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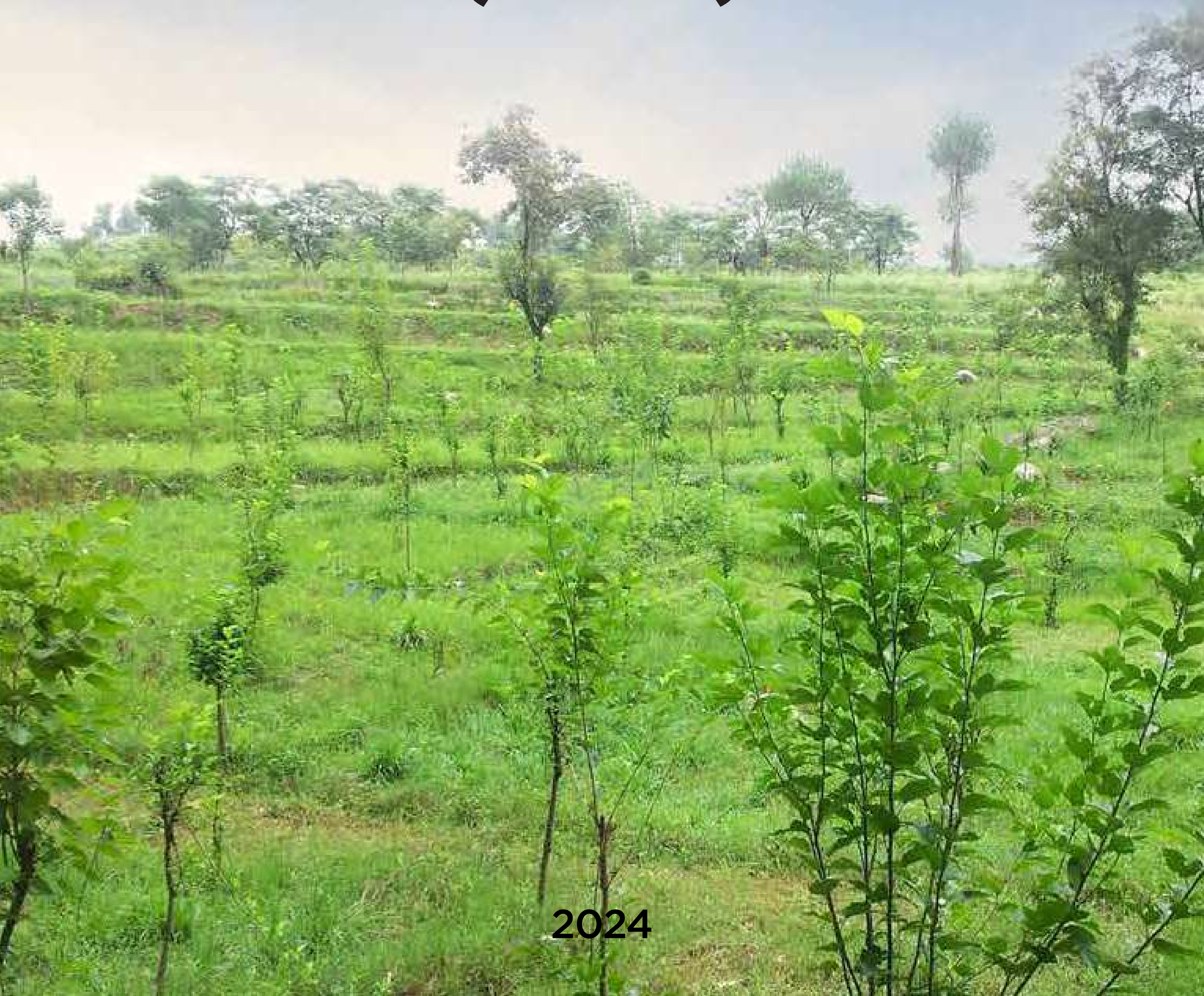
NITI Aayog

TECHNICAL REPORT ON

Greening and Restoration of Wastelands with Agroforestry (G.R.O.W)



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Disclaimer:

The thematic layer datasets used in study are provided by National Remote Sensing Centre, Hyderabad and Space Application Centre Ahmedabad. The datasets corresponds to scale and accuracy commensurable with planning requirements only. NITI Aayog shall not be liable for any loss or damage whatsoever, arising of, or in connection with use of or reliance on the statistic, information found in the document. The study methodology used is based on the expert views of contributing scientists. Personal views and are open or improvement that may be required over coming years.

1 Details of Authors and contributors are affiliation enclosed as Annexure- I

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भारत 2023 INDIA
प्रो. रमेश चन्द
सदस्य
Prof. Ramesh Chand
MEMBER

सत्यमेव जयते

आज़ादी का अमृत महोत्सव

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Foreword

Agriculture and allied sectors have four key sub-sectors, namely, crops, livestock, fishery and forestry. Out of these sub-sectors output of forestry showed very slow growth with very high year on year fluctuations. So much so that India meets a large share of demand for wood and wood products from imports whereas large tract of land remains unused without having any vegetation. Large number of studies and reports indicate scope for greening India and raising output of forestry by planting trees on land outside forest. It looks strange that fallow land in most states is showing an increase despite so much pressure on land resources. Agroforestry is an effective and viable option for raising output of forestry in India by raising agroforestry species on barren land, culturable wastes, fallow land and on field bunds and as a component of farming system in many areas. Beside economic gains this option is being suggested to address challenges of climate change and to ameliorate the environment.

Agroforestry is an ideal intervention for transforming wastelands to productive use that can play an instrumental role in achieving National goals and global commitments. At present, area under agroforestry in India is about 28.43 million hectare while the area under wastelands is 55.76 million hectares. This shows that area under agroforestry can be raised to three times of existing area by bringing wastelands under agroforestry. This is huge area considering the area under forests in the country. Conversion of culturable wastelands into productive use through agroforestry will surely provide multifold benefits to the environment, expansion of green cover, rural communities and wood-based economy.

A team at NITI Aayog under the leadership of Dr. Neelam Patel has developed Geographic Information System based analysis to assess the agroforestry suitability regimes in wastelands across the country. This is based on multi-thematic datasets on wastelands, land use/land cover, waterbodies, soil organic carbon and slope of land. This can go a long way in identifying suitable sites and areas for agroforestry. The proposed methodology excludes ecological sensitive envelopes, such as natural grasslands, from getting selected for agroforestry. To enable stakeholders to access the results of this analysis, a universal authorized access portal called "Greening and Restoration of Wasteland with Agroforestry (GROW)- Suitability Mapping" has been designed and developed that allows access to the findings at state and district level. The suitability area statistics are available on Bhuvan- India's Geoportal at https://bhuvan-app1.nrsc.gov.in/afsi/.

I appreciate the contributions of all team members for undertaking this study and preparing a tool that is useful in planning and implementing agroforestry activity. I hope this will lead to better planning and expansion of agroforestry activities in the country to generate multiple benefits for people, society, economy and environment.

(Ramesh Chand)

Place: New Delhi
Date: November 24, 2023

Acknowledgement

The technical report on Greening and Restoration of Wastelands with Agroforestry is an outcome of one of the action plans assigned to NITI Aayog's Agriculture Vertical, under supervision of Hon'ble Member (Agriculture) Prof. Ramesh Chand. The authors are grateful to Hon'ble Member (Agriculture) for his consistent guidance in the achieving objectives of the task. Authors are thankful to Hon'ble Vice Chairman, Mr. Suman K Bery and CEO, Mr. B.V.R Subrahmanyam for their encouragement and support for carrying out this project.

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Since the inception of the study, subject matter experts, Research Institutions, State Government officers, and State Agricultural Universities were involved in designing methodology for this project. With the support of Head/Incharge of ICAR-Krishi Vigyan Kendra (KVK) viz., KVK Sidhi, KVK Agra, KVK Bhavnagar and Vice Chancellors of State Agricultural University, namely, Mahatma Phule Krishi Vidyapeeth, Swami Keshwanand Rajasthan Agricultural University, Tamil Nadu Agricultural University, Assam Agricultural University, Dr YSR Horticultural University, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu and Odisha University of Agriculture and Technology for successfully conducting Ground validation of the Suitability Maps in selected districts.

We extend our sincere thanks to nominated officers that helped in ground validation of the suitability maps in selected districts. The details of the officers are enclosed in Annexure-II. We are thankful to International Centre for Research in Agroforestry (ICRAF) Head of Spatial Data Science and Applied Learning Lab, Dr Tor-Gunnar Vagen and Dr Chandrashekhar Biradar, Country Director India, Chief of Party Trees Outside Forest India; Network for Certification and Conservation of Forests (NCCF) DG A. K. Srivastava, for providing valuable inputs for the project.

I acknowledge the sincere efforts of Dr Tanu Sethi, Sr. Associate, NITI Aayog in developing the first draft report and portal design for Bhuvan under GROW Project with NRSC Team. I appreciate her in creating the acronym GROW.

Neelam Patel

Abbreviations and Acronyms

ACZ	Agro-Climatic Zones
AFOLU	Agriculture, Forestry and other Landuse
AOI	Area of Interest
ASI	Agroforestry Suitability Index
ATMA	Agricultural Technology Management Agency
CAFRI	Central Agroforestry Research Institute
CO_2e	Carbon dioxide Equivalent
DEM	Digital Elevation Model
FAO	Food and Agriculture Organisation of the United Nations
GHG	Greenhouse Gases
GIS	Geographical Information System
GROW	Greening and Restoration of Wastelands
Ha	Hectare
GT	Ground truth
HLEG	High Level Expert Group
HSA	Highly Suitable Area
HYV	High Yielding Variety
ICAR	Indian Council of Agricultural Research
IGFRI	Indian Grassland and Fodder Research institute
IPCC	Intergovernmental Panel on Climate Change
km	Kilometre
KVK	Krishi Vigyan Kendra
LULC	Land Use Land Cover
m	Metre

MoA & FW	Ministry of Agriculture and Farmers Welfare
MoEF&CC	Ministry of Environment, Forest and Climate Change
MSA	Moderate suitable Area
NAP	National Agroforestry Policy
NbS	Nature-based solutions
NDC	Nationally Determined Contribution
NDVI	Normalized Difference Vegetation Index
NRSC	National Remote Sensing Centre
QGIS	Quantum Geographic Information System
SAC	Space Application Centre
SDG	Sustainable Development Goals
SHG	Self-Help Group
SIS-DP	Space based Information Support for Decentralised Planning
SOC	Soil Organic Carbon
SOI	Survey of India
sq.km	Square Kilometres
Kg/m^2	Kilograms per square metre
TGA	Total Geographical Area
VEDAS	Visualisation of Earth Observation Data and Archival System

Executive Summary

India is the first country in the world to form and announce the National Agroforestry Policy in 2014, which focuses on enhancing productivity, profitability, diversity and ecosystem sustainability. Agroforestry is an agroecological nature-based land use system that can simultaneously address many ecological challenges of the current era viz. food, nutrition, energy, employment, natural resources and environmental security. It includes both traditional & modern land use systems. Integrating and optimising the interactions of the components of agroforestry i.e trees, crops and/or livestock, can lead to improvements in the soil quality, greater vegetation and tree cover. Agroforestry can simultaneously address the mitigation and adaptation needs of managing climate change, along with many social and economic gains in the long term. Globally, empirical evidence of beneficial socio-economic and ecological outcomes of agroforestry interventions, in rural and urban areas, wastelands and degraded lands, have added momentum to harness this set of practices for achieving targets under various National and International commitments viz. Nationally Determined Contribution (NDC) as part of the Paris Agreement on Climate Change, Bonn Challenge, UN Sustainable Development Goals, United Nations Convention on Combating Desertification (UNCCD), Doubling Farmers Income, Green India Mission, National Action Plan on Climate Change and Atmanirbhar Bharat. Due to the significance of goods and services provided by agroforestry, the Union Budget of Government of India (FY-2022-23) has underlined the promotion of agroforestry and private forestry as a priority.

India is the seventh largest country in the world, with an area of 328.73 million hectares and has the second largest total arable area, after USA. Due to anthropogenic activities, many regions have increased build up areas, degraded land, imbalanced natural resources that have adversely impacted the environment and lives on the planet. There has been a concomitant decline in per capita availability of land in the country. Hence, it is imperative to transform land-use systems across the country, especially when it comes to classified wastelands that need to be transformed to agricultural and other productive uses. About 55.76 million hectares i.e. 16.96% of Total Geographical Area (TGA) of the country is wastelands and are currently under-utilized and deteriorating due to a lack of appropriate resource management or on account of natural causes.

Geospatial Technologies have been effectively used in mapping these regions/geographies and activities of interest and development across various sectors. This technical report explores the application of remote sensing datasets with GIS technology in prioritising wastelands in the country suitable for greening with agroforestry intervention. To support this analysis, the

Agroforestry Suitability Index (ASI) was derived to develop a national level area prioritisation plan of wastelands for greening with agroforestry.

A multi-institutional team was formed by NITI Aayog to develop a Geographic Information System based analysis to assess the agroforestry suitability regimes in wastelands across the country. Multi-thematic datasets on wastelands, Land Use Land Cover, waterbodies, soil organic carbon & slope at 1:50,000 scale were identified, and after appropriate weightages were applied, these were used to carry out a national level overlay analysis. Ecological sensitive envelops, such as natural grasslands, were identified and excluded in the methodology. Three area prioritisation classes, i.e. highly suitable, moderately suitable and less suitable/not applicable were used to stratify wastelands across districts of the country, excluding the Union Territories of Lakshadweep, and Andaman and Nicobar Islands. Based on the analysis, 2,07,455.37 sq.km (6.31% of Total Geographical Area (TGA) area falls under 'highly suitable' category and 1,62,372.33 sq.km (4.94% of TGA) under 'moderately suitable' category. Madhya Pradesh (29,643.98 sq.km), Rajasthan (27,662.046 sq.km) and Maharashtra (24,228.03 sq.km) are the top 3 states with significant extents of area under the highly suitable class. Most areas fall under 'less suitable/not applicable' category and these include cropped areas, forests and other land use system, other than classified 'wastelands'. This report furnishes state-wise and district-wise area analysis of the results. Based on cumulative analysis of area under moderately suitable and highly suitable area, Rajasthan (60,922.40 sq.km) holds the largest area for greening, followed by Maharashtra (43,944.61 sq.km), Madhya Pradesh (41,474.16 sq.km), Andhra Pradesh (24,7328.11 sq.km) and Gujarat (24,658.88 sq.km), respectively. States have variable wastelands areas suited for taking up agroforestry for wasteland greening. The classification tool and results of subsequent analysis can play a pivotal role in supporting Research Institutions/ Central/State Government Departments, wood-based Industries and others to prioritise and initiate greening and restoration projects.

To enable Stakeholder to access the results of this analysis, a universal authorised access portal called "Greening and Restoration of Wasteland with Agroforestry (GROW)- Suitability Mapping" has been designed and developed that allows access to the results of state and district level datasets. The suitability area statistics are available on Bhuvan- India's Geoportal at *https://bhuvan-app1.nrsc.gov.in/asi_portal/*. The database can be quite easily extended in scope to bring in other related efforts to apply agroforestry to management and sustainability challenges that will be useful for the Indian farming community. A special tool was added in the system that provides flexibility to users to manipulate weightages and overlay criteria for customised local prioritisation. The national area prioritization will be available as the standard output against which the user can compare customised results, if required.

At present, total area under agroforestry is about 28.42 million hectares that covers about 8.65% of TGA of the country. The conversion of underutilised areas, esp. wastelands, can extend multiple benefits of agroforestry across vast areas in the country.

This technical report on Greening and Restoration of Wastelands with Agroforestry (GROW) will benefit for taking up restoration projects for achieving national commitments of Land Degradation Neutrality and restoring 26 million hectares of degraded land by 2030, as well as creating an additional carbon sink of 2.5 to 3 billion tonnes of carbon dioxide equivalent.

1 Introduction

India is the fifth largest global economy bestowed with rich natural resources. It is a powerhouse of biological, cultural and economic diversity that lays apt foundation for growth and development. India with 328.73 million hectares of geographical area holds the seventh position in world area and ranked second in arable area (180.8 million hectares) and 10th (80.9 million hectares) in forest area. This "land-use patterns" plays a key role in influencing economic growth, quality of life, natural ecosystem, goods and food supply. Globally and regionally, changes in the land use pattern have emerged as a major contributor to climate change, biodiversity loss and land degradation. The Intergovernmental Panel on Climate Change (IPCC) (2021) mentioned that the global transitions in Landuse system i.e. Agriculture, Forestry and Other Land Use (AFOLU) have contributed to about 23% of anthropogenic emissions of Greenhouse gases and 11-14 percent (%) biodiversity loss. Around 12 million hectare of land is annually lost due to degradation (*IPCC Special Report, 2019; IPBES, 2018*). Degradation of Earth's land surface through human activities is negatively impacting the well-being of at least 3.2 billion people, pushing the planet towards a sixth mass species extinction, and costing more than 10% of the annual global gross product in loss of biodiversity and ecosystem services (*IPBES, 2018*).

In India, Land use system is categorised in nine categories: (i) Forests area, (ii) Area under Non-Agricultural use, (iii) Barren and Uncultured Land, (iv) Permanent Pastures and other Grazing Land, (v) Land under Miscellaneous Tree Crops, (vi) Culturable Waste Land, (vii) Fallow Land other than Current Fallows, (viii) Current Fallows, and (ix) Net Area Sown (*Directorate of Economics & Statistics, 2021*). There was a significant change in India's land use during 20th century. From the mid 1900's onwards, there has been an extensive area expansion of the agriculture sector, coupled with deforestation and urbanisation (*Roy et al., 2015*). Over the years, these anthropogenic processes have led to an expansion in built-up area, environmental degradation and imbalance in natural resources. Primarily due to rise in population, there is a decline in per capita availability of land. Now, land under agriculture is decreasing at a rate 0.03 million hectares per year (*Handa et al., 2019*). Further, pressure on land and natural resources are rising due to population growth, urbanisation, low agri-productivity, excessive use of synthetic fertilisers, depletion of natural resources, deforestation and demands of lifestyle goods. The total Greenhouse Gas (GHG) emissions recorded in India during 2016 was 2,838.89 million tonne CO_2e, excluding Land Use Land Use Change and Forestry (LULUCF) and 2,531.07 million tonne CO_2e with inclusion of Land Use Land Use Change and Forestry (LULUCF) (*MoEF&CC, 2021*). Emission of carbon dioxide was estimated at 2,231 million tonne (78.59%), methane emissions at 409 million tonne CO_2e (14.43%) and nitrous oxide emissions at 145

million tonne CO_2e (5.12%), respectively. About 29.32% of India's land (96.40 million ha) is under degradation process (*Desertification and Land Degradation Atlas of India, 2016*). As per Wastelands Atlas of India published by Ministry of Rural Development, 55.76 million hectares i.e. 16.96% of TGA are wastelands.

Land, being a finite resource, requires judicious planning and management measures to foster sustainability and to avert the major crises that presently threaten ecology, society and economy. India has declared its commitment to the Bonn Challenge, Nationally Determined Contribution (NDC) to the Paris Agreement on Climate Change, the UN Sustainable Development Goals, UN Decade of Ecosystem Restoration, Doubling Farmers Income, the National Action Plan on Climate Change and *Atmanirbhar Bharat* that can significantly be realised by transforming land use systems to deliver optimal benefits. A plethora of schemes and programmes have been initiated by various government departments towards mitigation of green house gases, facilitation of adaption strategies, reversing degradation and improving biodiversity conservation. In all, 9.81 million hectares of area have been restored across India from 2011 to 2016-17.

Best practices like Agroforestry are a productive and affordable pathway to enable India to meet its land degradation neutrality and climate change adaptation commitments. Agroforestry is an agroecological practice and followed in more than 130 countries in the world. India is the leading nation to formalise and announce the National Agroforestry Policy in 2014, defining it as a land use system which integrates woody perennials (trees and shrubs) on farmlands and rural landscape to enhance productivity, profitability, diversity and ecosystem sustainability (*MoA&FW, 2014*). In other words, agroforestry is the integration of trees, crops and/or livestock on the same piece of land to enhance productivity and resilience of farms and deliver numerous vital ecological services. Hence, it can act as a promising land-based transformation solution with several co-benefits. Adoption of agroforestry can enhance farmers income, increase in green cover, natural resource conservation, production of forest based raw-materials, achieving NDC's, rural development and scalability - all at the same time from same land areas with different degrees. It is an ideal option to restore most of degraded and wastelands in the country *(Dhyani 2003; Dhyani et al., 2005 Chaturvedi et al., 2017 & 2018; Dagar and Tiwari, 2016; Mishra and Rath, 2013; Handa et al, 2015; Planning Commission, 2001; MoA&FW, 2014; Duguma et al., 2017*).

Due to the significant goods and services provided by agroforestry, the Union Budget of Government of India (FY-2022-23) has underlined the promotion of agroforestry and private forestry; and financial support to farmers belonging to Scheduled Castes and Scheduled Tribes, who want to take up agro-forestry *(MoF, 2022)*. This announcement has given impetus to scale-up agroforestry interventions in the country. Agroforestry can be well ingrained with ecosystem restoration intervention across landscapes and rehabilitation.

Present study is designed to harness the potential of agroforestry for Greening and Restoration of Wastelands (GROW) by using geospatial analysis and remote sensing datasets. Certain classes of existing country's wastelands are opportune sites and can be transformed to productive sites for multiple uses. Hence, prioritisation of these areas suitable for greening can play a pivotal role for undertaking greening and restoration projects by Research Institutions/ Central/State Government Departments, wood based Industries etc.

1.1 OBJECTIVES

Greening of wastelands with agroforestry intervention can play a significant role in mitigating climate change, bringing socio-economic welfare and achieving targets of the Bonn Challenge, the Sustainable Development Goals (SDGs), the Paris Agreement and meeting national target of 33% green cover. Before the potential of agroforestry can be harnessed in this way, it was crucial to scientifically identify potential sites for greening, including those that were most suitable and excluding sites that are required to be conserved, like grasslands, community owned lands etc. from the purview of GROW. This was achieved in the present study through complying with following objectives:

1. Deriving an Agroforestry Suitability Index (ASI) for delineating and prioritisation of suitable areas across the country especially wastelands based on suitable bio-geophysical parameters and geospatial technology, and
2. Developing a universal access platform for stakeholders to view suitability regions, statistics, maps at district level for planning greening projects across States and Districts.

A group of expert was consulted to achieve the study objectives and details are enclosed as Annexure I.

2 Prospects for wastelands greening and restoration with agroforestry

2.1 NATIONAL AGROFORESTRY POLICY

India is the first country in the world to develop and adopt an Agroforestry Policy. **The National Agroforestry Policy of Government of India (2014),** seeks to enhance productivity, profitability, diversity and ecosystem sustainability. It includes both traditional & modern land use systems where woody perennials (trees, shrubs, bamboos and palms) are managed together with crops and/or animals production system in agriculture settings *(MoA&FW, 2014)*. The policy was a cumulative result of many other policies and schemes emphasising on the importance of agroforestry like the National Forest Policy (1988), the Planning Commission Task Force on Greening India (2001), the National Bamboo Mission (2002), the National Policy on Farmers, (2007) and the National Mission for a Green India (2010). Agroforestry is considered a nature-based solution (NbS) that works within the functional limits of ecosystems to help societies address a variety of environmental, social and economic challenges in sustainable ways (*Meybeck et al., 2020*).

To operationalise the objectives envisioned in the policy, the Sub-Mission on Agroforestry (SMAF) under National Mission for Sustainable Agriculture (NMSA) and *Har Medh Par Ped* was launched in 2016-17 by Ministery of Agriculture and Farmers Welfare to encourage tree plantation on farm land along with crops/ropping system and make farming systems more climate resilient and adaptive. The Sub-Mission on Agroforestry objectives were defined for stimulating the growth of agroforestry in India (Figure 1).

The scheme was implemented in 20 States viz. Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, Mizoram, Meghalaya, Nagaland and 2 UTs viz. Jammu & Kashmir and Ladakh with funding pattern of 60:40 between Centre and State Govt. for all States, excepting NE & Hilly states, where it is 90:10 and 100% in case of UTs & National Level Agencies. Under the Mission, multipurpose tree species with short, medium and long term returns are encouraged, so that farmers may get additional income at regular intervals.

In India the total area under Agroforestry is about 28.42 million hectare (Mha) that covers about 8.65% of Total Geographical Area of the country *(Arunachalam et al., 2022)*. The area is varied across 15 Agro-Climatic Zones (ACZ) of the country and is highest in Upper Gangetic Plains Region i.e ACZ-V. The area under agroforestry across different ACZ is mentioned in Table. 1.

01 To encourage and expand tree plantation in complementary and integrated manner with crops and livestock to improve productivity, employment opportunities, income generation and livelihoods of rural households, especially the small farmers.

02 To ensure availability of quality planting material like seeds, seedlings, clones, hybrids, improved varieties, etc.

03 To popularise various Agroforestry practices/models suitable to different agro ecological regions and land use conditions.

04 To create database, information and knowledge support in the area of agroforestry.

05 To provide extension and capacity building support to agroforestry sector.

Figure 1. *Objectives of Sub-Mission on Agroforestry (SMAF)*

Table 1: Agroforestry area in 15 Agro-Climatic Zones (ACZs) of India

ACZ no.	ACZ	Geographical area (M ha)	Agroforestry area (M ha)	Agroforestry area (%)
I	Northern Himalayan Region	32.968	4.096	12.42
II	Eastern Himalayan Region	28.422	1.088	3.83
III	Lower Gangetic Plains Region	6.238	0.802	12.86
IV	Middle Gangetic Plains Region	16.526	1.304	7.89
V	Upper Gangetic Plains Region	14.367	2.234	15.55
VI	Trans Gangetic Plains Region	11.750	1.143	9.73
VII	Eastern Plateau and Hill Region	40.525	4.292	10.59
VIII	Central Plateau and Hill Region	37.435	1.924	5.14
IX	Western Plateau and Hill Region	32.539	1.556	4.78
X	Southern Plateau and Hill Region	39.294	2.976	7.57
XI	East Coast Plains and Hill Region	19.948	2.36	11.83
XII	West Coast Plains and Hill Region	11.69	1.632	13.96
XIII	Gujarat Plains and Hill Region	18.673	2.57	13.76
XIV	Western Dry Region	17.587	0.431	2.45
XV	The Island Region	0.785	0.019	2.42
	Total	**328.747**	**28.427**	**8.65**

Source: *Arunachalam et al., 2022*

The National Agroforestry Policy (NAP) (2014) envisioned agroforestry interventions in wastelands, described as “Non-forest wasteland barren community land to be encouraged for plantation of agroforestry tree species to provide opportunities of economic returns as well as contributing towards ecological benefits” *(Statement from NAP, 2014).* Empirical evidences have showed agroforestry interventions in degraded/wastelands restoration can create economic opportunities for the rural people and wood based industries (*Planning Commission 2001; FAO, 2017; Maji et al., 2010; Chavan et al., 2015*). Over decades, considerable area has been subjected to desertification or other types of degradation, that have resulted in depletion of natural resources, urbanisation and other antheropogenic activities. India is on track to achieve its national commitment of Land degradation neutrality and restoring 26 million hectares of degraded land by 2030 and creating an additional carbon sink of 2.5 to 3 billion tonnes of carbon dioxide equivalent, the wastelands are potential sites to initiate transformation to productive use through agroforestry interventions.

2.2 WASTELANDS: DEFINITION AND TYPES

As per the erstwhile National Wastelands Development Board (NWDB), now Department of Land Resources (DoLR) wastelands are defined as degraded land that can be brought under vegetative cover with reasonable effort and which is currently under-utilised and is deteriorating due to lack of appropriate water and soil management or on account of natural causes. Further, wastelands were classified into cultural and non-cultural wastelands (*http://dolr.nic.in/wasteland_division.htm*). *Mishra et al. (2013*), mentioned that wastelands are the underutilised area and produce less than 20% of its biological productivity. Wastelands are formed due to prolonged non-judicious and faulty land use practices. The key for land use transformation can be achieved by reversing soil salinity, water logging, droughts, excessive soil erosion caused due to deforestation, unscientific agricultural practices, over grazing etc.

In India, the National Remote Sensing Centre (NRSC) is the principal organisation to provide National level geospatial information on wastelands using remote sensing technology at the behest of the Department of Land Resources, Government of India. The estimated wastelands area in the country was 55.76 million hectares i.e 16.96% of total geographical area (TGA) in the year 2015-16 (Wastelands Atlas of India, 2019). The extent of variation in wastelands area in the country was estimated to be about 63.85 Mha in Atlas 2000; 55.27 Mha in Atlas - 2005, 47.23 Mha in Atlas – 2010 and 46.70 Mha in Atlas – 2011, respectively (Wasteland Atlas of India, DoLR, MoRD, GoI).

Wastelands is a consortium term that includes 23 categories such as gullied and/or ravinous land, land with dense scrub, land with open scrub, waterlogged and marshy land, land affected by salinity/alkalinity, degraded pastures/grazing land, under - utilised/degraded forest (agriculture) etc. (Table. 2). The area under the 23 wastelands classes are varied, occupying between 0.2% - 3.28 % of total 16.96 % wastelands of the country. The area under each category of wastelands class is shown in figure 2.

Table 2: Different classes of Wastelands as per Wastelands Atlas of India

1. Gullied and/or ravinous land (Medium)	12. Under–utilised/degraded forest (Agriculture)
2. Gullied and/or ravinous land (Deep)	13. Degraded pastures/grazing land
3. Land with Dense Scrub	14. Degraded land under plantation crop
4. Land with Open Scrub	15. Sands-Riverine
5. Waterlogged and Marshy land (Permanent)	16. Sands-Coastal
6. Waterlogged and Marshy land (Seasonal)	17. Sands-Desertic
7. Land affected by salinity/alkalinity (Medium)	18. Sands-Semi Stab. > 40m
8. Land affected by salinity/alkalinity (Strong)	19. Sands-Semi Stab. 15 - 40m
9. Shifting Cultivation-Current Jhum	20. Mining Wastelands
10. Shifting Cultivation-Abandoned Jhum	21. Industrial Wastelands
11. Under–utilised/degraded forest (Scrub dominated)	22. Barren Rocky/Stony waste
	23. Snow covered/Glacial area

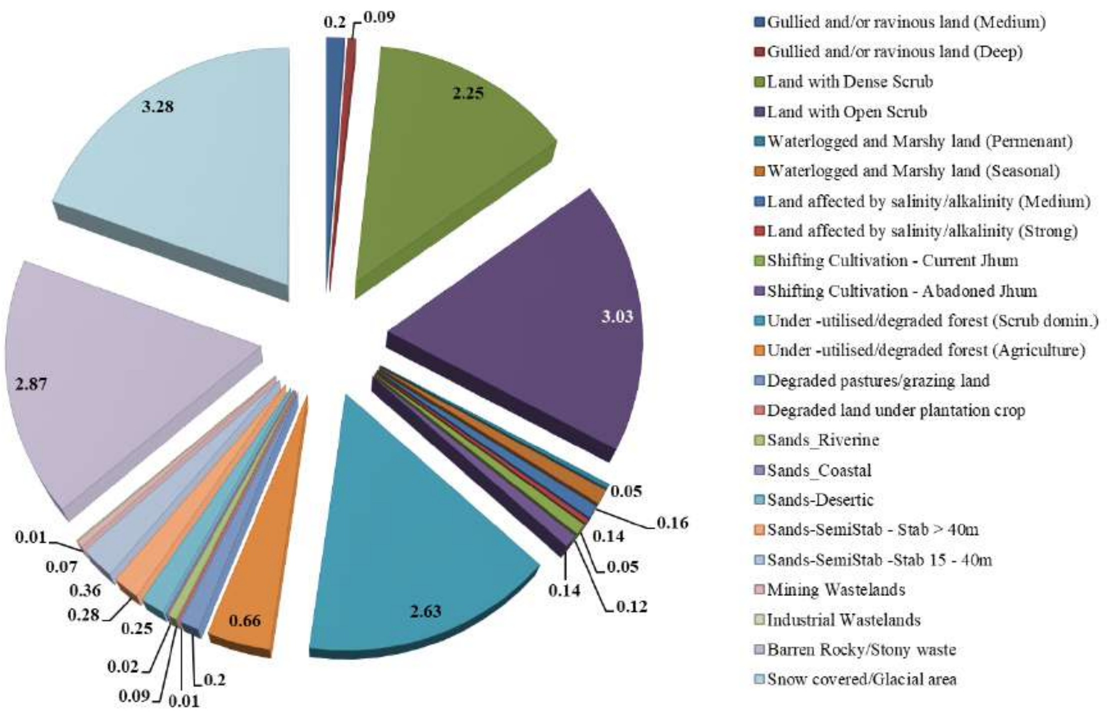


***Figure 2.** Percentage of area under 23 classes of wastelands*

Wastelands are also classified as culturable and unculturable wastelands. The cultural wastelands have potential for development and reclamation of its vegetative cover. These lands remain unproductive for various reasons such as water-logging, salinity, non-availability of water or aridity and unfavourable terrain, etc. that occurred due to faulty cultivation or other undesirable land use practices. Large areas are found in north western Himalayan states like Jammu and Kashmir, Himachal Pradesh, North Eastern states, Rajasthan, Uttar Pradesh, Bihar and Madhya Pradesh for various reasons *(Mishra and Rath, 2013).*

However, most of the regions demarcated as wastelands such as naturally rocky areas, or natural swamps – which are not 'wastelands' as most of these areas had favourable biophysical parameters that supported certain types of ecosystem. However, these regions are currently defined as wastelands because these were inappropriately managed in the past and are no longer suitable for developing vegetative cover.

National Academy of Agricultural Sciences (NAAS) report (2010) on degraded and wasteland provides state-wise analysis of land use systems and factors responsible for degradation and formation of different types of wastelands. The report highlighted the finite nature of land resources and need to take requisite measures to reclaim the degraded and wastelands through effective crop management and agricultural development activities in the affected areas with public and private investments (*Maji et al., 2010; Planning Commission, 2001).*

A country as diverse as India, can benefit by deploying most of these wastelands into productive areas through agroforestry intervention. While myriad manifestation of agroforestry systems are recorded across the globe and formalised through research. It is important to define a set of suitable sites or geographical extents to promote them, in light of sustainability and climate change. The suitability criteria can be derived from thematic information corresponding to biophysical determinants like slope, organic carbon, water etc. that supports in farming of tree with regular annual crops. Land use systems, related factors and appropriate spatial datasets are required in selecting areas that are best suited for the greening.

2.3 NECESSITY FOR WASTELANDS GREENING

Due to conventional land use practices, rising population, industrialisation, food demand etc. are exerting pressure on land resources that exceeded beyond its carrying capacity and resulting into land degradation. India has 18% of the world's population and only 2.4% of the global land area. At same time, per capita availability of agriculture land in India has decreased over the years. The per capita agriculture land in India is 0.12 ha whereas world per capita agriculture land is 0.29 ha.

Hence, it is imperative to transform these wastelands area into productive area to reduce pressure on natural resources. With implementation of various Government of India schemes, about 1.45 Mha wastelands are converted to productive *aka* non-wasteland categories from 2008-09 till 2015-16. These transformations was observed primarily in the categories of land with dense scrub, waterlogged and marshy land, sandy areas, degraded pastures/grazing land and gullied and/or ravinous land (*Ministry of Rural Development, 2019; NRSC, 2019)*.

Bringing areas, formerly classified as wastelands, into productive uses through agroforestry can enhance avenues of employment, not just from primary production but also from processing and other related value chain activities. These economic benefits come on top of improving soil fertility and helping to meet the targets for increasing tree cover and other environmental services. Tree cover increases, with the right species, can contribute in achieving *"Aatmanirbharta"* in wood production and import substitution *(HLEG, 2020)*.

As per the Fifteenth Finance Commission report, available underutilized land resources, like cultivable wastelands, fallow lands can be deployed in achieving self-sufficiency in wood and greening mission (*HLEG, 2020)*. Wood and wood products imports (HS Code 44) have increased due to rising demand (Table 3).

Table 3: India imports of wood and wood based by value (million USD), 2009-2019

Year	ITC HS Code							
	4403 Wood in rough	4404 Hoop wood	4407 Sawnwood	4408 Veneer sheets	4411 Fibreboard	4412 Plywood & panels	4703 Sulphate pulp	4704 Sulphite Pulp
2009	1,191.77	0.39	42.16	19.95	40.6	36.71	238.86	1.33
2010	1,334.26	0.38	57.43	27.02	77.25	52.32	394.41	2.13
2011	1,828.94	0.51	130.96	45.74	84.31	112.42	463.55	1.81
2012	2,004.68	1.61	159.73	55.8	91.67	90.24	414.67	1.41
2013	2,033.64	0.5	184.31	65.73	96.32	80.63	451.56	22.29
2014	2,010.89	0.7	205.37	91.19	87.63	84.9	461.77	22.39
2015	1,564.88	0.47	283.64	174.01	87.18	85.78	466.92	1.11
2016	1,277.53	0.25	275.44	200.19	88.46	79.84	445.38	0.65
2017	1,206.09	0.03	367.73	219.53	106.12	97.8	484.09	1.54
2018	1,117.66	0.04	423.05	234.34	121.9	121.41	561.3	3.21
2019	993.63	0.02	466.28	280.84	103.34	107.63	507.94	2.05

Source: *INDIA TIMBER SUPPLY AND DEMAND 2010-2030 (Dr Promode Kant and Raman Nautiyal)*

Also, wastelands greening can support to meet the fodder supply deficit to boost growth of dairy sector in the country. The country faces a net shortfall of 35.6% green fodder, 10.5% dry crop leftovers, and 44% concentrate feed ingredients and land area under fodder cultivation is very limited (Table 4) (*Singh et. al., 2022; Singh, G., 2015; Dixit et al., 2012*). The demand for green and dry feed has been increased and by 2050, the demand will be 1012 and 631 million tonnes, respectively (IGFRI Vision, 2050). The non-arable and wastelands can be utilized through viable fodder-producing agroforestry system to meet the fodder demand in the country. Several forage trees such as *Acacia eburnea, A. nilotica, A. leucophloea, Balanities roxburghii, Cordarothii, Azadirachta indica, Pongamia pinnata, Dichrostachis cineria* etc. are suitable for wastelands.

As per *Chand, R.* (2023), there is a huge scope of raising trees and agroforestry on fallow land, culturable waste and on field boundaries. India also has 12 million hectare of culturable wastelands that can support in meeting domestic demand for wood along with environment, ecology and sustainability. India has been importing large quantity of wood and wood products, which has significantly increased import bill. However, there is a low interest in tree plantations and agroforestry in India due to rigid restrictions on felling of trees grown on non-forest private land and their inter-state movement. The reform in forest regulations esp. removal of restrictions on tree felling on private lands, timber marketing encourage participation of wood-based industry in initiating greening projects as well as raise employment and income (*Chand and Singh,* 2023).

Table 4: Demand and supply estimates of dry and green forages (million tonnes)

	Demand		Supply		Deficit		Deficit as %	
Year	**Dry**	**Green**	**Dry**	**Green**	**Dry**	**Green**	**Dry**	**Green**
2010	508.99	816.83	453.28	525.51	55.72	291.32	10.95	35.66
2020	530.5	851.34	467.65	590.42	62.85	260.92	11.85	30.65
2030	568.1	911.67	500.03	687.46	68.07	224.21	11.98	24.59
2040	594.97	954.81	524.4	761.76	70.57	193.05	11.86	20.22
2050	631.05	1012.7	547.78	826.05	83.27	186.65	13.2	18.43

Source: *The Working Group Report on Demand and Supply, NITI Aayog, February, 2018*

2.4 AGROFORESTRY INTERVENTIONS IN TRANSFORMING WASTELANDS

Advance research has been carried out in developing empirical evidences on economics of benefits, both ecological and economical, offered by various agroforestry systems. Several agroforestry systems are developed for wastelands greening for different agroclimatic zones of the country that are remunerative for local farmers/growers (*Dixit et al.,2012; ICAR-CAFRI, 2016; Handa et al., 2019; Planning Commission 2001; Dagar et al,. 2014).* For such interventions, multipurpose tree species are integrated with crops and/or livestock (*Chaturvedi et al., 2017; Sarvade et al., 2017*). Silvipasture systems that deploy multipurpose trees (MPTs) and grass species such as *Cenchrus setigerus, Andropogon gayanus, Bothriochloea intermedia, Brachiaria decumbens, B. ruiziensis, Dichanthium annulatum, Panicum maximum, Pennisetum pedicellatum* etc. are considered suitable for the degraded lands in arid and semi-arid regions. *Aonla* based agri-horticultural system, *Subabool* based agrisilvicultural system, *Shisham* based silvi-pastoral system with *Napier* grass are few examples of species arrangements that thrive well under wasteland classes such as salt-affected and ravine lands with the minimum investments and higher economic return. *Subabool* based agri-silvicultural systems are very useful for the improvement of degraded land and wastelands. As per *Handa et al.* (2019) the estimated overall annual net income from this agroforestry system from degraded grassland is ₹12000/- to ₹14000/- per ha in the initial years which increases up to ₹50,000/- to ₹60,000/- per ha with the maturity of the system. Adoption of agroforestry in wastelands restores landscapes and bridge gap between demand and supply of food, fodder and timber too (*Planning Commission, 2001; Sharma et al., 2017; Handa et al. 2019; https://www.fao.org/forestry/agroforestry/80339/en/*). The ICAR-Central Agroforestry Research Institute (CAFRI) published a consortium of about 40 successfully tested well-researched

agroforestry systems suitable for wastelands and degraded lands (*Handa et al., 2019*). Also, successful agroforestry systems for income enhancement and ecosystems services are documented at country level by ICAR-CAFRI (*https://cafri.icar.gov.in/html/Technical_Bulletins/Agroforestry-for-Income-enhancement-Climate-resilience-and-Ecosystem-services.pdf*). Most preferred tree species in agroforestry systems are *Populus* spp., *Eucalyptus* spp., *Tectona grandis, Prosopis* spp., *Bamboo* spp., *Acacia* spp., *Gmelina* spp., *Grewia* spp., *Melia* spp., *Ailanthus* spp., *Dalbergia sissoo, Casuarina* spp., *Leucaena leucocephala, Azadirachta indica, Anthocephalus cadamba, Albizia* spp., *Terminalia* spp., *Salix tetrasperma* and *Hardwickia binata* (*https://cafri.icar.g ov.in/wp-content/u ploads/2024/02/2 5-Promising-agrof orestry-trees-in-In dia.pdf).* Plant species such as *Suaeda salsa, Kalidium folium, Tetragonia tetragonioides, Sesuvium portulacastrum, Arthrocnemum indicum, Suaeda frutica, S. portulacastrum, Atriplex* are identified for restoration of wastelands especially salt affected wastelands with high content of soluble salt usually more than 0.2% (*http://www.nbrienvis.nic.in/Database/1_2063.aspx*)

Based on the type of wasteland class, geography and available natural resources, suitable agroforestry systems can be planned and adopted based on local needs.

2.5 WASTELANDS SUITABILITY MAPPING USING GEOSPATIAL APPROACH

Remote sensing technology plays a key role to assess the suitability sites of wastelands for transformation through agroforestry. In the present study, suitable spatial data sets, coupled with limited ground truthing, are used for identifying areas most amenable for taking up cultivation along within existing land use patterns. Based on selected criteria, the result provides a prioritised planning, that indicates where it would be easiest to get successful transformation using agroforestry.

Till date, several studies are reported on national or regional level demarcation of agroforestry suitability area using geospatial technology like Geographical Information System (GIS), Remote Sensing (RS) and Geographical Positioning System (GPS). The integrated application of these technologies can help in taking informed decisions in mapping and analysis of natural resources. The geospatial technology is a valuable application for adoption and planning of land use and agroforestry systems in the country. Similarly, suitability of India's lands for various agroforestry system have been evaluated by using remote sensing and GIS, varying from coarse to medium resolution thematic layers. FAO land suitability criteria utilising Landsat-8 images (NDVI/wetness), ASTER DEM (elevation/slope/drainage and watershed), ancillary data source (rainfall/organic carbon/pH and nutrient status) were worked out to provide national level (*Ahmad et al., 2019; Ahmad et al., 2018*) and district level (Lohardaga, Jharkhand, India) prioritisation, while *Nath et al.* (2021) employed climate, soil, topography, socio-economic criteria along with remote sensing derived parameters to prioritise area at coarse scale. An agroforestry land suitability analysis study has been carried out in the Eastern Indian Himalayan region by *Nath et al.* (2021). It was concluded that agroforestry land suitability can be assessed through a multi-criteria approach too. Agroforestry suitability analysis study was carried out for part of Jharkhand area and was based upon nutrient availability mapping for the area (*Ahmad et al., 2017*).

A pilot study was undertaken by NITI Aayog, wherein, Agroforestry Suitability Index (ASI) was derived for wastelands suitability for agroforestry across selected districts by using GIS Technology. A weighted index approach was adopted to integrate identified parameters viz. Land Use Land Cover, wastelands, soil organic carbon, slope and waterbodies. The model was further validated based on ground truth (GT) data collected in selected 17 districts with the help of State Agricultural Universities and Krishi Vigyan Kendra's. Details of Ground truth data can be assessed at Visualisation of Earth Observation Data and Archival System (VEDAS) site using link *https://vedas.sac.gov.in/data-collection/*. The study area was distributed across 17 districts in 14 agroclimatic zones of India. Agroforestry Suitability was classified in 5 categories (High, Moderate, Less, Very Less and Not Suitable). The GT points collected in High and Moderate suitable wastelands regions showed good agreement with the model and registered an accuracy. of about 86.60% (*Patel et al., 2023*).

3 Methodology

3.1 STUDY AREA

The study was conducted for Indian region, excluding the Union Territories of Lakshadweep, Dadra and Nagar Haveli, Daman and Diu, Andaman and Nicobar Islands.

3.2 APPROACH AND METHODOLOGY

A multi-thematic GIS oriented weighted overlay analysis approach was adopted to analyse suitable areas, keeping in view the requirement for identifying suitable areas dependent on criteria that are available with Indian Space Research Organisation (ISRO). The methodology used to assess agroforestry suitability in wastelands was categorised into 4 broader steps viz. (1) Selection of appropriate parameters associated with Land Use Land Cover (2) Allocating weights to individual parameter after logical evaluation, (3) Assignment of ranks to each category within each parameter and (4) Integration of parameter (indicators) for spatial representation for suitability and analysis of output data.

3.2.1 Datasets used

Five thematic datasets prepared under various national initiatives of ISRO for Land Use Land Cover, wastelands, slope, water bodies and soil organic carbon have been used for this GIS analysis-based prioritisation. The selection and number of parameters may vary based on local site, its climate, community practices etc. Brief descriptions on the approach adopted to derive each of the themes are as follows:

1. **Land Use Land Cover (LULC):** Under the ISRO's National Natural Resource Census programme of Land Use Land Cover mapping on 1:50,000 scale for entire country has been taken up to study and understand the degree and magnitude of LULC changes at every 5-year time intervals starting from 2005-06. For the current study, LULC data for 2015-16 timeframe was used and feature level-2 classification covering 24 classes (Figure 3) is considered.
2. **Wastelands:** Under funding by Department of Land Resources, MoRD, GOI ISRO has carried out wastelands mapping at 1:50000 scale for entire country. This layer was used to identify wastelands classes. For the current study, wastelands data used is for the 2015-16 timeframe and feature classification covering 23 classes of wastelands (Figure 4).

3. **Slope:** Slope is described as the measurement of the rate of change of elevation of the land per unit distance. Slope surface is calculated as percent slope using Digital Elevation Model (DEM) of 30 m resolution derived from SIS-DP dataset (Figure 5).

4. **Waterbody:** All the information of the surface water, such as lakes, rivers, streams, ponds etc., derived from 1:50000 scale LULC dataset (Figure 6).

5. **Soil Organic Carbon (SOC):** Soil Organic Carbon surface has been prepared using random forests (RF) modeling based spatial prediction procedure, with climatic, land cover, rock type, soil type, multi-year NDVI, irrigation status as independent input variables. Models for predicting carbon density at 250 m spatial resolution developed by NRSC has been deployed herewith. The spatial distribution indicates that majority of the carbon stock resides in the northern part of India. The soil carbon stock of eastern India has contribution from organic carbon, while the western portion has contribution mainly from inorganic carbon (Figure 7).

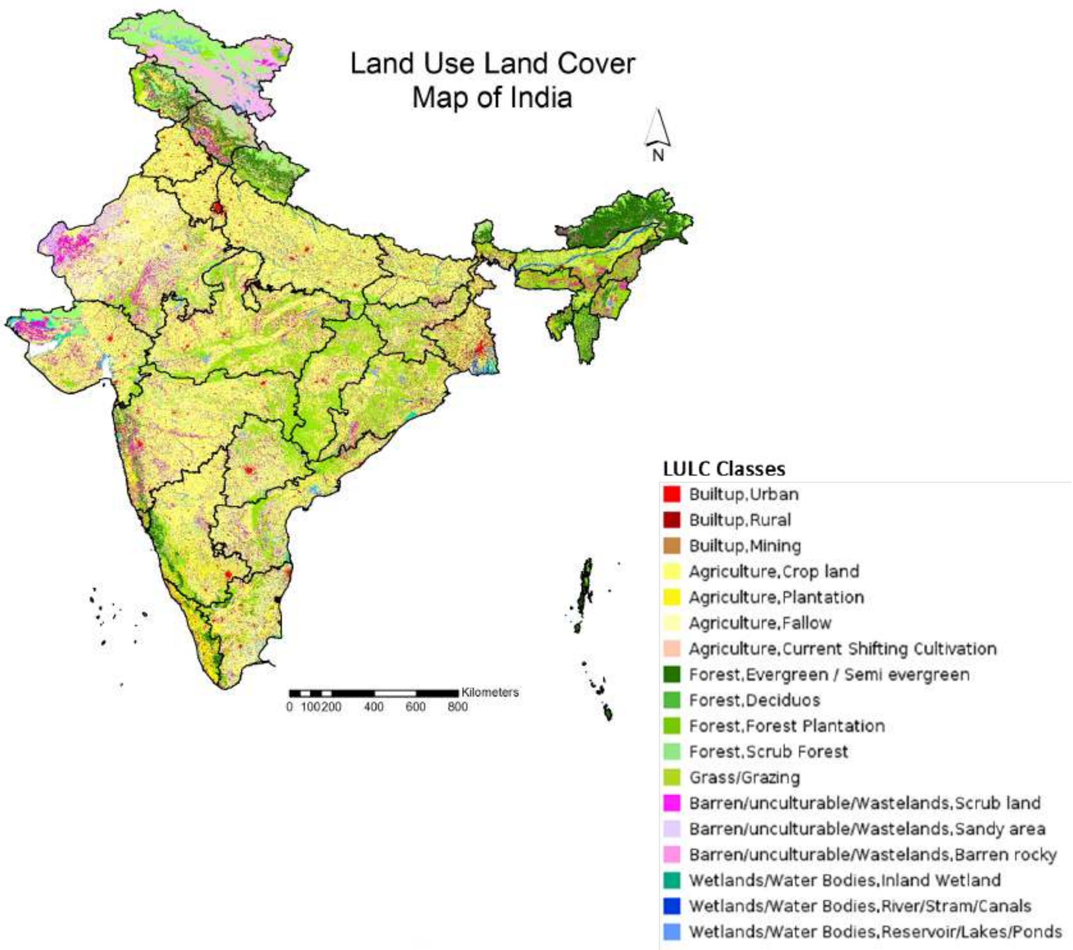


Figure 3. *Land Use Land Cover Map of India (2015-16)*

Figure 4. *Wastelands Map of India (2015-16)*

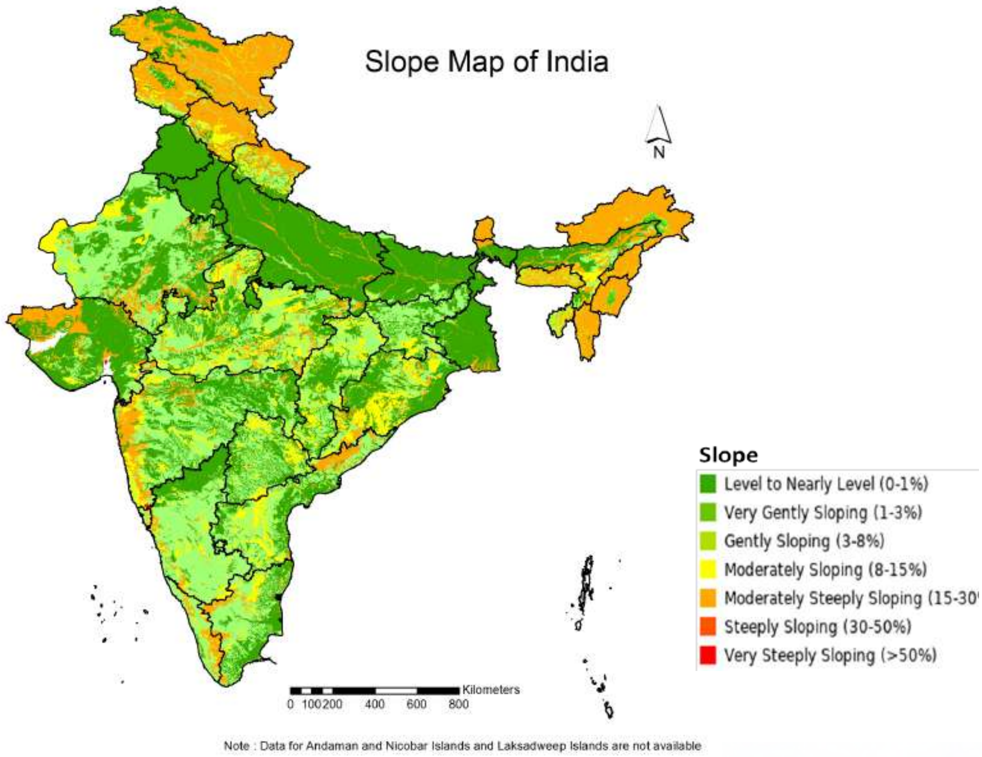


Figure 5. *Slope Map of India*

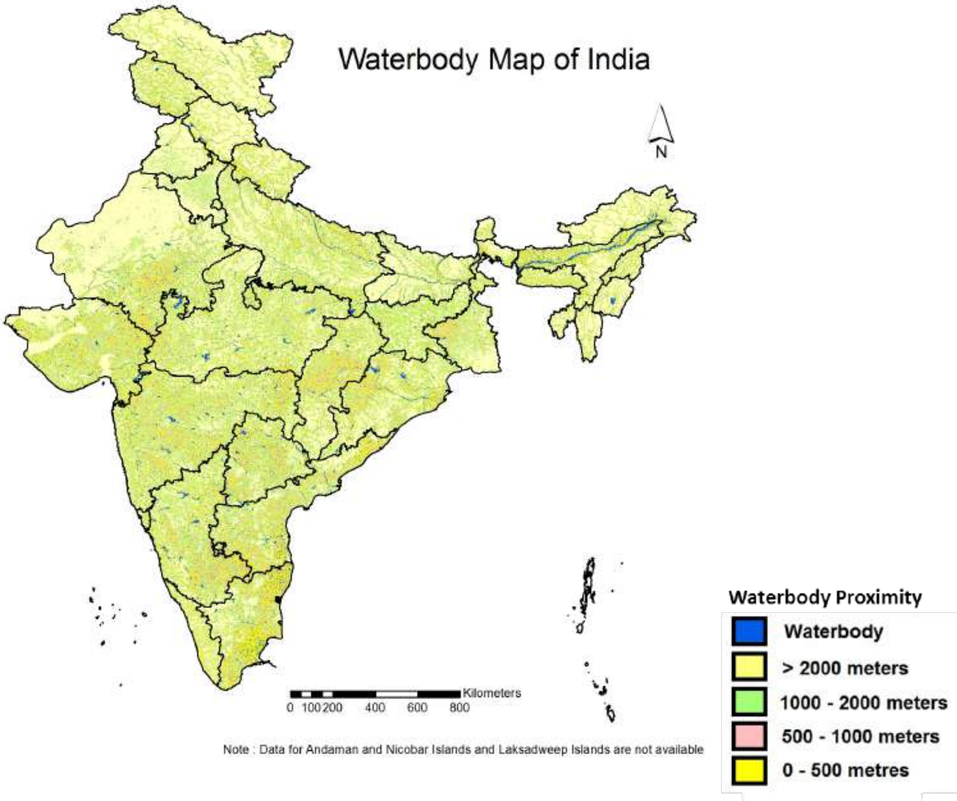


Figure 6. *Waterbodies Map of India (proximity distance in metres from waterbody)*

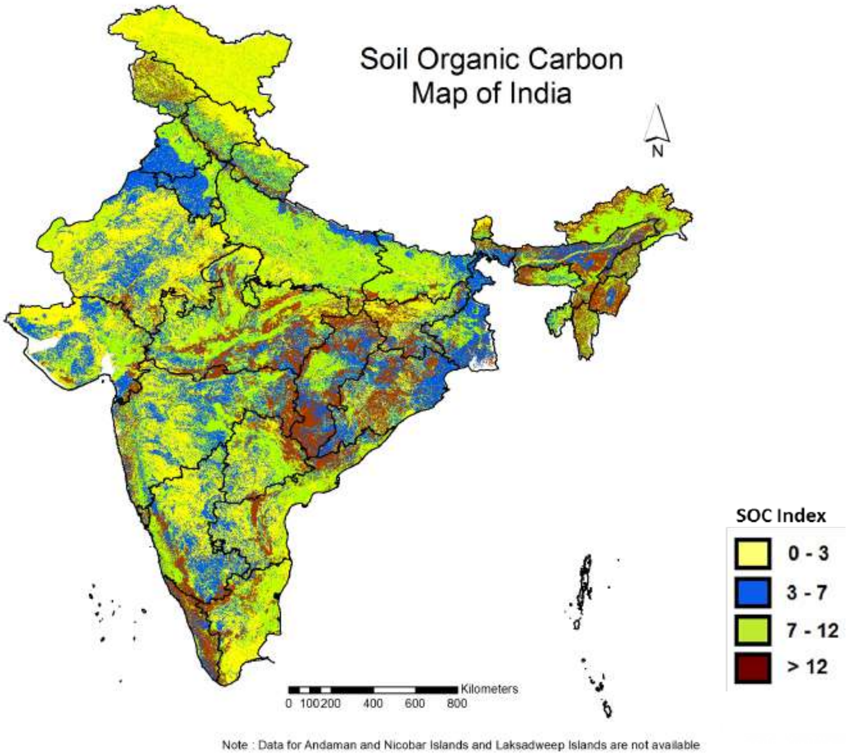


Figure 7. *Soil Organic Carbon Map of India (Kgs/m^2)*

3.2.2 Methodology

The work flow adopted to calculate the Agroforestry Suitability Index (ASI) is shown in the Figure 8. The methodology includes the pre-processing of input datasets related to generating surface areas of water bodies, slope and soil organic carbon data for each state, proximity analysis of the water bodies data, waterbody layers with classes for ASI computation, assignment of ranks, computation of ASI and finally classification of land using ASI to derive the output results.

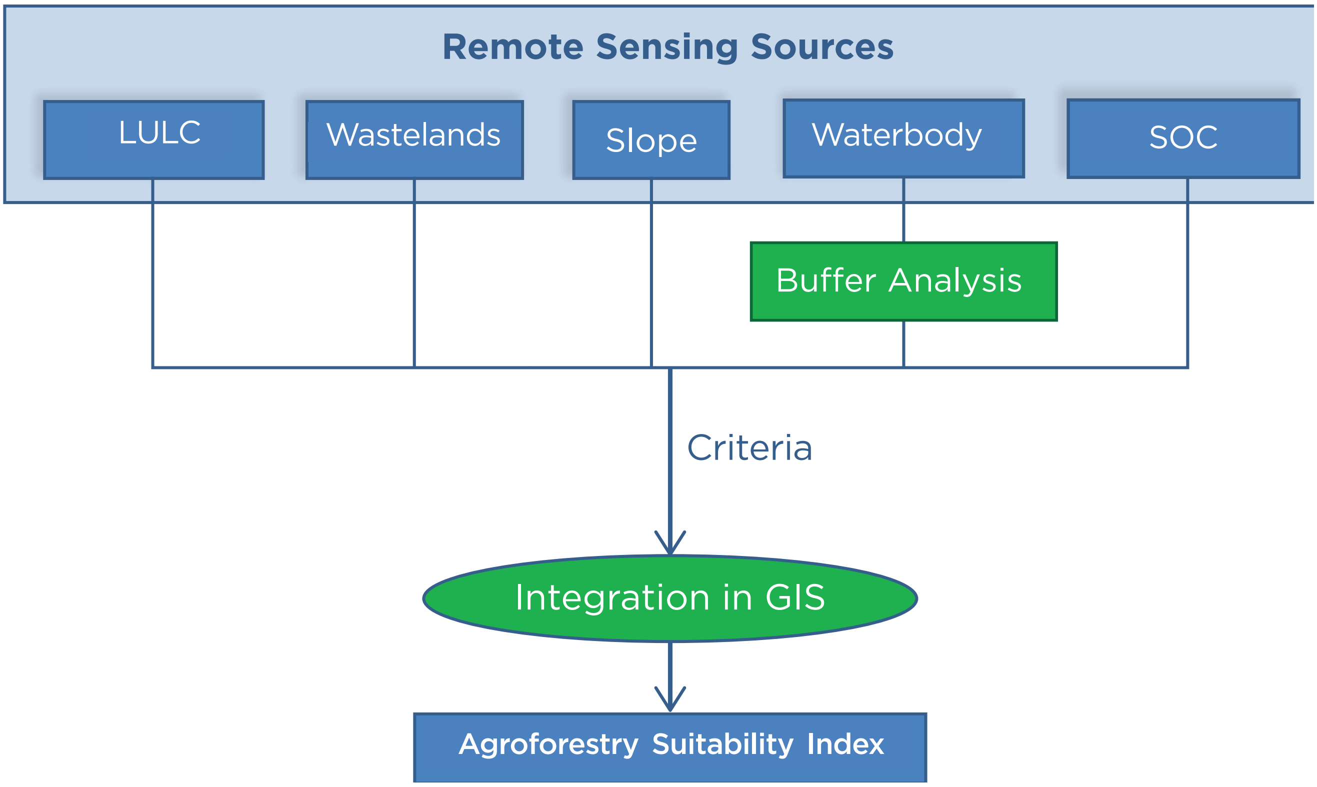


Figure 8. *Work flow for calculating the Agroforestry Suitability Index*

3.3 PRE-PROCESSING OF THE INPUT DATASETS

The Land Use Land Cover and Wastelands datasets are vector datasets prepared using on-screen visual interpretation technique at 1:50000 scale. The data volumes are very large and require huge computational capabilities. Keeping data volume and computational constraints in mind, the geo-spatial operations and analysis at state level was carried out. Further, it was integrated to a single PAN India dataset.

1. **Land Use Land Cover (LULC) data:** All the 24 classes in LULC are ranked from 0 to 4 depending on the LULC type and its role in the agroforestry suitability (Table. 5)

Table 5: Different Land Use Land Cover classes with ranking

LU Code	Level 1 Land Use Class	Level 2 LU Class	LU Rank
1	Builtup	Urban	0
2	Builtup	Rural	0
3	Builtup	Mining	0
4	Agriculture	Crop land	3
5	Agriculture	Plantation	1
6	Agriculture	Fallow	4
7	Agriculture	Current Shifting cultivation	4
8	Forest	Evergreen/Semi Evergreen	0
9	Forest	Deciduous	1
10	Forest	Forest Plantation	2
11	Forest	Scrub Forest	4
12	Forest	Swamp/Mangrove	1
13	Grass/Grazing land	Grass/Grazing land	1
14	Barren/Unculturable wastelands	Salt affected land	1
15	Barren/Unculturable wastelands	Gullied/Ravinous	2
16	Barren/Unculturable wastelands	Scrub land	3
17	Barren/Unculturable wastelands	Sandy area	1
18	Barren/Unculturable wastelands	Barren rocky	0
19	Barren/Unculturable wastelands	Rann	1
20	Wetland/Waterbodies	Inland wetland	0
21	Wetland/Waterbodies	Coastal wetland	0
22	Wetland/Waterbodies	River/Stream/Canals	0
23	Wetland/Waterbodies	Waterbodies	0
24	Snow	Snow	0

2. **Wastelands data** (WL): All the 23 classes in WL are ranked from 0 to 4 ranks depending on the WL type and its role in the agroforestry suitability (Table. 6).

Table 6: Different wasteland classes with ranking

WL Code	Wasteland	WL Rank
1	Gullied and/or ravinous land (Medium)	2
2	Gullied and/or ravinous land (Deep)	1
3	Land with Dense Scrub	3
4	Land with Open Scrub	4
5	Waterlogged and Marshy land (Permenant)	0
6	Waterlogged and Marshy land (Seasonal)	1
7	Land affected by salinity/alkalinity (Medium)	2
8	Land affected by salinity/alkalinity (Strong)	0
9	Shifting Cultivation (Current Jhum)	2
10	Shifting Cultivation (Abadoned Jhum)	4
11	Underutilised/degraded forest (Scrub dominated)	4
12	Underutilised/degraded forest (Agriculture)	4
13	Degraded pastures/grazing land	4
14	Degraded land under plantation crop	3
15	Sands Riverine	1
16	Sands Coastal	1
17	Sands-Desertic	0
18	Sands-Semi Stab Stab>40m	0
19	Sands-Semi Stab Stab 15-40m	1
20	Mining Wastelands	1
21	Industrial Wastelands	0
22	Barren Rocky/Stony waste	0
23	Snow covered/Glacial area	0

3. **Slope data**: The slope map is derived from the Digital Elevation Model (DEM) and is divided into 6 categories based on percentage of slope from 0 to 50% and above. The ranks are given to the 6 categories with higher ranks to gentle slope and lower value to steeper slope (Table. 7).

Table 7: Category of slopes (in %) with ranking

Slope Code	Slope (%)	Description	Slope Rank
1	0-3	Very Gentle	4
2	3-8	Gentle	4
3	8-15	Moderate	3
4	15-35	Moderately Steep	2
5	35-50	Steep	1
6	>50	Very Steep	0

4. **Waterbody (WB) data:** All surface water bodies like rivers, lakes, reservoirs, ponds etc. are considered within a single class as 'waterbody' and proximity analysis was carried out for them. Priority ranking was assigned based on different buffer range like 0 to 500m, 500 to 1000m, 1000 to 2000m and greater than 2000m. The waterbody ranks are given to the buffer range features from 0 to 4 (Table. 8).

Table 8: Proximity of waterbody (in meters) and its ranking

WBCode	Waterbody Proximity (meter)	WB Rank
1	0-500	4
2	500-1000	3
3	1000-2000	2
4	>2000	1
5	Waterbody	0

5. **Soil Organic Carbon (SOC) data**: The soil organic carbon index map was used as one of the indicators with index value ranging from 0 to greater than 12. Further, the index was classified into 4 categories (Table. 9).

Table 9: Soil Carbon (Kg/sq.m) with ranking

Soil Organic Carbon		
S. No	SOC Density	Rank
1	0-3	1
2	3-7	2
3	7-12	3
4	>12	4

3.3.1 Generating waterody, slope and soil organic carbon data for each state

The steps involved in generating waterbody, slope and soil organic carbon data are outlined below (Figure 9 and 10). An illustration for state of Madhya Pradesh is provided.

1. Extraction of state bodies from SOI India/state boundaries dataset:

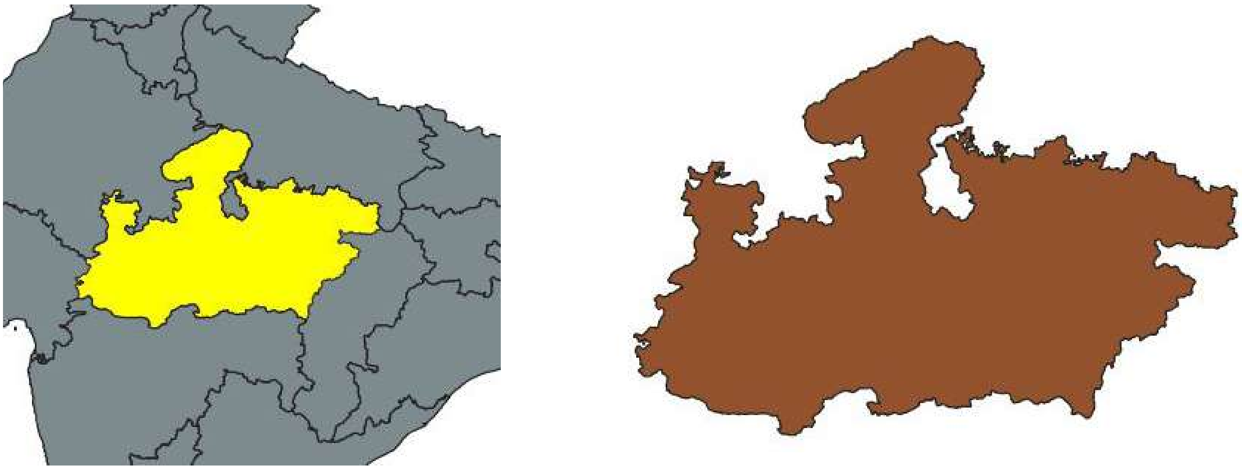


Figure 9. *Extraction of State boundary for Madhya Pradesh*

2. Clip operation was performed on the waterbody dataset using geo-processing tools for vector data in QGIS. Waterbody data for India is used as input layer and state polygon as overlay layer.
3. After getting the data for the waterbody layer for Madhya Pradesh state, Proximity analysis was carried out prior to assignment of ranks to the waterbody data.

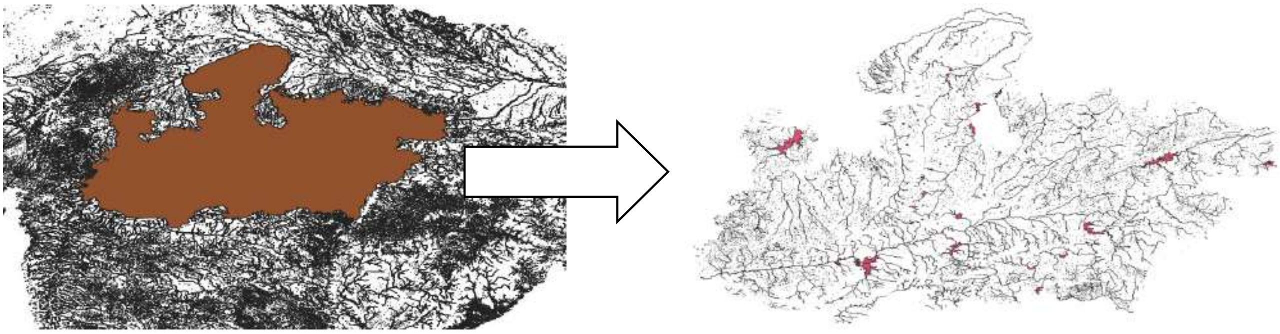


Figure 10. *Extraction of waterbody related proximity information for Madhya Pradesh*

The above example shows the extraction of waterbody for the state of Madhya Pradesh. In a similar geo-processing approach, Slope and SOC data were extracted for the respective states.

3.3.2 Proximity analysis of waterbody data.

Following steps are involved in proximity analysis of the waterbody data:

1. Considering the actual waterbody data, buffer range are created for different distance values from the water-body, i.e. 500m, 1km and 2km and above.
2. The buffer operation was carried-out and different buffers are created for above mentioned distances. Buffer tool under vector and geo-processing tools in QGIS was used.
3. Erase operation was performed to eliminate the waterbody portion in the layer. Difference tool under vector and geo-processing in QGIS are used.

After erasing the waterbody from the 500m buffer polygon, the output is shown in figure 12.

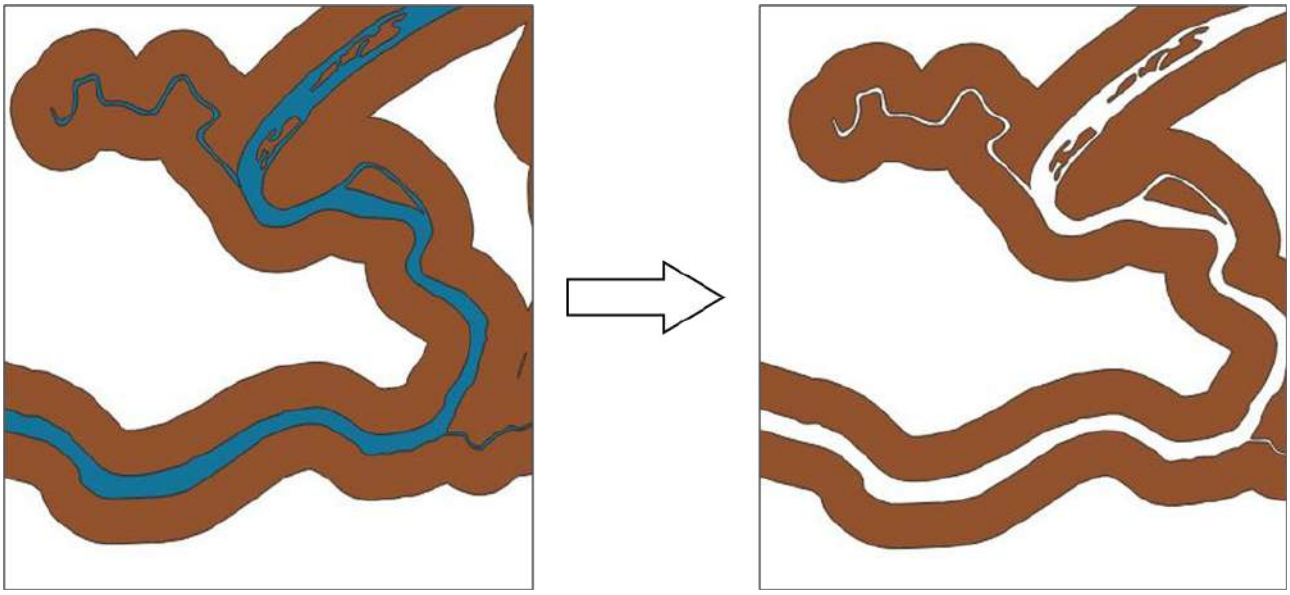


Figure 11. Preparation of waterbody proximity layer

4. Similarly, the areas for three different distances are obtained as below:
   a. 500m to 1000m from the waterbody was obtained by erasing the buffer of 500 m from the buffer of 1000m.
   b. 1000m to 2000m from the waterbody was obtained by erasing the buffer of 1000m from the buffer of 2000m.
   c. Greater than 2000m from the waterbody was obtained by erasing the buffer of 2000m from the entire state. **Note**: The whole process of difference operation was carried out because different area ranges are assigned with different ranks (Figure 12).
   d. Waterbody ranks are assigned to different layers as per the table 8.
   e. Merge operation was performed to integrate 5 polygon layers i.e. original waterbody, 0m to 500m, 500m to 1000m, 1000m to 2000m and greater than 2000m. Merge tool under vector and data management tool in QGIS was used. After the merge operation of the buffers, the actual waterbody data is shown in the figure 13.

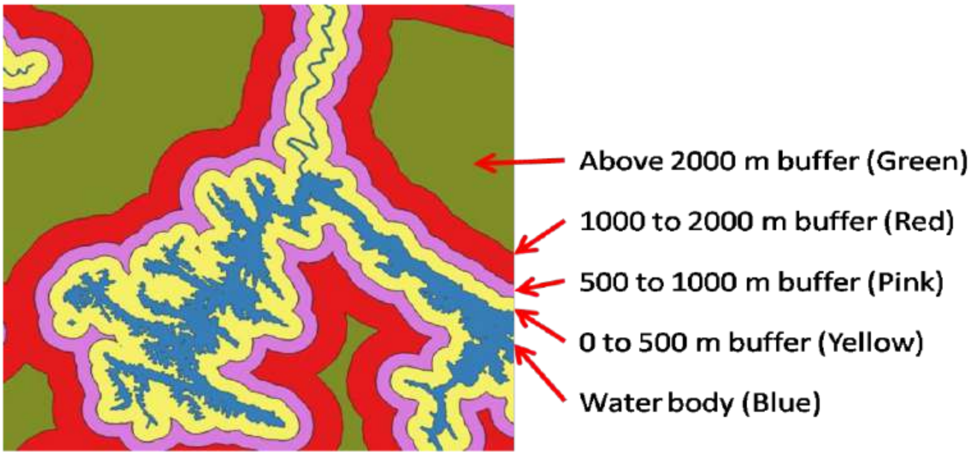


Figure 12. *Waterbody layers with classes for ASI computation*

Note: The '*Buffer Analysis'* of the waterbody data is done using a model builder written in QGIS software, which consists of all the operations listed above and takes in the India waterbody data and the state name as the parameter and gives the waterbody data for that particular state after the buffer analysis and ranks assignment. *For some cases, where the waterbody is near to a state boundary, the buffer analysis may lead to a final polygon which could exceed the state boundary. For such cases, the final waterbody was clipped using the clip operation to extract the state data.*

3.3.3 Assignment of ranks

Each category was ranked within the parameters (LULC, Wastelands, Waterbody, Slope and SOC) based on its suitability for transformation through agroforestry. In the present study, the highest weightage was given to wastelands (Table 10). Based upon these ranks, the suitability index was computed using following steps:

1. A new column for storing integer values, with a new name *(<input_layer>_rank)* is created and rank values are calculated as per respective table mentioned above. The process is carried out using editing the attribute table of a vector data layer.
2. The above-mentioned process was a manual step. So, for automating the process a python script is written which edits the .dbf file (*.dbf file forms the attribute table of a vector data layer*). The script adds a new column for rank and checks the column for the code/description to assign the ranks accordingly. It takes in all the states data at a time in a folder and updates the files.
3. LULC, Slope and Wastelands ranks are assigned using this python script.

Note: *SOC data was given in raster format. The raster reclassification was done based upon the classes given for different value ranges to SOC.*

Conversion of inputs from vector to raster

1. The coordinate system was converted from GCS to projected coordinate system i.e. Albers equal area.
2. Vector to Raster conversion was carried out to reduce ASI computation process. During conversion ranks are assigned as pixels value for each layer and spatial resolution of the output raster is fixed to 20m.

3.3.4 Computation of Agroforestry Suitability Index (ASI)

Agroforestry Suitability Index (ASI) for particular parameter was calculated by multiplying weightage of that parameters and ranks of each category within the parameter.

Calculation of Index for parameter-1

$$Index_{p1} = R_{p1} * W_{p1}$$

Where, R_{p1} : Rank of categories within parameter-1

W_{p1} : Weightage of parameter-1

Similarly, index for other parameters was calculated.

3.3.5 Integration of parameters in GIS and Calculation of Total ASI

All parameters are integrated in GIS and Total ASI was calculated by summing up of individual parameter index.

Total Index (ASI) = $Index_{p1} + Index_{p2} + Index_{p3}$ + —- —-+ $Index_{pn}$

Here, $Index_{p1}$: Index of parameter-1

ASI = [WLRank] * 0.4 + [LURank] * 0.3 + [SlopeRank] * 0.1 + [WBRank] * 0.1 + [SOC] * 0.1

For Built-up and waterbody, calculate ASI = 0

The raster datasets for all the input indicators of ASI was obtained and weighted sum operation was performed to compute Agroforestry Suitability Index (ASI). The criteria weights and ranking was adopted as per the expert-based standardisation are considered for ASI. The parameters and critical weights are shown in the Table 9.

Table 10: Parameters and weightages used for ASI.

S. No.	Parameter	Criteria Weights
1	Land Use Land Cover	0.3
2	Wastelands	0.4
3	Slope	0.1
4	Distance from Surface Waterbody	0.1
5	Soil Organic Carbon	0.1
	Total	**1**

The ASI raster data was obtained based on the performed weighted sum operation, where each pixel was assigned with ASI value and calculated based on the assigned rank to each five input data (*LULC, Wastelands, Slope, Waterbody and Soil Organic Carbon*). The raster datasets comprise of value ranging from 0 to 4 in scale. The ASI value with 4 representing highly suitable and 0 as not suitable as shown in the Table. 11.

3.3.6 Classification using Agroforestry Suitability Index

The ASI datasets are a raster continuous dataset with pixel value ranging from 0 to 4. The reclassify operation was carried out to classify ASI to discrete classified raster dataset comprising of 3 classes ranging from highly suitable, moderate suitable and other/Not applicable as shown in the Table 11.

Table 11: Ranking of classes used for Agroforestry Suitability Index

S. No.	ASI value	ASI Class	Final Class
1	> 3 &<= 4	3	Highly suitable
2	> 2 &<= 3	2	Moderately Suitable
3	>= 0 &<= 2	1	Others/Not Applicable

Note: *The above-mentioned processes can be done using a customized model/tool in QGIS/ArcGIS.*

4 Results

National level stratification of areas of wastelands suitable for transformation through agroforestry was carried out using the Agroforestry Suitability Index (ASI) on a state wise and district wise basis. Four minor geographic units viz. Union Territories of Lakshadweep, Dadra Nagar Haveli, Daman & Diu, Andaman & Nicobar Islands are not covered in the study.

4.1 NATIONAL LEVEL MAPPING OUTPUT

As suitability area was represented in terms of percent of the total geographic area of the state, results are collated in three size categories to retain comparability. States with more than 1 lakh sq.km are considered as large, while those having area between 10000 sq.km up to 1 lakh sq.km as medium and those below 10000 sq.km as small states (Table 12).

Amongst large size states, Madhya Pradesh, Telangana and Andhra Pradesh showed best extents under highly suitable areas for agroforestry. Each of these states have atleast 69% area under others category, which are equivalent to major cultivated tracts as such.

Tamil Nadu and Uttar Pradesh in the large state category showed only 3.6% and 1.5% land under highly suitable category. Jammu & Kashmir having vast extents of cold deserts had only a small area of wastelands considered highly suitable for transformation through agroforestry.

In medium sized states, four hill states viz., Manipur, Nagaland, Jharkhand & Mizoram had more than 10% of area under highly suitable category, closely followed by Meghalaya (9.8%). As per this analysis Punjab and West Bengal, showed lesser extents of highly suitable areas for wastelands transformation through agroforestry.

In the case of small size states, Goa, Tripura and Delhi showed the highest area under highly suitable category for taking up wasteland greening through agroforestry. Goa had dominant 45% of area under less suitable category, while Sikkim and Puducherry recorded less area under highly suitable category. This comparative analysis provides scope to understand states in terms of their amenability to use agroforestry approaches, systems and tools to greening wastelands into more productive uses, using multithematic criteria.

Although most areas fall under 'low suitability' as these are mostly cropped areas/sites which fall outside this study and have a different sort of amenability for agroforestry. However, the visualisation though portal on Bhuvan can resolve local level variation meaningfully so as to derive assessment of amenable areas. Based on the analysis, 2,03,245.08 sq.km (6.18% of TGA area falls under 'highly suitable' category and 1,61,366.65 sq.km (4.91% of TGA) under 'moderately suitable' category. Most areas fall under 'less suitable/not applicable' category and these include cropped areas, forests and other land use system, other than classified 'wastelands'. Statewise area, under highly suitable and moderate suitable category as per ASI, are mentioned in figure 14 and 15, respectively.

Table 12: Statewise distribution of potential areas for greening (as percent of TGA)

Agroforestry Suitability Extent (in % of TGA of the State)				
State Size	**State**	**Highly Suitable**	**Moderately Suitable**	**Others/Not Applicable**
Large (>1L sq.km)	Rajasthan	8.1	9.74	82.16
	Madhya Pradesh	9.65	3.85	86.5
	Maharashtra	7.97	6.49	85.55
	Uttar Pradesh	1.51	2.28	96.22
	Karnataka	5.05	1.97	92.98
	Gujarat	6.55	7.74	85.71
	Andhra Pradesh	8.66	6.63	84.7
	Ladakh	1.53	0.72	97.74
	Odisha	7.29	4.88	87.83
	Chhattisgarh	6.95	2.35	90.7
	Tamil Nadu	3.65	9.76	86.6
	Telangana	9.46	5.71	84.82
Medium (>10000 sq.km< 1 L sq.km)	Bihar	3.01	3.08	93.91
	Jharkhand	11.55	7.57	80.89
	West Bengal	1.49	0.87	97.64
	Arunachal Pradesh	3.04	2.71	94.26
	Assam	7.2	6.13	86.67
	Himachal Pradesh	6.33	4.13	89.54
	Jammu And Kashmir	17.97	5.03	77
	Uttarakhand	2.26	4.38	93.36
	Punjab	0.4	0.3	99.3
	Haryana	1.67	1.96	96.38
	Kerala	3.45	2.27	94.28
	Manipur	17.74	8.83	73.43
	Meghalaya	9.86	8.06	82.08
	Mizoram	11.1	9.04	79.86
	Nagaland	17.04	14.14	68.82
Small (<9999 sq.km)	Tripura	6.16	2.81	91.03
	Sikkim	0.93	0.72	98.35
	Goa	8.87	4.4	86.73
	Delhi	3.52	0.65	95.82
	Puducherry	0.5	2.47	97.03
	Chandigarh	0.33	10.88	88.79
	Dadra & Nagar Haveli	0.04	0.07	99.89
	Daman And Diu	0.00	0.00	100

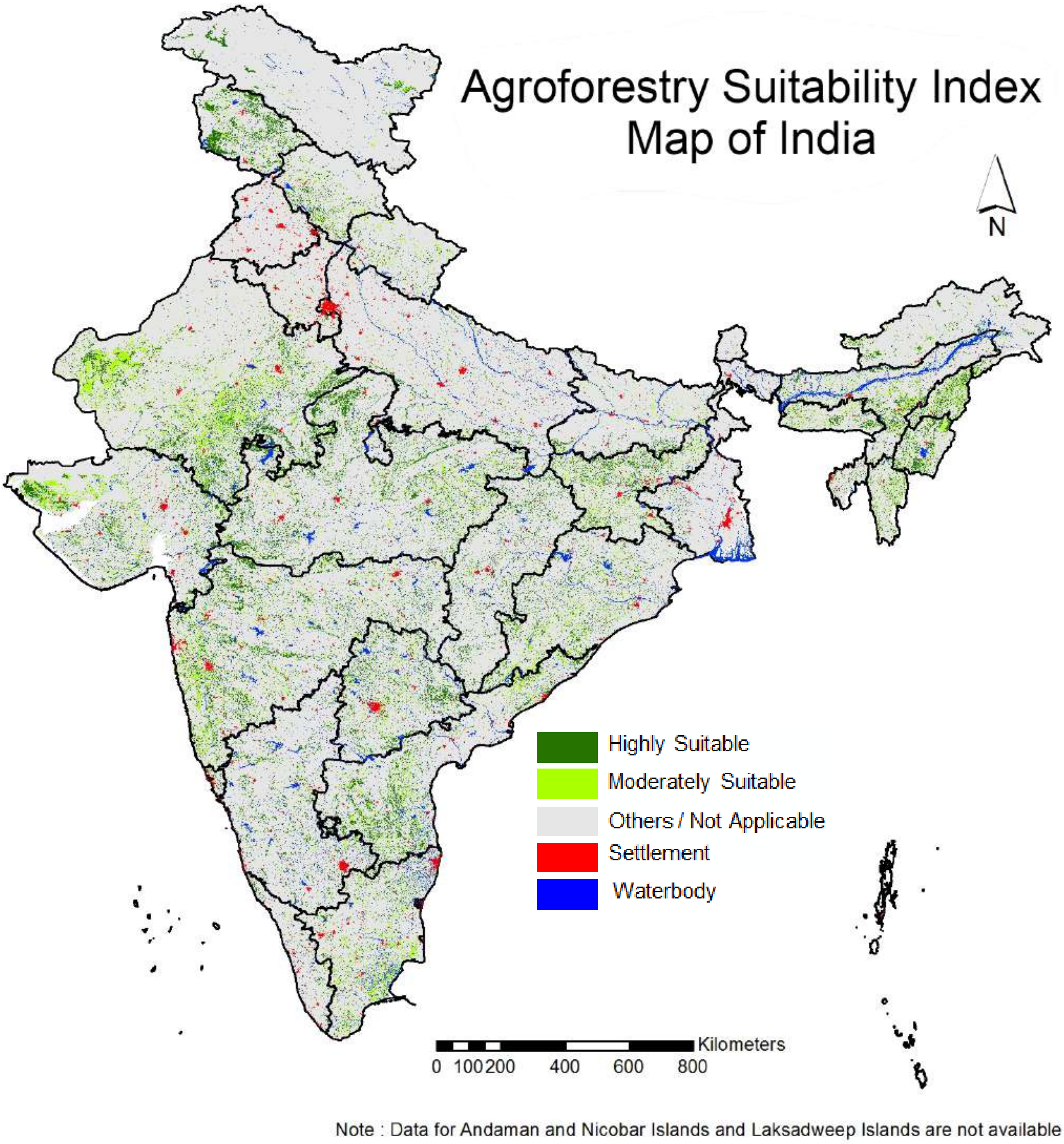


Figure 13. *Map with sites suitable for greening with Agroforestry*

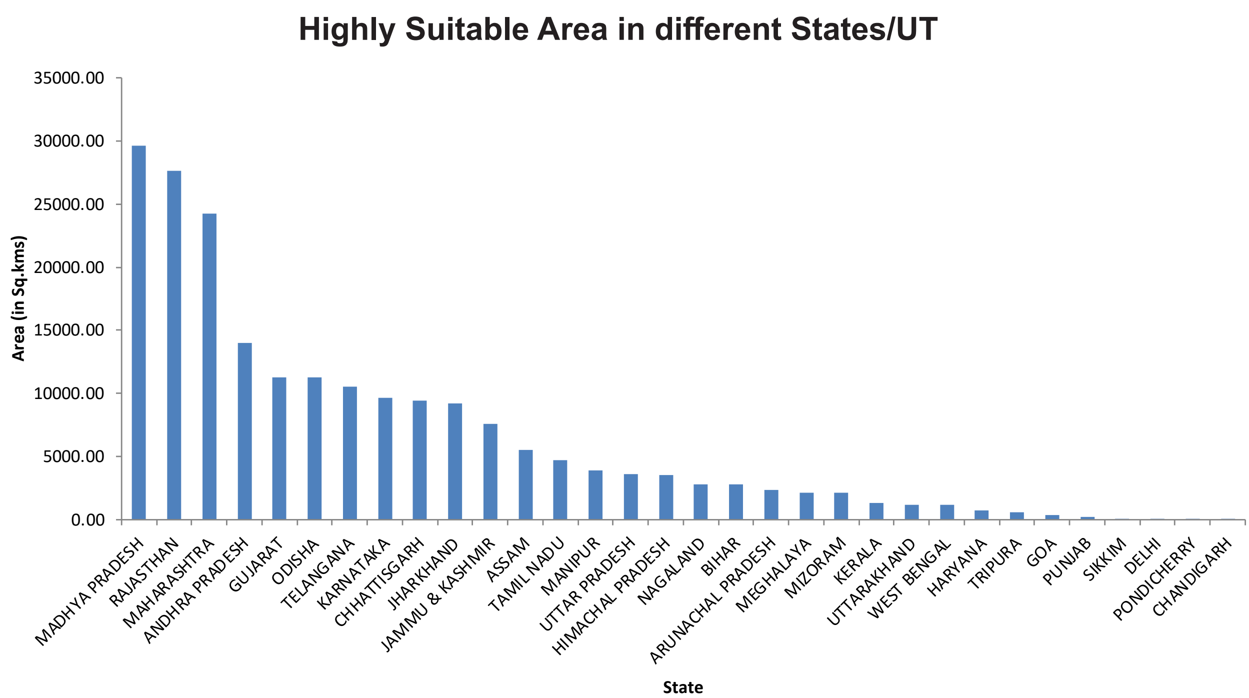


Figure 14. State-wise area under the highly suitable category as per ASI

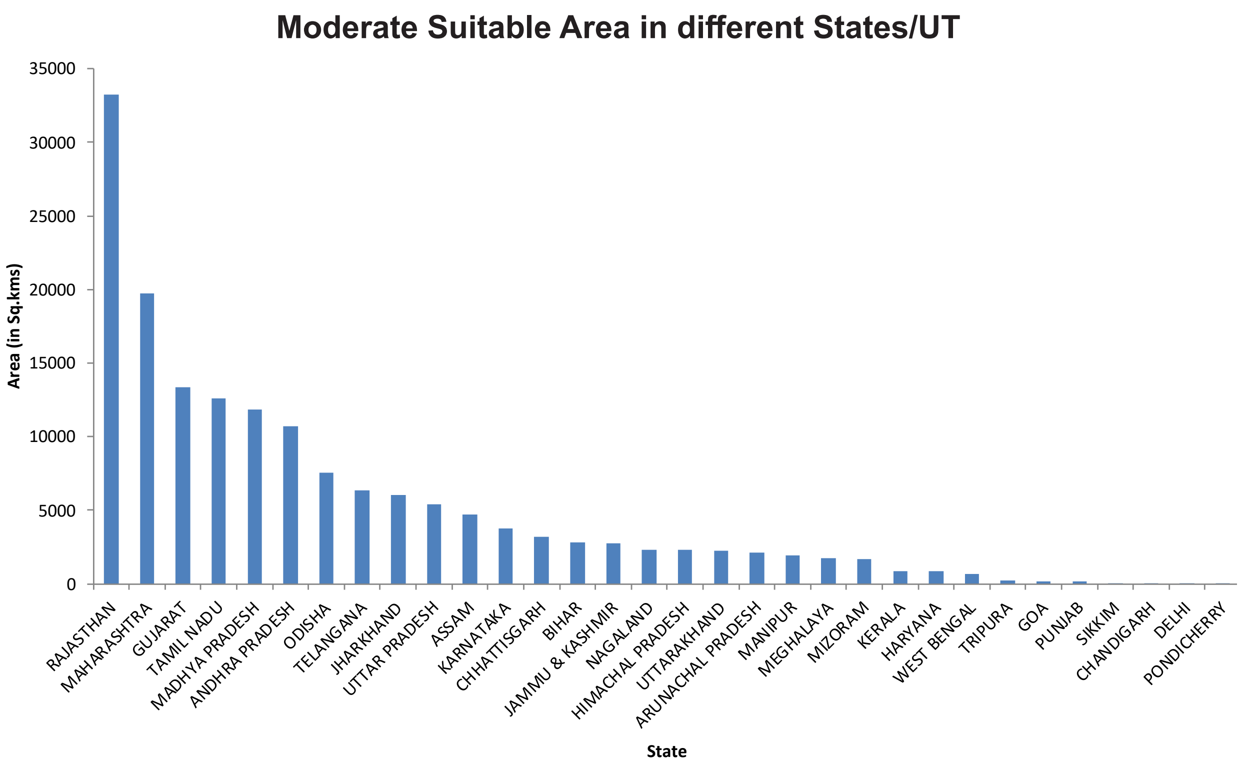


Figure 15. State-wise area under the moderate suitable category as per ASI

Based on the study approach, State-wise modeling was done along with district level characterisation across each State. A case study of Madhya Pradesh is presented in section 4.2 and similarly analysis was carried out for all states and UT's.

4.2 CASE STUDY OF ASI OF MADHYA PRADESH

State and district-wise prioritised areas for Agroforestry Suitability GIS Modeling with Inputs sets and result are as below:

i. Input data layers of five parameters of Madhya Pradesh used for ASI i.e LULC, wastelands, slope, water bodies and soil organic carbon are shown in figures 16, 17, 18, 19, 20. The parameters a, b, c, d and e were analysed based on the weightages approach to derive the ASI as mentioned in methodology section. The output i.e. classified area suitable for agroforestry was obtained for Madhya Pradesh.

   Based on the methodology adopted, district wise areas were classified for greening with agroforestry (Figure 21). In Madhya Pradesh, 11830.18 sq.km area is under moderately suitable class and 29643.98 sq.km area falls under highly suitable class (Figure 22). The data for 52 Districts of Madhya Pradesh is shown in figure 23. The Katni, Sagar, Mandla and Shahdol districts of Madhya Pradesh has potential area under moderate suitable category i.e 541.77 sq.km. 474.34 sq.km, 436.02 sq.km and 423.37 sq.km, respectively. The Shivpuri, Sheopur, Khargone and Sagar have considerable areas under highly suitable category i.e 1761.51 sq.km, 1488.23 sq.km, 1261.23 sq.km and 1244.66 sq.km, respectively (Figure 23).

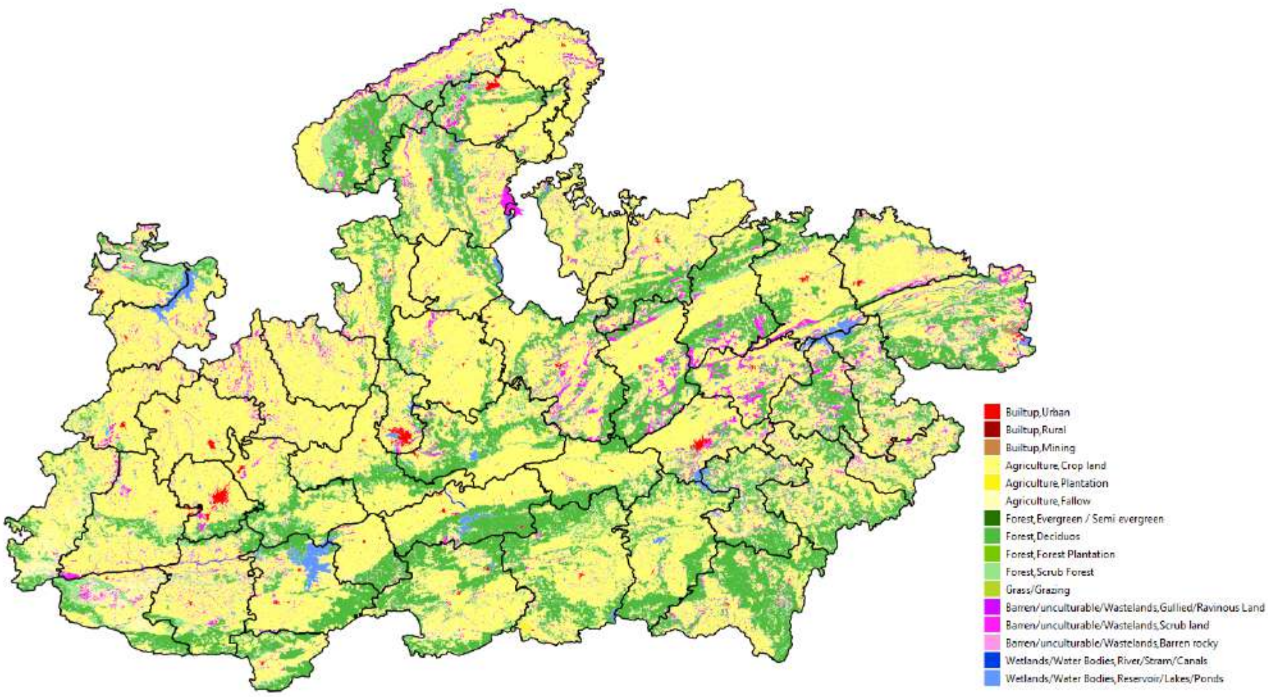


Figure 16. *Landuse/Land Cover map of Madhya Pradesh*

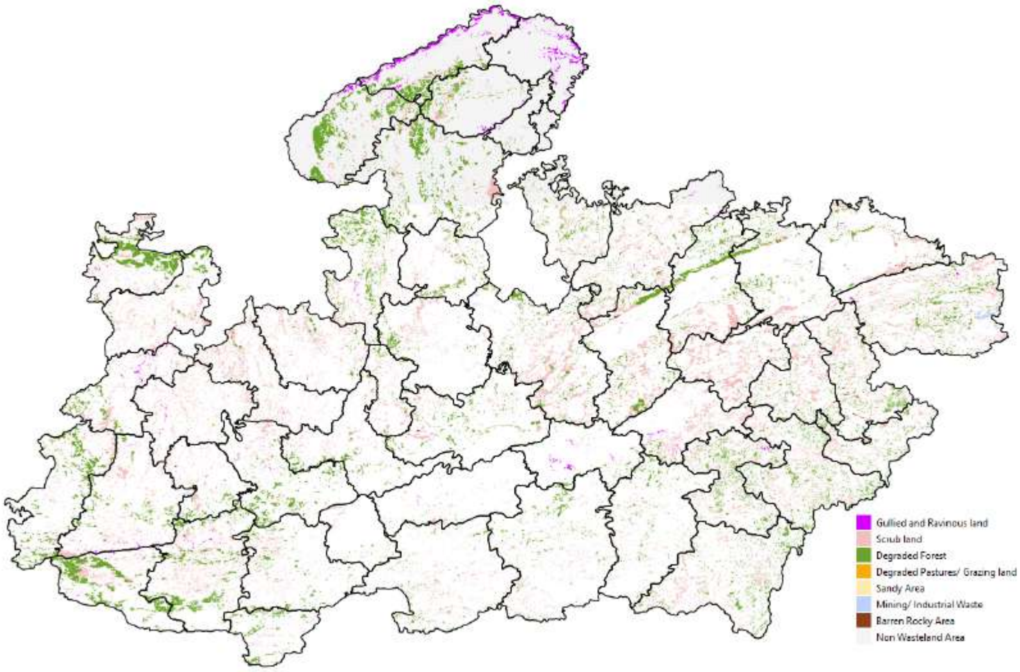


Figure 17. *Wastelands map of Madhya Pradesh*

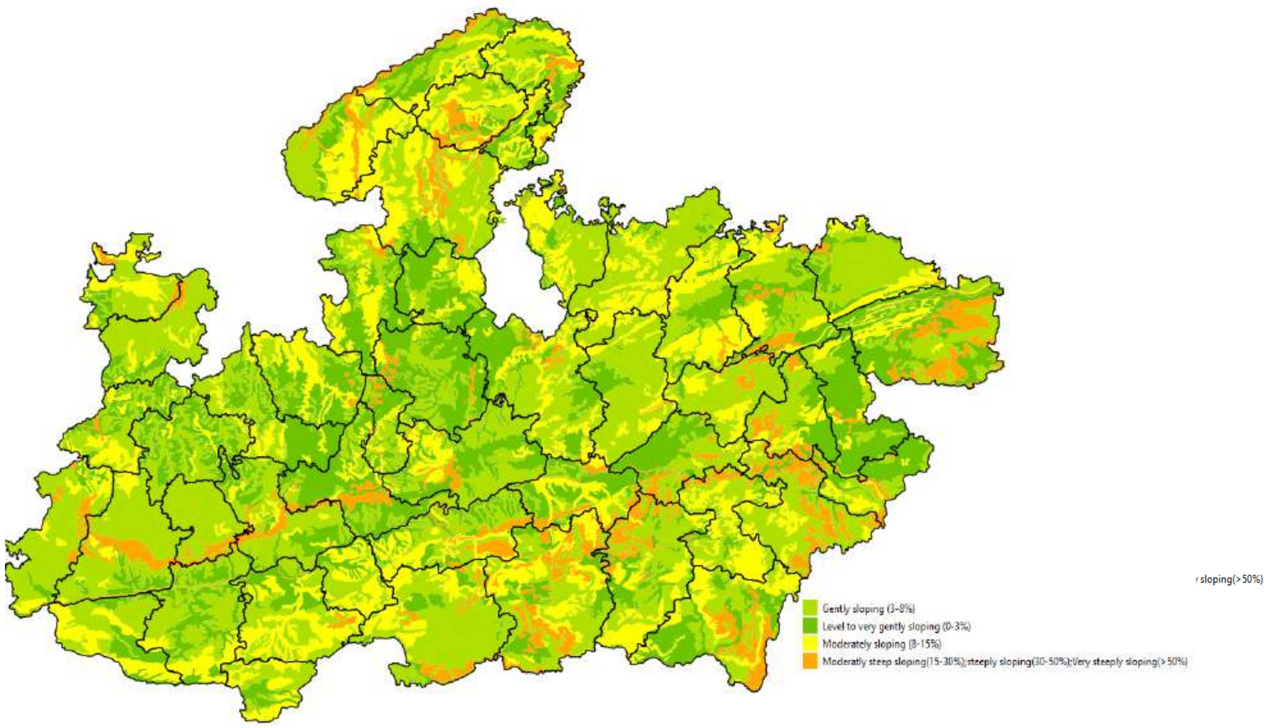


Figure 18. *Slope map of Madhya Pradesh*

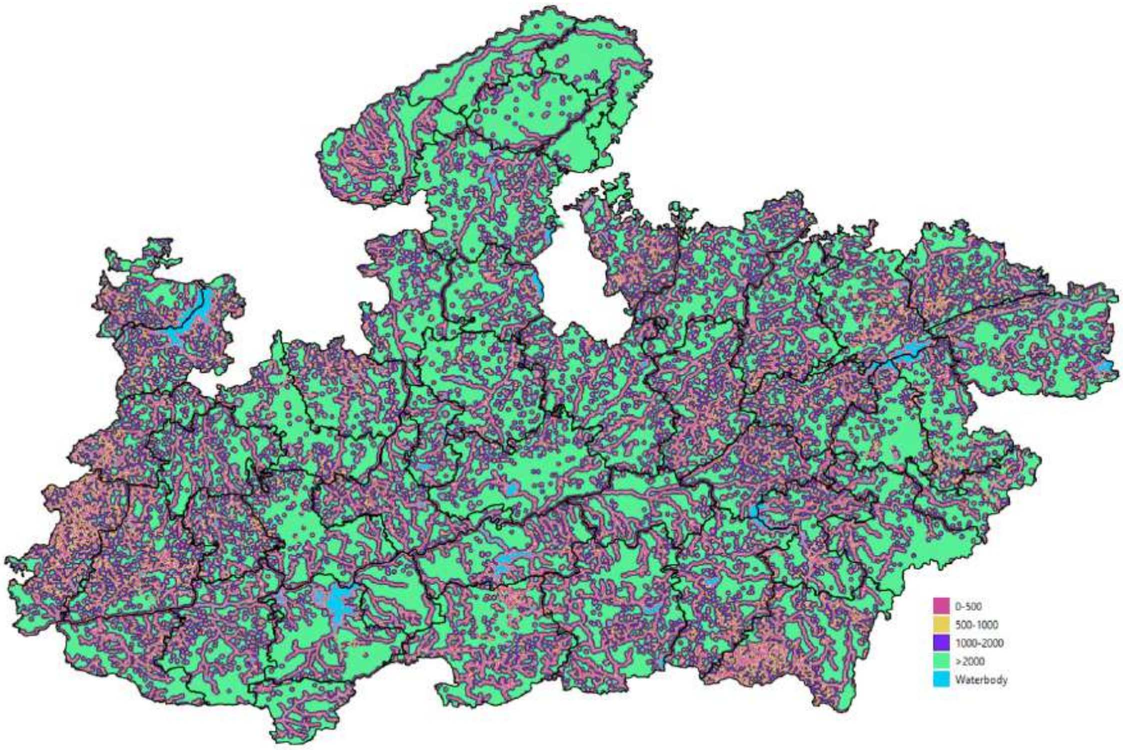


Figure 19. *Waterbody map of Madhya Pradesh (in meters)*

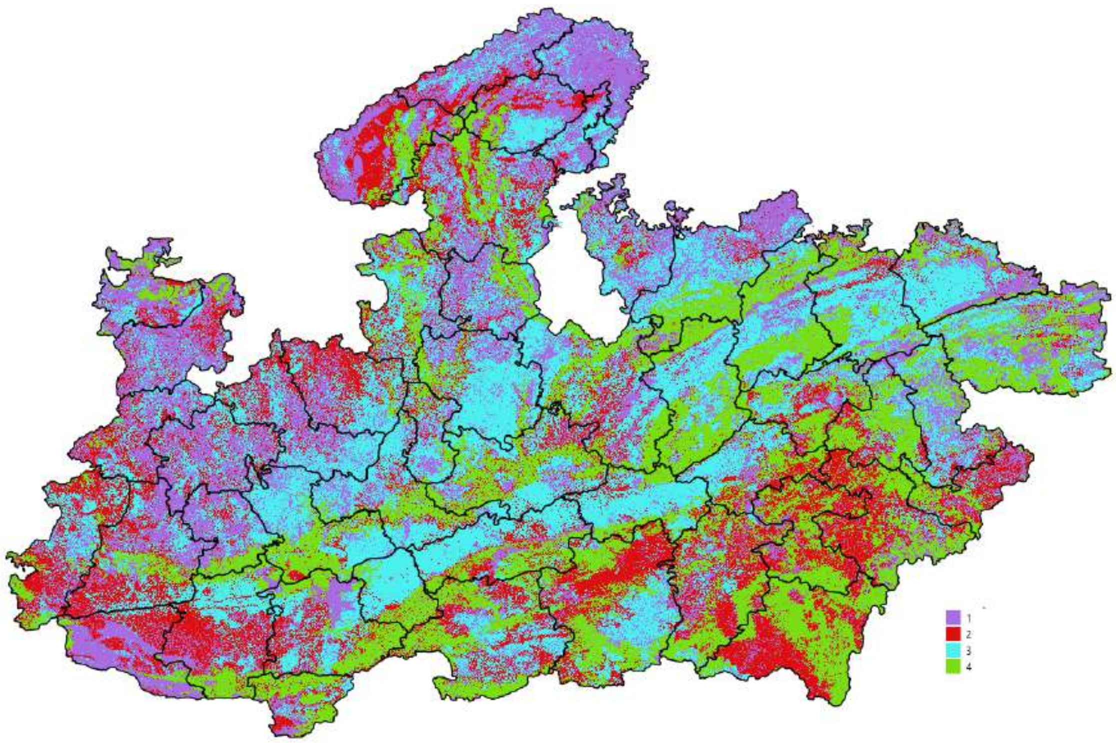


Figure 20. *Soil Organic Carbon map of Madhya Pradesh (as per index)*

ii. **Output Data: Agroforestry Suitability Index map of Madhya Pradesh**

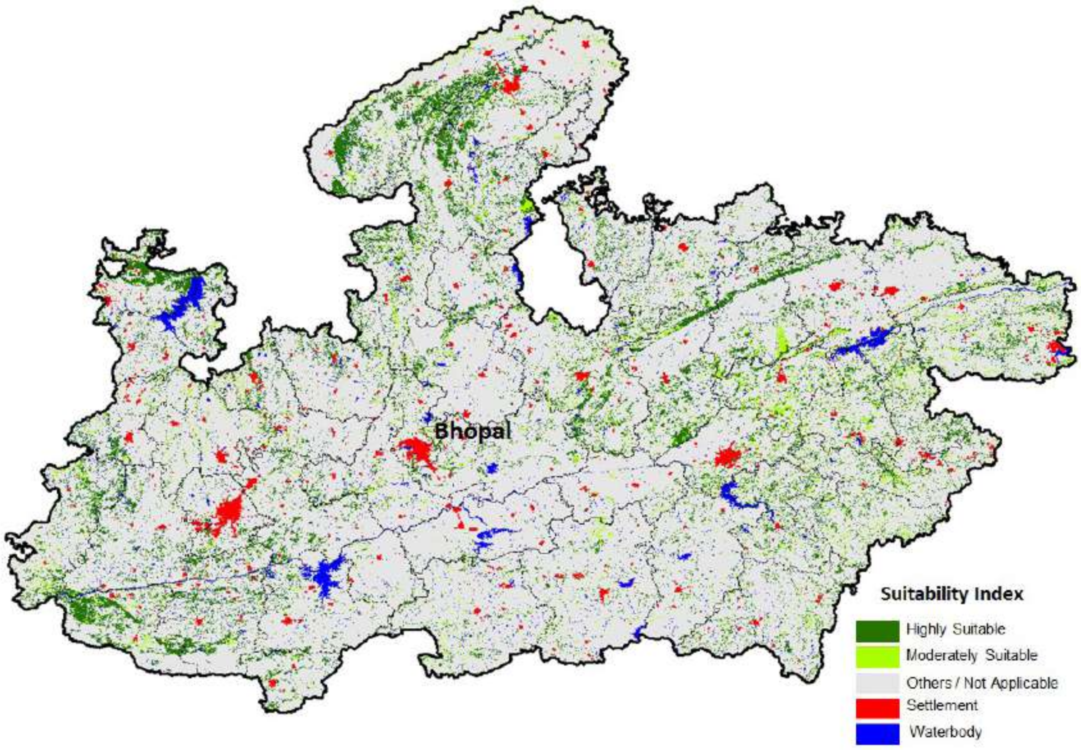


Figure 21. *Classified areas for greening in Madhya Pradesh*

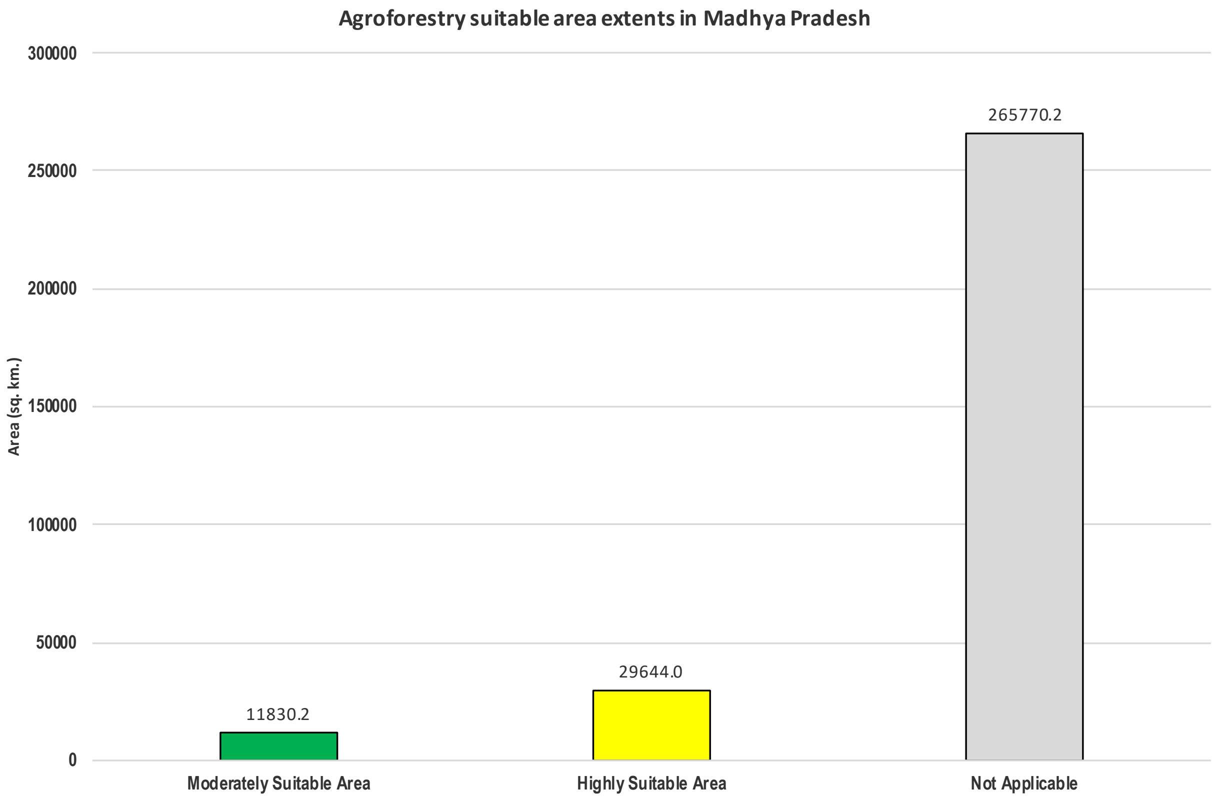


Figure 22. *The ASI data of Madhya Pradesh*

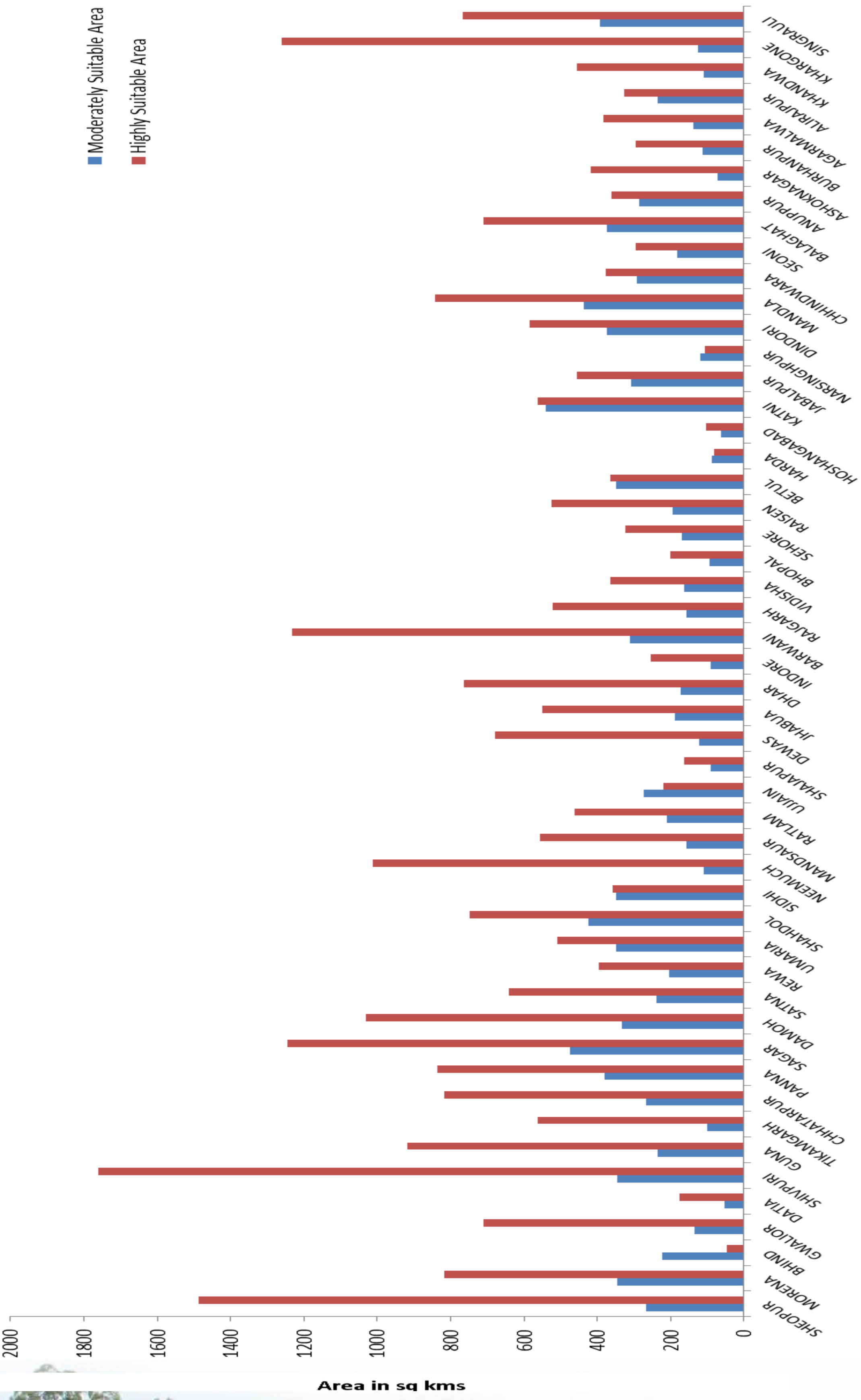


Figure 23. *District-wise classified area suitable for Agroforestry in Madhya Pradesh*

5

Access to State, UTs and District level area suitability maps for wastelands greening via Bhuvan Geoportal

Based on the study approach, area suitable for greening with Agroforestry across districts of 28 states and 4 UT's are calculated. The area statistic falling under different categories viz. highly suitable, moderate and less suitable/not available is placed in Table. 13.

The Agroforestry suitability Maps of all States and districts are made available in the Bhuvan Geoportal of ISRO under the project- Greening and Restoration of Wastelands with Agroforestry (G.R.O.W) - Suitability Mapping System. The classified maps ranging from highly suitable to not suitable category along with area statistics with legends, map viewer along with input datasets can be assessed using the web browser *https://bhuvan-app1.nrsc.gov.in/asi_portal/*. All users are required to create a log-in that will be authenticated by Bhuvan Team (Figure 24).

The maps can be accessed at different levels viz. Central, State and District level. The user access manual is enclosed as Annexure-IV. Also, a special feature was incorporated in this application that allows users to draw the area of interest and generate the statistics for the area drawn on the fly like AOI. Also, stakeholders can find information on selected agroforestry system and list of tree species exempted from transit and felling permit in the portal. **The key features of the system on Greening and Restoration Wastelands with Agroforestry-Suitability Mapping are:**

- Provides District level information of wastelands area suitable for agroforestry;
- Provides area prioritisation regime i.e. highly suitable area, moderate and less suitable areas for agroforestry;
- Provides State-wise & District-wise area analysis reports based on the suitability regimes;
- Provides information, such as potential agroforestry systems, list of tree species exempted for transits and felling permit.

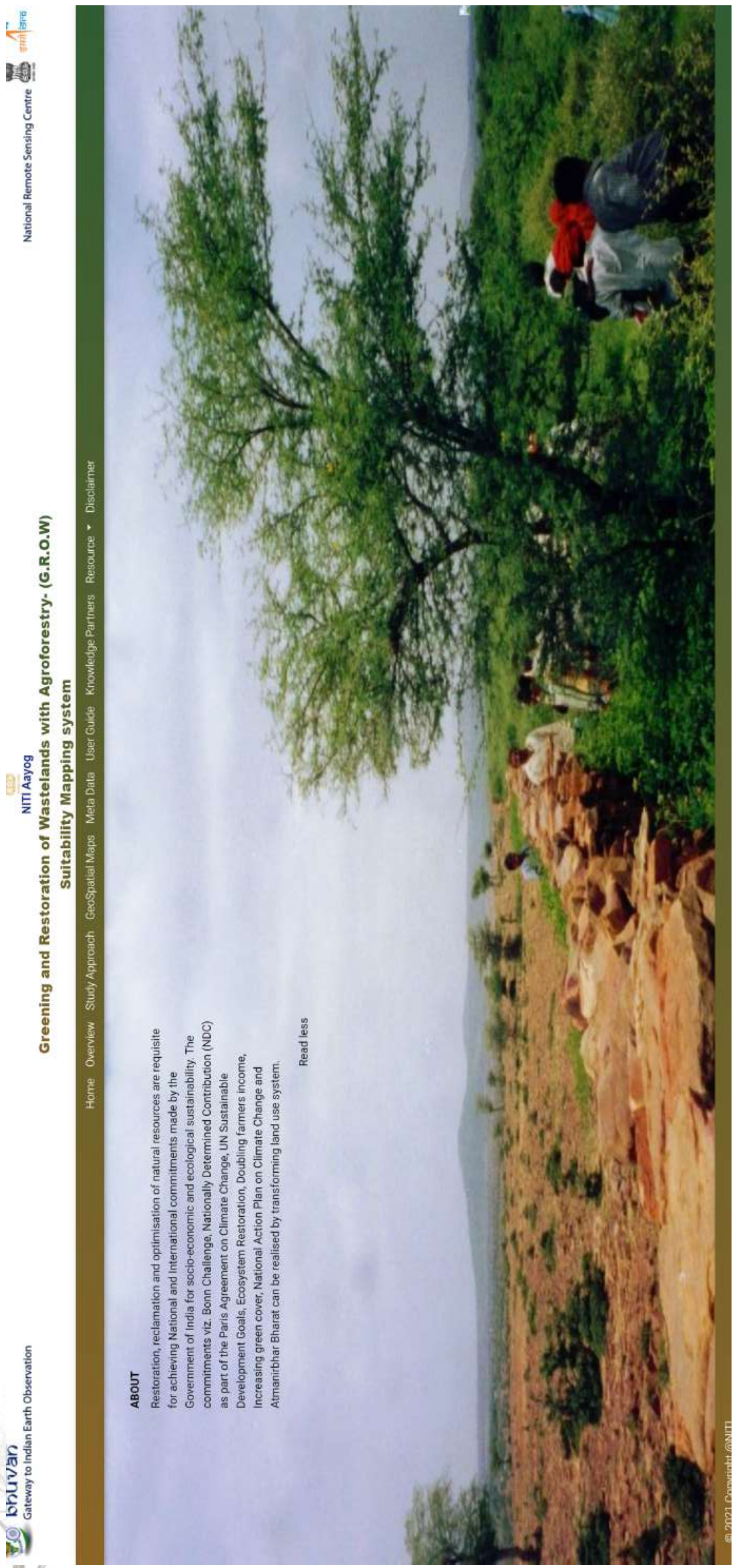


__Figure 24.__ Landing page on Wastelands greening with Agroforestry- Suitability Mapping on Bhuvan Geoportal

Table 12: District-wise area suitable for greening with Agroforestry

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
JAMMU & KASHMIR	Mirpur	1476.62	106.95	1476.60
	Muzaffarabad	465.81	126.42	3120.92
	Punch	351.67	173.06	3373.38
	Anantnag	406.56	79.54	2243.10
	Baramula	201.58	168.41	1693.37
	Kathua	315.00	208.38	1888.33
	Udhampur	152.34	84.08	2045.01
	Badgam	239.81	60.28	950.44
	Bandipura	1007.15	137.16	2901.32
	Ganderbal	583.65	45.99	991.26
	Kulgam	188.91	73.46	1003.34
	Kupwara	334.65	226.32	2184.57
	Pulwama	119.93	21.16	756.00
	Rajauri	539.30	321.22	1776.69
	Ramban	365.78	22.86	900.56
	Riasi	168.04	126.38	1639.41
	Shupiyan	36.72	35.71	433.52
	Srinagar	8.93	7.48	265.37
	Kishtwar	1893.98	270.96	5927.97
	Doda	245.66	84.02	2020.03
	Samba	71.61	76.78	699.59
	Jammu	184.07	162.08	1797.37
Total		**9357.77**	**2618.68**	**40088.15**
LADAKH	Leh	2269.31	1088.44	141826.75
	Kargil	172.14	64.08	13926.18
Total		**2441.45**	**1152.52**	**155752.94**

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
HIMACHAL PRADESH	Mandi	470.09	179.06	3305.78
	Kangra	446.64	306.23	4961.47
	Sirmaur	379.06	235.91	2186.95
	Solan	349.46	231.06	1347.93
	Shimla	337.29	445.79	4345.71
	Bilaspur	286.20	102.25	777.92
	Chamba	270.89	217.72	5979.30
	Kullu	263.85	163.51	5084.02
	Una	231.74	77.07	1228.35
	Kinnaur	174.80	122.73	5971.96
	Hamirpur	164.50	54.76	904.25
	Lahaul & Spiti	132.77	149.77	13512.91
Total		**3507.29**	**2285.86**	**49606.55**
PUNJAB	Rupnagar	56.28	28.47	1283.74
	Hoshiarpur	35.36	40.52	3281.61
	S.A.S. Nagar(Mohali)	28.02	14.05	1040.56
	Faridkot	15.45	0.12	1461.59
	Pathankot	14.63	12.49	832.88
	S.B.S. Nagar	13.13	7.11	1240.00
	Patiala	7.26	6.95	3296.41
	Ludhiana	4.87	3.25	3701.32
	Bathinda	3.86	1.18	3369.80
	Fazilka	2.60	2.16	2666.89
	Tarn Taran	2.44	5.35	2330.10
	Sangrur	2.38	0.73	3600.76
	Muktsar	2.13	0.56	2631.70
	Mansa	2.12	0.82	2163.16
	Gurdaspur	1.27	16.39	2478.97
	Kapurthala	1.25	3.01	1625.73
	Barnala	1.11	0.09	1412.87
	Ferozpur	1.02	1.45	2422.70
	Jalandhar	0.79	0.47	2630.65

(area in sq.km)

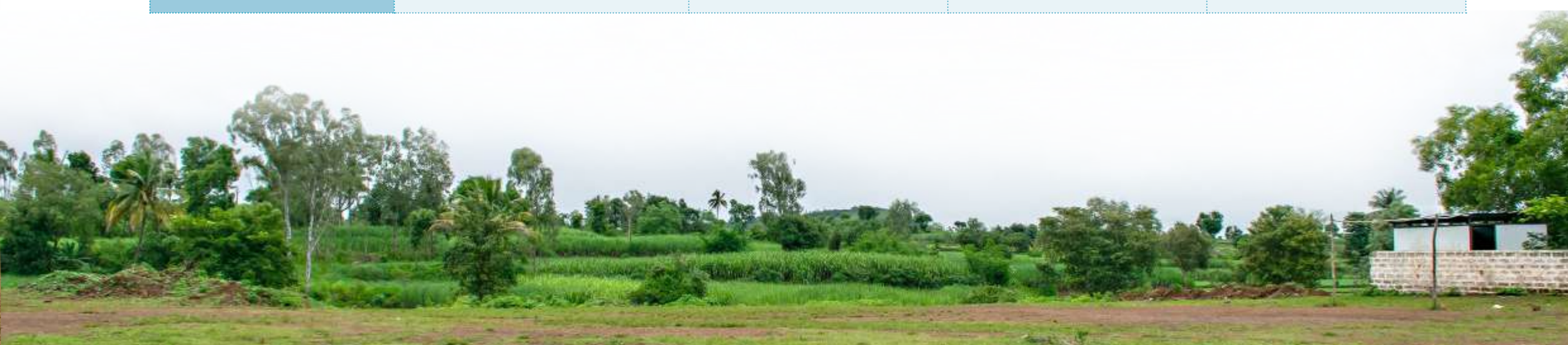
State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
PUNJAB	Amritsar	0.75	2.47	2473.88
	Moga	0.57	2.15	2230.03
	Fatehgarh Sahib	0.24	0.26	1142.38
Total		**197.53**	**150.07**	**49318.75**
CHANDIGARH	Chandigarh	0.38	12.69	103.60
Total		**0.38**	**12.69**	**103.60**
UTTARAKHAND	Pauri Garhwal	188.24	290.30	4953.84
	Pithoragarh	137.97	417.04	5796.43
	Tehri Garhwal	118.80	113.37	3637.88
	Uttarkashi	115.63	375.44	7256.03
	Bageshwar	101.54	115.66	2065.60
	Dehradun	101.36	109.49	2850.34
	Almora	84.77	105.90	2913.57
	Nanital	84.01	182.58	3849.74
	Chamoli	77.05	211.41	7187.29
	Champawat	66.01	37.34	1426.83
	Rudraprayag	45.21	112.52	1679.79
	Haridwar	30.30	133.30	2131.37
	Uddam S Nagar	16.14	60.98	2498.76
Total		**1167.03**	**2265.31**	**48247.47**
HARYANA	Mahendragarh	97.25	103.24	1687.68
	Gurugram	81.73	35.55	1123.62
	Panchkula	79.40	44.45	759.50
	Faridabad	74.17	19.38	627.25
	Hisar	66.13	65.93	3932.54
	Bhiwani	42.45	46.29	3140.40
	Mewat	41.44	59.42	1388.13

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
HARYANA	Yamunanagar	37.02	26.15	1657.61
	Rewari	30.50	46.93	1428.52
	Charkhi Dadri	30.46	39.61	1308.62
	Palwal	24.12	32.24	1310.06
	Jhajjar	21.83	66.00	1837.87
	Karnal	18.50	13.52	2437.70
	Sonipat	17.97	56.04	2091.82
	Ambala	12.80	31.24	1417.41
	Rohtak	10.61	44.19	1623.59
	Panipat	9.77	10.18	1230.33
	Sirsa	9.32	27.56	4181.06
	Kurukshetra	7.20	6.08	1663.12
	Kaithal	6.55	13.24	2258.79
	Fatehabad	6.53	23.59	2483.08
	Jind	5.81	47.09	2688.72
Total		**731.56**	**857.93**	**42277.40**
DELHI	Delhi	52.74	9.77	1434.75
Total		**52.74**	**9.77**	**1434.75**
RAJASTHAN	Jaisalmer	3975.33	7591.09	26423.18
	Udaipur	2431.29	1441.55	7900.52
	Bhilwara	1776.08	2948.87	5737.78
	Chittorgarh	1529.11	1036.58	8173.93
	Baran	1260.94	413.43	5131.74
	Karauli	1248.07	398.74	3799.11
	Ajmer	1076.43	1753.17	5692.49
	Dungarpur	1046.80	426.69	2309.29
	Jaipur	1013.44	1195.24	9055.80
	Sirohi	918.65	614.87	3620.93
	Barmer	906.63	1997.25	25257.40
	Jodhpur	871.81	1650.13	20345.04

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
RAJASTHAN	Banswara	866.75	277.62	3904.31
	Jhalawar	853.37	734.83	4652.61
	Bundi	820.21	319.67	4442.12
	Pali	754.45	2625.35	8975.66
	Kota	660.94	363.71	4482.51
	Sikar	574.27	320.51	6798.78
	Nagaur	567.74	1028.58	16089.37
	Rajsamand	550.91	1348.24	2753.63
	Bikaner	509.86	617.08	25874.57
	Tonk	487.95	701.03	6061.38
	Dholpur	482.02	378.13	2157.63
	Sawai Madhopur	475.89	317.22	4227.40
	Jhunjhunu	384.26	182.14	5350.78
	Alwar	298.03	526.99	7465.94
	Churu	292.17	252.64	16538.10
	Jalore	287.84	1147.16	9292.32
	Bharatpur	201.11	249.21	4593.76
	Dausa	186.06	236.05	2562.48
	Pratapgarh	180.70	30.44	754.10
	Sri Ganganagar	102.40	51.38	10342.30
	Hanumangarh	70.54	84.79	9835.11
Total		**27662.05**	**33260.36**	**280602.03**
UTTAR PRADESH	Jhansi	278.39	171.57	4504.97
	Mirzapur	266.08	150.86	3980.96
	Lalitpur	243.67	77.39	4602.51
	Etawah	229.85	133.80	1945.99
	Agra	229.23	156.95	3582.25
	Sonbhadra	223.25	280.11	6338.42

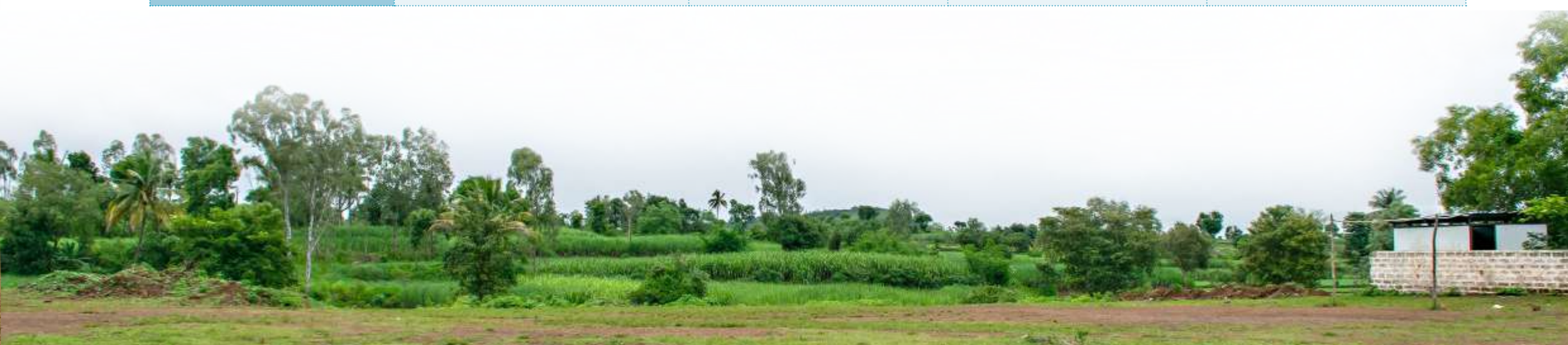


(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
UTTAR PRADESH	Allahabad	211.69	102.10	5162.20
	Lakhimpur	139.39	219.11	6690.65
	Jalaun	125.53	241.46	4192.06
	Chitrakoot	122.13	211.59	2729.45
	Hamirpur	105.38	242.55	3861.84
	Bahraich	92.85	78.64	4137.20
	Mahoba	80.17	178.32	2631.45
	Pilibhit	61.54	35.87	3057.99
	Pratapgrah	59.81	109.37	3548.87
	Firozabad	55.20	94.63	2219.29
	Sitapur	54.30	86.58	5599.79
	Budaun	53.18	85.10	4120.73
	Chandauli	52.12	27.97	2457.39
	Barabanki	51.32	61.69	3722.86
	Balrampur	47.26	44.72	2839.73
	Kanpur Dehat	43.96	125.93	3009.65
	Azamgarh	43.84	53.99	4117.90
	Gonda	41.89	35.75	3918.08
	Amethi	39.30	79.56	3207.71
	Sultanpur	36.67	42.99	2364.07
	Auraiya	35.55	43.50	1939.28
	Ballia	34.36	43.70	2884.55
	Jaunpur	33.46	76.04	3926.99
	J.p Nagar	32.79	22.03	2158.45
	Faizabad	30.39	37.13	2679.76
	Banda	28.15	272.36	4222.89
	Raebareli	27.11	65.27	3183.08
	Kanpur	26.61	66.68	2907.42
	Hardoi	25.93	177.32	5788.75
	Mahrajganj	20.41	21.76	2689.68

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
UTTAR PRADESH	Lucknow	19.79	74.75	2433.55
	Shahjahanpur	18.45	45.26	4507.17
	Gorakhpur	17.65	36.40	3284.29
	Fatehpur	16.98	168.11	3962.13
	Mathura	16.15	36.65	3260.02
	Muzaffarnagar	15.37	46.21	2598.51
	Bareilly	14.07	14.24	4045.77
	Basti	13.45	41.43	2631.06
	Ambedkar Nagar	12.56	22.00	2325.20
	Unnao	11.75	143.19	4405.16
	Farrukhabad	10.38	39.97	2130.79
	Bulandshahr	9.48	22.01	3474.05
	Kannauj	8.82	42.58	2040.35
	Mainpuri	8.55	86.10	2648.73
	Shravasti	8.40	16.71	1596.40
	Ghazipur	8.29	30.05	3333.21
	Varanasi	8.02	10.10	1510.23
	Siddharthnagar	7.89	47.53	2543.75
	Deoria	7.34	12.57	2485.82
	Hathras	7.18	16.23	1757.50
	Mau	6.86	3.16	1691.99
	Kansiramnagar	6.76	22.11	1929.24
	Aligarh	6.34	24.84	3682.74
	Gautam Budh Nagar	5.99	37.20	1401.17
	Bhimnagar	4.30	16.59	2378.33
	St. Kabir Nagar	3.73	27.40	1593.74
	Kaushambi	3.48	26.64	1751.37
	St. Rabidas Nagar	3.08	7.84	1004.09



(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
UTTAR PRADESH	Etah	2.76	37.30	2443.41
	Panchshil Nagar	2.21	7.05	1095.96
	Prabudhnagar	2.05	13.57	1312.79
	Rampur	2.01	33.97	2288.98
	Bijnor	1.84	63.78	4359.86
	Ghaziabad	1.56	15.93	850.39
	Kushinagar	1.25	12.76	2840.02
	Baghpat	1.04	16.49	1302.45
	Meerut	0.99	19.23	2561.96
	Saharanpur	0.98	90.26	3591.84
	Moradabad	0.12	14.30	2254.86
Total		**3580.62**	**5396.95**	**228233.69**
BIHAR	Jamui	538.84	69.48	2419.96
	Banka	514.71	41.16	2483.03
	Bhabhua	411.17	109.47	2833.03
	Gaya	295.44	117.30	4532.73
	Rohtas	237.31	72.66	3497.53
	Pashchim Champaran	134.46	78.71	4475.33
	Nawada	115.89	48.57	2295.32
	Aurangabad	77.55	27.32	3154.29
	Katihar	40.91	324.39	2646.69
	Chhapra	31.97	79.90	2522.53
	Purba Champaran	31.26	78.76	3549.54
	Bhagalpur	29.41	153.28	2348.69
	Munger	28.56	48.30	1353.68
	Gopalganj	28.27	69.57	1936.21
	Muzaffarpur	25.88	66.77	3089.59
	Bhojpur	21.52	9.98	2462.47
	Supaul	18.41	66.11	2121.05
	Kishanganj	16.61	47.98	1538.95
	Lakhisarai	15.63	44.60	1205.45
	Purnia	14.62	172.54	3053.34
	Patna	13.71	93.81	3074.26

(area in sq.km)

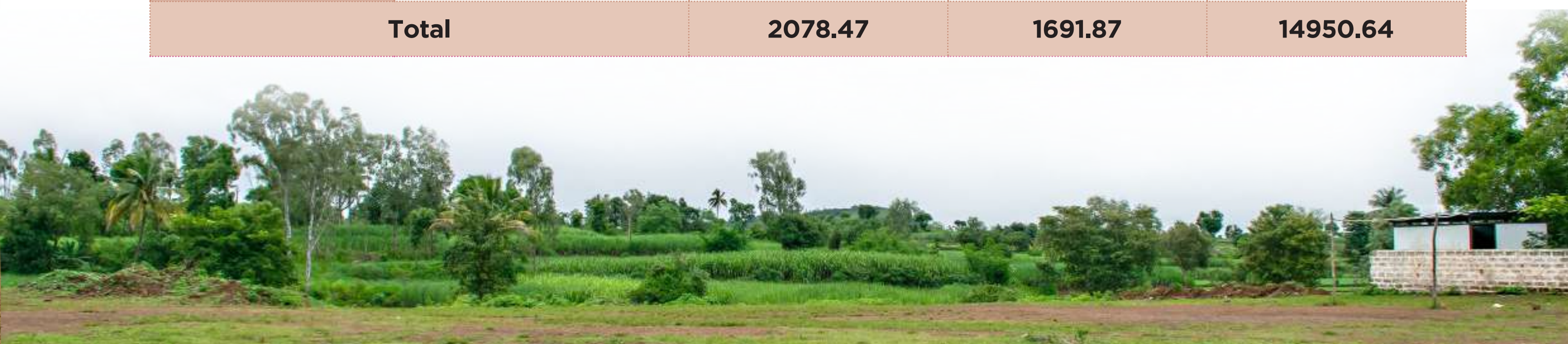
State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
BIHAR	Jehanabad	13.58	6.83	898.97
	Madhepura	12.79	144.80	1677.89
	Siwan	11.48	34.69	2169.88
	Madhubani	8.88	60.91	2878.21
	Buxar	8.00	11.65	1553.52
	Saharsa	7.66	68.61	1610.18
	Vaishali	7.40	72.78	1923.90
	Araria	7.24	52.11	2471.20
	Arwal	4.39	9.32	618.40
	Samastipur	4.04	141.04	2756.46
	Kaimur	4.04	0.42	24.94
	Begusarai	3.57	56.35	1876.33
	Khagaria	3.32	138.12	1347.58
	Sitamarhi	3.30	21.96	1966.23
	Darbhanga	1.87	124.65	2159.70
	Nalanda	1.71	20.46	2311.19
	Sheohar	0.39	2.21	285.56
	Jhanabad	0.36	0.26	63.66
	Sheikhpura	0.26	29.04	609.33
Total		**2746.40**	**2816.90**	**85796.78**
SIKKIM	North	23.50	19.17	3652.03
	East	13.49	6.87	915.27
	South	12.68	8.62	708.47
	West	10.75	12.02	1094.47
Total		**60.43**	**46.68**	**6370.25**
ARUNACHAL PRADESH	West Kameng	438.82	225.57	3774.48
	Tawang	342.88	212.92	1234.61
	Longding	178.98	166.73	502.07
	Lower Subansiri	148.03	112.77	1033.93
	Tirap	144.30	52.13	817.84

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
ARUNACHAL PRADESH	Dibang Valley	123.72	85.53	8714.43
	Shi-Yomi	103.36	25.33	2682.24
	Anjaw	93.08	45.85	5622.28
	Kamle	92.89	125.55	1723.49
	Changlang	75.25	89.10	3304.47
	Upper Siang	73.07	80.19	6284.40
	Papumpare	69.62	98.57	3209.03
	East Siang	69.27	185.14	1566.18
	Kurung Kumey	57.62	113.74	4145.30
	East Kameng	52.82	69.48	4181.98
	West Siang	50.76	32.10	1544.76
	Upper Subansiri	44.49	45.09	5645.75
	Lohit	42.47	103.30	2996.80
	Lower Dibang Valley	33.50	57.89	3508.55
	Leparada	29.83	24.31	751.70
	Kra Daadi	28.87	23.13	2297.71
	Siang	28.43	38.51	2898.75
	Lower Siang	25.25	21.10	1792.22
	Pakke-Kessang	6.41	17.99	1894.16
	Namsai	5.17	49.30	1074.86
Total		**2358.88**	**2101.31**	**73201.99**
NAGALAND	Mon	538.44	467.56	1140.72
	Phek	354.92	159.96	1327.93
	Zunheboto	330.11	188.32	1051.86
	Tuensang	327.40	455.90	1365.32
	Peren	264.68	128.88	1297.03
	Mokokchung	253.19	265.98	1097.70
	Kohima	173.47	118.93	996.87
	Longleng	170.67	102.78	292.53
	Kiphire	162.96	216.66	744.31

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
NAGALAND	Wokha	153.54	154.51	1302.08
	Dimapur	76.32	68.01	713.89
Total		**2805.70**	**2327.50**	**11330.24**
MANIPUR	Churachandpur	844.98	203.83	1465.44
	Senapati	572.82	186.22	1245.29
	Tamenglong	437.89	224.32	2360.42
	Kangpokpi	399.56	99.70	1046.49
	Pherzawl	384.07	226.49	1609.11
	Ukhrul	347.43	478.43	1391.55
	Chandel	318.85	191.25	1225.45
	Noney	197.64	63.47	694.96
	Tengnpoupal	177.57	100.62	951.74
	Kamjong	97.87	98.95	2094.34
	Imphal East	30.49	17.18	348.99
	Kakching	24.95	10.64	248.55
	Imphal West	19.13	6.63	476.61
	Thoubal	11.54	7.94	304.48
	Bishnupur	9.78	8.24	426.07
	Jiribam	3.18	6.68	159.18
Total		**3877.76**	**1930.59**	**16048.69**
MIZORAM	Aizawl	493.32	294.64	2931.72
	Champhai	393.87	439.64	1856.24
	Lunglei	384.49	359.45	3346.96
	Mamit	224.77	189.80	2594.24
	Lawngtlai	205.32	103.09	1403.78
	Serchhip	172.09	155.54	788.54
	Kolasib	110.25	51.58	1169.75
	Saiha	94.35	98.13	859.40
Total		**2078.47**	**1691.87**	**14950.64**

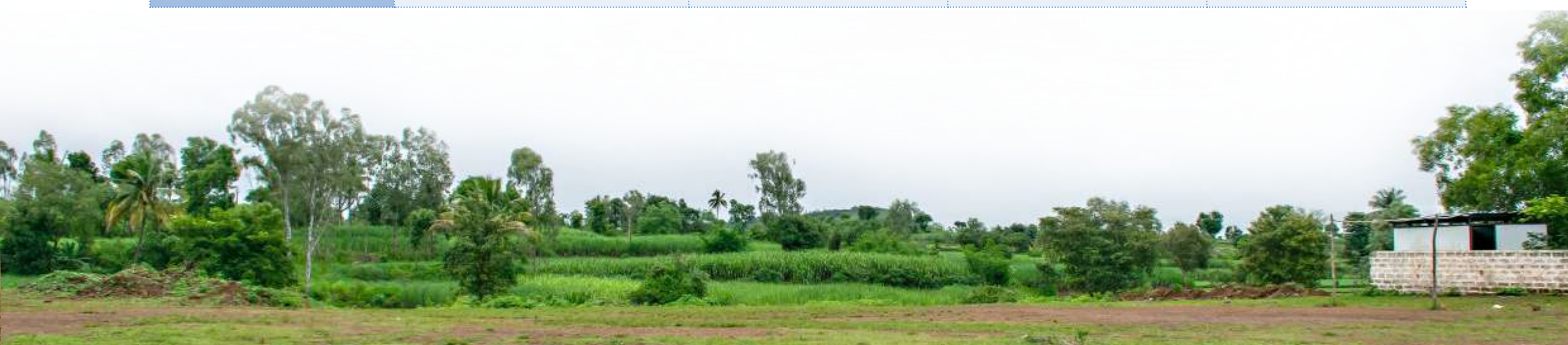


(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
TRIPURA	Dhalai	177.58	33.41	1734.58
	West Tripura	68.65	53.21	670.49
	North Tripura	67.02	15.18	1048.43
	Gomati	56.89	33.99	1248.73
	Sepahijala	53.24	36.39	910.26
	South Tripura	42.64	31.20	832.43
	Khowai	36.54	31.05	834.22
	Unakoti	25.06	5.81	517.57
Total		**527.61**	**240.25**	**7796.71**
MEGHALAYA	East Jaintia Hills	456.70	73.63	1217.96
	West Jaintia Hills	348.73	30.58	1387.66
	West Khasi Hills	302.73	314.34	3174.85
	West Garo Hills	237.14	362.29	2130.08
	South West Khasi Hills	176.36	143.60	1010.68
	East Khasi Hills	147.18	74.19	2401.95
	East Garo Hills	145.76	170.89	1862.53
	Ri Bhoi	122.37	350.85	1886.93
	South Garo Hills	100.35	137.36	1485.24
	North Garo Hills	48.36	30.37	650.31
	South West Garo Hills	14.28	29.00	271.70
Total		**2099.94**	**1717.10**	**17479.90**
ASSAM	Karbi Anglong	1614.78	1202.09	7598.32
	Nc Hills/Dima Hasao	1057.53	568.77	3219.89
	Sonitpur	536.13	137.47	4552.56
	Golaghat	455.80	172.41	2649.32
	Kokrajhar	337.15	210.30	2543.94
	Nagaon	196.49	351.99	3487.43
	Chirang	178.06	93.99	1590.63
	Tinsukia	130.22	95.64	3591.77
	Hailakandi	127.20	55.32	1139.45

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
ASSAM	Cachar	101.25	86.84	3333.84
	Kamrrup Rural	94.49	233.34	2747.46
	Baksa	93.42	119.50	2198.09
	Sivasagar	92.09	76.22	2460.14
	Goalpara	75.87	146.58	1723.39
	Jorhat	73.72	66.45	2940.25
	Udalguri	72.15	133.50	1775.21
	Dibrugarh	57.83	59.87	3263.28
	Karimganj	56.00	55.08	1209.88
	Lakhimpur	55.45	108.90	2720.09
	Dhemaji	35.90	167.90	2299.90
	Kamrup Metro	33.79	54.52	933.71
	Bongaigaon	13.28	69.99	1021.35
	Darrang	10.46	133.85	1436.12
	Morigaon	8.93	78.65	1379.66
	Dhubri	4.70	47.50	1467.00
	Barpeta	3.50	100.60	2155.38
	Nalbari	1.17	73.82	976.56
Total		**5517.36**	**4701.08**	**66414.60**
WEST BENGAL	Bankura	348.81	106.61	6434.95
	Purulia	308.34	143.97	5735.62
	Jhargram	198.43	46.52	2827.50
	Paschim Burdwan	103.44	48.69	6133.55
	Birbhum	80.50	32.72	4403.86
	Paschim Bardhhaman	76.20	42.32	1491.57
	Alipurduar	13.22	8.19	2690.16
	Jalpaiguri	10.39	14.98	3168.31
	Darjeeling	10.12	23.11	1631.18

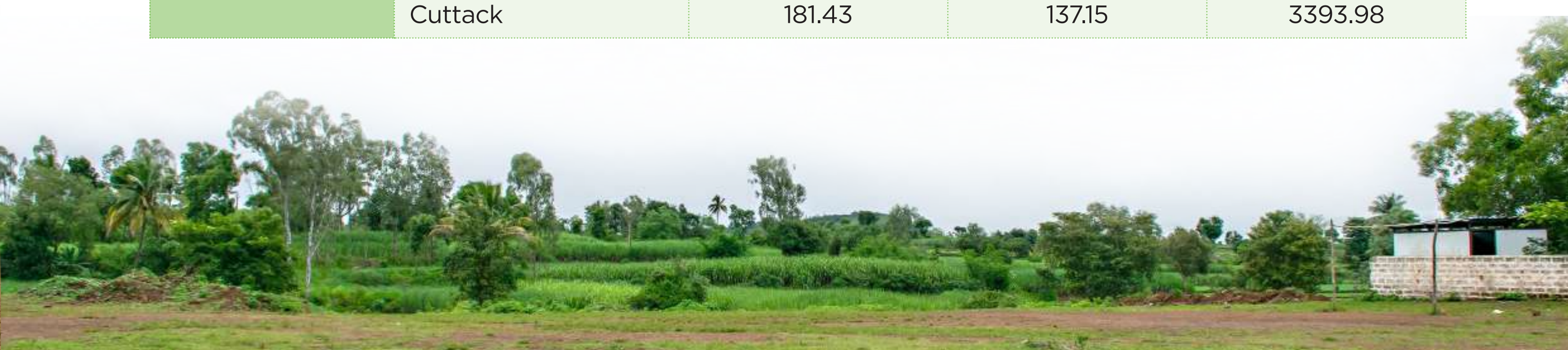


(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
WEST BENGAL	Kalimpong	8.11	2.48	1055.90
	Purba Burdwan	5.27	24.54	5377.45
	Cooch Bihar	0.73	36.79	2922.50
	Murshidabad	0.54	20.88	4870.21
	Nadia	0.33	26.08	3036.18
	Dakshin Dinajpur	0.13	5.18	2054.00
	Uttar Dinajpur	0.11	2.60	2987.14
	South 24 Parganas	0.08	9.92	5312.04
	Malda	0.01	13.73	3520.43
	North 24 Parganas	0.00	17.28	2485.67
	Hoogly	0.00	21.69	3130.12
	Howrah	0.00	13.11	1422.77
	Kolkata	0.00	0.00	94.66
	Purba Medinipur	0.00	22.90	3629.13
Total		**1164.77**	**684.30**	**76414.90**
JHARKHAND	Chatra	1078.58	289.21	2369.50
	Giridih	1007.53	183.29	3771.07
	Hazaribag	714.52	305.04	3769.91
	Latehar	664.11	509.73	3081.34
	Palamu	605.39	298.67	3462.78
	Simdega	579.80	503.09	2665.04
	Ranchi	561.39	523.85	6531.31
	Garhwa	532.41	363.79	3188.03
	Bokaro	424.19	215.55	2126.86
	Pashchimi Singhbhum	395.01	270.68	6509.37
	Kodarma	388.63	164.97	2079.50
	Deoghar	343.74	372.45	1714.35
	Purbi Singhbhum	299.60	354.67	2875.65
	Gumla	273.36	596.67	4480.16
	Dumka	244.87	122.71	3378.44
	Saraikela	216.68	192.19	2217.24

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
JHARKHAND	Godda	206.57	170.99	1853.97
	Dhanbad	162.28	123.50	1840.00
	Jamtara	158.99	34.84	1573.78
	Pakur	119.41	175.85	1498.11
	Sahibganj	109.74	114.98	1919.94
	Lohardaga	78.23	119.14	1299.61
	Khunti	0.40	0.87	7.02
Total		**9165.42**	**6006.71**	**64212.98**
ODISHA	Malkangiri	799.87	564.48	4376.72
	Gajapati	779.74	370.81	2945.67
	Ganjam	729.97	396.18	7257.27
	Nabarangpur	668.03	273.09	4478.00
	Kalahandi	660.45	482.34	6760.12
	Kandhamal (Phulbani)	586.35	748.79	6687.40
	Keonjhar (Kendujhar)	561.26	451.32	7287.48
	Sambalpur	554.16	234.95	5817.85
	Balangir	526.74	278.83	5747.68
	Angul	516.67	223.39	5633.04
	Nuapada	484.36	108.35	3247.72
	Bargarh	458.25	93.71	5275.73
	Sundargarh	457.09	257.19	8979.92
	Nayagarh	410.10	279.47	3207.84
	Mayurbhanj	397.53	164.91	9833.37
	Koraput	359.39	967.22	7060.78
	Raygada	341.79	453.48	6529.76
	Dhenkanal	328.42	222.60	3906.71
	Boudh	277.87	113.39	2711.52
	Deogarh (Debagarh)	276.07	106.82	2570.87
	Khordha	268.45	111.75	2500.94
	Sonepur	224.26	108.68	2029.63
	Cuttack	181.43	137.15	3393.98



(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
ODISHA	Jharsuguda	159.83	58.89	1897.08
	Jajpur	147.55	72.44	2676.65
	Balasore	69.86	39.17	3592.42
	Puri	21.82	101.50	3298.50
	Kendrapada	19.02	67.09	2260.63
	Jagatsinghpur	13.10	49.04	1789.45
	Bhadrak	2.28	16.28	2179.53
Total		**11281.71**	**7553.31**	**135934.27**
CHHATTISGARH	Bijapur	998.30	119.99	8253.11
	Balrampur	819.06	186.05	5210.24
	Surajpur	669.08	150.52	4620.84
	Koriya	582.18	99.17	5899.46
	Korba	539.46	93.14	5972.32
	Rajnandgaon	514.22	273.64	7277.59
	Surguja	485.08	142.71	3396.83
	Gariaband	479.68	120.03	4233.56
	Raigarh	420.32	145.85	6471.48
	Bilaspur	380.08	119.98	5036.73
	Sukma	344.56	90.39	4947.46
	Balodabazar	298.97	148.36	4219.14
	Kondagaon	283.43	57.92	4746.96
	Jashpur	278.14	143.70	5420.36
	Kanker	276.13	121.98	6799.59
	Mahasamund	255.34	284.29	4211.60
	Narayanpur	240.57	35.03	3431.73
	Raipur	214.89	144.86	2546.16
	Kawardha	191.13	73.71	3916.42
	Janjgir-Champa	188.65	108.39	3567.01
	Bastar	181.10	76.42	5123.72
	Balod	181.03	70.72	3109.16
	Dhamtari	167.09	61.01	3855.05
	Durg	117.25	139.75	2042.21

(area in sq.km)

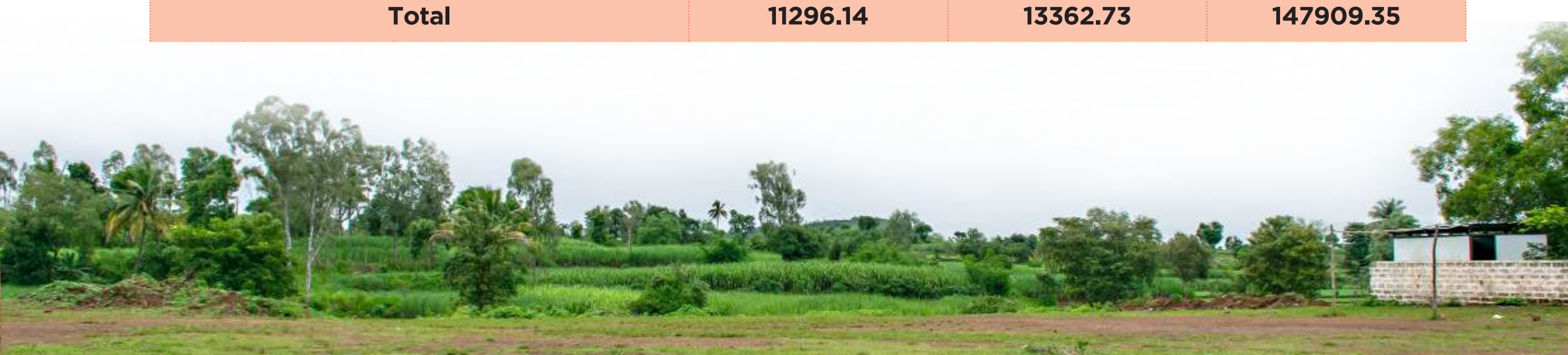
State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
CHHATTISGARH	Dantewada	106.89	57.47	2704.71
	Bemetra	93.67	76.98	2693.41
	Mungeli	77.35	23.60	2679.77
Total		**9383.60**	**3165.67**	**122386.62**
MADHYA PRADESH	Shivpuri	1761.51	346.62	7811.84
	Sheopur	1488.24	268.35	4757.16
	Khargone	1261.24	127.07	6618.26
	Sagar	1244.66	474.34	8505.18
	Barwani	1231.77	310.59	3858.20
	Damoh	1030.43	332.11	5940.16
	Neemuch	1011.33	109.01	2928.69
	Guna	919.09	236.66	5148.69
	Mandla	843.29	436.02	6225.28
	Panna	837.06	380.24	5887.32
	Morena	816.99	345.92	3829.36
	Chhatarpur	816.53	266.88	7593.32
	Singrauli	767.84	391.74	4638.75
	Dhar	763.87	173.55	7239.43
	Shahdol	748.21	423.37	4489.20
	Balaghat	710.79	373.56	8151.74
	Gwalior	710.29	134.08	3712.42
	Dewas	677.75	121.47	6205.60
	Satna	642.76	239.40	6571.97
	Dindori	583.56	373.58	4787.68
	Tikamgarh	563.79	101.35	4318.04
	Katni	562.52	541.77	3975.45
	Mandsaur	557.24	156.72	4719.91
	Jhabua	549.52	189.39	2694.56

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
MADHYA PRADESH	Raisen	524.73	193.98	7729.68
	Rajgarh	521.49	157.55	5473.77
	Umaria	509.76	349.74	3704.39
	Ratlam	461.11	209.19	4141.75
	Jabalpur	456.49	306.44	4337.73
	Khandwa	454.46	111.12	6880.21
	Ashoknagar	416.80	70.91	4250.69
	Rewa	394.94	203.63	5694.81
	Agarmalwa	383.68	136.70	2190.51
	Chhindwara	377.93	293.48	11107.49
	Betul	365.07	349.30	9332.75
	Vidisha	363.18	162.92	6794.43
	Anuppur	362.73	285.61	3134.76
	Sidhi	358.94	347.48	4037.57
	Alirajpur	328.06	236.57	2766.30
	Sehore	322.61	169.55	6078.87
	Burhanpur	294.59	113.14	2794.46
	Seoni	294.36	183.40	8284.73
	Indore	254.07	89.46	3567.95
	Ujjain	219.47	272.33	5608.86
	Bhopal	201.91	94.67	2473.47
	Datia	175.71	54.17	2780.90
	Shajapur	164.34	92.51	3206.70
	Narsinghpur	106.27	120.05	4913.47
	Hoshangabad	104.91	62.05	6526.19
	Harda	80.11	88.72	3162.16
	Bhind	46.02	221.72	4187.42
Total		**29643.98**	**11830.18**	**265770.23**
GUJARAT	Kutch	2590.70	5279.12	29788.32
	Surendranagar	757.71	981.03	7503.62
	Rajkot	699.60	324.55	6728.33
	Amreli	624.12	309.73	6303.96

(area in sq.km

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
GUJARAT	Morbi	442.67	331.12	4158.91
	Bhavnagar	436.67	633.08	5613.97
	Jamnagar	433.89	372.52	4782.01
	Dahod	400.00	588.46	2628.32
	Banaskantha	381.21	474.23	9781.61
	Chhota Udaipur	376.60	197.31	2875.81
	Mahisagar	335.87	181.30	1981.60
	Valsad	326.75	164.48	1841.87
	Sabarkantha	320.96	308.05	3574.10
	Narmada	320.12	152.79	2332.05
	Arvalli	287.99	145.20	2703.58
	Junagadh	250.17	128.67	4197.96
	Navsari	213.98	55.98	1640.45
	Bharuch	203.49	156.89	3684.10
	Ahmedabad	202.94	264.87	6599.12
	Gir Somnath	201.21	121.46	2167.51
	Vadodara	195.77	272.39	3597.98
	Dang	194.95	102.84	1459.12
	Botad	159.66	137.83	2182.53
	Panchmahal	158.26	224.37	2896.17
	Patan	154.35	559.25	5060.08
	Tapi	128.51	100.26	2885.42
	Mahesana	98.80	135.29	4180.93
	Kheda	97.45	54.41	3290.18
	Surat	87.04	104.69	3737.02
	Devbhumi Dwarka	68.77	267.29	2414.79
	Gandhinagar	59.07	101.50	1942.89
	Porbandar	52.80	66.85	753.38
	Anand	34.07	64.92	2621.67
Total		**11296.14**	**13362.73**	**147909.35**



(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
MAHARASHTRA	Ahmednagar	1835.36	512.52	14706.14
	Nashik	1783.02	795.76	12972.43
	Pune	1766.51	1845.92	12043.26
	Dhule	1759.36	368.68	5054.27
	Satara	1467.63	926.35	8112.82
	Beed	1072.43	469.64	9503.26
	Amravati	1012.40	716.18	10465.93
	Chandrapur	979.42	549.49	9769.51
	Yavatmal	917.01	832.40	11779.31
	Kolhapur	888.37	602.66	6167.94
	Jalgaon	811.53	603.69	10350.41
	Raigad	798.67	1223.71	4245.71
	Gadchiroli	796.32	355.65	13263.62
	Sangli	786.55	737.38	7032.07
	Solapur	729.92	931.02	13235.21
	Nandurbar	666.66	202.61	5017.47
	Nanded	655.61	469.85	9456.30
	Buldhana	640.59	565.24	8543.34
	Ratnagiri	583.39	962.94	6075.52
	Aurangabad	532.22	791.42	8792.20
	Hingoli	357.67	192.79	4139.80
	Palghar	355.18	400.98	3586.10
	Washim	350.46	196.99	4648.67
	Sindhudurg	327.20	633.18	3942.11
	Jalna	324.50	482.82	6962.93
	Nagpur	314.28	541.30	9052.67
	Thane	288.72	589.81	2781.72
	Parbhani	229.93	131.94	5976.04
	Gondia	228.98	444.57	4790.51
	Wardha	223.66	354.46	5731.27
	Osmanabad	221.78	747.33	6588.18
	Latur	207.63	218.22	6320.86
	Akola	189.02	146.34	5071.49
	Bhandara	123.48	158.31	3575.45
	Mumbai Suburban	2.59	14.47	270.52
	Mumbai City	0.00	0.00	41.01
Total		**24228.03**	**19716.58**	**260066.06**

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
ANDHRA PRADESH	Kadapa	2686.36	1293.91	11174.09
	Chittoor	2206.84	1523.9	11326.78
	Anantapur	2007.71	1275.4	15858.19
	Prakasam	1605.22	1324.15	14713.44
	Visakhapatnam	1228.41	1507.79	8617.91
	Nellore	1184.06	1114.48	10723.87
	Kurnool	978.91	788.93	15917.53
	Guntur	566.62	234.75	10548.77
	Srikakulam	547.65	380.22	5285.02
	Vizianagaram	402.49	512.28	4635.68
	Krishna	274.96	227.42	7872.86
	East Godavari	260.95	371.05	12783.3
	West Godavari	56.98	166.68	7485.85
Total		**14007.16**	**10720.96**	**136943.29**
KARNATAKA	Belgaum	870.00	234.78	12250.57
	Chitradurga	607.71	176.32	7637.54
	Uttar Kannada	550.87	133.86	9076.45
	Tumkur	507.11	303.17	9746.59
	Bangalkote	477.81	73.97	6021.38
	Shimoga	465.57	162.80	7849.42
	Gulbarga	455.63	65.86	10410.51
	Davangere	397.84	78.05	5447.05
	Raichur	394.05	43.98	7997.13
	Bidar	392.87	13.49	4994.54
	Bellary	384.58	266.89	7786.71
	Ramanagara	324.45	70.49	3115.14
	Chikkaballapur	322.44	451.67	3444.86

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
KARNATAKA	Hassan	308.04	126.92	6377.12
	Chikkamagaluru	269.36	109.53	6824.25
	Dakshina Kannada	260.58	32.84	4244.58
	Koppal	259.03	191.49	5126.06
	Kolar	254.97	259.29	3444.72
	Mysore	245.86	75.90	5979.96
	Udupi	242.62	58.29	3473.50
	Yadgir	239.71	98.69	4931.10
	Chamarajanagar	233.47	172.08	5233.87
	Mandya	229.06	108.96	4624.65
	Dharwad	180.78	53.62	4023.90
	Vijayapura	163.62	91.53	10218.40
	Haveri	159.51	56.55	4608.61
	Gadag	150.27	75.39	4429.16
	Bangalore Rural	110.18	91.38	2105.87
	Kodagu	103.26	54.78	3925.03
	Bangalore Urban	80.11	27.61	2076.60
Total		**9641.36**	**3760.16**	**177425.23**
GOA	North Goa	178.04	71.54	1386.70
	South Goa	131.55	82.10	1641.40
Total		**309.60**	**153.64**	**3028.10**
KERALA	Kasaragod	264.91	26.60	1639.82
	Palakkad	243.40	78.10	4133.51
	Idukki	202.96	371.88	4414.54
	Thiruvananthapuram	134.89	7.83	2015.88
	Kannur	116.99	34.33	2772.90
	Malappuram	95.65	47.92	3405.51
	Kottayam	51.90	42.37	2116.42
	Thrissur	48.31	35.22	2929.18
	Pathanamthitta	43.81	65.97	2532.83

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
KERALA	Ernakulam	41.07	21.57	2344.77
	Kozhikode	35.35	23.16	2261.46
	Wayanad	29.70	76.82	2011.52
	Kollam	23.27	22.23	2429.92
	Alappuzha	0.03	22.70	1393.36
Total		**1332.24**	**876.71**	**36401.63**
TAMIL NADU	Tiruvannamalai	436.63	501.28	5244.98
	Vellore	427.08	279.27	5325.64
	Erode	276.99	139.38	5333.91
	Krishnagiri	273.20	323.35	4516.09
	Tiruppur	270.22	401.86	4499.44
	Tirunelveli	258.41	736.75	5659.95
	Dharmapuri	238.81	247.81	4011.50
	Villupuram	228.93	954.87	5986.02
	Dindigul	225.32	650.96	5167.99
	Coimbatore	209.24	178.84	4314.32
	Kanchipuram	195.89	182.64	4065.01
	Salem	162.09	180.53	4895.12
	Thiruvallur	158.99	112.05	3028.46
	Thoothukkudi	139.16	444.88	4119.30
	Madurai	128.99	481.32	3098.32
	The Nilgiris	121.55	66.97	2343.15
	Virudhunagar	119.16	422.04	3680.61
	Theni	112.97	376.74	2367.02
	Tiruchirappalli	99.64	362.88	4049.66
	Kanniyakumari	98.54	62.92	1494.74
	Sivaganga	97.62	1156.82	2985.78
	Pudukottai	97.49	749.06	3808.42

(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
TAMIL NADU	Perambalur	89.54	223.23	1442.66
	Karur	80.28	150.54	2667.65
	Namakkal	63.75	142.27	3206.96
	Ariyalur	34.78	80.74	1823.89
	Cuddalore	34.67	168.44	3463.59
	Ramanathapuram	14.09	1350.81	2369.83
	Thanjavur	5.32	734.49	2647.05
	Thiruvarur	4.53	649.30	1569.52
	Nagapattinam	2.41	81.64	2422.12
	Chennai	0.66	0.40	174.76
Total		**4706.97**	**12595.08**	**111783.44**
PUDUCHERRY	Puducherry	1.49	4.20	268.33
	Karaikal	0.00	3.11	19.10
	Yanam	0.00	0.00	0.04
Total		**1.49**	**7.31**	**287.47**
TELANGANA	Bhadradri	1487.84	173.64	5235.16
	Nagarkurnool	763.06	258.95	5210.02
	Mahabubabad	675.43	256.12	2621.07
	Jayashankar	638.93	194.8	6267.17
	Adilabad	562.49	185.71	3144.11
	Nalgonda	553.37	493.56	6161.28
	Komarambhem	538.36	253.05	3671.15
	Kamareddy	535.13	366.5	2771
	Nizamabad	436.44	292.23	3430.12
	Sangareddy	413.44	316.62	3711.76
	Vikarabad	359.9	147.62	3089.94
	Mancherial	328.16	208.81	3348.29
	Medak	297.61	173.53	2296.57
	Mahabubnagar	295.44	224.97	4575.59
	Siddipet	251.7	264.4	3118.87
	Nirmal	246.62	214.26	3237.07
	Rangareddy	243.24	363.3	4362.04
	Khammam	227.63	113.37	4008.04

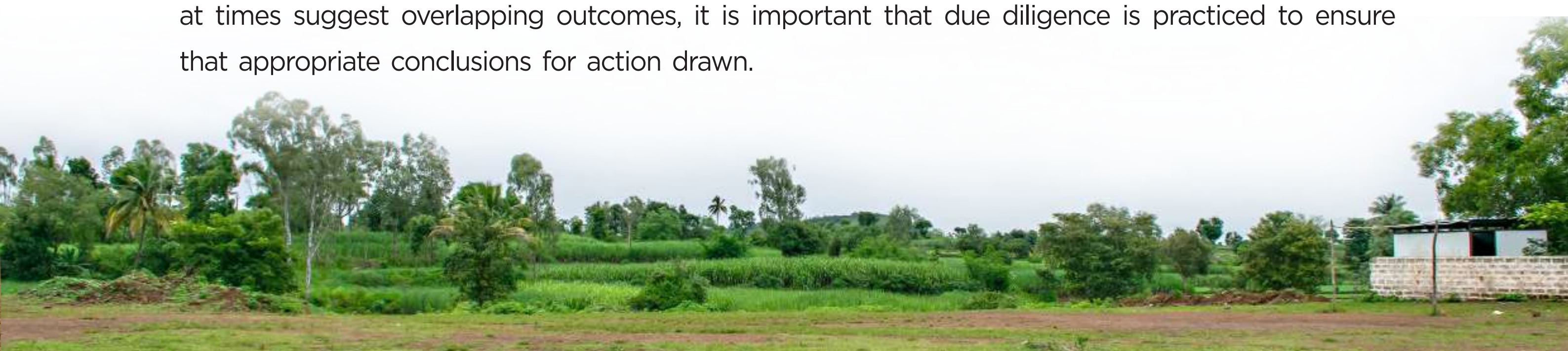
(area in sq.km)

State Name	District Name	Highly Suitable Area (HS)	Moderate Suitable Area (MS)	Others/Not applicable
TELANGANA	Yadadri	213	378.79	2666.01
	Jagtial	211.03	149.19	2491.27
	Peddapalle	182.63	101.88	1923.02
	Rajanna	182.36	95.91	1619.64
	Suryapet	182.35	141.25	3192.91
	Wanaparthy	147.56	102.96	1916.37
	Warangal (R)	132.96	118.32	1889.27
	Jangaon	107.2	249.97	1929.18
	Medchal	96.53	126.84	849.98
	Warangal (UR)	72.02	116.43	1106.22
	Karimnagar	70.23	214.26	1840.45
	Jogulamba	67.83	54.89	2440.05
	Hyderabad	1.43	3.43	209.95
Total		**10521.92**	**6355.56**	**94333.57**

GROW report and portal can prove to be a key tool in identifying wastelands suitable for greening through agroforestry, that can help the country in achieving its commitments and empowerment of the locals. These transformations of wastelands into more productive land use systems can help in meeting the demand for fodder, food and for substitution of wood imports, while, providing new income sources for people living in or around those areas. Under GROW project, scientifically wasteland areas are identified that are most likely to deliver successful sites with high-performance potential, in terms of adopting greening strategies based on agroforestry interventions and in terms of outcomes for restoration and agroecological amelioration.

The suitability area statistics mentioned in Table 13 serve as an operational baseline for the first level planning of state-wise requirements for greening and restoration of wastelands through agroforestry. Stakeholders including Government (Central/State), Research Organisation/Institution, Universities, Industries etc. can use the suitability data for initiating greening projects based on local needs by accessing maps and data at Bhuvan geo-portal *https://bhuvan-app1.nrsc.gov.in/asi_portal/.* Also, few agroforestry systems are proposed for wasteland in Annexure III.

This project interface provides a mechanism for user driven ranking and overlay analysis as well. With that application, a wide number of users can get customised outcomes. As the outputs can at times suggest overlapping outcomes, it is important that due diligence is practiced to ensure that appropriate conclusions for action drawn.



6 Way Forward: Scaling-up GROW in a Mission Mode

1. The GROW analysis presents a novel opportunity for advancement in agroforestry, especially in wastelands greening. Certain wasteland categories possess sufficient quantity and quality of soil organic content and water resources that can support agriculture and forestry plantations. The present study on mapping and prioritisation regime of wastelands can play an instrumental role in planning greening and restoration projects with agroforestry interventions. The prioritised area regime across various districts was based on geospatial analysis of 5 critical parameters i.e. Soil Organic Carbon, water proximity, Land Use Land Cover, Wastelands and Slope. In this project, limited ground-truthing was carried out in selected districts across different agroclimatic zones. With use of GROW datasets and portal by state agencies, researchers, universities and other stakeholders, their shared feedback and partnership, the database can be updated and improved at intervals. This will add robustness in GROW datasets. This study will open avenues for advancement in mapping and prioritisation of wastelands/other challenged regions with additional bio-geographical inputs at local or national level and advanced methods of multi-criteria evaluation.

2. To upscale agroforestry in wastelands, an improved mechanism for convergence of government schemes/programmes like MGNREGA, National Bamboo Mission (NBM), Rashtriya Krishi Vikas Yojana (RKVY), National Horticulture Mission (NHM), Sub-Mission of Agroforestry, Watershed Development Component of the Pradhan Mantri Krishi Sinchayee Yojana, National Biofuel Policy, Aspirational District Programme, One District One Product, State programmes, etc. can be developed.

3. Special provisions can be created to encourage participations of women, especially, rural women in restoration projects. There is evidence of success of women centric wastelands restoration and rehabilitation projects such as the model for Panchmahals, District of Gujarat State (*Sarin, M., 1993*). The Panchamahal project had raised awareness amongst rural women towards rehabilitation of degraded common land that enabled them to meet their needs for biomass in an economicaly and ecologicaly manner.

4. A hybrid scheme/programme implementation protocol can be developed to increase efficiency for adopting agroforestry in wastelands, as it involves diverse components viz. livestock, agriculture, forestry, land resources. Agriculture as well as land are state subjects and hence procedure and regulations may be streamlined for co-ordination amongst relevant departments to implement schemes/programmes. Forest on the other hand is in concurrent list. A hybrid implementation framework for achieving is suggested in figure 25.

5. India is a country with a strong institutional framework for protecting forests. The Forest

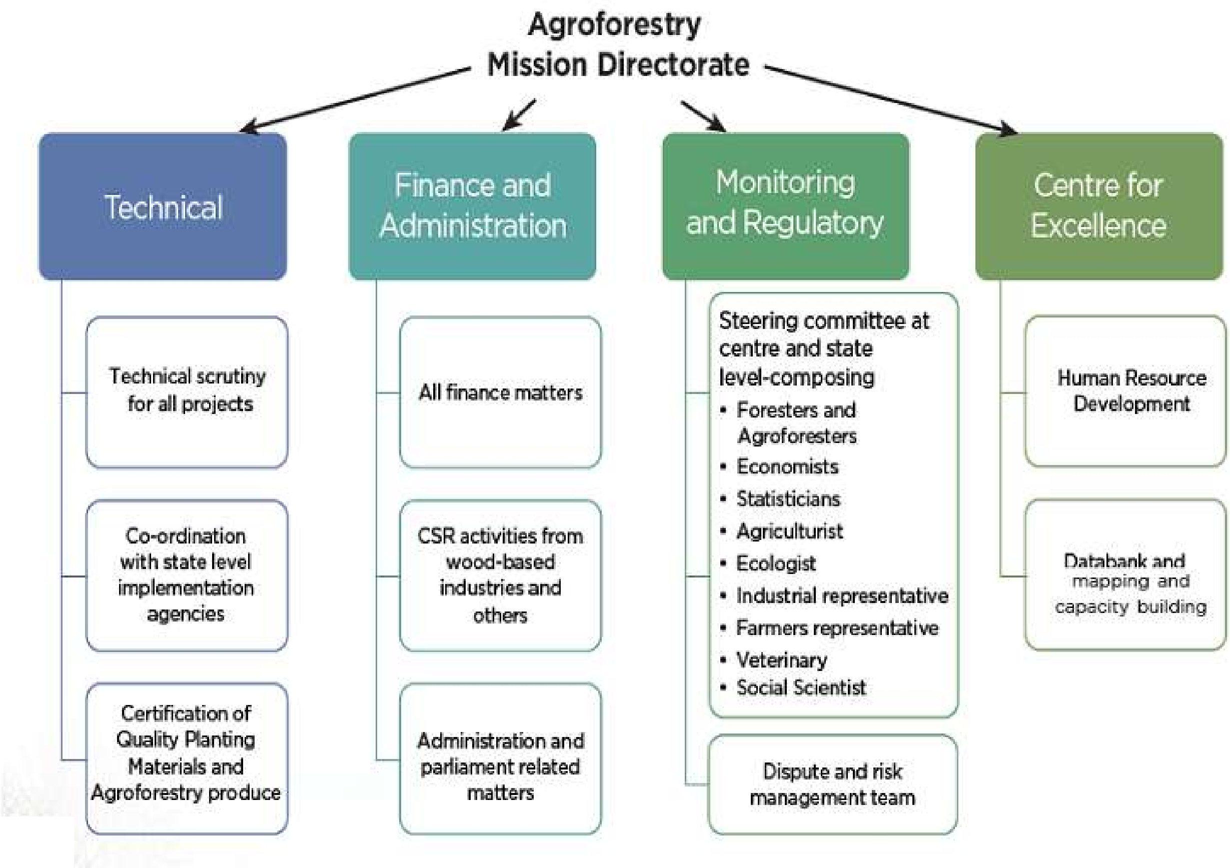


Figure 25. *Agroforestry Mission Directorate*

Department and the National Green Tribunal, are empowered by the Indian Forest Act (1927), Wildlife Protection Act (1972), Forest Conservation Act (1980), Forest Rights Act (2006), Environment Protection Act (1986) and many other forest regulations. States have enacted their own relevant acts and policies, specifically related to trees outside forests (TOFs), tree preservation and conservation and production of trees. As in many situations, trees on private lands/ farmlands are not fully regarded as property of the landowners which has been a bottleneck in marketing of trees grown as agroforestry. The relaxation provided by the States in forest rules esp. exemption in transit and felling permits for trees have encouraged tree plantation and agroforestry. However, the list of tree species are limited and varied extensively amongst States that restrict the scale of agroforestry adoption. Under the Sub-Mission of Agroforestry (SMAF), around 28 different species of trees are exempted from transit and felling permits by certain States. Also, prospective state-specific agroforestry tree species, developed agro climate-specific models by ICFRE supplemented with state-specific felling and transit regulations was published by Indian Council of Forestry Research and Education (https://moef.gov.in/wp-content/uploads/2023/08/FAQs-on-Agroforestry_Released_compressed.pdf) (Annexure-V). Exemption of more tree species from forest rules, ease in marketing of agroforestry goods can promote agroforestry across States.

6. Public private partnerships (PPPs) can be a beneficial model for scaling agroforestry in wastelands. The types of activities for which a PPP model could be implemented are timber production, non-timber-based forest products, fodder production, handicrafts, ecosystem services, food, Biofuel etc. The NAP (2014) also endorses to encourage agroforestry in

PPP models for barren community land/other non-forest waste lands that provides opportunities of economic returns and ecological services. Suitable agroforestry systems with multipurpose tree species can be planted in wastelands that are remunerative to the growers while providing environmental services. Bamboo based systems, energy farms (fuel plantations and shelterbelts), silvopastoral systems, agrosilvopastoral systems with plantation crops, fish culture in dammed sites, and the use of multipurpose trees etc. are other examples of models that can be adopted based on local needs.

7. Extension activities are the key for imbibing an integrated development of agriculture and forestry sector. This is important for penetration of agroforestry package of practices at grassroot level that can support in achieving SDG-1, 13, 16 targets for socio-economic and environmental sustainability. Concerted efforts in capacity building of extension personal of Agricultural Technology Management Agency (ATMA) and Krishi Vigyan Kendra (KVK) through crash courses and training modules on agroforestry practices in wastelands or degraded lands are required. The community awareness programmes in collaboration of SHGs, women SHGs, stewardship initiatives on agroforestry based land management systems, and forest product value chain systems etc. can be encouraged.

8. The Centre(s) for Excellence for Human Resource Deployment in Agroforestry and its monitoring can be established in selected ACZ. These centres can ensure imparting of capacity building training/modules, advanced research towards land degradation issues and stewardship over land. Strengthening agroforestry products marketing, value chain systems and access to quality planting material can promote adoption of agroforestry.

9. A national-level survey study to understand farmers' interests and socio-economic factors influencing the level of adoption of agroforestry can be conducted by the Central and State Governments.

10. A unified portal on agroforestry can be developed to enhance the scope of agroforestry adoption in the country. It will act as a one-stop solution for all agroforestry related information i.e programmes, state wise forest rule, updated list of tree species exempted from transits and felling permit, etc. required by various stakeholders. This will provide transparency, monitoring as well as ease of doing business.

7

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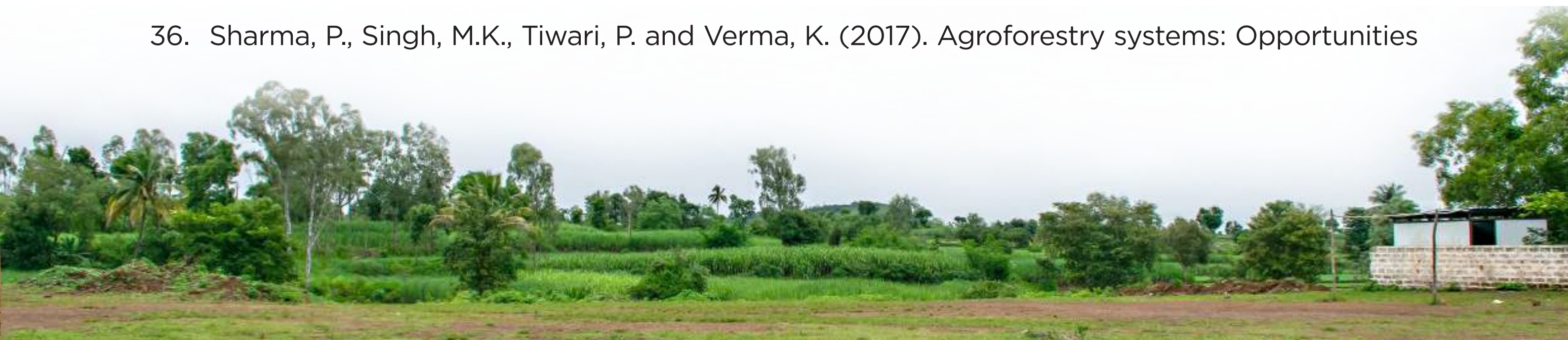

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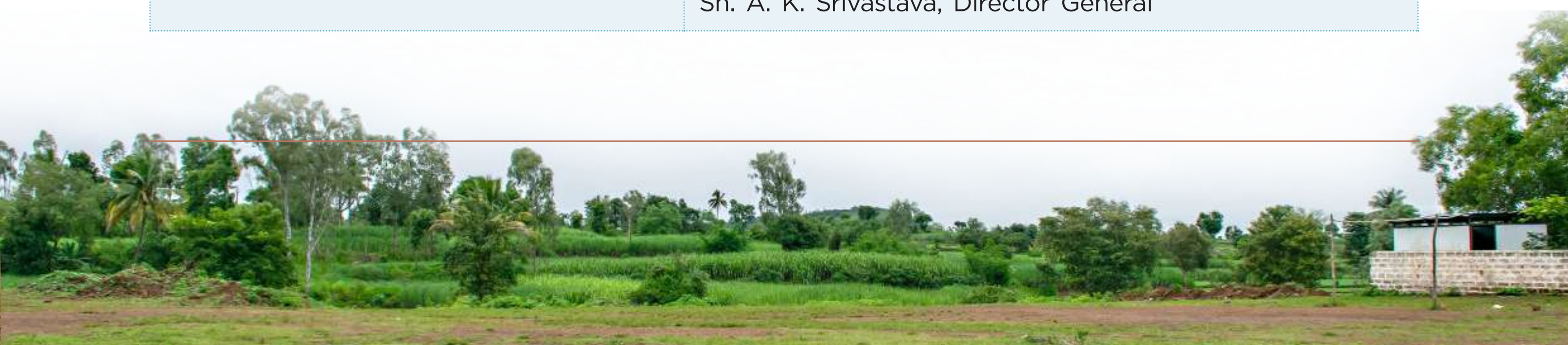

ANNEXURE-II: INSTITUTIONS SUPPORTED IN GROUND TRUTHING

S. No.	District	Institution/ Universities	Contributor
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S. No.	District	Institution/ Universities	Contributor
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S. No.	District	Institution/ Universities	Contributor
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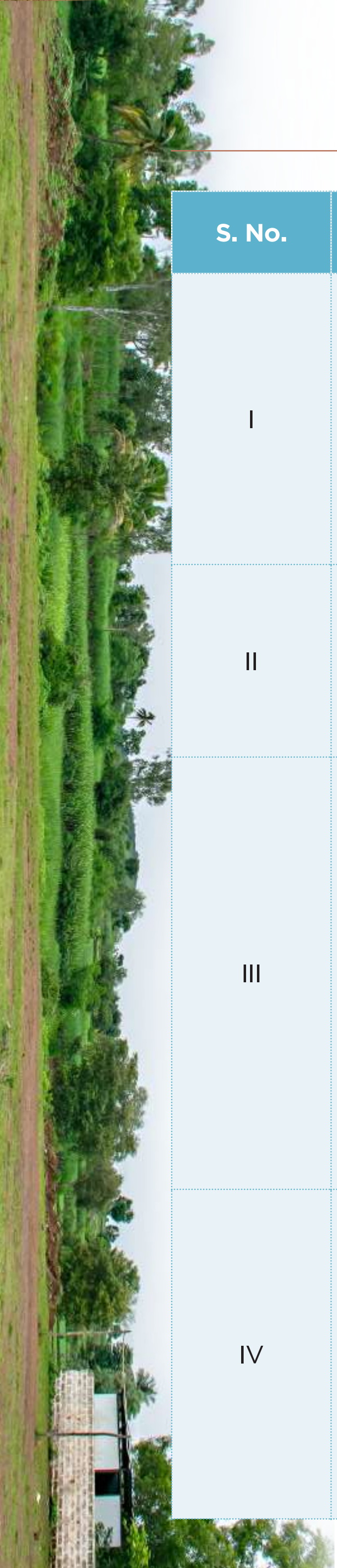
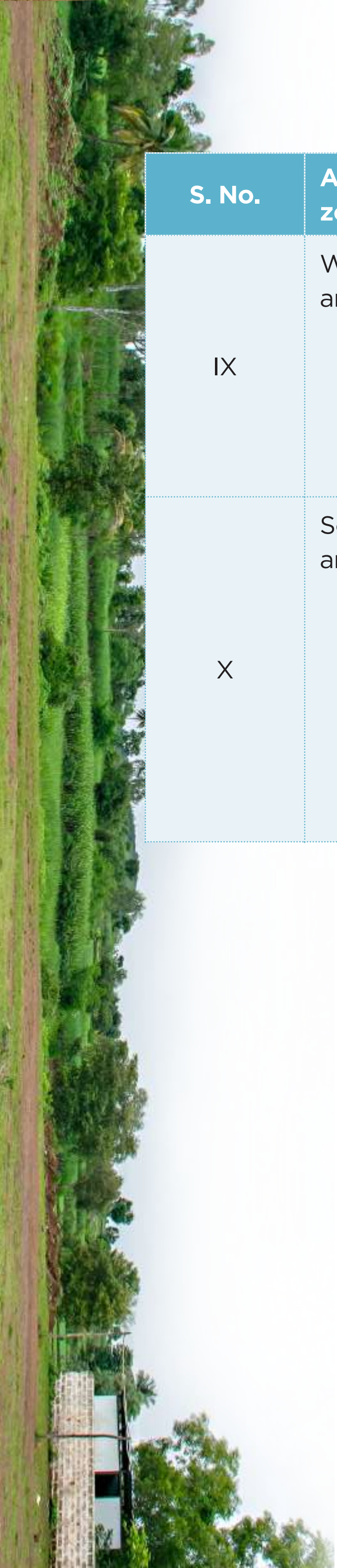
ANNEXURE-III: AGROFORESTRY SYSTEMS SUITABLE FOR WASTELAND GREENING IN DIFFERENT AGROCLIMATIC ZONES



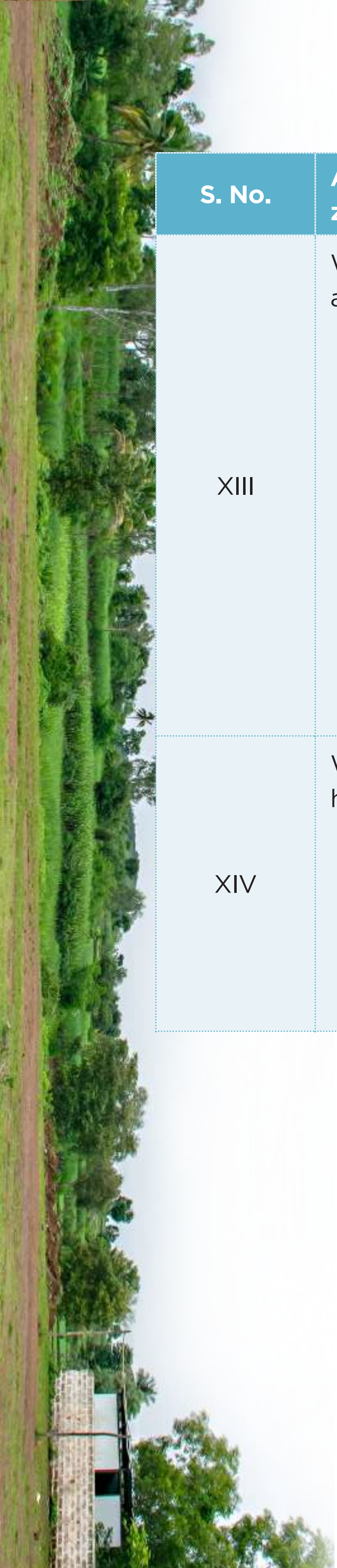
S. No.	Agro-climatic zones	State	District	Potential MPTS	Potential Agroforestry System
I	Western Himalayan division	Jammu & Kashmir (J& K), Himachal Pradesh and Uttarakhand	Jammu	*Populus deltoides, Salix alba, Melia azedarach, Toona ciliata, Grewia spp.*	1. Mulberry based silvipastoral system (Napier-Bajra hybrid/*Seteria*), 2. Apple based agroforestry system (fodder and agricultural crops like beans and vegetables), 3. Apricot based agroforestry system (Peas, Barley and mustard)
II	Eastern Himalayan division	Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, Tripura, West Bengal	Kamrup (Assam)	*Bamboo, Parkia roxburghii, Gmelina arborea, Arecanut, Acacia mangium*	1. Bamboo based agroforestry system (Pineapple, Banana, Papaya and lime)
III	Lower Gangetic plain region	West Bengal	Bankura (WB)	*Anthocephalus cadamba, Eucalyptus tereticornis, Acacia auriculiformis, Gmelina arborea, Tectona grandis, Zizyphus spp., Azadirachta indica, Dalbergia sissoo, Shorea robusta, Swietenia mahogoni, Diospyrus, Melanoxylon, Madhuca indica, Terminalia arjuna, D. latifolia, Pongamia pinnata,*	2. Kadamb based agroforestry system (Mustard, Lentil and Vegetables)
IV	Middle Gangetic plain region	Uttar Pradesh, Bihar	Banda, Sonbhadra (UP)	*Tectona grandis, Dalbergia sissoo, Acacia senegal, Acacia nilotica, Bamboo, Emblica officinalis, Azadirachta indica, Pongamia pinnata, Anogeissus latifolia, Melia dubia, Leucaena leucocephala,*	1. Teak based agroforestry system (Wheat, Gram, Sesamum or fodder crops) 2. Neem based agroforestry system (fodder crops) 3. Aonla-based agri-horticulture system

S. No.	Agro-climatic zones	State	District	Potential MPTS	Potential Agroforestry System
V	Upper Gangetic plain region	Uttar Pradesh	Lucknow (UP)	*Tectona grandis, Dalbergia sissoo, Anthocephalus cadamba, Bamboo, Emblica officinalis, Azadirachta indica, Pongamia pinnata, Terminalia arjuna, Melia dubia, Leucaena leucocephala,*	1. Aonla-based agri-horticulture system, Poplar-based agri-silviculture system, 2. Eucalyptus-based agroforestry system
VI	Trans-Gangetic plain region	Chandigarh, Delhi, Haryana, Punjab, Rajasthan	-	*Tectona grandis, Dalbergia sissoo, Anthocephalus cadamba, Populus spp, Bamboo, Emblica officinalis, Azadirachta indica, Pongamia pinnata, Terminalia arjuna, Melia dubia, Leucaena leucocephala, Casuarina equisetifolia*	1. Silvopastoral with *L. leucocephala* + Napier grass; and *Albizia amara* + grass+ stylo; Popular based agroforestry system (wheat and mustard)
VII	Eastern plateau and hill region	Chhattisgarh, Jharkhand, Madhya Pradesh, Maharashtra, Odisha, West Bengal	Sidhi (MP)	*Tectona grandis, D. sissoo, A. senegal, A. nilotica, A. cadamba, L. leucocephala, A. excelsa, G. arborea, Emblica officinalis,*	1. Amla based agroforestry system, 2. Boundary plantation of timber species
VIII	Central plateau and hill region	Madhya Pradesh, Rajasthan, Uttar Pradesh	Bikaner (Rajasthan)	*Acacia tortilis, D. sissoo, A. nilotica, P. cineraria, Azadirachta indica, Tecomella undulata, Pithecelobium dulci, Salvadora persica, Zyziphus nummularia*	1. *P. cineraria* + pearl millet/cluster bean/mothbean/medicinal plants/ groundnut (Agri-silviculture system) 2. Ber + kharif crops (Agri-horticulture)



S. No.	Agro-climatic zones	State	District	Potential MPTS	Potential Agroforestry System
IX	Western plateau and hill region	Madhya Pradesh, Maharashtra	Ahmednagar (Maharashtra)	*T. grandis, Terminalia paniculata, T. chebula, Madhuca indica, M. dubia, L. leucocephala, T. arjuna, Eucalyptus, D. sissoo, D. latifolia, P. pinnata, Bamboo spp.*	1. Bamboo based agroforestry system; Pongamia based agroforestry (Chickpea, Onion) 2. Boundary plantation of timber species
X	Southern plateau and hill region	Andhra Pradesh, Karnataka, Tamil Nadu	Erode (TN)	*Casuarina equisetifolia, Eucalyptus, Anthocephalus cadamba, Melia dubia, Bombax ceiba, Azadirachta indica, Leucaena leucocephala, Albizia lebbeck, Pongamia pinnata, Terminalia arjuna, Tamarindus indica*	1. Bund planting of *Albizia lebbeck*, *Ailanthus excelsa*, *Hardwickia binate* 2. Intercropping tapioca, groundnut, sesame with *E. tereticornis* Woodlots of *Ceiba pentandra* Silvipasture consists of *Acacia leucophloea* with fodder sorghum, *Cenchrus* spp. *Melia dubia* based Agroforestry system.

S. No.	Agro-climatic zones	State	District	Potential MPTS	Potential Agroforestry System
XI	Southern plateau and hill region	Andhra Pradesh, Karnataka, Tamil Nadu	YSR Kadapa (AP)	*Casuarina equisetifolia, Eucalyptus, Melia dubia, Dalbergia sissoo, Azadirachta indica, Albizia procera, Acacia nilotica, Azadirachta indica, Capparis deciduas, D. latifolia, Pongamia pinnata, L. leucocephala*	
			Chitradurga (Kar) Karnataka	*Tectona grandis, Melia dubia, Anthocephalus cadamba, Dalbergia latifolia, Casuarina equisetifolia, Acacia mangium, Acacia auriculiformis, Leucaena leucocephala, Sesbania grandiflora, Acacia nilotica, Pongamia pinnata, Terminalia arjuna, Eucalyptus, D. sissoo, P. pinnata*	Trees with fruit crops (*Mangifera indica, Manilkara zapota, Psidium guajava, Citrus limon*)
XII	East coast plain and hill region	Andhra Pradesh, Odisha, Puducherry, Tamil Nadu	Malkangiri (Odisha)	*A. mangium, T. grandis, Eucalyptus spp., C. equisetifolia, Sesbania grandiflora, G. arborea, D. sissoo, D. latifolia, P. pinnata, T. arjuna*	*Acacia mangium* based agroforestry (Maize, Ragi, Seasamum and Vegetables); Homegardens



S. No.	Agro-climatic zones	State	District	Potential MPTS	Potential Agroforestry System
XIII	West coast plain and hill region	Goa, Karnataka, Kerala, Maharashtra, Tamil Nadu	Coimbatore (TN)	*Casuarina equisetifolia, Eucalyptus, Anthocephalus cadamba, Melia dubia, Bombax ceiba, Artocarpus fraxinifolius, Azadirachta indica, Leucaena leucocephala, Albizia lebbeck, Hibiscus tiliaceaous, Calophyllum ionophyllum, Pongamia pinnata, Terminalia arjuna, Tamarindus indica, Prosopis juliflora, Acacia leucophloea*	1. Bund planting of *Albizia lebbeck*, *Ailanthus excelsa*, *Hardwickia binata* 2. Intercropping tapioca, groundnut, sesame with *E. tereticornis* Woodlots of *Ceiba pentandra* 3. Silvipasture consists of *Acacia leucophloea* with fodder sorghum, Cenchrus spp. 4. *Melia dubia* based agroforestry system
XIV	Western plain and hill region	Rajasthan	Jodhpur	*Prosopis juliflora, Acacia tortilis, D. sissoo, A. leucophloea, A. nilotica, P. cineraria, Azadirachta indica, Tecomella undulata, Pithecelobium dulci, Salvadora persica, Zyziphus nummularia*	1. *P. cineraria* + pearl millet/cumin/chilies/moth/cluster bean (Agri-silviculture system) 2. Ber + kharif crops (Agri-horticulture). 3. *C. ciliaris* dominant silvi-pastoral system

ANNEXURE IV: HELP DOCUMENT FOR "WASTELANDS GREENING WITH AGROFORESTRY - SUITABILITY MAPPING" PORTAL

1. User Roles

There are three user roles provided for login in the portal:

a. Central

  i. The user can visualise all states/districts data.

  ii. The user can view the statistics for State-wise, District-wise as well as Area to Class-wise for district level.

b. State

  i. The user can visualise all districts data of the user's authorised state.

  ii. The user can view the statistics for District-wise as well as Area to Class-wise for district level.

c. District

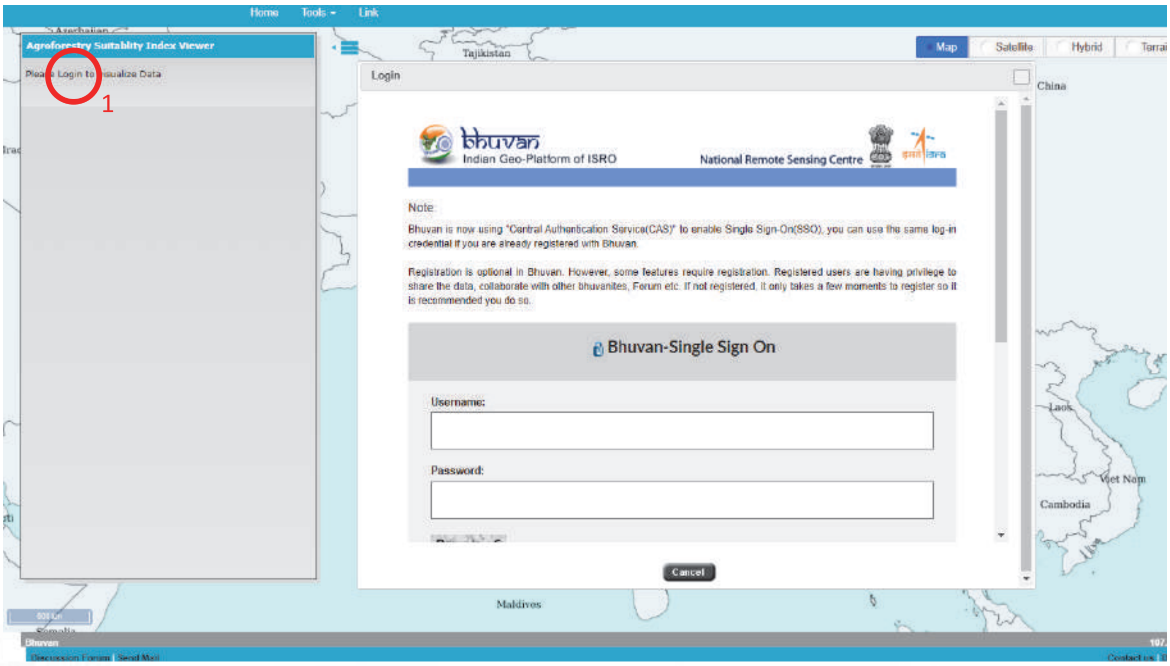
  i. The user can visualise only the district's data for which the user is authorized.

  ii. The user can view as Area to Class-wise for the district.

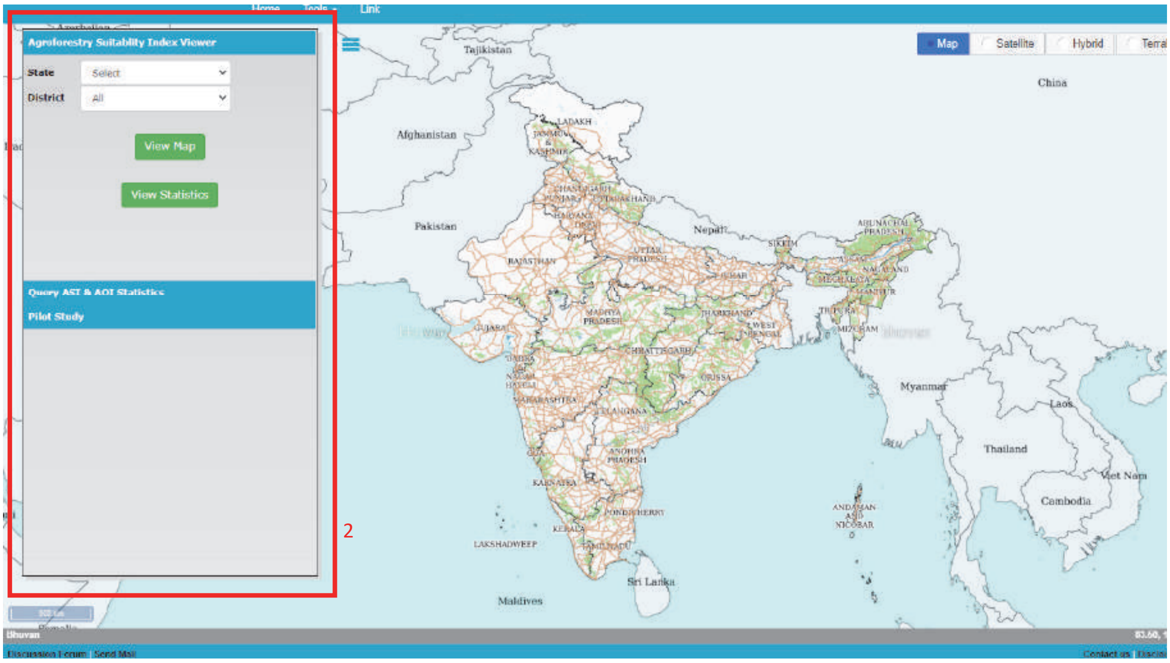
2. Login

The login page on the portal will look like given below.

1. Upon click on "Login" the login page appears on the screen.

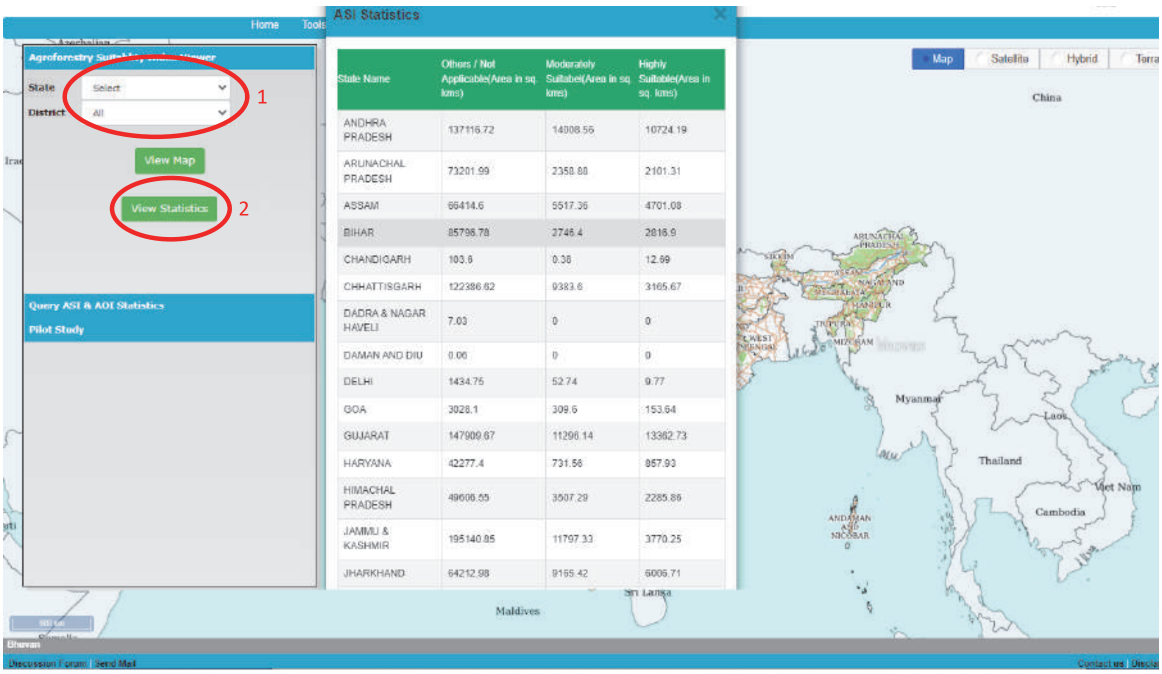


2. After the authorised user logins, the user will be able to view the Agro Forestry Suitability Map can be visualised. Along with this, user will be able to perform Query of ASI and fetch statistics for Area of Interest (AOI).



3. Visualisation of statistics data

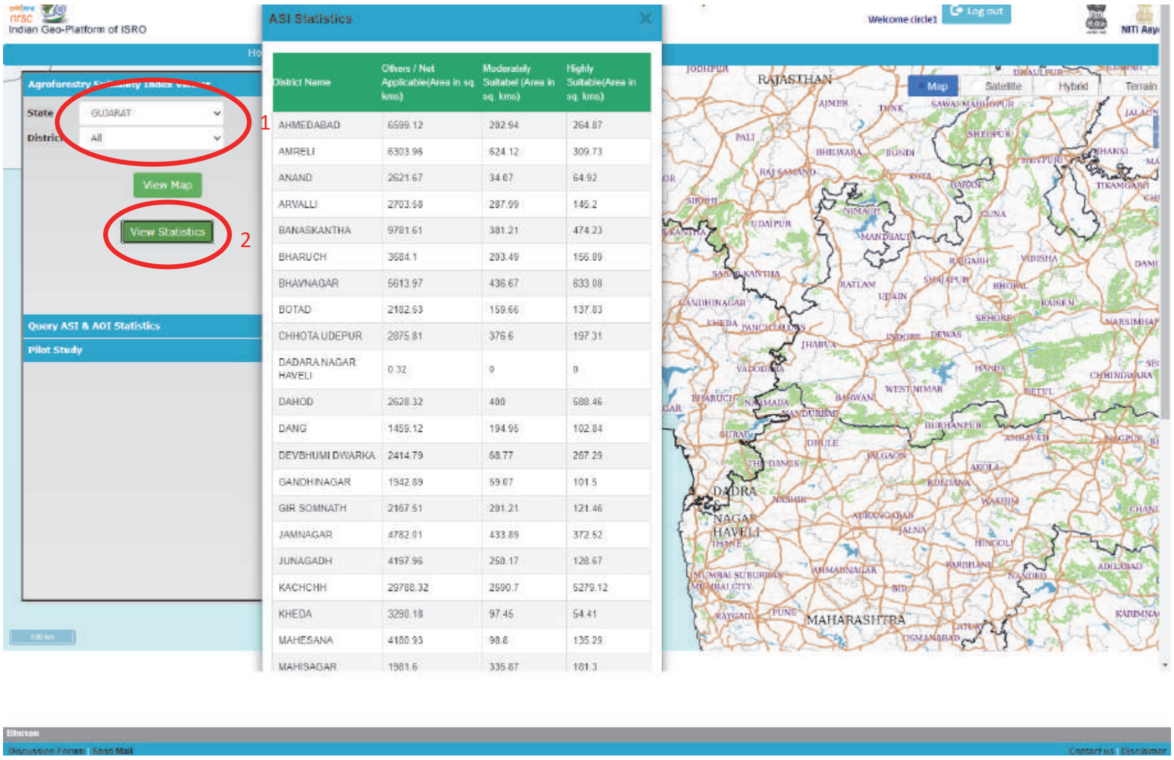
- For user with role as "Central", statistics of all states can be viewed.
  1. Without selection of any state/district pan-India statistics can be obtained.
  2. Click on statistics for viewing the statistics on pan India state-wise.



- For user with role as "State", statistics of all districts of the state the user belonging to, can be viewed.

1. Upon selection of any state and district kept as "All", the complete State's suitability area statistics can be obtained by clicking of "view statistics". Here Gujarat state is selected and district value is kept as "All".

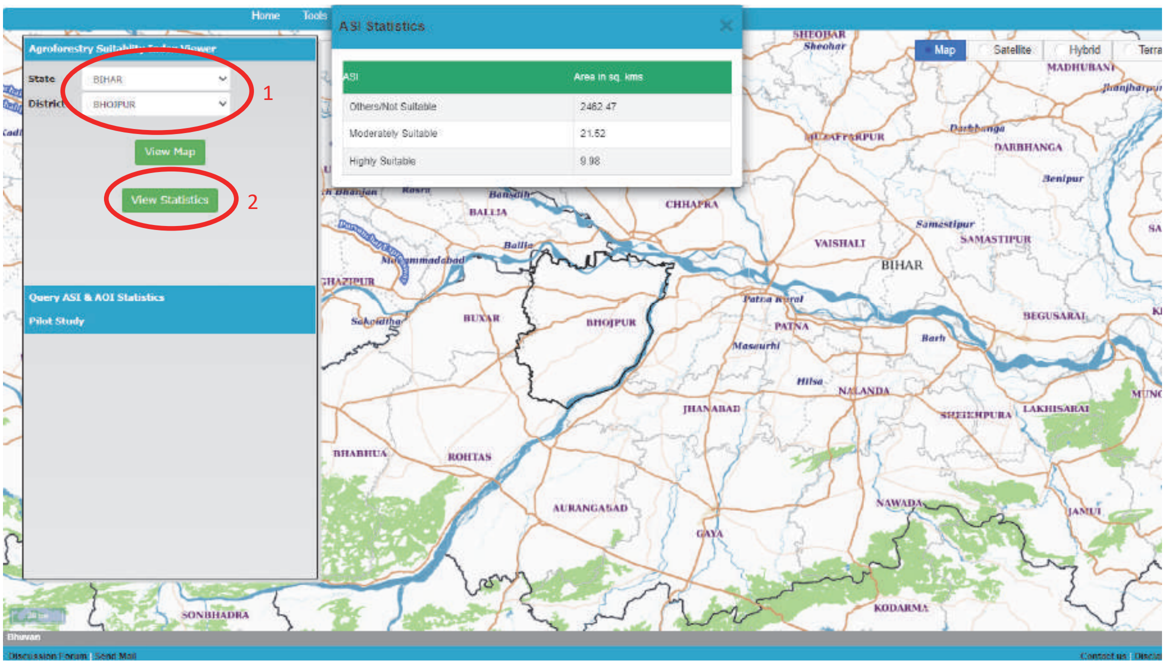
2. Click on statistics for viewing the statistics of the state district-wise.



- For user with role as "District", statistics of the district the user belonging to, can be viewed.

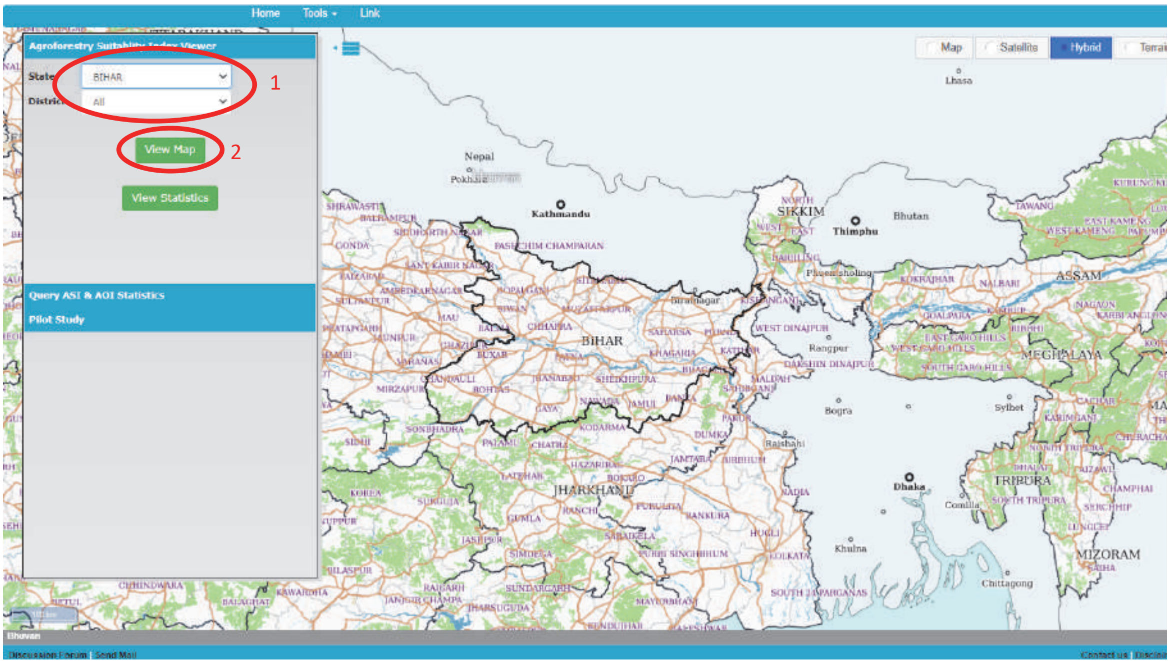
  1. Select any state and a district, and click "view statistics" to obtain the statistics under each suitability category in the district. Here Bihar state is selected and Bhojpur is selected.

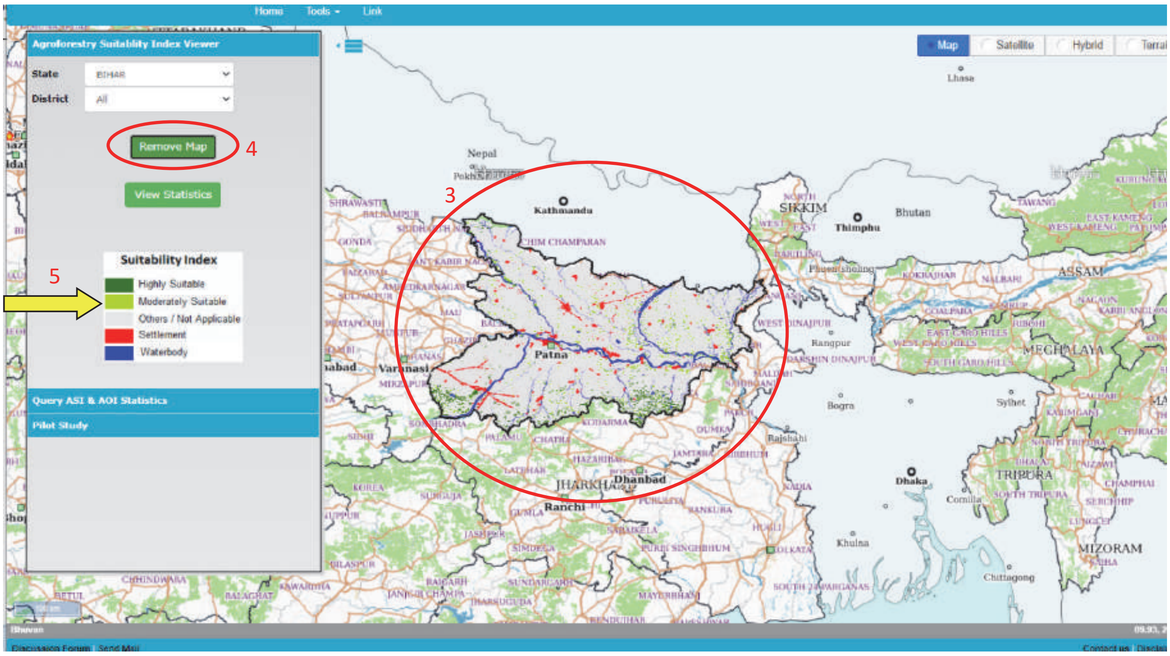
  2. Click on statistics for viewing the statistics of district class-wise.



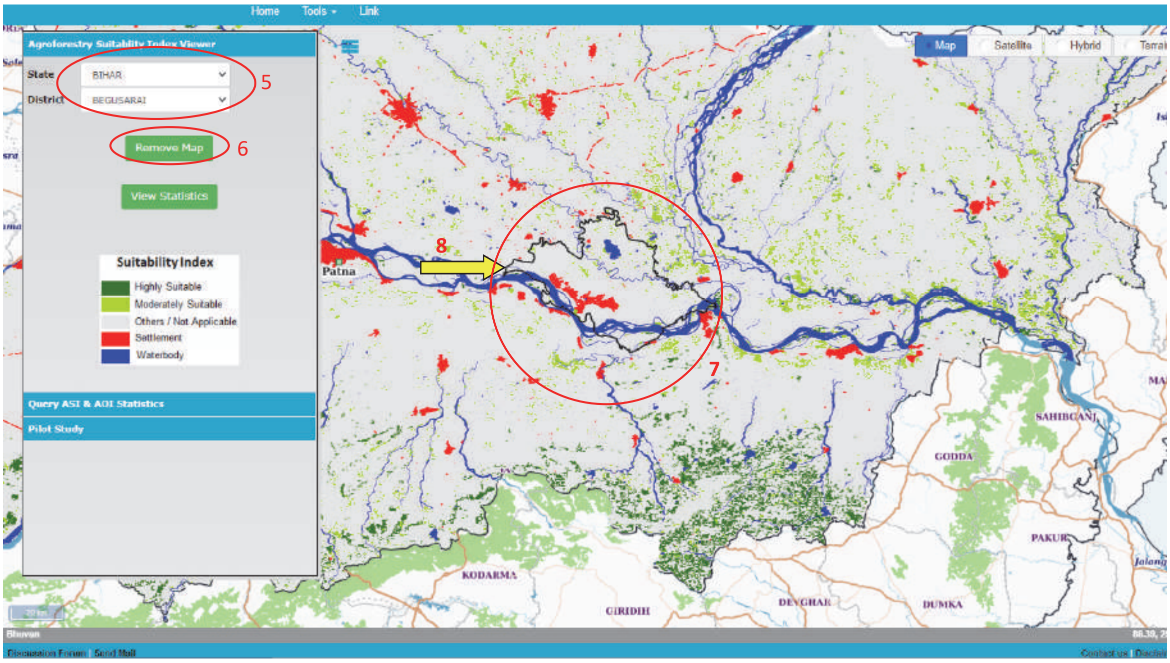
4. Map visualisation

1. For visualising state data, select a state from the dropdown and keep district value as "All". Here, Bihar state has been selected and district value is kept as "All".
2. Upon clicking on "View Map" button, agro forestry suitability map can be visualized on the map.
3. The agro forestry suitability map of Bihar state appears on the map.
4. "View Map" button changes to "Remove Map" button. Once the user clicks on "Remove Map" the map gets removed from the map.
5. Legend appears on the left panel.



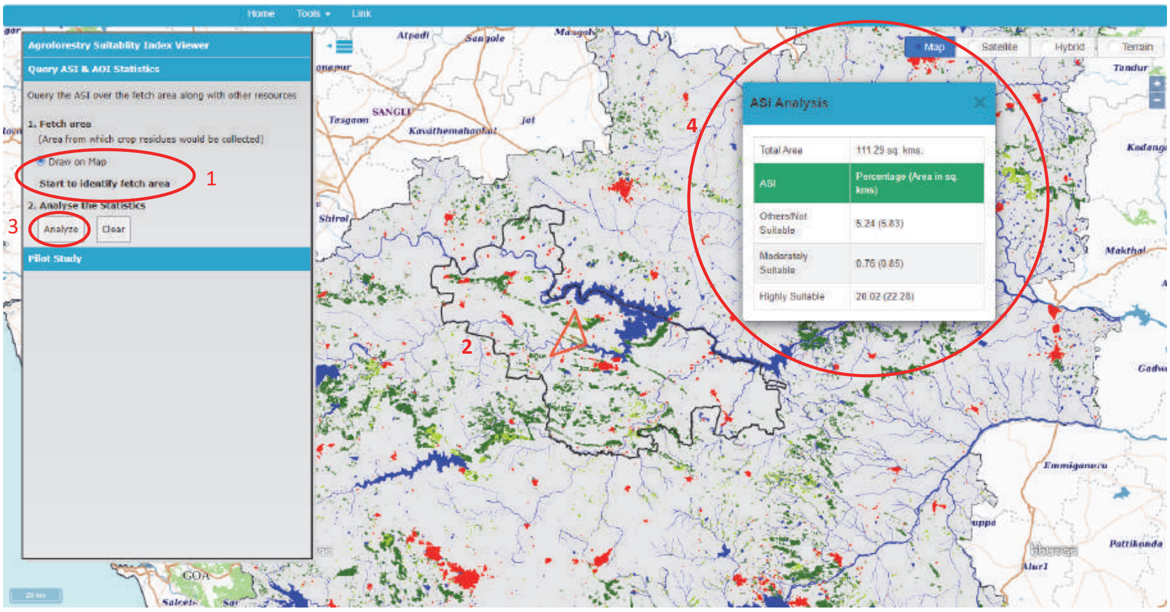


6. For visualising district data, select a state as well as a district from the dropdown. Here, Bihar state and Begusarai district has been selected.
7. Upon click on the "View Map" button, the agro forestry map appears on the map
8. "View Map" button changes to " Remove Map".
9. District boundary will be highlighted when map for district is to be visualised.



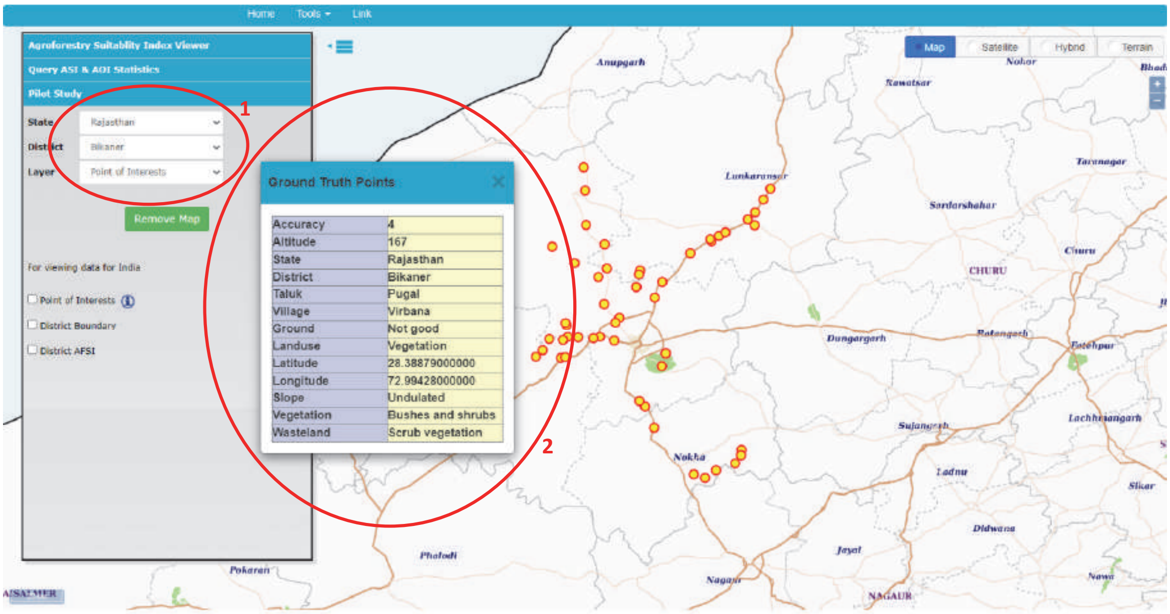
5. Statistics for Area of Interest (AOI) of the user.

1. User can draw AOI on the map. Upon clicking on "Start to identify fetch area", the user will be able draw an AOI upon the map. And to finish the drawing click on "Finish Drawing".
2. Below an example of AOI is drawn on the map.
3. Upon clicking on the "Analyze" button, the analysis is performed.
4. Once the analysis is over, it will be displayed in the popup.

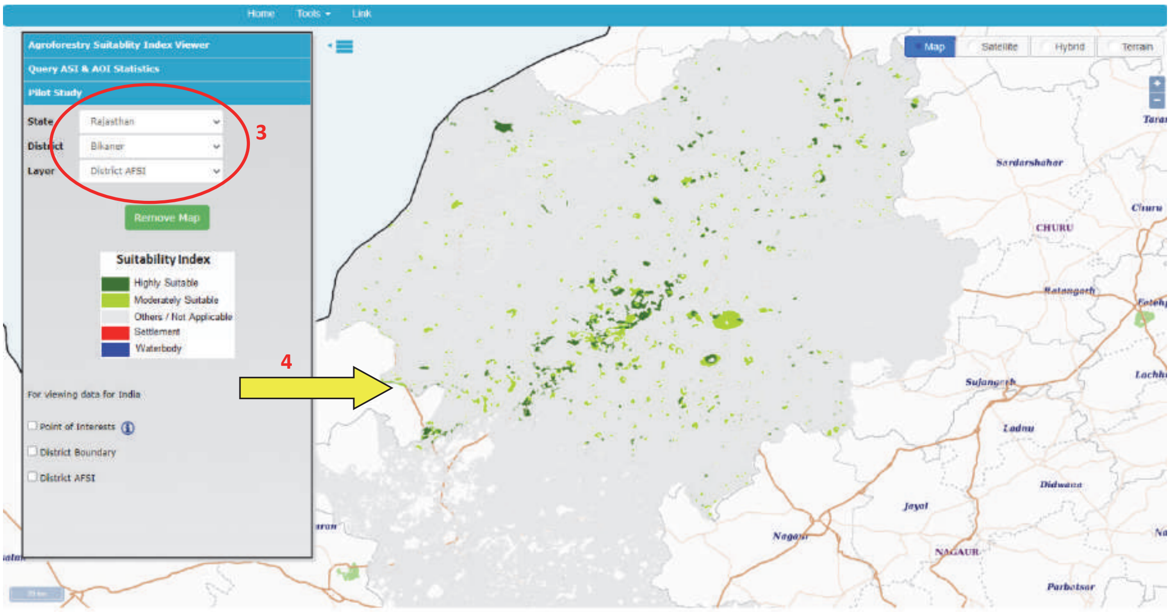


6. Pilot Study – This module is available for all authorized user roles.

1. State, district and layers (ground truth points, agroforestry suitability map, district boundary) can be selected for visualising the data. Here, Rajasthan state, Bikaner district and Point of Interests layer has been selected.

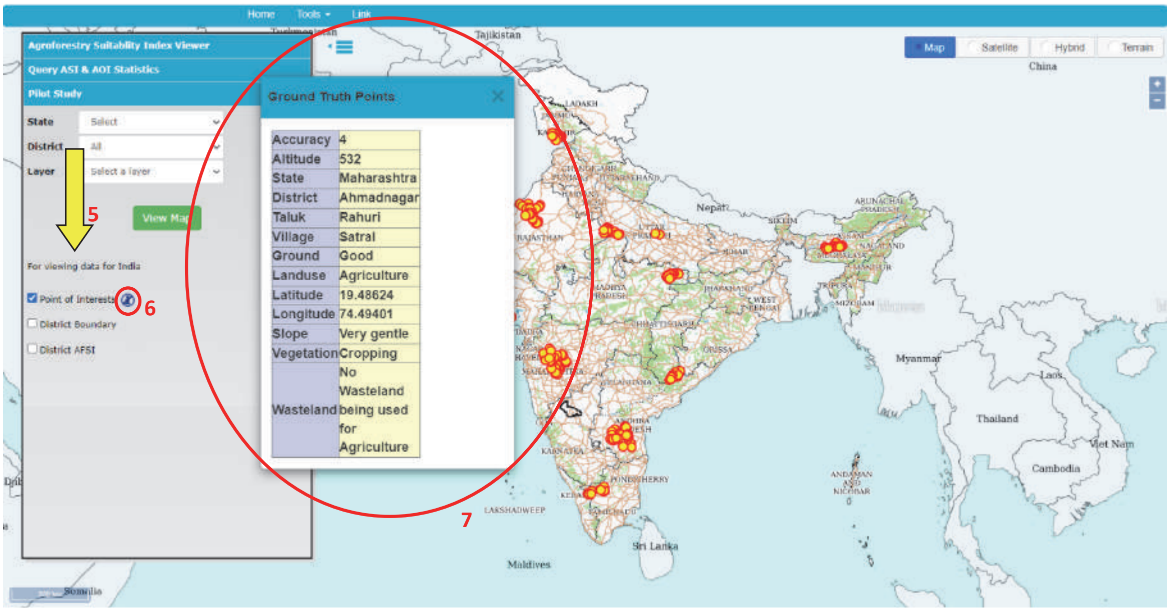


2. On click on the point data upon the map, information related to agro forestry suitability for that location comes in the popup.
3. Similarly, other layers also can be visualised. Here, Rajasthan state, Bikaner district and District AFSI layer has been selected.
4. The agroforestry suitability map as per pilot study will appear on the map.



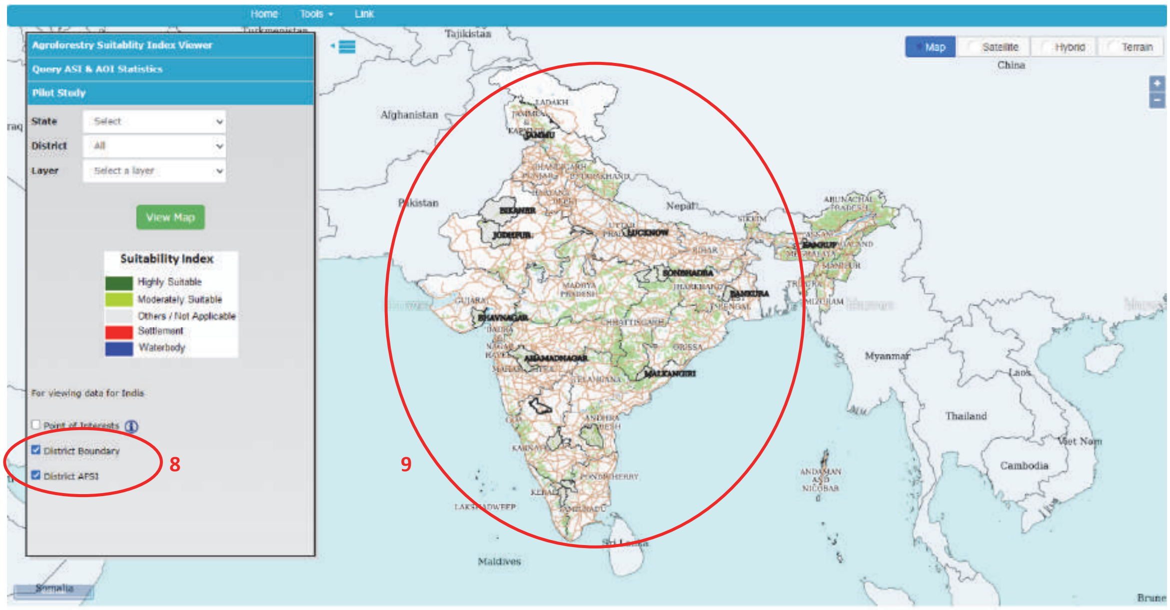
5. Complete data for the layers for the pilot study can also be viewed by selecting the check boxes.

6. On click of "i" button; user can enable viewing information on click in the ground truth point.



7. Information of the point data appears as a popup.

8. Similarly pan India agro forestry suitability pilot study maps can be visualised by clicking on the check box.



9. Agroforestry suitability maps user pilot study appears on the map.

ANNEXURE - V GREENING AND RESTORATION OF WASTELAND (GROW) - SUITABILITY MAPPING

S.No.	Name of States/UTs	Status
1.	Andaman & Nicobar Islands	• Transit Permit is required for transit of forest produce in A & N Islands and no exemption for any *sps.* has been provided in the Regulation.
2.	Assam	• No Felling Permission (FP) is required for home grown bamboo. • No Transit Pass (TP) is required. Certificate from Gram Panchayat is required.
3.	Andhra Pradesh	• No FP. All spp exempted. • No TP, All spp exempted.
4.	Arunachal Pradesh	• No FP is for bonafide use except commercial use • No TP is required except commercial and other use
5.	Bihar	• Tree *sps.*currently exempted from Transit Regulations (as on 27.02.2009) Poplar, Eucalyptus, Kadamb, Gamhar, Mango, Litchi, Toddy palm, Khajur, Bamboo sps (Except Dandrocalamus strictus), Semul. • Some more *sps.* are in process to be exempted.
6.	Chandigarh	• No interstate transit permit is being issued by Forest Department as no forest check posts have been established. • The permission for felling of trees on private /non-forest land is given only in two cases, i.e either for any development work or trees are dangerous to human life or property. As such no tree *sps.* is exempted under this.
7.	Chhattisgarh	• Timber *sps.* that have been exempted from transit regulations are Poplar, Casuarina, Su-babul, Israili babul, Vilayati babul, Manzium , Nilgiri
8.	Delhi	• Since land is a premium commodity in Delhi, farmers generally do not practice agroforestry here. Sps. like Poplar, Kikar and Eucalyptus have been proposed for exemption. So FP is required.
9.	Goa	• **No FP.** Omitted Bamboo from the definition of tree. • No TP. All types of bamboo grown in private areas (non forest areas) will not fall under the purview of forest produce and hence transit permit for bamboo felled from private areas are exempted
10.	Gujarat	• Nilgiri, Subabul, Saru, Champa, Laxmanfal, Ramfal, Sitafal, Asopalav, Pendula, Nagkesar, Nagchampha, Falsa, Ingorio/Angarea, Kamrakh, Kadhipatta, Limbu, Chikotru, Bijoru/Turanj, Narangi, Mausambi, Maharuk, Rukhdo, Motoarduso, Limdo,Neem, Bakan, Bakan, nim, Irani nim, Nimbara, Limbara, Mahanim, Mahogony, Bordi, Bor, Khati bor, Ghulbor, Liehi, Lilchi, Aritha, Aritha, Amba, Kadvo Saragavo, Saragavo, Agathin, Segto, Agastin, Desi Baval, Goras amlili, Gando baval, Ganda baval , Botlle Brush, Jamphal, Dadam, Chikoo, Boralli/Mursal/Vakal/ Varasd/ Bakul, Saptaparni, Champo, Safed champo, Liar/ Nani/Gundi/ Nagod, Nirgund/ Nargundi, Lingur Nirgudi, Ambla, Fanas, Pipli/papri, Shetur, Haredo, Harero, Poplar, Golden cane palm, Oilplam

11.	Himachal Pradesh	• Kala Siris/Ohi/Sriris, Kachnar/Karial, Safeda, Kimu/ Chirmu/Shahtoot/ Tut/Mulberry, Poplar, Indian Willow/Biuns,Kuth, Kala Zira, Japanese She-hoot/paper mulberry, Paik/Koi/ Kosh/Kunis/ Kunish/Nyun, Khirk/ Khad-ki, Darark/Bakin, Fagoora/ Phagoora/Tiamble/timla/ tirmal/anjiri/ clus-ter fig/goolar, Toon, Jamun, Teak/Sagun/Sagwan, Arjun, Semal, Shalmaltas, Bihul/Beul/Bhimal/Bhiunal/Dhaman, Paza/Padam, Kamala/ Raini/Rohan/Rohini/Sinduri, Aam (Mango wild variety), Rishtak/Ritha/ Dode
12.	Haryana	• Some *sps.* are exempted from regulations under Punjab Land Preservation Act, 1900. These are Eucalyptus, Poplar, Ailanthus, Eucalyptus and Acacia tortilis. There is no transit rules applied for timber sps.
13.	Jharkhand	• Eucalyptus (Safeda), Poplar, Casuarina, Maha Neem, Baken Kadmb, Subabool, Silver Oak, Israeli Babool Vilayati Babool, Babool, Plam, Ber, Munga, Mulberry, Guava, Nimboo, Santra, Mosambi, Ashok.
14.	Jammu & Kashmir	• Kikar, Bel, Siris, Champ, Neem, Malugarh, Kakrad, Palas, Amaltus/ Karangal, Sisoo/Tali, Dhamman, Nili Gulmohar, Akhrot (khod), Kehbal jhingar, Baronkal, Bilati Kikar, Safeda, Poplar, Robin, Chitta banddha, Rondu banddha, Sagwan, Arjun, Beheda, Tun/Toon, Bana, Dhoi.
15.	Karnataka	• Acacia hybrid, Acacia mangium, Tree of Heaven, Rain tree, All Cassias except Golden Rain tree, Cashew, Christmas tree, Arecanut, Casuarina, India Beef wood, Lemon, Ornage, Coconut, Coffee, Mayflower, Indian coral tree, Eucalyptus, Glyceridia/Quick stick, Silver Oak, Rubber, Jacaranda, Sausage tree, Subabul, Umbrella tree, Sapota/Chikoo fruit, Melia, Indian Cork tree, Drumstick, Mulberry, Curry leaf tree, Peltoform, Purple bauhinia, Pagoda tree, False Ashoka, Guava, Sesbania, Hummingbrid tree, Paradise tree, African tulip , Tabebula, Trumpet tree.
16.	Kerala	• **Species for Ply wood** Vellappine, Kurangandi/Narivenga/Mundani, Karakily/Kalpine, Kulamavu/Kulirmavu/Ooravu, Pali/Palendinjan, Kulavu, Red Cedar, Thellipine/Undapine, Poon/Punna/Punnappa, WVediplavu/ Mullampali, Charu, Pothundi/Perunthondi, Cheeni, Nedunar, Vallabham/ Varangu, Chorapine, Chemmaram, Champakam, Cherukonna, Mulliam, Neeramruthu, Peenary, Kumbil, Veembu, Gnavel, Kattunelli, Vakka, Thavala, • **Species for Matchwood :** Aspin/Kanala/Nasakam, Elavu/Poola, Pala/ Mukkampala, • **Species for Bobbin wood :** Vellakil, Manjakdambu, • **Species for pencil wood:** Venkotta, Perumtholi/Poochakadmbu, Attuthekku/Cadambu, • **Species for packing wood:** Kara/ Bhadraksham, Amazham, Aval, Arayanjili, Kalaveppu/Malaveppu, Vatta/Uppathi, • **Fire wood :** Palvu (Jack), Parankimavu (cashew), Kattadi (Casuarina), Poovarasu (Poovarasu), Mavu (Mango tree), Puli (Tamarind tree), Nattupunna (Nattupunna), Aanjili (Aanjili), Vaka (Vaha- species), Poovam, (Poovam), Konna, Thanni (Thanni), Uthi (Uthi), Aal Jatikal (Ficus species), Matti, Murukku, Elappu (Iloia) and Kodamuli (Koadampuli).
17	Lakshadweep	• No FP. IFA or any Forest Act is not enforced in Lakshadweep. Also, Bamboo is not grown anywhere in Lakshadweep. Therefore amendment in IFA or any Forest Act does not arise in this state. • No TP.

18. Madhya Pradesh	• Neelgiri, Casuarina , Poplar, Subabul, Israili Babul, Vilayati Babul, Australian Babul, Babul, Khamer, Maharukh, Kadamb, Cassia siamea, Gulmohar, Jacaranda, Silver oak, Plam, Ber, Mulberry, Katahal, Amrood, Nimbu, Santra, Mussambi, Munga, Molshri, Ashok, Putranjiva, Imli, Jamun, Mango, Saptparni, Kaitha, Jungle Jalebi, PetItaphorum, Neem, Bakain, Sissoo, Karanj, Palash, Safed Sirus, Pipal, Bargad, Gular, Rubber, Semal, Kapok, Chirol, Gliricidea, Rimjha, meithi Neem, Gurhal, Jasoun, Conifers, imported Timber Species.
19. Maharashtra	• Nilgiri trees, Babhul, Subabhul, Prosopis, Ashok, Drumstick, Sindi, Orange, Chiku, Bhendi, Acacia, Poplar, Lac, Casuarina equisetifolia, Rubberwood
20. Meghalaya	• Meghalaya being a Hilly state, there is no Agroforestry at all, since percentage of states land covered by agriculture is very small. If any blank interstate movement o timber is permitted, state will lose meagre resource of forests under control of the State Government.
21. Mizoram	• Kothal, Tung, Eucalyptus spp., Mulberry, Neem, Rubber tree, Imli, Silver Oak, Subabul, Mango, Guava, Coconut, Citrus, Areca nut
22. Manipur	• No Felling Permission (FP) is required • No Transit Pass (TP) is required for home grown within state. • TP is required outside state
23. Nagaland	• Aam, Korei, Walnut, Neem, Alder, Manipur Sim, Kadam, Hollock, Khokan, Teak, Gamari
24. Odisha	• Bada chakunda, Sana Chakunda, Jhaun, Sliver Oak, Patas/Nilgiri, Sunajhari/Acacia, Subabul, Kaitha, Ambada, Batapi, Oau, Sajana, Karamanga, Sahada, Plam tree, Debadaru, Bhersunga, Gohira, Giliricidia, Paladhua, Coconut
25. Punjab	• "Forest produce" shall specifically mean timber (converted or otherwise), firewood, charcoal, katha and resin, but shall not include Non Timber Forest Produces (NTFPs) like bamboos and agro-forestry species such as Populus spp., Eucalyptus spp., Melia azedarach (Drek), Morus alba (Mulberry), Leucaena leucocephala (Subabul), Casuarina spp., Grevillea robusta (Silver Oak), Acacia mangium, Melia dubia (Malabar Neem), Prosopis cineraria (Khejri), Salix alba (Indian willow), Gmelina arborea (Gamari) or any other species declared by the State/authorized agency as agro-forestry species from time to time.
26. Rajasthan	• Casuarina, Australian babul, Khamer, Caaia Siamea, Gulmohar, Jaccaranda, Silver oak, Plam, Ber, Mulberry, Katahal, Amrood, Sehjana, Molshri, Ashok, Putranjiva, Imli, Jamun, Saptarni, Kaitha, Jungle Jalebi, Petaphorum, Bakain, Karanj, Safed Sirus, Semal, Kapok, Churel, Mithi neem
27. Sikkim	• No permission for felling of trees on any private or Forest land has been granted.If anyone wishes, he have to apply to Block Officer.
28. Tamil Nadu	• Mesquite, Casuarina, Subabul, Palmyrah, Dadops, Umbrella thom, White Back Acacia/Panicled Acacia, Maharuch, Maharukh/East India Walnut/ Siris, Cashew, Kadam, Jack, Neem/Margosa, Red silk cotton/Kapok, Sappan, Cassia, white silk cotton tree/kapok, Sissoo, Coral tree, Eucalyptus, Gamari, Rubber, Sea Hibiscus, Mohua, Mango, Persian Lilac, Malabar Neem, Morinda/Suranji, Manila/Tamarind, Pongam/Indian Beach, Rain tree, Mahogeny, Jamun/Indian cherry, Tamarind, Esperanaza, Indian Portia tree/Indian Tulip, Red Cedar/Toon, Silver Oak.

29. Telangana	• Eucalyptus, Neelagiri, Jama oil, Casurina, Sarugudu, Sarvi, Saru Poplar, Subabul, Israeli Babool, Seema, Thumma, Australian babul Gummaadi teak, Pddamanu, Kadamb, Seema/ Tangedu, Jacaranda, Silver oak, Regu, Ber Mulberry, Jama, Guava, Orange and related species, Mungam, Ashok/Naramamidi, Mahaputrajivi/Putrajeevi, Edakulapala, Turakavepa, Kanuga, Rubber/ Seemamarri, Tella Tumma , Gliricidea/ Seema/Kanuga, Tella Tumma, Kaivepaku, Mandara, Conifers (chir, Kail, Deodar, Pine species), Tati, Tadi, Palmyrah, Sapota, Coconut, Kobbari, Tenkai, Cashew, Jeedimamidi, Semma, Chinta, Raint ree, Nidragannreru, Mango, Mamidi, Panasa, Jackfruit.
30. Tripura	• Tree species like Mango, Litchi, Drumstick, Guava, Rubber and bamboo are exempted from extraction from private land. Bamboo sps. have been exempted from transit permits both from Private and Forest land. Transport of Timber is also permitted.
31. Uttar Pradesh	• Aru, Casuarina, Jangal Jalebi, Poplar, Babool, Vilayati Babool, Rabania, Siris, Su-babool, Kathber, Jamun, Eucalyptus, Dhak Palas, Paper Mulberry, Ber, Sainjana, Shah toot, Mango (Desi, Tukhmi or Kalmi)
32. Uttarakhand	• 27 tree species have been exempted from the provision of Tree protection Act, 1976. This includes fodder and small timber species that are being used in small scale industries, animal husbandry, agricultural implements and allied activity. Other 07 tree species like Walnut , Neem, Oak , Ficus (Peepal and Banyan) and Deodar have been placed in the restricted category and felling permission can be granted only in case of dead or dangerous trees.

Source: *FAQs on Agroforestry. Published by Indian Council of Forestry Research and Education on 16-08-2023.*

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