various types of water-borne diseases. This phenomenon has also caused the ground water table to suddenly rise.
- Thousands of livestock either fled away in flood water or died in the wake of fodder shortage.
- Due to over flow of flood water in various rivers, tributaries, canal and drains there always remained the threat of breaches and seepage at several vulnerable points.
- Production of certain agricultural crops including cash crops either gone down drastically or lost their quality and quantity.
- National and state highways including their other associated link roads have been submerged in flood water leading to subsequent failure of traffic for several weeks or causing heavy disruption of economic and commercial activities.

23.8 Benchmarking Remedial Strategies for Floods Mitigation

It is a well accepted fact that recurring floods cannot be prevented. However, their adverse societal and economic impact can be reduced substantially by undertaking preparedness and benchmarking remedial measures by active community involvement. Minimizing the loss of precious human life is the first priority in flood management strategies. Almost each and every year stories of misery, devastation, death and epidemic that monsoon left in its aftermath is repeated. But with poor planning, mismanagement of water resources, lack of political will and allocation of meagre money for flood controlling purposes, it is rather a very difficult task to control the frequent floods.

Hence, it is necessary to suitably "*Manage Floods*" with a view to reduce the damage potential and avoid loss to lives of humans and cattle. So, in this direction "*A better understanding of behaviour of rivers*" could help in order to prevent loss due to flood hazards. The Central as well as State Governments should review such measures time to time and take appropriate and meaningful steps. But even then, many other things have gone wrong with most of the damage in floods being due to increase in population along the banks. Another factor is mass destruction of forests to earn livelihood. Besides, reclamation of more and more lands even within the riverside areas have caused changes in the river regime system over the years. All these have led to increasing flood damage in spite of various control measures undertaken in the country as a whole and study region in particular.

Keeping in mind the rising trends of flood loss the Govt. of India and several states are doing their best job in order to prevent flood loss by applying various methods both old and latest. It is necessary to mention here that the Govt. of India including the concerned state Govt. have taken keen interest in order to protect soil loss due to floods. The Govt. of India has spent huge money for the protection of embankments and constructed drainage channels under management works mostly till 2007 (Table 23.5). About 524 villages and towns have been protected under flood management works out of these 524 villages 448 belong to Haryana state, 71 villages from U.P. and Uttaranchal, 3 villages from Rajasthan and 12 villages from Jammu & Kashmir.

23.9 Strategy for Flood Management and Sustainable Development

In order to achieve sustainable development, the model Flood Plain Zoning Bill should be introduced in all the Indian states including the states of Study region. Although, the bill came into force in 1975 but Manipur is the only state which has enacted legislation on the basis of this model bill. Keeping in mind its relevance and importance, the adoption of the bill should be made compulsory so that fruitful results may come forward in the affected region.

The flood plain zoning is one of the best methods for mitigation. This method is considered the most effective and reliable for flood prevention. But before identification for flood plain zoning, there is an urgent need for the better understanding of behaviour of rivers that can help to prevent recurring floods disasters. Therefore, flood-prone areas should be identified and mapped. Aerial survey should be made especially to assess loss of agricultural crops, vegetation cover and property to the exact flow of flood water. During critical flood hours, along the sides of river and canals strict vigil by army/police personals should be kept in order to face any eventuality and to safeguard local population. Apart from all these efforts and techniques which have already been initiated, the other one more significant and important method is the advance warning system which is now easily possible and easier with the help of satellites and INSATS. By adopting all the stated important methods, techniques including strategies, it may be possible to achieve the sustainable development which can save millions and avoid the huge burden on national economy spending on flood measures. Apart from that, it will also be helpful to maintain the ecological balance of the flood affected areas.

23.10 Conclusions

On the basis of the above discussion, it has been observed that most parts of northern India are severely affected by flood hazards almost every year particularly in Uttar Pradesh, Uttaranchal, Punjab, Haryana, Jammu & Kashmir and Delhi primarily located in the Indo-Gangetic plains. Almost all the anthropogenic and

Table 23.5 State-wise progress (study region) of physical works under flood management works till March 2007

Sl. no	Name of the state	Area benefi-tted upto March 2007 (Mha)	Length of emban-kments (km)	Length of drainage channels) km	Villages raised/ protected (No.)	Town/village protection work (No.)	Raised platforms (No.)
1	J & K	0.217	230.000	14.000	5	12	–
2	Himachal Pradesh	0.012	58.000	11.000	0	0	–
3	Punjab	3.190	1,370.000	6,622.000	0	3	–
4	Haryana	2.000	1,144.000	4,385.000	98	448	–
5	Delhi (U.T.)	0.078	83.000	453.000	0	0	–
6	UP + Uttaranchal	1.705	2,106.000	3,995.000	4,511	71	–
	Total of Study Region	7.202	4,991.000	15,480.000	4,614	524	–
	Other States	11.02	28,937.642	23,329.86	102	1,924	11.02
	All India	18.222	33,928.642	38,809.86	4,716	2,458	18.222

Source: Central Water Commission (FMP Dte.)

commercial activities have been severely hampered on large scale by the recurring flood hazards during the past 52 years leading to destabilization of regional and national economy. So, in order to mitigate flood disasters, there is an urgent need first of all to find out and map flood-prone areas as suggested in the above discussions. Secondly, the new modern techniques should be applied for instance, advance warning system which is possible now through various satellite and remote sensing services. Hence, the flood forecasting and warning system should be adopted because it is one of the most reliable and cost effective methods. Massive afforestation programmes should be launched in the flood prone areas evolving local people especially women and school children. Similarly special *"clean up drive"* should also be launched in order to remove the deposited debris and silt in all the vulnerable rivers, canals and drains (at local level) in the presence of expert engineers, right before the arrival of monsoon season. By adopting all these benchmark measures and flood management works in the country, it would be possible to save the precious lives of human-beings including cattle wealth and considerably reduce the immense flood damages not only in the study region but also in the entire country.

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Chapter 24
Microwatershed Level Conservation Strategies for Effective Land Management in Haheom Watershed, Kashmir Valley (J & K)

Abaas Ahmad Mir and Pervez Ahmed

Abstract The present study is an attempt to delineate the different land use/land cover categories in the Haheom watershed of the Kashmir valley. A total of 09 classes were delineated. Out of which dense forests were the major class with 32.43 % area. It was followed by sparse forests with 17.40 % and Apple orchards with 9.37 % area respectively. It was observed that over the period of time, a considerable change in the land use/land cover had occurred. This change has been unplanned and unscientific in majority of the cases and has resulted in serious soil erosion problems necessitating immediate remedial measures. In order to initiate effective management strategies in the watershed, proper soil and water conservation measures need to be taken in accordance to the magnitude of the problem. This includes prioritization at the micro watershed level and subsequent conservation measures. The present watershed has been divided into seven micro watersheds. After calculating the Sediment Yield index (SYI), the micro watersheds have been ranked from one to seven. This ranking basically highlights the intensity of soil erosion problems in the watershed. In the micro watersheds, where the Sediment Yield Index was high, a combination of engineering and biological measures were recommended.

Keywords Erosion Intensity Mapping Unit (EIMU) • Micro watershed • Prioritization • Sediment Yield Index (SYI)

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24.1 Introduction

The land use/land cover pattern of a region is an outcome of natural and socio economic factors and their utilization by man in time and space. Land use means the use to which the land is being put or the utilization of land devoted to human activities. Sekliziotis (1980) defines land use as the human action of a given area while land cover is the physical surface of the land.

Watershed is a topographically delineated area draining into a single channel (Brooks 1985). Watershed management implies rational utilization of land, soil and water resources for optimum and sustained production with minimum hazards to natural resources and environment. The basic objective of watershed management is to identify the problems and to adopt the judicious approach for solving the problems and optimum utilization of all natural resources. For any management plan, the identification of the problematic areas is a prerequisite. In order to opt for land conservation measures in a watershed, one of the important approaches is to identify the problematic areas at the micro level. Hence, the management plan of hydrologic units within the vast catchments is done for initiating conservation measures (Ahmed 2013). The purpose is to arrest the further degradation of these units. The watershed/sub watershed/micro watersheds are subsequently rated into various categories corresponding to their respective Sediment Yield Index (SYI) values. Sediment yield is the total sediment outflow from a catchment/basin, measurable at a point of reference and a specified point of time (Anonymous 1991). The sediment yield process can be divided into upland and lowland phases. The sediment detachment process predominates in the upland phase whereas sediment transport and deposition are the main processes in the low land phase (Anonymous 2002). Specific needs of sediment yield modeling are varied. No single model can meet the requirement fully. Sediment prediction requirements for each of the available models are determined largely by the duration of the event to be simulated; size, shape, the morphometry of the area and the sources of the sediment.

24.2 Study Area

The studies were carried out in the Haheom Watershed of the Pohru Catchment of the Kashmir valley (Fig. 24.1). The Haheom watershed lies between 34° 30′ and 34° 39′ N Latitude and 74° 12′ and 74° 18′ E Longitude. The Haheom Watershed is bounded by Kahmil watershed in the west, Dangarwari watershed in the south and Lolab watershed on the east side. It has been divided into seven micro watersheds (Fig. 24.5) in accordance to the guidelines of the Watershed Atlas of India (WAI).

This watershed can be divided into three distinct physiographic units i.e. the Mountains, the Karewas and the Flood plains. The main ridges of the mountain ranges run in a northwest to southeast direction. The mountains are conical in shape with steep to very steep slopes in all directions. The southern slopes, on account of

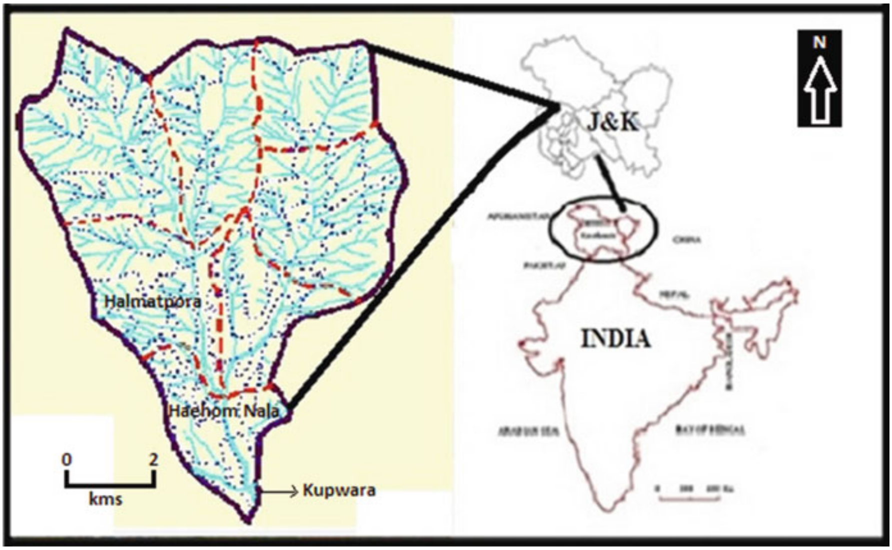


Fig. 24.1 Location map of the study area

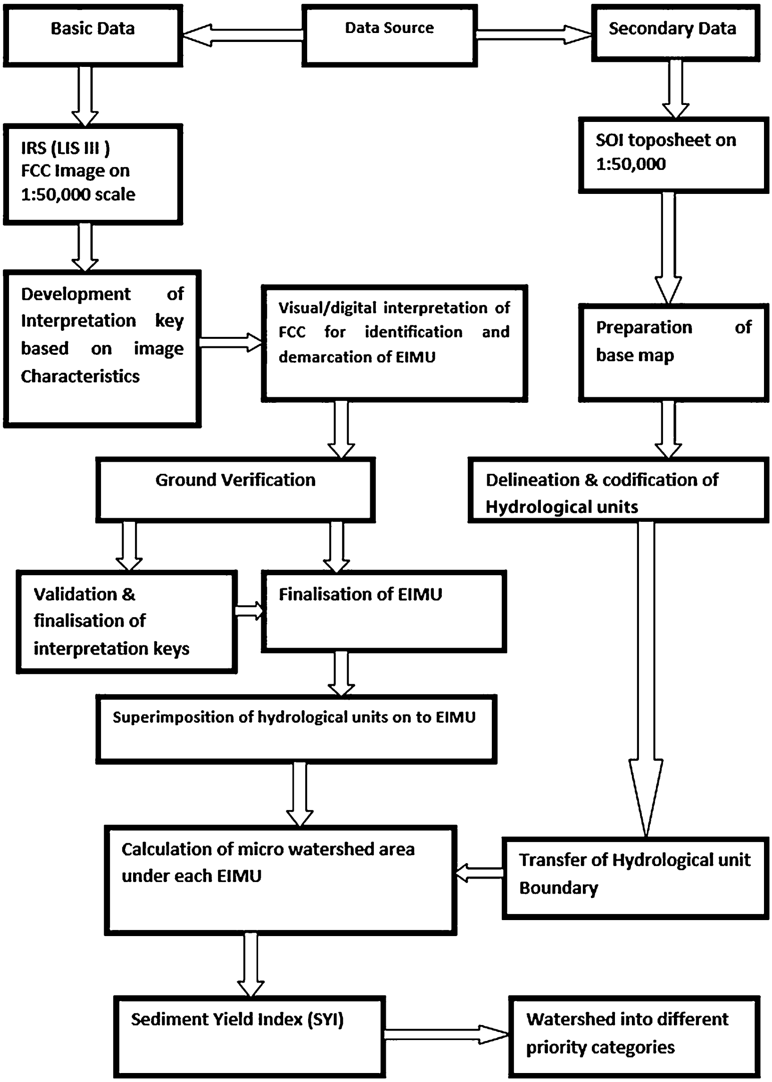
less vegetation, have very excessive runoff leading to accelerated erosion, where as the northern slopes have comparatively thicker vegetative cover which checks erosion and runoff to a large extent. The Karewas are the remnants of lacustrine deposits, which are highly dissected. The Karewas of the higher reaches have coarser sediments, supporting good forests while Karewas nearer the flood plains have finer sediments. The watershed is mostly under bench terraces but they are susceptible to accelerated erosion during floods.

24.3 Objectives

1. To analyze the present land use/land cover of the Haheom watershed.
2. To calculate the Sediment Yield Index (SYI) for prioritization of microwatersheds for conservation measures.
3. To suggest suitable conservation measures for effective Land Management in the study area.

24.4 Data Base and Methodology

The database employed for this study was Survey of India (SOI) toposheets on 1:50,000 scale and IRS-1D LISS III FCC satellite data of July, 2008 complimented by requisite ground truthing for validation of mapping units. The detailed methodology is given in the flow chart.



24.5 Results and Discussion

Land use/land cover analysis of the study area reveals that there are 09 categories out of which dense forests were the major class with 32.43 % area. It was followed by sparse forests with 17.40 % area and Apple orchards with 9.37 % area (Fig. 24.2).

In order to understand the soil erosion conditions of the study area, a soil texture map was prepared, wherein a total of 4 classes were delineated. Out of which Loamy soil was the major class with 69.04 % area. It was followed by Fine silty soil with 14.65 % area, Silty soil with 13.93 % area and Loamy skeletal soil with 2.38 % area (Fig. 24.3).

In the soil erosion map of the study area, 5 soil erosion categories were identified, the major portion of the area was under slight to moderate erosion

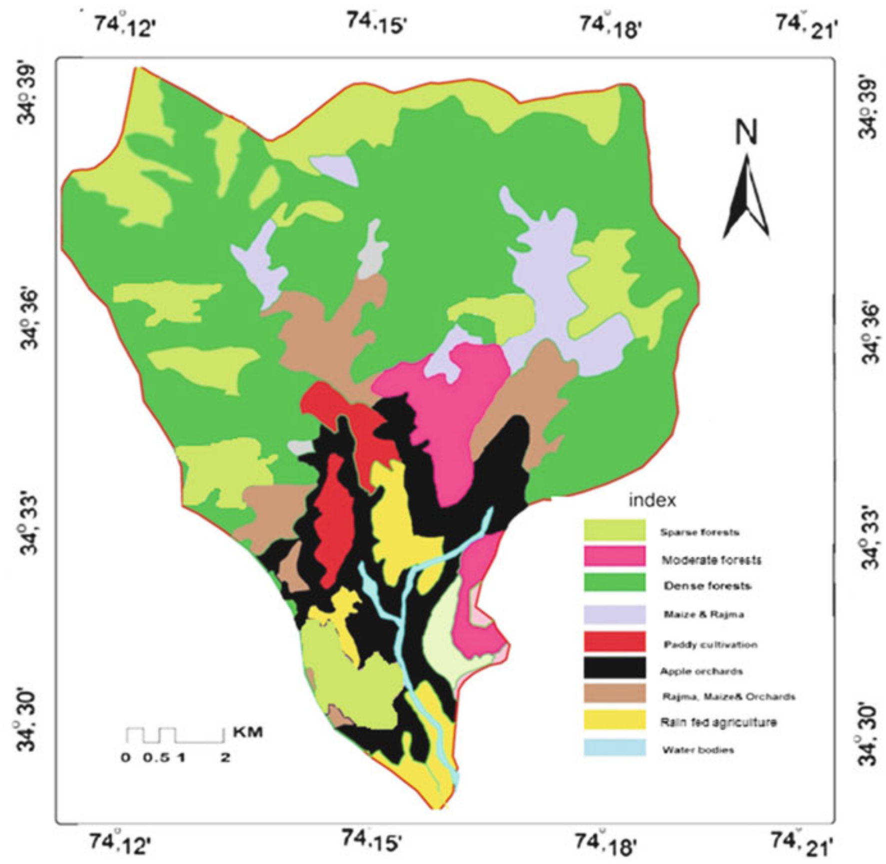


Fig. 24.2 Land use/land cover map of the study area

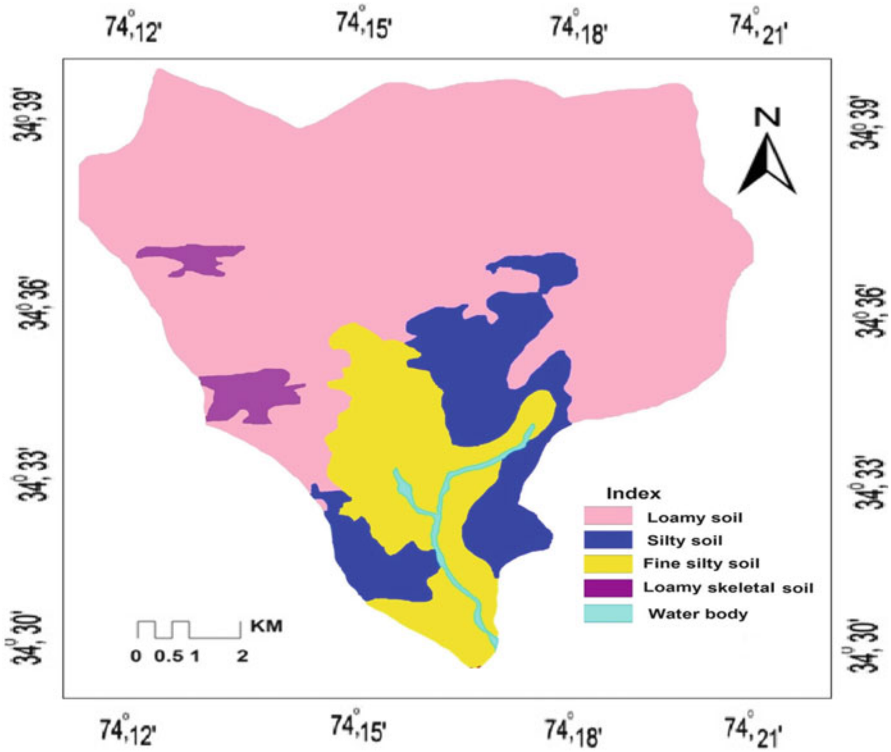


Fig. 24.3 Soil texture map of study area

which accounts to 45.45 % followed by moderate to severe erosion with 23.64 %, severe erosion with 15.59, slight erosion with 11.48 and 2.82 % in the none to slight erosion category (Fig. 24.4).

24.5.1 Prioritization of Microwatersheds

Sediment Yield Index model (SYI) was calculated for each micro watershed of Haheom watershed (Table 24.1). The erosion intensity mapping units (EIMU) were assigned with their respective weight age values and delivery ratios (Table 24.2). These values were calculated by using INGRESS software wherein a customized program has been prepared by AISLUS to calculate the delivery ratios and weight age values in accordance to the input data based on the different characteristics of each mapping unit such as physiography, slope, soil texture, erosion class, management status, soil colour, surface condition, land use/land cover etc.

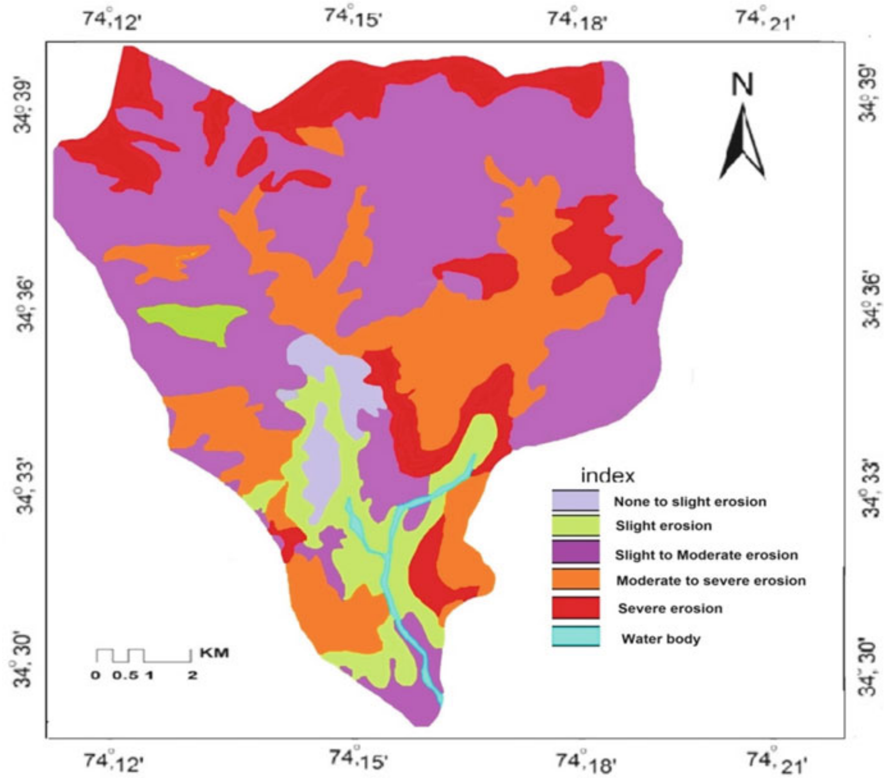


Fig. 24.4 Soil erosion map of the study area

Table 24.1 Sediment Yield Index (SYI) of microwatersheds in the Haheom watershed

S. NO	Hydrologic unit (Micro watershed)	Area in Ha	Weightage product	Relative silt yield index	Sediment yield index	Relative priority
1.	1E1B6j1					
	Total	825	12,533	802,507	972.73	7
2.	1E1B6j2					
	Total	1,055	16,840	1,174,032	1,112.82	6
3	1E1B6j3					
	Total	1,355	21,121	1,860,620	1,373.15	1
4	1E1B6j4					
	Total	1,272	19,878	1,475,266	1,159.80	4
5	1E1B6j5					
	Total	959	13,567	1,101,195	1,148.27	5
6	1E1B6J6					
	Total	1,528	25,093	1,866,395	1,221.46	2
7	1E1B6j7					
		908	14,164	1,058,400	1,165.63	3

Table 24.2 Weight age value and delivery ratios of Erosion Intensity Mapping Units (EIMU) Considered for calculating sediment yield index (SYI) of Haheom micro watersheds

S.no	Erosion intensity mapping unit	Weight-age value	Delivery ratio
1	A1	12	0.56
2	A2	14	0.60
3	A3	15	0.63
4	A4	12	0.57
5	K2	18	0.70
6	K3	15	0.64
7	K5	13	0.60
8	K6	20	0.79
9	K7	19	0.74
10	M1	20	0.85
11	M3	17	0.69
12	M 4	20	0.81
13	M5	14	0.70
14	M 7	17	0.74
15	River		

Table 24.3 Micro watersheds under different priority categories with their SYI

High (1,200 and above)	Medium (1,000 to 1,199)	Low (Below 999)
J3(1,373.15)	J2(1,112.82)	J1(972.73)
J6(1,221.46)	J4(1,159.80)	
	J5(1,148.22)	
	J7(1,165.63)	

The Sediment Yield Index was calculated by using the empirical formula:

$$\mathrm{SYI} = \frac{\sum_{i=1}^{i=n} (\mathrm{Ae1} \times \mathrm{We1} \times \mathrm{De1}) \times 100}{\mathrm{AMW}}$$

where,

SYI is the Sediment Yield Index
Ae1 is the Area (ha) of ith Erosion Intensity Mapping Units
We1 is the Weight age value of the Erosion Intensity Mapping Unit
De1 is the Delivery Ratio of ith Erosion Intensity Mapping Unit
AMW is the Total area of the micro watershed.

The Sediment yield index of seven micro watersheds along with their relative priority is given in the Table 24.1.

Sediment yield index (SYI) reveals the present status of erosion problems in the Haheom sub watershed. Out of the total 7 micro watersheds in the watershed, 2 are placed in the high category and 4 in Medium category and only 1 micro watershed is placed in the low category (Table 24.3 and Fig. 24.6).

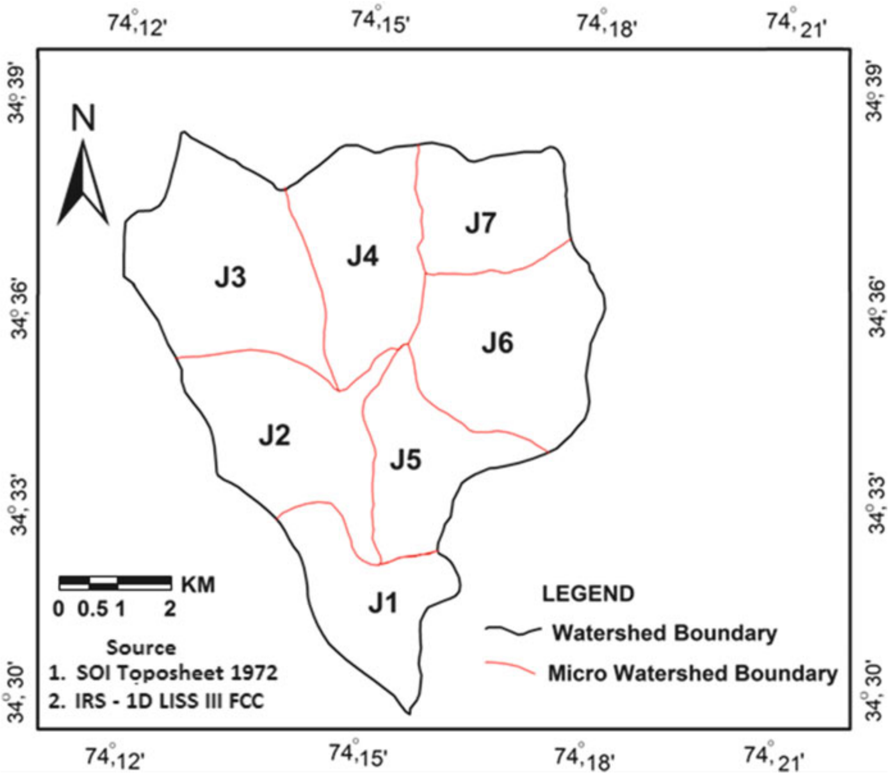


Fig. 24.5 Haheom watershed micro watershed index map

24.6 Recommendations and Suggestions

In order to initiate effective management strategies in the watershed, proper soil and water conservation measures need to be taken in accordance to the magnitude of the problem (Ahmed 2013). In the micro watersheds, where the Sediment yield was high, combinations of engineering and biological measures were recommended.

Forests in the Haheom watershed include sparse, moderate, and dense classes. These are being continuously depleted and as a result are facing tremendous stress and need immediate conservation measures. The first priority should be to preserve the existing forest cover by reducing/removing the biotic and other pressures. Forest lands with severe erosion need both Biological and Engineering measures. In Biological measures, the following operations should be involved i.e. Afforestation, Direct sowing, Patch sowing, Dibbling, Vegetative Gully plugging, Vegetative Hedges, Nursery cutting, etc. In addition to Biological measures, some Engineering measures should also be taken up for effective control of the soil erosion. These include construction of check dams, which include Dry Rubble Stone Masonary (DRSM) and Gunny bag check dams, laying of crates, contour

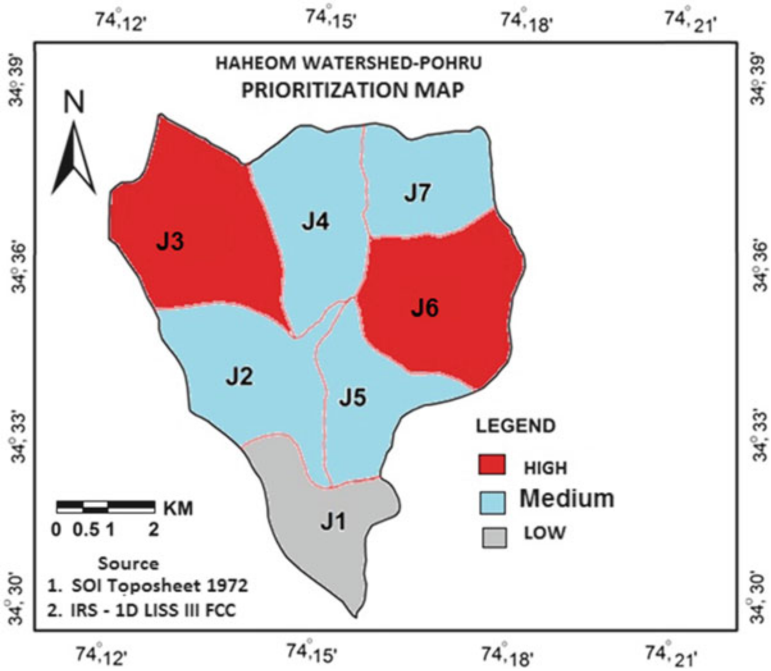


Fig. 24.6 Microwatershed prioritization map

bunding construction of Diversion dams, laying of crates, construction of diversion drains and channels, Gully Plugging, Contour trenching, Desilting and dredging of Nallah beds, construction of bypass channels and settling basins.

Forest areas with moderate erosion problems primarily associated with sheet and rill erosion with occasional shallow gullies also need due attention. The conservation measures to be adopted in forest areas under this category call for treatment under forestry and soil conservation sector.

In soil conservation sector, the problem is to be dealt by adopting both Biological as well as Engineering methods. In Biological measures, there is immediate need of Afforestration, Path sowing, Dibbling, Vegetative Hedges, and Vegetative Spurs. Besides Biological measures, Engineering measures should also be used for tackling the problem. These should consist of Dry Rubble Stone Masonary Works, (DRSM), check dams, contour bunding, construction of diversion measures, gully plugging, bench terracing, contour trenching, and construction of settling basins.

Those forest areas, with slight erosion in the study area also needs several measures of conservation in order to mitigate the problems and arrest it from further degradation. In the Haheom watershed, these areas are very rich areas having good density of forests with fair growing stock. The strategy for managing these forests should be to preserve the growing stock, increase the productivity, and expand the forest cover by reducing the demand on forests. Besides these things there is need of proper management practices as envisaged in the working plans should be used for supplementing and promoting the natural regeneration of the forest.

Besides forest areas several agricultural practices are also practisized in the study area which accounts for nearly 9.37 % area. These areas also need to be brought under scientific management. These lands should be managed to maximize the in-situ moisture conservation. In these areas, engineering measures which include DRSM works, Crate wire dams, construction of bypass channels and setting basins are recommended.

More than 5 % area of the study area is under horticulture land use. These areas are also facing erosion problems and conservation measures like the construction of Dry Rubble Stone Masonary (DRSM), Crate wire dams, gully plugging, stream bank erosion control, setting basins, diversion channels, landslips and landslide control could be taken.

24.7 Conclusion

The Haheom watershed of the Pohru catchment comprises of seven micro watersheds. The perusal of the Table 24.1 reveals that all the seven micro watersheds are facing soil erosion problems, although the intensity and magnitude of the problem is not same through the length and breadth of the watershed. The two micro watersheds i.e. j3 and j6 fall in the high category, where the slope is very steep of southern aspects with moderate forests, and are poorly managed. The four micro-watersheds j2, j4, j5, and j7 fall in the medium priority category. The slope is very steep; the forests are in medium to dense category with slight to moderate erosion conditions. In the low priority category, only one micro watershed j1 is included. The slope here is gently sloping flood plains with slight erosion. The prioritization of micro watersheds for soil and water conservation measures would prove to be a very fruitful exercise to initiate remedial measures in accordance to the intensity and magnitude of the problem. The micro-watersheds in the high category need immediate conservation measures and these would include both engineering and biological measures. The biological measures include Afforestation, Direct sowing, patch sowing, Dibbling, vegetative Gully plugging, vegetative hedges, Nursery cutting, and so on. In the engineering measures, Gunny bag check dams, crates, stream bank protection, and landslip/slide control could be used in accordance to the intensity of problem.

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