Forest cover assessment and change detection analysis using remote Sensing and GIS in Pir Panjal Forest Division of Kashmir Himalayan region

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Thesis

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DEDICATE MY THESIS

TO

“MY BELOVED PARENTS,

RESEARCHERS AND THOSE WHO WORK DAY AND NIGHT FOR FORESTS”

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Faculty of Forestry, Benhama, Ganderbal

Certificate – I

This is to certify that the thesis entitled, **"Forest cover assessment and change detection analysis using remote Sensing and GIS in Pir Panjal Forest Division of Kashmir Himalayan region"** submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science in Forestry,** to the **Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Yasir Amin (Regd. No. 2013-For-43-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that any help or information received during the course of investigation has duly been acknowledged.

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We, the members of the Advisory Committee of **Mr. Yasir Amin (Regd. No. 2013-For-43-M)** a candidate for the degree of **Master of Science in Forestry** have gone through the manuscript of the thesis entitled, **"Forest cover assessment and change detection analysis using remote Sensing and GIS in Pir Panjal Forest Division of Kashmir Himalayan region"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the award of the degree.

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ABSTRACT

Remote sensing (RS) techniques have proved to be powerful tool for the monitoring of various referred environmental features, such as vegetation cover, soil erosion, as well as urban expansion and more generally, the variations in the landuse/land cover (LULC) over a period of time. The use of remote sensing data in recent times has been of immense help in monitoring the changing pattern of forest cover. Mapping of LULC and change detection using remote sensing and GIS techniques is a cost effective method of assessment of forest area and forest density of an area. Drivers for deforestation and forest degradation like Agricultural expansion, timber extraction and logging activities account for more than 70% of total degradation worldwide.

This research was focused on assessing forest cover and analysis of change detection using remote sensing and GIS in Pir Panjal Forest Division of Kashmir Himalayan region of over an 10 year period i.e., from 2003 to 2013. LANDSAT ETM+ Satellite imageries (of 30 m resolution) were used and mapping was done using ARC-GIS software with a scale of 1:50000 and ERDAS Imagine was used for image processing. A total of 133 ground truth points were taken for data collection, which was used for accuracy assessment. The overall classification accuracy of the mapping was 92.48% and the kappa 0.87. The satellite data was delineated into 11 different landuse/landcover (LULC) viz., forest, forest scrub, grassland, agriculture, agriculture plantation/agroforestry, wetland, wasteland, horticulture, habitation, water body and snow. The different forest classes on the basis of crown density were delineated into closed forest, open forest, forest scrub and non-forest. The results obtained from change analysis were used to identify the drivers of forest cover change using a close ended semi-structured interview schedule. The responses were assigned scores for ranking of drivers using statistical analysis. Top ranking drivers led us to the critical drivers of change.

The result of the comparison of maps of 2013 and 2003 showed that the area under forest has decreased by 0.84%. The area under agriculture has decreased by 2% during the same period. The area under horticulture has increased by 1.26% from 2003-2013. It was also found that the area under closed forest has increased by 1.01% from 2003-2013.Area under open forest, forest scrub and grasslands has decreased by 0.08, 0.54 and 0.18% respectively during the last decade. The conversion of open forest into forest scrub was equal to 5.24 km^2 and into grasslands 1.02 km^2. The results from change matrix indicate a high forest degradation of closed forests to open forests (8.27 km^2) open forest into forest scrub (5.24 km^2).

The responses from respondents were taken at places experiencing change in forest cover (both negative and positive) were analyzed using statistical methods. The negative drivers of forest cover change were found to be illicit felling and poverty/unemployment. The positive drivers of forest cover change were found to be afforestation done by State forest department and high degree of forest protection. In general the study revealed that the forest area of Pir Panjal Forest Division has reduced in the last decade, most of the forests are in degraded condition. A check in timber smuggling, addressing the issues of unemployment, afforestation and highest degree of forest protection can control further degradation of the forests of the said division. There is a need to prioritize and act on the identified drivers of change by the concerned forest department so as to reverse the trend of deforestation and forest degradation in the study area

Keywords: Landuse/landcover, Forest cover density, change detection, remote sensing, GIS, Landsat ETM+, kappa, Pir Panjal, afforestation.

Signature of Student — Signature of Major Advisor

Dated: ___________ — Dated: ________________

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Place :

Date :

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ABBREVATIONS

AP	Aerial Photographs
ETM	Enhanced Thematic Mapper
EDC	EROS Data Centre
FCC	False Colour Composite
FAO	Food and Agriculture Organization
FSI	Forest survey of India
GIS	Geographical Information System
GPS	Global Positioning System
IRS	Indian Remote Sensing
LISS	Linear Imaging Self Scanning
km	Kilometer
LULC	Landuse/landcover
LULUCF	Landuse, Landuse change and Forestry
NASA	National Aeronautics and Space Administration
NRSA	National Remote Sensing Agency
RS	Remote Sensing
TM	Thematic Mapper
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey

Chapter-1

INTRODUCTION

Forest is a valuable resource providing food, shelter, wildlife habitat, fuel, and daily supplies such as medicinal ingredients and paper. Forests play an important role in balancing the Earth's carbon dioxide (CO_2) supply and exchange, acting as a key link between the atmosphere, geosphere and hydrosphere. The benefits of forests are both tangible and intangible. The chief economic product is timber, others being non timber forest products like resins, gums, medicinal herbs etc. their economic values have been calculated. The intangible benefits of forests like climate control, pollution abatement, and wildlife maintenance, have rarely been calculated. The forest is also vital as a watershed. Because of the thick humus layer, loose soil, and soil retaining powers of the trees forests are vitally important for preserving adequate water supplies. Almost all water ultimately feeds from forest rivers and lakes and from forest derived water tables. In addition, the forest provides shelter for wildlife, recreation and aesthetic renewal for people, and irreplaceable supplies of oxygen and soil nutrients. Forests are the renewable resources; occupy a place of considerable importance in our socio-economic development and are more popularly known as green gold.

The current United Nations Framework Convention on Climate Change (UNFCCC) definition of forest as adopted in 2005 for landuse, landuse change and forestry (LULUCF), in Decision 16/CMP.1 states, "Forest is a minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 per cent with trees with the potential to reach a minimum height of 2-5 meters at maturity in situ. A forest may consist either of closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground or open forest. Young natural stands and all plantations which are yet to reach a crown density of 10-30 per cent or tree height of 2-5 meters are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting or natural causes but which are expected to revert to forest". FSI (2011) defines forest cover as, "All lands, more than one hectare in area, with a tree canopy density of more than 10 per cent irrespective of ownership and legal status. Such lands may not necessarily be a recorded forest area. It also includes orchards, bamboo and palm".

According to Food and Agriculture Organization (FAO), the global rate of deforestation is reported to be 0.7% per year from 1990to 1995 (FAO, 1997).The net rate of forest loss in the tropics is 21 m ha, which means that about 1.2% of all remaining tropical forests were cleared annually (Myers, 1993). Nearly 1.8% of the forests is estimated to be degraded every year, the major cause being deforestation (Skole and Tucker, 1991). If the current rate of deforestation continues, the world's tropical forests will vanish within 100 years-causing unknown effects on global climate and eliminating majority of the species (NASA, 1998). Absence of reliable spatial datasets on deforestation is a major obstacle for modeling global environmental change (Murari, 1995). Monitoring of deforestation is perceived as the most important contribution of remote sensing technology to the study of global change (Chape *et al.*, 2005). In this back drop, the combination of remote sensing as well as GIS technology with ground surveys has emerged as a powerful tool to closely map and monitor the forest cover of these areas economically, accurately and repetitively within a short period of time. Considerable accuracy can be achieved through the combination of high-resolution satellite data, automated method and high level of human expertise (Townshed, 1995).

India has varying climate, thus diverse physio-geographic regions. These diverse regions support varying forest types. The forest cover as per different densities in India is given in Table 1.1 below.

Table-1.1: Forest cover of India

Class	Area km^2	Per cent of geographic area
Forest cover		
a) Very dense forest	83,502	2.54
b) Moderately dense forest	318,745	9.70
c) Open forest	295,651	8.99
Total forest cover	**697,898**	**21.23**
Scrub	41,383	1.26
Non forest	2,547,982	77.51
Total geographic area	**3,287,263**	100.00

[Source : FSI, 2015]

Jammu and Kashmir state is called paradise on earth. The state has varying agro-climatic zones comprising subtropical, tropical, temperate and cold zone resulting in rich variety of forests. Total geographical area of India is 32,87,263 km^2, having recorded forest area of 6,97,898 km^2 (Table 1.1). The total volume of growing stock in forest and in tree outside forest is 4498.731 and 1548.427 $m.m^3$ respectively. Total geographical area of Jammu and Kashmir is 2,22,236 km^2 with forests occupying 22,539 km^2 amounting to 10.14 per cent of total geographical area of the state. In Kashmir valley, area under forests is 11,488 km^2 (50.97%) and in Jammu and Ladakh area under forests is 10,343 km^2 (45.89%) and 36 km^2 (0.05%), respectively. The total volume of growing stock in Jammu and Kashmir in forest and in tree outside forest is 227.38 mm^3 and 147.74 mm^3 respectively. Coniferous forests occupy 40 per cent of the total growing stock while as 9.32 per cent is occupied by broad leaved forests (FSI, 2013).

Due to increasing population, forests throughout the world are facing tremendous pressure and Jammu and Kashmir forests are not an exception. With the ever-increasing population of state, forests have been placed under tremendous pressure arising out of increasing demand for fuel wood, fodder, timber and other forest products. This has resulted in acute degradation of forest resources (Wani *et al.*, 2014). Hence, there is an immense need of assessing the forest cover and detection of change in forest cover. The management strategies could be based on the results of forest cover dynamics. Though the state forest department of Jammu and Kashmir keeps on manually surveying and assessing the forest cover from time to time but the lack of appropriate data collected, analyzed and presented in a scientific manner has been a major weakness in these surveys in India (Singh, 1986) and Jammu and Kashmir in particular (Wani, 2008, Wani *et al.*, 2013). Hence the spatial changes that take place in the forests often go unnoticed. However if the forests are regularly monitored using Remote Sensing (RS) and Geographical Information System (GIS) technology, the observations could be a significant input into in the working plans for efficient management of forests.

Remote Sensing and Geographical Information System

Remote Sensing (RS) as defined by Lillesand (1979) is "the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in direct contact with the object, area or phenomenon under investigation". Remote sensing has emerged as an important tool for assessing the forest resources rapidly and remote sensing techniques are best suited to provide data in several key areas related to forest landscape patterns (Jensen, 2000).

The remote sensing satellite provides the best synoptic view with repetitive coverage of the forest landscape and hence through satellite data, it is possible to assess the forest cover density classes accurately. Using remote sensing data, forests can be stratified into homogenous sections making field inventory quite representative, efficient and cost effective. Using very high resolution satellite data, it is also possible to discern isolated patches of trees and other tree resources outside the forest. Remote sensing plays a significant role in mapping and monitoring of forest cover using visual, digital and hybrid techniques. Several studies have been carried out regarding applications of remote sensing technology (Mohan *et al.,* 1990; Navalgund, 2006; Navalgund *et al.,* 2007).

The GIS is powerful set of tools and an organized collection of computer knowledge and software with supporting data and personnel that captures, stores, manipulates analyses and displays all forms of geographically referenced information (Sabins, 1997). It involves following steps:

- Compilation of source data
- Georefrencing by registration to a geographic co-ordinate system
- Digitizing and deriving attributes
- Analysis of attributes
- Displaying results

Accurate and current information on landuse/landcover is essential for many planning activities. GIS uses computer technology to merge the remote sensing images with other data sets and to produce specially synthesized technological products, which can handle and analyze spatially referenced data. The potential uses of GIS in forest management and inventory are immense. This includes production, revision and updating of stock maps and accurate estimation of forest areas. Typical spatial information needed for forest management like administrative boundaries, infrastructure, forest characteristics are assessed and analyzed easily using GIS (Porwal *et al.*, 1989).

Remote sensing technology has emerged as an efficient and powerful tool in providing reliable information on various natural resources of a region in a spatial format so essential for planning (Roy *et al.*,1991). The use of Remote Sensing (RS) and GIS technologies can greatly facilitate the process of collection, analysis and presentation of resource data. Repeated satellite images and/or aerial photographs (AP) are useful for both visual assessments of natural resources dynamics occurring at a particular time and space as well as quantitative evaluation of landuse/landcover changes (Trapp and Mool, 1996).

1.1 Landuse/landcover mapping

Landuse/landcover change is a key driver of global change (Vitousek, 1992) and has significant implications for many international policy issues (Nunes and Auge, 1999). Changes in landcover and in the way people use the land has become recognized over the last 15 years as important global environmental changes in their own right (Turner, 2002).

Landuse is defined by economic, cultural, political, and historical and land-tenure factors at multiple scales. Landusereferred to as man's activities and the various uses which are carried on land.Landcover is referred to as natural vegetation, water bodies, rock/soil, artificial cover etc. resulting due to land transformation. As both landuse/landcover are closely related and are not mutually exclusive they are interchangeable as the former is inferred based on landcover and on their contextual evidence (Manonmani, 2010).

To prepare a landuse map using satellite data, image classification is a powerful method of information extraction. Successful use of satellite remote sensing for landuse/landcover change detection depends upon an adequate understanding of landscape features, imaging systems and information extraction methodology employed with relevant to the aim of analysis. The information may be obtained by visiting sites on the ground and/or extracting it from remotely sensed data. Many studies have demonstrated the effectiveness of using remotely sensed data as a powerful tool to detect landuse change for critical environmental areas, vegetation dynamics and urban expansion. Remote sensing makes a major technological breakthrough in the method of acquiring information on land resources, agriculture, forestry, ocean resources and other studies (Singh, 1989; Rao, 1991).

Landuse data are needed in the analysis of environmental problems that must be understood if living condition and standards are tobe improved or retained at current level (Anderson *et al.,* 1976). Landuse is a dynamic phenomenon and both its value and pattern change spatially and temporally with varying efficiencies, priorities and needs. The information on landuse/landcover patterns, their spatial distribution and changes over a time scale are the prerequisite for making development plans (Dhinwa *et al.,* 1992, Bisht and Tiwari, 1996). The use of remote sensing data in recent times has been of immense help in monitoring the changing pattern of forest cover. It provides some of the most accurate means of measuring the extent and pattern of changes in cover conditions over a period of time (Miller *et al.,* 1998). Satellite data have become a major application in forest change detection because of the repetitive coverage of the satellites at short intervals. Forest cover today is altered primarily by direct human use and any conception of global change must include the pervasive influence of human action on land surface conditions and processes. As indicated in their studies general information about change is necessary for updating forest cover maps and the management of natural resources (Mas, 1999).

1.2 Change detection

Change detection is a process of identifying changes in the state of an object or phenomenon by observing images at different times (Singh, 1986). Change detection studies seek to know pattern of forest cover change, processes of forest cover change and human response to forest cover change (IGBP/IHDP, 1999). Lambin and Strahler (1994) also listed five categories of causes that influenced forest cover change. The changes in forest cover are often the result of anthropogenic pressure (e.g. population growth) and natural factors such as variability in climate (Boakye *et al.,* 2008).

Remote sensing techniques offer benefits in the field of landuse/landcover mapping and their change analysis. One of the major advantages of remote sensing systems is their capability for repetitive coverage, which is necessary for change detection studies at global and regional scales (Miller *et al.*, 1998). Detection of changes in the landuse/landcover involves use of at least two period data sets. The changes in landuse/landcover due to natural and human activities can be observed using current and archived remotely sensed data. Landuse/landcover change is critically linked to natural and human influences on environment. With the availability of multi-sensor satellite data at very high spatial, spectral and temporal resolutions, it is now possible to prepare up-to-date and accurate landuse/landcover map in less time, at lower cost and with better accuracy (Jensen, 1996).

1.3 Drivers of forest cover change

Drivers of forest cover change are defined as the causes or factors of forest cover change, which may be either due to human activities agricultural expansion (subsistence and commercial), infrastructure expansion and wood extraction from forest or complex interactions of fundamental social, economic, political, cultural and technological processes that are often distant from their area of impact and afforestation and forest protection by various agencies from time to time (Kissenger *et al.*, 2012). Globally, forests cover about 4 billion hectares or 31% of the total land area. From 2000 to 2010, around 13 million ha of forest were converted to other landuses, mostly to agricultural land for commercial agriculture (32%) or subsistence farming (42%) (UNFCCC, 2007). These landcover and landuse changes are due to both sectoral and extra-sectoral drivers. While many changes in forest cover and condition originate from within the forest sector, the drivers that originate from outside the forest sector (extra-sectoral) can be more powerful than the sectoral drivers in shaping the future of forests and forestry. Prior analyses of the causes of forest conversion have led to the identification of direct and underlying causes of deforestation. Extra-sectoral influences, such as agricultural expansion, cattle ranching, mining, and gas and oil extraction, as well as construction of dams and roads, are considered as major direct drivers. Since the forest sector is more embedded in the global economy than ever, major industries have become predominant drivers of deforestation. In countries with high forest cover (e.g., Brazil, Cameroon, Indonesia), the expansion of markets into areas with large, contiguous forests has significantly contributed to deforestation, especially in old-growth forests. Such direct causes are often driven by underlying causes of forest decline, which include market failures, mistaken policy interventions, governance weaknesses, and broader socioeconomic and political causes. In addition, urbanization is also analyzed as an extra-sectoral driver of both deforestation and forest expansion within and outside of urban areas (Rudel, 2005).

Increasing populations, rising purchasing power and increasing levels of international trade are placing greater demands on forests. Road network development is widening accessibility and international investment in agriculture is driving new trends in rural economic activity. Extraction of forest products and establishment of agriculture and planted forests, are altering the extent and species composition of forests and reshaping the rural landscape. In general, low wages, rich soils, favourable climate and higher prices for agricultural goods motivate deforestation (Chomitz, 2007). Since the forest sector is more embedded in the global economy than ever, major industries have become predominant drivers of deforestation (Rudel, 2005).

The ever increasing demand of timber, fuelwood and fodder in the state of Jammu and Kashmir and the population expansion has had some unnecessary pressure on forests in the recent past (Wani *et al.,* 2015). Additionally the state forest cover hovering below 10% as reported by Forest Survey of India (FSI) is far away from the target as envisaged under State and National Forest Policy which indicates the level of anthropogenic pressure the state's forests are going through. Under such circumstances it becomes inevitable to have accurate data on quantity and extent of forest resources for building futuristic strategies towards conservation and climate change. Keeping in view the significance of the study and need of forest cover assessment in Kashmir, Remote Sensing and GIS techniques were used with Pir Panjal Forest Division being the study area.

The objectives of the study were three fold, viz.,

- To generate Landuse/Landcover maps of 2013 and 2003.
- To assess changes in forest density classes from 2003 to 2013.
- To identify drivers of forest cover change.

Chapter 2

REVIEW OF LITERATURE

Ecosystems are continuously changing, where change is defined as 'an alteration of the surface component of vegetation cover' (Milne, 1988). Deforestation leads to a drastic change in a forest ecosystem, seeking to identify statistically the determinants of deforestation, literature finds various factors and/or change drivers (Wulder *et al.,* 2007).With rising concern over environmental issues related to deforestation, increasing efforts are being made by ecologists, economists, geologists etc. in order to understand causes of changes in ecosystems in general and that of deforestation in particular (Roy *et al.*, 2010). A lot of workers have made a significant contribution in the proposed field of study. Keeping in view the multiple perspectives of the study, an account of literature was reviewed under different headings as given below.

2.1 LULC/forest cover mapping

In India National Remote Sensing Agency (NRSA), in the year 1984, with the help of satellite remote sensing technology prepared for the first time forest vegetation map of the country at 1:1 million scale by visual interpretation. In 1986, the mandate to prepare forest cover maps of the country on two year cycle using remote sensing technology was given to Forest survey of India. In 1987, first forest report was prepared by Forest Survey of India. In 1989, mapping was done at a scale of 1:250,000, with minimum mappable unit (mmu) of 25 ha. Presently 1:50,000 scale is used and minimum mappable area is 1 ha. Since 2002, NRSA has been using a high resolution of 5.8m by 5.8m for assessment of tree outside forest cover (FSI, 2013).

Negi (1984) analyzed the rate of forest recession in Garo hills of Meghalaya which is prone to heavy shifting cultivation (Jhum) by using remote sensing techniques viz., aerial photographs and Landsat data subsequently pertaining to year 1973 and 1977. It was observed that annually 4.5% area under tree forest recedes by the way of shifting cultivation alone. Landsat data provide repetitive data periodically which helps in monitoring changes in landuse patterns in less time and at low cost. Application of Landsat data is recommended for such type of studies to have accurate data for regional development planning.

The forest survey of India presented forest cover scenario of India based on visual interpretation of Landsat imagery pertaining to the period 1985-87. The assessment revealed that actual forest cover of the country was 64.01 million ha thereby showing a loss of 0.19 ha from previous assessment. The study also revealed that there has been some increase in the extent of dense forest cover i.e., forest cover with a density of 40% or more. It has increased to 37.84 million ha from 36.14 million ha (FSI, 1989).

Dale *et al.* (1991) estimated the effects of landuse change on CO_2 Concentration at global level. They researched on South and Southeast Asia because the region is a victim of major landuse changes and makes a significant contribution to the global CO_2 concentration.

The forest survey of India assessed the forest cover of the country, Landsat imagery pertaining to the period 1987-89 on a scale of 1:250,000. The extent of forest cover in India was revealed to be 19.44% of the total geographic area of the country. It was during this assessment that the district wise estimation of forest cover was recorded (FSI, 1991).

Zhu and Waller (2000) produced a global forest cover map under FRA program of 2000 in order to provide spatial context to the extensive survey. The forest cover map, produced at the U.S Geological Survey (USGS) EROS Data Centre (EDC) has five classes: closed forest, open forest, other wooded forest, other landcover and water. The first two forested classes at the global scale were delineated using combinations of temporal composition, modified mixture analysis, geographic stratification etc. the remaining three classes were derived primarily from USGS global landcover database (Loveland *et al.*,1999). The first four classes had an accuracy of 77 and 86% for the other.

Sharma *et al.* (2001) studied interpretation of multi-date satellite imagery and revealed changes in landuse/landcover pattern in Godavari deltaic region during the past 26 years. The study showed that the area under intensive agriculture has increased from 1459 to 3500 km^2 and the extent of wetland from 368 to 648 km^2 during 1973-1999, while the seasonal fallow has decreased by 2321 $km^{2.}$ Climatic data of the study area was also analyzed which indicated that the daytime temperatures have increased by 0.4^{o}C during past 30 years. They concluded that the varying trends in the climatic parameters are attributed to increased vegetation cover and wetland extent in the Godavari deltaic region.

Jayakumar and Arockiasamy (2003) attempted landuse/landcover mapping and change detection in Kolli hills, part of Eastern Ghats in Tamil Nadu using Remote sensing and GIS. They observed an increase of 467ha in single crop category and a decrease of 434 ha in land with or without scrubland. Lesser changes could be noticed in double crop, plantation and barren rocky categories.

Dewidar (2004) used two sets of landsat thematic mapper TM data inorder to study landuse/landcover along the study area. Owing to high spatial resolution, spectral resolution and low repetitive acquisition (16 days) TM data is useful for this type of study. Many methods used were assessed and checked in field. Nine landuse/landcover classes thus produced had an accuracy of 78% for an image of 1984 and 80% for an image of 1999.

Li *et al.* (2004) investigated landuse change dynamics by combining use of remote sensing and geographical information system (GIS). Their objectives were to determine landuse transition rates among landuse types in Yulin prefecture over 14 years from 1986-2000 and to derive change matrics. They used 30m resolution Landsat Thematic Mapper (TM) data and Chinese images were classified into 6 landuse types: cropland, forestland, water, urban and/or built up land, and barren land. They found that the significant decrease in barren land was primarily due to conversion to grasslands. They found that landscape has become more continuous, clumped and more homogenous. The study demonstrated that the integration of satellite remote sensing and GIS was an effective approach for analyzing the direction, rate and spatial pattern of landuse change.

Linkie *et al.* (2004) mapped rate and pattern of Sumatra's lowland areas. Satellite imagery was used to map and analyze forest loss in an area that overlaps with a national park at Sumatra. The basic objective of the study was to identify the areas susceptible to illegal logging. From 1985-1992 forest located to the lower elevation and close to the road was most vulnerable to felling. Construction of road through the study area increased the rate of deforestation from 1.1% to over 35% per year over the two study periods. It was also established that such an approach of research could be more widely used in conservation, planning and protection of under threat sites.

The Landsat programme is the oldest Earth Observation programme. It started in 1972 with Landsat-1 satellite carrying the MSS multispectral sensor. After 1982, Thematic Mapper (TM) replaced the MSS sensor. Previous studies have indicated that remote sensing technology can complement and enhance the quality of estimates besides saving lot of money and time (Whittaker, 1966; Tiwari, 1995; Benchalli and Prajapati; 1998). A lot of work has been previously done on forest density mapping using visual and digital mapping techniques (Porwal and Pant, 1989; Joshi *et al.*, 2002; Roy *et al.*, 2002; Wani, 2008; Wani *et al.*, 2009).Some earlier works have also been carried out on forest cover/type and forest density mapping in the Kashmir Himalayan region (Joshi *et al.*, 2001;Wani *et. al.*, 2014). Some works have used visual interpretation techniques using Landsat TM, ETM+ data (Wani *et al.*, 2014; Wani *et al.*, 2014).

Assessing forest canopy cover is readily accessible due to advancement in remote sensing technology and availability of many sources of imagery and various digital classification techniques. Banerjee *et al.* (2014) estimated large area tree canopy density at spatial resolutions of 30m coarse resolution satellite images and tested the FCD model by using LANDSAT TM image in an old growth forest of north forest division of India. It was observed that the overall accuracy for classified TM image is 80.00% and Kappa Coefficient was 0.7360.

Deilami *et al.* (2014) conducted a research to detect and monitor landuse/landcover change in Iskandar Malaysia using remote sensing and GIS. Maximum likelihood supervised classification technique and a post-classification change detection strategy were employed for spotting and monitoring landuse/cover changes. Four classes of landuse and landcover classes were identified and mapped as forest, oil palm, urban and water body. They also reported that forest cover and urban area had increased by almost 16.74, 3.94 and oil palm area had decreased by almost 8.57.

2.2 Change detection

Das *et al.* (1996) have attempted forest cover and riverbed changes by using temporal aerospace data of the year 1960 and 1993. PAMAP GIS has been used for change detection analysis. They observed that the landcover changes are mainly due to biotic factors. Some of the important in the forest cover are; transformation of mixed forest to scrub forest in 67 ha, the Sal mixed and mixed Sal forest categories have replaced Sal forest in 262 ha, significant increase in forest plantations i.e. 2075 ha in the year 1960 to 3793 ha in the year 1993, the eighteen times increase in Chirpine are, it increased from 13 ha in 1960 to 230 ha in 1993. The consequential change in riverbed with boulders increased by 87 ha.

Chauhan *et al.* (2003)revealed the change in vegetation cover in Sal dense to Sal medium and sal open in 6 mosiacs owing to biotic and abiotic conditions prevailing in specific areas. They used thematic map derived from aerial photograph of 1976 and satellite data of IRS 1C LISS 111 False Colour Composite (FCC) of March 1999 revealed the cause for change in forest density classes. They noticed a remarkable change among vegetation classes from 1976 to

1999. Forest type and density map revealed that Sal density has significantly reduced from Sal Dense 65.61% in 1976 to Sal Dense 11.12% in 1999. The overall change has been estimated to be 42.115 of the total forested area.

Coppin *et al.* (2004) analyzed the digital change detection from three perspectives. First the perspective from which the variability in ecosystem and the change events have been dealt with. Second, pre-processing routines either to establish a more direct linkage between remote sensing data and bio-physical phenomena are analyzed. Third, the actual change detection methods themselves are categorized in analytical framework and critically evaluated. It thus summarizes the new developments that can be expected in near future.

Guild *et al.* (2004) compared change detection techniques for identifying deforestation and grazing rates during colonization era and farm expansion in the vicinity of Jamari, Rondonia. They used multi-date land satthemetic mapper (TM) data between 1984 and 1992 for examining 94,370 ha area of active deforestation to map landcover change. The multi-date TC composite classification had an accuracy of 0.78 (kappa). By 1984, only 5% of the study area had been cleared, but by 1992, 11% of the area had been felled, specifically for pasture, 7% lost due to flooding.

Lu *et al.* (2004) also analyzed change detection techniques. Previous reviews had shown that image differencing, principal component analysis (PCA) and post classification comparison are the most common methods used for change detection analysis. Different change detection methods have their own advantages and disadvantages and no single approach is optimal and applicable to all cases. In practice, different methods are often compared to find the best change detection results for a specific application. Race of change detection is still an active topic and new techniques are needed to efficiently use the increasingly complex and diverse remotely sensed data available.

Vina *et al.* (2004) analyzed the satellite change detection of deforestation rates and patterns along the Columbia-Ecuador border. Landsat data was used to study the rates and patterns of landcover change along a portion of the said border between 1973 and 1996. Human settlements have resulted in extensive deforestation in both countries. It was observed that the annual rates of deforestation were considerably higher for the Columbian side of the border. Change detection analysis revealed that loss of forest cover on Columbian side was 43%, while as 22% on Ecuadorian side. The study of drivers of change revealed that the higher rates of deforestation on Columbian side were due to higher colonization pressure and intensification of illegal coca cultivation.

Yuanbo *et al.* (2004) studied by comparing image differencing, image rationing, image regression from a mathematical perspective. Error analysis showed that no change pixels with errors are expected to be located within error zone in bi-temporal space.

Yen *et al.* (2005) assessed the major forest cover changes using remote sensing imagery (Landsat: MSS, TN, +ETM) between the years prior to the establishment of national park status and the years following. From 1973 to 2001 it was noticed that 45% of the buffer zone was modified, or lost its forest cover with most changes occurring around 1989, just before park establishment. These changes can most likely be attributed to forest and resource extrapolation that coincided with a high human population density.

Assessment of forest cover on continuous basis is of utmost importance. Firstly, it helps us to understand status of forests and secondly to evaluate our earnest efforts of greening our land. Nowadays remote sensing plays a pivotal role in forest cover assessment and change detection (Negi, 2009).

Aasim *et al.* (2014) used Landsat 5, Landsat ETM+ 7 and IRS LISS 4 data for the year 1992, 2001 and 2012 for geospatial monitoring of Pir Panjal forests. Change detection analysis of the study area 475 km^2 revealed that during the past four decades (upto 2012), the area under forests has decreased by 4.98% out of total area from 1972-2012.

Ahmadizadeh *et al.* (2014) used remote sensing and GIS for landuse and change detection analysis from 1986 to 2010 in Brijand Iran. They used confusion matrix to detect changes ('from' to 'to') in defined landuse classes. They found that the area under pastures has got converted into barren land.

Sreenivasulu *et al.* (2014) worked on landuse/landcover and change detection in Rajampet Kapada district Andhra Pradesh, India. The mapping was done at a scale of 1:50000 and the softwares used were Erdas Imagine and Arc GIS. They found expansion of built up area and encroachments in forest area in the previous decade. The dense forest had got converted into open forest and open forest area has increased 0.55 and 0.47% respectively during the time period.

Kayat and Pathak (2015) worked on landuse/landcover change detection in Saranda forest in Jharkhand between 1992, 2005 and 2014. They used ERDAS Imagine and Arc GIS softwares for the purpose. The overall result which they found was that the forest is getting converted into other landuse classes. Intersection method revealed that 0.58% of the dense forest area has got converted into open forest during the study period. The present revision the overall classification accuracy was found to be 88.54% in 1992, 89.23% in 2005 and 90.03% in 2014.

2.3 Drivers of change

Ali *et al.* (2008) analyzed myths and realities relating to deforestation in North-West Pakistan. They found that 90% of the population of the study area were living below poverty level and using fuel wood obtained from forests for cooking food. Results also indicated that unemployment was the main cause if timber smuggling. The main drivers to deforestation were found to be poverty, illiteracy, less degree of protection by forest department.

The major drivers of forest cover changes in India are shifting cultivation along with encroachment for agriculture land, mining quarrying, expansion of settlements, dam construction and illegal logging (Lele and Joshi 2009; Reddy *et al.*, 2013).

Hosonuma *et al.* (2012) worked on deforestation and drivers of forest cover change in developing countries. Driver data of 46 countries were summarized for each phase and by continent, and were used as a proxy to estimate drivers for the countries with missing data. The deforestation drivers are similar in Africa and Asia, while degradation drivers are more similar in Latin America and Asia. Commercial agriculture is the most important driver of deforestation, followed by subsistence\ agriculture. Timber extraction and logging drives most of the degradation, followed by fuelwood collection and charcoal production, uncontrolled fire and livestock grazing. The results reflect the most up to date and comprehensive overview of current national-level data availability on drivers, which is expected to improve over time within the frame of the UNFCCC REDD process.

Louman (2012) worked on Forest Biodiversity and Ecosystem Services: Drivers of Change, Responses and Challenges. He found that the conversion of forests into agricultural lands, over-exploitation, air pollution leading to climate change and acid rain, and invasive species, all cause great stress on forest ecosystems. Conscious of the negative effects of human activities, society has responded by increasing the area of protected and well-managed forests, and by incorporating management of trees and forest patches into the management of agricultural landscapes. Still, most natural forests and agricultural landscapes are not well managed and their existence continues to be threatened by these same four drivers.

Goll *et al.* (2014) worked on drivers of deforestation and forest degradation in Liberia and found that chief drivers of deforestation and forest degradation in Liberia were (as per ranking) fuelwood collection, Charcoal production, Bushmeat trade, mining, commercial logging, agricultural expansion and urbanization and unemployment.

FAO (2015) has assessed global forest resources in 2015 and found thatover the past 25 years forest area has changed from 4.1 billion ha to just under 4 billion ha, a decrease of 3.1 per cent. The rate of global forest area change has slowed by more than 50 per cent between 1990 and 2015.The main driver of deforestation was found to be illegal fellings for sustenance and unemployment.

Shah and Sharma (2015) worked and landuse change detection and forest degradation causes in Solan forest. They used LISS 3 satellite data to assess landuse and forest degradation from 1998-2010. They found area under forests has been decreased during the study period. The conversion rate from forest to bamboo cultivation was high because of the high anthropogenic pressure (to meet their livelihood demands).

Chapter 3

MATERIAL AND METHODS

3.1 Study area

The present study **"Forest cover assessment and change detection analysis using remote sensing and GIS in Pir Panjal forest division of Kashmir Himalayan region"** was carried in Pir Panjal Forest Division.

3.1.1 Location of study area

The total number of forest divisions in Jammu and Kashmir is 30. Pir Panjal forest division is located on south-western part of Kashmir and falls in Srinagar circle. It has 3 territorial and 2 non territorial ranges, there are 16 and 10 territorial and non-territorial blocks respectively. The study will be done on Pir Panjal forest division. The forest division is situated between 33^{o} $44'$ North Latitude and 74^{o} $24'$ East longitude covering an area of about 429.9 km^2. Romshi Nallah acts as a natural separating body to distinguish it from Shopian forest division in the south-east while as in the North-West, it is Bahak Nallah which separates this division from Tangmarg forest division. The forests of this division are spread over the administrative districts of Pulwama, Srinagar and Budgam represented over topo sheets of Forest Survey of India on the scale of 1:50,000 (FSI, 2013). The Pir Panjal Forest Division comprises of four ranges as:

1. Doodhganga Range with its head quarter at Chadoora
2. Raithan Range with its head quarter at Raithan
3. Sukhnag Range with its headquarter at Arizal
4. Budgam soil range with its headquarter at Budgam

3.1.2 Configuration of study area

Forests of this Division are mainly spread over Pir Panjal mountain tract. Tatakuti with an altitude of 4745 m is the highest mountain peak on extreme

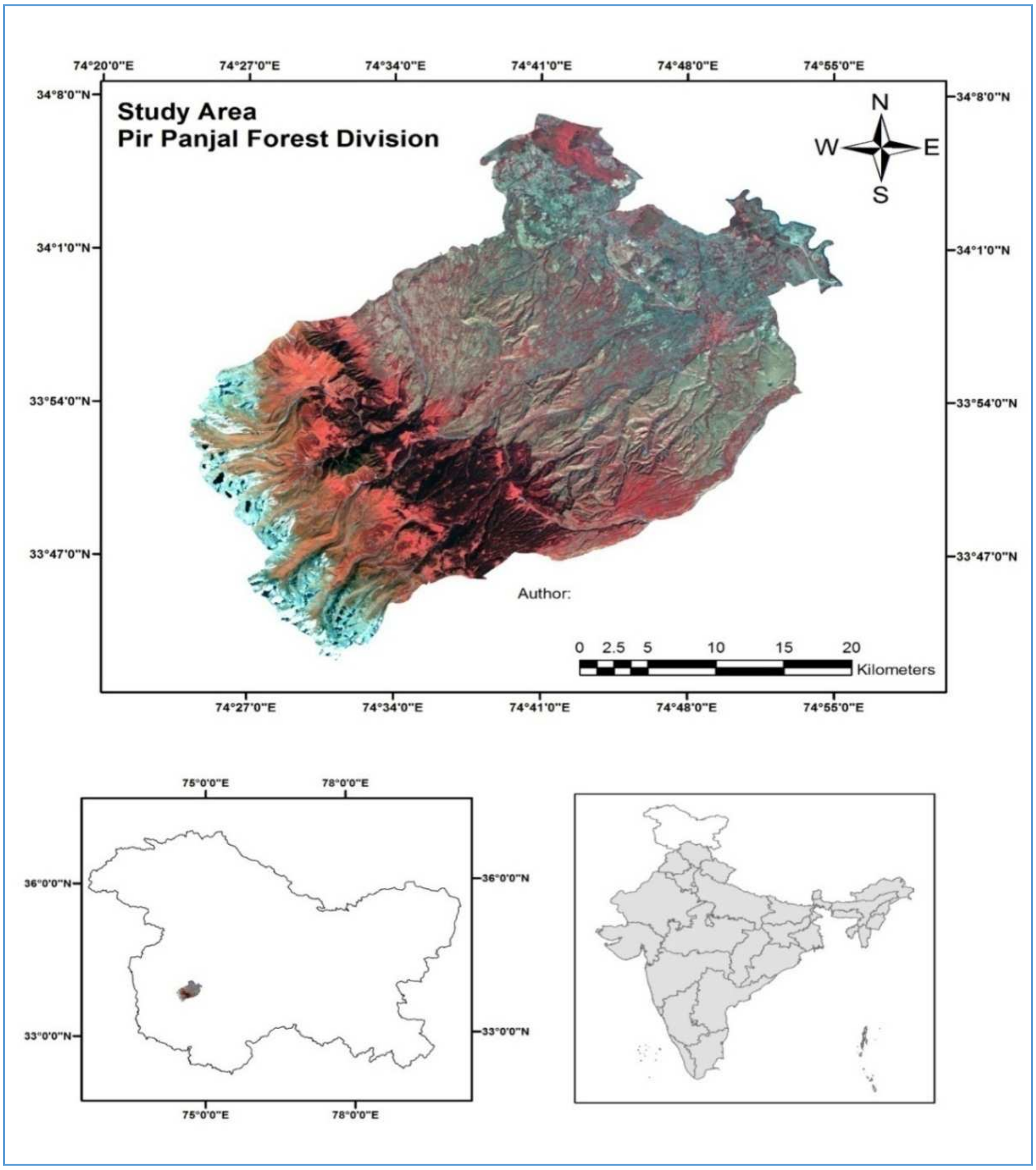

Fig. 3.1: Study area- Pir Panjal Forest Division

North-West of this division. The glacier formation between Tatakuti and Ashidar Gali forms perennial water source base for Ashidar Nalla in the highest rugged zone. Other peaks of prominence falling on western ridge are Shilmahinu (4612 m), Nurpur Naza (4502 m), Shivnag (4359 m), Kharanag (4341 m) etc. Some of the important meadows are Tosamaidan, Yousmarg, Doodhpathri, Chhanz, Bargamaidaan etc.

While the southern face of Pir Panjal mountain range is steep and precipitous, the Northern face constituting the Pir Panjal forest division is gently sloping. Though the general topography varies from gentle to moderate, yet some steep and precipitous slopes do occur. Towards the foot of the mountains fan like projections run at a very gentle angle towards the valley. These are known as 'Karewas'.

The study area lies between elevations of 1820 to 4745 m, however the tree belt occurs between 1820 to 3200 m.

3.2 Lab Work

1) Satellite data

- Landsat ETM+

Table 3.1: Specifications of Landsat ETM+ sensor

Sensor	Landsat ETM+
Spatial resolution	30 m (60 m - thermal, 15-m pan)
Spectral range	0.45 - 12.5 µm
Number of bands	8
Temporal resolution	16 days
Image size	183 km × 170 km
Swath	183

2) Software

- Image processing software (ERDAS Imagine)
- Mapping software (ARC GIS)
- Statistical for data analysis

3.3 Field work

- GPS (Ground truth location, Latitude/Longitude/Altitude)
- Spherical crown densiometer (crown density)
- Abney's level (slope)
- Pegs (Laying tree plot)
- Rope (Laying tree plot)
- Map prints (ground truthing)

3.4 Methodology

The following method was adopted to fulfill the first objective:-

a) Procurement of satellite data : Satellite data was procured from United States Geological Survey (USGC).

b) *Preprocessing of satellite data :* The satellite data procured was preprocessed for different making a False Color Composite (FCC) with the desired band combinations using image processing software. Different image enhancement techniques were also employed for better interpretation of different landuse types.

c) Preliminary survey : Preliminary survey was carried out in the study area to get the first hand information about the landuse, vegetation types and biodiversity, topography, accessibility etc. The information generated was used to decide about the nature of mapping to be done and the number of landuse classes to be delineated.

d) *Landuse/landcover map/Forest density map (2013/2003) :* Mapping of satellite data was carried out using a mapping software at 1:50000 scale. The satellite data was delineated into different landuse types (LULC) and different forest classes on the basis of crown density as follows:

LULC Map

i. Forest
ii. Forest scrub
iii. Grassland
iv. Agriculture
v. Agricultural Plantation/Agroforestry
vi. Horticulture
vii. Habitation
viii. Water body
ix. Wetland
x. Wasteland
xi. Snow

Forest density Map (FSI, 2005)

i. Forest (closed) 40-70% crown density
ii. Forest (open) 10-40% crown density
iii. Forest scrub< 10% crown density
iv. Grasslands
v. Non forests

a) *Accuracy Assessment :* The forest density map generated using the required software was validated on the ground through ground truth points. The following information was collected from the ground for accuracy assessment:

i. Forest type

ii. Latitude/longitude

iii. Altitude (m)

iv. Crown density

v. Slope (%)

b) *Accuracy assessment for validation of maps :* The producer's accuracy and overall accuracy of the forest type density maps was generated using error matrix and on the basis of these accuracies KAPPA (khat coefficient) was also be calculated. *Producer's accuracy* is a measure of error of omission and *User's Accuracy* is a measure of error of commission. KAPPA analysis is a discrete multivariate technique used in accuracy assessment (Congalton *et al.*, 1983).

$$\text{Producer's accuracy} = \frac{\text{No. of correctly classified pixels in each category}}{\text{Total No. of validation points used for that category (column total)}}$$

$$\text{User's accuracy} = \frac{\text{No. of correctly classified pixels in each category}}{\text{Total No. of validation points used for that category (row total)}}$$

$$\text{Overall accuracy} = \frac{\text{No. of correctly classified pixels}}{\text{Total No. of validation points}}$$

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

Where

k = Kappa coefficient

r = number of rows in the error matrix

N = Number of observations

x_{ii} = the number of observations in row *i* and column *i* (on the major diagonal)

x_{i+}= total number of observation in row *i*(shown as marginal total to right of the matrix)

x_{+i}= total number of observation in column *i*(shown as marginal total at bottom of the matrix)

The following method was adopted to fulfill the second objective:-

a) *Generation of forest change maps and change matrices :* The forest density maps generated for 2003 and 2013 was used to generate a change map and change matrices using the intersection method in an image processing.

b) *Analysis of change matrices :* The change areas were identified and the percentage of area transferred to the other category were assessed for the time period.

The following method was adopted to fulfill the third objective:

The results obtained from change analysis were used to identify the drivers of change. The change in different categories was assessed for identification of drivers of deforestation. The whole methodology, as per objectives has been shown in Fig. 3.2

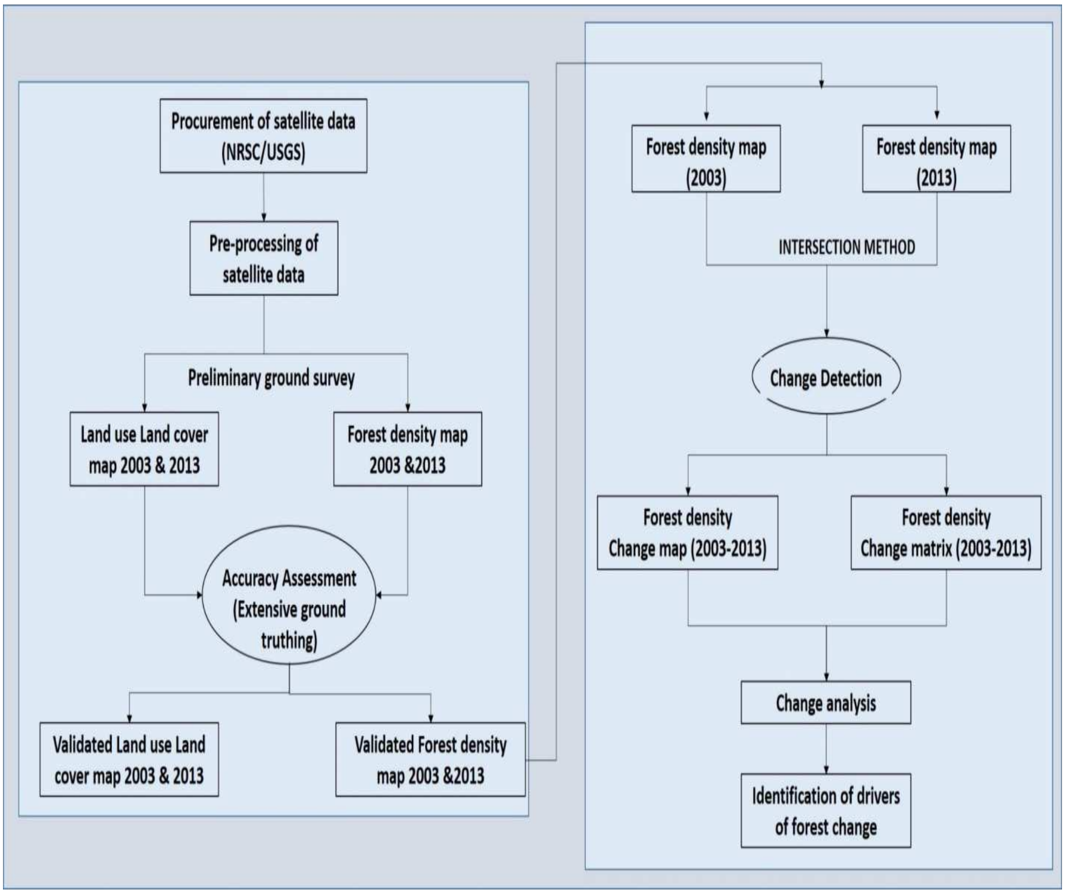

Fig. 3.2: Schematic representation of methodology

Chapter 4

EXPERIMENTAL FINDINGS

4.1 Landuse/Landcover

Landuse/Landcover map (2013) reveals that there has been a significant change in landuse from 2003-2013 in Pir Panjal forest division. The percentage of land under builltup class has increased from 4.10% in 2003 to 5.05% in 2013. The percentage of area under water bodies has increased from 2.35 to 2.39% from 2003 and 2013. The wetland area has shown a decrease from 3.18 to 2.76% from 2003 to 2013. The percentage of area under horticulture has shown a sharp increase from 18.98 in 2003 to 20.24% in 2013. The area under forest has decreased from 19.12 to 18.28% during 2003 to 2013. Likewise forest scrub area has shown an increase from 11.25 to 11.79% between 2003 and 2013. The percentage of area under agriculture has decreased from 28.05 to 26.05% from 2003 to 2013. The area under grasslands has increased from 2.94% in 2003 to 3.12% in 2013. Agricultural plantation area has seen a sharp decrease from 2.95% in 2003 to 2.70% in 2013. Percentage of area under wastelands have shown a slight increase while as snow bound area has remained unchanged at 6.77% between 2003 to 2013 (Table 4.1 and 4.2). Landuse/landcover map (2003) versus Landuse/landcover map (2013) depicted that the area under forests (designated by dark green colour) has reduced as shown in Fig. 4.1 and Fig. 4.2. Different colours have been used to designate various landuse/landcover map.

Table-4.1: Landuse/Landcover of Pir Panjal Forest Division (2003)

Class	Area (km^2)	%age
Agricultural plantation	33.62	2.95
Agriculture	319.82	28.05
Builtup	46.72	4.10
Forest	218.04	19.12
Forest scrub	128.25	11.25
Grassland	33.55	2.94
Horticulture	216.38	18.98
Snow	77.14	6.77
Wasteland	3.61	0.32
Water body	26.81	2.35
Wetland	36.24	3.18
Total	**1140.17**	**100**

Table-4.2: Landuse/Landcover of Pir Panjal Forest Division (2013)

Class	Area (km^2)	%age
Agricultural plantation	30.83	2.70
Agriculture	297.06	26.05
Builtup	57.54	5.05
Forest	208.38	18.28
Forest scrub	134.37	11.79
Grassland	35.63	3.12
Horticulture	230.77	20.24
Snow	77.14	6.77
Wasteland	9.70	0.85
Water body	27.26	2.39
Wetland	31.51	2.76
Total	**1140.17**	**100**

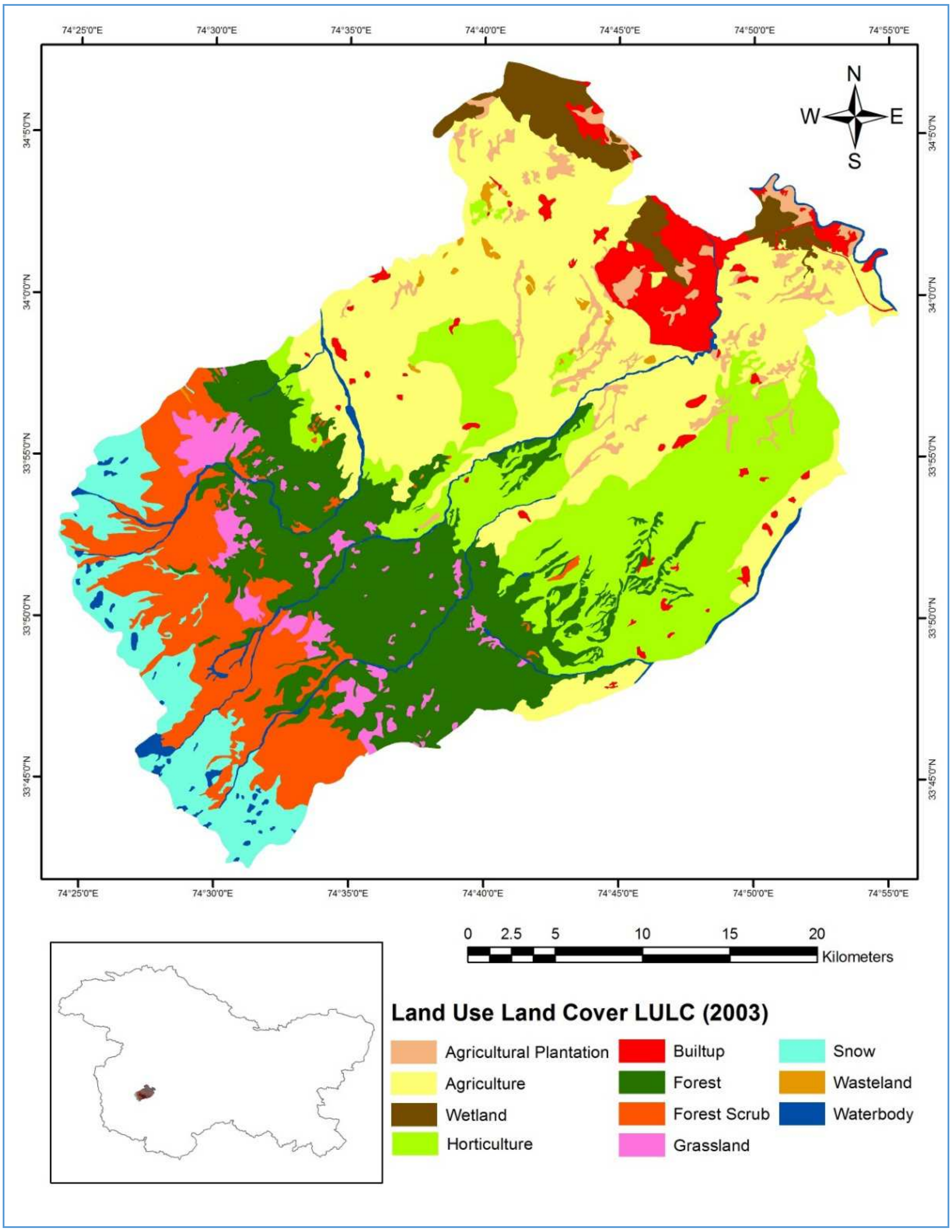

Fig. 4.1: Landuse/Landcover map (2003) of Pir Panjal Forest Division

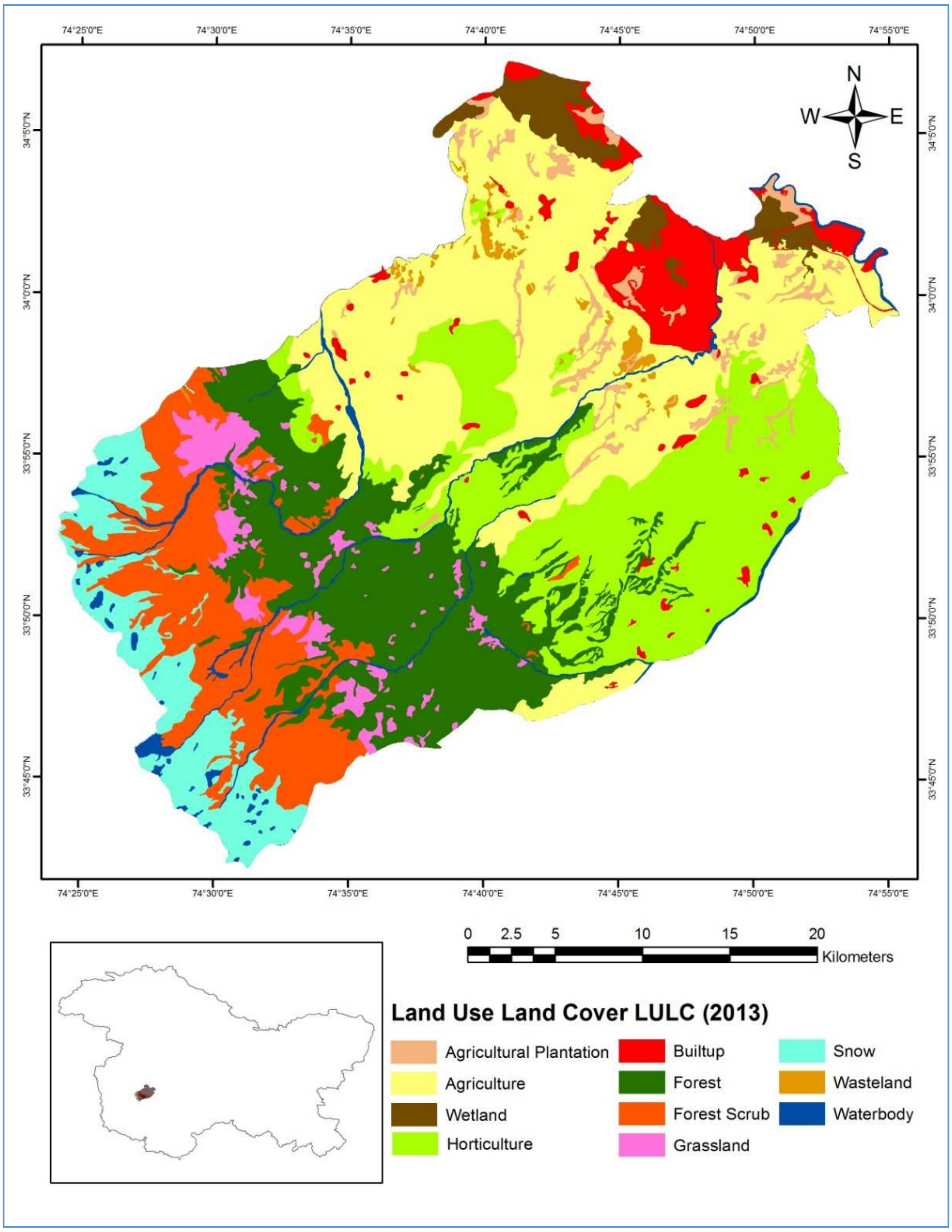

Fig. 4.2: Landuse/Landcover map (2013) of Pir Panjal Forest Division

4.2 Forest cover density

Forest cover density of Pir Panjal Forest Division of 2013 and 2003 has been shown in Table 4.3 and Table 4.4 respectively. Out of 1140.17 km^2 non forest occupied 66.81% of the total area in 2013 while as the same category occupied an area of 66.69% of the total area of the division in 2003. The percentage of area under open forest category in 2013 was 5.40% while as it was 5.32% of the total area in 2003. Forest scrub category witnessed a slight decrease from 11.79% of the total area in 2003 to 11.25% in 2013. The area under closed forest has decreased by 1.07% of the total area of the forest division.

The forest cover density maps of 2013 and 2003 have been shown in Fig. 4.3 and Fig. 4.4, respectively. The area under non forest category is maximum covering an area of 760.33 km^2 i.e., 66.69% of the total area, thus covers maximum portion of the map.

Table 4.3: Forest cover density Pir Panjal Forest Division for the year 2013

Forest category	Area (km^2)	% of total area 2013
Non-forest	761.79	66.81
Open forest	61.55	5.40
Forest scrub	134.37	11.79
Closed forest	146.83	12.88
Grassland	35.63	3.12
Total	**1140.17**	**100.00**

Table 4.4: Forest cover density Pir Panjal Forest Division for the year 2003

Forest category	Area (km^2)	% of total area 2003
Non-forest	760.33	66.69
Open forest	60.60	5.32
Forest scrub	128.25	11.25
Closed forest	157.44	13.81
Grassland	33.55	2.94
Total	**1140.17**	**100.00**

The forest cover status (km^2) under different forest categories for the years 2003 and 2013 has been shown above in Figs. 4.5, 4.6 and 4.7. The figures reveal that the area under forest scrub is lesser in 2013 than in 2003, however the trend is reverse in case of open forest category where the area under open forest is more in 2013 than in 2003. The figures further reveal that the area under non forest category, open forest and grassland category has remained broadly unchanged with no significant increase or decrease in area under these categories as shown in histogram chart and two pie charts above (Figs. 4.5, 4.6 and 4.7).

4.3 Accuracy assessment

The total number of reference points (ground truth points) for accuracy assessment and map validation was 133 at various places of the study area (Fig. 4.8). Table 4.5 shows the error matrix for forest density map of 2013 for Pir Panjal forest division, which was used to calculate overall classification accuracy. The overall classification accuracy of forest density map of 2013 came out to be 92.48%. The overall classification accuracy of forest density map 2013 was calculated on the basis of producers accuracy and users accuracy as shown in Table 4.6.

The conditional kappa for each category was calculated using kappa formula. Kappa for non-forest, open forest, forest scrub, closed forest and grassland category was found to be 0.8549, 0.839, 1, 0.9035 and 0.8992 respectively. The overall kappa statistics was calculated as 0.8757 as shown in Table 4.7.

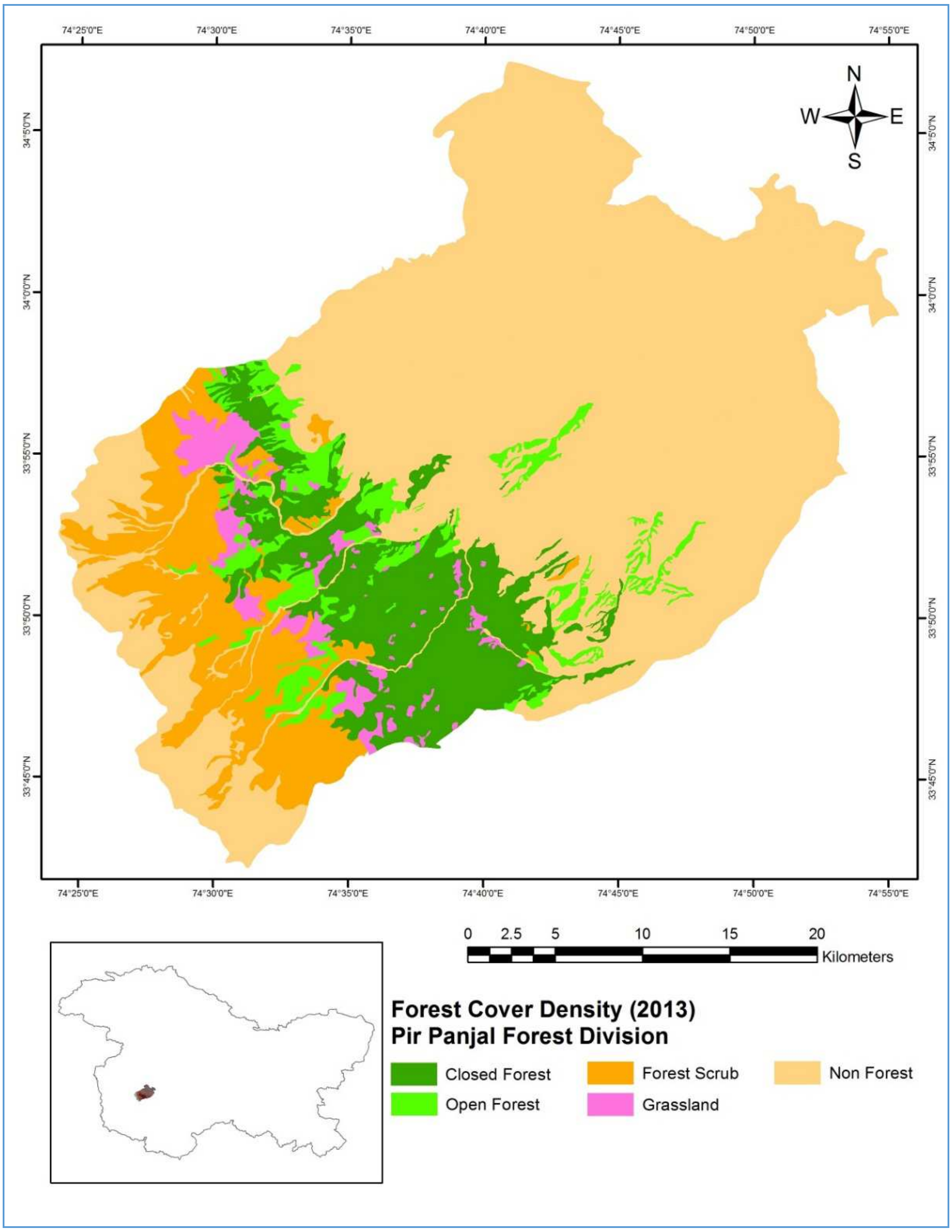

Fig. 4.3: Forest cover density map of Pir Panjal Forest Division 2013

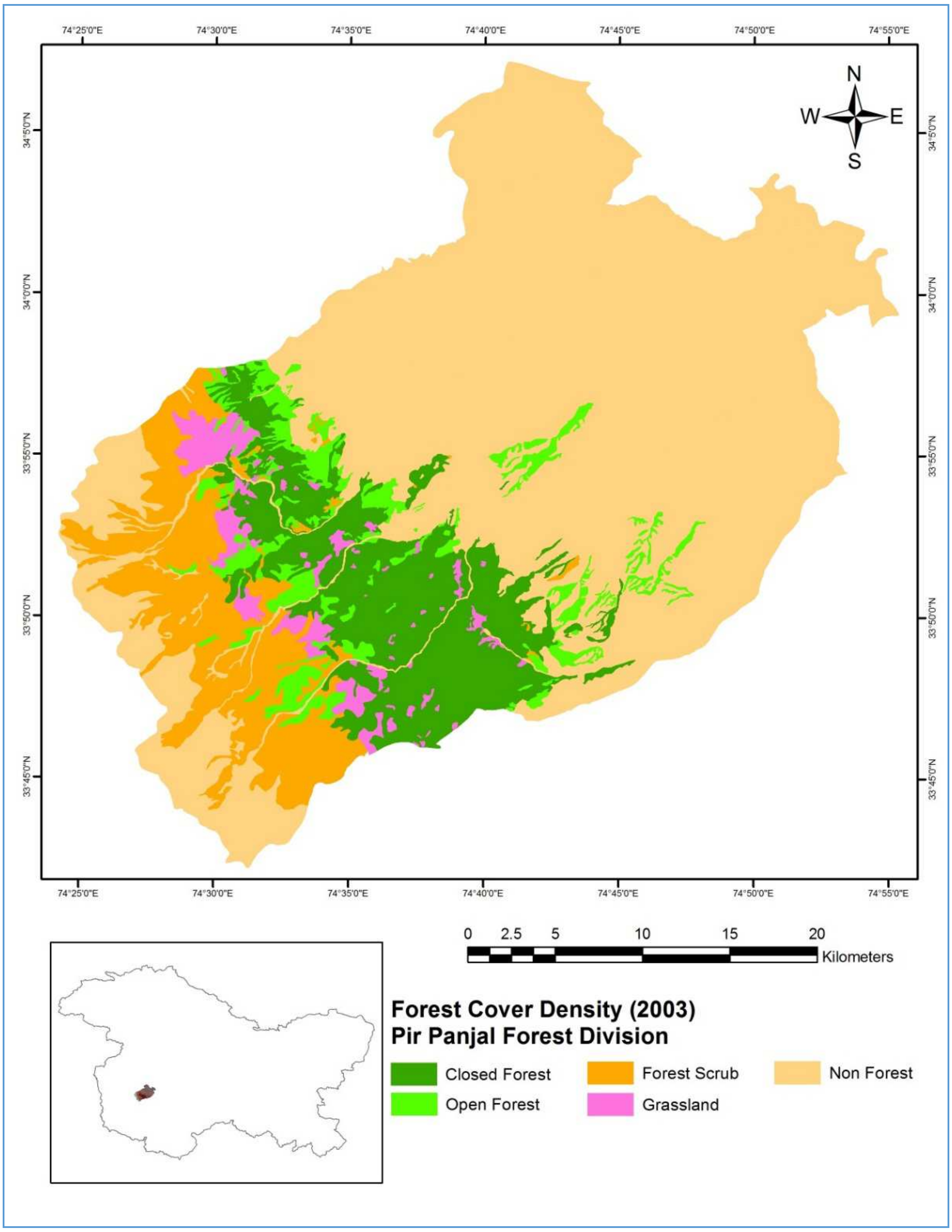

Fig. 4.4: Forest cover density map of Pir Panjal Forest Division 2003

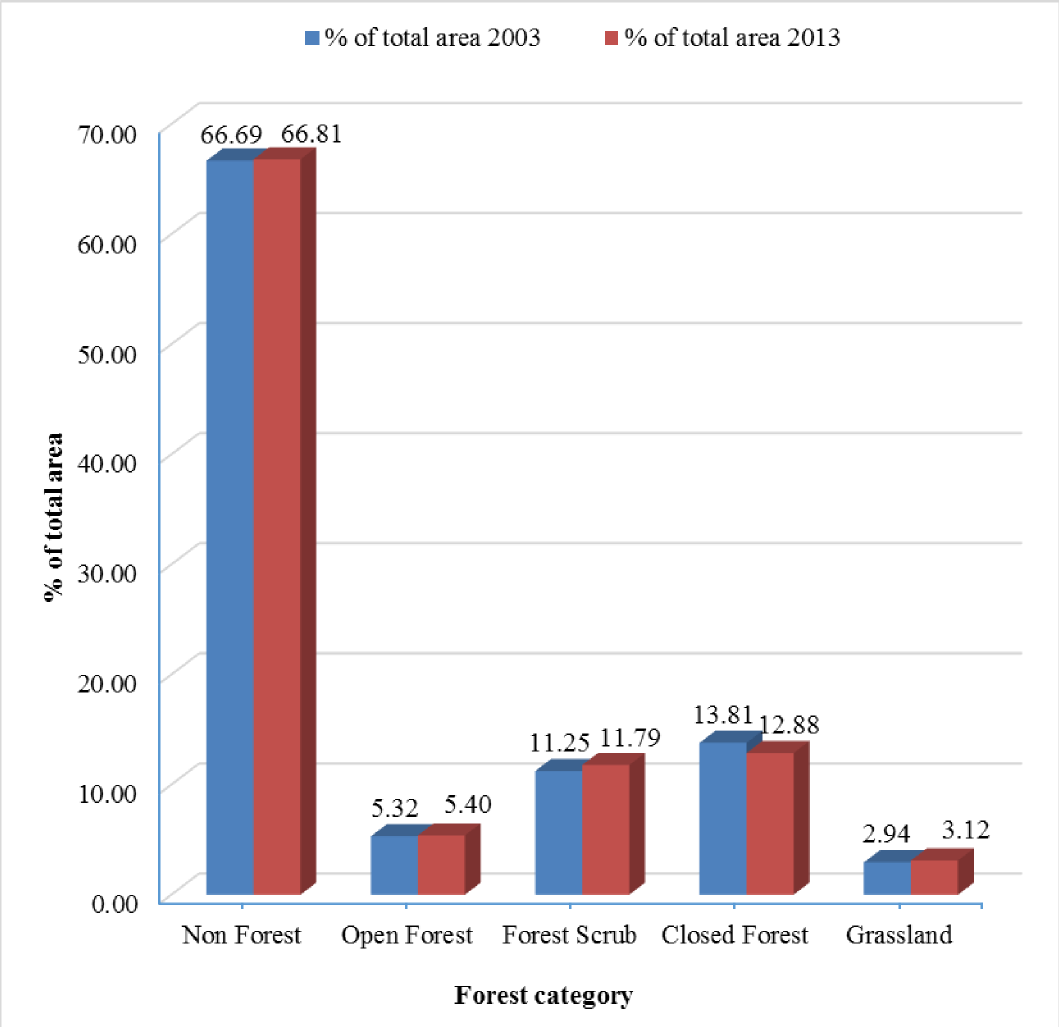

Fig. 4.5: Forest cover status (km^2) under different forest categories for the years 2003 and 2013

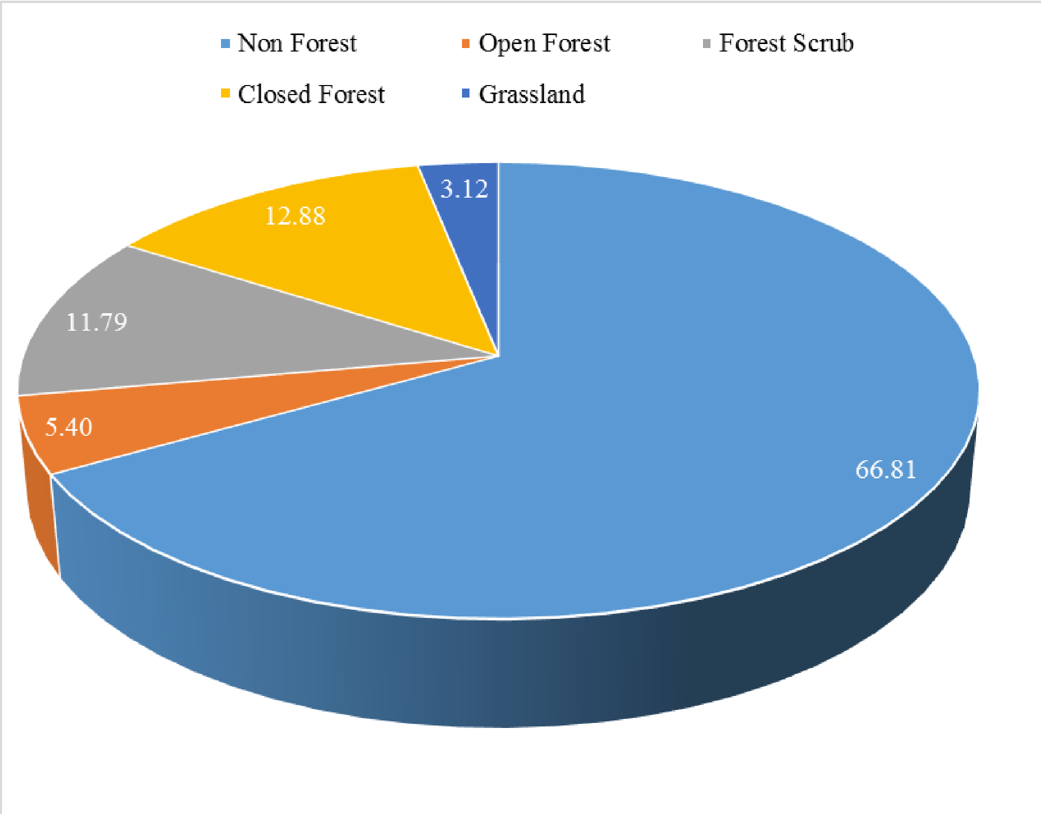

Fig. 4.6: Forest cover of Pir Panjal Forest Division under different categories (%) in 2013

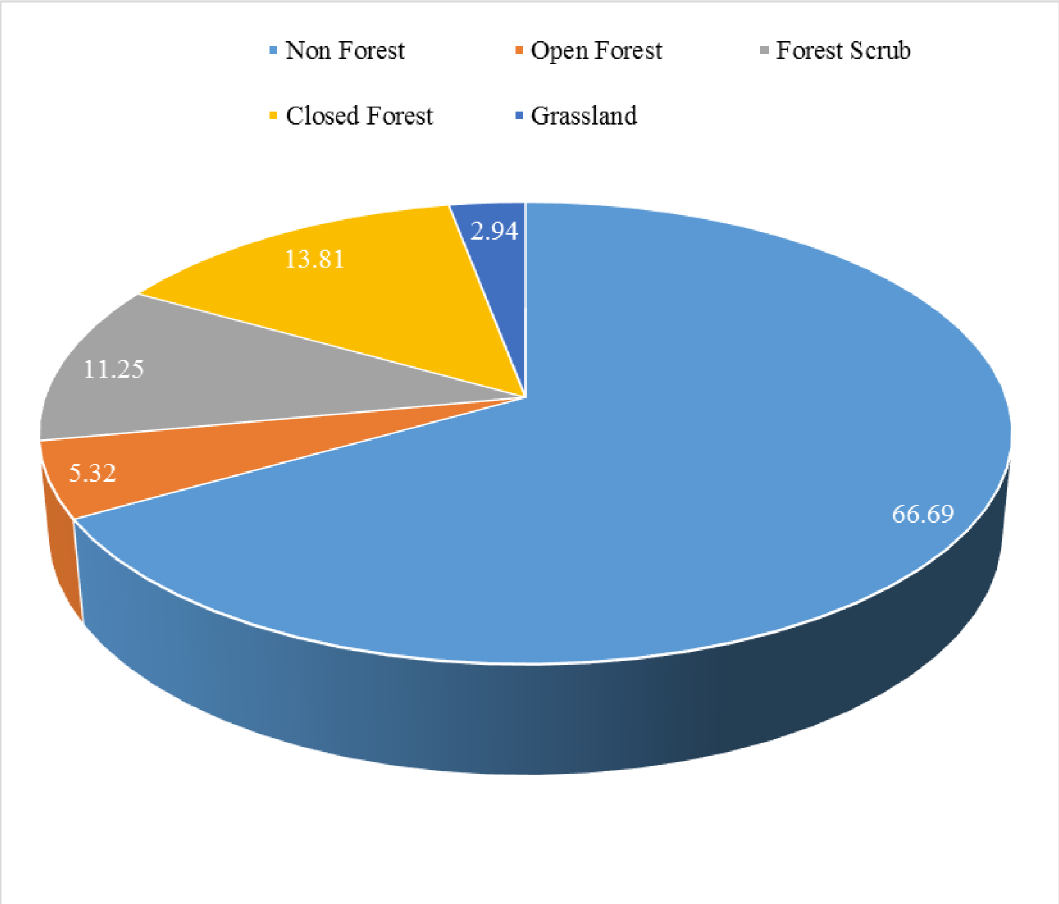

Fig. 4.7: Forest cover of Pir Panjal Forest Division under different categories (%) in 2003

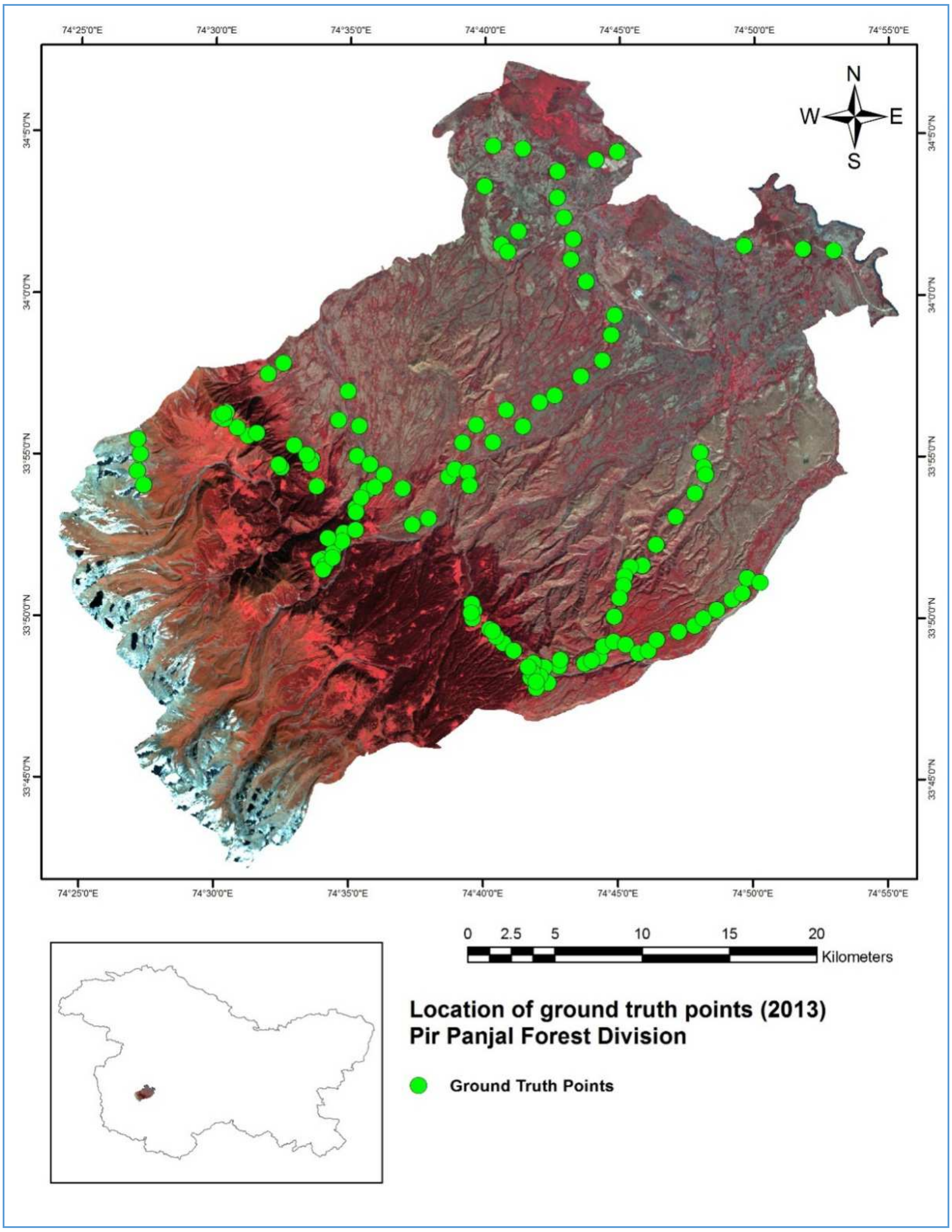

Fig. 4.8: Location of ground truth points of Pir Panjal Forest Division (2013)

Table 4.5: Error Matrix for forest density map 2013 for Pir Panjal Forest Division

Classified Data	Non-forest	Open forest	Forest scrub	Closed forest	Grass-land	Row Total
Non-forest	74	1	0	1	3	79
Open forest	0	12	0	2	0	14
Forest scrub	0	0	3	0	0	3
Closed forest	0	2	0	24	0	26
Grassland	1	0	0	0	10	11
Column total	**75**	**15**	**3**	**27**	**13**	**133**

Table 4.6: Accuracy Assessment for validation of 2013 Forest Density Map

Class	Reference totals	Classified totals	Number correct	Producers accuracy (%)	Users accuracy (%)
Non-forest	75	79	74	98.67	93.67
Open forest	15	14	12	80.00	85.71
Forest scrub	3	3	3	100.00	100.00
Closed forest	27	26	24	88.89	92.31
Grassland	13	11	10	76.92	90.91
Totals	**133**	**133**	**123**		

Overall Classification Accuracy = 92.48%

Table 4.7: Conditional Kappa for each category

Class	Kappa
Non-forest	0.8549
Open forest	0.839
Forest scrub	1
Closed forest	0.9035
Grassland	0.8992
Overall Kappa Statistics = 0.8757	

4.4 Forest cover density change

Change matrix in km^2 (Forest cover density) of Pir Panjal Forest Division from 2003 to 2013 has been shown in tabular form in Table 4.8 as well as in Fig. 4.9. However, the Figs. from 4.10 to 4.14 define it more precisely. Forest cover change from closed forest to others (2003-2013) as shown in Fig. 4.11 above reveals that out of 157.44 km^2 area under closed forest in 2003 has now reduced to 146.83 km^2 and the rest of its area has got changed into open forest (8.27 km^2), non-forest (0.91 km^2), forest scrub (1.53 km^2) and grasslands (0.54 km^2).

The area under open forest in 2003 was 60.60 km^2 but in 2013 it was found to be 53.18 km^2, the rest of the area has got converted into forest scrub (5.24 km^2), grasslands (1.02 km^2), non-forest (0.99 km^2) and closed forest category (0.17 km^2) as shown in Fig. 4.12. The total area under forest scrub in 2003 was 128.25 km^2, however in 2013 it was found that the area under forest scrub was 127.60 km^2, the rest of the area has got converted into grasslands (0.58 km^2) and closed forest (0.07 km^2) as shown in Fig. 4.13

The area under grasslands in 2003 was 33.55 km^2 while as in 2013 it was 33.48 km^2 out of total area of the study area (1140.17 km^2). The rest of the area has got converted into open forest (0.07 km^2) as shown in Fig. 4.14. The area under non forest in 2003 was found to be 760.33 km^2 while as in 2013 it was 760.30 km^2. The rest of the area has got converted into open forest (0.03 km^2) as shown in Fig. 4.15.

Table-4.8: Change Matrix km^2 (Forest Cover Density) of Pir Panjal Forest Division from 2003 to 2013

2003	2013					
	Non forest	**Open forest**	**Forest scrub**	**Closed forest**	**Grassland**	**Grand total**
Non-forest	760.30	0.03	0.00	0.00	0.00	760.33
Open forest	0.99	53.18	5.24	0.17	1.02	60.60
Forest scrub	0.00	0.00	127.60	0.07	0.58	128.25
Closed forest	0.51	8.27	1.53	146.59	0.54	157.44
Grassland	0.00	0.07	0.00	0.00	33.48	33.55
Grand total	**761.79**	**61.55**	**134.37**	**146.83**	**35.63**	**1140.17**

An interpretation key was used for change detection purpose as shown in Fig. 4.10. Interpretation was done on the basis of tone and reflectance of images of 2003 and 2013. It was obvious from the interpretation of tone and reflectance of images of 2003 and 2013 that the forest of Pir Panjal forest division have been deforested and degraded over the last decade. The tone for 2003 image is dark brown at most of the places depicting dense forests while as tone of 2013 shows most of the area as devoid of such tone. The tone here is slightly light brown or pink depicting open forest/grasslands (Fig. 4.10).

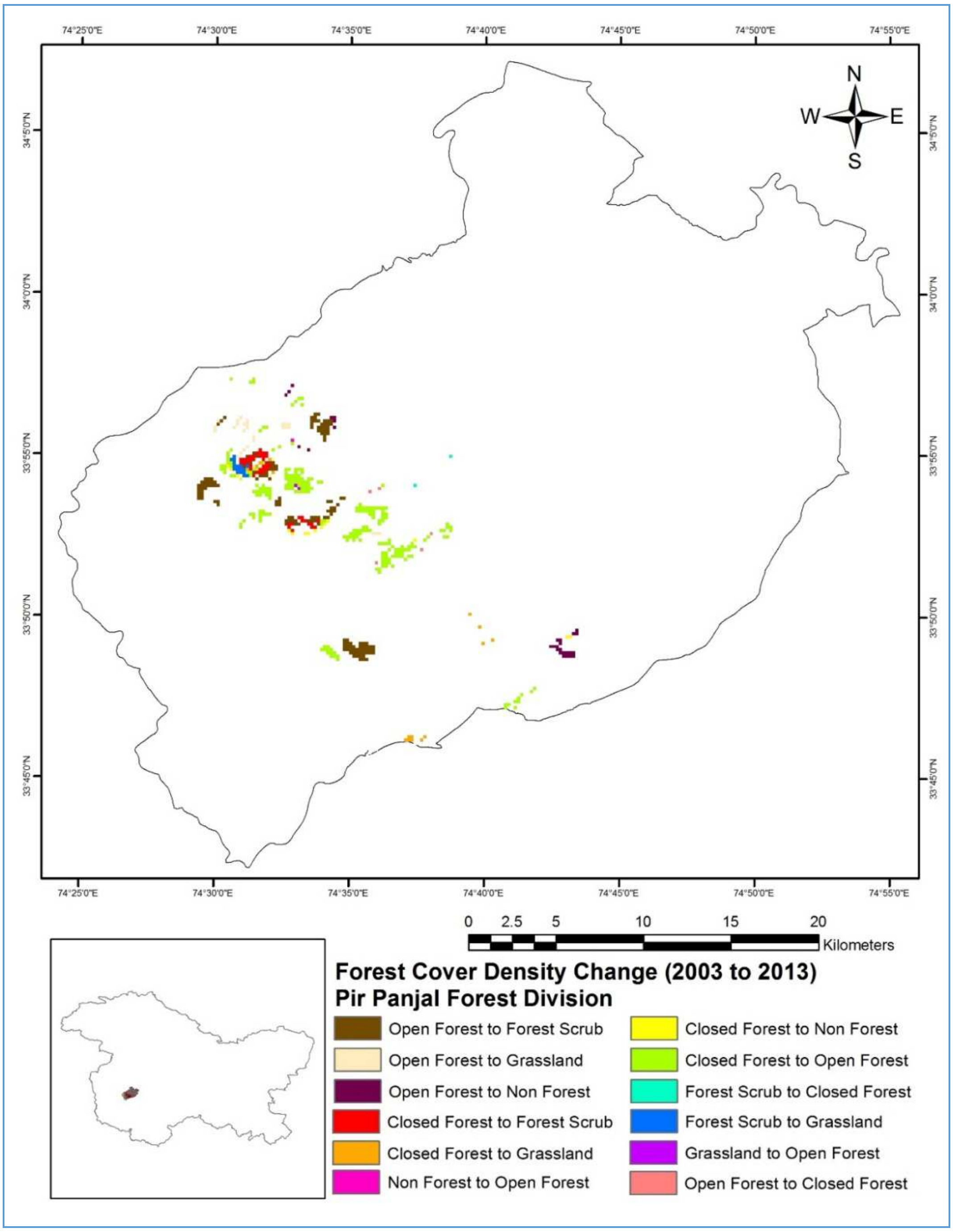

Fig. 4.9: Forest cover density change 2003-2013 in Pir Panjal Forest Division

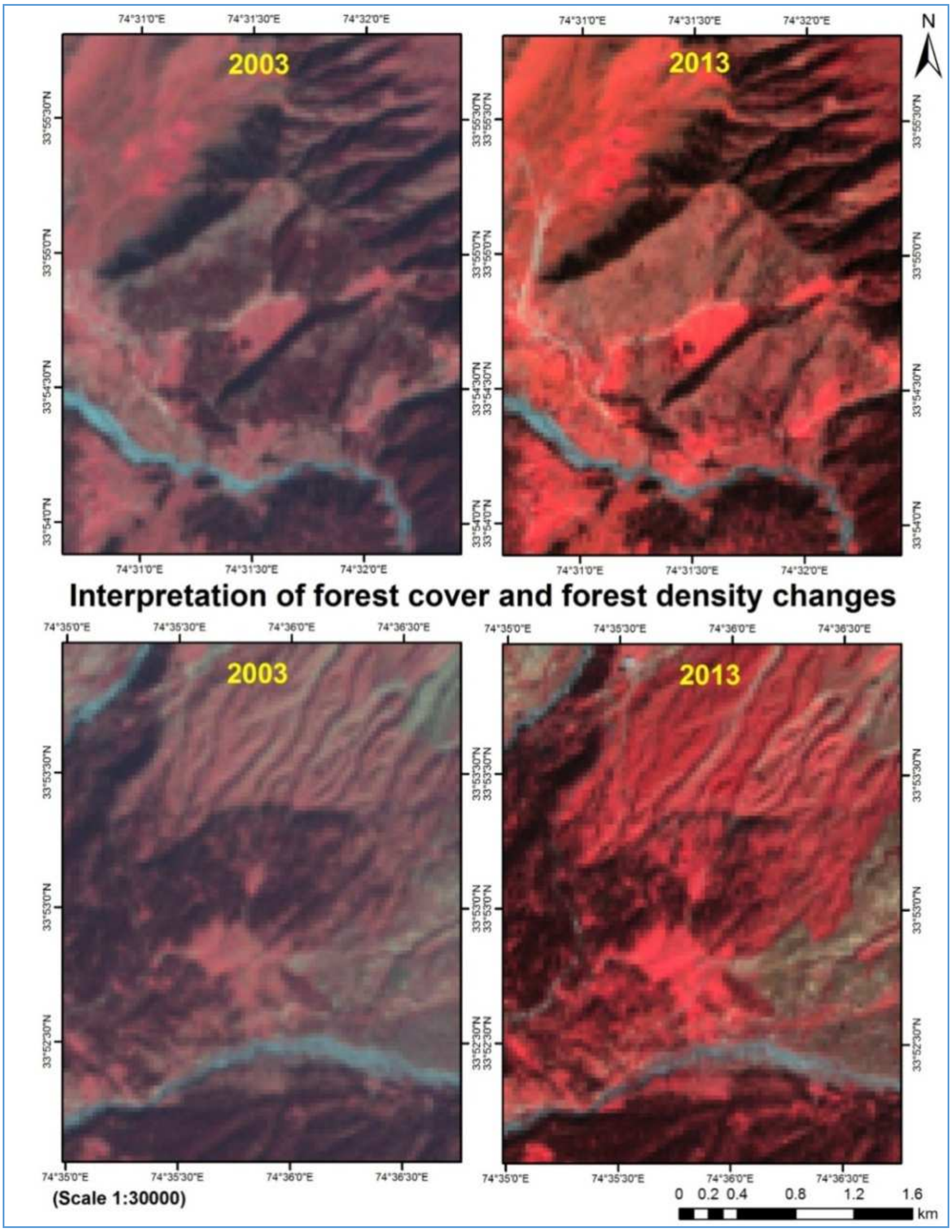

Fig. 4.10: Image interpretation key for visualization of deforestation and forest degradation in Pir Panjal Forest Division from 2003-2013

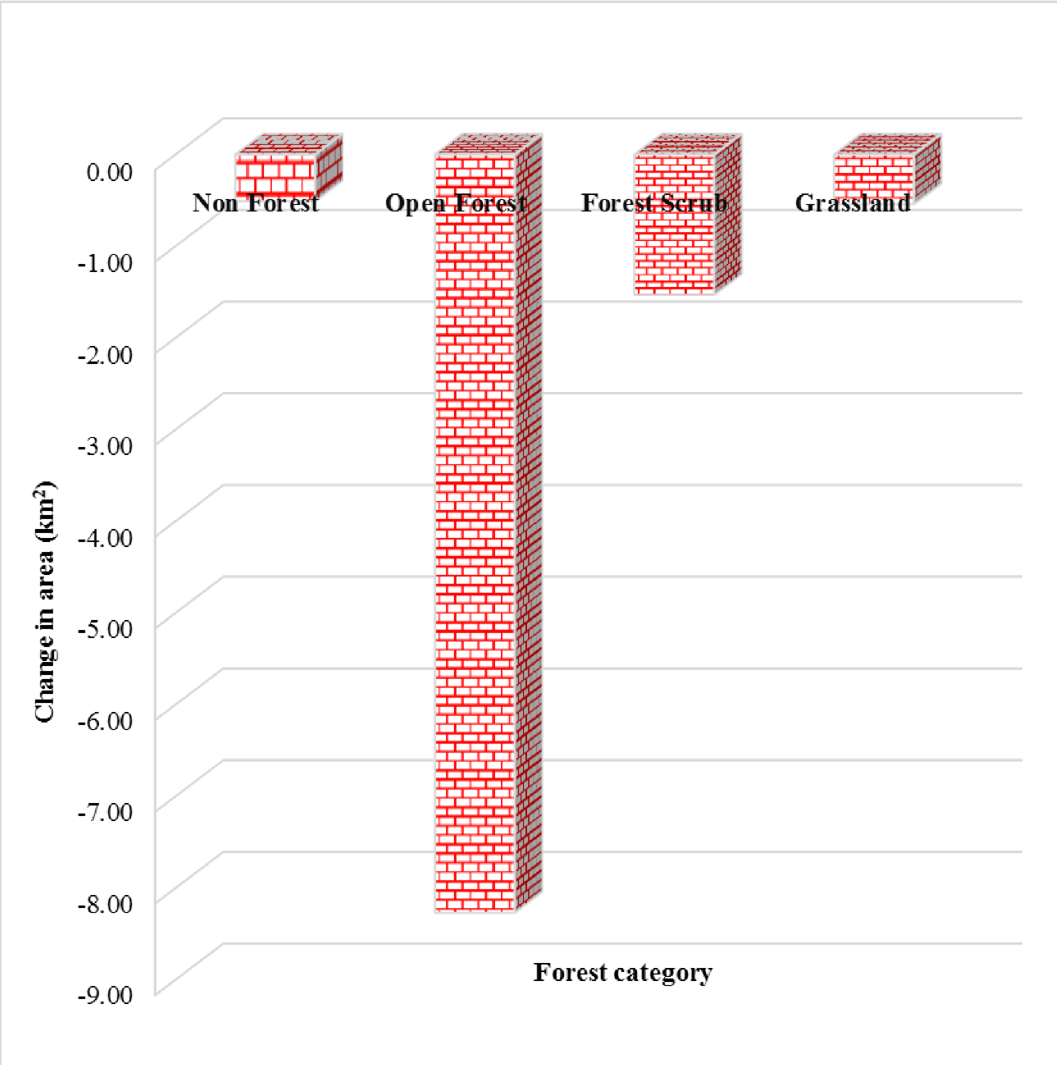

Fig. 4.11: Forest dynamics from closed forest to others (2003 to 2013) in Pir Panjal Forest Division

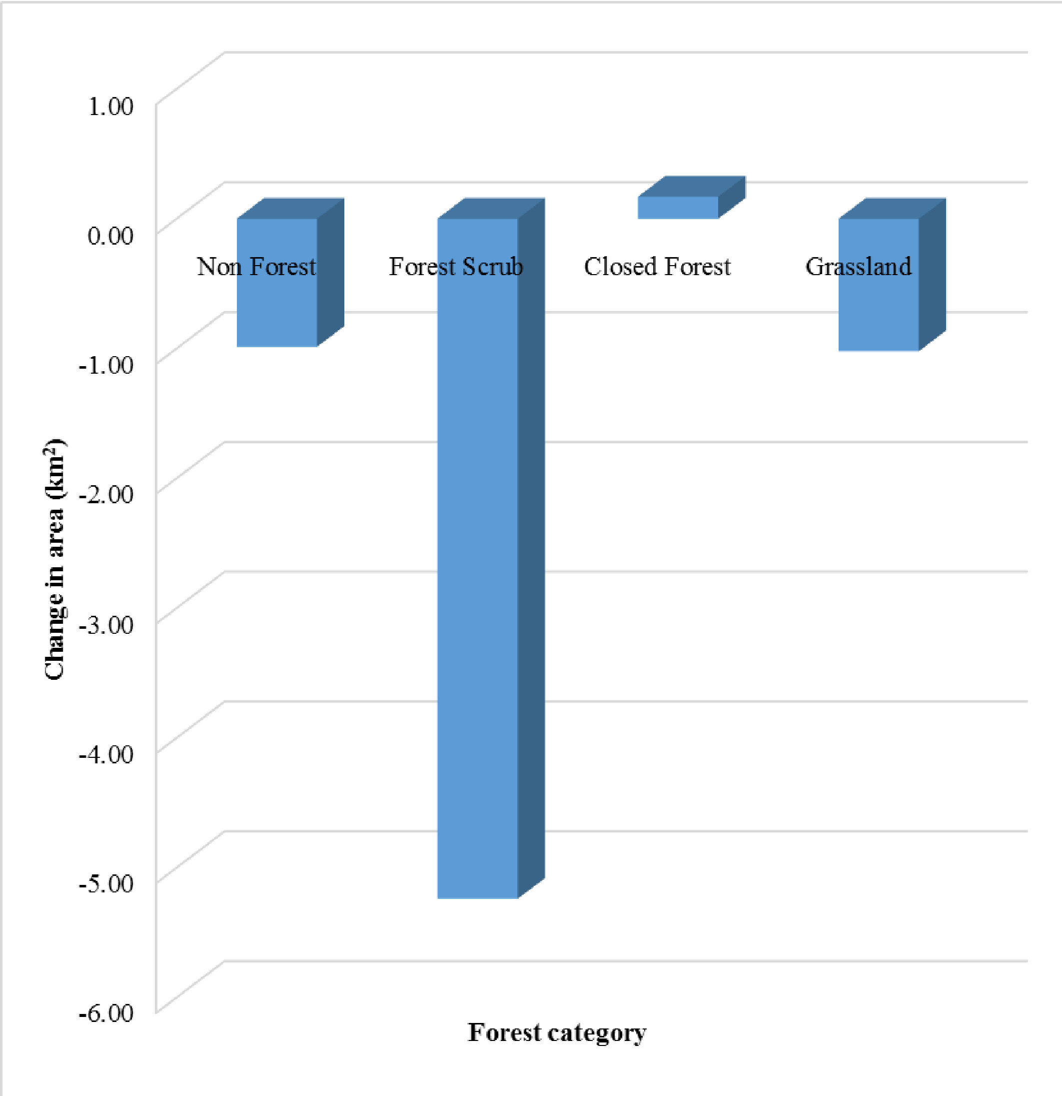

Fig. 4.12: Forest dynamics from open forest to others (2003 to 2013) in Pir Panjal Forest Division

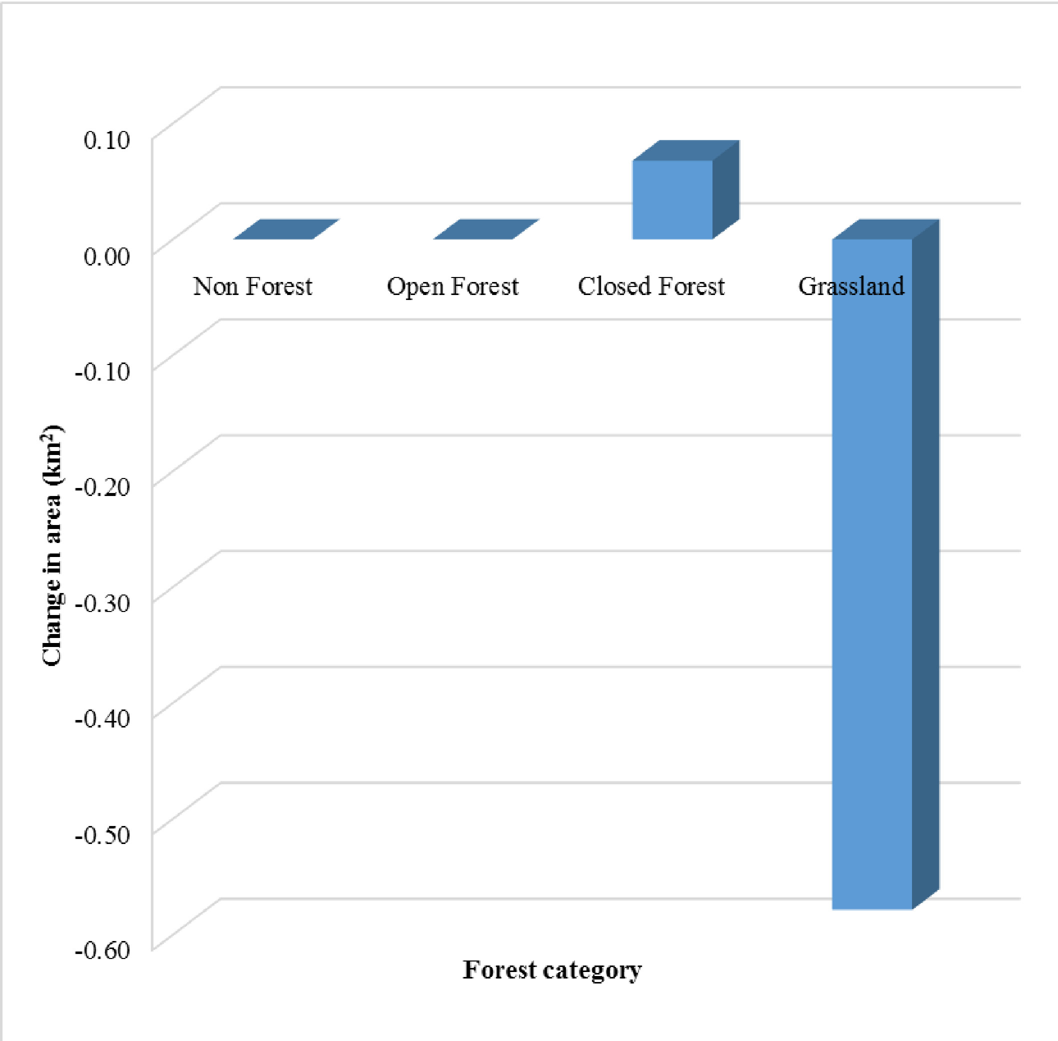

Fig. 4.13: Forest dynamics from forest scrub to others (2003 to 2013) in Pir Panjal Forest Division

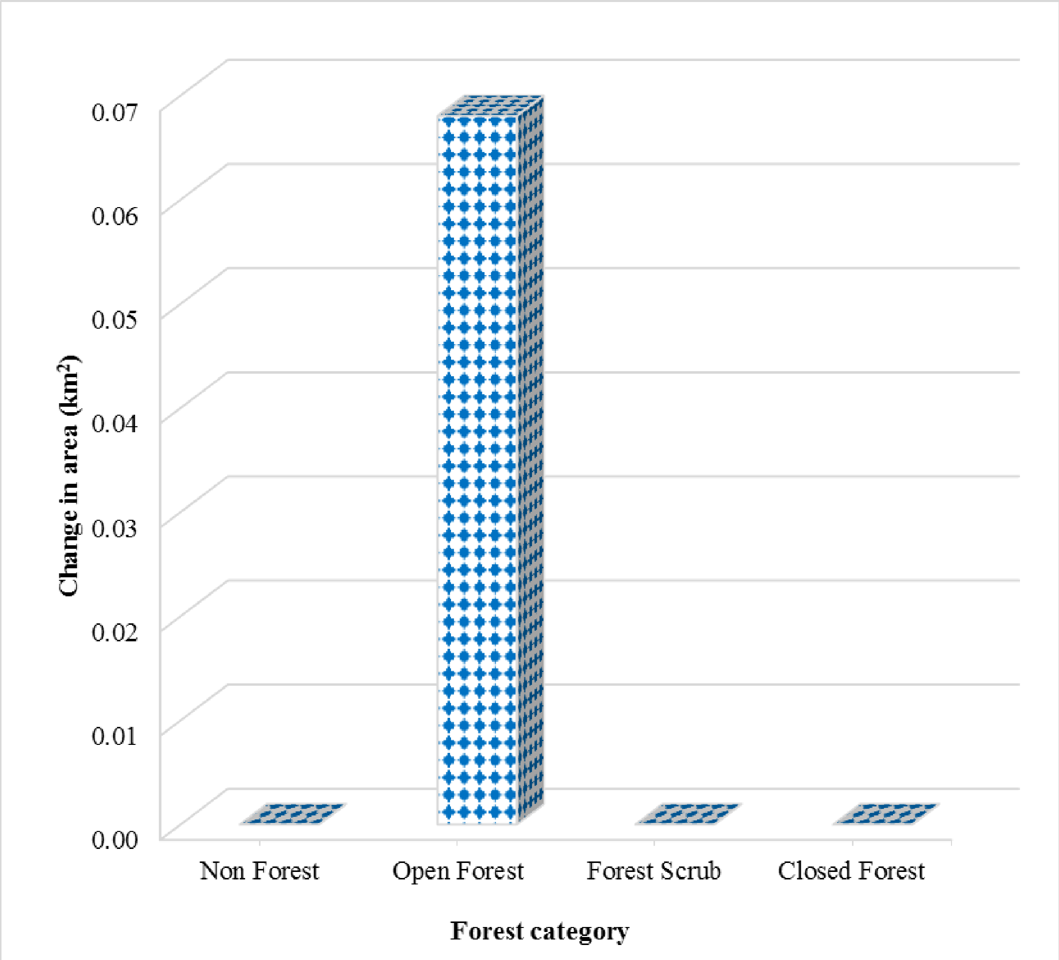

Fig. 4.14: Forest dynamics from grasslands to others (2003 to 2013) in Pir Panjal Forest Division

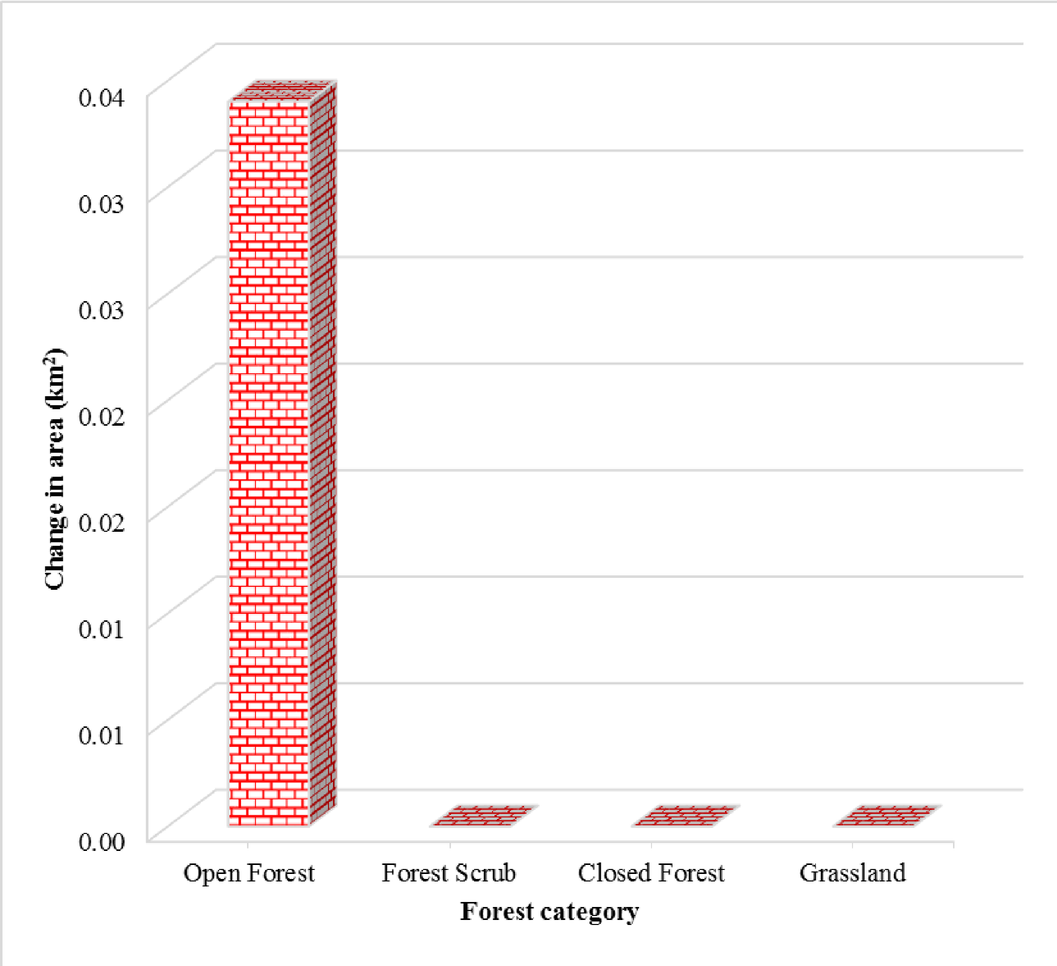

Fig. 4.15: Forest dynamics from non-forest to others (2003 to 2013) in Pir Panjal Forest Division

4.5 Drivers of change

Drivers of change in forest cover of Pir Panjal Forest Division were studied in four villages in each category viz., four villages for the positive drivers of change and four villages for the negative drivers of change (Appendix 1 and 2). Ten respondents were selected and questions related to forests were asked to them on the basis of questionnaire. The approach of the respondents regarding drivers of change was ranked from 1-6, rank 1 depicted strong agreement while as rank 6 depicted strong disagreement. The total number of respondents for both categories was 80 (Appendix 3 and 4). The questionnaire was analyzed using simple statistics and following two tables were obtained. The results obtained have been shown in Table 4.9 and 4.10.

Drivers of change fall under two categories viz., direct drivers and indirect drivers of change. The direct drivers of change include expansion of agriculture, illicit felling of timber, excessive fuelwood extraction, excessive grazing and plantation/afforestation measures by SFD, the last one being positive driver of change. The indirect drivers of change are population growth, subsistence, poverty/lack of employment, lack of awareness about importance of forests, Degree of forest protection (Positive driver), and increasing demand for timber leading to smuggling.

Analytical results for drivers of change in adjoining villages witnessing negative change from mapping as shown in Table 4.9 revealed that geometric mean was lowest for 'illicit felling of timber, hence ranked as 1 among all drivers of change. Poverty/lack of employment had second lowest geometric mean hence ranked 2 among all drivers of change. Similarly population growth, excessive fuelwood extraction, increasing demand for timber leading to smuggling, excessive grazing, lack of awareness about importance of forests and expansion of agriculture were ranked in the increasing order of geometric mean of their corresponding frequencies. Similarly in areas which have witnessed positive change from mapping the top driver for the same was afforestation done by State Forest Department and the Forest Protection which they provide (Table 4.10).

Table 4.9: Analytical results for drivers of change in adjoining villages witnessing negative change from mapping

Type	S. No	Drivers of change	Frequency against each score						N	Weighted mean score	Variance (σ^2)	Std deviation (σ)	Range	Rank
			1	2	3	4	5	6						
Direct drivers	1	Expansion for agriculture	0	11	12	14	3	0	40	3.23	22.23	4.72	2-5	**8**
	2	Illicit felling for timber	30	9	1	0	0	0	40	1.28	24.23	4.92	1-3	**1**
	3	Excessive fuel wood extraction	11	14	13	2	0	0	40	2.15	19.08	4.37	1-4	**4**
	4	Excessive grazing/fodder extraction	7	11	18	4	0	0	40	2.48	24.14	4.91	1-4	**6**
	5	Plantation/Afforestation measures by the SFD*	0	6	13	13	7	1	40	3.60	18.53	4.31	2-6	**9**
Indirect drivers	1	Population growth	21	12	5	2	0	0	40	1.70	16.24	4.03	1-4	**3**
	2	Subsistence	10	18	9	2	1	0	40	2.15	18.48	4.30	1-5	**4**
	3	Poverty/Lack of employment	28	11	1	0	0	0	40	1.33	23.14	4.81	1-3	**2**
	4	Lack of awareness about importance of forests	5	8	15	8	4	0	40	2.95	16.26	4.03	1-5	**7**
	5	Degree of forest protection*	0	0	0	12	18	10	40	4.95	33.76	5.81	4-6	**10**
	6	Increasing demand for timber leading to smuggling	10	12	11	7	0	0	40	2.38	15.36	3.92	1-4	**5**

(1= Strongly agree; 2 = Moderately agree; 3= Slightly agree; 4 = Slightly disagree; 5 = Moderately disagree; 6 = Strongly disagree)

** Positive drivers of change*

Table 4.10: Analytical results for drivers of change in adjoining villages witnessing positive changes from mapping

Type	S. No	Drivers of change	Frequency against each score						N	Weighted mean score	Variance (σ^2)	Std deviation (σ)	Range	Rank
			1	2	3	4	5	6						
Direct drivers	1	Expansion for agriculture	0	0	0	2	4	34	40	5.80	126.18	11.23	4-6	**10**
	2	Illicit felling for timber	0	0	0	3	5	32	40	5.73	109.28	10.45	4-6	**8**
	3	Excessive fuel wood extraction	0	0	1	2	3	34	40	5.75	126.23	11.24	4-6	**9**
	4	Excessive grazing/ fodder extraction	0	0	0	3	7	30	40	5.68	94.52	9.72	4-6	**7**
	5	Plantation/Afforestation measures by the SFD*	25	15	0	0	0	0	40	1.38	24.09	4.91	1-2	**1**
Indirect drivers	1	Population growth	0	0	0	4	6	30	40	5.65	94.01	9.70	4-6	**6**
	2	Subsistence	0	0	0	6	6	28	40	5.55	80.27	8.96	4-6	**5**
	3	Poverty/Lack of employment	0	0	0	5	4	31	40	5.65	101.56	10.08	4-6	**6**
	4	Lack of awareness about importance of forests	0	0	4	4	6	26	40	5.35	66.48	8.15	3-6	**3**
	5	Degree of forest protection*	22	18	0	0	0	0	40	1.45	25.20	5.02	1-2	**2**
	6	Increasing demand for timber leading to smuggling	0	0	4	4	5	27	40	5.38	72.66	8.52	3-6	**4**

(1= Strongly agree; 2 = Moderately agree; 3= Slightly agree; 4 = Slightly disagree; 5 = Moderately disagree; 6 = Strongly disagree)

** Positive drivers of change*

Chapter-5

DISCUSSION

In the light of available literature from different sources, the results obtained from the present study are discussed under the following headings:

5.1 Landuse/landcover maps and forest cover density map of 2013 and 2003

Landsat images (ETM+) were used to generate Landuse/Landcover maps of 2013 and 2013 using visual interpretation in the present study. Researchers in the past have reported application of Landsat data as potential to map forests and detect the changes for its synoptic view and temporal resolution (Aldrich, 1975; Burns and Joyce, 1981; Gautam and Chenniah, 1985). Aasim *et al.* (2014) used Landsat-5, Landsat ETM+ and IRS LISS 4 satellite data of 1992, 2001 and 2014 respectively for geospatial monitoring of Pir Panjal Forest Division in a similar type of study.

A visual interpretation approach was used in the current study to identify and delineate the landuse/landcover classes on image overlays. Visual interpretation is effective for utilizing the photographic elements of tone, texture, hue, size, shape, pattern, shadow and geographic context, whereas these elements are often disregarded by more automated digital mapping techniques (Gray and Cushing, 2004).

The area in the present study was classified into 11 landuse classes viz., builtup, water body, wetland, horticulture, forest, forest scrub, agriculture, grassland, snow, wasteland and agricultural plantation. Landuse/landcover map (2013) reveals that there has been a significant change in landuse from 2003-2013 in Pir Panjal forest division. In landuse/landcover map Agriculture has registered a sharp decrease in its area from 2003 to 2013 which can be mainly attributed to increased conversion of agricultural land to Horticulture and wasteland. This has also been reported by several works from the region in the recent past (Showki and Bhat, 2014; Wani *et al.,* 2014). The conversion of agriculture to wasteland has also been verified from ground truthing and could be attributed to formation of brick kilns on agricultural lands. In the present study Landsat data of 2003 and 2013was mapped using visual interpretation and appropriately classified into two density classes of dense forest (40-100%) and Open forests (10-40%). Additionally, Forest Scrub, Grasslands and Non Forests were also delineated for assessing change dynamics. September-October images for this region were found to be most appropriate for interpretation due to minimal cloud and snow cover. Landsat data combined with field data has also been used by various workers for forest type differentiation (Magnussen *et al.,* 2004; Salovaara *et al.,* 2005; Yang *et al.,* 2007). A similar kind of work has been carried out in the past by different researchers (Gautam *et al.,* 2002; Mon *et al.,* 2008; Farooq and Rashid, 2010; Mya, 2010; Vemu and Bhaskar, 2010; Kiran, 2013; Aasim *et al.*, 2014; Sajjad *et al.,* 2015 and Wani *et al.*, 2016).

5.2 Forest cover density dynamics (2003 to 2013)

The results on change matrix (Table 4.8) indicate conversion of closed forests to Open Forests (8.27 km^2) Open Forest into Forest Scrub (5.24 km^2) which can be purely attributed to degradation as conversion takes place from higher category of forest to the lower. Similarly an area of open forest (0.99 km^2) and closed forest (0.51 km^2) was converted to non-forest and can be attributed to deforestation. Similar results were found for Lidder forest division and Anantnag Forest Division (Wani *et al.,* 2014; 2016), Doodganga Watershed (Farooq and Rashid, 2010).

Farooq and Rashid (2010) in a similar study on spatio-temporal change detection analysis in Doodhganga range of Pir Panjal Division of Kashmir Himalayas using IRS1D LISS III & LANDSAT-5 TM revealed that the study area (141 km^2) from 1994-2004 has witnessed a significant loss of 5.07 $km^2$from very dense category to moderately dense category in forest cover. The study also revealed that the loss of open forests (3.48 km^2) has increased the area under blank and forest scrub (3.12 and 0.71 km^2).

Ravindranath *et al.* (2012) in a similar study on REDD+ at national level used FSI data of 2005, 2007 and 2009 and reported a net loss of forests which can be considered under 'deforestation' option of REDD+ in India with 1004.00 km^2 for 2003-2005, 636.50 km^2 for 2005-2007 and 998.50 km^2 for 2007-2009.

Wani *et al.* (2016) in a similar study in the southern region of Kashmir Himalayas using Landsat ETM+ data revealed that the study area (3375.62 km^2) from 1980-2009 has suffered deforestation and forest degradation of about 126 and 139.02 km^2 respectively. An area of 23.31 km^2 was also registered as a positive change during the study period.

5.3 Accuracy assessment and conditional kappa

The total number of reference points (ground truth points) for accuracy assessment and map validation was 133 at various places of the study area (Fig. 4.8). The overall classification accuracy of forest density map of 2013 came out to be 92.48%. The overall classification accuracy of forest density map 2013 was calculated on the basis of producers accuracy and users accuracy as shown in Table 4.6.

The conditional kappa for each category was calculated using kappa formula. The overall kappa statistics was calculated as 0.8757 as shown in table 4.7. Azizi *et al.* (2008) got overall accuracy of 84.4% and kappa 78.3% while as Ismail and Jusoff (2008) got overall accuracy equal to 83.5% and kappa 75% for a similar type of study.

5.4 Drivers of change

Analytical results for drivers of change in adjoining villages witnessing negative change from mapping as shown in Table 4.9 revealed negative change in forest cover and density mainly due to Illicit Felling and Poverty/Lack of employment.

Drivers of change also indicate a small positive change in the forest areas at certain places mainly due to plantation/afforestation measures (Table 4.10). Similar types of results were obtained by Lasco (1998); Geist and Lambin (2002); Chomitz *et al.* (2007); Antonio *et al.* (2012) and FAO (2015).

Chapter 6

SUMMARY AND CONCLUSION

Forest cover assessment of any region as such is always in great demand. As the lack of appropriate data collected, analyzed and presented in a scientific manner has been a major weakness in the forest planning and management throughout India especially in Jammu and Kashmir. Forests throughout the world are facing tremendous pressure and Jammu and Kashmir forests are not an exception. With the ever-increasing population of state, forests have been placed under tremendous pressure arising out of increasing demand for fuel wood, fodder, timber and other forest products. This has resulted in acute degradation of forest resources. Hence, there is an immense need of assessing the forest cover and detection of change in forest cover. The management strategies could be based on the results of forest cover dynamics.

Pir Panjal Forest Division has not been mapped before using the present scheme of classification of forest categories based on density classes using remote sensing and GIS. Visual interpretation of satellite data has been done in the current study. The maps obtained from visual interpretation of satellite data are highly accurate. The maps generated in the current studies are accurate with overall classification accuracy being 92.48% and kappa equal to 0.8757 which is considered highly accurate.

In landuse/landcover map agriculture has registered a sharp decrease in its area from 2003 to 2013 which can be mainly attributed to increased conversion of agricultural land to Horticulture and wasteland.

The results on change matrix indicate conversion of closed forests to Open Forests (8.27 km^2) Open Forest into Forest Scrub (5.24 km^2) which can be purely attributed to degradation as conversion takes place from higher category of forest to the lower. Similarly an area of open forest (0.99 km^2) and closed forest (0.51 km^2) was converted to non-forest and can be attributed to deforestation.

Top drivers of change in adjoining villages witnessing negative change from mapping were identified to be illicit felling and poverty/lack of employment. Similarly positive drivers of change were identified to be plantation/affforestation measures.

The conclusion of whole study is as under:

- The area under agriculture has decreased by 2% during the study period.
- Horticulture has increased by 1.26% from 2003 to 2013 probably due to conversion of agricultural landuse to horticulture.
- The total forest area has decreased by 0.84% from 2003 to 2013 due to deforestation.
- The results from change matrix indicate a high forest degradation of closed forests to open forests (8.27 km^2), open forest into forest scrub (5.24 km^2).
- Drivers of change indicate a negative change in forest cover and density mainly due to illicit felling and poverty/lack of employment.
- Drivers of change also indicate a small positive change in the forest areas at certain places mainly due to plantation/afforestation measures.
- There is a need to prioritize and act on the identified drivers of change by the concerned forest department so as to reverse the trend of deforestation and forest degradation in the study area.

LITERATURE CITED

Aasim, M., Farooq, M., Amin, A. and Rashid, H. 2014. Geospatial monitoring of forests, a case study of Pir Panjal forest division, J&K. *International Journal of Remote Sensing and Geoscience* **3**(3):16-25.

Ahmadizadeh, S., Yousufi, M. and Saghafi, S. 2014. Landuse change detection using remote sensing and artificial neural network: Application to Birjand, Iran. *Computational Ecology and Software* **4**(4): 276-288.

Aldrich, R.C. 1975. Detecting disturbances in a forest environment. *Photogrammetric Engineering and Remote Sensing* **4**1(1):39-48.

Ali, T., Shahbaz B. and Suleri, A. 2008. Analysis of myths and realities of deforestation in North-West Pakistan, Implications of forestry extension. *International Journal for Agriculture and Biology* **8**(1): 107-110.

Anderson, J.R., Hardy, E., Roach, J. and Witmer, R. 1976. A Land use and Land cover classification system for use with remote sensor data. Washington, DC: US *Geological Survey Professional Paper* **964**: 28.

Antonio, P., Leonida, A., Priscila, B., Dolom, C., Garcia, L., Magdalena, M. and Nena, O. 2012. *Analysis of key drivers of deforestation and forest degradation in Phillipensis*. GIZ Manilla, Phillipensis pp. 73-88.

Azizi, Z., Najafi, A. and Sohrabi, H. 2008. Forest canopy density estimation using satellite image. *The International Archives of Photogammetry, Remote Sensing and Spatial Information Sciences* **37**(8):1127-1130.

Banerjee, K., Surajit, P., Jatisankar, B. and Manish, K.J. 2014. Forest canopy density mapping using advance geospatial technique. *International Journal of Innovative Science, Engineering and Technology* **1**(7): 358-363.

Benchalli, S.S. and Prajapati, R.C. 1998. Modeling for forest growing stock assessment using satellite data, a case study. *Journal Indian Society of Remote Sensing* **26**(1-2): 15-22.

Bisht, B.S. and Tiwari, P.C. 1996. Landuse planning for sustainable resource development in Kumaun lesser Himalaya-A study of the Gomti watershed. *International Journal of Sustainable Development and World Ecology* **3**: 23-34.

Boakye, E., Odai, S.N., Adjei, K.A. and Annor, F.O. 2008. Landsat images for assessment of the impact of land use and land cover changes on the Barekese Catchment in Ghana. *European Journal of Scientific Research* **22**(2): 269-278.

Burns, G.S. and Joyce A.T. 1981. Evaluation of land cover change detection techniques using Land sat MSS data. **In**: *Proceedings of the 7th Pecora Symposium*, South Dakota' Sioux Falls pp. 252- 260.

Chape, S., Harrison, J., Spalding, M. and Lysenko, I. 2005. Measuring the extent and effectiveness of protected areas as an indicator for meeting global biodiversity targets. *Philos. Trans. R. Soc. London* **360**: 443-455.

Chauhan, P.S., Mahesh, C.P., Lalit, S.J. and Dev, S.N. 2003. Change detection in Sal forests in Dehradun forest division using remote sensing and GIS. *Journal of Indian Society of Remote Sensing* **31**(3): 212-218.

Chomitz, K. 2007. Agricultural expansion, poverty reduction, and environment in the tropical forests. *Current Sciences* **80**(3): 321-334.

Congalton, R.G., Oderwald, R.G. and Mead, R.A. 1983. Assessing landsat classification accuracy using discrete multivariate statistical techniques. *Photogrammetric Engineering and Remote Sensing* **49**(12):1671-1678.

Coppin, P., I. Jhonceekeri, K., Nackaerts, B. Muys and Lambin, E. 2004. Digital change detection methods in ecosystem monitoring: a review. *International Journal of Remote Sensing* **25**(9): 1565-1596.

Dale, V.H. Houghton, R.A. and Hall, C.A.S. 1991. Estimation of effects of Land use change on global atmospheric CO_2 concentrations. *Canadian Journal of Forestry Research* **21**: 87-90.

Das, K.K., Ravan, S.A., Negi, S.K., Abhineet, J. and Roy, P. S. 1996. Forest cover monitoring using Remote Sensing and GIS-A case study in Dhualkand range of Rajaji National Park, Uttranchal. *Journal of Indian Society of Remote Sensing* **24**(1): 33-42.

Deilami, B.R., Baharin, B.A., Malik, R.A.S. and Hafiz, A.U. 2014. Using remote sensing and GIS to detect and monitor land use and land cover change in Iskandar Malaysia during 2007-2014. *Middle-East Journal of Scientific Research* **22**(3): 390-394.

Dewidar, K.M. 2004. Detection of land use/land cover changes for the Northern part of Nile Delta Burullus region Egypt. *International Journal of Remote Sensing* **25**(20):4079-4089.

Dhinwa, P.S., Pathak, S.K. and Sastry, S.V.C. 1992. Landuse change analysis of Bharatpur District using GIS. *Journal of Indian Society Remote Sensing* **20**(4): 237-250.

FAO 1997. *State of the world's forests*, Food and Agriculture Organization of the United Nations, Rome **2**: 32-45.

FAO 2015. *Global forest resources assessment 2015*. Food and Agriculture Organization of the United Nations, Rome pp. 14-18.

Farooq, M. and Rashid, H. 2010. Spatio temporal change analysis of forest density in Doodhganga forest range, Jammu & Kashmir. *International Journal of Geomatics and Geosciences* **1**(2):132-140.

FSI, 1989. *India State of Forest Report,* Forest Survey of India, Dehradun. Ministry of Environment and Forests, Govt. of India.

FSI, 1991. *India State of Forest Report,* Forest Survey of India, Dehradun. Ministry of Environment and Forests, Govt. of India.

FSI, 2011. *India State of Forest Report*, Forest Survey of India, Dehradun. Ministry of Environment and Forests, Govt. of India.

FSI, 2013. *India State of Forest Report*, Forest Survey of India, Dehradun. Ministry of Environment and Forests, Govt. of India.

FSI, 2015. *India State of Forest Report*, Forest Survey of India, Dehradun. Ministry of Environment and Forests, Govt. of India.

Gautam, N.C. and Chennaiah, C.H. 1985. Landuse and landcover mapping and change detection in Tripura using satellite Landsat data. *International Journal of Remote Sensing* **6**(3): 517-528.

Gautam, A.P., Shivakoti, G.P. and Webb, E.L. 2002. GIS assessment of landuse/landcover changes associated with community forestry implementation in the middle hills of Nepal. *Mountain Research and Development* **22**: 63-69.

Geist, J.H. and Lambin, E.F. 2002. Proximate causes and underlying driving forces of tropical deforestation. *Bioscience* **52**(2): 143-150.

Goll, I., Nick, B., Li-Jianhua, Mc-Kay, J. and John, S. 2014. Analysis on the causes of deforestation and forest degradation in Liberia, Application of the DPSIR Framework. *Research Journal of Agriculture and Forestry Sciences* **2**(3): 20-30.

Gray, T. and Cushing, M. 2004. Use of SLC-Off Landsat image data for monitoring landuse/landcover trends in West Africa. USGS EROS Data Center, Sioux Falls, SD pp. 11.

Guild, L.S., Cohen, W.B. and Kaufman, J. B. 2004. Detection of deforestation and land conversion in Rondonia, Brazil using change detection techniques. *International Journal of Remote Sensing* **25**(4): 731-750.

Hosonuma, N., Herold M., Veronique, D., Fries, R., Brockhaus, N., Verchot, L., Angelsen and Erika, R. 2012. An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letter* pp. 12-17.

IGBP-IHDP. 1999. Landuse and landcover change implementation strategy. IGBP Report 48 and IHSP Report 10. IGBP Secretariat, Stockholm, Sweden pp. 287. *International Journal of Remote Sensing* **10**(6): 989-1003.

Ismail, M. and Jusoff, K. 2008. Satellite data classification accuracy assessment based from reference dataset. *International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering* **2**(3): 23-29.

Jaykumar, S. and Arockiasamy, D. 2003. Landuse/ landcover mapping and change detection on part of eastern ghats of Tamil Nadu Using remote Sensing and GIS. *Journal of Indian Society of Remote Sensing* **31**(4): 252-260.

Jensen J.R. 1996. *Introductory digital processing: A remote sensing perspective,* Second Edition. Prentice Hall. New Jersey p. 318.

Jensen, J.R. 2000. *Remote sensing of the environment: an earth resource perspective*, Prentice Hall, Saddle River, NJ pp. 544.

Joshi, P.K., Singh, S., Agarwal, S. and Roy, P.S. 2001. Landcover assessment in Jammu & Kashmir using phenology as discriminant - An approach using wide swath satellite (IRS - WiFS). *Current Science* **81**(4): 392-398.

Joshi, P.K., Roy, P.S., Singh, S., Agarwal, S. and Yadav, D. 2002. Biome level characterization of Western India -Rajasthan. *Tropical Ecology* **43**(1): 213-228.

Kayat, N. and Pathak, K. 2015. Remote sensing and GIS based landuse/landcover change detection mapping in Saranda Forest, Jharkhand, India. *International Research Journal of Earth Sciences* **3**(10): 1-6.

Kiran, V. 2013. Change detection in Landuse/Landcover using remote sensing and GIS techniques: A case study of Mahananda catchment, West Bengal. *International Journal of Research in Management Studies* **2**(2): 68-72.

Kissenger, G., Herold, M. and Sy, V.D. 2012. Drivers of deforestation and forest degradation: A synthesis report for REDD + Policymakers. Lexeme consulting, Vancouver Canada p. 10.

Lambin, E.F. and Strahler, A. 1994. Remotely-sensed indicator of landcover change for multi-temporal change-vector analysis. *International Journal of Remote Sensing* **15**(10): 2099-2119.

Lasco, R.D. 1998. Management of tropical forests in Philippines. World resource review **10**(3): 410-418.

Lele, N. and Joshi, P.K. 2009. Analyzing deforestation rates, spatial forest cover changes and identifying critical areas of forest cover changes in North-East India during 1972-1999. *Environmental Monitoring Assessment* **156**: 159-170.

Li, Z., Li, X., Wang, Y., Ma, A. and Wang, J. 2004. Landuse change analysis in Yulin prefecture northwestern China using remote sensing and GIS. *International Journal of Remote Sensing* **25**(24): 5691-5703.

Lillesand, T.M. and Kiefer, R.W. 1979. *Remote Sensing and Image Interpretation*, New York, Chichester: John Wiley pp. 612.

Linkie, M., Smith, R.J. and Leader-Williams, N. 2004. Mapping and predicting deforestation patterns in in the low lands of Sumatra. *Forestry Abstracts* **65**(12): 1716.

Louman, B. 2012. Forest biodiversity and ecosystem services : Drivers of change, responses and challenges. *Forests and Society - Responding to Global Drivers of Change* **6**: 95-112.

Lu, D., Mausel, P., Batistella, M. and Moran, E. 2004. Landcover binary change detection methods for use in the moist tropical region of the amazon. *International Journal of Remote Sensing* **26**(1): 101-114.

Magnussen, S. Boudewyn, P. and Wulder, M. 2004. Contextual classification of Landsat TM images to forest inventory cover types. *International Journal of Remote Sensing* **25**(12): 2421-2440.

Manonmani, R., Mary, G. and Suganya, D. 2010. Remote sensing and GIS application in change detection study in urban zone using multi temporal satellite. *International Journal of Remote Sensing* **10**: 989-1003.

Mas, J.F. 1999. Monitoring landcover changes: A comparison of change detection techniques. *International Journal of Remote Sensing* **20**(1): 139-152.

Miller, A.B., Bryant, E.S. and Birnie, R.W. 1998. An analysis of landcover changes in the Northern forest of New England using multi-temporal LANDSAT MSS Data. *International Journal Remote Sensing* **19**(2): 215-265.

Milne, A.K. 1988. Change detection analysis using Landsat imaging: A review of methodology. **In:** *Proceedings of IGARSS 88 Symposium.* Edinburgh Scotland, ESASP **1**: 284.

Mohan, S., Mehta, N.S. and Patel, P. 1990. Radar remote sensing for land applications - A review, *Scientific Report* pp. 36-91.

Mon, M.S., Tsoyoshi, K., Mizoune, N. and Youshida, S. 2008. Study on the changes of forest canopy density using landsat images and field data. *International Journal Remote Sensing* **24**(2): 203-211.

Murai, S. 1995. Development of global eco-engineering using remote sensing and geographic information systems. **In**: *Towards Global Planning of the Sustainable Use of the Earth Resources*, *Proceedings of 8th Toyota Conference Elsevier* **2**: 123.

Mya, J. 2010. Analysis of forest cover change process, using remote sensing and GIS: A case study in Sultan Syarif Hasyim Grand Forest Park, Riau Province, Indonesia. M.Sc Thesis submitted to University of Twente, Enschede, Netherlands.

Myers, N. 1993. Tropical forest: the main deforestation fronts. *Environmental Conservation* **20**: 9-16.

NASA, 1998. *Tropical deforestation*, NASA facts, National Aeronautics and Space Administration pp. 111-120

Navalgund, R.R. 2006. Indian earth observation system: An overview. *Asian Journal of Geoinformatics* **6**(1): 17-25.

Navalgund, R.R., Jayaraman, V. and Roy, P.S. 2007. Remote sensing applications: an overview. *Current Science* **93**(12): 1747-1766.

Negi, G.S. 1984. Landsat data in study of forest recession due to shifting cultivation. A case study in Garo hills of Meghalaya. *Indian Journal of forestry* **7**(4): 273-280.

Negi, S.P. 2009. Forest cover in Indian Himalayan states- an overview. *Indian Journal of Forestry* **32**(1): 1-5.

Nunes, C. and Auge, J.I. 1999. Landuse and landcover implementation strategy. *International Journal of Remote Sensing* **15**: 546-559.

Porwal, M.C. and Pant, D.N. 1989. Forest cover type and landuse mapping using Landsat thematic mapper, false colour composite (FCC)- A case study for Chakrata in Western Himalayas. *Journal of Indian Society of Remote Sensing (Photonirvachak)* **17**(1): 33-40.

Rao, D.P. 1991. IRSIA application for landuse/landcover mapping in India. *Current Science* pp. 153-167.

Ravindranath, N.H., Srivastava, N., Murthy, I.K. and Malaviya, S. 2012. deforestation and forest degradation in India-implications for REDD+. *Current Science* **102**(8): 1117-1125.

Reddy, C.S., Jha, C.S. and Dadhwal, V.K. 2013. Assessment and monitoring of long-term forest cover changes in Odisha, India, using remote sensing and GIS. *Environmental Monitoring Assessment* **185**: 4399-4415.

Roy, P.S., Ranganath, B.K., Diwakar, P.G., Vohra, T.P.S., Bhan, S.K., Singh, I.J. and Pandian, V.C. 1991. Tropical forest type mapping and monitoring using remote sensing. *International Journal of Remote Sensing* **12**: 2205-2225.

Roy, D.P., Lewis, P.E. and Justice, C.O. 2002. Burned area mapping using multi-temporal moderate spatial resolution data- A bi-directional reflectance model-based expectation approach. *Remote Sensing of Environment* **83(**1): 263-286.

Roy, D.P., Scaramuzza, P.L., Kovalskyy, V., Hansen, M.C., Loveland, T.R., Vermote, E.F. and Zhang, C. 2010. Web enabled Landsat data (WELD): Landsat ETM+ Composited mosaics of the conterminous United States, *Remote Sensing of Environment* **114**: 35-49.

Rudel, T.K. 2005. *Tropical Forests:* Regional Paths of Destruction and Regeneration in the Late 20th Century. Columbia University Press p. 18.

Sabins, F.F. 1997. *Remote Sensing: Principles and Interpretation.* 3rd Edition. W.H Freeman and Company. New York.

Sajjad, A., Hussain, A., Wahab, U., Adnan, S., Ali, S., Zahoor, A. and Ashfaq, A. 2015. Application of remote sensing and GIS in forest cover change in Tehsil Barawal, District Dir, Pakistan. *American Journal of Plant Sciences* **6**:1501-1508.

Salovaara, K.J., Thessler, S., Malik, R.N. and Tuomisto, H. 2005. Classification of Amazonian primary rain forest vegetation using Landsat ETM+ satellite imagery. *Remote Sensing of Environment* **97**(1): 39-51.

Shah, S. and Sharma, D.P. 2015. Landuse change detection in Solan forest Division, Himachal Pradesh India. *Forest Ecosystems* **2**: 26.

Sharma, V.V.L.N., Murali, K., Hema, M.B., Nageswara, K. and Roa, P. 2001. Land use land cover change detection through remote sensing and its climatic implications in the Godaveri delta region. *Journal of Indian Society of Remote Sensing* **29**(1-2): 85-91.

Showqi, I. and Bhat, G.A. 2014. Evaluating spatio-temporal dynamics of landuse/landcover in romshi watershed of Jhelum Basin, Jammu and Kashmir-India. *World Applied Sciences Journal* **32**(5): 848-852.

Singh, A. 1986. *Review Article*: Digital Change Detection Techniques using Remotely Sensed Data. *International Journal of Remote Sensing* **10**: 989-1003.

Singh, A. 1989. Digital change detection techniques using remotely-sensed data. *International Journal of Remote Sensing* **10**: 989-1003.

Skole, D. and Tucker, C. 1991. Tropical deforestation and habitat fragmentation in the Amazon: satellite data from 1978 to 1988. *Current Science* **260**: 1905-1910.

Sreenivasulu, G., Jayaraju, N., Kishore, K. and Prasad, L. 2014. Landuse and landcover analysis using remote sensing and GIS: a case study in and around Rajampet, Kadapa district, Andhra Pradesh, India. *Indian Journal of Science Research* **8**(1): 123-129.

Tiwari, A.K. 1995. Net flux of carbon in forest ecosystems of Rajaji National Park, Uttar Pradesh. **In**: *Proceedings of national symposium on remote sensing of environment with special emphasis on Green evolution* (November 22-24). Sahai, (Eds. B. Sharma, P.K. Bhan, S.K. Parihar, J.S. Ravindran, K.V. and V. Jayaraman). *Indian Society of Remote Sensing*, Dehardun pp. 239-242.

Townshed, J.R. 1995. The NASA landsat pathfinder humid tropical deforestation project. **In**: *Proceedings of the ASPRS Conference on Land Satellite Information in the Next Decade* **4**: 76-87.

Trapp, H. and Mool, P. 1996. Lamjung district information system for local planning and assessment of natural resources using GIS and remote sensing technology. ICIMOD, Kathmandu **2**: 228-229.

Turner, B. 2002. *Towards integrated land-change science*. Advances in sustained research on landuse and landcover change. Springer pp. 21-26.

UNFCCC (United Nations Framework Convention on Climate Change). 2007. Investment and financial flows to address climate change p. 272.

Vemu, S. and Bhaskar, P. 2010. Change detection in landuse and landcover using remote sensing and GIS techniques. *International Journal of Engineering Science and Technology* **2**(12): 7758-7762.

Vina, A., Echavarria, F.R. and Rundquist, D.C. 2004. Satellite change detection analysis of deforestation rates and patterns along the Columbia Equador border. *Forestry Abstracts* **65**(9): 1273.

Vitousek, P.M. 1992. Global Environmental Change: An introduction. *Annual Revision of Ecological System* **23**: 1-14.

Wani, A.A. 2008. Forest cover assessment and trend in central India using Remote Sensing and GIS. *Indian Forester* **134**(11): 1529-1538.

Wani, A.A., Singh, S., Joshi, P. K., Zargar, M.A. and Wani, A.A. 2009. Forest cover mapping and change detection analysis (1960 to 1970) in some parts of central India using remote sensing and GIS 2009. **In**: *Proceedings of IV National Forestry Conference, Forest Research Institute Dehradun.*

Wani, A.A., Joshi, P.K., Singh, O. and Bhat, J.A. 2013. Estimating soil carbon storage and mitigation under temperate coniferous forests in the southern region of Kashmir Himalayas. *Mitigation and Adaptation Strategies for Global Change* **19**(8): 1179-1194.

Wani, A.A., Joshi, P.K. and Singh, O. 2014. Mapping agroforestry cover and trend in the southern region of Kashmir Himalayas using remote sensing and GIS. *Abstract in 3rd J&K Agricultural Science Congress, Organic Agriculture Prospects in Jammu and Kashmir* (12-14 May, 2014), SKUAST-Kashmir p. 68.

Wani, A.A., Joshi, P.K. and Singh, O. 2015. Estimating biomass and carbon mitigation of temperate coniferous forests using spectral modeling and field inventory data. *Ecological Informatics* **25**: 63-70.

Wani, A.A., Joshi, P.K. and Singh, O. 2016. Multi-temporal (1980-2030) forest cover dynamics in Kashmir Himalayan region for assessing deforestation and forest degradation in the context of REDD+ policy. *Journal of Mountain Science* (in press).

Whittaker, R.H. 1966. Forest dimensions and production in the Great Smoky Mountains. *Ecology* **47**(1): 103-121.

Wulder, M.A., White, J.C., Cranny, M., Hall, R.J., Luther, J.E., Beaudoin, A., Goodenough, D.G. and Dechka, J.A. 2007. Regional scale boreal forest cover and change mapping using Landsat data composites for European *Russia, Canadian Journal of Remote Sensing* **34**: 549-562.

Yang, X., Skidmore, A.K., Melick, D., Zhou, Z. and Xu, J. 2007. Towards an efficacious method of using Landsat TM imagery to map forest in complex mountain terrain in Northwest Yunnan, China. *Tropical Ecology* **8**(2): 227-239.

Yen, P., Ziegler, S. and Huetmann, F. 2005. Change detection of forest and habitat resources from 1973-2001 in Bach Ma National Park, Vietnam using remote sensing imagery. *International Forestry Review* **7**: 1.

Yuanbo, L., Sochi, T. and Tomisha, G. 2003. Analysis of four change detection algorthims bi-temporal space with a case study. *International Journal of Remote Sensing* **25**(11): 2121-2139.

Zhu, Z. L. and Waller, E. 2000. Global forest cover mapping for the United Nations Food and Agriculture Organization. *Forest Resources Assessment 2000 Program. Forestry Abstracts* **65**(12): 16-17.

<u>Appendix 1</u>

Preliminary details of villages adjoining forest witnessing negative forest cover change from mapping

	Preliminary details of village		Respondent No.	Name & Parentage	Profession (Agr/ Employed/ Daily wager/ None)	No of family dependent family members	Average monthly family income (Rs.)	Altitude (m)	Dependence on forests (timber, fuel, fodder etc.) %	Land holding (ha) Agri/Hort/ unproductive	No. of livestock
Village 1	Address (Village, Tehsil, Distrct)	Sutharan Khag Budgam	1	Ab Rahman hajam S/O GhRasool	Agr	6	5000		30	0.3	4
	Population:	3622	2	AbGaniTantary S/o GhahmadTantary	labour	4	4500		40	0.2	2
	No of households:	395	3	Rahman shekh S/o Akbar Shekh	Agr	4	6000		25	0.5	2
	Location (Lat/Long):	74.5528/ 33.9147	4	Hamid Sheikh S/o Ahmad Sheikh	Labour	5	2000		50	0.4	3
	Altitude (m):	2301	5	MohidinDohli S/o Ahmad Dohli	Agr	8	2500		50	0.1	5
	Distance from nearby forest:	0.5 km	6	Shafi Sheikh S/o Rahman Sheikh	Agr	3	6000		60	0.1	1
	Dominant changes in the nearby forest observed from mapping	Deforestation	7	QadirHajam S/o Akbar Hajam	Agr	8	10,000		20	0.3	4
	Major profession of villagers	Farming	8	WaliHajam S/o Gh. Ahmad Hajam	Barber	9	3000		60	0.5	2
	Connected to forest by kutcha/pucca road	Pucca	9	Bashir Ah S/o GhRasoolhajam	Barber	4	4500		40	0.3	1
	Distance from neaest forest check post	8 km	10	Gh Ahmad sheikh S/o rasool Sheikh	Agr	11	12,000		10	0.6	6

Village 2	Address (Village, Tehsil, Distrct)	Lasipora	1	Ashraf Shah S/o Gh Ahmad Shah	Agr	4	4000		50	0.1	2
	Population:	900	2	FirdousParray S/o Mohmad parry	Agr	3	3000		40	00	1
	No of households:	230	3	GhMohidin Shah s/o Ahad Shah	Labour	3	2000		30	0.2	0
	Location (Lat/Long):	74.5590/ 33.9143	4	Ahad Khan S/o Qadir Khan	Agr	2	5000		50	0.3	0
	Altitude (m):	2295	5	Raheem wani S/o samad Wani		6	6000		40	0.6	5
	Distance from nearby forest:	0.7 km	6	Altaf Khan S/o gaffer Khan	Agr	4	4500		20	0.3	4
	Dominant changes in the nearby forest observed from mapping	Deforestation	7	ManzoorParray S/o KhaliqParray	Agr	4	12000		30	0.5	2
	Major profession of villagers	Farming	8	Arshid Khan s/o Razzaq Khan	Agr	7	10000		20	0.5	15
	Connected to forest by kutcha/pucca road	Pucca	9	Majeed Khan S/o ahsan Khan	Agr	2	7000		40	0.2	10
	Distance from neaest forest check post	8 km	10	Ahmad Shah S/o Subhan Shah	Dailywage	2	3000		50	0.3	3
Village 3	Address (Village, Tehsil, Distrct)	SozlipatherKhagbudgam	1	Amin Khan S/o Ahmad Khan	Agr	3	3000		60	0.2	1
	Population:	950	2	Sattar Khan S/o Rasool Khan	Agr	3	4000		40	0.3	00
	No of households:	140	3	Tawseefbhat S/o MajeedBhat	Labour	5	4000		60	0.1	1
	Location (Lat/Long):	74.5570/ 33.91200	4	Sadeeq Shah s/o ahmad shah	Agr	6	7000		40	0.1	2
	Altitude (m):	2300	5	WaliMohmad Shah	Labour	2	1500		70	00	00

	Distance from nearby forest:	1 km	6	Kareem Khan S/o rasool Khan	Agr	8	2000		40	0.1	1
	Dominant changes in the nearby forest observed from mapping	Deforestation	7	Waheed Shah s/o Mehraj Shah	Agr	8	5000		20	0.2	2
	Major profession of villagers	Farming	8	Riyaz Khan S/o Khaliq Khan	Agr	12	8000		20	0.3	1
	Connected to forest by kutcha/pucca road	Pucca	9	Gaffer Bhat S/o SadeeqNhat	Agr	5	1000		50	0.2	00
	Distance from neaest forest check post	7km	10	Tariq Sofi S/o Rasheed sifi	Agr	8	3500		60	0.1	4
Village 4	Address (Village, Tehsil, Distrct)	Khaipora	1	GhMohidinhajam	Labour	4	1000		40	00	00
	Population:	100	2	Gh. Rasoolhajam	Agr	7	1500		30	0.1	1
	No of households:	850	3	Abganihajam	Agr	8	4000		40	0.2	1
	Location (Lat/Long):	74.5407/ 33.9216	4	M. Subhanhajam	Barber	6	3000		30	0.1	1
	Altitude (m):	2351	5	Bashir Hajam	Barber	5	2000		40	0.2	4
	Distance from nearby forest:	0.5	6	MohamadNajar	Labour	3	1000		60	00	00
	Dominant changes in the nearby forest observed from mapping	Deforestation	7	Rashed Khan	Agr	4	2500		20	0.5	4
	Major profession of villagers	Farming	8	SamadNajar	Agr	2	1500		20	0.3	3
	Connected to forest by kutcha/pucca road	Pucca	9	GhMohamadBhat	Agr	7	5000		30	0.5	4
	Distance from neaest forest check post	8 km	10	Riyaz khan	Labour	11	5000		40	0.1	2

Appendix 2

Preliminary details of villages adjoining forest witnessing positive forest cover change from mapping

Village No	Preliminary details of village		Respondent No.	Name & Parentage	Profession (Agr/Employed/ Daily wager/None)	No of family dependent family members	Average monthly family income (Rs.)	Altitude (m)	Dependence on forests (Timber, Fuel, Fodder etc.) %	Land holding (ha) Agri/Hort/ unproductive	No. of livestock
Village 1	Address (Village, Tehsil, Distrct)	Nagbal (Chrar)	1	Shareefwani	Labour	4	2500		30	0.1	1
	Population:	650	2	Sartajwani	Agr	3	3000		20	0.1	1
	No of households:	120	3	Bashir Khan	Agr	4	3000		40	0.1	2
	Location (Lat/Long):	74.7334/ 33.81094	4	Sattarbhat	Agr	4	5000		10	0.3	1
	Altitude (m):	2395	5	Nazirdarzi	Agr	3	2000		10	0.2	2
	Distance from nearby forest:	3 km	6	Samad rather	Agr	5	3500		30	0.2	1
	Dominant changes in the nearby forest observed from mapping	Increase	7	Habeeb rather	Agr	6	4000		30	0.2	3
	Major profession of villagers	Farming	8	Hameed Bhat	Agr	6	5000		40	0.1	4
	Connected to forest by kutcha/pucca road	Pucca	9	RiyazNajar	Labour	5	2500		60	00	4
	Distance from neaest forest check post	7 km	10	RiyazBhat	Agr	7	5000		20	0.3	2
Village 2	Address (Village, Tehsil, Distrct)	Sonabanjar (Chrar)	1	Gh Ahmad Kumar	Agr	9	4000		30	0.1	5
	Population:	400	2	GhNabi Kumar	Agr	3	2000		30	0.3	3
	No of households:	70	3	Gani Kumar	Labour	4	1500		60	00	30
	Location (Lat/Long):	74.67200/ 333.82603	4	Habibulah Khan	Agr	3	2000		70	00	4
	Altitude (m):	2190	5	Rahman Khan	Agr	3	2500		30	0.2	1
	Distance from nearby forest:	2 km	6	Rayees khan	Agr	8	3000		50	0.3	2
	Dominant changes in the nearby forest observed from mapping	Increase	7	SubhanRathr	Agr	9	4000		60	0.1	1
	Major profession of villagers	Farming	8	Ashraf wani	Agr	5	6000		30	0.1	2
	Connected to forest by kutcha/pucca road	Katcha	9	Firdousmalik	Labour	6	8000		20	00	0
	Distance from neaest forest	6 km	10	Ahadmogray	Agr	6	4500		40	0.5	2

	check post										
Village 3	Address (Village, Tehsil, Distrct)	Kanidajan	1	Parvez Khan	Agr	2	2500		20	0.1	0
	Population:	1100	2	Farooq Parray	Labour	3	4000		30	0.3	1
	No of households:	290	3	Firdous Malik	Agr	3	3500		30	0.3	1
	Location (Lat/Long):	74.33/33.	4	Shafat Malik	Agr	9	4000		30	0.5	2
	Altitude (m):		5	Riyaz Malik	Agr	11	3000		50	0.5	4
	Distance from nearby forest:	1 km	6	Khurseed Khan	Labour	2	1500		40	00	0
	Dominant changes in the nearby forest observed from mapping	Increase	7	Rasheed shekh	Labour	7	3000		30	00	2
	Major profession of villagers	Farming	8	Raheem Shekh	Agr	6	4000		20	0.2	3
	Connected to forest by kutcha/pucca road	Pucca	9	Mohidin Khan	Agr	8	5500		20	0.5	4
	Distance from neaest forest check post		10	Shafinajar	Agr	3	2500		30	0.1	1
Village 4	Address (Village, Tehsil, Distrct)	Sangerwani	1	Bashir Khatana	Agr	4	2000		50	0.1	0
	Population:	550	2	MerajSood	Labour	6	3000		30	0.2	1
	No of households:	110	3	ShowkatBith	Agr	11	12000		10	0.4	5
	Location (Lat/Long):	74.73702/33.82005	4	WaliBokan	Labour	2	1000		70	00	1
	Altitude (m):	2351	5	Khaliqdar	Agr	7	1500		70	00	2
	Distance from nearby forest:	2 km	6	Unjum Khan	Agr	4	3000		20	0.2	14
	Dominant changes in the nearby forest observed from mapping	Increase	7	Rasheed Wani	Agr	3	2500		50	0.1	2
	Major profession of villagers	Farming	8	Mushtaq Khan	Agr	8	6000		40	0.2	1
	Connected to forest by kutcha/pucca road	Pucca	9	Hameed Malik	Labour	9	5000		50	0.3	1
	Distance from neaest forest check post	6 km	10	Afrooz Khan	Agr	7	4500		30	0.1	3

Appendix 3

Interview Schedule for assessing drivers of change (Negative)

Close ended semi-structured interview (Villages adjoining negative forest cover change from mapping)

Perceived reasons for drivers of forest cover change by village respondents based on six dominant perceptions with an assigned score from 1 to 6 (1 = Strongly agree; 2 = Moderately agree; 3 = Slightly agree; 4 = Slightly disagree; 5 = Moderately disagree; 6 = Strongly disagree)

Village No.	Respondent No.	Expansion for agriculture (1-6)	Illicit felling for timber (1-6)	Excessive fuel wood extraction (1-6)	Excessive grazing/ fodder extraction (1-6)	Plantation/Afforestation measures by the SFD (1-6)	Population growth (1-6)	Subsistence (1-6)	Poverty/Lack of employment (1-6)	Lack of awareness about importance of forests (1-6)	Degree of forest protection (1-6)	Increasing demand for timber leading to smuggling (1-6)
Village 1	1	3	1	3	3	4	1	2	2	3	5	3
	2	2	1	2	3	5	1	2	1	3	4	2
	3	3	1	3	3	4	2	2	1	4	5	2
	4	4	1	1	2	3	1	3	1	3	6	1
	5	4	1	1	1	3	3	1	1	3	6	2
	6	3	1	3	1	2	3	1	1	4	4	3
	7	4	1	2	2	4	2	4	1	5	5	1
	8	3	1	2	3	3	4	3	1	3	5	2
	9	4	1	1	4	2	1	4	1	3	4	1
	10	5	1	1	1	3	2	5	1	3	5	2
Village 2	1	5	1	2	3	4	1	2	1	6	6	4
	2	3	1	2	2	3	1	1	1	4	4	4
	3	4	1	1	3	4	2	2	1	5	4	3
	4	2	1	1	3	4	2	3	1	5	5	4
	5	2	2	1	1	4	1	2	1	4	6	3
	6	4	1	3	2	2	1	2	1	3	5	2
	7	4	1	1	2	4	1	3	2	4	5	3

	8	4	2	1	3	3	3	1	1	4	4	3
	9	3	1	2	3	3	2	2	1	5	5	2
	10	3	1	2	4	2	1	2	1	3	5	1
Village 3	1	3	1	3	3	5	2	2	1	3	5	2
	2	4	1	2	4	5	1	2	1	2	6	2
	3	4	1	3	4	4	1	1	1	2	5	3
	4	2	1	3	3	5	1	2	2	3	5	1
	5	2	2	4	2	3	3	2	1	1	6	1
	6	3	1	2	3	5	1	3	1	2	4	1
	7	3	2	2	3	6	1	3	2	3	4	2
	8	4	2	3	2	3	1	2	2	4	4	1
	9	2	2	2	3	4	2	1	1	3	5	1
	10	2	1	2	3	3	2	2	1	1	5	1
Village 4	1	3	1	3	1	4	1	3	2	2	6	4
	2	2	1	2	1	2	4	3	1	2	6	4
	3	4	2	3	2	2	3	1	1	2	4	3
	4	5	3	3	2	3	2	1	1	3	4	4
	5	4	1	3	3	5	2	2	2	4	4	3
	6	4	1	1	2	4	1	2	2	1	5	4
	7	3	1	1	2	4	1	1	3	2	5	3
	8	2	2	2	3	3	1	1	2	2	6	3
	9	2	1	3	1	3	1	2	1	1	6	2
	10	2	2	3	3	5	2	3	2	1	5	2

Appendix 4

Interview Schedule for assessing drivers of change (Positive)

Close ended semi-structured interview (Villages adjoining positive forest cover change from mapping)

Perceived reasons drivers of forest cover change by village respondents based on six dominant perceptions with an assigned score from 1 to 6 (1 = Strongly agree; 2 = Moderately agree; 3 = Slightly agree; 4 = Slightly disagree; 5 = Moderately disagree; 6 = Strongly disagree)

Village No.	Respondent No.	Expansion for agriculture (1-6)	Illicit felling for timber (1-6)	Excessive fuel wood extraction (1-6)	Excessive grazing/ fodder extraction (1-6)	Plantation/ Afforestation measures by the SFD (1-6)	Population growth (1-6)	Subsistence (1-6)	Poverty/Lack of employment (1-6)	Lack of awareness about importance of forests (1-6)	Degree of forest protection (1-6)	Increasing demand for timber leading to smuggling (1-6)
Village 1	1	6	6	6	6	1	6	6	6	6	1	5
	2	6	6	6	5	1	5	6	6	6	1	6
	3	6	6	6	6	1	6	5	6	6	1	6
	4	6	6	6	6	1	6	4	6	5	1	4
	5	6	5	6	6	2	6	6	5	6	2	6
	6	6	6	5	5	2	6	6	6	3	2	6
	7	5	6	6	6	1	5	6	4	4	1	6
	8	6	6	6	6	1	6	4	6	6	2	3
	9	6	6	6	6	1	6	5	6	5	1	6
	10	6	6	6	5	2	6	5	5	6	1	4
Village 2	1	6	5	6	6	2	6	6	6	6	2	5
	2	5	6	5	6	1	6	6	6	4	1	6
	3	6	6	6	5	1	5	5	4	6	1	6
	4	6	6	6	6	2	6	6	6	6	1	6
	5	6	6	6	6	1	6	6	6	3	1	6
	6	5	6	6	6	2	6	6	6	6	1	6

	7	6	6	6	6	2	6	4	6	6	2	4
	8	6	6	5	6	2	6	6	6	6	2	6
	9	6	5	6	6	2	5	6	6	5	2	3
	10	6	6	6	6	1	6	6	5	6	2	5
Village 3	1	5	6	6	6	1	4	6	6	6	2	6
	2	6	6	6	6	1	4	6	6	3	1	6
	3	6	6	6	6	1	6	5	6	6	1	6
	4	6	6	4	6	1	6	6	5	6	2	6
	5	6	6	4	5	1	5	4	6	6	2	6
	6	6	6	6	6	1	4	6	6	6	1	5
	7	4	6	6	6	1	6	6	6	6	2	6
	8	4	6	6	6	2	6	6	6	4	2	4
	9	6	6	6	6	2	6	6	6	5	1	6
	10	6	6	3	5	1	5	6	6	6	2	6
Village 4	1	6	4	6	6	1	6	6	4	6	2	6
	2	6	4	6	6	1	6	4	6	5	1	3
	3	6	4	6	4	1	6	6	6	4	1	6
	4	6	6	6	6	1	4	5	6	6	1	6
	5	6	6	6	5	2	6	6	6	6	1	5
	6	6	5	6	4	2	6	4	6	3	2	6
	7	6	6	6	6	1	6	6	4	5	1	6
	8	6	6	6	5	2	6	6	4	6	2	6
	9	6	5	6	6	1	6	6	6	6	2	3
	10	6	6	6	4	2	6	6	6	6	1	6

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Certificate

Certified that all the corrections/amendments as suggested by External Examiner Dr. P. K. Joshi, Professor, School of Environmental Sciences, JNU, New Delhi, during Viva-Voce examination held on 28-12-2016 have been incorporated in the manuscript entitled **“Forest cover assessment and change detection analysis using remote Sensing and GIS in Pir Panjal Forest Division of Kashmir Himalayan region”** submitted by **Mr. Yasir Amin (Regd. No. 2013-For-43-M).**

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