



Mapping Transformation of Degraded Lands to Potential Agro-Forestry in West Haryana, India: A Geo-Spatial Approach

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Received: 7 July 2020 / Accepted: 1 April 2021 / Published online: 7 May 2021
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Abstract

Degradation of land in any form (natural or anthropogenic) poses a threat to economic, social and sustainable development on global, national and local level. The study carried out in West Haryana extracts the area transformed to agro-forestry from the degraded area. A merge of different datasets LISS IV and Cartosat 2 for 2016–17 on a scale of 1:10,000 was used for the agro-forestry patches (Horticulture, Farm forests, miscellaneous and shrub land) to be identified. LISS III data on a scale of 1:50,000 were used for demarcation of degraded lands for the year 2005–2006 and 2015–2016. The conversion of degraded categories of land over a decade into various agro-forestry practices has been identified and mapped. The Hisar District is found to have maximum degraded area converted to agro-forestry while a total of 7236.9 hectares area is converted to agro-practices in West Haryana. With a total conversion of 7236.9 sq. km. of degradation to agro-practices, the maximum transformation has been brought about in category of partially stabilized dunes where a total of 5167.05 sq. km. of area is converted to assorted categories of agro-forestry. A district-wise variation was observed in the emergent categories on degraded lands. Bhiwani showed maximum conversion to miscellaneous plantations while horticulture surfaced Fatehabad and Sirsa districts. The study also aims to suggest floral species suitable to be planted in the degraded land based on their capability to survive the hostile conditions of soil .

Keywords Degradation · Agro-forestry · Spectral reflectance

Introduction

The fast-growing agricultural-based economy of India contributes to 17% of national income which serves as a livelihood to 58% of the population of the country (Nedumaran, 2020). Being an agrarian country, the climate change causing changes in the weather pattern with

variation in the rainfall pattern is bound to have adverse effects on the income of agriculture-based sector. The skewed rainfall observed in the year 2019 proved the adversity of climate change. This challenges to secure our economy with alternatives serving to secure rural livelihood while maintaining the ecological balance by adopting a National Agriculture Policy (2000). The policy emphasizes on reclaiming degraded lands and categorizing the unutilized wastelands to agriculture and afforestation purposes. The creation of conducive climate for agriculture and agro-based industries is focused to achieve an encouraging price and trade regime. The goal to achieve sustainability with future population projections is a promising challenge for the country. Being an agriculture-dominant economy agro-forestry lies at a forefront to address this key challenge and meet the food security. Our country, India, with its different agro-ecological zones has numerous agro-forestry practices prevailing under different climatic conditions illustrative of surveys conducted. Although it has been practiced all over the country, a major

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input from northern states—Uttar Pradesh, Uttarakhand, Haryana and Punjab—in this regard has been achieved. The State Haryana being forest deficit alone contributes to 1/3rd of the agro-forest production in the form of farm woods (HFD, 2020). The farm woods are found in the form of strip plantations (linear), horticulture, shrubs, miscellaneous plantations, etc. To visualize the emphasis of agro-forestry, its importance and benefits have been discussed from time to time. The economic, social and ecological benefits (Depommier, 2003; Kumar, 2016; Mbow et al., 2014a, 2014b; Watson et al., 2000) have been explored as a resultant of study in different countries. An increase in income derived from agro-forest production (Garrity, 2006; Kumar, 2016; Verchot et al., 2007) has been observed by many researchers. The enhanced benefits from agro-forestry are in the form of nitrogen fixation and nutrient cycling enhancing soil fertility leading to improved production (Albrecht & Kandji, 2003; Nair, 2012). Specific tree species of higher values can also serve as a benchmark to increased income (Mbow et al., 2014a, 2014b). Agro-forestry can also serve as a powerful tool to mitigate and adapt to climate change (Newaj et al., 2013; Schoeneberger et al., 2012; Thorlakson et al., 2012; Nguyen et al., 2013) which is an acute threat to global development (The World Bank). Other benefits relate to increased livelihood security to rural households (Kumar, 2016; Pandey, 2005) restoring capacity of weaker sections (Mbow et al. 2014a, 2014b), conserving biodiversity (Jose, 2012; McNeely, 2004; McNeely & Schroth, 2006; Ramos et al., 2015) and ameliorating air and water quality (Anderson et al., 2009; Asbjornsen et al., 2014; Hernandez et al., 2012). Agro-forestry also has a great potential to conserve resources, rehabilitate degraded lands (Dagar et al., 2014; Dhyani et al., 2005) and utilization of fallow lands (NRCAF, 2007). The emergence of agro-forestry on degraded lands is concern of the study and their surfacing has been recorded.

The adoption of agro-forestry on degraded lands with its many benefits could serve the dual purpose of mitigation of degradation with rewarding outcomes to the land holder eventually meeting the environment protection concern. The holistic management of rainfed areas by agro-forestry provides for efficient nutrient cycling; addition of organic matter, nitrogen fixation and diversification are emphasized by National Agriculture Policy (2000). Various issues related to remote sensing data with medium resolution were highlighted by Rizvi et al. (2013). An area of 14.46 Mha was found to extend in agro-forestry in India as estimated by Rizvi et al. (2014). The satellite data collected have enhanced quality, reproductivity and consistency in providing synoptic view of the earth and hence have potential to allow user to observe and study earth as an integrated system (Yang et al., 2013). Dhyani et al., 2013

attempted to estimate areas of agro-forestry spread in the country without inclusion of ground truthing, and hence, it is indicative but not exact.

The study is focused on exploiting the potential of remote sensing and GIS to identify the change in land degradation and exploring the agro-forestry practices to be carried out on degraded lands with collection of ground truths. Various forms of degradation dunes, waterlogging, salinity needs attention and their attenuation through adopting indigenous practices of agro-forestry could act as a mitigative measure.

Materials and Methodology

Study Area

The study area comprises of West Haryana with four districts—Sirsa, Fatehabad, Hisar and Bhiwani, extending to an area of 15,576 sq. km as shown in Fig. 1 (Statistical Abstract of Haryana, 2017–18). Haryana is divided into five natural topographic divisions (Bagar, Alluvial plain, Aravali outliers, Shiwaliks and the Foothills zone) which

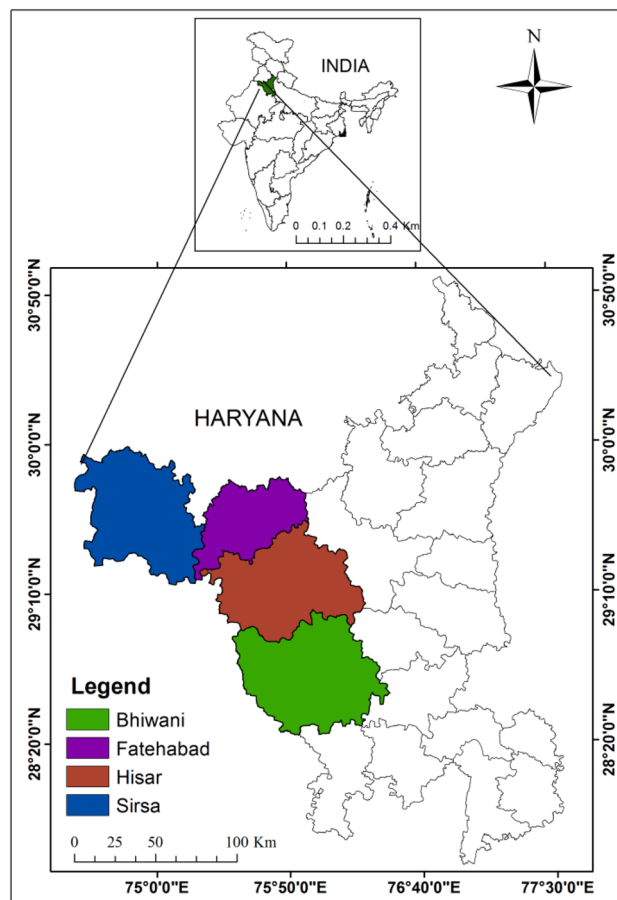


Fig. 1 Map depicting the selected study area

provide a suitable framework to a landform environment. The south western part of Haryana is found to be covered by steppe vegetation over the undulating dunes of different shape and size with the vegetation blooming over the rainy season. Parts of Sirsa, Hisar and Bhiwani districts are found to fall under Bangar having a significant amount of wind-blown sand, piled-up to form uplifted structures. Sand dunes, found on a massive scale in this belt, extend from the south-east of Sirsa District along the Rajasthan border with Hisar District, and the sand dune belt widens gradually through the Bhiwani District. Further, the rocky projections present in Bhiwani district are known to break the monotony of heaped sands. The flat alluvial plains lie in the north-eastern parts of Hisar comprising of narrow low laying flood plains, known as Khadar of Yamuna, Nali of Ghaggar and Belt of Markanda rivers. The Bangar region is characterized by patches of saline efflorescence resulting from the mechanical composition of alluvium and the capillary action during hot dry season, though the facilitated irrigation facilities are known to minimize the effect. However, the flood plain found in Fatehabad tehsil is narrow. Ghaggar Nali once covered with natural vegetation has been devoid of it for conversion to cultivable land, while Sirsa Nali is wide and shallow.

Methodology Adopted

The devised methodology comprised of initial collection of geo-spatial data applying various image pre-processing operations (Fig. 5). The collected datasets were subjected to stacking, geo-referencing, histogram equalization, mosaicking and sub-setting to extract the area of interest (shown in Fig. 1) from various scenes of satellite imagery. A merge of different datasets LISS IV and Cartosat 2 for 2016–17 on a scale of 1:10,000 was used for the agro-forestry patches (Horticulture, Farm forests, miscellaneous and shrub land) to be identified. LISS III data on a scale of 1:50,000 were used for demarcation of degraded lands for the year 2005–2006 and 2015–2016. Various identified categories of degraded lands included Dunes (partially stabilized and stabilized depending on its vegetal cover), sheet erosion, waterlogging (permanent and seasonal), rocky surface and mining area. The demarcation of different LDD and Agro-forestry categories was based on their spectral signature considering size, shape, tone, texture and pattern (Table 1). The homogeneity and heterogeneity of occurrence in different landforms can also serve advantageous.

The appearances of identified categories of degradation are shown in Fig. 2a, b and c and agro-forestry through Fig. 3a, b, c and d on FCC with their associated ground truth photographs. Ground truth surveys were conducted with a scanned copy of FCC highlighting identified

categories. The accuracy of digitized data attained through collection of GPS readings was found to be 94 percent indicative of ratio of matched GTs (for the identified categories on FCC) to the total collected GTs.

The changes were observed in degraded lands in different districts over a decade, and the concerned change of degraded lands to agro-forestry was intensively studied as visible in Fig. 4. The yellow lines visible in the figure indicate degraded areas while the area marked with red boundaries is emerged agro-forestry areas (Fig. 5).

The conversion of degraded lands to agro-forestry although requires a large task force with monetary expenses; however, the end results are satisfactory and fruitful to the growing need of food and livelihood security achievement. With this target, the categorical shifts studied unfold useful resources to be exploited aiming at achievement of national agriculture policy. Depending on the type of affected land, different species of plants are explored to be planted on the concerned degraded lands. Agro-forestry practices are carried out in the form of point, line and polygon features; however, our interest in degraded lands limits our study to polygon features only relating to altering degraded areas. The identified floral species are such as to suit the soil type of degradation depending on their survival potential in deprived soils.

Results

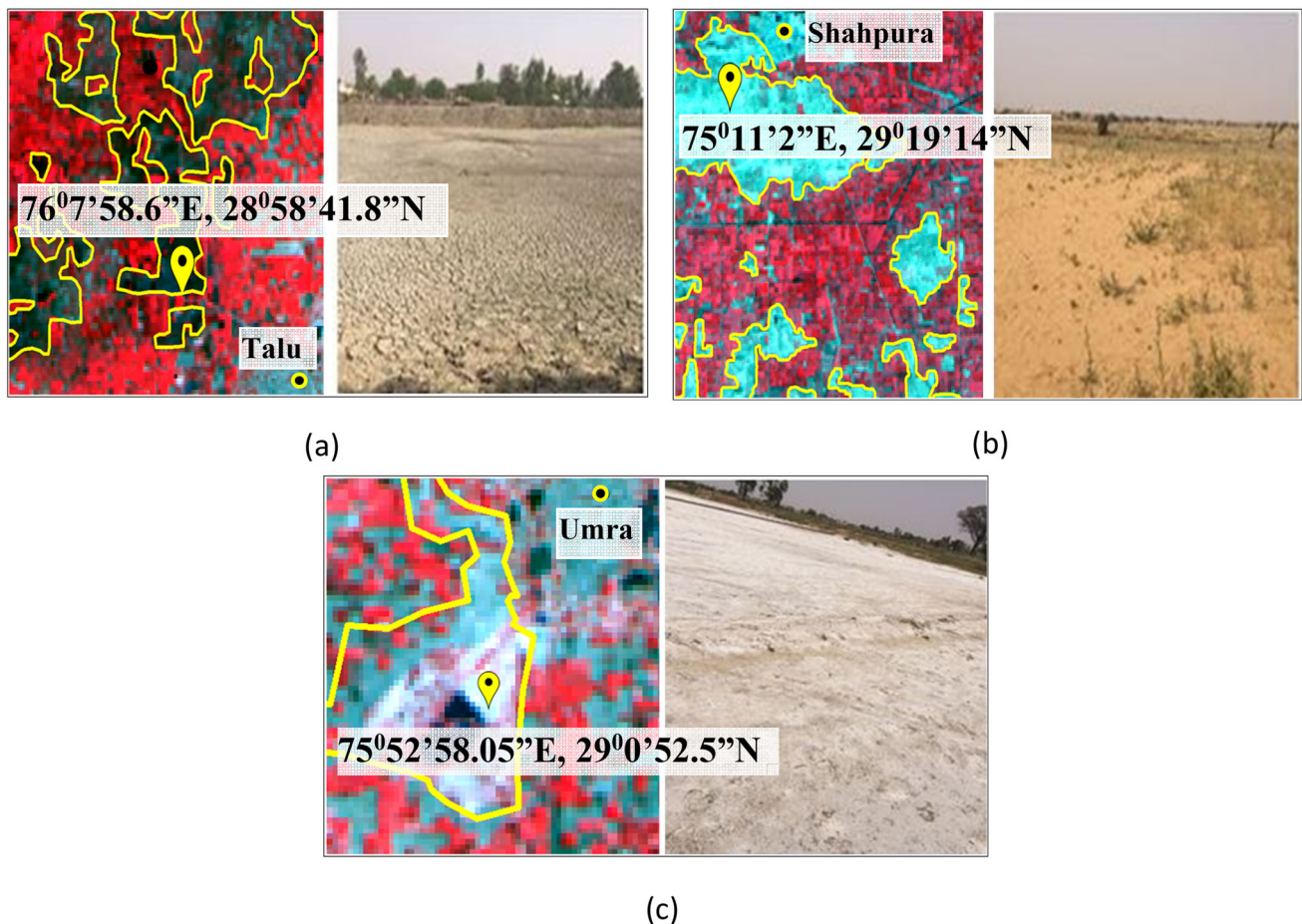
The transformation of degraded areas owes to dynamicity of soils as well as human intervention to cause change. Various categories of degradation have seen tremendous shift to other degraded forms or normal land forms. The normal land forms include agricultural advancements and at present agro-forestry practices in the form of horticulture, farm forests, scrubland and miscellaneous plantations. This paper studies the alteration in the pattern of land degradation in various categories of agro-forestry practices practiced by the state involving the investments undertaken by the local authorities, farmers as well as the government. A district-wise study has been performed for West Haryana (Sirsa, Fatehabad, Hisar and Bhiwani) which is tabulated and summarized in Tables 2, 3 and 4.

Bhiwani District

The district having total geographic area as 4778 sq. km. has maximum of its total degraded area under partially stabilized dunes extending more than half of total degradation followed by seasonal waterlogging. Water erosion has also left a telltale in the foothills of Aravali. The signifying contribution has been brought about the forest department in the district establishing 2057.3 hectares of

Table 1 Associated characteristics for identification of degradation and agro-forestry categories

S. No	Category	Description
1	Partially stabilized dunes	Light to medium gray with light yellowish tone on the satellite image associated with red tinge due to rabi crops
2	Stabilized dunes	Medium gray to yellowish color and pink mottles of glooming seasonal grasses seen in rainy season forming discrete patches
3	Waterlogged	Associated with depressions in inland plains, irrigated areas or plains with higher water table. They appear light blue to dark blue (permanent) or medium to dark gray (seasonal)
4	Salt affected	Discrete patches appearing light gray to white
5	Barren rocky	Light to medium gray/yellowish white found in hilly or pediment region
6	Farm Forests	Farm Forests are the area with trees of commercial importance and are identified based on their location around agricultural fields in defined pattern
7	Horticulture	Horticulture plantations (fruit crops) are found on the agricultural fields; sometimes along with crops appear in regular defined pattern. They have a uniform pattern and a dark red tinge added to canopy
8	Miscellaneous	Areas having trees of forestry importance with defined boundary walls. The sharp boundary exhibited by them and appearance in light red to red color in contiguous pattern aids in their identification
9	Scrub land	Scrubs emerge on the area with shallow soils generally, with depleted nutrients having a tendency to intermingle with cropped areas. The open scrubs possess sparse vegetation having a thin soil cover. They are inclined to follow an irregular pattern

**Fig. 2** Spectral signatures of degradation categories as seen on the satellite image and in ground **a** waterlogged, **b** wind erosion, **c** salt affected

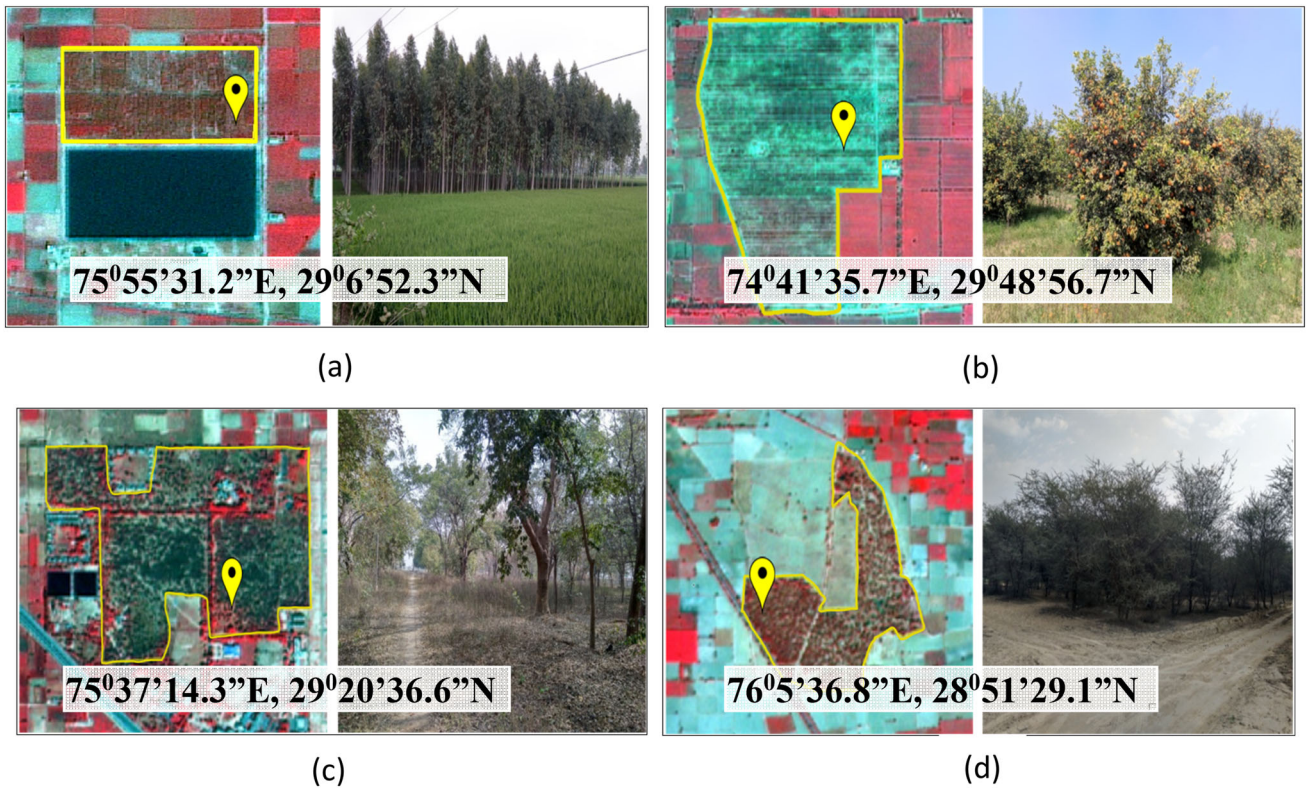
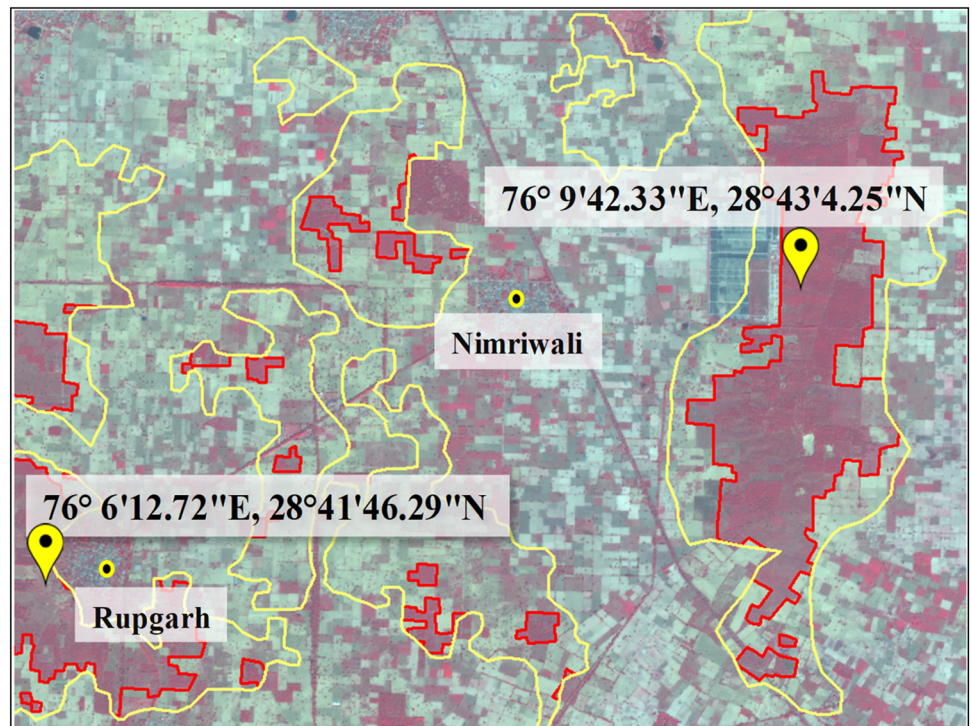


Fig. 3 Spectral signatures of agro-forestry as seen on the satellite image and in ground **a** farm forests, **b** horticulture, **c** miscellaneous plantations, **d** scrub land

Fig. 4 Satellite image showing emerged agro-forestry (red outline; 2016–17) over degraded lands (yellow outline; 2005–06)



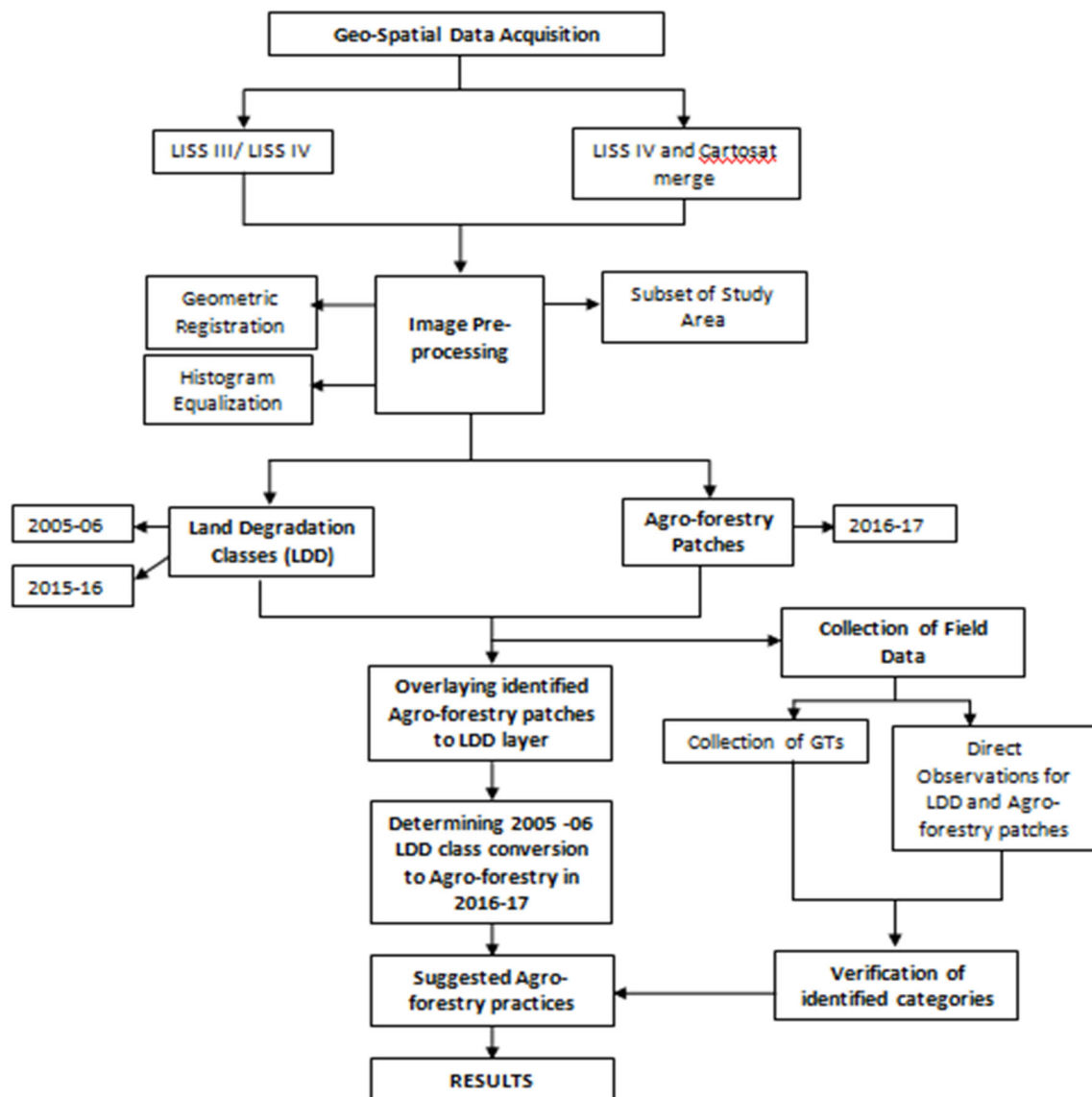


Fig. 5 Methodology flowchart

area under miscellaneous which regards appreciation. The contribution of farmers can be seen in the form of farm forests which embarks to be next category of agro-forestry in the extent of area. Table 2 summarizes LDD (degraded lands) and AGF (agro-forestry) categories area establishing their coverage in the district comparative to its total geographical area (TGA).

Hisar District

The district extending its boundary to 3983 sq. km. marks an area of 5% of degradation to be converted to agro-forestry which is highest among selected study area. The partially stabilized dunes category of degradation has topped with respect to area coverage while scrub land

(reclaimed category of agro-forestry) has been found to be the most prominent category extending to an area of 2655.46 ha. The Farm forest follows scrubland which is a result of intense agricultural practices adapted by local farmers and authorities. Table 2 briefs the categorical extent with respect to area for various degradation and agro-forestry classes.

Sirsa and Fatehabad Districts

The Fatehabad District is known to have a smaller extent of area, i.e., 2538 sq. km., so it has been studied along with Sirsa district having an area of 4277 sq. km. When summed, these districts have a total of 55,311.67 ha area under degradation with partially stabilized dunes followed by

Table 2 Extent of degraded lands and their reclamation to agro-practices in Bhiwani District

Sr. No	Categories	Area (ha.)	Area (%)
Degraded lands (LDD 2005–06)			% LDD
1	Partially stabilized dunes	68,499.81	57.41
2	Stabilized dunes	237.8	0.2
3	Seasonal waterlogging	38,444.24	32.22
4	Permanent waterlogging	2156.6	1.81
5	Salt affected	885.03	0.74
6	Water erosion	8178.21	6.85
7	Barren rocky	916.88	0.77
Total		119,318.57	100
Agro-forestry (AGF 2016–17)*			% AGF
7	Farm forests		1.5 22.87
	Under stocked	51.63	
	Well stocked	787.02	
8	Horticulture plantations		0.58 1.04
	Under stocked	19.76	
	Well stocked	35.91	
9	Miscellaneous plantations		18.96 40.83
	Under stocked	652.45	
	Well stocked	1404.85	
10	Scrub		12.99 1.23
	Open	446.79	
	Dense	42.14	
Total		3440.55	100

*AGF 2016–17 is resultant of conversion of degraded area

seasonal waterlogging marking maximum area under deprivation as summed in Table 4. An attempt to reclaim these degraded lands to agro-practices has been known to have developed scrub and horticulture plantations categories to be at the peak with respect to area which also acts as a source to achieve sustainable goals.

Area Statistics for Transformed Degradation to Agro-Forestry

The conversion of different categories of land degradation in West Haryana shows a positive response indicating the intense work performed in the study area. The results are indicative that all the categories have a tendency to regain its lost strength. However, it requires a lot of task force, financial assistance and better management policies. The

Table 3 Extent of degraded lands and their reclamation to agro-practices in Hisar District

Serial No	Categories	Area (ha.)	Area (%)
Degraded lands(LDD 2005–06)			% LDD
1	Partially stabilized dunes	47,210.64	82.91
2	Stabilized dunes	1602.19	2.81
3	Seasonal waterlogging	6376.96	11.2
4	Permanent waterlogging	686.91	1.21
5	Salt affected	356.98	0.63
6	Water erosion	663.4	1.16
7	Eolian sheet erosion	41.92	0.08
Total		56,939.0	100
Agro-forestry Area (AGF 2016–17)			% AGF
7	Farm forests		3.12 3.67
	Under stocked	96.96	
	Well stocked	114.32	
8	Horticulture plantations		1.95 0.54
	Under stocked	60.68	
	Well stocked	16.92	
9	Miscellaneous plantations		0.69 4.73
	Under stocked	21.54	
	Well stocked	147.37	
10	Scrub		85.3
	Open	2655.46	
Total		3113.25	100

*AGF 2016–17 is resultant of conversion of degraded areas

category of degradation with maximum transformed area to agro-forestry is Partially Stabilized Dunes (PSD) followed by Water Erosion (WE) as indicated in Table 5. Scrub open has come out to be most dominant category of reclaimed degraded lands followed by Well-Stocked Miscellaneous Plantations. Farm forests have also shown a measured input to the agro-practices (Table 6).

The graphical representation (Fig. 6) of the produced pivot table makes a clear portrayal of the transformed categories of degraded lands to agro-forestry. The partially stabilized dunes are condemned to convert to each category of agro-forestry while showing maximum conversion to scrub land followed by well stocked farm forests. A rise in miscellaneous plantations is found in water eroded degraded lands. Miscellaneous plantations also form the second highest converted category transformed from degraded

Table 4 Extent of degraded lands and their reclamation to agro-practices in summed Sirsa and Fatehabad District

Serial No	Categories	Area (ha.)	Area (%)
Degraded lands (LDD 2005–06)			% LDD
1	Partially stabilized dunes	26,644.11	48.17
2	Stabilized dunes	4545.01	8.22
3	Seasonal waterlogging	16,959.2	30.66
4	Permanent waterlogging	6387.97	11.55
5	Salt affected	130.12	0.23
6	Water erosion	33.39	0.06
7	Eolian sheet erosion	611.87	1.11
	Total	55,311.67	100
Agro-forestry area (AGF 2016–17)			% AGF
7	Farm forests		4.89
			6.51
	Under stocked	26.55	
	Well stocked	35.33	
8	Horticulture plantations		32.91
			1.86
	Under stocked	178.54	
	Well stocked	10.08	
9	Miscellaneous plantations		1.73
			7.80
	Under stocked	9.39	
	Well stocked	42.34	
10	Scrub		40.48
			3.82
	Open	219.61	
	Dense	20.71	
	Total	542.55	100

*AGF 2016–17 is resultant of conversion of degraded area

lands which is a sole example of practices and policies adopted by the state government in respect to augment agro-forestry area. The conversion to seasonal waterlogging to horticulture plantations is acclaimed to be the farmer's allegiance in revolution of converting degraded lands to productive area. A map has been composed to locate the sites undergone conversion from degradation category to agro-forestry depicted in Fig. 7. Different sub-categories have been added in their particular category to attain a total conversion of the latter.

Suggested Agro-Practices as Mitigation Measure to Combat Degradation

In the era of growing food and fodder demand with over mounting population, the increase in area for food and fodder production adds to maintain national security while securing poor population economically. The area of 7236.9 hectares converted profitably to agro-forestry is an exemplar for more resurgence of degraded areas in the approaching years. The conversion of degraded lands to agro-practices requires knowledge of soil type, physiography, ground water availability and quality and species able to survive hostile environments. Table 6 sums up a few species of flora which have suitability to grow under adverse conditions of soil. These species can also act as a buffer to maintain equilibrium with disturbed ecosystem. The degraded lands which have yet not been converted to fruitful areas can be transformed based on integrated approach adopted by various departments and working of public and private sectors in harmony.

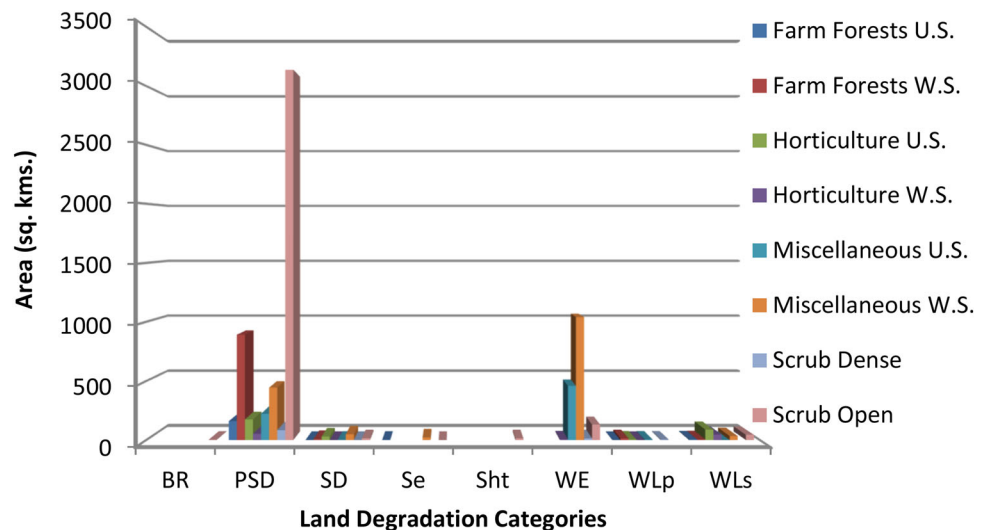
Table 5 Dynamics of degradation to agro-forestry categories over West Haryana

LDD to Agro _Area (sq. km.)	Farm forests		Horticulture plantations		Miscellaneous plantations		Scrub		Grand total	
	U. S	W.S	U. S	W.S	U. S	W.S	Dense	Open		
BR									2.99	2.99
PSD	160.38	891.22	175.09	53.41	223.41	444.89	84.35	3134.3	5167.05	
SD	0.89	8.97	31.01	1.26	2.53	49.87	1.14	16.68	112.35	
Se	3.1					22.68		1.24	27.02	
Sht								16.03	16.03	
WE				5.84	459.97	1039.8	14.86	131.61	1652.09	
WLP	0.46	16.85	4.2	0.92	4.84		4.26		31.53	
WLS	5.36	6.3	88.8	46.93	0.23	34.68		45.54	227.84	
Total	170.19	923.34	299.1	108.36	690.98	1591.92	104.61	3348.39	7236.9	

*BR barren rocky; PSD partially stabilized dunes; SD stabilized dunes; Se salt affected; Sht sheet erosion (eolian); WE water erosion; WLP waterlogged—permanent; WLS waterlogged—seasonal; U.S. Under stocked; W.S. Well stocked

Table 6 Floral species tolerant to degradation category

Degradation category	Tolerant species	References
Sand dunes	<i>Colophospermum mopane</i> , <i>Acacia tortilis</i> , <i>Citrullus colocyntis</i> , <i>Prosopis cineraria</i> and <i>Lasiurus indicus</i>	Beena et al. (2000)
Waterlogged area	<i>Eucalyptus spp.</i> , <i>Casuarina equisetifolia</i> , <i>Bambusa arundinacea</i> , <i>Tamarix</i> , <i>Lucerne</i> , <i>Syzygium cumini</i> , <i>Terminalia arjuna</i> , <i>Corymbia tessellaris</i> , <i>Barringtonia acutangula</i> , <i>Psidium gujava</i> , <i>Ficus glomareta</i>	Uthappa et al. (2015)
Salt affected	<i>Sporobolus sp.</i> , <i>Salvadora sp.</i> , <i>Capparis</i> , <i>Prosopis juliflora</i> , <i>Acacia nilotica</i> , <i>A. tortilis</i> , <i>Tamarix</i> , <i>Prosopis pallida</i> , <i>P. tamarugo</i> , <i>P. chilensis</i> and <i>A. triplex sp.</i>	Khan and Shukla (2003)
Water erosion	<i>Acacia auriculiformis</i> , <i>Albizia lebbek</i> , <i>Dalbergia sissoo</i> , <i>Eucalyptus tereticornis</i> , <i>Pongamia pinnata</i> , <i>Populus deltoids</i> , <i>Terminalia arjuna</i> , and <i>Syzygium cumini</i>	Prasad (2007)
Eolian sheet erosion	<i>Acacia tortilis</i> , <i>Ziziphus mauritiana</i> , <i>Azadiracta indica</i>	Tilak and Sundan (2015)
Barren Rocky	<i>Waltheria indica</i> , <i>Combination of Aristida-Eleusine-Cenchrus</i> , <i>Acacia tortilis</i> , <i>A. senegal</i> , <i>Prosopis juliflora</i> and <i>Euphorbia sp.</i>	Krishnaiah et al. (2003)

Fig. 6 Graphical representation of transformed degraded lands to Agro-forestry

Conclusion

The study carried out in four districts of State Haryana concludes that a variation is found in the degraded lands as well as the transformed categories in agro-forestry with respect to extent of area. The District Bhiwani with maximum geographical area also has more area under degradation while Hisar shows most improvement in terms of transformed degraded categories to agro-practices. Bhiwani shows maximum emergence of miscellaneous plantation on degraded lands while Fatehabad and Sirsa surfaced horticulture plantations. The dunes (partially stabilized and stabilized) have shown conversion to each

category of agro-forestry in West Haryana. With a total conversion of 7236.9 sq. km. of degradation to agro-practices, the maximum transformation has been brought about in category of partially stabilized dunes where a total of 5167.05 sq. km. of area is converted to assorted categories of agro-forestry. The open scrub followed by well-stocked category of miscellaneous plantations surpasses other categories being on the lead to be higher emerged with respect to other categories of agro-forestry. Various tolerant species which can survive the hostile condition of soils in degraded lands has also been summarized which can be implied to management practices to carry the transformation to further extent.

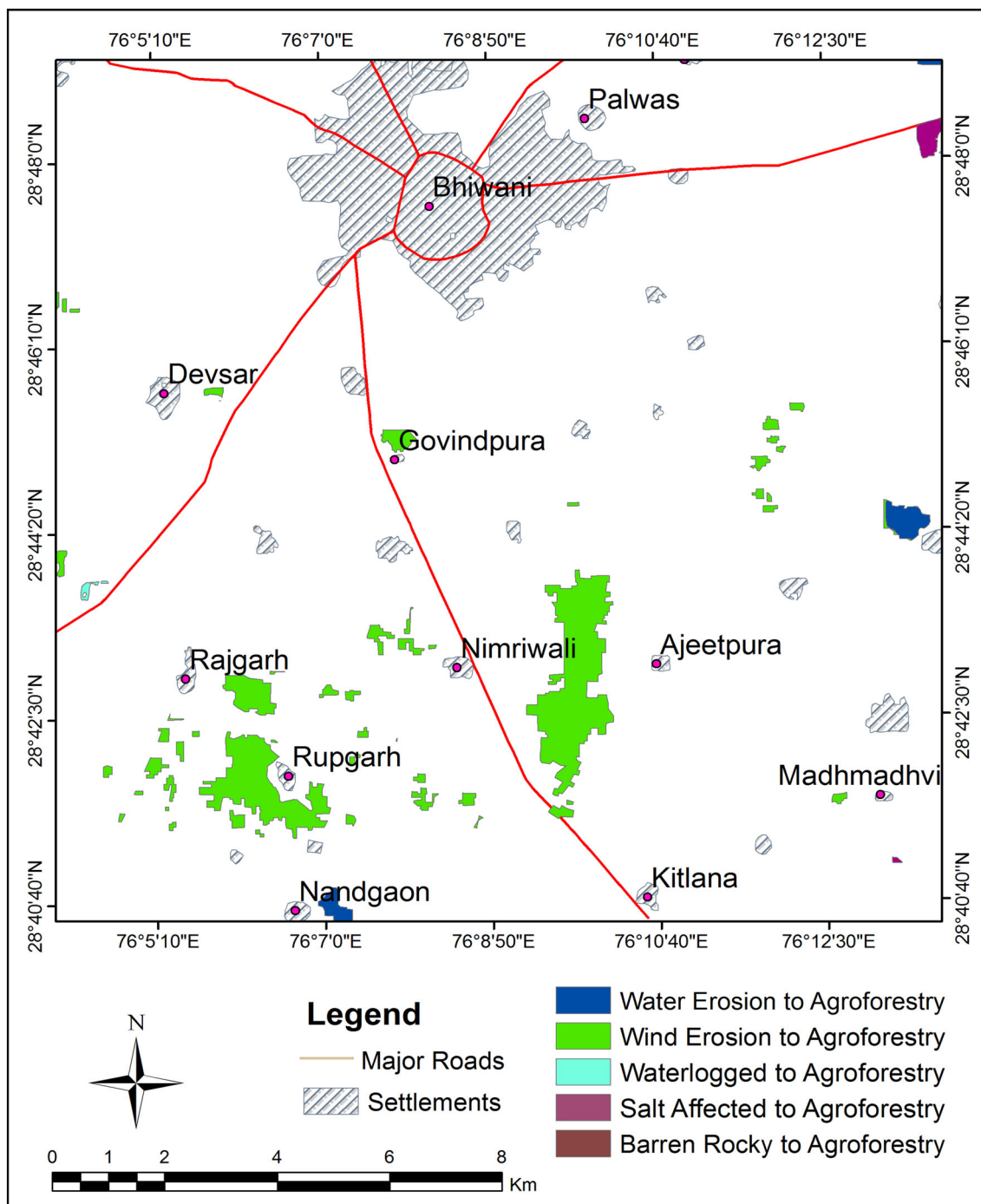


Fig. 7 Map depicting transformed categories of degraded lands in portions of Bhiwani district

Acknowledgements The first author extends her gratitude to University Grants Commission-Basic Science Research scholarship for providing with financial support to carry out the research. The facilities provided by Director, HARSAC, are also thankfully acknowledged.

Funding The research was carried out as a part of doctoral degree to be submitted to Department of Environment Science and Engineering, GJUS&T funded by University Grants Commission-Basic Science Research Scholarship.

Data availability The data are scrupulous enough to bear public scrutiny.

Declarations

Conflict of interest We affirm that the article has not received prior publication and is not under consideration for publication elsewhere. We affirm that the article is author's original work and it is also

confirmed that all the authors have seen and approved the manuscript been submitted to Journal of Indian Society of Remote Sensing.

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