Biological Forum – An International Journal **14(2): 450-456(2022)**

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Mapping and Change Detection Analysis of Agroforestry area in Ambala District of Haryana State, India using Geospatial Techniques

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(Received 28 January 2022, Accepted 09 April, 2022)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Currently, agroforestry is a very common practice on land use in almost all developed and developing nations and sustainable research is devoted to the design, testing and dissemination of agroforestry techniques. Agroforestry systems not only satisfy the need for wood to wood-based Industries, but also contribute significantly to employment development and the reduction of atmospheric Carbon dioxide (CO_2) vis-à-vis mitigating climate change. Mapping and change detection analysis of agroforestry area by using the LISS-III and LISS-IV Satellite Remote Sensing data in the Ambala district of Haryana has been undertaken to develop an operational method in the present article. Supervised classification method was used for Land-Use/Land-Cover analysis for the year 2000, 2005, 2010, 2015 and 2019 in which training sites for seven parameters *viz,* agroforestry (Poplar, Eucalyptus based), agriculture, plantations (Horticulture, Scrub plantations, miscellaneous plantations) water bodies, forest, buildups, riverbed areas were mapped. The maximum area was estimated under agroforestry systems i.e.1.71%, 2.37%, 4.7%, 7.84% and 9.8%, which includes both poplar and eucalyptus based Agri-silviculture and boundary systems for the year 2000, 2005, 2010, 2015, and 2019 respectively. Change detection analysis from 2000 to 2019 in the study showed that mainly agriculture, plantations and sizeable water bodies areas were converted to agroforestry. Satellite data for 2019 driving forces behind agroforestry changes have also been investigated by GPS (Global Positioning System) based Ground Truth verification.

Keywords: Agroforestry, Remote sensing, Geospatial Techniques, Climate change, Global Positioning System.

INTRODUCTION

Agroforestry is defined as Trees Outside Forest (TOF) cultivated on farmlands, farm bunds as boundary plantations which are well stocked or under stocked with some agricultural crops and fruit crops which are sustainable and systematically in same unit of land area. Several forms of agroforestry are common throughout the country that contribute to local communities and produce raw material for industry. (Pathak *et al.,* 2000) gave an account of prominent agroforestry systems in different agro-climatic regions of India. In addition to this, multifunctional agroforestry can contribute to several (SDGs) Sustainable Developmental Goals by integrating medicinal plants (Bimlendra & Nandal 2010). Agroforestry improves soil productivity apart from providing an assurance to the farmers against any uncertainty (Arya & Toky, 2017). Agri-silviculture and agri-horticulture systems in western and eastern Himalyan regions; Agri-horti-silviculture system in upper and trans-gangetic plains; agri-silvi-culture and silvi-pastoral systems in southern plateau & Hilly regions are some of them. The prominent agroforestry systems practiced by farmers in Ambala district are Poplar and Eucalyptus based agri-silvi-cuture systems, boundary plantations and mango based agri-horticulture system. Reason for growing Poplar and Eucalyptus species is their fast growth and also the availability of wood market. Trees on agricultural lands are capable of solving a number of complications of agricultural systems for example sustainable biological production, indiscriminate deforestation, declining soil fertility, occurring of droughts and increasing use of dangerous chemicals (Arya *et al.,* 2018). A chief use of remotely sensed data is to produce a classification map of the identifiable or meaningful features or classes of the land cover types in a scene. In the field of remote sensing, image classification is a process in which pixels or the basic element unit of an image are assigned to classes. (Kumar *et al*. 2021) mapped Tree Outside Forest (TOF) in the Haryana state by using very high-resolution satellite data LISS-IV and recorded about 128.83 sq km of the area in the state was occupied by linear formations of TOF and 20.51 sq km area was occupied by block formations. By comparing pixels to one another and to those known identity, it is possible to assemble groups of similar pixels into classes and produce a thematic map. Image classification is defined as the process of creating thematic maps from satellite imagery (DeFries *et al.*, 1999).

Ambala is considered as one of the model district for the adoption of agroforestry and this district is mostly dominated by eucalyptus & poplar based agroforestry systems (Kumar *et al.,* 2004). These systems has important ecological role as these planted trees help to prevent high surface runoff and thus prevent the soil erosion. It also helps to minimize the flooding and works as fence to protect crops from strong winds. Some estimations on area and production of wood for the trees outside forest are available (Forest Survey of India 2013), but these estimates also include trees on canal side, on roadside and in urban regions and thus do not represent true agroforestry area. (Rizvi *et al.* 2020) described a synergistic approach on the estimation of agroforestry areas in *Populus deltoides* based agroforestry systems at various districts of Haryana and Punjab states such as Karnal, Hoshiarpur, Rupnagar, Yamunanagar, Kurukshetra, Shahid Bhagat Singh Nagar and to assess area under agroforestry, a survey was conducted in these districts. They analysed poplar plantations areas by using High-resolution satellite data such as LISS-IV, (Spatial Resolution of 5.8m) and resulted in Karnal 0.97%, Kurukshetra 1.58%, Yamunanagar 7.25%, Shahid Bhagat Singh Nagar 0.43%, Ludhiana 1.02%, Rupnagar 4.09% and Hoshiarpur 3.19% in the districts. (Ahmad *et al.,* 2007) proposed a methodology to estimate the area under agroforestry. However, the exact figure of area and change detection from 2000 to 2019 under agroforestry systems in the district is not yet known. And no accurate figures are available for agroforestry areas in parts of Haryana and there is need to develop the methodology scientifically for agroforestry area for mapping by using Geospatial Techniques. (Rizvi *et al.* 2016) have developed agroforestry mapping methods and (Ahmad *et al*., 2016) have used LISS-IV high resolution data for agroforestry area estimations in Ludhiana, Punjab. The present research work has been undertaken to map agroforestry area in the Ambala district for the year 2000, 2005, 2010, 2015 and 2019 time period and detect change analysis using Indian Remote sensing satellite data of LISS-IIIand LISS-IV.

Study Area. Ambala district is located at 30°07′N to $30^{0}34^{'}$ N latitude and 76°20′E to 77°10′E longitude at the altitude of 264 m and having the total Geographical area of 1574 sq km. The Ambala district comprises of six blocks, namely Ambala-I, Ambala-II, Barara, Naraingarh, Saha and Shazadpur. District shares its borders with Punjab on western side, Yamunanagar on east, Panchkula on northern side. The area falls in Survey of India Toposheet Numbers of 53 F/2, 53 F/3, 53 B/11, 53B/15 on 1:50,000 scale. District area physiographically is of flat terrain and occupied by the Shiwallik foot hills in North Eastern part.

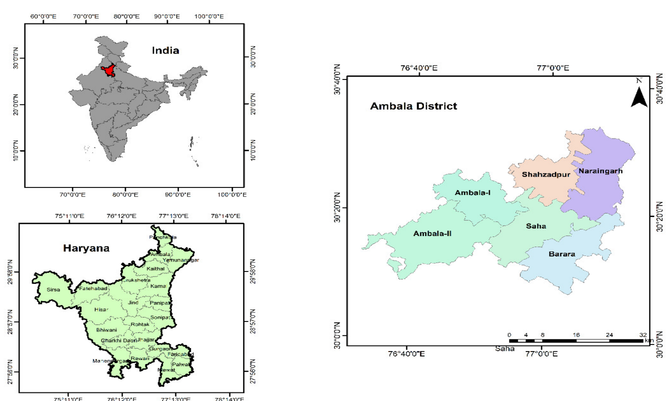

Fig. 1. Location map.

Data base & Methodology. For identification of agroforestry area in the study area for the year 2000, 2005, 2010, 2015 and 2019, Remote Sensing satellite data such as Indian Remote Sensing (IRS) P6 Resourcesat LISS-III and LISS IV sensors were used for Land-Use/Land-Cover analysis. Pre-processing of remote sensing images includes layer stacking, mosaicing and subsetting with district boundary by Geo referencing/rectification was carried out. The methodology adopted are given in flow chart below Fig. 2.

Software Used. Land-Use/Land-Cover classification was done by supervised method of classification in the district using ERDAS-2011standard image processing software and ARC-MAP.

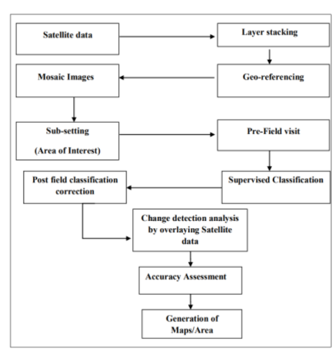

Fig. 2. Flowchart for methodology adopted to estimate Agroforestry area.

Ground Truth Survey. Extensive ground truth survey for image analysis was conducted at the study area. The data collected through Geographical Position System (GPS) during Ground truthing survey was treated as training site data and it was applied to interpretation of the whole image. It was observed during Ground truth survey that mainly Eucalyptus and Popular plantations are associated with agricultural lands as agroforestry systems. Mostly agroforestry with block formations and boundary plantations like linear formations of poplar and eucalyptus species were seen which extensively covered along the river, roads, railway line and nearby canals. In Agri-Silviculture systems poplar with wheat, poplar with sugarcane, rice with eucalyptus mainly as boundary plantations are the main cultivation practices followed in the Ambala district which are shown in the following maps and photographs (Figure 3). However, it was observed that poplar and eucalyptus species are the major tree species under different agroforestry practices in the district.

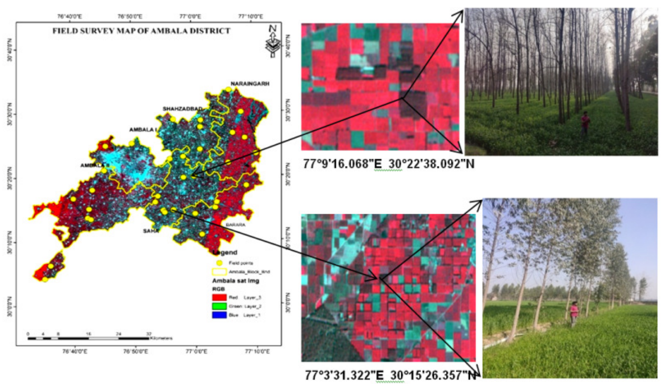

Fig. 3. Field Photographs of Agroforestry Systems in Ambaladistrict of Haryana with GCPs.

Post classification correction. Corrections were made by visually comparing the classified image to False Colour Composite (FCC) image, delineating the agroforestry area and obtaining a statistical area. The recoding classification and accuracy estimation of remote sensing images were performed and post classified.

RESULTS AND DISCUSSION

Land-Use/Land-Cover classification for the Year 2000 and 2005. Based upon the analysis of the satellite data, seven LU/LC (Land-Use/Land-Cover) classes were identified in the district namely agroforestry, agriculture, forest, plantations which includes horticulture, scrub and miscellaneous plantations, built-up areas and riverbed areas. By usingsupervised method of classification,the estimation of area under agroforestry along with other classes were obtained. In classification it was observed that sandy areas and dry streams were intermixed with buildup areas, so in order to rectify such an error, buildup area and river bed areas were masked and recoded with the help of FCC and toposheets. Similarly agroforestry area and forest were intermingled, to minimize the intermingled pixels, same approach was implemented to find area under Agroforestry category.

A close perusal of the Table 1 has revealed that agriculture occupied a major area in the district followed by built-up and agroforestry. The analysis of 2000 data revealed that about 1,35,860.4 ha (86.3% of TGA) of land is reported to be under agriculture land, while the agroforestry area was found to be 2,696.48 ha (1.71% of TGA). And also estimated area under forest (Protected forest and Reserved forest) was 1,783.18 ha (1.13% of TGA), built-up land (includes urban and rural settlements) 10,264.41ha (6.52% of TGA), waterbodies (rivers, canals, ponds etc) 2,613.76 ha (1.66% of TGA), riverbed (sandy area) 1,135.64 ha (0.72% of TGA) and other plantations which includes horticulture, scrub plantations and miscellaneous plantations occupied 3,058.95 ha (1.94% of TGA) within the district for the year 2000. Land-Use/Land-Coverof Ambala district for the year 2005 showed that agriculture occupied a sizeable area in the district and followed by built-up and agroforestry. The analysis of 2005 data revealed that about 1,33,439.7 ha (84.77% of TGA) was reported to be under agriculture land, while the agroforestry area was found to be 3,745.33 ha (2.37% of TGA). And also estimated area under forest was 1,520 ha (0.96% of TGA), built-up land 12,758.74 ha (8.1% of TGA), waterbodies 1,535.21 ha (0.97% of TGA), riverbed 1,553.81 ha (0.98% of TGA) and plantations occupied 2,859.36 ha (1.81% of TGA) within the district for the year 2005. A close perusal of the Table 2 has revealed that categories like agroforestry, built-up and riverbed areas in the district was increased in its Land-Use/Land-Cover from the year 2000 to 2005 by 0.66%, 1.58%, and 0.26%, respectively. Agriculture, forest, plantations and waterbodies in the district shown decreased by 1.53%, 0.17%, 0.13% and 0.69%, respectively from the year 2000 to 2005. The increase in forest area in the district during this period was compared with the data of Forest Survey of India, (2005, 2011, 2013, 2015 and 2019) and results found comparable. Similar methodology for mapping by using remote sensing techniques like GIS was used by Vyas and Singh (2020).

Land-Use/Land-Cover classification for the Year 2010, 2015 and 2019. Land-Use/Land-Coverof Ambala district for the year 2010 showed that agriculture occupied a sizeable area in the district and followed by built-up and agroforestry. The analysis of 2010 data revealed that about 1,27,862.3 ha (81.22% of TGA) was reported to be under agriculture land, while the agroforestry area was found to be 7,400.92 ha (4.7% of TGA). And also estimated area under forest was 1,590 ha (1.01% of TGA), built-up land 12,859.9 ha(8.16% of TGA), waterbodies 2,712.02 ha (1.72% of TGA), riverbed 499.08 ha (0.31% of TGA) and plantations occupied 4,488.35 ha (2.85% of TGA) within the district for the year 2010. A close perusal of the Table 2 has revealed that categories like agroforestry, forest, built-up, plantations and waterbodies in the district was increased in its Land-Use/Land-Cover from the year 2005 to 2010 by 2.33%, 0.05%, 0.06%, 1.04% and 0.75%, respectively. Agriculture and riverbed areas in the district shown decreased by 3.55% and 0.67%, respectively from the year 2005 to 2010.

The analysis of 2015 data from the Table 1 revealed that about 1,20,840 ha (76.76% of TGA) was reported to be under agriculture land, while the agroforestry area was found to be 12,350.91 ha (7.84% of TGA).And also estimated area under forest was 1,610.25 ha (1.02% of TGA), built-up land 13,973.4 ha (8.87% of TGA), waterbodies 1,849.13 ha (1.17% of TGA), riverbed 2,231.82 ha (1.41% of TGA) and plantations occupied 4,557.21 ha (2.89% of TGA) within the district for the year 2015. A close perusal of the Table 2 has revealed that categories like agroforestry, forest, built-up, plantations and riverbed area in the district was increased in its Land-Use/Land-Cover from the year 2010 to 2015 by 3.14%, 0.01%, 0.71%, 0.04% and 1.1%, respectively. Agriculture and waterbodies in the district shown decreased by 4.46% and 0.55%, respectively from the year 2010 to 2015. The analysis of 2019 data revealed that about 1,17,298.6 ha (74.51% of TGA) was reported to be under agriculture land, while the agroforestry area was found to be 15,552.53 ha (9.8% of TGA). And also estimated area under forest was 1,660.96 ha (1.05% of TGA), built-up land 14,355.07 ha (9.11% of TGA), waterbodies 2,185.96 ha (1.38% of TGA), riverbed 896.58 ha (0.56% of TGA) and plantations occupied 5,462.41 ha (3.47% of TGA) within the district for the year 2019. A close perusal of the Table 2 has revealed that categories like agroforestry, forest, built-up, plantations and waterbodies in the district was increased in its Land-Use/Land-Cover from the year 2015 to 2019 by 1.96%, 0.03%, 0.24%, 0.58% and 0.21%, respectively. The increase in forest area in the district during this period was compared with the data of Forest Survey of India, (2019) and results were found comparable. Agriculture and riverbed areas in the district shown decreased by 2.25% and 0.85%, respectively from the year 2015 to 2019. The Land-Use/Land-Cover map of the Ambala district for the year 2000, 2005, 2010, 2015 and 2019 was shown in Fig. 4, 5, 6, 7 and 8, respectively. Similar studies were carried out by Kumar *et al.* (2019) in Ambala range of Haryana state. Present study was mainly focused on poplar and eucalypts based agroforestry mapping, similarly, grewia, celtis and quercus based agroforestry mapping was carried by Vikranth *et al.* (2018); Rizvi *et al.* (2017).

Change detection analysis. From the Table 3 the changes were observed in the conversion of different LU/LC categories to agroforestry over a decade and the concerned change of different lands to agroforestry was intensively studied as visible in Fig. 9. A close perusal of Table 3 revealed that some of the categories in the year 2000 were converted to agroforestry areas in 2010, such as about 6,783.6 ha of the agriculture land in the year 2000 was converted to agroforestry in the year 2010. Some of the plantations like horticulture nearly 83.7 ha of the area was converted to agroforestry in 2010 and 19.5 ha of the area under waterbodies were converted to agroforestry in 2010 and around 513.9 ha of agroforestry area in the year 2000 remained same as in 2010 without any harvesting. From the Table 4 the changes were observed in the conversion of different LU/LC categories to agroforestry over a decade and the concerned change of different lands to agroforestry was intensively studied as visible in Figure 10. A close perusal of Table 4 revealed that some of the categories in the year 2010 were converted to agroforestry areas in 2019, such as about 13,534.8 ha of the agriculture land in the year 2010 was converted to agroforestry in the year 2019. Conversion of other categories to agroforestry areas is mainly due to the adaptation of tree farming by farmers for multiple outputs (medicinal, fodder for animals, etc) from the same field. Similarly, Land-Use/Land-Cover change conversion of areas from agriculture to agroforestry in Nathusari Chopta block of Sirsa district of Haryana state from 2007 to 2010 was reported by Singh *et al.* (2015). Some of the plantations like horticulture nearly 249.4 ha of the area was converted to agroforestry in 2019 and 26.2 ha of the area under waterbodies were converted to agroforestry in 2019 and around 1,742.1 ha of agroforestry area in the year 2010 remained same as in 2019 without any harvesting.

Table 1: Land-Use/Land-Cover (LU/LC) analysis of Ambala district (2000 to 2019).

Sr. No.	Land-Use/Land-Cover Classes	2000		2005		2010		2015		2019	
		Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)
1.	Agroforestry	2,696.48	1.71	3,745.33	2.37	7,400.92	4.70	12,350.91	7.84	15,552.53	9.8
2.	Agriculture	1,35,860.4	86.30	1,33,439.70	84.77	1,27,862.30	81.22	1,20,840.00	76.76	1,17,298.60	74.51
3.	Forest	1,783.18	1.13	1,520.00	0.96	1,590.28	1.01	1610.25	1.02	1,660.96	1.05
4.	Built-up area	10,264.41	6.52	12,758.74	8.1	12,859.90	8.16	13,973.40	8.87	14,355.07	9.11
5.	Plantations	3,058.95	1.94	2,859.36	1.81	4,488.35	2.85	4,557.21	2.89	5,462.41	3.47
6.	Waterbodies	2,613.76	1.66	1,535.21	0.97	2,712.02	1.72	1,849.13	1.17	2,185.96	1.38
7.	Riverbeds	1,135.64	0.72	1,553.81	0.98	499.08	0.31	2,231.82	1.41	896.58	0.56
	Total	1,57,412	100	1,57,412	100	1,57,412	100	1,57,412	100	1,57,412	100

Table 2: Change in Land-Use/Land-Cover (LU/LC) analysis of Ambala district (2000 to 2019).

Sr. No.	Categories	% of TGA (2000)	% of TGA (2005)	% of TGA (2010)	% of TGA (2015)	% of TGA (2019)	Change from (2000-2005)	Change from (2005-2010)	Change from (2010-2015)	Change from (2015-2019)
1.	Agroforestry	1.71	2.37	4.70	7.84	9.80	+0.66	+2.33	+3.14	+1.96
2.	Agriculture	86.30	84.77	81.22	76.76	74.51	-1.53	-3.55	-4.46	-2.25
3.	Forest	1.13	0.96	1.01	1.02	1.05	-0.17	+0.05	+0.01	+0.03
4.	Built-up area	6.52	8.10	8.16	8.87	9.11	+1.58	+0.06	+0.71	+0.24
5.	Plantations	1.94	1.81	2.85	2.89	3.47	-0.13	+1.04	+0.04	+0.58
6.	Waterbodies	1.66	0.97	1.72	1.17	1.38	-0.69	+0.75	-0.55	+0.21
7.	Riverbed	0.72	0.98	0.31	1.41	0.56	+0.26	-0.67	+1.1	-0.85

Table 3: Change detection analysis in the Ambala district (2000 to 2010).

Sr. No.	Categories		Change detection (ha)
	2000	2010	
1.	Agriculture	Agroforestry	6,783.6
2.	Agroforestry	Agroforestry	513.9
3.	Plantations	Agroforestry	83.7
4.	Waterbodies	Agroforestry	19.5
Total			7400.7

Table 4: Change detection analysis in the Ambala district (2010 to 2019).

Sr. No.	Categories		Change detection (ha)
	2010	2019	
1	Agriculture	Agroforestry	13,534.8
2	Agroforestry	Agroforestry	1,742.1
3	Plantations	Agroforestry	249.4
4	Waterbodies	Agroforestry	26.2
Total			15,552.5

Accuracy assessement. Accuracy assessement of agroforestry category was tested in terms of Kappa coefficient, based on supervised method of classification, ground truth based data on different land uses with agroforestry was gathered from the blocks of the district and classification accuracy was being computed, using Maximum likelihood method. Error matrix was generated and the classification accuracy, Kappa coeffiecient were acquired. A close perusal of the Table 5 revealed that, among 80 Ground Truth Points (GTPs) of agroforestry class, 76 were correctly matched within the same category of agroforestry, 4 GTPs were intermixed with plantation category. The producers and users accuracy of agroforestry class was assessed over 95% and 96.2% respectively. The producers and users accuracy of agriculture class was assessed over 93.33% and 98.25% respectively, 80% of each producers accuracy and users accuracy was observed in plantation category, about 83.33% and 75% of producers and users accuracy was observed in forest category, built-up area category in the district assessed 90% of each producers and users accuracy. The river bed class assessed over 90% and 75% of producers and users accuracy and waterbodies assessed 93.33% accuracy in producers and users accuracy. The total overall accuracy of 90.98 % and 0.88 of Kappa coefficient was obtained using confusion matrix method of accuracy assessment (Table 5).

Table 5: Accuracy assessment of Ambala district.

		Reference Category								
		Riverbed	Agriculture	Agroforestry	Built-up Area	Plantations	Forest	Waterbodies	Row Total	Users Accuracy
Classification Category	**Riverbed**	9	1	0	2	0	0	0	12	75.00
	Agriculture	0	56	0	0	0	0	1	57	98.25
	Agroforestry	0	1	76	0	1	1	0	79	96.20
	Built-up Area	1	1	0	18	0	0	0	20	90.00
	Plantations	0	0	4	0	24	2	0	30	80.00
	Forest	0	0	0	0	5	15	0	20	75.00
	Water bodies	0	1	0	0	0	0	14	15	93.33
	Column Total	10	60	80	20	30	18	15	233	
	Producers Accuracy	90.00	93.33	95.00	90.00	80.00	83.33	93.33	**Overall Accuracy = 90.98 Kappa Coefficient =0.88**	

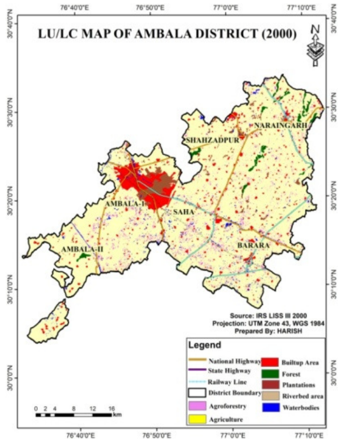

Fig. 4. LU/LC of Ambala district 2000.

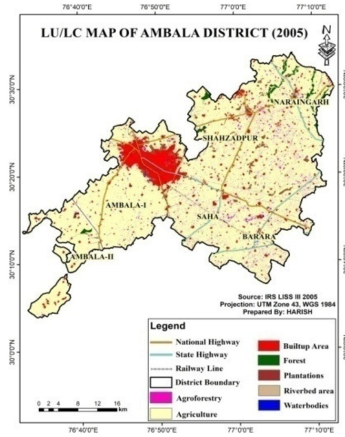

Fig. 5. LU/LC of Ambala district 2005.

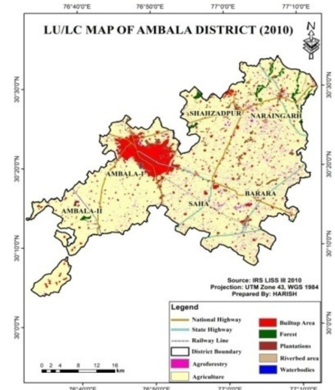

Fig. 6. LU/LC of Ambala district 2010

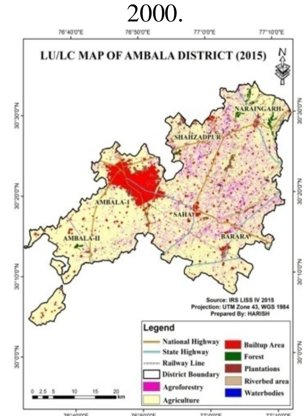

Fig. 7. LU/LC of Ambala district 2015.

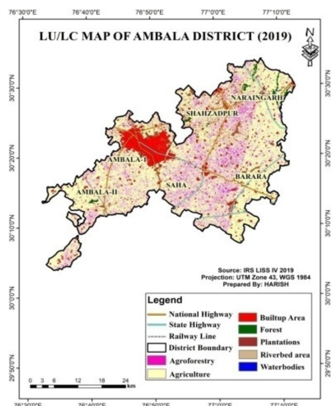

Fig. 8. LU/LC of Ambala district 2019.

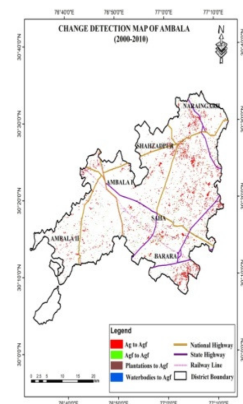

Fig. 9. Change detection from 2000 to 2010.

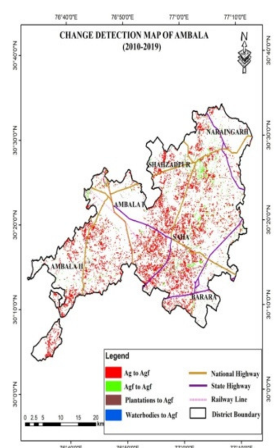

Fig. 10. Change detection from 2010 to 2019.

CONCLUSION

In order to harness the full potential of agroforestry, an accurate estimation of extent of area under agroforestry in the country is required. This can be done with the help of Geospatial technologies which includes Remote Sensing, GIS (Geographical Information System). This study concluded that agroforestry based systems in the district occupied maximum area along with agriculture and other classes. Poplar and eucalyptus based agroforestry systems occupied considerable area in Ambala and have significant contribution towards rising and increasing green cover in the state. The methodology adopted in this current study for mapping of agroforestry area using high resolution remote sensing data like LISS-IV yielded promising results. It was also concluded that with judicious use of Geospatial technologies, assessment of natural resources like agroforestry can be done accurately which will provide desired spatial information for planners and decision makers in the state.

FUTURE SCOPE

There is a need to replicate such work at district levels and state level which are a potential research gap in the state of Haryana and also in India.

Acknowledgements. Authors are thankful to the Director, Haryana Space Applications Centre (HARSAC), CCS HAU Campus, Hisar, Haryana for carrying out research work and providing satellite data.

Conflict of Interest. None.

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How to cite this article: Bojja Harish Babu, Mothi Kumar K.E., Sandeep Arya, Bimlendra Kumari and Krishma Nanda (2022). Mapping and Change Detection Analysis of Agroforestry area in Ambala District of Haryana State, India using Geospatial Techniques. *Biological Forum – An International Journal*, *14*(2):450-456.