

Assessment of natural resource degradation in cities of Uttarakhand: A geospatial approach

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Ankita Dabas (PRN: 14070241005)

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Under the guidance of

External supervisor: Dr. G. Areendran, Director

Remote Sensing & GIS, IGCMC, WWF- India

Internal supervisor: Dr. Navendu Chaudhary, Associate Professor

Symbiosis Institute of Geoinformatics, Pune

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Preface

Since man has starting evolving, nature has been experiencing. The changes were in balance. But in the twenty-first century it is not so. There has been huge changes in the status of natural resources. Today man has become a determinist and is clearing up forests and other natural resources for its own greed. The state of Uttarakhand has experienced significant changes from year 2000 to 2015. In these fifteen there has been drastic change in the status of natural resources. The natural resources emphasized in this research work is forests. Mainly, forest resource degradation throughout whole of Uttarakhand has been studied about. Also, due to urbanization the cities are expanding immensely and therefore the one lakh cities of Uttarakhand have been focused to study the urban sprawl and the expanding cities. Through this work I tried to explain how the Landcover changes through time and how anthropogenic factors like urbanization effect the natural resources. How the forests are being converted into agricultural land to bear the pressure of growing population and how the agricultural land has been cleared off further and converted to urban area.

Through this paper I have tried to study the status of forests through remote sensing and GIS techniques. The vast development in terms of infrastructure in India has made me to think to do such work. I have always been very keen about knowing how human actions affect our environment. Also, the time period spent in doing the dissertation has been such a great experience. I got to talk to experts related to this field. I also got exposure as how other countries are studying and developing tools to study phenomena such a forest/landscape fragmentation. Another important matter which was looked upon in this paper is urban sprawl. To study urban sprawl in Uttarakhand it would have been really unrealistic and challenging. Therefore, population figures were considered and thus decision was made as to which cities would be chosen to study urban sprawl in Uttarakhand state.

Uttarakhand is a state that has a very rich natural resource base also significantly rick flora and fauna. There are many tourist spots in Uttarakhand. Due to which there has been some environmental impact which is affecting the natural ecosystem of this state. There are towns like Dehradun which have become tourist hubs and therefore forests and agricultural land around it has been severely impacted.

I wanted to study to what extent can natural resources (forests) change in the time period of 15 years? Therefore, a temporal study has been done. This report not only discusses the change in forest resources and landuse/cover pattern qualitatively but also quantitatively as each analysis done has some facts and figures attached to it.

Chapter-1 Introduction

Introduction

Remote Sensing and GIS tools are quite useful in the fields of forestry, hydrology, land use analyses, etc. Remote sensing technology has ability to do spatial-temporal and spectral analysis of the information. Remote sensing technology is used to measure spatial, spectral, and temporal information and provide data on the state of the earth's surface. It provides observation of changes in natural resources, which vary over both time and space that can be used to monitor forest cover conditions and changes. GIS and remote sensing tools help professionals to integrate the spatial science with forestry, agriculture, inventory studies and various other fields and do interdisciplinary studies. Remote sensing is applied to study the status of natural resources in various aspects like degradation over time, damage caused due to several natural and anthropogenic factors, spatial-temporal changes in the inventory of natural resources, effect of changes in natural resources over biodiversity etc.

Since the age of industrialisation there has been constant forest resource degradation. The rate is increasing at an alarming rate. Every year thousands of acres of virgin forests are being cut and being converted into secondary forest. This is leading to increased level of pollutants in the atmosphere as well as water resources. These pollutants have even entered the food chain due to which human beings are paying a great price. Deforestation impacts each and every organism that exists on earth in some way or the other. It is leading to vast extinction of species of both flora and fauna, hundreds of species are under serious threat. This is affecting the vast genetic diversity and the gene pool.

Chapter 2 of this report contains a summary of the literature reviewed. Numerous researchers have previously studied landscape/habitat fragmentation across the globe.

Chapter 3 contains description of the Study area that is Uttarakhand.

Chapter 4 briefs the extensive methodology used in this study.

Chapter 5 contains discussion and analysis of the results.

Chapter 6 contains the conclusion of this report.

The last sections include References.

Objective

The main Objectives of the present research work are:

- i) Classification of forest and non-forest classes using Erdas imagine.
- ii) Preparation and analysis of input datasets for forest fragmentation.
- iii) Monitoring of the forest resource degradation based on anthropogenic factors
- iv) Forest Fragmentation for the year 2000 and 2015 using Landscape Fragmentation Tool in ArcMap.
- v) Urban sprawl mapping (of Cities having population 1 lakh and above)

Chapter 2 Literature review

The basic inputs required for the assessment forest resource degradation for any given region is a classified image of the study area in forest and non-forest classes. Increasing human population has caused resource exploitation at an increased rate and alteration of land cover pattern. Anthropogenic pressure on natural resources leads to illicit cutting of forest trees leading to deforestation which is occurring at an alarming rate (Whitmore 1997)

Extensive literature has been reviewed for this research work. Numerous research work carried out by researchers around the world have been referred such as:

- Assessment of Forest Fragmentation in Southern New England Using Remote Sensing and Geographic Information Systems Technology by JAMES E. VOGELMANN (1995) , University of New Hampshire, U.S.A.
- The Effect of Landscape Fragmentation and Forest Continuity on Forest Floor Species in Two Regions of Denmark by B. J. Graae (Graae 2000).
- Dynamics of land use/cover changes and the analysis of landscape fragmentation in Dhaka Metropolitan, Bangladesh by Ashraf M. Dewan, Yasushi Yamaguchi and Md. Ziaur Rahman (2012) (Ashraf M. Dewan 2012).
- Effects of Habitat Fragmentation on Biodiversity by Lenore Fahrig (2003), Carleton University, Canada (Fahrig 2003).
- Landscape fragmentation assessments using a single measure by Jan Bogaert (Jan Bogaert (Winter, 2000))
- Road Development, Housing Growth, and Landscape Fragmentation in Northern Wisconsin:1937-1999 by Todd J. Hawbaker (Todd J. Hawbaker June, 2006)
- Tropical forest disturbance, disappearance, and species loss by Whitmore (Whitmore 1997).
- Fragmentation of Continental United States Forests by Kurt (Kurt H. Riitters 2002).
- Monitoring land use/cover change using remote sensing and GIS techniques: A case study of Hawalbagh block, district Almora, Uttarakhand, India (J.S. Rawat 2015)
- Monitoring urban growth and land use change detection with GIS and remote sensing techniques in Daqahlia governorate Egypt (Ibrahim Rizk Hegazy 2015)

- Degradation of Natural Resources and its Impact on Environment: a Study in Guwahati City, Assam by Lakhimi Gogoi (Gogoi December 2013).
- Urban Sprawl Impact Assessment on the Fertile Agricultural Land of Egypt Using Remote Sensing and Digital Soil Database, Case study: Qalubiyah Governorate (Shalaby n.d.)
- Habitat Fragmentation, Landscape Context, and Mammalian Assemblages in Southeastern Australia by Lindenmayer (David B. Lindenmayer 2000).
- Effects of Dispersal, Population Delays, and Forest Fragmentation on Tree Migration Rates by Malanson (Cairns 1997).
- Independent Effects of Fragmentation on Forest Songbirds: An Organism-Based Approach by Betts (Matthew G. Betts 2006).

Degradation of natural resources and Environmental pollutions are most concerning subject in present day context among the social scientist as well as the environmentalist. Degradation of natural resources can also mean a loss of biodiversity and a loss of environment in an area. The greater demands placed on the environment by an ever increasing human population is putting a great strain and drain on the earth's limited natural resources (Gogoi December 2013). Deforestation and forest fragmentation are clearly causing a loss of species from tropical forests (Saunders 1991).

Forest fragmentation is the process in which large continuous forest patches are divided into small isolated patches which leads to habitat loss. Thousands of scientific studies have shown unequivocal evidence for the impacts of patch area, edge effects, patch shape complexity, isolation and landscape matrix contrast on community structure and ecosystem functioning. However, striking disparities showcased in the results of these studies have raised considerable debate about the relative importance of different mechanisms underlying fragmentation effects, and even about the utility of the 'fragmentation' concept in general. These debates can be resolved by clear discrimination of direct v/s indirect causal relationship among patch and landscape variable. The most important recent advances in our understanding of fragmentation effects all stem from recognition of strong context-dependence in ecosystem responses, including spatial context-dependence at multiple scales, time-lagged population declines, trait-dependent species responses and synergistic

interactions between fragmentation and other components of global environmental change (Didham 2010).

There has been a growing interest in analyzing and monitoring forest fragmentation. There are few studies in India which deal with quantified fragmentation and its impact on species diversity in northeast India (P. a. Roy 2000), Vindhya (Jha, et al. 2005) and eastern Himalayas (Behera 2010).

Roy and Joshi have done a general study on the fragmentation of the natural landscape of Himalayas and biodiversity conservation. They have studied the landscape approach with the aim of characterizing the complexity of landscape boundaries by remote sensing in the North East India. Landscape analysis has showed that the indices of shape, richness and diversity provides an additional evaluation of land cover spatial distribution within the complex mountain landscape. This analysis has also provided an outline of the degree of propagation of the disturbance from the non-biotic sources and fragmentation. It is revealed that fragmentation has caused loss of connectivity, ecotones, corridors and the meta population structure (P. a. Roy 2001).

Armenteras et al (2003) have studied the Andean forest fragmentation & the representativeness of protected natural areas in the eastern Andes, Colombia. He has carried out Ecosystem mapping by visual interpretation of false color digital satellite imagery (12 Landsat TM scenes) for the following years: 1989, 1991, 1992, 1994 and 1996. ERDAS Imagine, Arcview and FRAGSTATS software have been used to the study. Several Fragmentation parameters like patch size, patch shape, number of patches, mean nearest neighbor distance and landscape shape index were analyzed. It was observed that Andean, sub Andean and dry forests are highly fragmented ecosystems but there is a clear latitudinal gradient of fragmentation (D and H n.d.).

The tool used for this research work "Landscape Fragmentation Tool" belongs to CLEAR (Center for Land Use Education and Research) University of Connecticut.

Forest fragmentation can mean different to different people. For some it may be a regional phenomenon whereas for some it may be understood as global phenomena.

The Society of American Foresters defines forest fragmentation as "The process of dividing large tracts of contiguous forest into smaller isolated tracts surrounded by human modified

environments”. Which means removal of tree cover and replacing it with non-forested land cover.

It should be noted that the concept of forest fragmentation is different from *parcelization* which means “changes in ownership patterns whereby large forested tracts are divided into smaller parcels” (Yale Forest Forum n.d.). Though *parcelization* does not always result in fragmentation, but it increases the likelihood that the forest will become fragmented (i.e. the construction of roads and structures).

Figure 1: Images showing intact forest, parcelization and fragmentation



Not parceled and not fragmented Parceled but not fragmented Parceled and fragmented

Based on the input land cover map, the forest fragmentation model categorizes the forest pixels into one of four types: core forest, perforated forest, edge forest and patch forest. Forested areas were classified into 4 main categories of increasing disturbance—core, perforated, edge and patch—based on a key metric called edge width (CLEAR 2006).



Figure 2: Core Forest

Core forest - Forest pixels that are far from the forest/non-forest boundary. These are forested areas surrounded by more forested pixels.

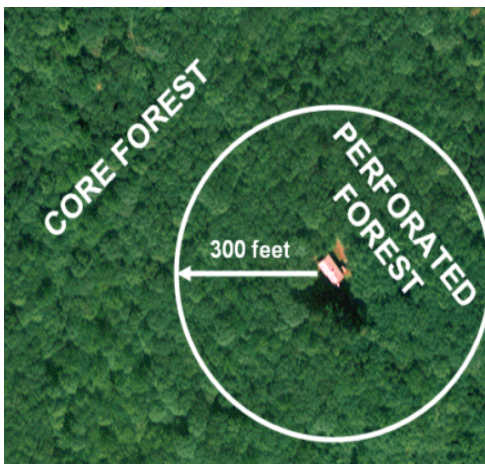


Figure 3: Perforated Forest

Perforated Forest - Forest pixels that define the boundary between core forest and relatively small clearings (perforations) within the forested landscape.

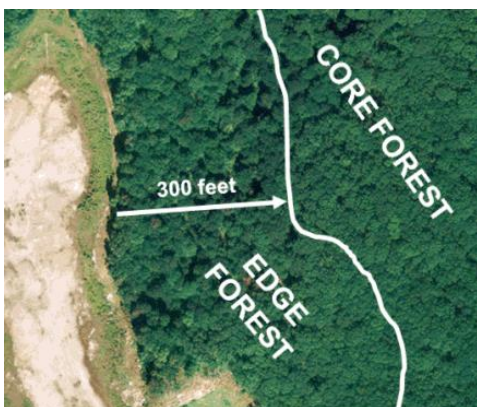


Figure 4: Edge Forest

Edge Forest - Forest pixels that define the boundary between core forest and large non-forested land cover features.



Figure 5: Patch Forest

Patch Forest – Forest pixels that comprise a small forested area surrounded by non-forested land cover.

The landscape fragmentation tool gives a raster output with the image divided into 6 forest categories, in which core forests are further divided into 3 types:

- Large Core Forest
- Medium Core Forest
- Small Core Forest

The literature suggests that total forest cover within a landscape has a greater role in maintaining biodiversity than forest patch size (Lee M 2002). However, the importance of forest patch size is still clearly significant for certain species (Lee M 2002) (Mortberg 2001). The Environment Canada report (2004) suggests that 250 acres should be considered the *absolute minimum* forest patch size needed to support area-sensitive edge-intolerant species. The *recommended minimum* forest patch size is 500 acres, as this is likely to provide enough suitable habitat to support more diversity of interior forest species. These two guidelines are reflected in the medium and large core categories in this study. The smallest core size in this study is smaller than these habitat-based guidelines, based on the fact that these smaller areas are still valuable from forestry and other perspectives. As the literature suggests these standards for forest patch size according to Canadian standards, these would differ from region to region as different countries have a distinct spatial pattern of forests. Thus, the

spatial parameters are taken as the default values as defined in the landscape fragmentation tool guidelines.

Table 1: Showing categories of core forest

Class	Description
Core Forest in general	Forest pixels that are relatively far from the forest-nonforest boundary. Essentially these are forested areas surrounded by more forested areas.
Small Core Forest	Core forest patches that are less than 250 acres.
Medium Core Forest	Core forest patches that are between 250-500 acres.
Large Core Forest	Core forest patches that are greater than 500 acres.

Landscape fragmentation caused by transportation infrastructure and built-up areas has a number of ecological effects (Agency 2011). Urbanization is an inevitable process due to progress and development however the encroachments of urban settlements on expense of agricultural lands may pose dire consequences (Shalaby n.d.).

According to Census of India 2011, Uttarakhand consists of 6 cities having population more than one lakh. Those cities in Uttarakhand are namely as show in the table below.

Table 2: Table showing cities of Uttarakhand having population more than one lakh

S.no	Cities	Population(in persons)
1	Dehradun (M Corp.)	578,420
2	Haldwani-cum-Kathgodam (NPP)	156,060
3	Kashipur (NPP)	121,610
4	Rudrapur (NPP)	140,884
5	Roorkee (NPP)	118,188
6	Haridwar (NPP)	225,235

(Census of India 2011)

According to the Census of India, 2011 there are 6 cities in Uttarakhand having population of one lakh and more Dehradun city had population of 578,420, Haldwani-cum-Kathgodam had 156,060 persons, Kashipur had 121,610 persons, Rudrapur had 140,884 persons, Roorkee had 118,188 persons and Haridwar having 225,235 persons respectively.

Chapter 3 Study area

Geography

For the present study Uttarakhand has been chosen as a study area. Uttarakhand was formerly known as Uttaranchal. it extends from Latitude 28°43' N to 31°27' N and Longitude 77°34' E to 81°02' E. . it is a north Indian state. It is a land of temples and therefore also known as Devbhumi as many Hindu temples and pilgrimage centres are found throughout the state. Uttarakhand is very well known for its scenic beauty of the Himalayas, the Bhabar and the Terai region. On 9 November 2000, this 27th state of the Republic of India was created from the Himalayan and adjoining northwestern districts of Uttar Pradesh. It borders Tibet in the north; the Mahakali Zone of Nepal on the east; and the Indian states of UP to the south and Himachal Pradesh to the west as well as Northwest and Haryana in the south western corner (Wikipedia n.d.)

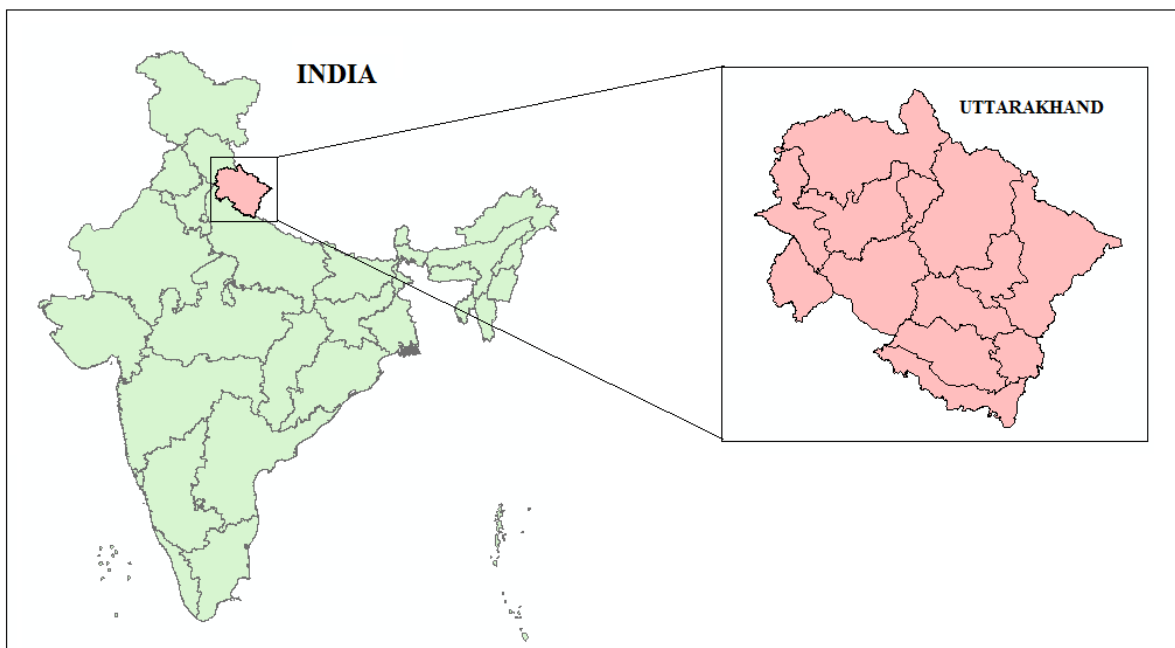


Plate 1: Study area

The state is divided into two divisions: Garhwal and Kumaon, which is divided into 13 districts as shown in the administrative map of Uttarakhand.

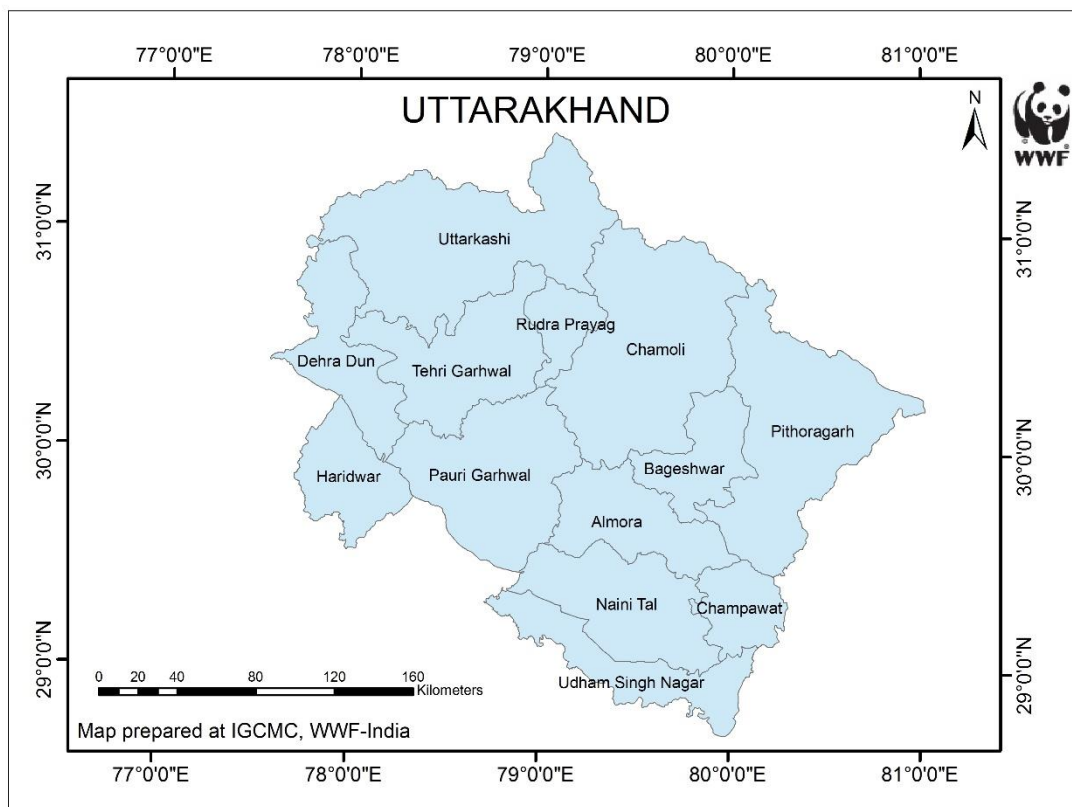


Plate 2: Administrative map of Uttarakhand

Drainage

The state of Uttarakhand is drained by various tributaries of Ganga river system. Yamuna river and its major tributaries form the westernmost watershed. East of this basin is drained by the Alaknanda and the Bhagirathi, which further joins to form the Ganga river at the town of Devprayag and Mandakini, Pindar and Dhauliganga. East of which are Ramganga and Kosi river which flows southward and both of which join Kali at Uttarakhand’s eastern border with Nepal.

Soil type

The state of Uttarakhand has various varieties of soil which are susceptible to soil erosion. In the north the soil varies from Gravel to stiff clay. In the south brown forest soil is found, which is shallow, gravelly and rich in organic content. The Bhabar contains soils that are coarse textured, sandy to gravelly, which are highly porous and are largely infertile. The Terai region which is the extreme southeastern part of the state has soils which are most rich, clayey loam mixed to varying degrees with fine sand and organic matter. These soils are quite suitable to the cultivation of rice and sugarcane.

Climatic conditions

Summer

Plain regions of Uttarakhand have similar climate as other surrounding plain regions of different states. The maximum temperature can cross 40°C and can be considerable humid. Warm temperate conditions are present in the middle Himalayan valleys with temperature around 25°C. Whereas in the higher areas of middle Himalayas the temperature is around 15°C to 18°C. This season extends from April to June.

Winter

The climate of Uttarakhand during winters can be really chilly with times when temperature can go below 5°C. The winters in middle Himalayan valleys are very cold and in the higher areas the temperature may fall below the freezing point. The Himalayan peaks remain snow covered throughout the year and many places receive regular snowfall. Throughout the state the temperature remains sub-zero to 15°C. This season lasts from November to February.

Monsoon

Monsoon season differs from 15°C to 25°C at most places which lasts from July to September. The state receives 90% of its annual rainfall in this season.

National parks and Sanctuaries

The state has 12 national parks and wildlife sanctuaries. Some of them are: Corbett national park, rajaji national park, nanda devi national park, gangotri national park etc. they cover about 13.8% of the total area of the state.

Cities having population more than 1 lakh are Dehradun, Haldwani, Haridwar, Kashipur, Roorkee and Rudrapur (as shown in Plate 3: One lakh cities in Uttarakhand).

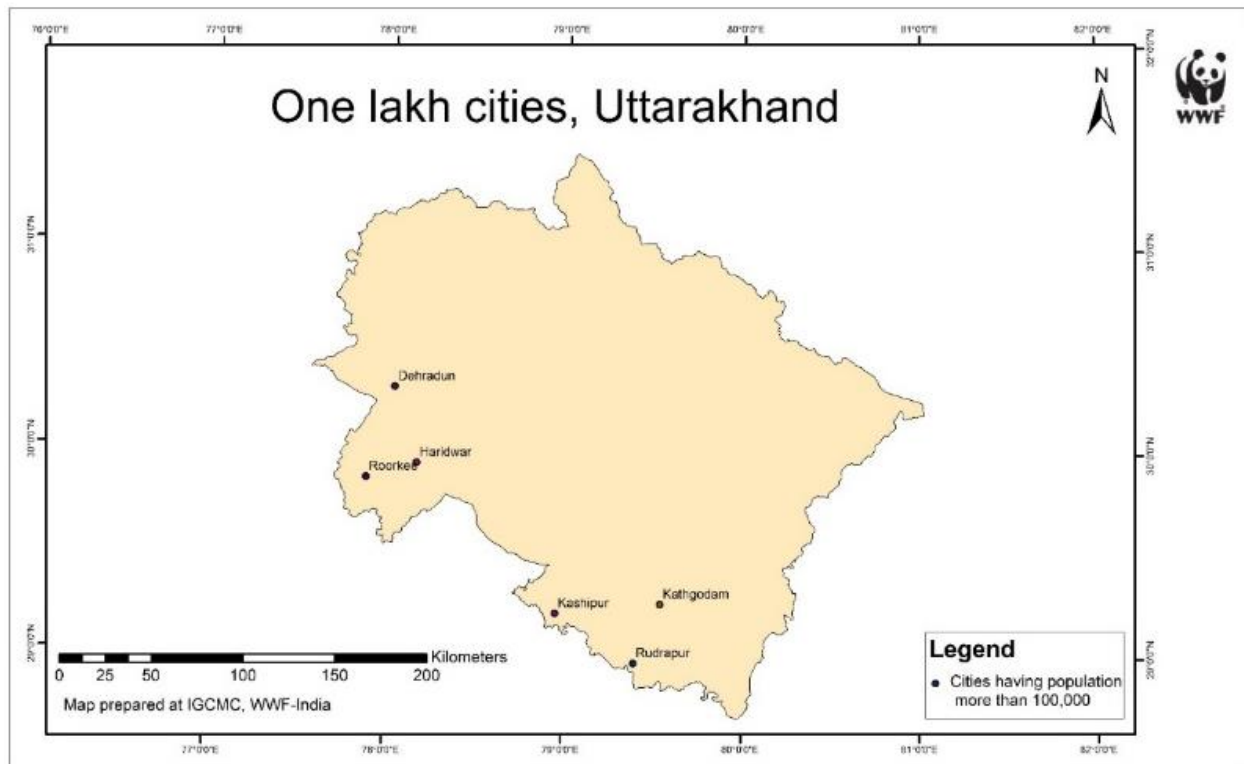


Plate 3: One lakh cities in Uttarakhand

Chapter 4 Methodology

The methodology is divided into 3 parts:

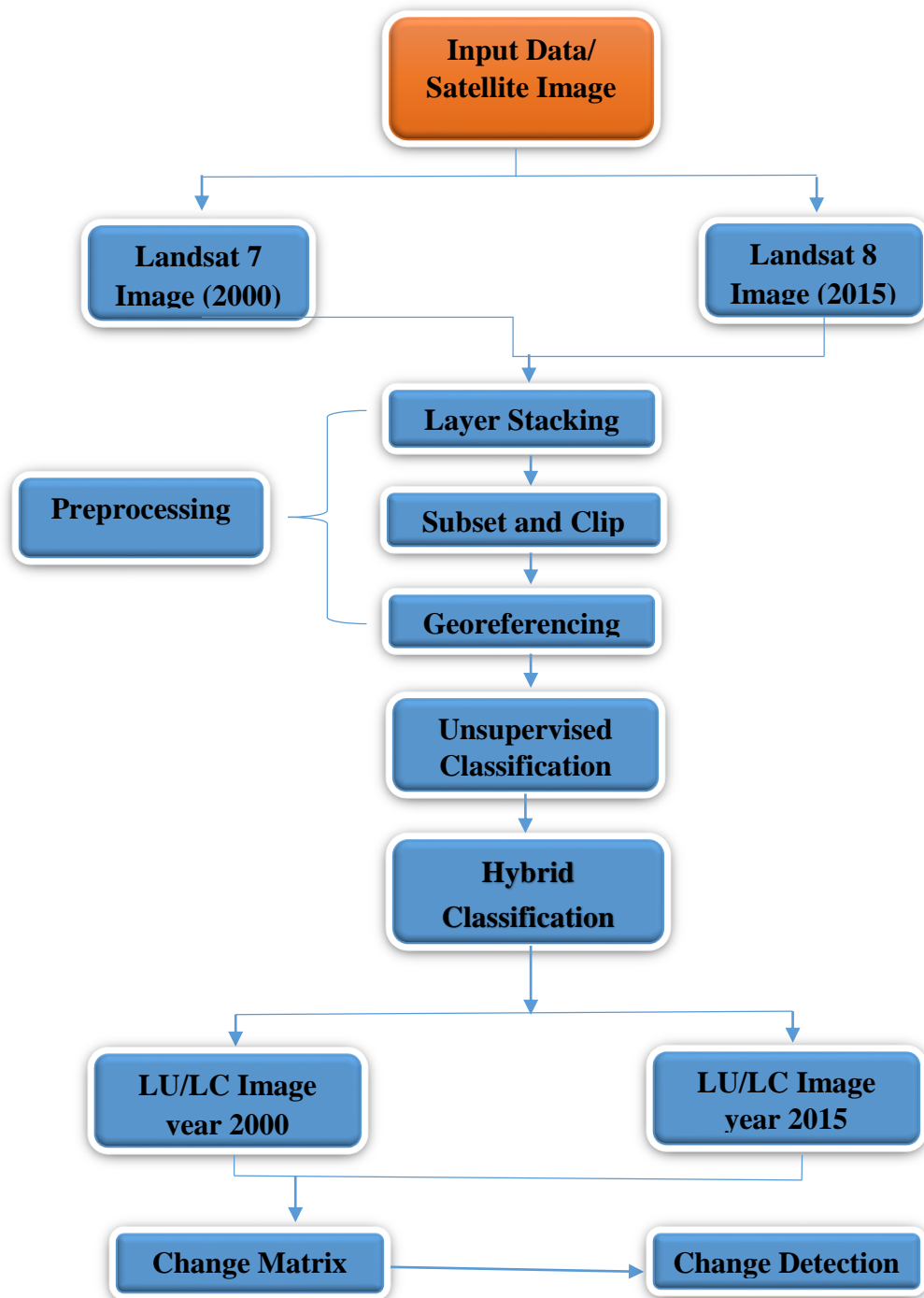


Figure 6: Methodology part-a

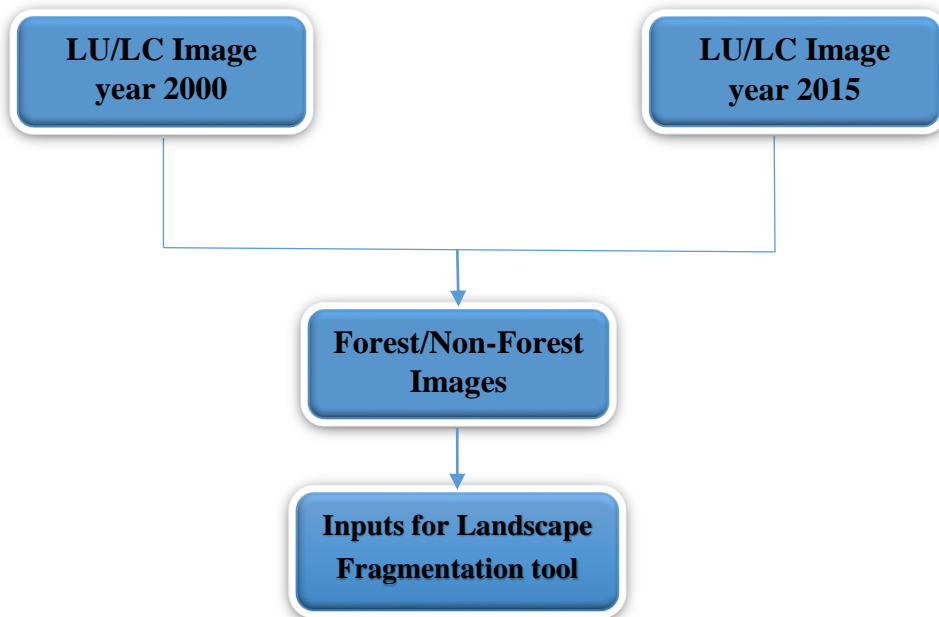


Figure 7: Methodology part-b

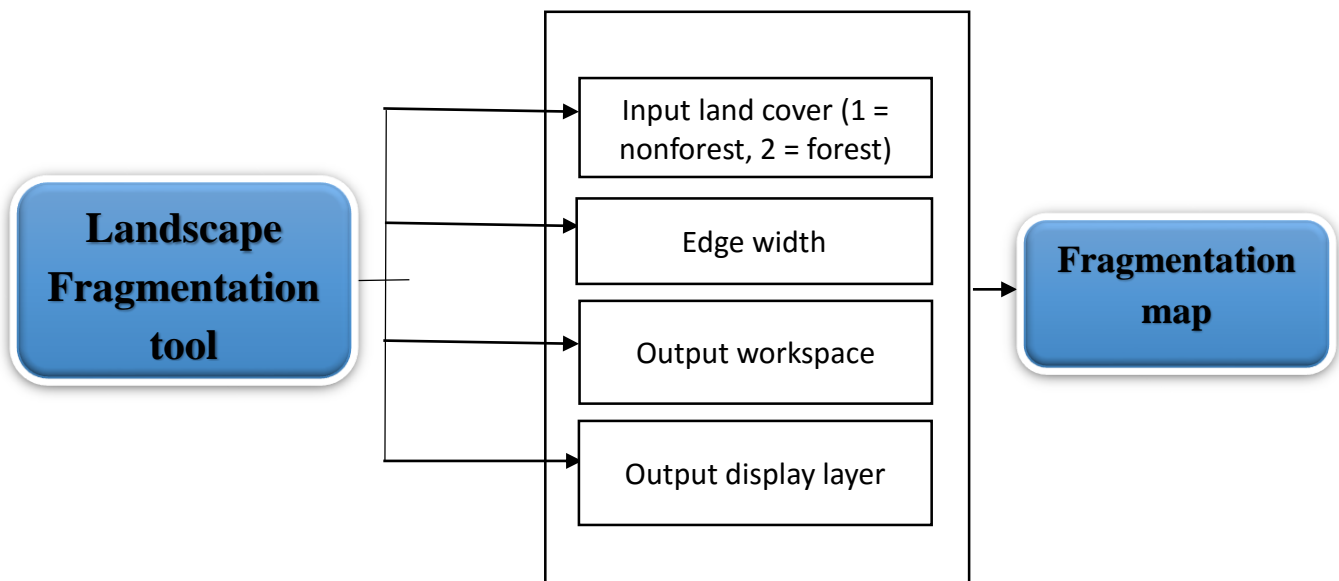


Figure 8: Methodology part-c

Material and methods used

- Landsat 8 imagery
- ERDAS IMAGINE 2011
- ArcMap 10.1

Method

Literature and several research papers on applications of remote sensing and GIS were carefully reviewed before selecting the topic. After several discussions with external supervisor, the topic was selected. As the study is a spatio-temporal Landsat 8 and 7 data. had to downloaded. Landsat 8 for the year 2015 and Landsat 7 for the year 2000. In total 6 tiles were required to cover whole of Uttarakhand. The images for whole of Uttarakhand were classified for both year 2000 and 2015 respectively.

- Firstly the year 2000 was taken up.
 - For the acquired tiles, the bands (1, 2, 3, and 4) were stacked together for each tile.
 - Then all the multi-spectral tiles were mosaicked using the mosaic tool in ERDAS.
 - Several colour correction techniques like Colour Balancing, Histogram Matching were performed on while mosaicking to correct any colour differences in the mosaicked image.
 - Overlap function was set to feathering to get seamless image as seamlines were quite visible in the mosaicked image.
 - Then shapefile for Uttarakhand was acquired.
 - The mosaicked image was then clipped as per the shapefile of Uttarakhand.
- Then the year 2015 was taken up and the same steps as above were performed for 2015 tiles to get a mosaicked, color corrected and clipped Uttarakhand image for the year 2015.
- After obtaining mosaicked, color corrected and clipped Uttarakhand image for both years 2000, 2015 respectively.
- Unsupervised classification with 85 classes and 25 iterations were performed.
- The resulted 85 classes were further narrowed down to 9 classes namely:

- Dense Forest
 - Open forest
 - Scrub forest
 - Agriculture
 - Wasteland
 - Water
 - Urban
 - Snow
 - River-bed
- Then images were further classified using Hybrid Classification.
 - Pixels of features like water bodies and snow were mixing together and hence hybrid classification was performed to differentiate the two feature classes, which was also used to clean the classified image.
 - As numerous pixels of settlements were mixing together with pixels of fallow agricultural land therefore, it posed a serious challenge to identify settlements/built-up area in the classified image.
 - After some research, statistical filtering was considered to be used.
 - Firstly, a subset of the image was created (where settlements could be identified using satellite imagery). Unsupervised classification with 30 classes in 15 iterations were performed. These classes were further narrowed down to only two class namely:
 - Urban
 - Unclassified
 - Statistical filtering was used (using median and minimum function with window size 3x3) to eliminate settlement pixels which were not actually settlements.
 - This class was then mosaicked with the classified image of Uttarakhand.

All the steps mentioned above have been performed on both the images i.e. 2000 & 2015 respectively.

- Images were further cleaned
- Some parts of both the images have been reclassified, as settlements were not classified properly
- Image was reclassified class-wise to further check any chances of inaccuracies.

- Literature and figures were reviewed on million cities of Uttarakhand

Landsat 8 imageries were acquired for the study area. Then various bands of each image were stacked together to make multispectral imagery. Then all the tiles were mosaicked together. Shapefile of Uttarakhand was acquired and then the mosaicked image was clipped according to that. Then the output image was classified. Unsupervised classification was performed with 85 classes and 25 iterations. After the image was classified using unsupervised classification then forest classes (Dense, Open, Scrub forests) were considered and pure pixel classification was performed for Urban, River, Agriculture, Wasteland, Snow and riverbed class. Unsupervised classification was run for each of these and then all the pixels belonging to pure pixel of one class was recoded as '1' and the rest were recoded as '0'.

- Forest fragmentation analysis was performed using landscape fragmentation tool in ArcMap 10.1.
 - Edge width was set to 300m.
- Literature has also been reviewed about work previously been done in Uttarakhand about forest fragmentation and natural resource degradation.
- Million Cities are also being studied for urban-sprawl analysis.
- Urban sprawls analysis was done for cities of Uttarakhand having population more than 1 lakh.
- Urban sprawl maps were prepared for the following cities:

Table 3: Table showing cities with population more than one lakh

S.no	Cities	Population(in persons)
1	Dehradun (M Corp.)	578,420
2	Haldwani-cum-Kathgodam (NPP)	156,060
3	Kashipur (NPP)	121,610
4	Rudrapur (NPP)	140,884
5	Roorkee (NPP)	118,188
6	Haridwar (NPP)	225,235

- Changes were analysis from classified LULC maps.

There has been significant changes in the land cover categories in the time period of 15 years, in some categories one can analyse huge changes have taken place on the contrary there has been very minute increase or decrease in some classes. In total dense forest accounts for 36.82 % in 2000 which has decreased to 26.06% in 2015, there has been 10.76% decrease in dense forest. There has been 4.28% increase in open forest, while only 2.61 % increase in scrub forest category. There has been 5% increase in agricultural land, 2.11% increase in wasteland, a drastic 3.36% decrease in snow-cover also urban area has been increased by 0.46%.

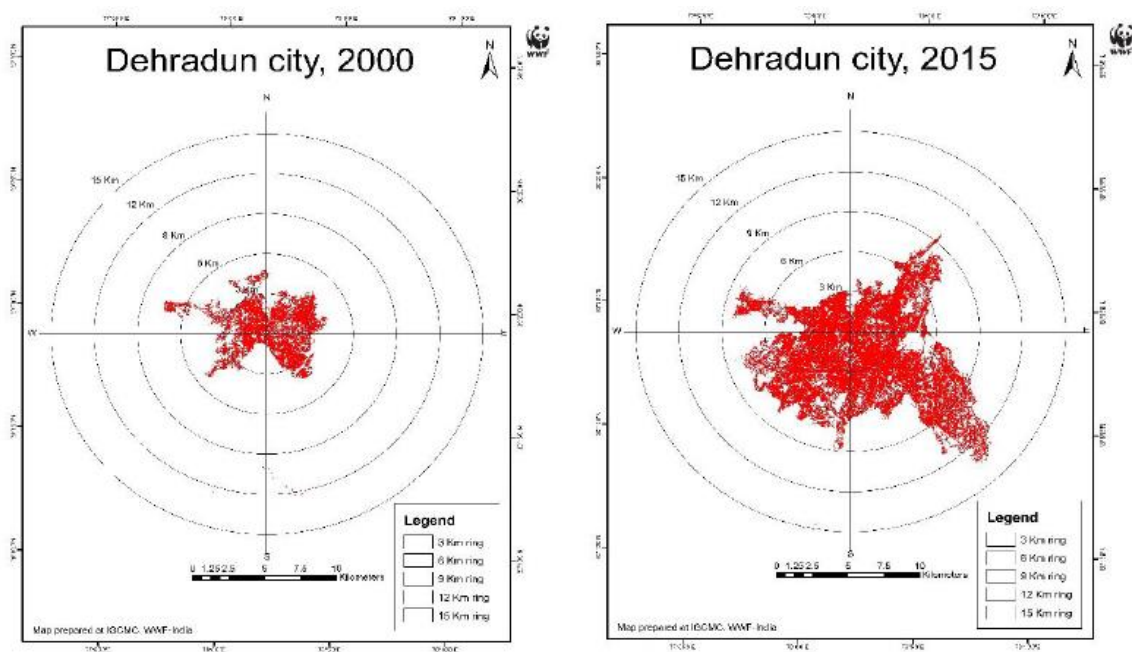


Plate 4: Dehradun city urban sprawl maps

Just like the above maps of Dehradun, maps have been prepared for all the 6 cities.

These maps have been prepared from the classified images. The urban pixels were recoded as '1' and pixels belonging to all the other classes were recoded as '0'. Also, change matrix was prepared to see which pixels have been converted into which categories.

Chapter 5 Result and Discussion

The classified image was divided into Forest and non-Forest classes. The 9 classes are: Dense Forest, Open forest, Scrub forest, Agriculture, Wasteland, Water, Urban, Snow and Riverbed.

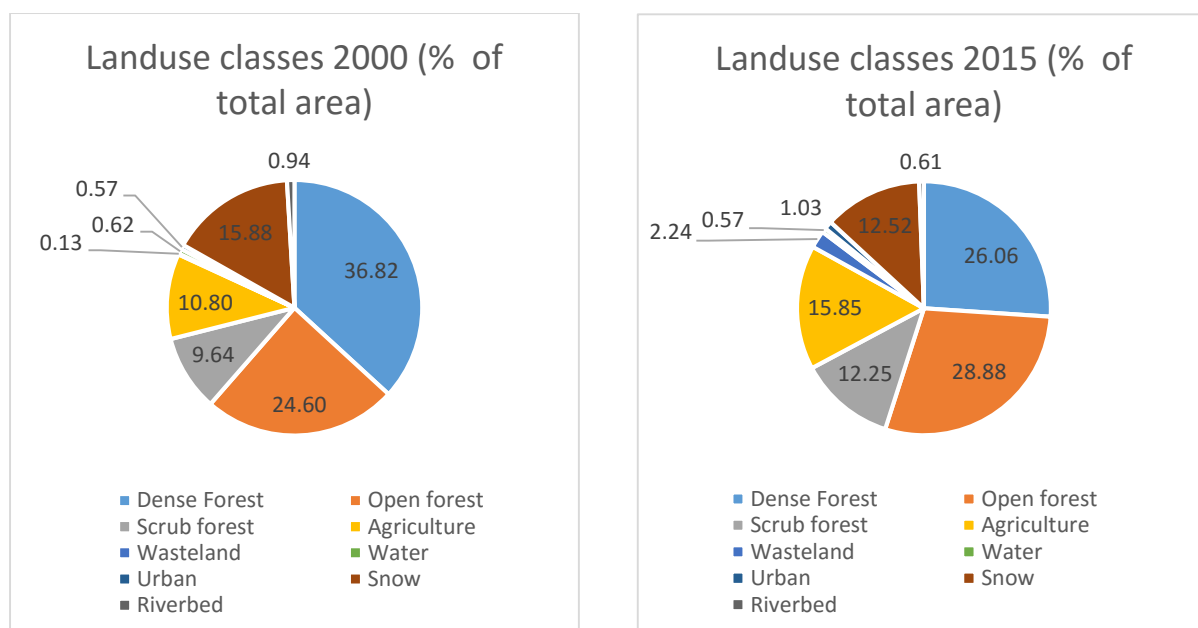


Figure 9: Pie-chart showing proportion of each land use for year 2000 and 2015

Status of LULC in the year 2000

In the year 2000 Dense Forest covers 36.82% of the total area, Open Forest covers 24.6%, Scrub Forest covers 9.64%, Agriculture consists of 10.8% area, 0.13% is wasteland, 0.62% area is rivers and waterbodies, 0.57% of the total area comes under urban area, 15.88% area is snow-covered and 0.94% consists of riverbed.

Status of LULC in the year 2015

In the year 2015 Dense Forest covers 26.06% of the total area, Open Forest covers 28.88%, Scrub Forest covers 12.25%, Agriculture consists of 15.85% area, 2.24% is wasteland, 0.57% area is rivers and waterbodies, 1.03% of the total area comes under urban area, 12.52% area is snow-covered and 0.61% consists of riverbed.

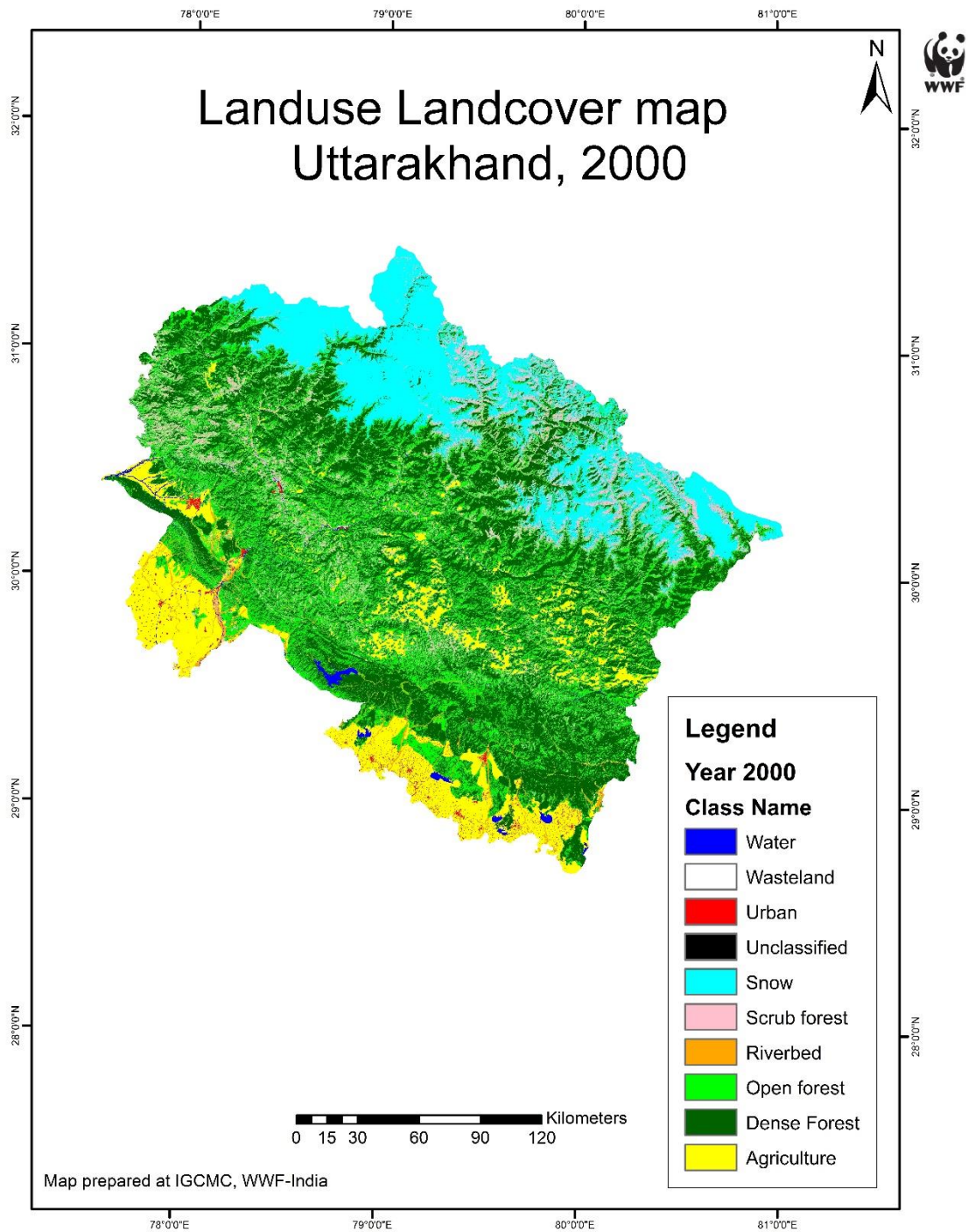


Plate 5: LULC map of Uttarakhand, 2000

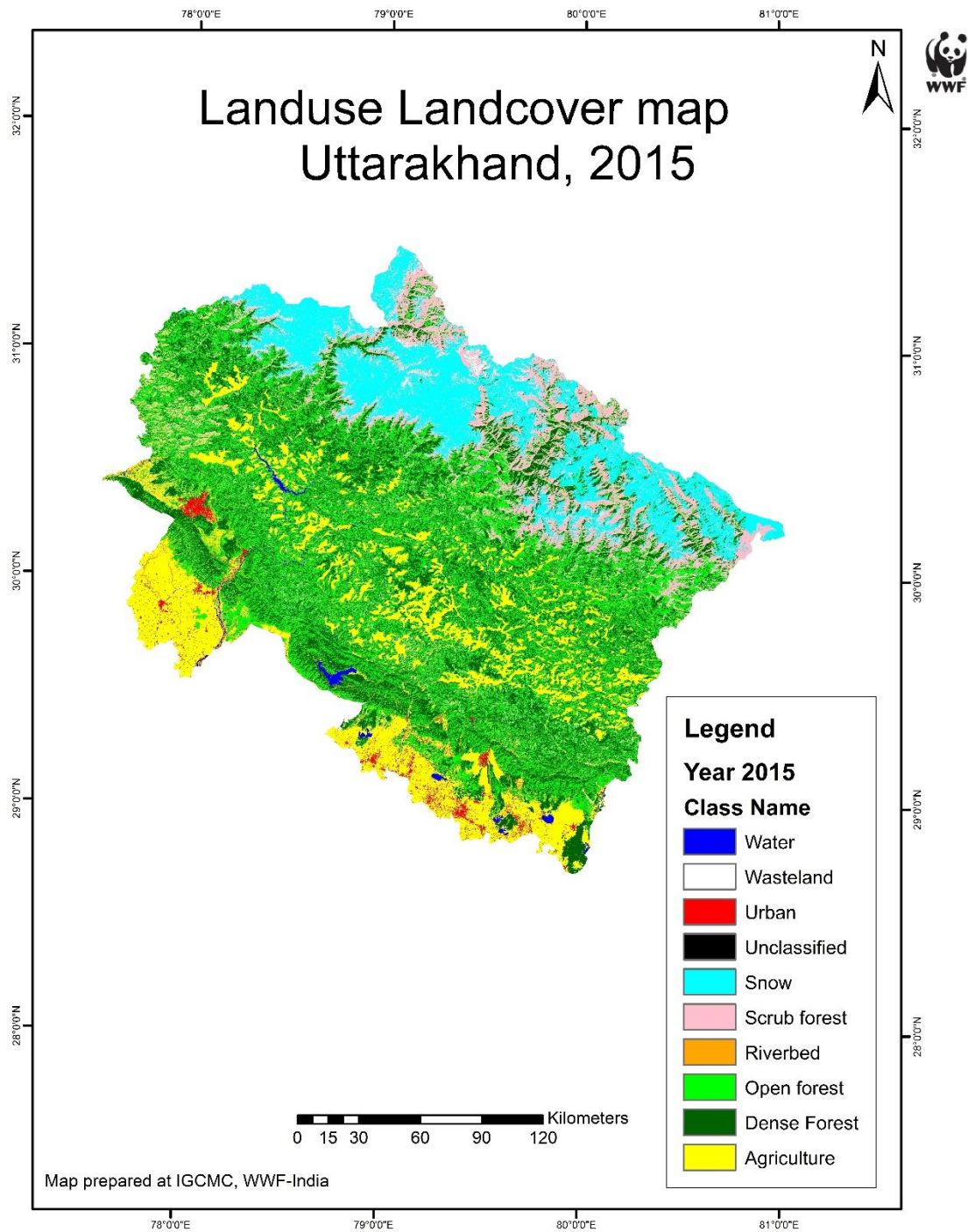


Plate 6: LULC map of Uttarakhand, 2015

Changes in LULC in 15 years (2000 to 2015)

There has been significant changes in the land cover categories in the time period of 15 years, in some categories one can analyse huge changes have taken place on the contrary there has been very minute increase or decrease in some classes. In total dense forest accounts for 36.82 % in 2000 which has decreased to 26.06% in 2015, there has been 10.76% decrease in dense forest. There has been 4.28% increase in open forest, while only 2.61 % increase in scrub forest category.

Categories	Year 2000(in %)	Year 2015(in %)	Change
Dense Forest	36.82	26.06	-10.76
Open forest	24.6	28.88	4.28
Scrub forest	9.64	12.25	2.61
Agriculture	10.8	15.85	5.05
Wasteland	0.13	2.24	2.11
Water	0.62	0.57	-0.05
Urban	0.57	1.03	0.46
Snow	15.88	12.52	-3.36
Riverbed	0.94	0.61	-0.33
Total	100	100	0

Table 4: Table 3: Table showing Changes in Landuse/cover (2000-2015)

There has been 5% increase in agricultural land, 2.11% increase in wasteland, a drastic 3.36% decrease in snow-cover.

	YEAR 2000 (Area in %)										Total
	Dense Forest	Open forest	Scrub forest	Agriculture	Wasteland	Water	Urban	Snow	Riverbed		
YEAR 2015 (Area in %)	Dense Forest	52.40	39.59	3.15	2.41	0.17	0.13	0.04	1.95	0.15	100
	Open forest	21.64	44.64	15.98	14.51	0.30	0.21	0.12	2.33	0.26	100
	Scrub forest	4.39	19.34	38.42	21.57	3.74	0.38	0.08	11.84	0.23	100
	Agriculture	3.85	7.12	2.28	79.28	0.07	0.29	6.53	0.00	0.58	100
	Wasteland	10.44	36.78	18.15	27.67	1.95	1.02	1.17	0.37	2.44	100
	Water	5.22	7.74	2.54	21.46	0.80	49.06	1.28	0.02	11.87	100
	Urban	0.05	0.11	0.02	0.35	0.06	1.05	98.35	0.00	0.00	100
	Snow	2.86	3.07	19.76	0.05	10.68	0.00	0.00	63.57	0.01	100
	Riverbed	5.61	8.88	3.17	35.13	2.96	8.39	2.02	0.00	33.83	100
	Total	26.01	28.86	12.25	15.61	2.23	0.56	1.34	12.52	0.60	100

Table 5: Description of Land cover classes and changes in 15 years using change matrix

Also, change matrix was prepared to see which pixels have been converted into which categories.

Dense forest

52.40% pixels of dense forest remain unchanged while 39.59% of dense forest pixels have been converted into Open forest and about 3.15% into Scrub forest.

2.41% of dense forest pixels have been transformed into Agriculture. 0.17 % into Wasteland, 0.13% into water, 0.04% into Urban, 1.95% into Snow and 0.15% into Riverbed.

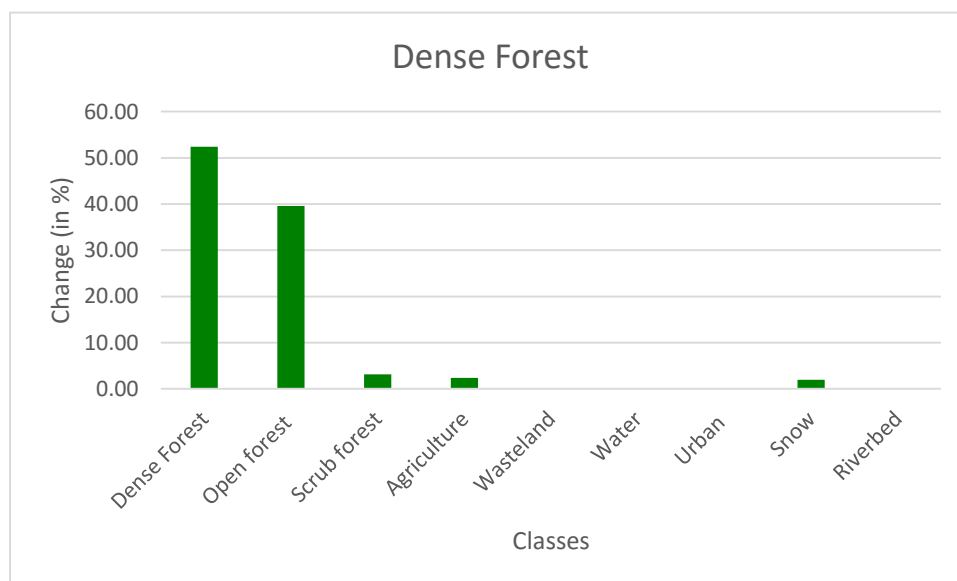


Figure 10: Bar-Graph showing changes from Dense Forest category to other categories

Highest change in this category is that 39.59% of dense forest pixels have been converted into open forest. Whereas the lowest change is that only 0.04% of dense forest pixels have been converted into urban pixels.

Open forest

44.64 % pixels of open forest remain unchanged while 21.64 % of open forest pixels have been converted into dense forest and about 15.98 % into Scrub forest.

14.51 % of open forest pixels have been transformed into Agriculture, 0.30 % into Wasteland, 0.21 % into water, 0.12 % into Urban, 2.33 % into Snow and 0.26 % into Riverbed.

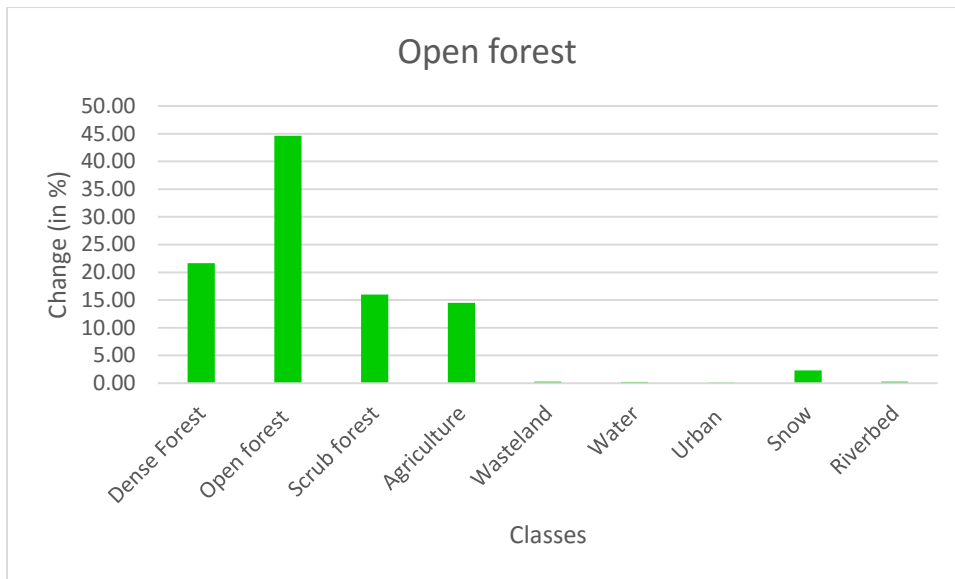


Figure 11: Bar-Graph showing changes from Open Forest category to other categories

Highest change in this category is that 21.64% of open forest pixels have been converted into dense forest. Whereas the lowest change is that only 0.04% of dense forest pixels have been converted into urban pixels. This might be a result of shift in the tree-line due to the changing climate.

Scrub forest

4.39 % of the scrub forest has been transformed in Dense Forest, 19.34 % has been converted from Scrub to open forest, 38.42 % of Scrub forest has remained unchanged, 21.57 % has changed into Agricultural land, 3.74 % into Wasteland, 0.38 % in water, 0.08% into Urban, 11.84 % in Snow, 0.23 % Riverbed.

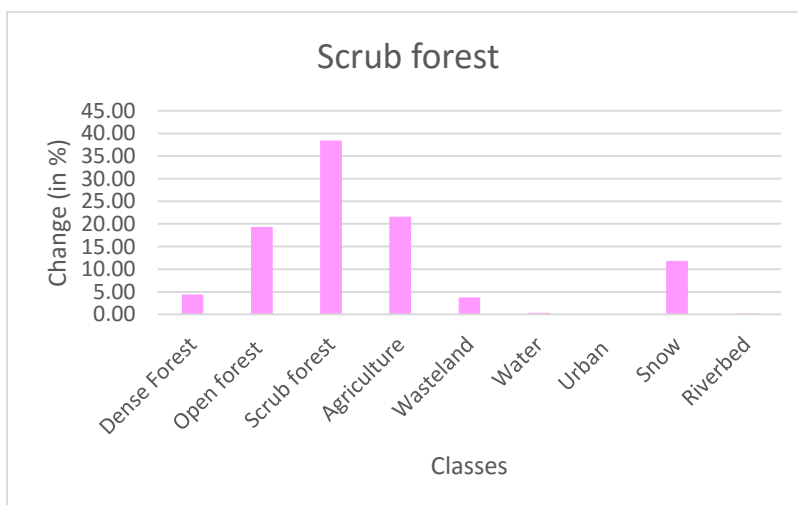


Figure 12: Bar-Graph showing changes from Scrub Forest category to other categories

Highest change in this category is that 21.57 % of Scrub forest pixels have changed been converted to Agriculture. Whereas the lowest change is that only 0.08 % of scrub forest has been converted into urban area.

Agriculture

3.85% of agricultural land has been converted to dense forest, 6.53% to open forest, 2.28% to scrub forest, 79.28% agricultural land remains unchanged. 0.07% has been converted to wasteland, 0.29% to water, 7.12% to urban area, 0% in snow and 0.58% in riverbed.

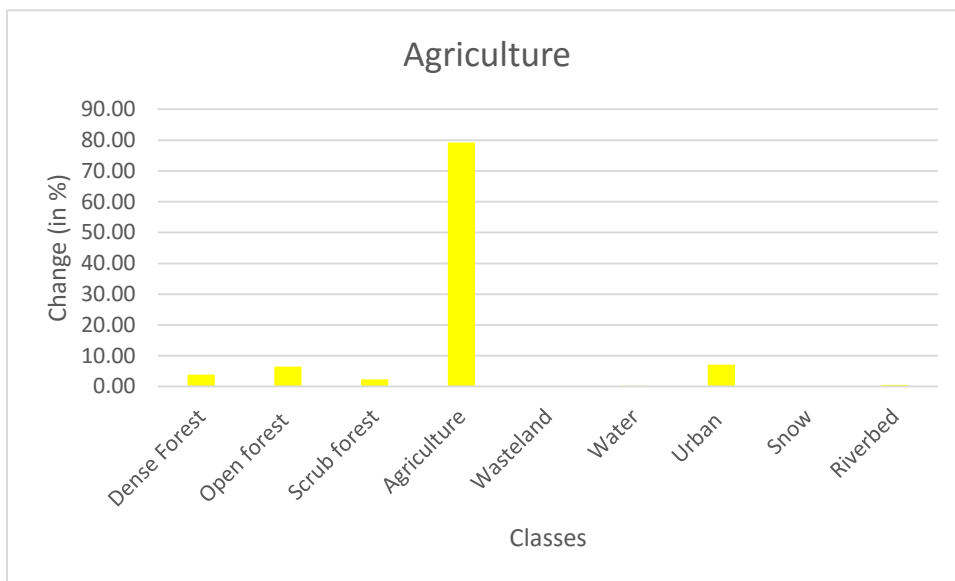


Figure 13: Bar-Graph showing changes from Agriculture category to other categories

Highest change in this category is that 7.12% of Agriculture pixels have changed been converted to Urban. Whereas the lowest change is that no pixels of agriculture has been converted into snow.

Wasteland

10.44% of wasteland has been converted into dense forest, 36.78% to open forest, 18.15% has changed to scrub forest, 27.67% to agriculture, 1.95% of wasteland remain unchanged, 1.02% to water, 1.17% to urban area, 0.37% to snow and 2.44% to riverbed.

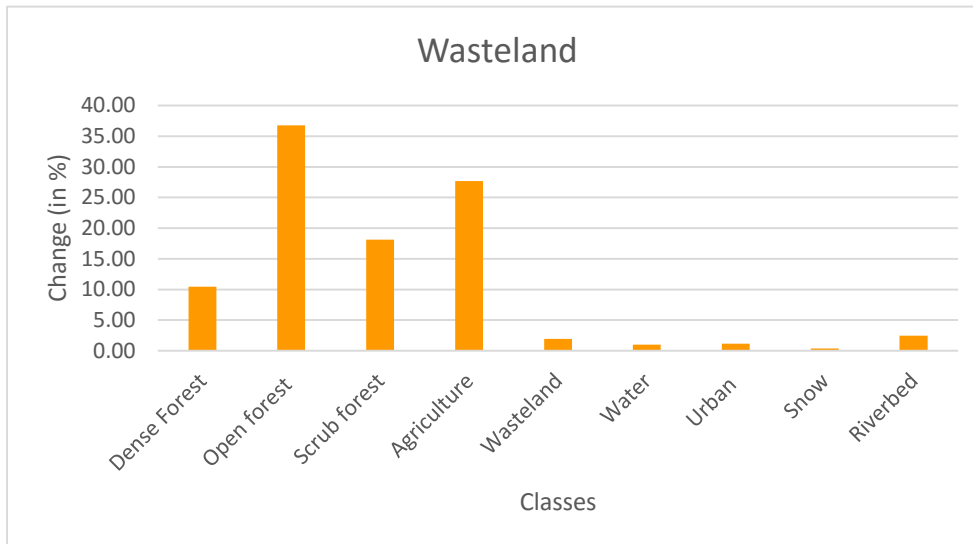


Figure 14: Bar-Graph showing changes from Wasteland category to other categories

Highest change in this category is that 36.78% % of wasteland has changed been converted to open forest. Whereas the lowest change is that 1.02% of wasteland has been converted into snow.

Water

5.22% of water has been converted into dense forest, 7.74% in open forest, 2.54% in scrub forest, 21.46 % into agricultural land, 0.80% into wasteland, 49.06% area remain unchanged, 1.258% in urban area, 0.02%in snow and 11.87% in riverbed.

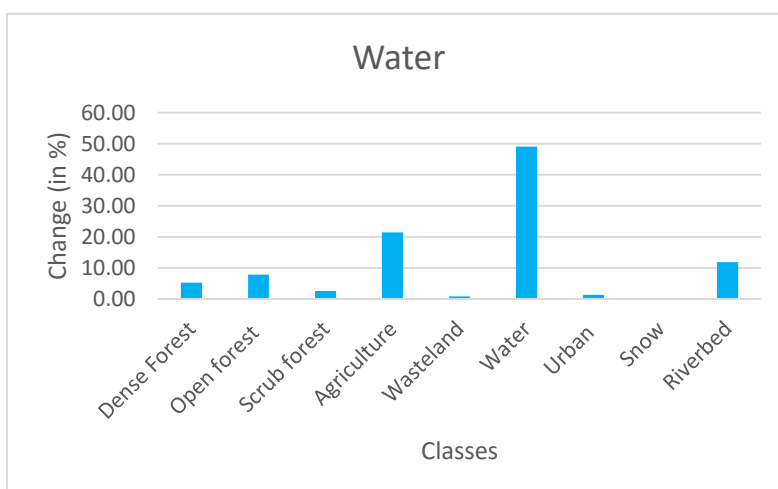


Figure 15: Bar-Graph showing changes from water category to other categories

Highest change in this category is that 21.46% of water pixels have been converted into agriculture pixels. Whereas the lowest change is that 0.02% of water pixels have been changed into snow pixels.

Urban

0.05% of urban has been converted into dense forest, 0.11% in open forest, 0.02% in scrub forest, 0.35 % into agricultural land, 0.06% into wasteland, 1.05% into water, 98.35% area remain unchanged, 1.258% in urban area, 0% in snow and 0 % in riverbed.

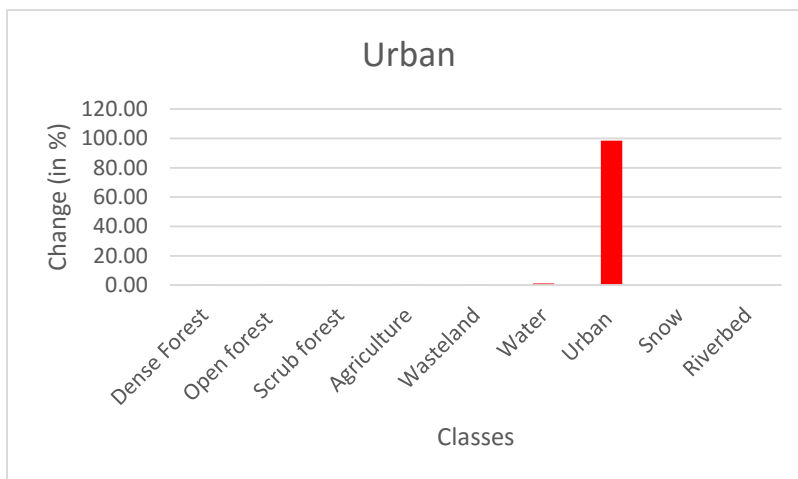


Figure 16: Bar-Graph showing changes from Urban category to other categories

Highest change in this category is that 0.11 % of urban pixels have been converted into open forest pixels. Whereas the lowest change is that no urban pixels have been changed into snow and riverbed pixels.

Snow

2.86 % of snow has been converted into dense forest, 3.07% in open forest, 19.76% in scrub forest, 0.05 % into agricultural land, 10.68% into wasteland, 0% into water, 0% in urban,

63.57% area remain unchanged and 0.01 % in riverbed.

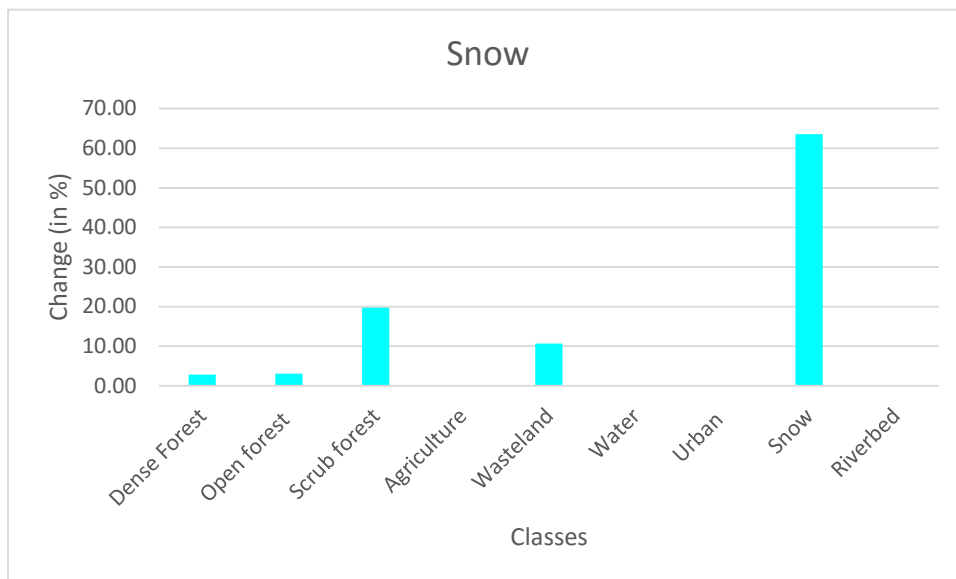


Figure 17: Bar-Graph showing changes from Snow category to other categories

Highest change in this category is that 19.76 % of urban pixels have been converted into scrub forest pixels. Whereas the lowest change is that no snow pixels have been changed into water and urban pixels.

Riverbed

5.61 % of riverbed has been converted into dense forest, 8.88% in open forest, 3.17% in scrub forest, 35.13 % into agricultural land, 2.96% into wasteland, 8.39% into water, 2.02% in urban, 0% in snow and 33.83 % area remain unchanged.

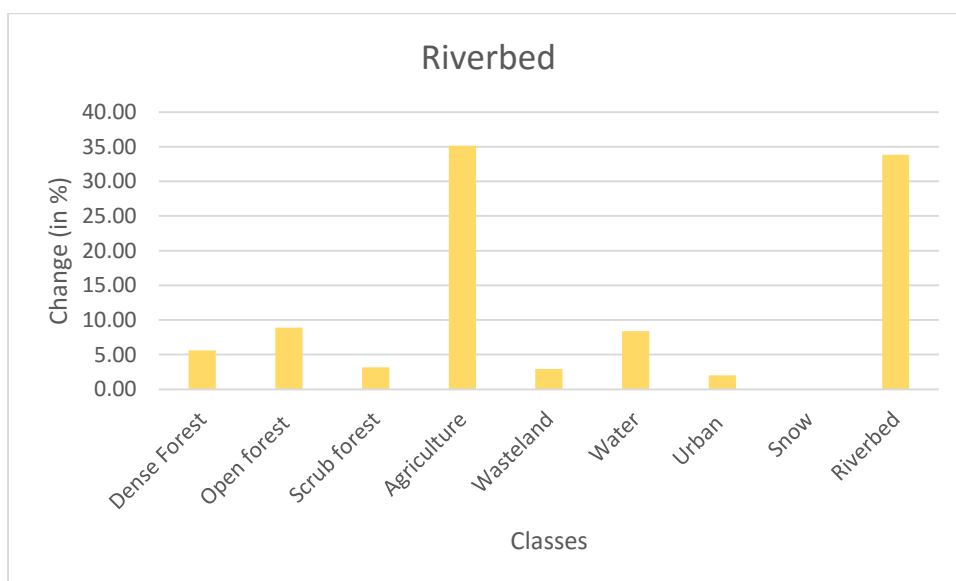


Figure 18: Bar-Graph showing changes from Riverbed category to other categories

Highest change in this category is that 35.13% of riverbed pixels have been converted into agriculture pixels. Whereas the lowest change is that no riverbed pixels have been changed into snow pixels.

Accuracy assessment

Accuracy assessment means comparing the classification to geographical data that are assumed to be true, in order to determine the accuracy of the classification process.

After the classification was done, accuracy assessment was performed using field and secondary sources of data.

Using accuracy assessment tool in ERDAS IMAGINE 2011. Accuracy assessment was performed using this tool. Primary field survey data and secondary data (google earth, cadastral maps) was used for validation. About 100 points were taken during the field study and 200 points were generated from random sampling and then field data and google earth data was used for validation of the classified image. Field study was done in Roorkee and Haridwar city.



Photo 1: Photographs showing popular tree plantation along with other crops in Roorkee



Photo 2: Photograph of River in Haridwar

According to the accuracy report generated - Overall Classification Accuracy is 76.52%, Overall Kappa Statistics is 0.7072.

Kappa measures the percentage of data values in the main diagonal of the table and then adjusts these values for the amount of agreement that could be expected due to chance alone. Kappa is always less than or equal to 1. A value of 1 implies perfect agreement and values less than 1 imply less than perfect agreement. Kappa can be interpreted as follows:

- Poor agreement = Less than 0.20
- Fair agreement = 0.20 to 0.40
- Moderate agreement = 0.40 to 0.60
- Good agreement = 0.60 to 0.80
- Very good agreement = 0.80 to 1.00

Kappa statistics for each individual class is as follows:

Table 6: Description of kappa statistics

S.no	Class Name	Kappa
1	Dense Forest	0.7332
2	Open forest	0.6496
3	Scrub forest	0.45
4	Agriculture	0.8065
5	Wasteland	0.459
6	Water	0
7	Urban	0.8491
8	Snow	0.7576
9	Riverbed	1

As per the accuracy report generated kappa statistics for Dense forest is 0.7332 which means there is 73% agreement between classified image and the geographical data for this class, Open forest is 0.6496 which means there is 64 % agreement between classified image and the geographical data for this class, Scrub forest is 0.45 which means there is 45 % agreement between classified image and the geographical data for this class, Agriculture is 0.8065 which means there is 80% agreement between classified image and the geographical data for this class, Wasteland is 0.459 which means there is 45% agreement between classified image and the geographical data for this class. Water is 0, it is so because there was no sample point which was falling in this category neither in the random sample nor in the field study. The Kappa statistics for Urban is 0.8491 which means there is 84% agreement between classified image and the geographical data for this class, Snow is 0.7576 which means there is 75% agreement between classified image and the geographical data for this class and for Riverbed kappa statistics is 1 which means there is 100% agreement between classified image and the geographical data for this class.

After classifying the images of Uttarakhand into various classes as shown above, it was then reclassified into two classes:

- 1) Non-forest class
- 2) Forest class

Non-forest class is the class which includes Agriculture, Wasteland, Water, Urban, Snow and Riverbed classes.

Forest class is the class which includes Dense Forest, Open forest and Scrub forest classes.

These maps were the required inputs for the Landscape fragmentation tool as shown below:

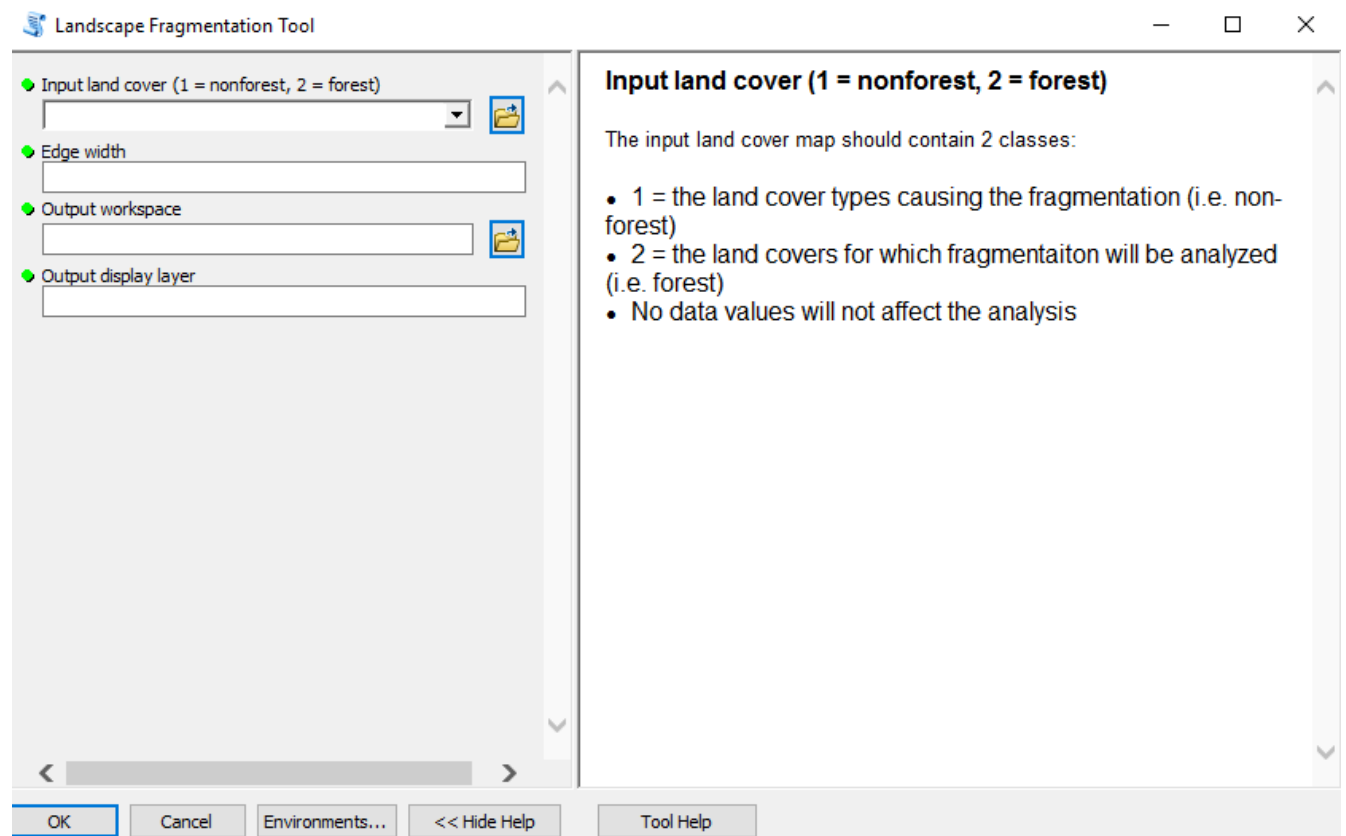


Figure 19: Figure showing Interface of Landscape Fragmentation Tool

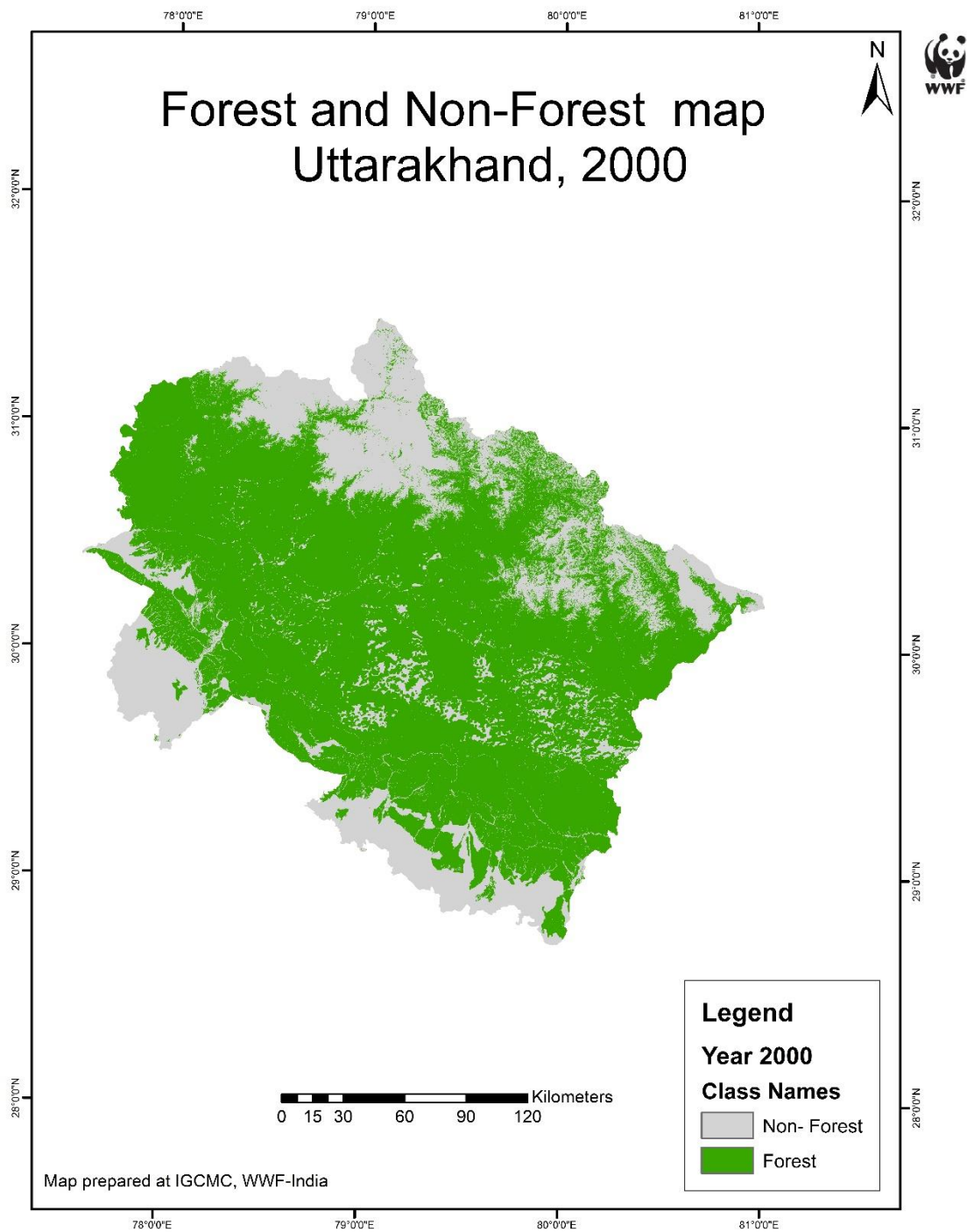


Plate 7: Map showing Forested, Non-Forested area of Uttarakhand

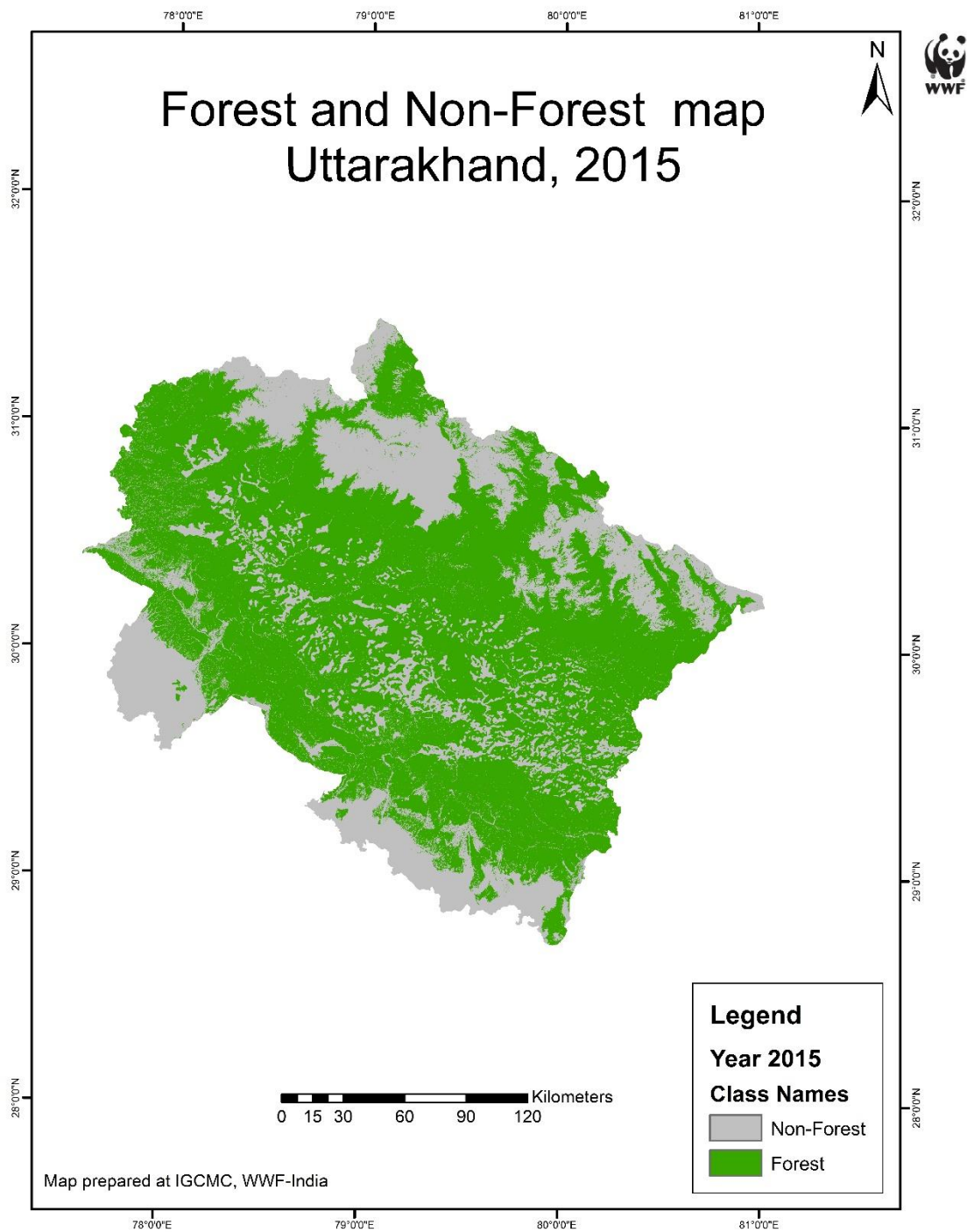


Plate 8: Map showing Forested, Non-Forested area of Uttarakhand

Forest fragmentation

Forest fragmentation is the process in which large continuous forest patches are divided into small isolated patches which leads to habitat loss. The landscape fragmentation tool divides the fragmented map into 5 parts:

- Patch
- Edge
- Perforated
- Core (< 250 acres)
- Core (250-500 acres)
- Core (> 500 acres)

All these terms have been explained well in the literature review. The tool used here that is Landscape fragmentation tool is a tool owned by University of Connecticut.

Table 7: Showing details of forest fragmentation

		2000		2015	
S.no	Category	Count	Area (in %)	Count	Area (in %)
1	Patch	288707	2.73	195715	1.95
2	Edge	1038701	9.81	1201024	11.99
3	Perforated	1710915	16.15	3051803	30.48
4	Core (< 250 acres)	52798	0.50	112941	1.13
5	Core (250-500 acres)	25222	0.24	47720	0.48
6	Core (> 500 acres)	7474435	70.57	5404329	53.97
TOTAL		10590778	100	10013532	100

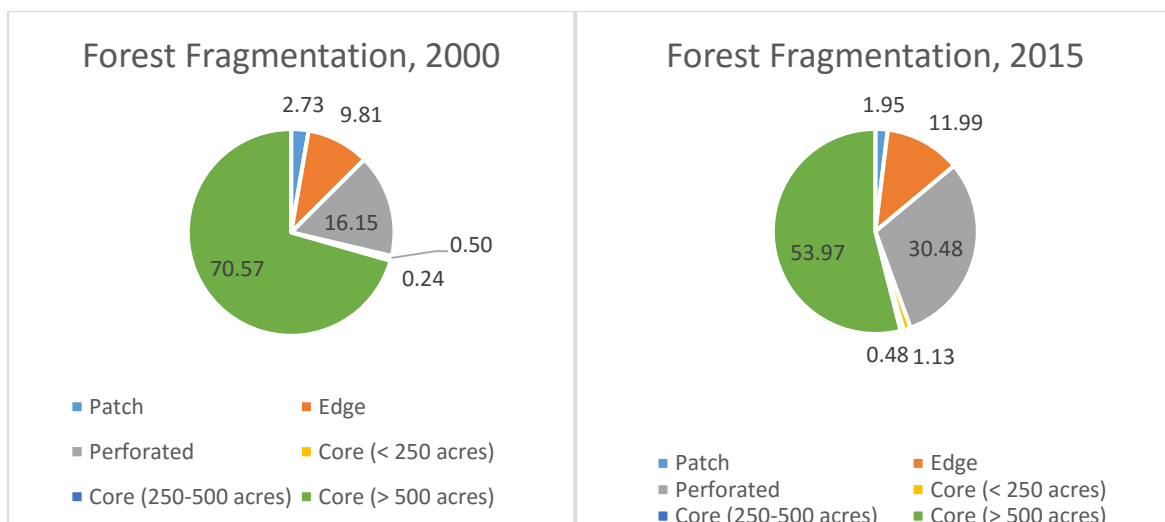


Figure 20: Pie-chart showing details of forest fragmentation in the year 2000 and 2015

According to the output obtained by landscape fragmentation tool, the total forested area in the year 2000 was 10590778 hectares which has decreased to 10013532 in the year 2015. Focusing individual categories out of the total fragmented forests in the year 2000, 2.73% is under patch forest that comprises a small forested area surrounded by non-forest land cover. 9.81% comes under edge forest that define the boundary between core forest and large non-forested land cover features. 16.15% are perforated forest that define the boundary between core forest and relatively small clearings (perforations) within the forested landscape. 0.50% are Small core forest which are forest patches that are less than 250 acres, 0.24% are Medium core forest which are forest patches that are between 250-500 acres and 70.57% are the Large core forest which are forest patches that are greater than 500 acres.

Focusing individual categories out of the total fragmented forests in the year 2015, 1.95 % is under patch forest that comprises a small forested area surrounded by non-forest land cover. 11.99% comes under edge forest that define the boundary between core forest and large non-forested land cover features. 30.48% are perforated forest that define the boundary between core forest and relatively small clearings (perforations) within the forested landscape. 1.13% are Small core forest which are forest patches that are less than 250 acres, 0.48% are Medium core forest which are forest patches that are between 250-500 acres and 53.97% are the Large core forest which are forest patches that are greater than 500 acres.

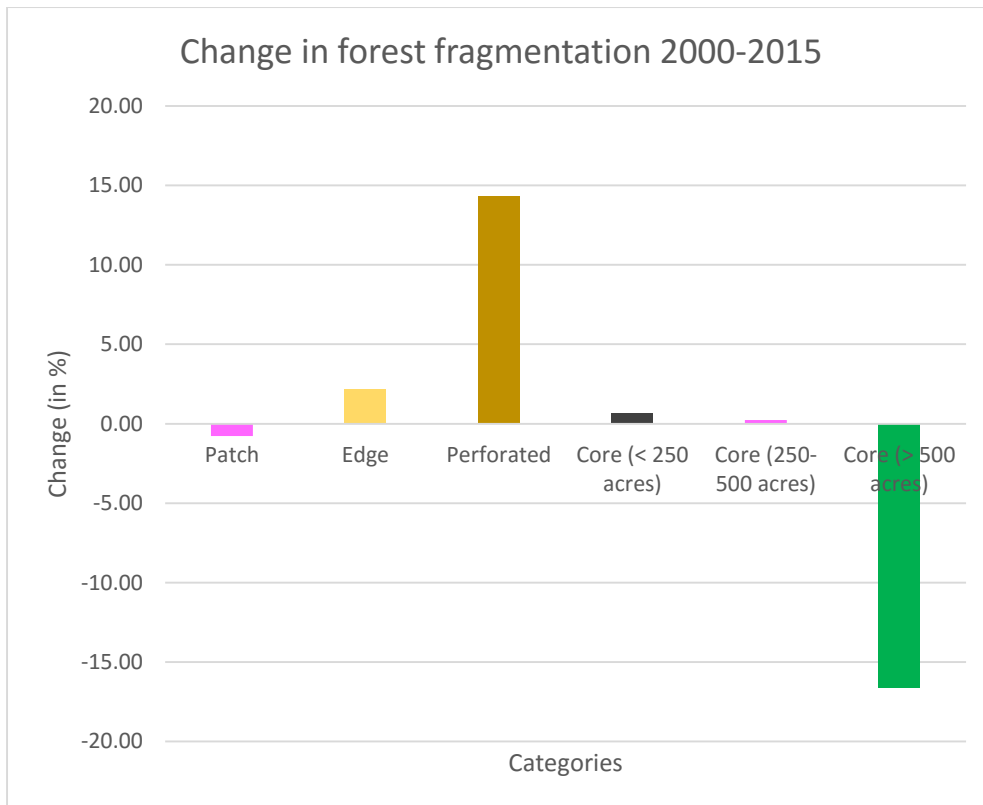


Figure 21: Bar-graph showing change in forest fragmentation in different categories from 2000 to 2015

There has been 0.77% decrease in patch forest, 2.19% increase in Edge forest, 14.32% increase in perforated forest, 0.63% increase in small core forest, 0.24% increase in medium core forest and 16.60% decrease in large core forests.

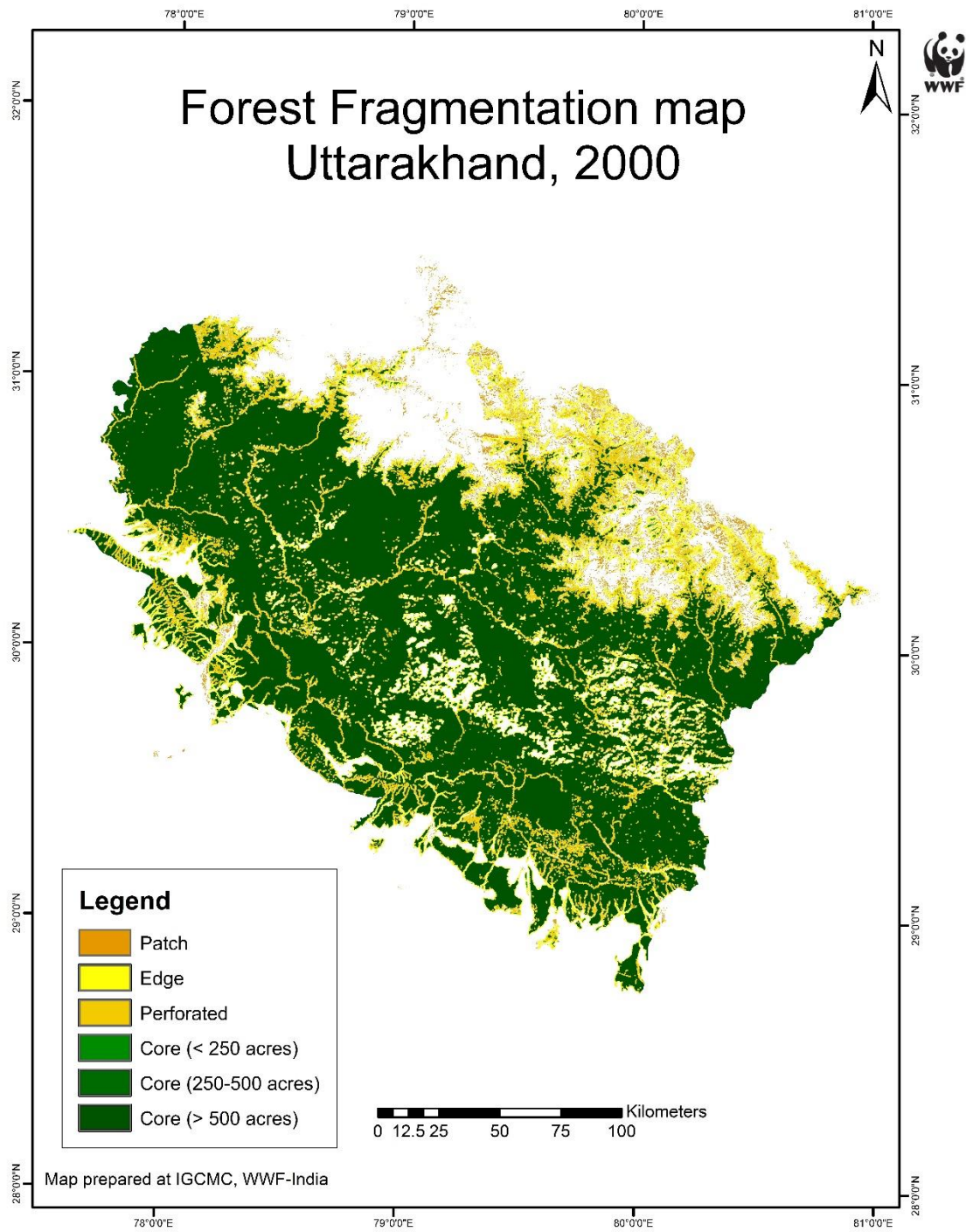


Plate 9: Forest Fragmentation map of Uttarakhand, 2000

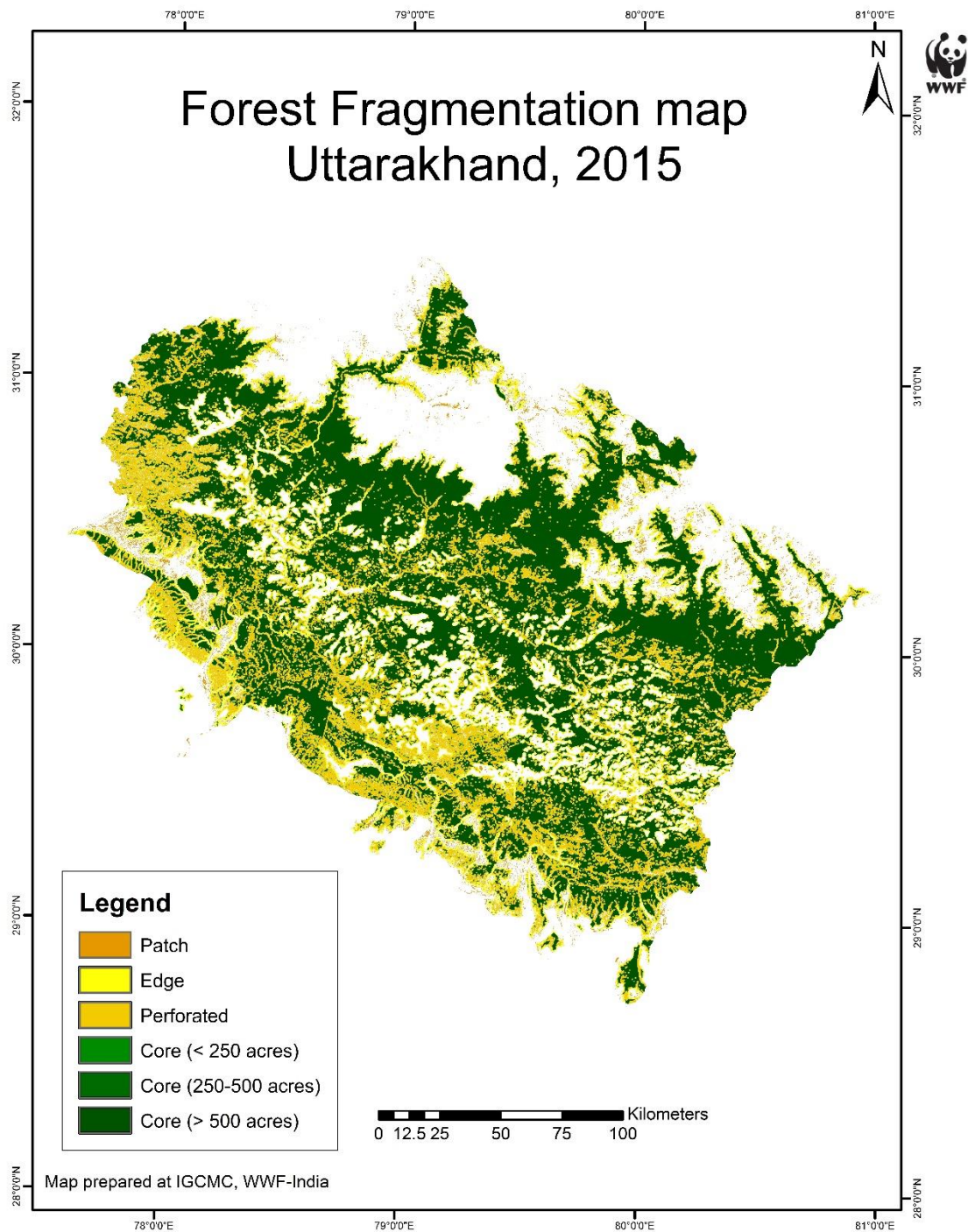


Plate 10: Forest Fragmentation map of Uttarakhand, 2015

Urban sprawl mapping

For urban sprawl mapping the cities having population more than one lakh have been considered for this research work. The cities in Uttarakhand having population more than 1 lakh are :

S.no	Cities	Population(in persons)
1	Dehradun (M Corp.)	578,420
2	Haldwani-cum-Kathgodam (NPP)	156,060
3	Kashipur (NPP)	121,610
4	Rudrapur (NPP)	140,884
5	Roorkee (NPP)	118,188
6	Haridwar (NPP)	225,235

Table 8: Table showing cities with more than one lakh population

For the cities there has been great changes and some cities have expanded tremendously, through the analysis of urban sprawl by classification following figures have been obtained:

S.no	Cities	Urban area		Change (in ha)	Increase in times(X)
		Year 2000	Year 2015		
1	Dehradun (M Corp.)	7158	27194	20036	3.80
2	Haldwani-cum-Kathgodam (NPP)	3269	5131	1862	1.57
3	Kashipur (NPP)	3107	7174	4067	2.31
4	Rudrapur (NPP)	4150	13419	9269	3.23
5	Roorkee (NPP)	1639	4301	2662	2.62
6	Haridwar (NPP)	3838	8480	4642	2.21

Table 9: Showing urban area (in ha) and increase in percentage

Dehradun

The city of Dehradun having population 578,420 (Census of India 2011) has expanded to a large extent. In the year 2000 it was spread in an area of about 7158 hectares, whereas in the year 2015 it was spread across an area of 27194 hectares. The city of Dehradun has expanded by 3.80 times as per the analysis done in this study. Although the city has expanded in all the directions but it has spatially expanded more towards the south. In the year 2000, the whole

city of Uttarakhand could fit in the 6 Km ring (as shown in the map) but in the year 2015, an additional ring upto 15 Km was required to spatially fit the city.

Haldwani-cum-Kathgodam

The city of Haldwani-cum-Kathgodam having population 156,060 (Census of India 2011) has expanded spatially. In the year 2000 it was spread in an area of about 3269 hectares, whereas in the year 2015 it was spread across an area of 5131 hectares. The city of Haldwani-cum-Kathgodam has expanded by 1.57 times as per the analysis done in this study. Although the city has expanded in all the directions but it has spatially expanded more in the south-west direction. In the year 2000, the whole city of Uttarakhand could fit in the 6 Km ring (as shown in the map) and even in the year 2015 city fits well in the 6 Km ring which means it has expanded more in terms of density and not much spatially.

Kashipur

The city of Kashipur having population 121,610 (Census of India 2011) has expanded spatially. In the year 2000 it was spread in an area of about 3,107 hectares, whereas in the year 2015 it was spread across an area of 7,174 hectares. The city of Kashipur has expanded by 2.31 times as per the analysis done in this study. Although the city has expanded in all the directions but it has spatially expanded more in the south and north-west direction. In the year 2000, the whole city of Uttarakhand could fit in the 4 Km ring (as shown in the map) but in the year 2015 city does not fit in the 4 Km ring and therefore the 6Km ring had to be added in the year 2015. This means it has expanded more in terms of both in terms of density and also spatially.

Rudrapur

The city of Rudrapur having population 140,884 (Census of India 2011) has expanded spatially. In the year 2000 it was spread in an area of about 4150 hectares, whereas in the year 2015 it was spread across an area of 13,419 hectares. The city of Rudrapur has expanded by 3.23 times as per the analysis done in this study. The city has expanded in all the directions. In the year 2000, the whole city of Rudrapur could fit in the 4 Km ring (as shown in the map) but in the year 2015 city does not fit in the 4 Km ring and therefore the 8 Km ring had to be added in the year 2015. This means it has expanded more in terms of both in terms of density and also spatially.

Roorkee

The city of Roorkee having population 118,188 (Census of India 2011) has expanded spatially. In the year 2000 it was spread in an area of about 1639 hectares, whereas in the year 2015 it was spread across an area of 4301 hectares. The city of Roorkee has expanded by 2.62 times as per the analysis done in this study. The city has expanded in all the directions but has become more dense in the centre. In the year 2000, the whole city of Roorkee could fit in the 2 Km ring (as shown in the map) but in the year 2015 city does not fit in the 2 Km ring and therefore the 3 Km ring had to be added in the year 2015. This means it has expanded more in terms of both in terms of density and also spatially.

Haridwar

The city of Haridwar having population 225,235 (Census of India 2011) has expanded spatially. In the year 2000 it was spread in an area of about 3838 hectares, whereas in the year 2015 it was spread across an area of 8480 hectares. The city of Haridwar has expanded by 2.21 times as per the analysis done in this study. The city has expanded in all the directions in terms of density. In the year 2000, the whole city of Haridwar could fit in the 15 Km ring (as shown in the map) and also in the year 2015 the city fits well in the 15 Km ring. This means it has expanded more in terms of both in terms of density and not much spatially except the south-west corner of the city.

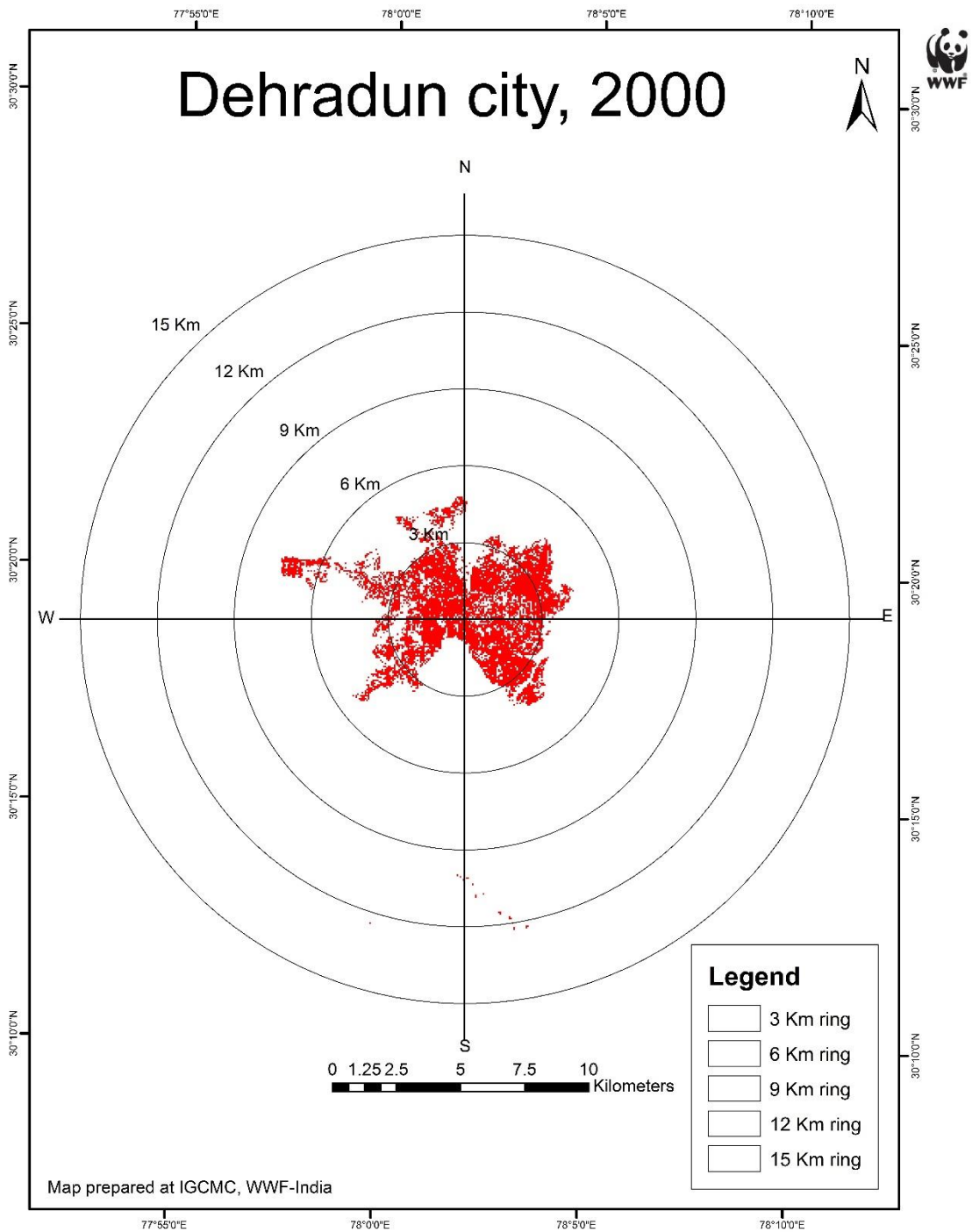


Plate 11: Dehradun city, 2000

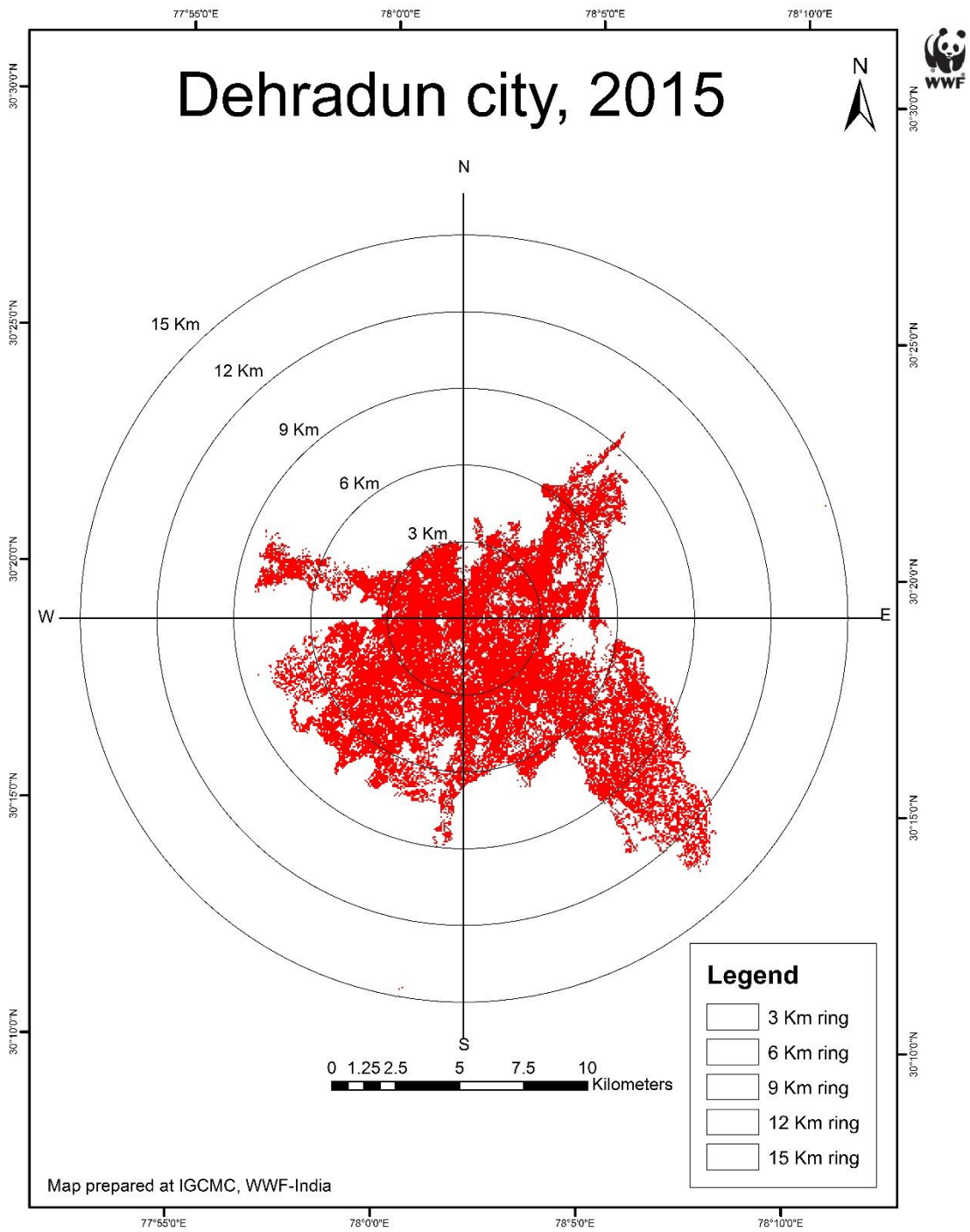


Plate 12: Dehradun city, 2015

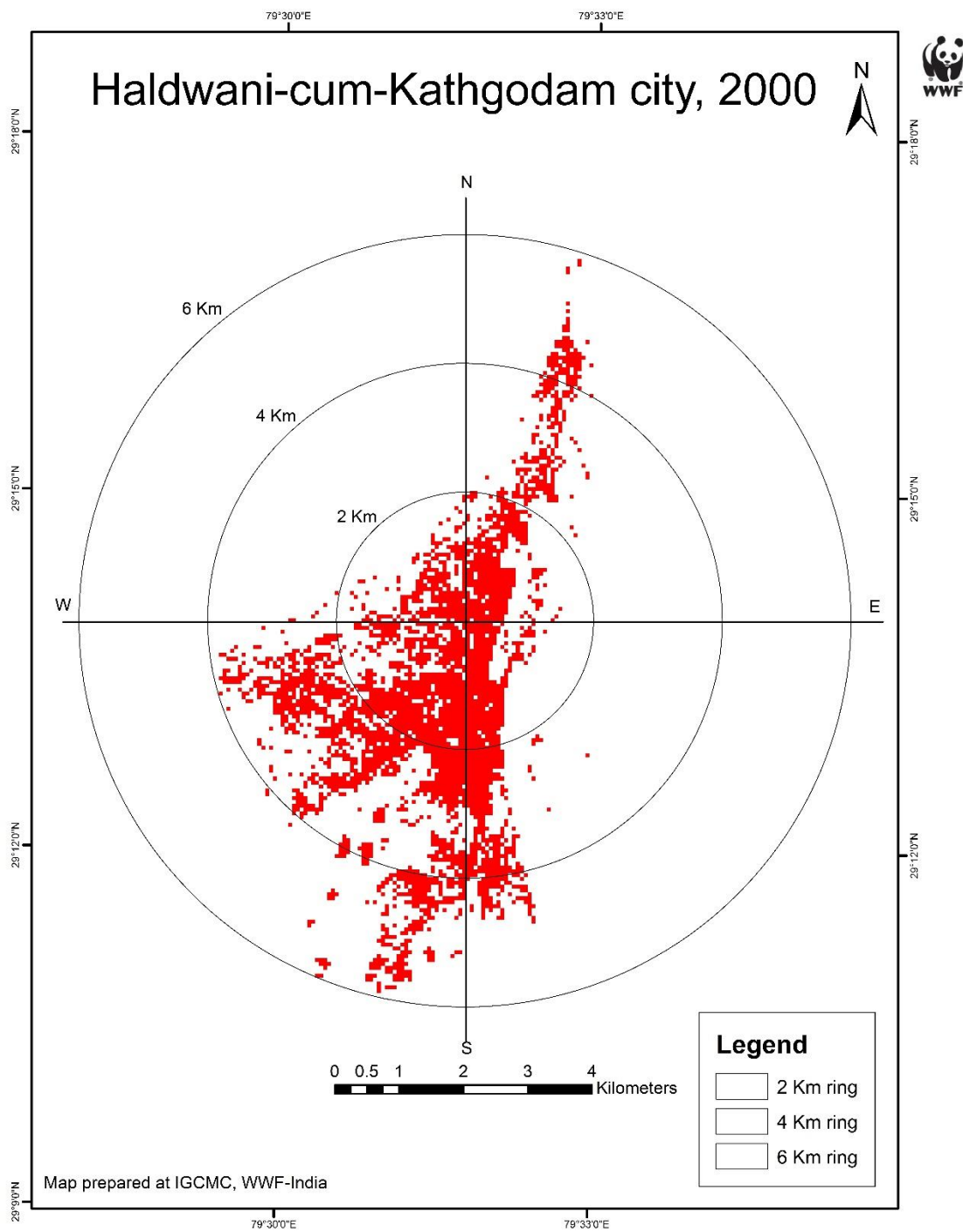


Plate 13: Haldwani-cum-Kathgodam city, 2000

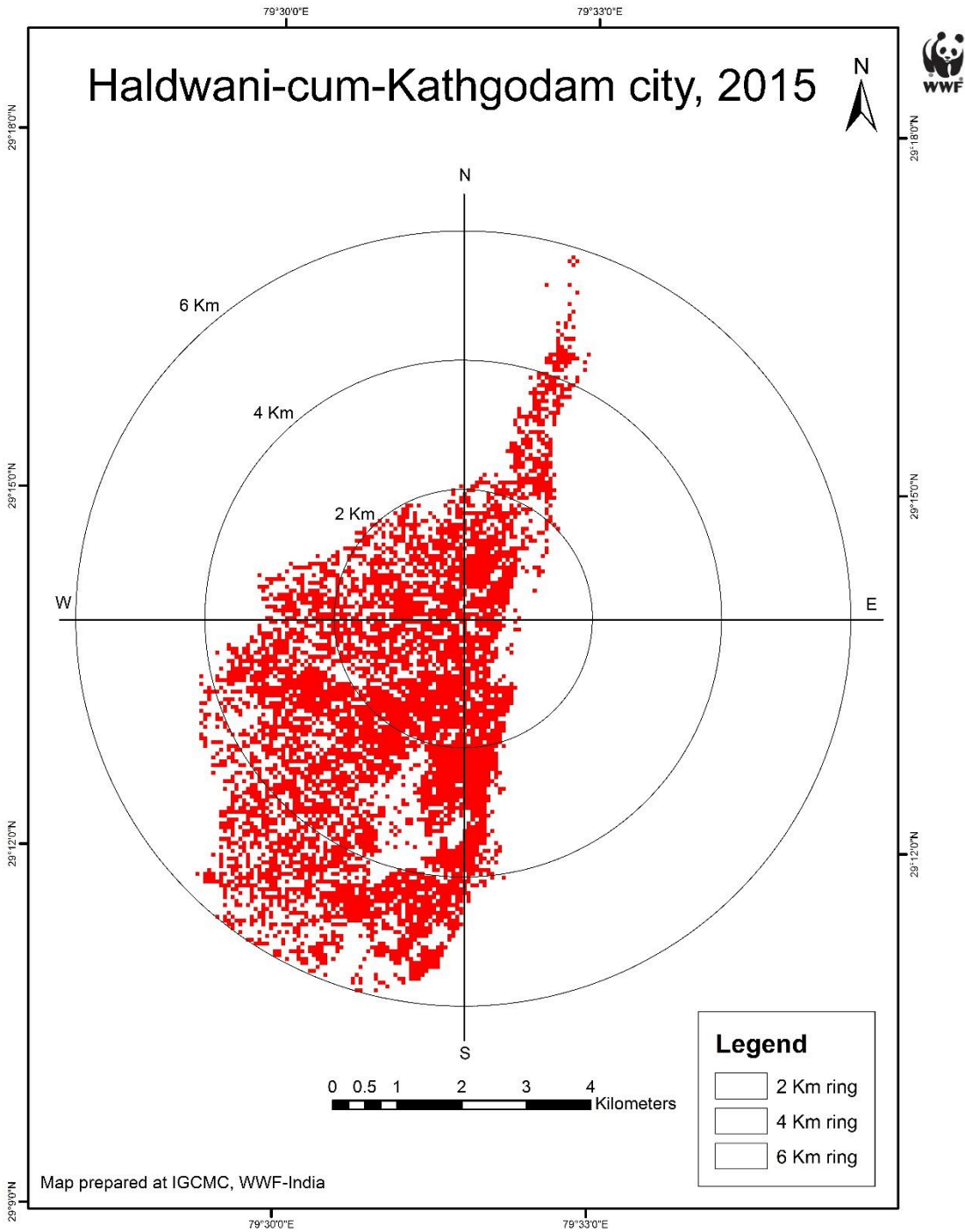


Plate 14: Haldwani-cum-Kathgodam city, 2015

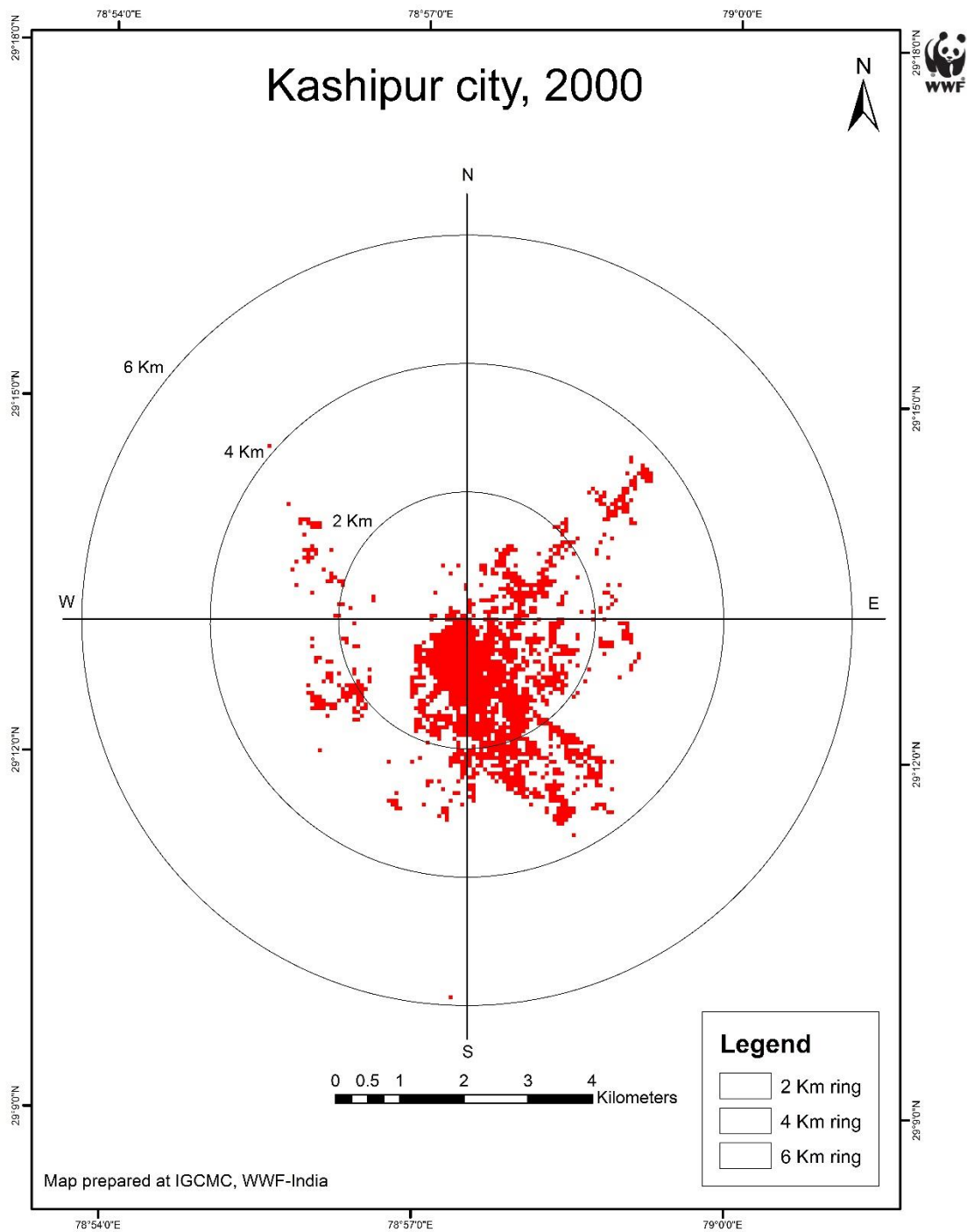


Plate 15: Kashipur city, 2000

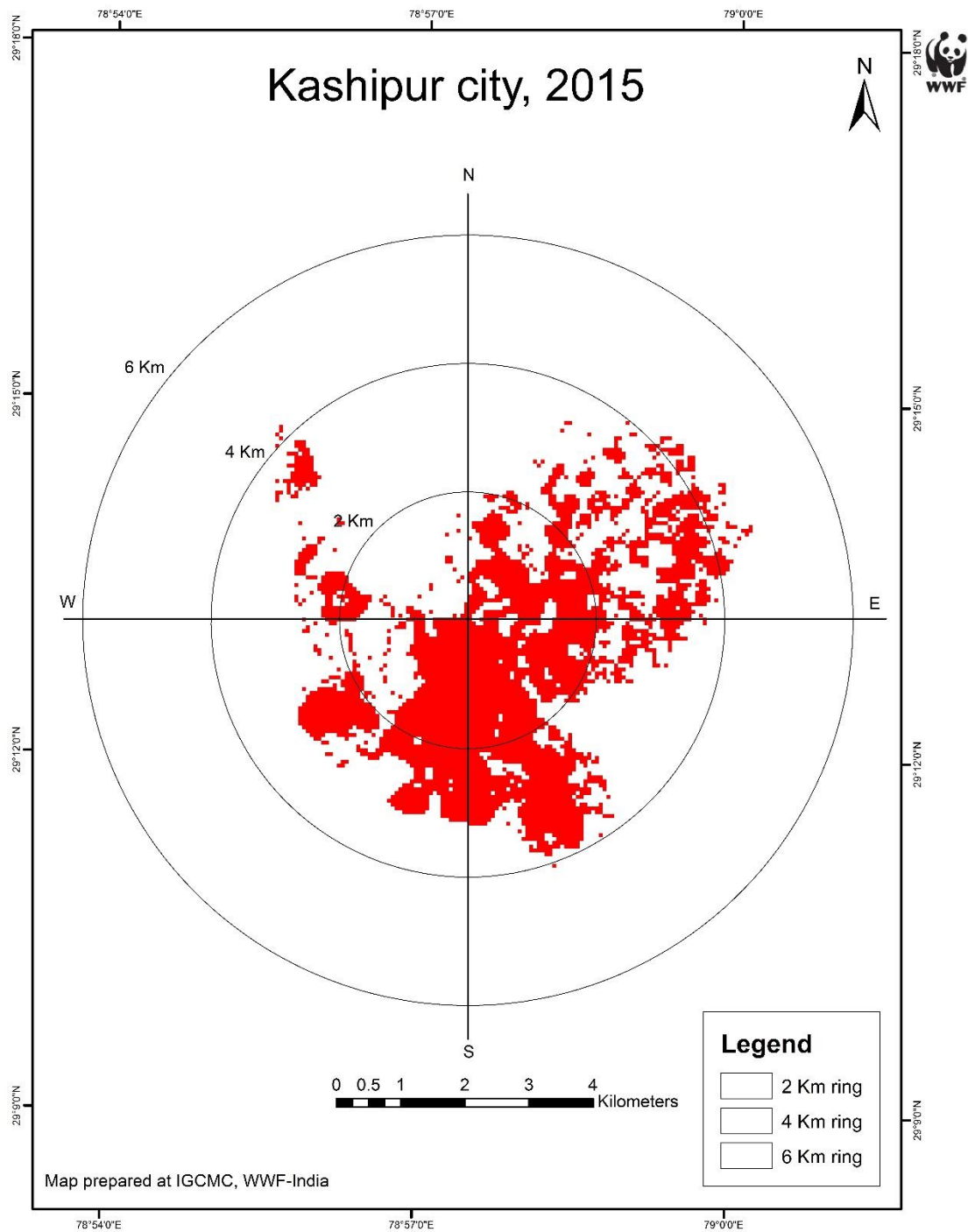


Plate 16: Kashipur city, 2015

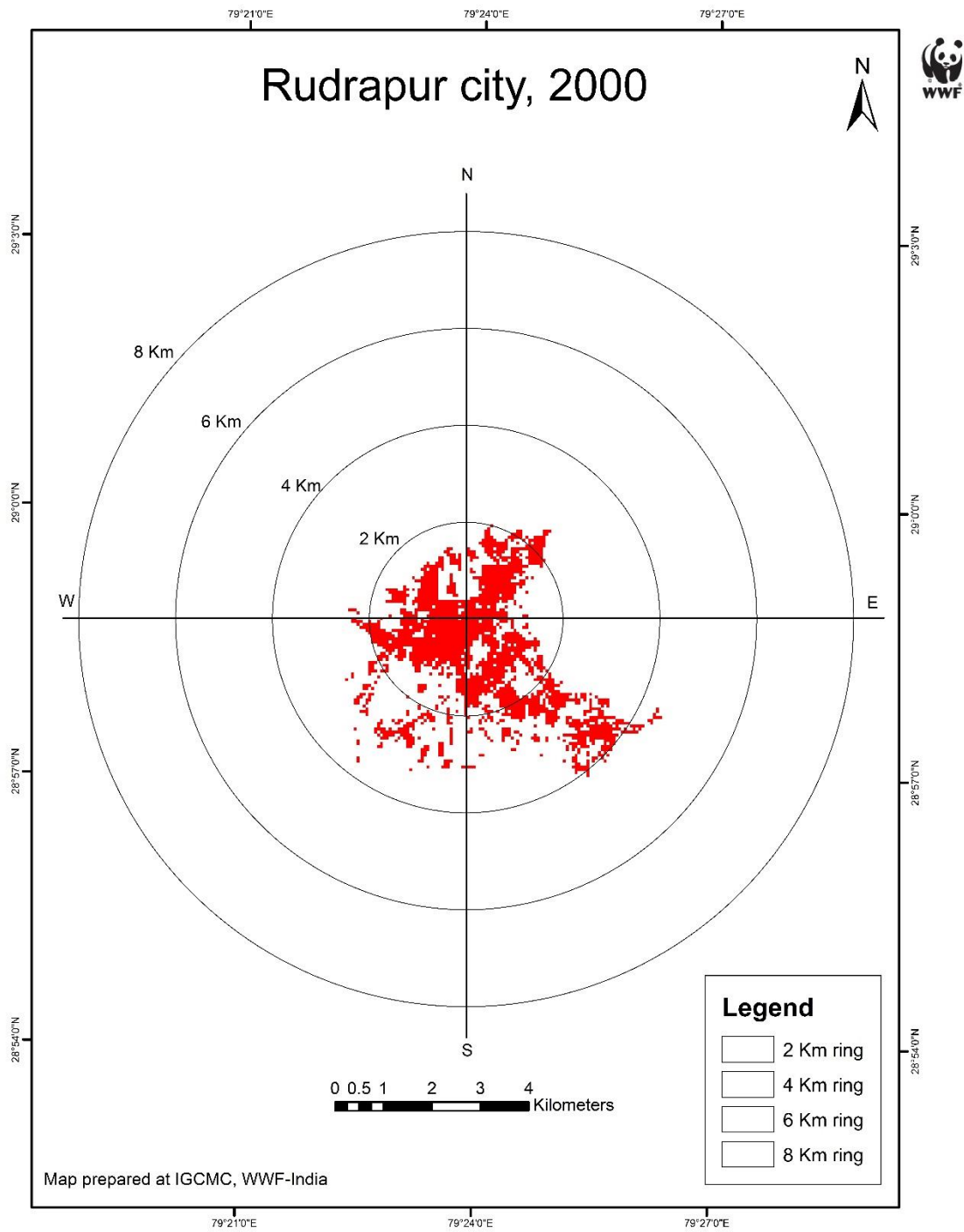


Plate 17: Rudrapur city, 2000

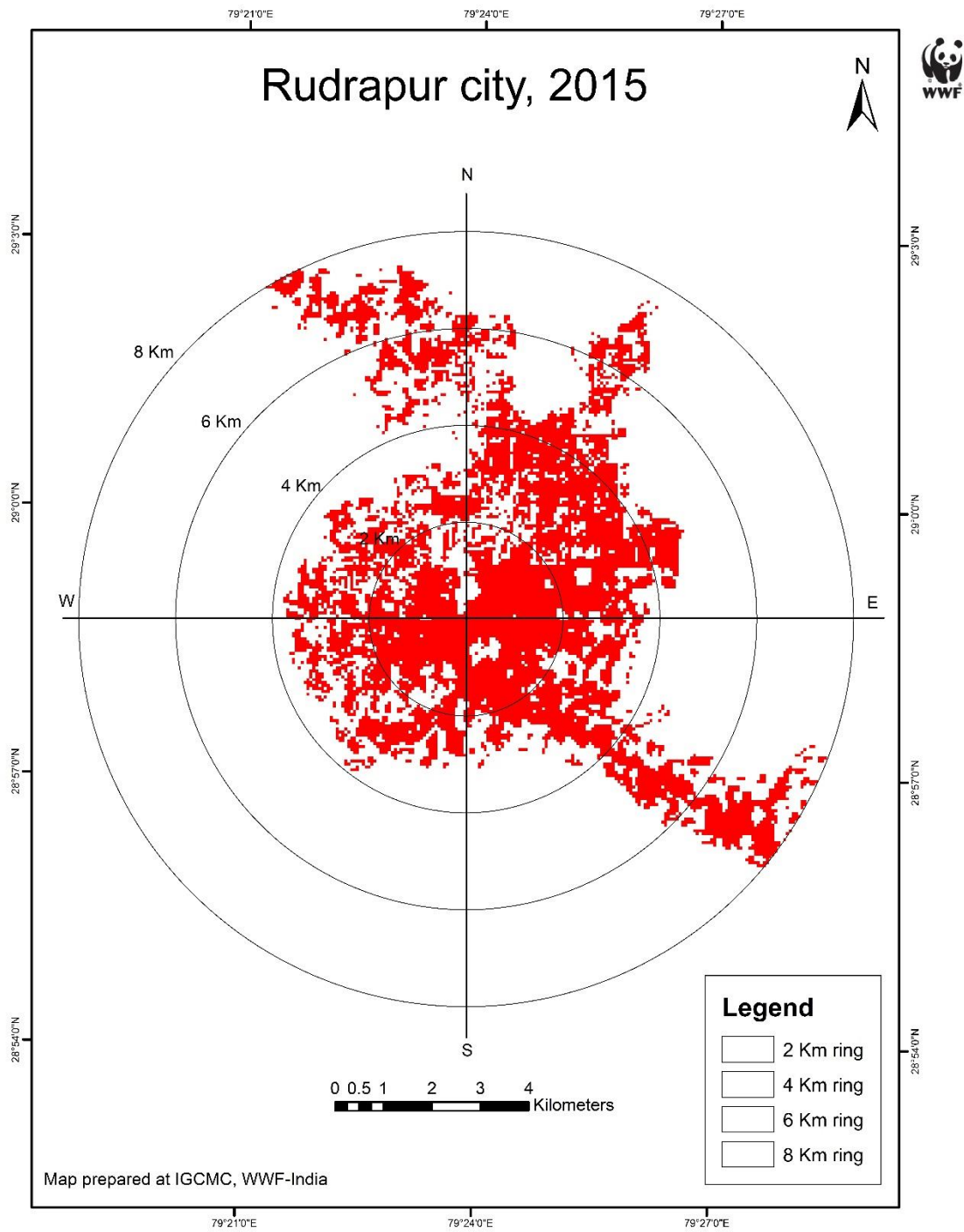


Plate 18: Rudrapur city, 2015

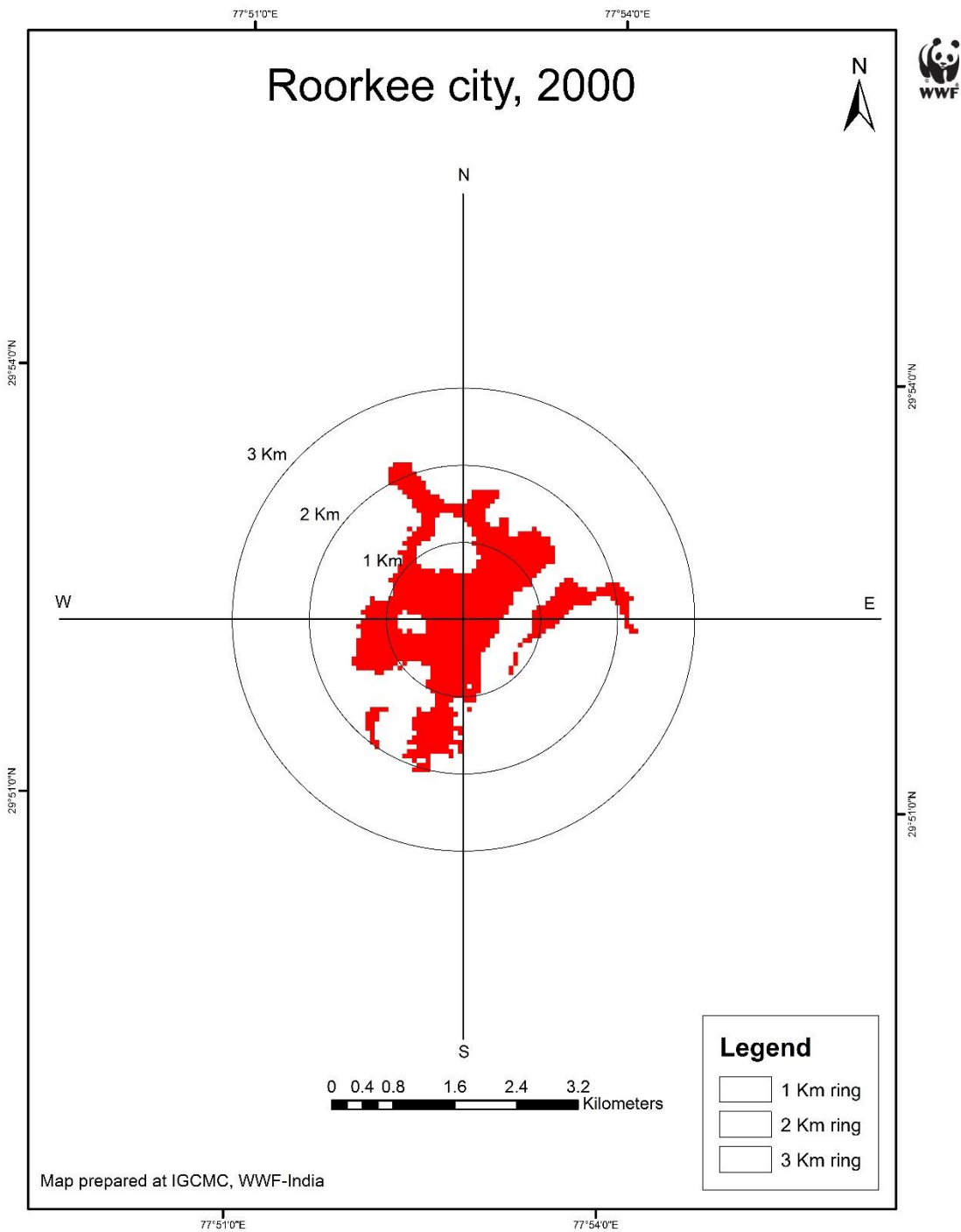


Plate 19: : Roorkee city, 2000

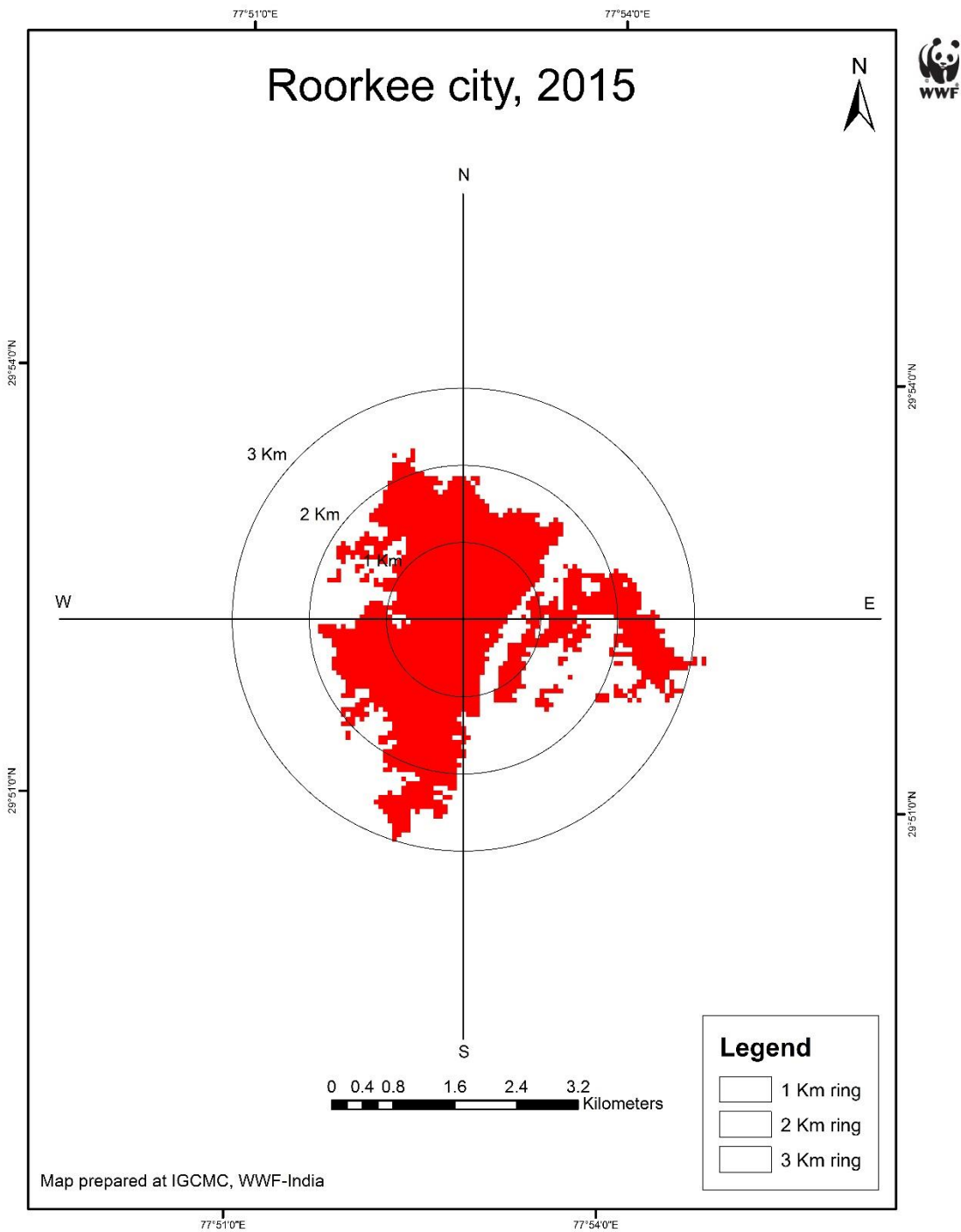


Plate 20: Rudrapur city, 2015

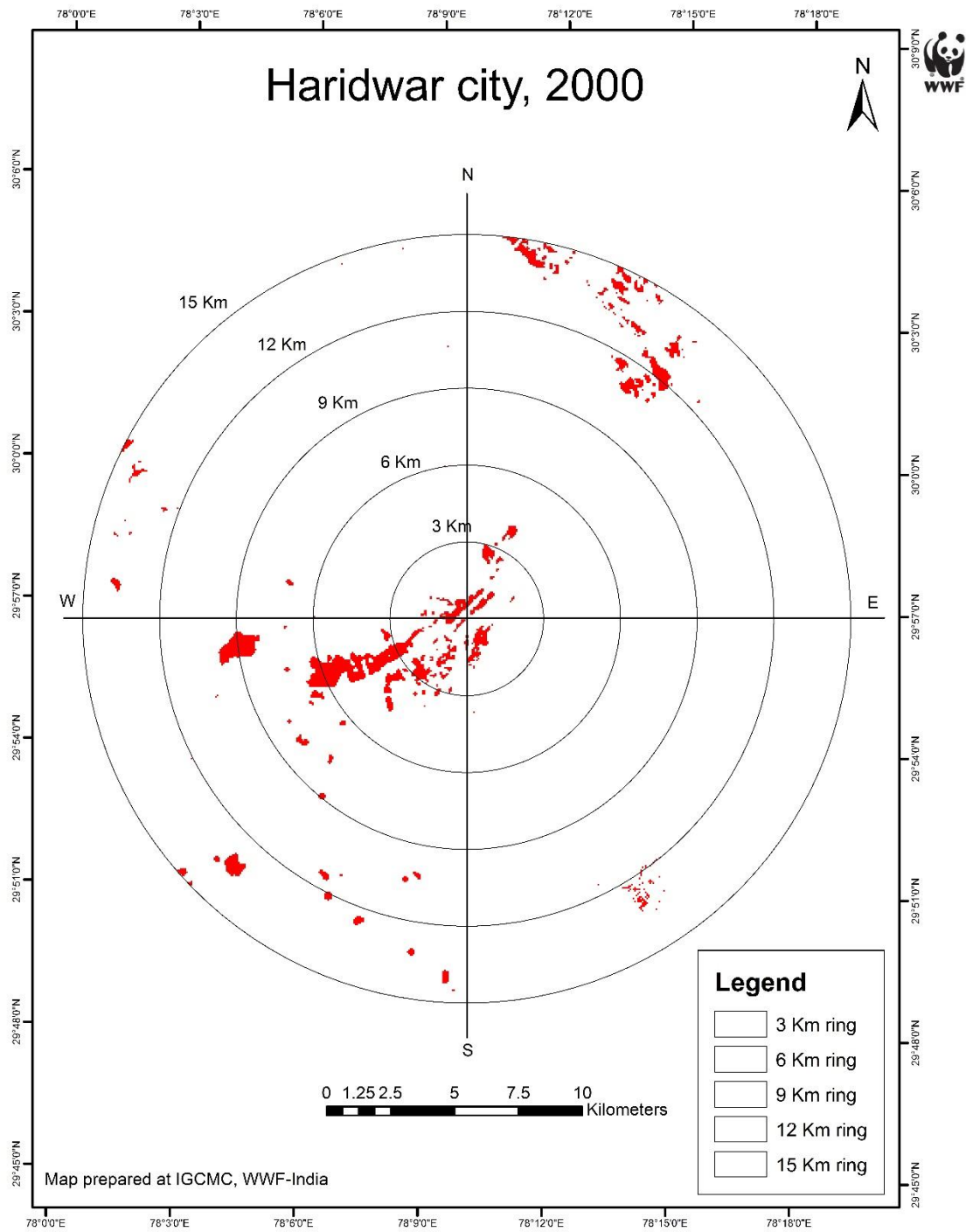


Plate 21: Haridwar city, 2000

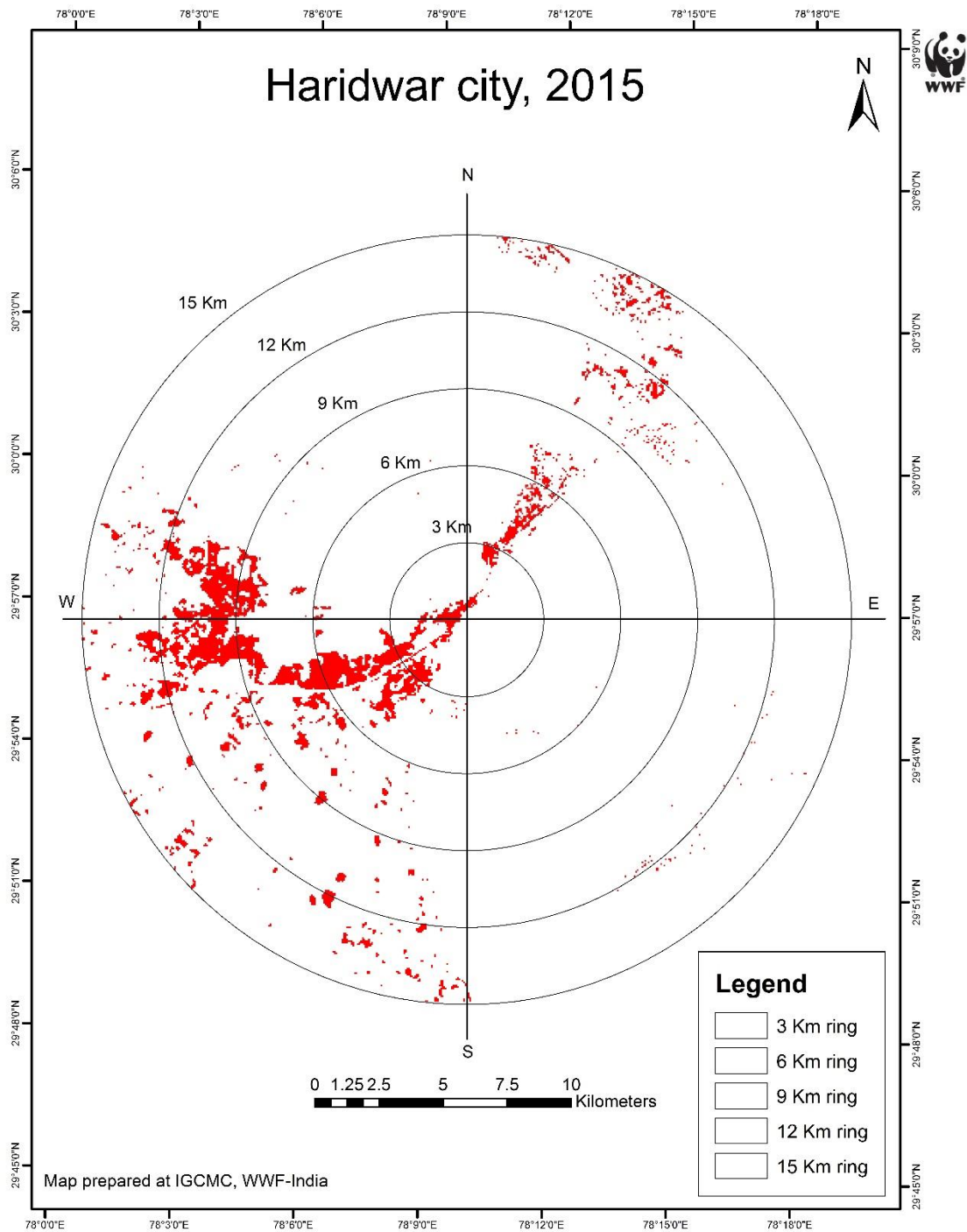


Plate 22: Haridwar city, 2015

Chapter 6 Conclusion

The state of Uttarakhand has experienced significant changes from year 2000 to 2015. In these fifteen there has been drastic change in the status of natural resources. The natural resources emphasized in this research work is forests. Mainly, forest resource degradation throughout whole of Uttarakhand has been studied about. Also, due to urbanization the cities are expanding immensely and therefore the one lakh cities of Uttarakhand have been focused to study the urban sprawl and the expanding cities. Through this work I tried to explain how the Landcover changes through time and how anthropogenic factors like urbanization effect the natural resources. How the forests are being converted into agricultural land to bear the pressure of growing population and how the agricultural land has been cleared off further and converted to urban area. The greed of human will never end, without thinking about the conclusion of our activities which are all so selfish and the kind which creates misbalance between various ecosystems and natural resources.

There has been significant changes in the land cover categories in the time period of 15 years, in some categories huge changes have taken place on the contrary there has been very minute increase or decrease in other classes. There has been drastic change in the dense forest. Dense forests have shifted because of the shift in the tree-line due to vast deforestation and urbanization and due to climate change. Agriculture pixels have changed been converted to Urban. Agricultural land is converted into urban area because of the expansion of the urban areas spatially. This is the evidence that urban areas are increasing day by day. For urban sprawl mapping the cities having population more than one lakh have been considered for this research work. The six one lakh cities which have been focused in this research work have also increased and spread drastically in all the directions. This has been the effect of increasing rate of urbanization. More and more agricultural land is being converted into urban area resulting in urban sprawl.

The state of Uttarakhand has experienced vast forest fragmentation and urban sprawl in 15 years. There has been severe degradation in the natural resources like forest resources due to anthropogenic factor. The greed of human beings has taken over the nature and ecosystems of Uttarakhand. If the trend of forest fragmentation continues at this rate in Uttarakhand then there would hardly be any forest cover left in Uttarakhand in the near

future. Government agencies and environmental agencies need to take over and look into this matter very seriously. This might not be able to rectify the damage caused till now but it will surely prevent any damage to the environment and ecosystems in future.

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