Available online at www.sedindia.in/ewijst

ISSN: 0975-7112 (Print)
ISSN: 0975-7120 (Online)

Environ. We Int. J. Sci. Tech. 18 (2023) 11-17

Environment & We An International Journal of Science & Technology

Change Detection in Forest Types – A Case Study of Yamunanagar Forest, Haryana, India

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Article history:
Received 22 June 2023
Received in revised form
16 July 2023
Accepted
23 July 2023
Available online
31 July 2023

Keywords:
Remote sensing;
Digital image processing;
NDVI;
Carbon sequestration

Abstract

Forest ecosystem has a vital role in regulating climate change, providing ecological services to human population and in improving the socio-economy of a country. However, with a rapidly growing population a wide gap between demand and supply of goods and services provided by forests has been observed. This has lead to a reduction in forest cover and therefore a need arises to monitor it at regular interval of time. The continuously evolving remote sensing technology is capable of providing satellite images of Earth's surface at large scale. The current study utilizes Landsat series of satellite images to derive information on forest type in the Yamunanagar forest division for the year 2000, 2010 and 2020 and find temporal changes in its cover. The forest area is extracted using the boundary of the Yamunanagar forest division. The normalized difference vegetation index (NDVI) algorithm is used to distinguish green vegetation cover from other land use land use land cover (LULC) classes. The forest cover was further classified in to deciduous and coniferous type using the satellite images of leaf-on and leaf-off season. Both, field observations and forest cover derived from satellite images showed that not only quantitative estimation but qualitatively growth of the two types of forest can be explained well with the input data and method.

1.Introduction

Globally, more than 1.6 billion people depend on forests for their livelihoods (Chao, 2012). Carbon is one of the ecosystem services provided by forests (Forest Trends, 2016). Therefore, any change on forest structure and composition can disturb the entire ecosystem services including global carbon budget leading to climate change (Jenkins and Schaap, 2018). The diversity of forests in India makes it resilient to climate change and an efficient sink of carbon. The carbon budget of a forest ecosystem depend on site conditions, vegetation composition and attributes, forest management as well as biotic and abiotic interferences (Tupek *et al.,* 2010). The result of various reports as shown in Table 1 revealed the fact that India's carbon stock is gradually increasing (FSI, 2017; IFSR, 2013; IFSR, 2015; IFSR, 2017; IFSR, 2019; IFSR 2021). However, as shown in Table 2, Haryana State is facing reverse trend due to gradual decrease in forest cover (FSI, 2017; IFSR, 2017; IFSR, 2019; IFSR 2021). The negative change in forest cover of Haryana is due to rotational felling and diversion of land for non-forestry purposes (IFSR, 2015).

In the last 50 years since the launch of first fully operational Earth observation Landsat satellite in 1972, a gradual development of sensing technology, digital image processing (DIP) technique and geographical information system (GIS) has led in continual growth of application of technologies in both horizontal and vertical directions. Furthermore, the forest types or tree species information generated in the form of maps and data are derived by scientific community is largely from passive optical satellite images which has open access with time series information (Hermosilla *et al*., 2022). The new series of Landsat 8 and 9 Operational Land Imager (OLI) multispectral sensor offer real-time monitoring of changes in land cover including forest with a reliable degree of accuracy and open accessibility (Kennedy et al., 2014; Wulder et al., 2012).

In India, Haryana State, after Ladakh which is a Union Territory, occupy lowest fraction (3.63%) of recorded forest area (1603000 ha) (IFSR, 2021). Most of the forests of Haryana is distributed on its northern territory along the upper Siwalik range in the Panchkula and Yamunanagar district. The forest of Yamunanagar district occupy largest area covered with very dense forest (more than 70% density), and is home to patches of diverse plant species including both deciduous and evergreen tree species (Anuradha and Gupta, 2022). The forests are important sink of atmospheric carbon sequestration in the terrestrial ecosystem and in this quantitative presence of evergreen and deciduous tree is one of the important determinants. Further, literature survey shows that there is a gap of studies on forest types distribution in the district. This study aim to highlight the quantity as well as decadal changes from year 2000 to 2020 in the evergreen and deciduous forests using remote sensing, DIP and GIS technology.

Table .1 Carbon stock of India

Year	Total Carbon Stock ('000 tonnes)	*Carbon stock tCO_2 (tonnes of CO_2 eq.)
[1]1994	6071000	22280570
[1]2004	6662574	24451647
[2]2011	6941000	25473470
[3]2013	7044000	25851480
[4]2015	7082063	25991171
[5]2017	7124676	26147561
[6]2019	7204000	26438680

[1](FSI, 2017); [2](IFSR, 2013); [3](IFSR, 2015); [4](IFSR, 2017); [5](IFSR, 2019); [6](IFSR, 2021)
*Carbon stock (tonnes of CO_2 eq.) = Carbon stock×3.67 (IPCC, 2003).

Table 2 Carbon stock of Haryana

Year	Total Carbon Stock ('000 tonnes)	*Carbon stock tCO_2 (tonnes of CO_2 eq.)
[1]1994	12681	46539
[2]2015	12411	45548
[3]2017	10466	38410
[4]2019	10232	37551

[1](FSI, 2017); [2](IFSR, 2017); [3](IFSR, 2019); [4](IFSR, 2021)

2. Materials and Methods

2.1 Study Area: Yamunanagar district is a north-eastern part of Haryana State of India that lies from 29^0 55' to 30^0 31'north latitude and from 77^0 00' to 77^0 35' east longitudes and occupies 1756 km^2 area. The climate of the study area has a subtropical continental monsoon, mild and dry winter, hot summer and sub-humid, which is especially dry with summer and winter except during the monsoon season. The district is mainly drained by the river Yamuna, Markanda and their tributaries. The headquarter of the division is situated in the city of Yamunanagar. The normal annual rainfall of the district is 1107 mm, and is unevenly distributed over the area. The average rainy days are 43. The income of residents mainly depends on the agriculture and agro-forestry (Directorate of Census Operations, 2014). The forest of the Yamunanagar district is classified into three categories – reserved, protected, and unclassified. The thickness of the forest lies in large belt along the northern boundary of the area that extends west from the river Yamuna to a length of 26 km forming the core bulk of the forest. Apart from this bulk, there are several small compact blocks of forest. The area includes upper Siwaliks which are characterized by rough and broken terrain with gentle to steep slopes. These hills rising up to an elevation of 650 meters and are subject to erosion of all forms and degrees. The map of the study area is shown in fig 1.

2.2 Data Acquisition: The Landsat 7, Landsat 5 and Landsat 8 satellite images having 30-meter pixel resolution is used in this study. The images of the study area was acquired by Landsat satellite on 15 October 2000, 03 October 2010 and 28 September 2020 and is available for download on United State Geological Survey (USGS) Earth Explorer open source platform. This study also includes field data and data from secondary sources such as topographic maps. The GPS-based field data is collected for ground verification of forest types. The change detection technique was used in GIS environment to find out decadal changes in forest types from year 2000 to year 2020. Additionally, we used satellite image of leaf-off period to discriminate and estimate both deciduous and evergreen forest cover. For this, we used Landsat satellite images acquired on 24 May 2000, 13 June 2010 and 17 June 2020, respectively.

2.3 Ground Truth Strategy: GPS-based locational information is used for forest type mapping obtained after normalized difference vegetation index (NDVI)-based forest classification using satellite data of the leaf-on and leaf-off period. The type of forest on image is verified on the ground assisted by GPS. The Survey of India (SOI) topographic sheet of 1:50,000 is used for additional verification.

2.4 Digital Image Interpretation: In these different methods were applied on digital images to perform processing, analysis and information extraction. Pre-processing, augmentation, conversion, and classification are the four general processes used in processing a digital image. Further, feature interpretation was done using image interpretation element - tone, size, texture, shape, pattern, association, aspect, shadow and by using ground knowledge.

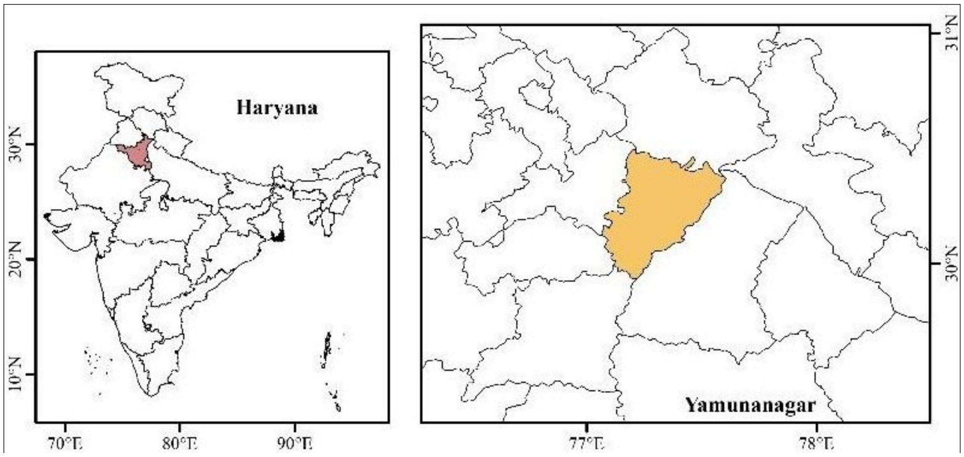

Fig 1: Map showing the study area

2.5 Forest Cover Type Mapping: As stated by the Ministry of Environment, Forest and Climate Change, the lands with a tree canopy of more than 10% and have an area of more than half hectare is called as 'forest' . The tree should be able to reach a minimum height of 5 meter. This class includes all the areas where the canopy cover/density is above 10%. According to Champion and Seth (1968) classification of India's forests, the forests of Yamunanagar district of Haryana occupies: i) Tropical Northern Dry Mixed Deciduous Forests and ii) Sub-tropical Dry Siwalik Sal (*Shorea robusta*) Forests.

The forest cover type reflects the diversity of plant species in an area and indirectly shows health of a forest. Therefore, estimation of forest cover type is important in this study. For this, normalized difference vegetation index (NDVI) method is applied to distinguish vegetation cover from other land cover type. NDVI uses brightness values recorded in the visible and near-infrared wavelength regions and it ranges between -1 to +1. The negative value shows no vegetation, and when the value is positive it is the presence of vegetation (Tucker, 1979). The more closer it is to +1 value, the more healthier is vegetation. This method is adopted to examine remote sensing measurements and evaluate to whether the target being experiential have lived green vegetation or not. The forest boundary of the Yamunanagar recorded forest area is used to obtain forest cover. The forest cover was further classified in to deciduous and coniferous type using the satellite data of leaf-on and leaf-off season. The satellite images of the leaf-off months yield evergreen forest cover only and thus when compared with leaf-on months we can distinguish deciduous from evergreen forest cover.

3. Results and Discussion

3.1 Decadal Changes in Forest Cover Type: The Yamunanagar forest division is rich in the presence of both deciduous and evergreen forest cover types, particularly for very dense forest areas having canopy density more than 70%. Thus, studying the changes in two forest cover type is an important step forward to identify linked issues. The area and extent of changes in deciduous and evergreen forest cover is shown in fig 2, fig 3 and Table 3. Several studies have examined changes in broad land use land cover in the Himalayan region (Rao and Pant, 2001; Gautam *et al*., 2002; Yu *et al*., 2007). But, ground data, knowledge and data on changes in spatio-temporal patterns in land cover, the driving causes and their implications in the context of sustainable development are small in number (Hurni, 2000; Sankhayan et al., 2003). The present study fulfills the gap by collecting ground data, field knowledge and deriving data on changes in spatio-temporal patterns of forest type. The field study shows that Papri, Jamun, Jamoya, Kachnaar, Jaal, Kair, Sirus are the dominated evergreen plant species, and Safed Babul, Neem, Dhak, Tendu, Sal, Shisham, Khair, Kikar are the major deciduous plant species found in the study area.

Fig 2: Forest cover type map of Yamunanagar district (year 2000, 2010, 2020)

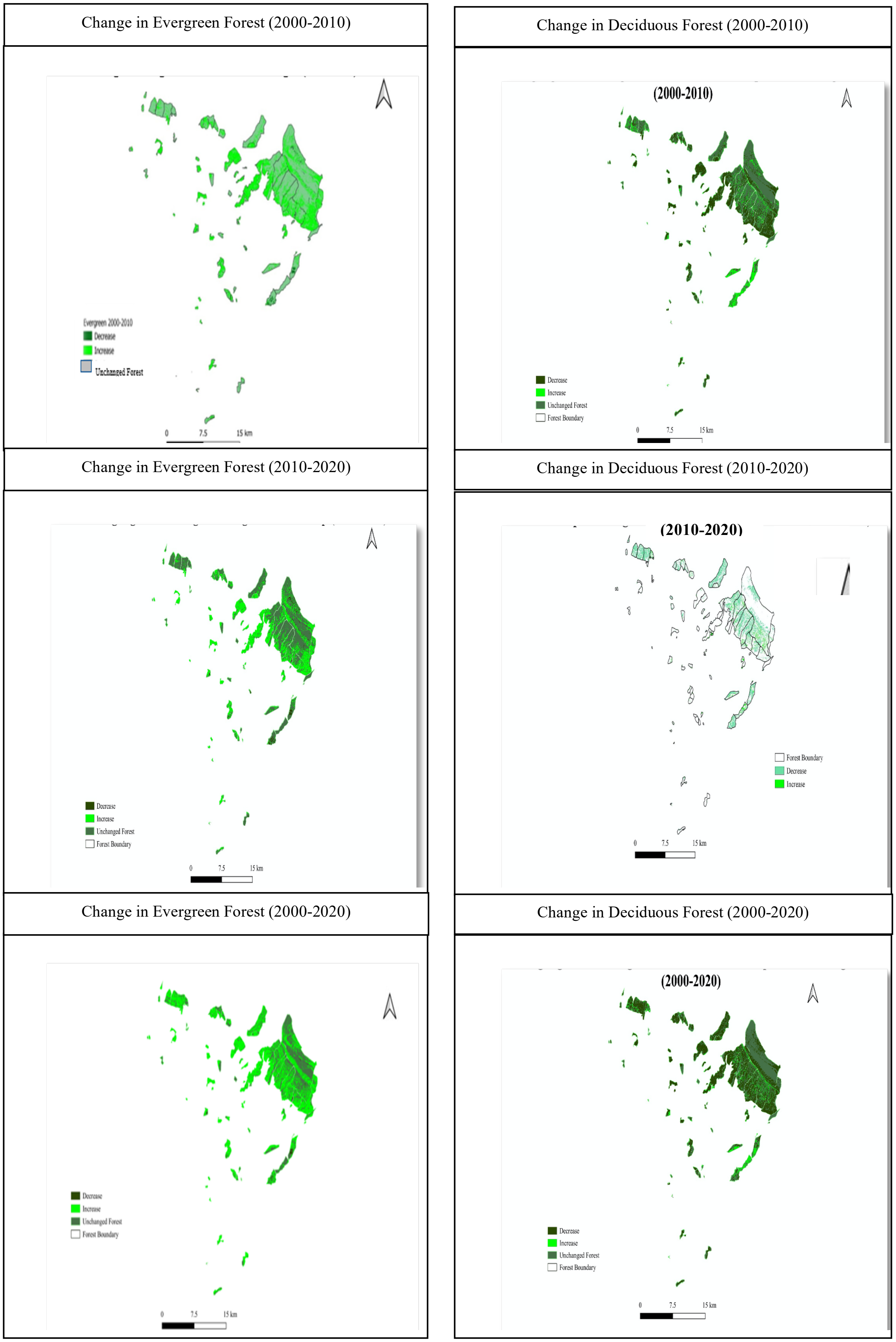

Fig 3: Decadal change in forest cover type of Yamunanagar district (year 2000-2010, 2010- 2020, 2000-2020)

The result shows that there is a gradual increase in evergreen forest cover in the study area occupying 17.79% of the total forest cover in year 2000 to 81.28% in year 2020. Whereas, a gradual decrease in deciduous forest cover is observed from 82.21% in year 2000 to 18.72% in year 2020. The potential causes of change in forest area are changes in vegetation vigor, short rotational period of plantation made by forest department, wild-fire and anthropogenic activities at the boundary of forest.

Table 3 Change in forest cover type (evergreen/deciduous) area in hectare (ha) and percentage (%) estimated from the multispectral satellite images between the year 2000-2010, 2010-2020 and 2000-2020. (The negative sign shows a decrease in area)

Class Name	2000	2010	2020
Forest cover - Evergreen	2039.13 (17.79%)	8310.33 (58.76%)	12134.88 (81.28%)
Forest cover - Deciduous	9420.66 (82.21%)	5832.72 (41.24%)	2795.31 (18.72%)
Decadal Change in forest cover	2000-2010	2010-2020	2000-2020
Forest cover - Evergreen	6271.2 (407.54%)	3824.55 (146.02%)	10095.75 (595.1%)
Forest cover - Deciduous	-3587.94 (-38.09%)	-3037.41 (-52.08%)	-6625.35 (-70.33%)

3.2 Forest type in carbon fixation: The number of plantations in afforestation program is not the only factor to increase the green area. The type of trees planted, their survival rate and how well are they grown up is the basis of carbon fixation in plants and thereby their role in mitigating the rising global temperature is measured. In Europe, a lot of afforestation activities has been done with evergreen conifers to raise the forest cover to cross the target of 33% of land covered under forest. The European Forest breath under cold to very cold climatic condition which result in low carbon fixation capability, and this capacity further slowed due to low canopy surface area of conifer trees. When we compare the situation in Indian forests and also in our study area, the forests are covered mostly with broad-leaved trees, both deciduous as well as evergreen type. Thus, when we compare the Indian forests lying at the equivalent altitude considering both leaf-fall period and the net leaf area, then the forest of our study area, where dry mixed deciduous forests and evergreen dry Siwalik Sal forests having broad leaves are found, has more carbon sequestration potential than forests of European countries, particularly the developed ones situated at the Northern and Central Europe. In addition, broad-leaved canopied forest performs two functions in parallel to a higher extent: one is it has higher shielding effect in which broad-leaved evergreen forest blocks and absorbs higher amount of solar radiation throughout the year, and the other is the higher evaporation from the larger leaf surface area which mitigates warming to larger extent. Therefore, decline in deciduous tree species in Yamunanagar forest, as indicated in table 3, is alarming and need afforestation with native broad-leaved deciduous tree species. This will result in raising carbon fixation capacity of the forests as well as their greater role in mitigating warming effects. In addition, replicating such concepts in other parts of the country will help in achieving the target to become a carbon neutral economy by the year 2070.

4. Conclusions

The result shows an increase in evergreen forest type and decrease in deciduous plants. One of the key factors for this is the plantation of mostly evergreen type of tree species compare to deciduous ones in the Yamunanagar forest division. A trans-boundary conflicts between fringe villages and forest department for the land ownership was revealed in the region. It was found that to minimize soil erosion along river bed, plantation initiatives are carried out in such lands by forest department and other active organizations in the study area. The ground survey suggests that the changes in the recorded forest boundary of Yamunanagar forest division is likely to intensify in the future due to ever increasing need of growing human population. The influence of human encroachment and illegal harvesting of plants from forest area will help in changing the pattern of forest growth and thereby the status of expected services provided by the forests of the study area in near future. In order to improve the adverse impact of urbanization on land cover, particularly on forest, water bodies and agriculture, a policy of environmentally measured zonation for residential, commercial and industrial development of the region is required that will reduce the encroachment on those land covers. It has been realized during the field survey that there is a need to spread the research findings and raising awareness programs which can lead to forest protection, conservation and management.

Acknowledgements: The authors are also thankful to the Forest Department, Haryana for granting access to forest area for ground truthing. The author thanks to other stakeholders who represented their view on the issue of sustainability during the survey.

Authors' contributions: *The research work was carried out under the guidance of Dr. Sandeep Gupta (SG) who designed the methodology of the work, helped in analysing the results and also corresponding author of manuscript. Ms. Anuradha carried out the experimental and field work, performed the GIS analysis and drafted the manuscript.*

Conflict of Interest: The authors declare that they have no conflict of interest.

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