Preparing Decision Support Tool - Region and Context Dependent Afforestation for Water Conservation and Run-off Avoidance

Submitted to
ACT - Climate Change Innovation Programme

Submitted by:

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Table of Contents

List of Figures

List of Tables

Acknowledgements

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ABBREVIATIONS

ACT	Action on Climate Today
ADSS	Afforestation Decision Support System
ANSI	American National Standard Institute
API	Application Programming Interface
ART	Android Run Time
AWS	Amazon Web Service
CCIP	Climate Change Innovation Programme
CGWB	Central Ground Water Board
DEM	Digital Elevation Model
DFID	Department for International Development –UK
EC2	Elastic Compute Cloud
GIS	Geographic Information System
GoM	Government of Maharashtra
GUI	Graphic User Interface
HAL	Hardware Abstraction Layer
HDD	Hard Disk Drive
IFZ	Integrated Forest Z score
LULC	Land Use and Land Cover
MFD	Maharashtra Forest Department
MVC	Model View Controller
NRSC	National Remote Sensing Centre
SRTM	Shuttle Radar Topographic Mission

Executive Summary

Maharashtra, a rapidly developing state is experiencing deficient and erratic rainfall patterns. Water overuse, pollution and vegetation changes are progressively intensifying over the years. Taking the cognizance of the situation, the Government of Maharashtra (GoM) has now been focussing on afforestation programmes on public and private lands, and land areas reserved for community purposes. The GoM has taken up a plantation program of 50 crore trees across the State to increase the forest cover from the current 20% to 33% of Maharashtra's land area by 2019 and improving the ecosystem-based services with emphasis on water conservation.

With a view to this, a project was taken up by IORA Ecological Solutions under the ACT CCIP programme. The main purpose of this project is to develop a region - and context - based decision support tool (DST) for those engaged in afforestation activities for water conservation and runoff avoidance. This system provides a plantation suitability map that helps in the selection of water conserving tree species. It integrates Climatic (Precipitation, Temperature, etc.), Silvicultural, Environmental (Land use land cover, soil type, etc.), Topographical (Elevation, slope, etc.) and Infrastructural (road, settlement, etc.) factors to build a Spatial Decision Support System - Afforestation Decision-Support System (ADSS). The system follows the Agile software development lifecycle using REST (Representational State Transfer) architecture on both web and mobile platform. The system is based on Python Django framework in the backend for its efficient handling of geospatial data. It is very robust for rapid development and is immune to most of the cyber-attacks. PostgreSQL has been used as a database support for the whole platform. Based on the users and their requirement a customized interface / dashboard is provided for the access to the services. The web interface incorporates semantic web design which allows data to be shared and reused across application, enterprise, and community boundaries and also deal with common issues of vastness, vagueness, uncertainty, inconsistency as well as deceit. It enhances the usability and usefulness of the web and its interconnected resources by creating Semantic Web Services. The UAC (User Access Control) has been provided for different level of users such as admin and user.

The ADSS can retrieve and display species information (local name, scientific name, characteristics and uses) from the database by matching species-specific characteristics with the site-parameters (such as temperature, rainfall, soil, etc.) for the chosen location based on a decision tree. The database is available for a total of 230 tree species that have been selected based on review of forest working plans, silvics of tree species, and stakeholders consultations. ADSS has been tested for Chandrpur and Latur districts of Maharashtra.

1. Introduction

1.1. Background

Water is an essential element for sustaining life on Earth. The perennial flow of goods and services that various ecosystems provide, depend on water. Particularly, the occurrence of forests is always associated with natural abundance of water and climatic water balance characterized by average annual rainfall. This relationship governs various other natural processes like surface water runoff, availability and quality of water in ecosystems. With rapid changes in climatic projections, coupled by unsustainable extraction of water; erratic precipitation; higher runoffs and extreme events are leading to disruptions in water resource availability. Climate change has altered and continues to pose a significant threat impact the environmental conditions for many sectors. One of the potential solutions for improving water management is to take a step towards better planning of forestry activities with due consideration to the needs of runoff avoidance, water harvesting etc. Maharashtra is a fast growing state in terms of industrialization at the same time the state is facing challenges like deficit rainfall, over use of water, uncontrolled pollution and illegal logging in forests. To these challenges, Government of Maharashtra (GoM) has initiated policy interventions that lay emphasis on afforestation on public and private lands, lands reserved for community purposes for protection and sustenance of biodiversity.

Since forests are seen as one of the major sources of sink for carbon, it helps in mitigating global climate change. Considering this importance, the GoM has taken up a goal to plant 50 crore trees by 2019 with the mandate of increasing the forest cover and improving the ecosystem-based services and also emphasizes conservation of water. To support this activity, IORA Ecological Solutions with support from ACT- CCIP has worked towards the development of a user-friendly site-specific Decision Support System (DSS) for afforestation activities that will go a long way in informing forest staff and other stakeholders to carry out afforestation activities with a linkage to water conservation goals and leverage the current substantial outlay from the government for this purpose. Further, such a tool would inform non-governmental institutions, prominently CSR departments of large corporates who invest substantially in afforestation but often lack the technical know-how on species and plantation practices. This can be facilitated using geospatial tools that can provide significant information about the forests and its biophysical parameters at regional and global scale in a cost-efficient manner. Remote sensing data in conjunction with GIS can be used for forest resources mapping, monitoring and modelling that may aid in effective forest planning and management.

1.2. Objectives of ADSS

The main objective of the proposed project was to develop a region and context-based Decision Support System (DSS) for the Department of Forest, Government of Maharashtra to undertake afforestation programmes that have a positive impact on water conservation and runoff avoidance. The DSS has to be easily accessible on a handheld device like tablet, smartphone or PC, laptop while having a server backend to store data and information. The system shall also provide information for developing adaptation strategies for forest management valid for entire Maharashtra.

1.3. Climate change and Maharashtra

The State has a tropical monsoon climate with mean annual temperature ranging between 25 to 27.5 degree celsius and average annual rainfall between 1600 and 2000mm. Maharashtra experiences a typical monsoon climate (North-East and South West), with hot, rainy and cold weather seasons. Summer month extends from March, to May where April and May are the hottest months. Rainfall starts normally in the first week of June andJuly is the wettest month in Maharashtra, while August too gets substantial rain. Monsoon starts its retreat with the coming of September from the state. Cool dry spell, with clear skies gentle breeze and pleasant weather prevails from November to February. But the eastern part of Maharashtra sometimes receives scanty rainfall. Temperature varies between 12-34°C during this season. Rainfall in Maharashtra differs from region to region. Thane, Raigad, Ratnagiri and Sindhudurg districts, receive heavy rains of an average of 200 cm/year. However, the districts of Nasik, Pune, Ahmednagar, Dhule, Jalgaon, Satara, Sangli, Solapur and parts of Kolhapur get rainfall less than 50 cm. Central Maharashtra receives less rainfall. However, under the influence of the Bay of Bengal, eastern Vidarbha receives good rainfall in July, August and September.

Maharashtra is one of the most visible and extreme examples of agrarian crisis in India. Productivity is severely affected by fluctuations in rainfall and temperatures, as well as unsuitable agricultural practices. For example, in 2015, the late, inadequate monsoon left 60% of villages in the State facing drought-like conditions and affected nearly nine million farmers. To tackle such adversities and in order to help farmers and the other sector as a whole is, therefore, a government priority. The expanding power and industrial sectors both require large amounts of water resulting in growing tension in the allocation of water between sectors and areas. Changing patterns of land use and deforestation, which has been steadily rising since the 1990s has aggravated the situation.

Impacts of the projected climate change on forests are manifold. These are likely to change the growth conditions of forests having positive as well as negative effects. However, the projected changes will differ temporally and spatially. Thus, choosing a tree species, rotation time, and forest treatment are solely based on experiences that may become inadequate in the light of new combinations and dynamics of environmental factors.

1.4. Afforestation Programme in Maharashtra

Ever since the formation of the Forest Development Board in 1969, the plantations have been raised under various programmes/schemes. Tree Plantation is one of the most ambitious initiatives of the Government of Maharashtra. Maharashtra Government has also launched a massive drive to increase the green cover across the state. As a part of this initiative, the Maharashtra Government decided to plant around 2 crore trees across the state in the year 2016. The State Government has also announced the plantation of 50 crores sapling in the next three years (2016 – 2019), which is proving to be another courageous effort to combat climate change.

1.5. Forest Conservation

Maharashtra's forest is rich and diverse in flora and fauna. The forest cover in the State is approximately 50,650 sq. km, which is 16.46% of the state's geographical area. One of the main tree species is Teak (*Tectona grandis*), found to occur over an area of approx. 10.18 thousand sq. km, and Bamboo (Mainly *Dendrocalumus strictus*) over 10.10 thousand sq km area. Among the non-wood forest products, Bamboo and Tendu leaves constitute the important resource. There has been a continuous demand for forest land for various purposes, which may include a requirement for the exclusive use like cultivation or for the public utility purposes like irrigation, road, hospitals, transmission line etc. This insatiable demand of forest land in the past, had a reduction in its area, since 1947 and continued till 1980. This diversion was controlled after the promulgation of Forest (Conservation) Ordinance followed by Forest Conservation Act 1980, by the Government of India. The Act also puts a restriction on conversion of natural forest to a man-made of forests. Nearly 10,0000 hectares of forest land was diverted for non-forestry use before the enactment of this Act since 1947. After the enactment of this Act, nearly 65749.202 hectare of forest land has only been diverted for 1692 projects, the majority of which are irrigation and other public projects. There has been no diversion for agricultural purpose except for rehabilitating persons for S.S.P. Few earlier agricultural practices have been regularized[1].

1.6. Need for ADSS

Although all these attempts are important to understand the single aspect of climate change impacting forests. In the end, this knowl¬edge has to be combined into an integrated assessment to support decision making. Decision Support Systems (DSS) are important tools which can fill this gap. DSS are usually employed for complex decision-making problems for upper-level managers where models are combined with data. They are flexible and adaptable, but at the same time, access to the system for non-computer-expert users is easy. Therefore, DSS is an ideal platform for transferring knowledge from science into practice and have been already applied to forest management problems. DSS can integrate a wide range of data and models into a single system.

2. Project Area

2.1. Geography

Maharashtra is known for its great geographical features. It is situated between the latitude of 15˚ 41' to 22˚ 6' N and longitude of 72˚ ,36' to 80 ˚ 54' E. The geographical area of the state is 307713 sq. km. Firstly, it is located at the centre of Peninsular Part of India and surrounded by the Arabian Sea as well. One of the highlighting features of this state is its plateau character, which catches the attention of many people. The coastal plains of Maharashtra including western parts rise to become a part of Sahyadri Range and finally, sloping towards the east as well as southwest directions, even the major rivers as well as its tributaries are responsible for the curve ends of the plateau and thus overriding regions like Buldana, Ahmednagar and Yavatmal.

[1] http://mahaforest.gov.in/

2.2. Geology

Maharashtra is known for its flat and uniform skyline that differentiates it from other states and regions. This topography has resulted from the geographical structure of this state. The area is mostly surrounded by the Vidarbha region, Deccan Traps, Sindhudurg and Kolhapur. About 60 to 90 million years before, the lava fissures formed the horizontal basalt over several areas. The basalt areas not only differ in composition but also in structure and that are why the huge grey cliffs, ash layers and amygdaloidal lava are responsible for the plateaus as well as pyramid-shaped hills. The earth sculpturing easily defines the excellent landform features, the semi-arid climate and the hilltops. The river valleys and plateau interfluves are the results of the fluvial action caused by the Wardha-Wainganga River, Krishna, Godavari and Bhima. Even, the 100 km long hill torrents flow down as loud streams thus putting an end to the tidal estuaries also.

Sahyadri Range is considered to be the backbone of the state having a height of 1000 m. The range falls to different steep cliffs like the Konkan in the west and Malwa at its eastern ends. A huge crest of 1564 m forms to be a distinctive feature of this range and that is why it is one of the most attention-grabbing features of this state. A narrow coastline of Konkan is located between the Sahyadri Range and the Arabian Sea. It is a 50 km wide coastal lowland and known for its steep sides, laterite plateau and broken areas. Unlike the other states which have a plain area, Maharashtra is slightly different with dissected areas surrounding it.

2.3. Climate (Rainfall and Temperature)

Maharashtra is known for its tropical monsoon climate due to which the summers are really hot and humid starting from March with the monsoons arriving during the month of June. The state receives a heavy rainfall of 400 cm owing to the western sea clouds. Even the windward side of the Konkan region is responsible for the heavy rainfalls that make the atmosphere pleasant. In the Sahyadri region, the rainfall is limited to only 70 cm with the Solapur-Ahmednagar being the dry regions. The Marathwada and Vidarbha areas receive the rainfall a little later in the season.

2.4. Soil

Soils are varied in nature and their extent and development depend on the environmental setting in which they have been evolved. The knowledge of the types of soils and their extent is very essential for sustainable land use planning. Soil resource inventory provides this kind of information, obtained through a systematic interpretation of satellite data, aerial photographs, field survey, laboratory characterisation and cartography. People deal with soils in their own way suiting to convenience and short-term benefits. As a result, most of the soils are not managed properly and continued negligence of soils leads to severe degradation of this precious resource. This region has seven types of soil viz., the black soil of varying depths, alluvial saline-alkali soils, shallow grey soil, red soil, alluvial sandy loams, hill and forest soil, and deep alluvial soils.

2.5. Water Resources

A large number of villages lack drinking water, especially during the summer months, even in the wet Konkan. Barely 11% of the net sown area is irrigated. Perched water tables in the basalt aquifers have contributed to increased well irrigation, which accounts for approximately 55% of the irrigable water. The granitic-gneissic terrain in the eastern hilly area of Vidarbha accounts for all tank irrigation. Tube-wells in the Tapi-Purna alluvium and shallow wells in the coastal sands are the other main sources of water. Special wells are being made by the Government for the villages lacking water.

River networks in Maharashtra, of the 5 river basin systems, 55% of the dependable yield is available in the four river basins (Krishna, Godavari, Tapi and Narmada) east of the Western Ghats. These four river basins comprise 92% of the cultivable land and more than 60% of the population in rural areas. Maharashtra has more than 11 important west flowing rivers including Damanganga Surya, Vaitarna, Ulhas, Savitri, Kundalika, Patalganga, Vashisti, Shastri, Karli, and Terekhol. There are numerous smaller rivers joining the creeks. There are numerous smaller rivers joining the creeks. These rivers contribute to about 44.54% of the yield at 75% dependability of Maharashtra. Maharashtra state roughly has 1822 numbers of notable dams and some of the dams have hydroelectric power generating plants for state grid.

Table 1 List of major Dams in Maharashtra (Source: Wikipedia)

SL.no.	Dam Name	Place	Impound	Type	Height (m)
1.	Mula Dam	Ahmednagar	Mula River	Earthfill Gravity	48.17
2.	Koyna Dam	Aurangabad	Koyna River	Gravity	102.3
3.	***Ujani Dam***	Pune	Bhima River	Earthfill Gravity	56.4
4.	Mulshi Dam	Pune	Mula River	Gravity	48.8
5.	***Panshet Dam***	Thane	Ambi River	Earthfill Gravity	63.56
6.	***Bhandardara Dam***	Ahmednagar	Pravara River	Gravity	150
7.	***Vaitarna Dam***	Thane	Vaitarna River	Gravity	82
8.	***Pawna Dam***	Pune	Pavana River	Earthfill Gravity	1329
9.	***Girna Dam***	Nashik	Girna River	Earthfill Gravity	55
10.	Kolkewadi Dam	Ratnagiri	Vashishti River	Gravity	63.3

2.6. National Parks and Biodiversity

Maharashtra has a huge floral and faunal diversity . About 17% of this state is covered by the thick forests consisting of deciduous plants. Most of the forests are found in the Sahyadri region and are very dense. Maharashtra has three game reserves, five national parks and 24 bird sanctuaries. Some of these areas are converted into wildlife reserves thus preserving

the biodiversity. Dhokna-Kolkaz forest of Maharashtra is known for its excellent wildlife that includes flying squirrels, tigers, antelope etc.. The Nagzira Wild Life Sanctuary is also a famous for the presence of blue bull, panthers, sloth bear, birds etc. In the south, there is the Nawagaon National Park and the Tadoba National Park known for the ducks and waterfowls. And the Karnala Bird Sanctuary, which is located at a distance of 60 kms from Mumbai.

2.7. Forest Type

Forests are essential for survival and sustenance of life. They are sources of many direct and indirect benefits and need to be managed in such a way that extraction of benefits does not deplete the resource. Their growth should be optimized so that greater benefits are derived from them. The forests of Maharashtra have special significance as they represent a variety of habitats which are very important from the forestry perspective. The forest area of the state is 61934 sq. km constituting 20.13% of the geographical area of the state. According to Champion & Seth classification, the state has 16 forest types, which belong to six forest type groups, Tropical semi-Evergreen, Tropical Moist Deciduous, Littoral and Swamp, Tropical Dry Deciduous, Tropical Thorn and Subtropical Broadleaved Hill Forests. Each of these Forest types represent a unique ecosystem.

2.7.1. Southern Tropical Semi-Evergreen Forest

This forest type consists of mainly Forests of this type occur mostly on upper hill slope from 450 meters to 1050 metres above the mean sea level in the Western Ghats. The main species are Kinjal *(Terminalia paniculata)*, Anjani (*Memocylon umbellatum)*, Hirda *(Terminalia chebula)*, Jambul *(Syzigium cumini)*, Parjamun *(Olea diocea)* and Mango *(Mangifera indica)*, Pisa *(Actinodaphne hookeri)*, etc.

2.7.2. Southern Moist Deciduous Forest

Two main sub-types occur under this group.

i) ***Moist Teak bearing Forests***: Important and valuable forests of the State from commercial view point, these are mainly confined to Project Tiger area in Melghat region of Amrawati district, Chandrapur, Gadhchiroli and Thane districts with Teak *(Tectona grandis)*, the associates are Ain *(Terminalia tomentosa)*, Shisham (*Delbergia latifolia)*, Haldu (*Adina cardifolia)*, Moha (*Madhuca indica)*, Bija (*Pterocarpus marsupium)*, Kalam (*Mitragyna parviflora)*, Semal (*Salmalia malabaricum)* and Bamboo (*Dendrocalamus strictus)* etc.

ii) ***Moist Mixed Deciduous Forests***: Teak is present occasionally and the evergreen component of species is larger than in case of Teak bearing forests. The main species are *Pterocarpus marsupium* (Bija), *Salmalia malabaricum* (Semal), *Terminalaia bellarica* (Behada), *Dalbergia latifolia* (Shishum), *Syzigium cumini* (Jambul), *Terminalia tomentosa* (Ain), *Lagerstremia parviflora* (Bendara) etc.

2.7.3. Southern Tropical Dry Deciduous Forests:

Following are the main forest subtypes.

i) ***Dry Teak Bearing Forests***: Principal species is Teak *(Tectona grandis)* and the associates are Tiwas *(Ougeinia dalbergiaoides)*, Khair (*Acacia catechu)*, Shivan *(Gmelania arborea)* and Dhawada (*Anogeissus latifolia)* etc.

ii) ***Dry Mixed Forests****:* This type of Forests occurs mostly on upper hill slope from 450 m to 1050 metres above the mean Sea Level in the Western Ghats. The main species are Kinjal *(Terminalia paniculata)*, Anjani (*Memocylon umbellatum)*, Hirda *(Terminalia chebula)*, Jambul *(Syzigium cumini)*, Parjamun *(Olea diocea)* and mango *(Mangifera indica)*, Pisa *(Actinodaphne hookeri)* etc.

2.7.4. Southern Tropical Thorn Forests

Under this forest type fall the forests of the low rainfall areas of Marathwada, Vidarbha, Khandesh and Western Maharashtra. Majorities of these forests are heavily degraded due to low fertility coupled with low rainfall. The main tree species found in these forests are Babul *(Acacia arabica)*, Hiwar *(Acacia leucophloea)*, Bor *(Zizyphus jujuba)*, Palas *(Butea monosperma)*, and Hinganbet *(Belanites roxburghii)* etc. These forests are full of Euphorbia and Cassia scrub.

2.7.5. Littoral and Swamp Forests

The littoral and swamp forests occur along the creeks and littoral in Sindhudurg and Thane district. Although their comparative extent in the State is marginal, these forests are important for the protection of seacoast and marine life. The typical mangrove species found in this area are Avicennia spp. and Rhizophora spp. etc.

3. Geospatial data analysis

3.1. Role of Geospatial data for Natural resource management

The GIS in Natural Resource Management identifies the human impacts on natural resource and support for the utilization of natural resources. Firstly, the data are collected from the land cover, vegetation, soil and geology, which are the parts of natural resources, and then they are mapped using GIS technology. These data are collected using remote sensing technique through aerial photographs or satellite images for study. The major application of GIS in natural resource management is in confronting with environmental issues like a flood, landslide, soil erosions, drought, earthquake etc. GIS in natural resource management also address the current problems of climate change, habitat loss, population growth, pollution etc. Various geospatial layers have integrated using regression and other algorithms as detailed in the subsequent sections:

3.2. Geospatial Layers used in this study

3.2.1 Elevation

The elevation of a geographic location is its height above or below a fixed reference point, most commonly a reference geoid, a mathematical model of the Earth's sea level as an equipotential gravitational surface. Elevation is distance above sea level and usually measured in meters or feet. They can be shown on maps by contour lines, which connect points with the same elevation; by bands of colour; or by numbers giving the exact elevations of particular points on the Earth’s surface. Maps that show elevations are called topographic maps. Elevation influences climate, as well as where and how people live. For the study, SRTM DEM has been used to find the elevation for the respective region.

3.2.1. Slope

The slope can be defined as an element of the surface inclined to the horizon. A slope possesses a gradient, giving it a direction or orientation in space. The gradient in the terrain is the result of several factors viz. relief, drainage, climate and geology operating in the area. The slope is the rate of maximum change in z-value from each cell. Slope tool calculates the maximum rate of change in value from that cell to its neighbours. The maximum change in elevation over the distance between the cell and its eight neighbours identifies the steepest downhill descent from the cell.

Conceptually, the tool fits a plane to the z-values of a 3 x 3 cell neighbourhood around the processing or center cell. The slope value of this plane is calculated using the average maximum technique (see References). The direction the plane faces is the aspect for the processing cell. The lower the slope value, the flatter the terrain; the higher the slope value, the steeper the terrain. If there is a cell location in the neighbourhood with a NoData z-value, the z-value of the center cell will be assigned to the location. At the edge of the raster, at least three cells (outside the raster's extent) will contain NoData as their z-values. These cells will be assigned the center cell's z-value. The result is a flattening of the 3 x 3 plane fitted to these edge cells, which usually leads to a reduction in the slope. The output slope raster can be calculated in two types of units, degrees or percent (percent rise). The percent rise can be better understood if one considers it as the rise divided by the run, multiplied by 100.

3.2.2. Aspect

In physical geography aspect is the compass direction that a slope faces. The aspect of the slope can have a significant influence on the climatic condition for site suitability for individual plants. Aspect identifies the downslope direction of the maximum rate of change in value from each cell to its neighbors. It can be thought of as the slope direction. The values of each cell in the output raster indicate the compass direction that the surface faces at that location. It is measured clockwise in degrees from 0 (due north) to 360 (again due north), coming full circle. Flat areas having no downslope direction are given a value of -1. The value of each cell in an aspect dataset indicates the direction the cell's slope faces.

3.2.3. Groundwater depth

Estimation of groundwater is also important for the construction and the maintenance of the State’s water supply infrastructure, especially those that are dependent on groundwater. It will form the basis for understanding the existing and planning the future use of groundwater and to decide the management options on a holistic basis. This data has been used to understand the dynamics of the ground water level to ensure sustainability for different water sector activities.

3.2.4. Soil layer

The soils of Maharashtra are residual, derived from the underlying basalts. In the semi-dry plateau, the regur (black-cotton soil) is clayey, rich in iron, but poor in nitrogen and organic matter; it is moisture-retentive. Where redeposited along the river valleys, those kali soils are deeper and heavier, better suited for Rabi crops. Farther away, with a better mixture of lime, the morand soils form the ideal Kharif zone. The higher plateau areas have pather soils, which contain more gravel. In the rainy Konkan, and the Sahyadri Range, the same basalts give rise to the brick-red laterites productive under a forest-cover, but readily stripped into a

sterile varkas when the vegetation is removed. This has been used to decide species in a particular agro-ecological region.

3.2.5. Rainfall

Maharashtra, a state in India, has a monsoon climate. It receives major part of the annual rainfall during the summer (southwest) monsoon season (SMS), *viz.,* June through September. Monsoons are characterized by phases such as the onset and advance (June), peak (July and August), and retreat (September). By mid-June, most parts of the state come under the influence of a monsoon. July is the wettest month and there is also substantial rainfall during August. The monsoon weakens during the month of September, and hence the rainfall decreases. The rainfall is highly variable over all of Maharashtra with the coefficient of variability of the daily rainfall varying between 100and 300%. Seasonal distribution of the number of rainy days shows 90–100 over southern Konkan, 80–90 over northern Konkan, 50–60 over eastern Vidarbha, and the southeast Maharashtra has the lowest number of about 15–20 rainy days. The highest values of maximum daily rainfall are located over the Sindhudurg, Ratnagiri, Raigadh, Mumbai and Thane districts of the Konkan region followed by that over eastern Vidarbha. The rainfall data have been divided into three categories (moderate rainfall, heavy rainfall and extreme heavy rainfall) based upon seven categories used by the India Meteorological Department. Heavy rainfall zones lie over the southern Konkan region, whereas extreme heavy rainfalls occur over northern latitudes.

3.2.6. Temperature

Maharashtra has typical monsoon climate, with hot, rainy and cold weather seasons. Tropical conditions prevail all over the state, and even the hill stations are not that cold. Dew, frost, hail can also be happened sometimes according to the seasonal weather.

Summer: March, April and May are the hottest months. During April and May thunderstorms are common all over the state. Temperature varies between 22-39°C during this season.

Rainy: Rainfall starts normally in the first week of June. July is the wettest month in Maharashtra, while August too gets substantial rain. Monsoon starts its retreat with the coming of September from the state.

Winter: Cool dry spell, with clear skies gentle breeze and pleasant weather prevails from November to February. But the eastern part of Maharashtra sometimes receives some rainfall. Temperature varies between 12-34°C during this season.

All the geospatial layers have been used for arriving at location specific species ranking.

Table 2 Source of geospatial data layers

Sl. No.	Geospatial layers	Sources	Web link
1.	Multispectral satellite data (Sentinel-2)	Remote pixel	https://remotepixel.ca/
2.	SRTM DEM	Earth Explorer	https://earthexplorer.usgs.gov/
3.	Maharashtra District Boundary	Forest department	---
4.	Ground water level data	CGWB	http://www.india-wris.nrsc.gov.in/GWL/GWL.html?UType=R2VuZXJhbA==?UName=

5.	Rainfall, Temperature and Wind data	Worldclim	http://www.worldclim.org/
6.	Soil texture and moisture data	Bhuvan	http://bhuvan.nrsc.gov.in/data/download/index.php

Sl. No.	Layer	Unit	Min	Max	Mean	Median	Mode	Std. Dev	Remarks
1.	Elevation	m	1	1556	436.67	444	493	202.12	SRTM DEM
2.	Slope	degree	0.11	89.86	3.01	1.16	0.46	5.49	SRTM DEM
3.	Aspect								North, South, East, West
4.	Rainfall	mm	452	5912	1205.56	903	830	850.85	WorldClim
5.	Temperature	°C	19	28	25.76	25.99	25.99	1.16	WorldClim
6.	Wind	m/s	1.44	3.31	2.02	2.02	2.05	0.23	WorldClim
7.	Ground Water Depth	m	0.24	36.69	4.45	3.8	3.37	2.87	CPWG
8.	Soil Texture								Loamy, Clay, Sandy, Sandy clay
9.	LULC								Forest, Agriculture, Settlement, Water, Other lands
10.	Soil Moisture	m^3/m^3	0.08	0.37	0.16	0.16	0.16	0.03	

Table 3 Value range of different geospatial data layers

3.3. Geospatial data processing

3.3.1 Pre-processing

Pre-processing included radiometric and geometric correction. Geometric correction ensures that images overlay properly on to each other and to other GIS maps used in the analysis. The average error between two images must be less than or equal to one pixel.

3.3.2 Green cover

Green cover refers to the amount of green vegetation present in the landscape. We used a vegetation detection-tracking model to automatically map the vegetation. This model can be used to detect changes in vegetation due to anthropogenic disturbances, forest fires etc. over the different time points for temporal analysis.

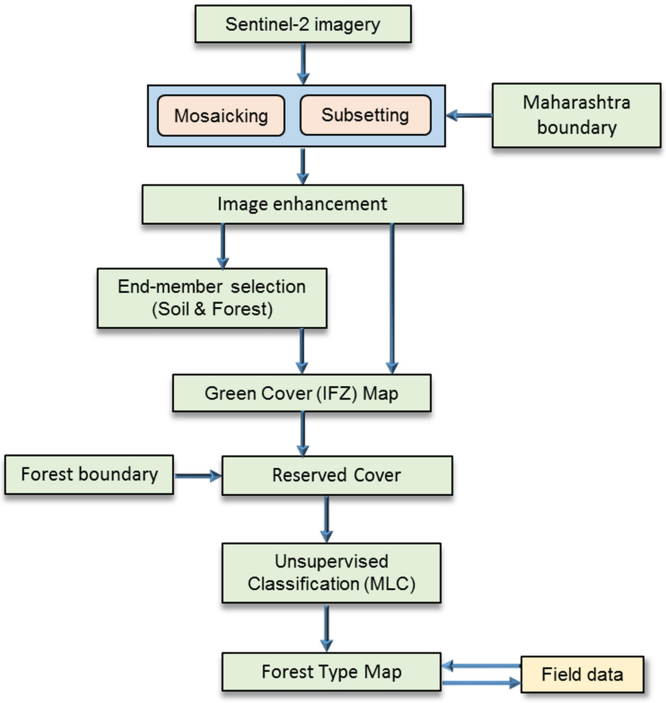

Figure 1 Flowchart for Methodology

The model is called Integrated Forest Z-score (IFZ) model which consists of an equation *i.e.* $IFZ = \sqrt{\frac{1}{n}\sum_{i=1}\left(\frac{B_i-u_i}{\sigma_i}\right)^2}$ where $u_i$the mean value of forest end members, B_i is the pixel value and σ_i is the standard deviation of forest end member. With training forest pixels determined according to ground surveys or visual interpretation, the mean (B_i) and standard deviation (σ_i) of band i for the training forest samples can be calculated from the satellite image. The IFZ value for that band is defined as follows :

$$IFZ = \sqrt{\frac{1}{n}\sum_{i=1}\left(\frac{B_i-u_i}{\sigma_i}\right)^2} \quad .$$

With training forest pixels determined according to ground surveys or visual interpretation, the mean (u_i) and standard deviation (σ_i) of band i for the training forest samples can be calculated from the satellite images The forest z-score (IFZ) value for that band is defined as follows:

For multi-spectral images, the IFZ (integrated forest z-score) value of each pixel is then defined $IFZ = \sqrt{\frac{1}{n}\sum_{n=5,7,8}\left(\frac{B_i-u_i}{\sigma_i}\right)^2}$ as where n is the number of bands used. For Satellite images, a number of combination of bands can be used for IFZ. For example, 5, 7, and 8 correspond to Red, NIR1 and NIR2 respectively.

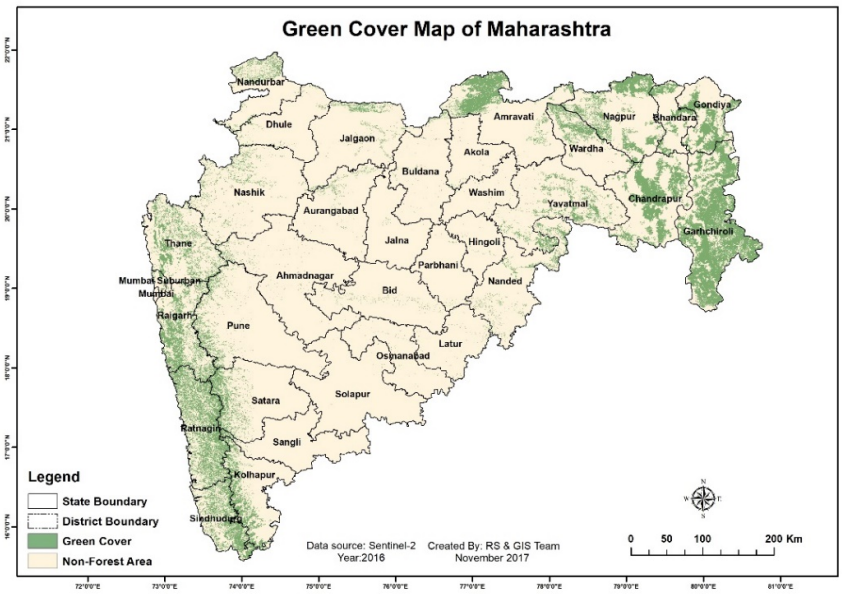

Figure 2 Green cover map of Maharashtra

3.4. Forest Type mapping

Forest type mapping was done using supervised and unsupervised image classification techniques together as per the revised forest type classification of Champion and Seth (1968). The technique involved an unsupervised classification on several image subsets, labelled the spectral groups to classes, and then combined these groups to account for within class spectral variation. These combined classes were then used as training statistics to classify the image with a supervised technique. In Maharashtra, 16 forest type classes have been broadly classified (SFR, 2015 and Champion & Seth, 1968).

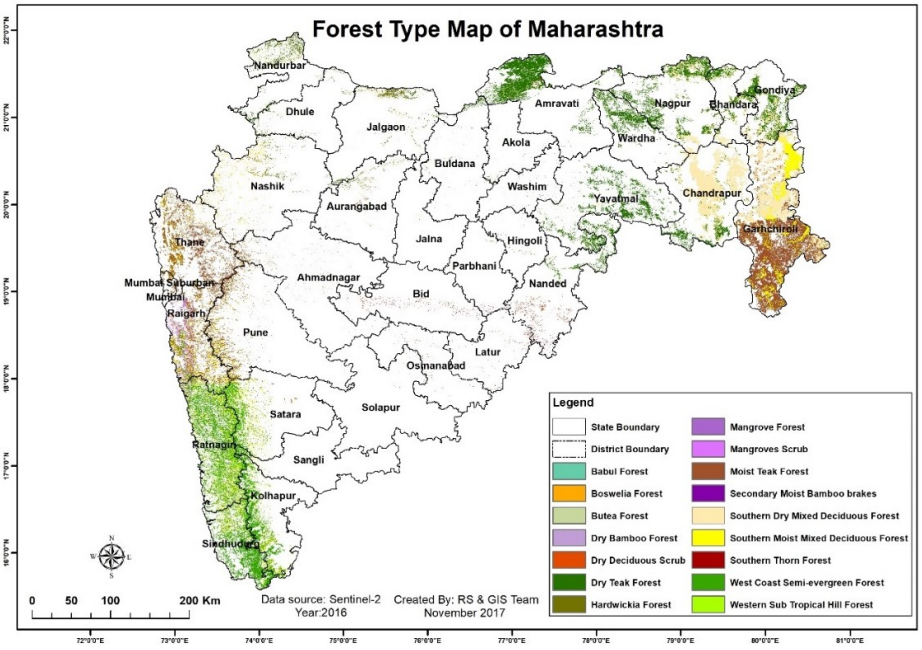

Figure 3 Forest type map of Maharashtra

Table 4: Area statistics of Forest type

Sl. No.	Forest Type	Area (sq. km)
1.	Babul Forest	00.01
2.	Boswelia Forest	00.13
3.	Butea Forest	00.01
4.	Dry Bamboo Forest	00.26
5.	Dry Deciduous Forest	08.36
6.	Dry teak Forest	19.42
7.	Hardwickia Forest	00.32
8.	Mangrove forest	00.44
9.	Mangrove scrubs	00.39
10.	Moist teak forest	14.96
11.	Secondary Moist Bamboo brakes	00.06
12.	Southern Dry Mixed Deciduous Forest	30.33
13.	Southern Moist Mixed Deciduous Forest	15.37
14.	Southern Thorn Forest	00.96
15.	West Coast Semi-evergreen Forest	07.31
16.	Western Sub Tropical Hill Forest	01.67

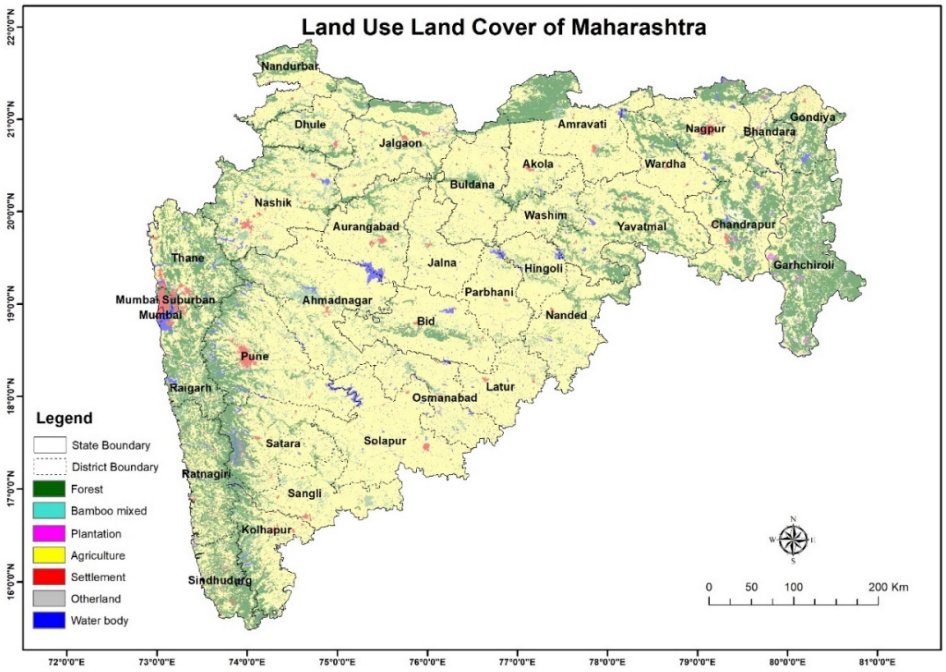

Table 5 Area statistics of Land Use Land Cover

Sl. No.	Class	Area (%)

1.	Forest	19.27
2.	Bamboo mixed	3.32
3.	Plantation	0.15
4.	Agriculture	72.43
5.	Settlement	1.99
6.	Other land	0.38
7.	Waterbody	2.45

4. Life cycle of the project

Module 1: Finalizing Decision support system parameters

Step 1: IORA has developed a detailed site information parameter set which will serve as a basis for the species selection. The parameters include those related to site quality, site suitability, forest types, growth rates, indicator tree species and their characteristics, socioeconomic considerations including community preference, timber and non-timber produce, edaphic and topographical parameters etc. Traditional knowledge existing among communities on the relationships between tree species and water conservation has also been internalized by initiating discussions with community-based organizations and literature. Strong emphasis has been given toon ensure gender equality and inclusive coverage of socioeconomic status during the discussions. Correlation analysis has been done to verify their relationships with water conservation.
Multiple regression has been used to develop the most precise equation to predict the outcome, i.e. water conservation, then those influence that are not statistically significant has been removed in stepwise deletion. The least significant variable has been removed at each step and the analyses was repeated further until all the independent variables all statistically significant. A detailed consultation has been done with the officials from Maharashtra forest department, ACT-CCIP to jointly get their feedback on the parameters.

Step 2: Shortlisted parameters set was shared with the scientific organizations working in the forestry and water conservation areas for a final peer review feedback.

Output: Set of DSS parameters to assist afforestation for water conservation has been finalized. The parameters will provide options for species related to sites based on their categorization.

Module 2: Generate parameter specific spatial layer

Step 1: Assembling of secondary data for the site information related parameters for the whole state of Maharashtra, disaggregated by regions.
Step 2: Projection of the analyzed data in the spatial domain and creation of an "Afforestation Species Suitability GIS" layer. This layer uses current RS information, current Forest Type and Land Use Type maps as base layers. This layer is the basis for the DSS. This was further stratified this into region wise seven site classes.
Step 3: Validation of the GIS layer with the MFD and other relevant stakeholders

Output: Development of DSS parameter specific spatial layers.

Module 3: Research & analysis to identify species suitable for each parameter set

Step 1: Prioritization of the entire exercise to identify Maharashtra specific suitable tree species. Species has been allotted grades from 0 to 70, based on the following seven characteristics namely, a) its ability to conserve water, b) less evapotranspiration, c) ability to replenish soil nutrients, d) high survival in denuded area with less care, e) easy availability of planting materials, f) ability to grow fast and g) multipurpose uses. Based on the cumulative

grades, species has been ranked and a list of twenty to twenty-five tree species was prepared. The species have also been categorized along the lines of suitability to various site categories based on the site information analysed above.
Step 2: Extensive review on the silvics of the ranked tree species has been carried out to revalidate the species ranking. The species-ranking list has been shared with MFD, ACT-CCIP and other relevant stakeholders for incorporating any feedback.
Step 3: The ranked species has been further grouped into four categories based on the four regions of Maharashtra (Vidarbha, Marathwada, Northern Maharashtra and Western Maharashtra).

Output: Development of list of species suited for specific sites in Maharashtra.

Module 4: Consultation and validation across the six divisions of Maharashtra

Step 1: Consultations across the four regions (and possibly across each forest division within these regions) of Maharashtra was conducted to validate the region-specific tree species ranking which was developed under Module 3.
Step 2: Focussed group discussions was conducted to record the perceptions of communities on the species ranking species. Gender equality and inclusive coverage of socioeconomic status during the discussions has been given due consideration in this FGD.
Step 3: Random field visits was conducted in the divisions to capture geotagged morphology of the existing tree species.

Output: Validated datasets.

Module 5: Generate species-centric plantation and management plans

Step 1: Correlation analysis was carried out to scrutinize the relationships between parameter sets developed in the first module and list of species validated under Module 4. Step 2: Digital field planting plans of the ranked species was developed. These plans will simplify vegetative/ mechanical land development procedures, any land ameliorations, microsite planting techniques, acclimatization's and design options on site-species prioritization.

Output: Development of digital species-centric afforestation plans for water conservation in all the six divisions of Maharashtra.

Module 6: Compilation of information into database

Step 1: Development of database form. The database form was shared with MFD, DFID ACT-CCIP for validation. Suggestions has been incorporated and the database form finalized.
Step 2: Each of the fields in the form was coded and linked so that it can quickly deliver query outputs and support the decision making process.
Step 3: The validated form was pre-populated with data on parameters set, tree species, site classes and spatial layers. This was coded and linked to deliver query outputs on spatially delineated layers for afforestation.

Output: Generation of a database for afforestation including final spatial layers and species coding.

Module 7: Development of a decision support system tool

Step 1: Coding at server end to host the database, with an administrator interface and application programming interface for both the apps to use the database
Step 2: Coding of the android/iOS systems to access the database.
Step 3: Development of the Android based mobile app. The app will feature automated geo-coordinate based shortlisting of species (linked to the spatial layer generated above).

Step 4: Programming for the development of a web-enabled portal (WEP) that can host the GIS layer and the database to generate query for both android and web users.
Step 5: Scrutiny of the web and the app versions for any bugs
Step 6: Testing of DSS and its validation under simulated field conditions for the six different regions of Maharashtra state.
Step 7: Sharing of the beta version with MFD, ACT-CCIP for their feedback. Incorporation of suggestions. Handing over the database, portal and the apps to the MFD.
Step 8: Development of a user documentation and flyer on the DSS.

Outputs: a) Development of a mobile app for Android users and a WEP, along with design/development of the interface that rests on the server and will host database that both can query.
b) User documentation for both mobile app and web app
c) Briefing note or leaflet explaining the value of the tool, which can be used for publicity and information sharing.

Module 8: Launch of the DSS – mobile app and web version
Under this module IORA has provided technical support to the MFD, ACT-CCIP to organize a high level event with Senior Government stakeholders (Ministers and Secretaries) to launch the mobile app and the web app which finally was launched at CoP23, Katowice in Poland.

Output: Media coverage and proceedings of the launch event.

5. Software Design of ADSS

5.1 ADSS App: Features

I. Differential login and landing/home page functionality based on the user-group (Forest / non-forest): Display of forest boundaries-based location hierarchy (Division, Range, Compartment, beat) for Maharashtra Forest Department (MFD) users, and administrative boundaries (Region, District, Taluka) for non- MFD users.
II. Filtering out of “unsuitable (unsuitable for plantations)” areas such as water-bodies, built-up areas, etc. based on land-use land cover GIS layer.
III. Retrieval and display of species-list and information (local name, scientific name, characteristics and uses) from the database by matching species-specific characteristics with the site-parameters (such as temperature, rainfall, soil, etc.) of the chosen location retrieved from 16 corresponding GIS layers.
IV. Species-list and information retrieved from a database of 150 tree species, which were shortlisted after extensive review of silvics from relevant scientific literature (such as Maharashtra Working Plans, Champion & Seth’s classification, The Silviculture of Indian Trees by R.S. Troup, etc.), and were segregated region-wise based on the suitability for specific sites/conditions in the 6 regions of Maharashtra.
V. Region-wise lists of the shortlisted species, along with their characteristics relevant to water conservation and run-off avoidance, has been ranked and validated in consultation with the MFD.
VI. Display of site-parameters - temperature, rainfall, soil, etc. of the chosen location- in both ranges (high, medium, low) and actual values.
VII. Display of month/season-wise plantation and management prescriptions, along with sending alerts/email to the user through the app for the user-registered species.
VIII. Ability to integrate Differential accounts and email-alerts with MFD-defined user schema, in addition to the overall integration of the ADSS App into MFD’s IT infrastructure.

5.2 Architecture

5.2.1 Model View Controller (MVC)

MVC is a software architecture pattern, commonly used to implement user interfaces: it is, therefore, a popular choice for designing web apps. In general, it separates out the application logic into three separate parts, promoting modularity and ease of collaboration and reuse. It also makes applications more flexible and welcoming to iterations.

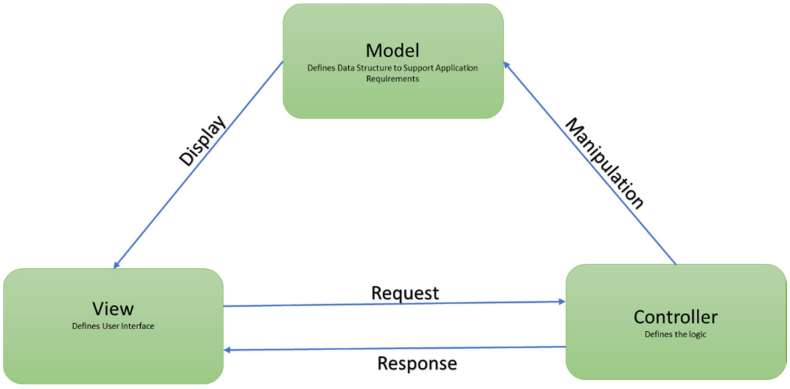

Figure 5 Diagram to show the different parts of the MVC architecture.

(a) *The Model*
The model defines what data the app should contain. If the state of this data changes, then the model will usually notify the view (so the display can change as needed) and sometimes the controller (Whether a different logic is needed to control the updated view).

(b) *The View*
The view defines how the app's data should be displayed.

(c) *The Controller*
The controller contains logic that updates the model and/or view in response to input from the users of the app.

5.2.2 Django

Django is a widely-used Python web application framework with a "batteries-included" philosophy. The principle behind batteries-included is that the common functionality for building web applications should come with the framework and not as separate libraries.
For example, authentication, URL routing, a template engine, an object-relational mapper (ORM), and database schema migrations are all included with the Django framework. Compare that included functionality to the Flask framework which requires a separate library such as Flask-Login to perform user authentication. The batteries-included and extensibility philosophies are simply two different ways to tackle framework building. Neither philosophy is inherently better than the other one[2].

Testing a Web application is a complex task, because a Web application is made of several layers of logic – from HTTP-level request handling, to form validation and

[2] https://www.fullstackpython.com/django.html

processing, to template rendering. With Django's test-execution framework and assorted utilities, one can simulate requests, insert test data, inspect application's output and verify code's performance.

5.2.3 PostgreSQL

PostgreSQL is a powerful, open source object-relational database system with over 30 years of active development that has earned it a strong reputation for reliability, feature robustness, and performance, which makes this ADSS database more robust for an easy access.

PostgreSQL isn't just relational, it's object-relational. This gives it some advantages over other open source SQL databases like MySQL, MariaDB and Firebird[3].

A fundamental characteristic of an object-relational database is support for user-defined objects and their behaviours including data types, functions, operators, domains and indexes. This makes PostgreSQL extremely flexible and robust. Among other things, complex data structures can be created, stored and retrieved. In some of the examples below you'll see nested and composite structures which standard RDBMS' don't support.

There's an extensive list of data types that PostgreSQL supports. Besides the numeric, floating-point, string, boolean and date types you'd expect (and many options within these), PostgreSQL boasts uuid, monetary, enumerated, geometric, binary, network address, bit string, text search, xml, json, array, composite and range types, as well as some internal types for object identification and log location. To be fair, MySQL, MariaDB and Firebird each have some of these to varying degrees, but only PostgreSQL supports all of them.

PostgreSQL decidedly strives to conform to the ANSI-SQL: 2008 standard, is fully ACID (Atomicity, Consistency, Isolation and Durability) compliant, and is well-known for its rock-solid referential and transactional integrity. Primary keys, restricting and cascading foreign keys, unique constraints, not null constraints, check constraints and other data integrity features ensure only validated data is stored.

Geodata is fast becoming a core requirement for many applications. PostgreSQL has long supported a variety of geometric data types such as points, lines, circles, and polygons. The PATH data type is one of these. A path consists of multiple points in a sequence and can be open (the beginning and end points are not connected) or closed (the beginning and end points are connected).

5.2.4 PostGIS

The PostGIS extension available for PostgreSQL augments the existing geometric data featues with additional spatial types, functions, operators and indexes. It's location-aware and supports both raster and vector data. It also provides for interoperability with a variety of 3rd party open source and proprietary geospatial tools for working with, mapping and rendering the data.

ADSS follows a MVC architecture. This architecture isolates the application logic from the user interface layer and supports separation of concerns. Here the Controller receives all requests for the application and then works with the Model to prepare any data needed by the View. The View then uses the data prepared by the Controller to generate a final presentable response.

[3] https://www.compose.com/articles/what-postgresql-has-over-other-open-source-sql-databases/

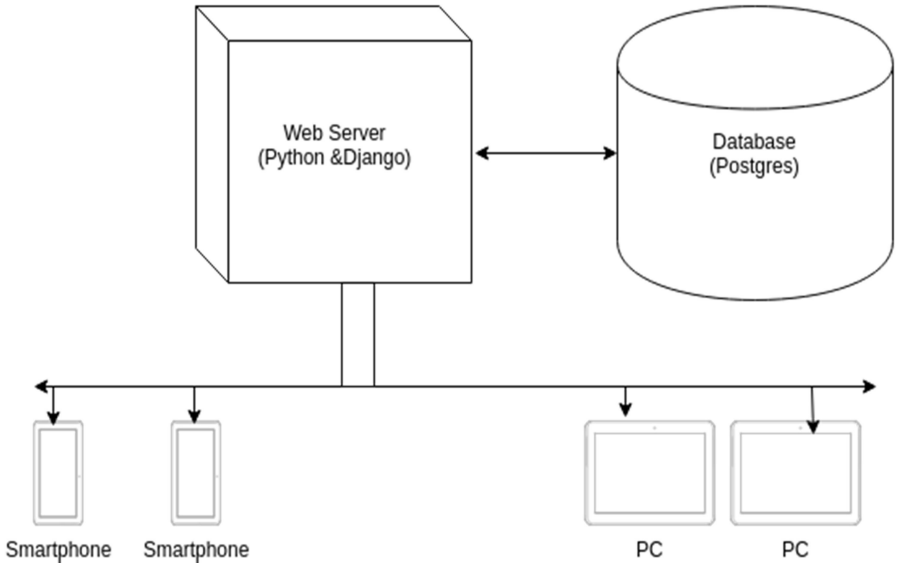

Figure 6 Flowchart for Methodology

5.3 Platform

The ADSS Platform consists of the following Software components:

- Programming Languages: Python v 2.7, HTML, CSS, JavaScript, jQuery, Java
- Web Framework: Django version 1.10, Android Studio
- Database:
  - PostgreSQL Version 9.2.9
  - PostGIS: Version 2.1.3
- Web Server: Nginx version 1.4.6
  - WSGI: Gunicorn version 19.4.5
- Deployment: Amazon Web Services (AWS) Elastic Container Service (EC2)

REST API's:

1.Login Api
URL : /api/v1/user/login/
Request Params : username, password
Request Type : POST
Response : {'success': True, 'api_key': api_key, 'userid': userid, 'group': x}
2.Logout Api
URL : /api/v1/user/logout/
Request Params : api_key, user_id, token, device_id
Request Type : POST
Response : {'success':True}

3.Register Api
URL : /api/v1/register/
Request Params : username, first_name, last_name, email
Request Type : POST
Response : 201 (HTTP 201 Created)

3. Google Cloud Messaging (GCM) Api's

URL : /api/v1/gcm/update/
Request Params : token, user_id,device_id
Request Type : POST
Response : {'success':True}
URL : /api/v1/gcm/sendNotification/
Request Params : token, user_id,device_id,sp_id
Request Type : POST
Response : {'success':True}

4.GIS Api's
URL : /api/v1/gis/check_non_plantable/
Request Params : geom (Point Coordinates)
Request Type : POST
Response : {'success':True}

URL : /api/v1/gis/getBeatData/
Request Params : geom (Point Coordinates)
Request Type : POST
Response : {'div':x, 'range': S,'comp':y, 'beat': q}

URL : /api/v1/gis/getDistrictData/
Request Params : geom (Point Coordinates)
Request Type : POST
Response : {'region': x, 'district': y, 'taluk': z}

URL : /api/v1/gis/getSpecies/
Request Params : geom (Point Coordinates),lang
Request Type : POST
Response : [{'scName': x, 'id':y, 'locaName':z}]

URL : /api/v1/gis/ getSpeciesUses/
Request Params : sp_id,lang
Request Type : POST
Response : {'uses':z, 'characteristics': q}

5.4 Hardware Requirements

The ADSS may be deployed on a single server. However, it is recommended to have separate database and web servers.

- Recommended Web Server Specifications:
  - Ubuntu 14.04 Long Term Support (LTS) 64bit
  - 3 GB RAM
  - 1TB HDD (this is used to store GIS Data. It may fill up quickly)
  - 2 CPU Cores
- Recommended Database Server Specifications
  - Ubuntu 14.04 LTS
  - 3 GB RAM
  - 1TB HDD
  - 2 CPU Cores

The ADSS should be run on Ubuntu 14.04 LTS. It is recommended that the deployment of the DSS is done on AWS EC2.

5.5 Mobile App Design

The ADSS App is built on top of Android Ecosystem to support ADSS Web App. The simplified yet intuitive design helps users to easily access & use platform features. The App provides the same features as web app.

5.5.1 Android

Android is a mobile operating system developed by Google, based on a modified version of the Linux kernel and other open source software and designed primarily for touchscreen mobile devices such as smartphones and tablets. In addition, Google has further developed Android TV for televisions, Android Auto for cars, and Wear OS for wrist watches, each with a specialized user interface. Variants of Android are also used on game consoles, digital cameras, PCs and other electronics. Undoubtedly, Android is the most widely used platform by the smartphone users. The coming of Android was definitely the biggest turning point in the phone market and it changed the entire scenario. Android has been continuously developing and improving over the years unlike other platforms. The interface, if considered from the very beginning to now has come a long way. It has become more innovative and intelligent. The prime feature of this platform is the navigation buttons, which make it easier for the user to navigate around the phone. Supporting more than 5, 00,000 applications, Android gives users the option to explore more with the Google Play Store. It is a platform which does not limit itself to the host but allows people to upload and publish the apps created by them unlike other platforms. Google calendar, Google earth, Google voice, Google translate, Blogger and Chrome are some features exclusively related to these mobile phones. The Android applications come with framework which provides all key APIs counting things like accessing the telephony system, sharing and receiving the data along with the notifications.

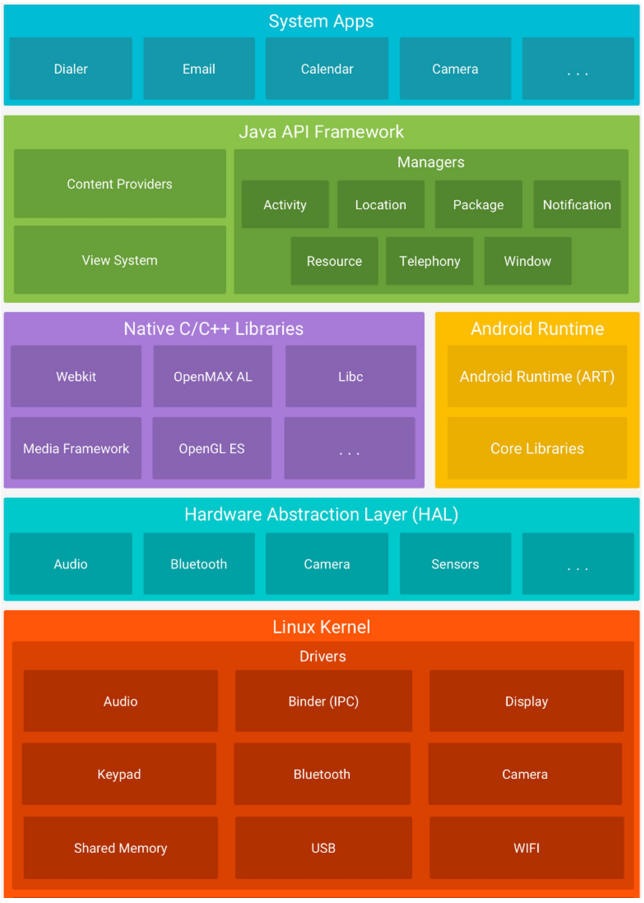

Figure 7 Android architecture

5.5.2 Android Architecture

Android is an open source, Linux-

based software stack created for a wide array of devices and form factors. The following diagram shows the major components of the Android platform.

5.5.2.1 The Linux Kernel

The foundation of the Android platform is the Linux kernel. For example, the Android Runtime (ART) relies on the Linux kernel for underlying functionalities such as threading and low-level memory management.

5.5.2.2 Hardware Abstraction Layer (HAL)

The hardware abstraction layer (HAL) provides standard interfaces that expose device hardware capabilities to the higher-level Java API framework. The HAL consists of multiple library modules, each of which implements an interface for a specific type of hardware components, such as the camera or Bluetooth module. When a framework API makes a call to access device hardware, the Android system loads the library module for that hardware component.

5.5.3 Android Runtime

For devices running Android version 5.0 (API level 21) or higher, each app runs in its own process and with its own instance of the Android Runtime (ART). ART is written to run multiple virtual machines on low-memory devices by executing DEX files, a bytecode format designed especially for Android that's optimized for minimal memory footprint. Build toolchains, such as Jack, compile Java sources into DEX bytecode, which can run on the Android platform. Some of the major features of ART include the following:

- Ahead-of-time (AOT) and just-in-time (JIT) compilation
- Optimized garbage collection (GC)
- Better debugging support, including a dedicated sampling profiler, detailed diagnostic exceptions and crash reporting, and the ability to set watchpoints to monitor specific fields

6. Stakeholder Consultation

On June 2, 2018 a Stakeholder Consultation Meeting for piloting Afforestation decision support system (ADSS) was held with CCF Chandrapur, Shri. Vijay Shelke, I.F.S and Chief Minister's Fellow Mr. Shubham Rathi, to discuss about the 50 crore-plantation program across the State by GoM to increase the forest cover from the current 20% to 33% of Maharashtra's land area by 2019, and also improving the ecosystem-based services with emphasis on water-conservation to combat adverse effects of climate change.

Figure 8 Stakeholder consultation meeting at Chandrapur

Figure 9 Stakeholder consultation meeting at Latur

7. Conclusions

Maharashtra is a fast-growing state and facing many challenges due to the change in climatic condition and pressure on its natural resources like vegetation, and water. Simultaneously, the state is experiencing deficient and erratic rainfall patterns leading to low availability of both surface as well as groundwater. One of the potential solutions to improving water availability is better planning of forestry activities with due consideration to the needs of runoff avoidance, water harvesting etc. Forests regulate water runoff, availability and quality of water in ecosystems. Forests play a special role in carbon sequestration and global carbon cycle thereby helps in mitigating global climate change. So, suitable and rigour method to accurately estimate forest biomass (as well as carbon) is of utmost required. Remote sensing technique is a multipurpose tool that can provide significant information about the forest biophysical parameters at a regional and global scale in a cost-efficient manner. Remote sensing data in conjunction with GIS can be used for forest resources mapping, monitoring and modelling that may aid in effective forest planning and management

In this view Department for International Development (DFID) – under its Climate Change Innovation Programme (CCIP) program, appointed IORA Ecological Solutions as subject matter expert agency for the development of an Afforestation Decision-Support System (ADSS). The system has been developed on two platforms -have - Web-based and a Mobile App that has all silvics features along with other parameters for appropriate species identification to support water conservation efforts in Maharashtra. The app is available to common citizens and government officials and this entire initiative is focussed on supporting the greening vision of the Hon'ble Chief Minister of Maharashtra. DSS are usually employed for complex decision-making problems of upper-level managers where models are com¬bined with data. They are flexible and adaptable, but at the same time, access to the system for non-computer-expert users is easy. Therefore, DSS are ideal platforms for transferring knowledge from science into practice and have been already applied to forest manage¬ment problems. DSS can integrate a wide range of data and models into a single system.

Stakeholders, especially, the rural population have large dependency over the forest resources. It is both for ecological (Fast growing with large canopy, Fruit bearing capacity/High yield, Good regeneration, Fibrous root system, Native) as well as economical (Timber, NTFP, Ornamental, Land reclamation, Agro-forestry/Fodder species) reasons for which these species are grown or are need to be grown. These reasons shoulb be factored in any forest decision policy to fulfil its goal of forest conservation and sustainable management of forest resources. Through this ADSS, we have tried to incorporate these factors with prime importance to make this decision support system as a medium, to provide afforestation solutions to non-forestry users. Thus, ADSS is an integration of geospatial, ecological, economic and ground information that makes it a reliable system with first of its kind to provide a solution for runoff avoidance with plantation prescription.

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Annexure I

Stakeholder consultation for piloting Afforestation Decision-Support System (ADSS)
Venue: District Collector Office, Latur, Maharashtra
Date: 8th June 2018
Participant List

Sl. No.	Name	Organization	Designation	Phone/ Mobile No.	Email-id
1.	Dr. Vipin	Zilla Parishad	CEO, Zilla Parishad	7060731408	dr.vipin.itankar@gmail.com
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4.	Chitakal Bamankar	(CHRDF) VSTF	--	9096836150	bamankarc@gmail.com
5.	Maruti Shahaji Thadsare	CMRDF, Tattapur	--	9604868222	marutithadsare@gmail.com
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8.	Lokhande VG	B.D.O. Renapur	--	7588611300	belorenapur@gmail.com
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14.	Mahajan R.S.	Tehsil Karyalay Nithanga	Lasadi	7588294246	--
15.	Shrimangle Manisha Srinivas	Sarpanch	--	7744880727	--
16.	Sri Bhosle G.R.	Gramseva Makri	--	9881160292	--
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18.	Kenche V	Tehsil Karyalay	--	9764213080	vishalkenche2014@gmail.com
19.	Upparwad T.M	Z.P.	Extension Officer	9552361840	--

			(P), Zilla Parishad		
20.	Patange AD	G.M.	CMRDF (KM)	9527393509	--
21.	Jadhav Nilesh	Gram Panchayat	CMRDF	9922751617	--
22.	Anagha D. Mhaishale	Gram panchayat	CMRDF	7083794684	--
23.	Ajij R. Tambol	Utaka	CMRDF	9657340502	--
24.	Kulkarni SS	Utaka (Gramseva)	--	9422303783	--
25.	Taakajan RS	--	--	7588294246	--
26.	CG Potulwar	--	--	7038193333	--
27.	Bove B S	--	--	9420016802	--
28	Harkale P S	--	--	9423720625	--
29.	Barkhare R G	--	--	7620206020	--
30	Neeta Sharad Pawar	--	--	9707194444	--
31	More RA	--	--	9404380166	--
32.	Bhise SN	--	--	7517950569	--
33.	IS Kandre	--	--	9067104444	--
34.	Sure BV	--	--	9011252059	--
35.	Harmate VS	--	--	8007834385	--
36.	Deshmukh AG	--	--	9420290939	--
37.	Lomte VK	--	--	9404965203	--
38.	Dharmashetty RP	--	--	9421410487	--
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43.	Surajit Ghosh	IORA ESPL	Manager (RS & GIS)	9205272826	surajit@ioraecological.com

Stakeholder consultation for piloting Afforestation Decision-Support System (ADSS)
Venue: District Collector Office, Chandrapur, Maharashtra
Date: 20th June 2018

Participant List

Sl. No.	Name	Organization	Designation	Phone/ Mobile No.	Email-id
1.	Vijay Shelke	Forest Department (IT)	Chief Executive of Forest (Chandrpur)	9765500416	Vijayshelke22@gmail.com
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Annexure II

Python Modules Used / Dependencies

Sl. No	Module Name	Version
1	amqp	2.2.2
2	apns2	0.3.0
3	asn1crypto	0.23.0
4	attrs	17.2.0
5	billiard	3.5.0.3
6	celery	4.1.0
7	certifi	2017.11.5
8	cffi	1.11.2
9	chardet	3.0.4
10	click	6.7
11	cryptography	2.1.3
12	Django	1.11.5
13	django-colorful	1.2
14	django-common-helpers	0.9.1
15	django-cron	0.5.0
16	django-excel	0.0.9
17	django-leaflet	0.22.0
18	django-push-notifications	1.5.0
19	django-raster	0.5
20	django-registration-redux	1.8
21	django-tastypie	0.14.0
22	django-user-agents	0.3.2
23	django-wms	0.1.12
24	enum34	1.1.6
25	geojson	2.3.0
26	h2	2.6.2
27	hpack	3.0.0
28	hyper	0.7.0
29	hyperframe	3.2.0
30	idna	2.6
31	ipaddress	1.0.18
32	kombu	4.1.0
33	lml	0.0.1
34	numpy	1.13.1
35	olefile	0.44
36	Pillow	5.1.0
37	psycopg2	2.7.3.1
38	pyasn1	0.3.7
39	pyasn1-modules	0.1.5
40	pycparser	2.18
41	pyexcel	0.5.4
42	pyexcel-io	0.5.1
43	pyexcel-webio	0.1.2
44	pyexcel-xls	0.5.0
45	PyJWT	1.5.3
46	pyOpenSSL	17.3.0
47	pyparsing	2.2.0

48	python-dateutil	2.6.1
49	python-gettext	3.0
50	python-mimeparse	1.6.0
51	pytz	2017.2
52	PyYAML	3.12
53	requests	2.18.4
54	service-identity	17.0.0
55	six	1.11.0
56	texttable	0.9.1
57	ua-parser	0.8.0
58	urllib3	1.22
59	user-agents	1.1.0
60	utm	0.4.2
61	vine	1.1.4
62	xlrd	1.1.0
63	xlwt	1.3.0

Chandrapur Field Photograph











Latur Field photograph





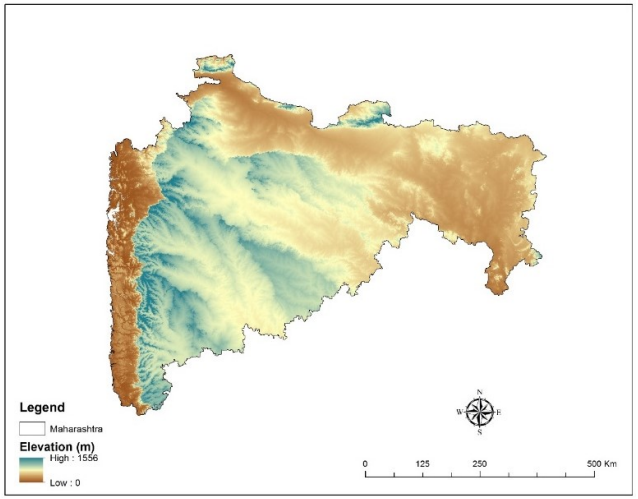


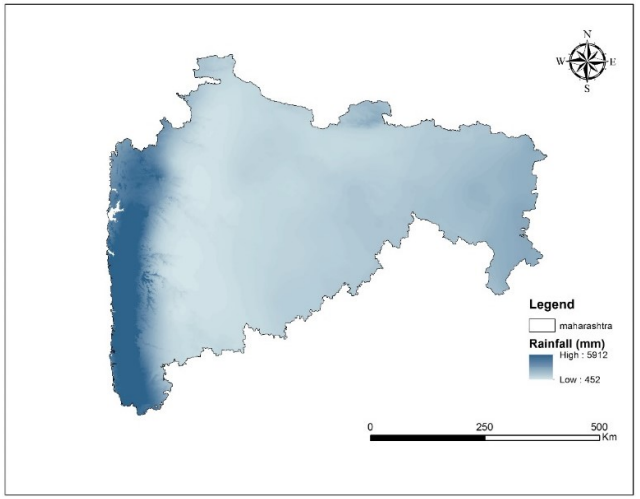


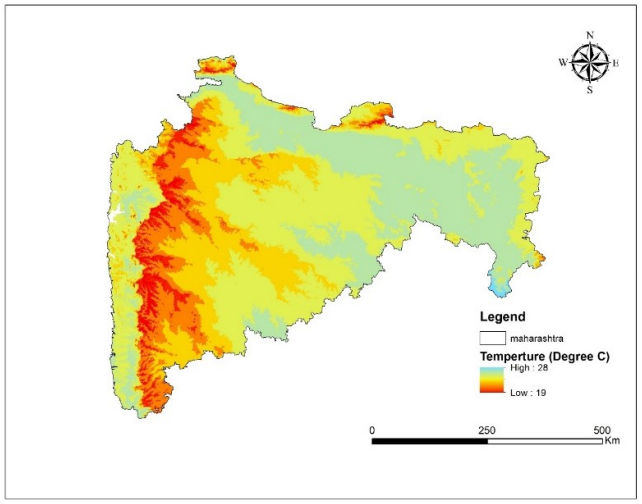


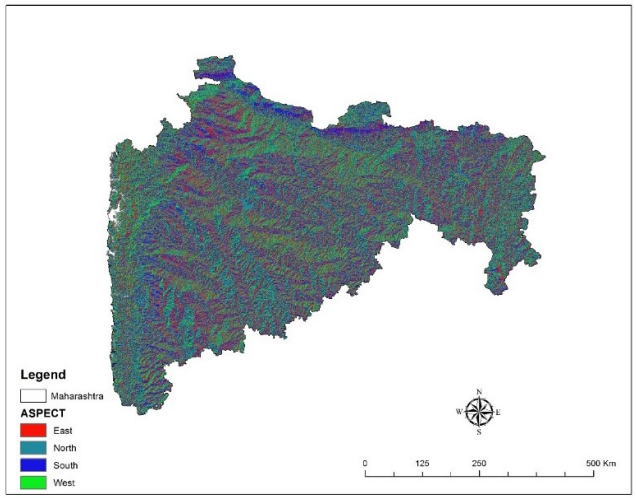

Annexure IV

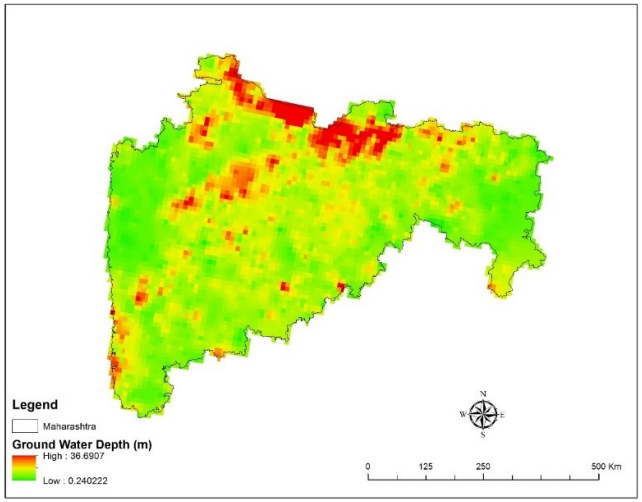
Geospatial layers

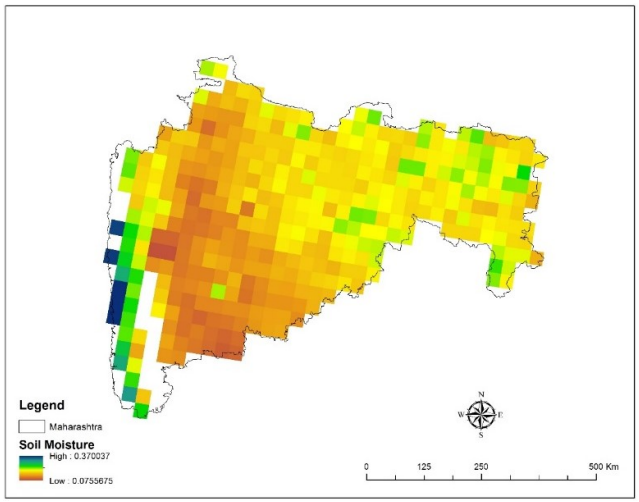









Legend
Maharashtra
Ground Water Depth (m)
High : 36.6907
Low : 0.240222
N
W
E
S
0
125
250
500 Km


Legend
Maharashtra
Soil Moisture
High : 0.370037
Low : 0.0755675
N
W
E
S
0
125
250
500 Km

Annexure V

Ecological and Economic Indicators

Ecosystem goods and services refer to the dependence of economic wealth and human well-being on natural systems. The relationship between changes in natural systems and corresponding changes in human welfare is one of the focus area of ecology and economics under changing climate. Preservation and management of natural wealth are essential policy goals. Adapting to climate change will involve the protection and management of natural wealth as it changes or is threatened by climate change. In this scenario, the most important question is what kinds of adaptation challenges will be created by climate-driven changes in the form, scale, and location of ecosystem goods and services? To understand and address this question, we have tried to identify the ecological indicators, which can provide a buffer resilience for a landscape due to climate change. At landscape level, the intricate relationship of forests with surrounding habitats defines the ecological and economic characteristics of the landscape and generates several ecosystem services. In the present project, five Ecological indicators have been identified, which can help to prevent the adverse effect of climate change, and run-off induced soil erosion. In addition, we have also included five economic indicators, which will be helpful in understanding the direct economic benefit of the ecosystem services. The species ranking has been done based on these ten indicators (**Table 1**).

Table 1. List of Ecological and Economic Indicators

Sl. No.	Ecological Indicators	Sl. No.	Economic Indicators
1.	Fast growing with large canopy	1.	Timber
2.	Fruit bearing capacity/High yield	2.	Non Timber Forest Product (NTFP)
3.	Good regeneration	3.	Ornamental
4.	Fibrous root system	4.	Land reclamation
5.	Native	5.	Agro-forestry/Fodder species

Each indicator has been assigned a score of either 1 or 0 for a particular species where the score of "1" indicates that the service is available and vice versa. After completing the scoring process, all the species will be re-ranked from 1 to 10 by combining the scores of each indicator.

A. Ecological Indicators

1. Fast growing with large canopy/ Good shade provider

Large canopy cover reflects the good health of species. Green leaves also possess a significant characteristic to absorb atmospheric CO_2. A tree with the dense crown cover not only helps in naturally reducing atmospheric CO_2 but also reduces the direct splash impact of raindrops on soils. Raindrops with high velocity make soil loose and aggravates the chance of soil erosion during floods

2. Fruit bearing capacity /High yield

The high yield production of fruits helps to maintain the food chain cycle thereby creating ecological balance in the ecosystem. High fruit and seed yielding trees accompanied with their crowded seedling regeneration create a competitive environment at intra as well as inter- species level. The seedlings along with their competitors form a cover crop to the topsoil of the forest floor and aids in arresting runoff. This increases the infiltration rate of water in soil hence protecting the soil quality.

3. Good regeneration /Coppice generation

Species richness is a link between biodiversity and ecosystem functioning. Seed generation is one of the ways to raise plants which is very liable to get influenced by climatic impacts like deluge, forest fire etc. On the other hand, coppice is very If any species is able to produce good numbers of coppice then automatically increase the richness of species in a piece of land.

Moreover, it helps in smooth running of the ecosystem through vegetative cover and soil. Adaptive to such hazardous climatic events and grow rapidly as compared to seeds.

4. *Fibrous root system*

Dense fibrous root system plays a vital role at the time of high flood and erosion. The soil-binding property of the fibrous root system is more robust and tight as compared to taproot system. During extreme climatic events like landslide and flash deluge, fibrous root system resists uprooting of trees thereby preventing soil erosion.

5. *Native*

Plantation of native species acts as a bridge for the biological control of deforestation. These species also help in restoring the ecosystem. Native species help in sustaining the growth of other associated species as these species well suited with prevailing climatic and edaphic conditions maintaining the physiognomy of the vegetation. The occurrence of native species in an area also reflects that species is allowing a healthy competition among each other and also native species never make any adverse impact over any level in the food chain, soil, environment etc.

B. Economic Indicators

6. *Timber*

Other than tress direct and indirect ecological importance such as oxygen regulation, restrict soil erosion etc. This also has a direct intake from many established furniture industry's to make many things like door, table, bed, chair, railway trek etc.

7. *NTFP*

Non-timber forest products are any product or service which are provided by any forest other than timber products. It includes fruits, gum, resin, seeds etc. and play a very vital role in human's life. It is equally essential as high valued timber product.

8. *Ornamental*

Ornamental trees are the plants which have grown in an area to beautify any place. These trees have more aesthetic value and less ecological importance. While if they can able to provide both this will treat as an added advantage.

9. *Fuelwood species*

Any tree species which can provide fuel-woods such as small twigs, dry leaves, roots etc. which can be used in day to day life for food preparation, to get rid of different small insects etc. In rural areas, fuelwood is an integral part of the daily life of villagers as a direct source from the trees.

10. *Agroforestry /Fodder species*

It's a kind of animal feed used to feed domesticated livestock like cattle, sheep, horse etc. Sometimes this also grows in association with agriculture crops known as Agro-forestry practices.

Database schema

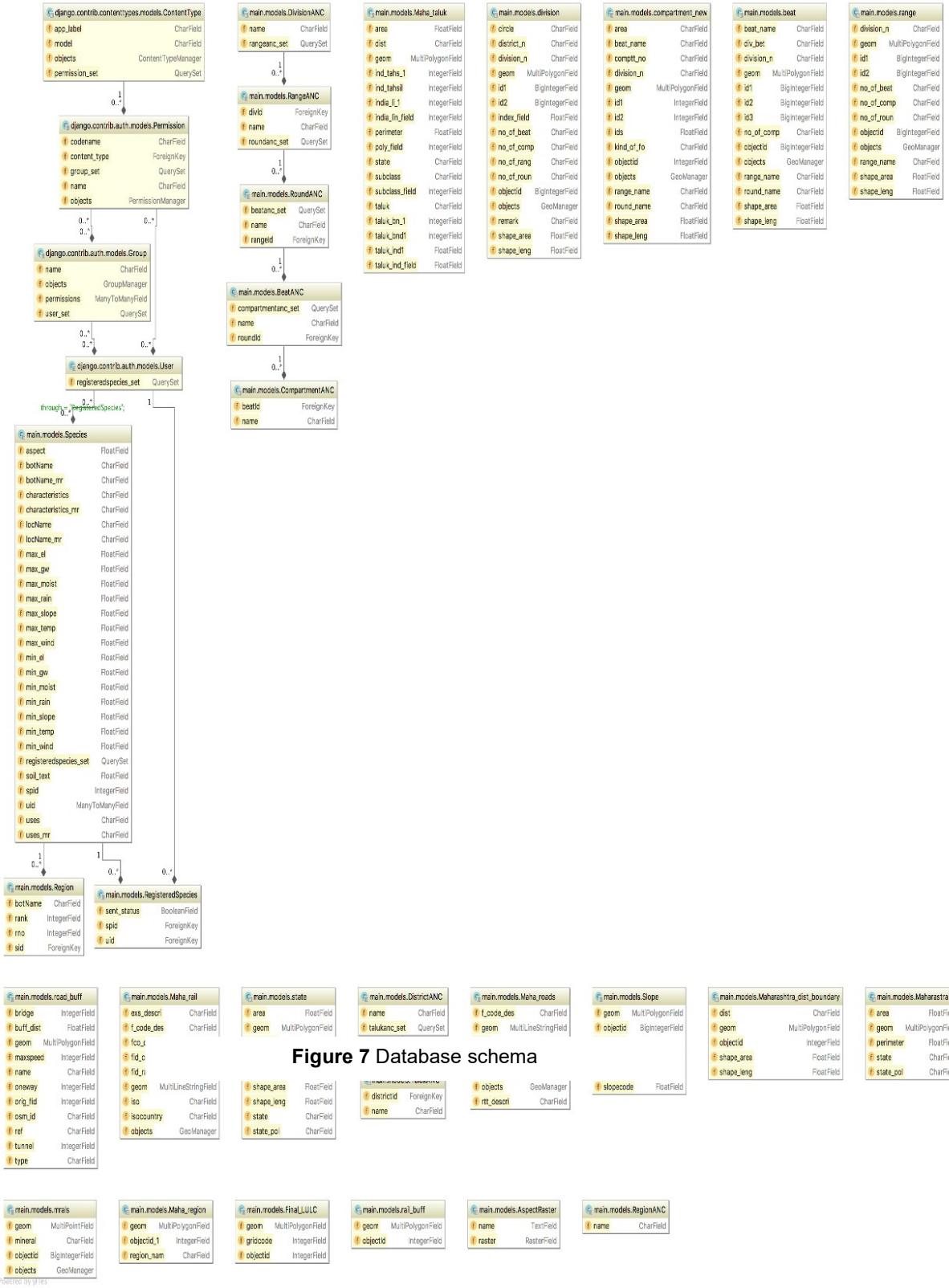


Figure 7 Database schema

Annexure VII

List of Species

S.No..	Botanical Name	Local Name	Local Name
1	*Acacia auriculiformis* A.Cunn. ex Benth.	*Australian Babhool, Akashia*	*ऑस्ट्रेलियन बाभुळ , अकाशिया*
2	*Acacia catechu* L.F. (Willd).	*Khair*	*खैर*
3	*Acacia ferruginea* D.C.	*Safed-khair, , Pandhra khair*	*सफेद खैर, पंधारा खैर*
4	*Acacia leucophloea* (Roxb.) Willd.	*Himvar*	*हिंवर*
5	*Acacia nilotica* (L.) Delile	*Babhud*	*बाभूळ*
6	*Actinodaphne hookeri* Meis.	*Pisa*	*पीसा*
7	*Aegle marmelos* (L.) Correa	*Bel*	*बेल*
8	*Ailanthus excelsa* Roxb.	*Maharukh*	*महारुख*
9	*Alangium salvifolium* (L.f.)	*Ankol*	*अंकोळ*
10	*Albizia amara* (Roxb.)B.Boivin	*Lallei*	*लालेई*
11	*Albizia lebbeck* (L.) Benth.	*Shirish*	*शिरीष*
12	Albizia odoratissima (L.f.) Benth.	*Chinchava*	*चिंचवा*
13	*Albizia procera* (Roxb.)Benth.	*Kinhai*	*किन्हई*
14	*Alstonia scholaris* (L.) R. Br.	*Satvin*	*सातवीण*
15	*Anacardium occidentale* L.	*Kaju*	*काजू*
16	*Annona squamosa* L.	*Sitaphal*	*सीताफळ*
17	*Anogeissus acuminata* (Roxb. ex DC.) Guillaum. & Perr.	*Dhawu*	*धावू*
18	*Anogeissus latifolia* (Roxb.) Bedd.	*Dhawda*	*धावड़ा*
19	*Artocarpus heterophyllus* Lam.	*Phanas*	*फणस*
20	*Avicennia officinalis* L.	*Tiwar*	*तिवर*
21	*Azadirachta indica* A.Juss.	*Nimbay*	*निम्बे*
22	*Balanites aegyptiaca* (L.) Delile	*Hingalbet , Hingam*	*हिंगलबत, हिंगाम*
23	*Barringtonia acutangula* (L.) Gaertn.	*Tiwar*	*तीवर*
24	*Bauhinia malabarica* Roxb.	*Mmli , Koral*	*अम्ली, कोरळ*
25	*Bauhinia purpurea* L.	*Kanchan*	*कांचन*
26	*Bauhinia racemosa* Lam.	*Apta , Sona*	*अपटा, सोना*
27	*Bauhinia variegata* L.	*Kanchan*	*कंचन*
28	*Bombax ceiba* L.	*Katesavar , Shalmali*	*कांटेसावर, शाल्मली*
29	*Borassus flabellifer* L.	*Taad*	*ताड*
30	*Boswellia serrata* Roxb. ex Colebr.	*Salai*	*साळई,*
31	*Bridelia retusa* (L.) A.Juss.	*Asana*	*असणा*

S.No..	Botanical Name	Local Name	Local Name
32	*Buchanania lanzan* Spreng.	*Charoli*	*चारोळी*
33	*Butea monosperma* (Lam.)Taub.	*dhak, palas*	*ढाक, पळस*
34	*Calophyllum wightianum* Wall.	*Undi*	*उंडी*
35	*Carallia brachiata* (Lour.) Merr.	*Phanshi*	*फणशी*
36	*Careya arborea* Roxb.	*Kumbhi*	*कुंभी*
37	*Caryota urens* L	*Sur-maad , Bherli-maad*	*सुरमाड, भेरली माड*
38	*Casearia tomentosa* Roxb.	*Modgi*	*मोदगी*
39	*Cassia fistula* L.	*Amaltash*	*अमलताश*
40	*Cassia siamea* Lam.	*Kasod*	*कसोद*
41	*Cassine glauca* (Rottb.) Kuntze	*Motha bhutya*	*मोठा भुत्या*
42	*Casuarina equisetifolia* L.	*Suru*	*सुरू*
43	*Ceiba pentandra* (L.) Gaertn.	*Samali , Safeta Savara*	*शमली, सफेत सावरा*
44	*Ceriscoides turgida* (Roxb.) Tirveng.	*Khurphendra, Pendra , Pendri , Phanda , Phethra*	*खुरफेन्द्र, पेंद्र, पेंद्री, फांद , फेथरा*
45	*Chloroxylon swietenia* (Roxb.) DC.	*Mirara*	*मिरारा*
46	*Cinnamomum zeylanicum* Bl.	*Dalchini*	*दालचिनी*
47	*Cleistanthus collinus* (Roxb.) Benth. Ex Hook.f.	*Garadi*	*गराडी*
48	*Cochlospermum religiosum* (L.) Alston	*Sonsavar Ganeri*	*सोनसावर गनेरी*
49	*Cordia dichotoma* Gürke	*Bhokar*	*भोकर*
50	*Cordia macleodii* Hook. Fil. & Thoms.	*Duhipalash*	*दुहिपलश*
51	*Cordia myxa* L.	*Bhokar*	*भोकर*
52	*Dalbergia lanceolaria* L.f.	*Dandus*	*दांडूस*
53	*Dalbergia latifolia* Roxb.	*Shisham*	*शीशम*
54	*Dalbergia sissoo* DC.	*Sisoo*	*सीसु*
55	*Dichrostachys cinerea* (L.) Wight & Arn. ssp. cinerea var. cinerea	*Durangi babool*	*दुरंगी बबूल*
56	*Dillenia pentagyna* Roxb.	*Piwala Karmal*	*पिवळा करमळ*
57	*Diospyros chloroxylon* Roxb.	*Ninai , Nensi*	*निनावी, नेन्सी*
58	*Diospyros malbarica* Thwaites	*Timburi , Temburni*	*तिंबूरी, टेमबुर्णी*
59	*Diospyros melanoxylon* Roxb.	*Temru , Timburni*	*टेमरु, तेमुरणी*
60	*Diospyros montana* Roxb.	*Lohari*	*लोहारी*
61	*Ehretia laevis* (Rottler ex G. Don) Roxb.	*Datrang*	*दतरंग*
62	*Erythrina indica* Lam.	*Pangara*	*पांगारा*
63	*Eucalyptus camaldulensis* Dehnh.	*Nilgiri*	*निलगिरी*

S.No..	Botanical Name	Local Name	Local Name
64	*Eucalyptus robusta* Sm.	*Nilgiri*	*निलगिरी*
65	*Falconeria insignis* Royle	*Hura , Kirkind*	*धुरा, किरकिदी*
66	*Feronia elephantum* Corrêa	*Kavath*	*कवठ*
67	*Ficus amplissima* Sm.	*Pimpara*	*पिंपरा*
68	*Ficus bengalensis* L.	*Vad*	*वड*
69	*Ficus glomerata* Roxb. syn of *Ficus racemosus*	*Umbar*	*उंबर*
70	*Ficus religiosa* L.	*Ashwattha , Pimpal*	*अश्वत्थ, पिंपळ*
71	*Ficus retusa* L.	*Nandruk*	*नांद्रक*
72	*Flacourtia latifolia* (Hook. f. & Thomson) T. Cooke	*Tanbat*	*तांबट*
73	*Flacourtia montana* J. Graham	*Raan-tambut*	*रान तांबूट*
74	*Garcinia indica* (Thouars) Choisy.	*Bheranda*	*भेरंड*
75	*Garcinia spicata* Kurz ex Talbot	*Ratamba*	*रातांबा*
76	*Gardenia latifolia* Aiton	*Ghogara*	*घोगरा*
77	*Gardenia lucida* Roxb.	*Dikamali*	*डिकामाली*
78	*Garuga pinnata* Roxb.	*Kakad*	*काकड*
79	*Glochidion lanceolarium* (Roxb.) Voigt	*Bhoma*	*भोमा*
80	*Gmelina arborea* Roxb. ex Sm.	*Shivan , Thorshivani*	*शिवण, थोरशिवणी*
81	*Haldina cordifolia* (Roxb.) Ridsdale	*Haldu , Hedu)*	*हळ्दू, हेद्दू*
82	*Hardwickia binata* Roxb.	*Anjan , Jiran , Kattudugi*	*अंजन, जिरं, कट्टुडुगी*
83	*Holarrhena antidysenterica* (Roxb. ex Fleming) Wallich ex A. DC.	*Pandhra Kuda*	*पंधरा कुडा*
84	*Hymenodictyon excelsum* (Roxb.) Wall.	*Bhorsal*	*भोरसाळ*
85	*Limonia acidissima* L.	*Kovit*	*कोवीत*
86	*Madhuca indica* J.F.Gmel.	*Kat-illipi*	*कात-ललिपी*
87	*Mallotus philippensis* (Lam.) Muell.-Arg.	*Kapila , Kesari , Shendri*	*कपिला, केशरी, शेंदरी*
88	*Mangifera indica* L.	*AAmba*	*आम्बा*
89	*Manilkara hexandra* (Roxb.) Dubbard	*Karani ,Khirni , Rajana*	*करणी, खिरणी, राजण*
90	*Melia azedarach* L.	*Bakan-nimb*	*बकाणनिंब*
91	*Mesua ferrea* L.	*Nagchafa*	*नागचाफ़ा*
92	*Michelia champaca* L.	*Sonchafa*	*सोनचाफ़ा*
93	*Miliusa tomentosa* (Roxb.) J. Sinclair	*Humb*	*हुम्ब*
94	*Miliusa velutina* (Dunal) Hook. f. & Thomson	*Chopar chilla*	*चॉपर चालला*
95	*Millingtonia hortensis* L.fil.	*Buch , Akash Chameli ,Kaval Nimb*	*बुच, आकाश चमेली, कावळ निम्ब*
96	*Mimusops elengi* L.	*Bakuli*	*बकुळी*

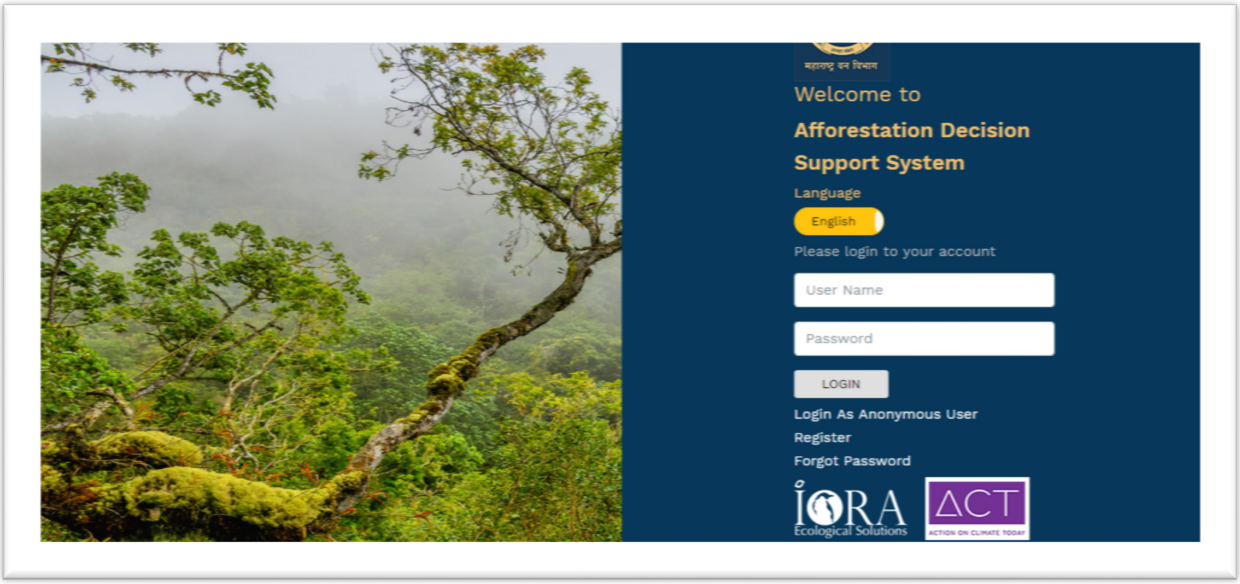
S.No..	Botanical Name	Local Name	Local Name
97	*Mitragyna parvifolia* (Roxb.) Korth.	*Kalam*	*कळम*
98	*Morinda coreia* Buch.-Ham.	*Bartondi*	*बारतोंडी*
99	*Moringa oleifera* Lam.	*Shevga*	*शेवगा*
100	*Murraya koenigii* (L.) Spreng.	*Kari Patta*	*करी पत्ता*
101	*Neolamarckia cadamba* (Roxb.) Bosser	*Kadamb*	*कदंब*
102	*Nyctanthes arbor-tristis* L.	*Paarijat*	*पारिजात*
103	*Olea dioica* Roxb.	*Parjambud*	*पारजांबूड*
104	*Oroxylum indicum* (L.) Kurz	*Tetu*	*टेटू*
105	*Ougeinia dalbergioides* Benth.	*Tiwas*	*तिवस*
106	*Phoenix sylvestris* (L.) Roxb.	*Shindi*	*शिंडी*
107	*Phyllanthus emblica* L.	*Amla*	*आवळा*
108	*Plumeria rubra* L.	*Chafa*	*चाफा*
109	*Polyalthia longifolia* (Sonn.) Thwaites	*Ashok*	*अशोक*
110	*Pongamia pinnata* (L.) Pierre	*Karanj*	*करंज*
111	*Prosopis cineraria* (L.) Druce	*Saunder, Savandad, Shamee, Shambaree*	*सौंदर, सवांदाद, शमी), शंभरी*
112	*Pterospermum acerifolium* Zorr. & Moll.	*Karnikar*	*कर्णिकार*
113	*Putranjiva roxburghii* Wall.	*Jivanputra, Patravanti*	*जीवनपुत्र, पत्रवंती*
114	*Radermachera xylocarpa* (Roxb.) Roxb. ex K. Schum.	*Khadshingi*	*खडशिंगी*
115	*Randia dumetorum* (Retz.) Lam.	*Geka*	*गेका*
116	Randia uliginosa (Retz.) Poir.	*Kalaphendra*	*कलफेन्द्र*
117	*Salix tetrasperma* Roxb.	*Bachcha*	*बच्चा*
118	*Santalum album* L.	*Chandan, Gandhachakoda*	*चंदन, गंधाचाकोडा*
119	*Sapindus trifoliatus* L.	*Rinthi*	*रिंठी*
120	*Saraca indica* L.	*Jasundi*	*जासुंदी*
121	*Schleichera oleosa* (Lour.) Oken	*Kusumb*	*कुसुम्ब*
122	*Schrebera swietenioides* Roxb.	*Mokha*	*मोखा*
123	*Semecarpus anacardium* L.f.	*Biba*	*बीबा*
124	*Soymida febrifuga* (Roxb.) Juss.	*Rakt-Rohan*	*रक्त रोहन*
125	*Spondias pinnata* (L.f.) Kurz	*Amada*	*अमडा*
126	*Sterculia urens* Roxb.	*Kulu*	*कुलु*
127	*Stereospermum chelonoides* (L.fil.) DC.	*Parad*	*पाड़द*
128	*Streblus asper* Lour.	*Poi, Karera, Kharoli, Kharota, Sahor*	*पोई, करार, खारोली, खारवट , सहार*

S.No..	Botanical Name	Local Name	Local Name
129	*Strychnos nux-vomica* L.	*Kajar, Kuchala, Jharkhatchura*	*कजर, कुचला, झरखतचुरा*
130	*Strychnos potatorum* L. fil.	*Kharkatchura, Kajrakar, Kara, Karo*	*खारकरचुर, काजरेकर, करा, करो*
131	*Syzygium cumini* (L.) Skeels	*Jambhul*	*जांभूळ*
132	*Tabernaemontana alternifolia* L.	*Nag-kuda*	*नाग कुडा*
133	*Tamarindus indica* L.	*Chinch*	*चिंच*
134	*Tectona grandis* L.f.	*Sag, Sagwan, Saya, Sayawan*	*साग, सागवान, साय, सायवान*
135	*Terminalia alata* Heyne ex Roth	*Ain, Asan, Satada*	*ऐन,असण , साताडा*
136	*Terminalia arjuna* (Roxb.) Wight & Arn.	*Arjuna, Arjun Sadada, Sadura*	*अर्जुन, अर्जुन सदादा, सादर*
137	*Terminalia bellerica* (Gaertner) Roxb.	*Behada or Bhenda*	*बेहडा, भेंडा*
138	*Terminalia catappa* Wight & Arn.	*Jangli Badam*	*जंगली बादाम*
139	*Terminalia chebula* Retz	*Hirda*	*हिरडा*
140	*Terminalia crenulata* (Heyne) Roth	*Asan, Marti*	*असं, मारुती*
141	*Terminalia paniculata* Roth	*Kindal, Kinjal*	*किंडल , किंजल*
142	Terminalia tomentosa	*Ain*	*ऐन*
143	*Thespesia populnea* (L.) Soland. ex Correa	*Kendi*	*केंडी*
144	*Trewia nudiflora* L.	*Petari*	*पेटारी*
145	*Vitex altissima* L.f. var. *altissima*	*Bavalgee, Dhavi-Rivti*	*बावळगी, दहावी-रिव्हीटी*
146	*Wrightia arborea* (Dennst.) D.J. Mabberley	*Pandu Kuda, Tambda Kuda*	*पांडु कुडा, तांबडा कुडा*
147	*Wrightia tinctoria rothii* (G.Don) Ngan	*Kala kuda*	*काळा कुडा*
148	*Xylia xylocarpa* (Roxb.) Taub.	*Surya*	*सूर्या*
149	*Zanthoxylum rhetsa* (Roxb.) DC.	*Chiphal, Chirphala, Kokli*	*चाफळ, चिरफाळा , कॉकली*
150	*Ziziphus jujuba* Miller	*Bor*	*बोर*

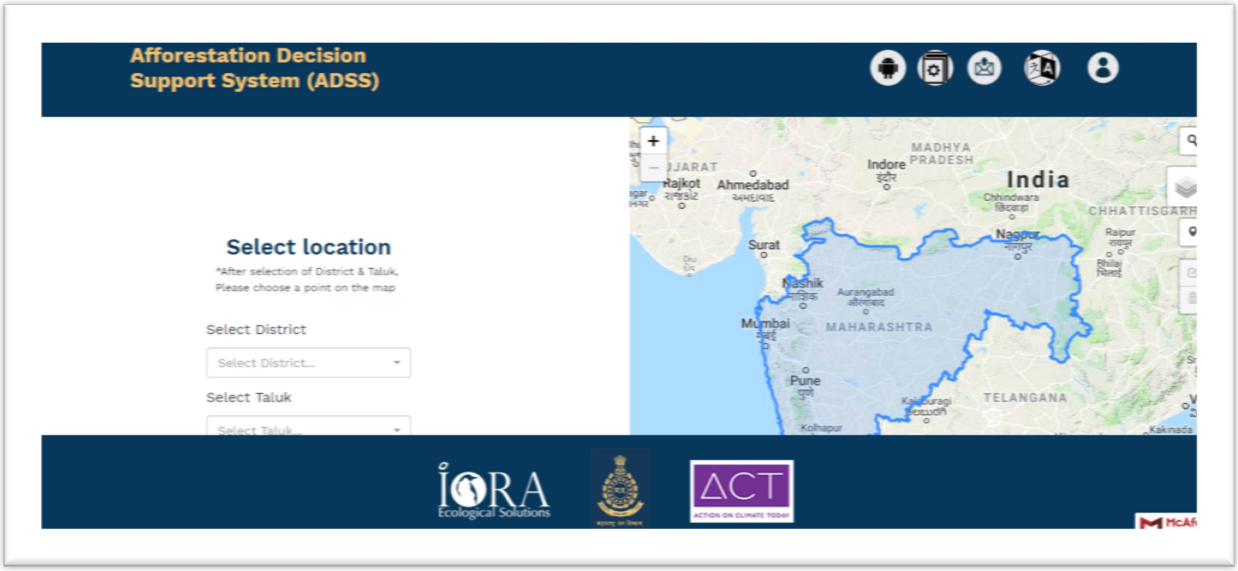
User Manual for Afforestation Decision Support System (ADSS)

Manual for ADSS (Web version)

Step 1:
Open the link in the browser https://mhadss.in/login/

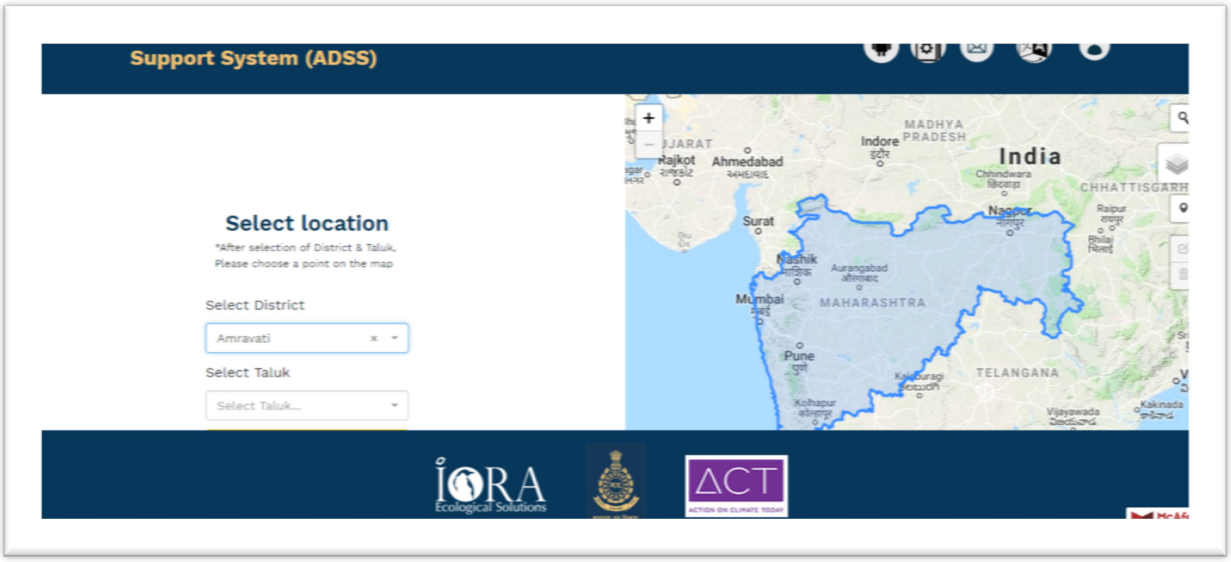


Step 2:
Click on **Register** to get membership access And/or Login as an Anonymous User to get an access to the ADSS:



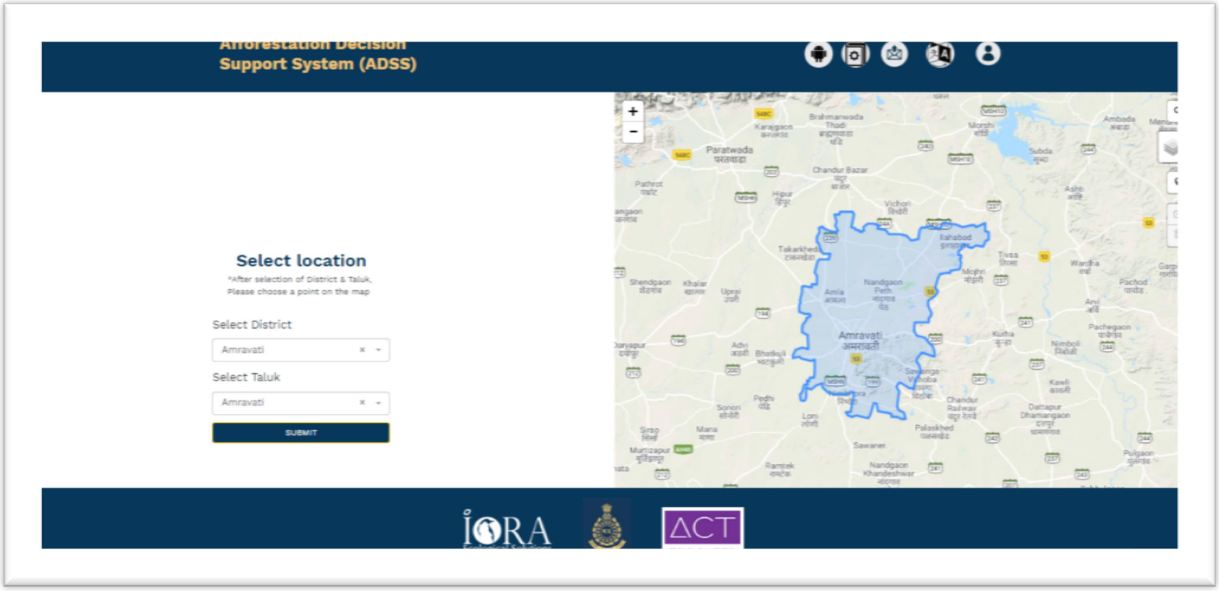
Step 3:

Scroll down to **Select district** for the selection of district from the drop down list:



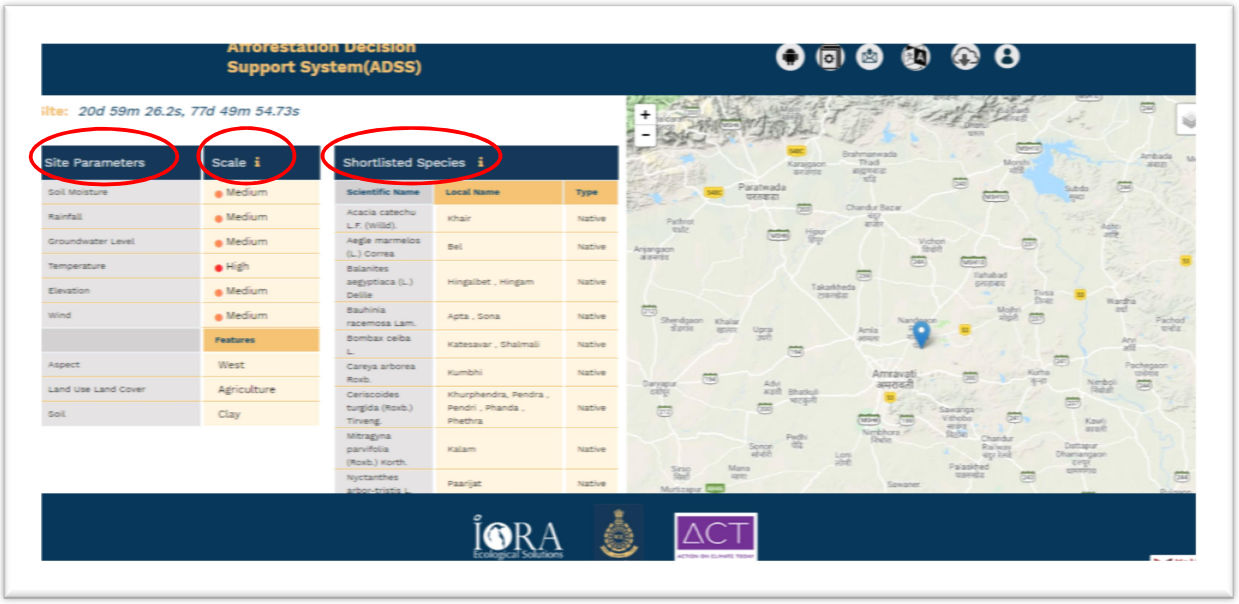
Step 4:

Scroll down to **click on Taluk** and from the Taluk list and select the taluk of interest:



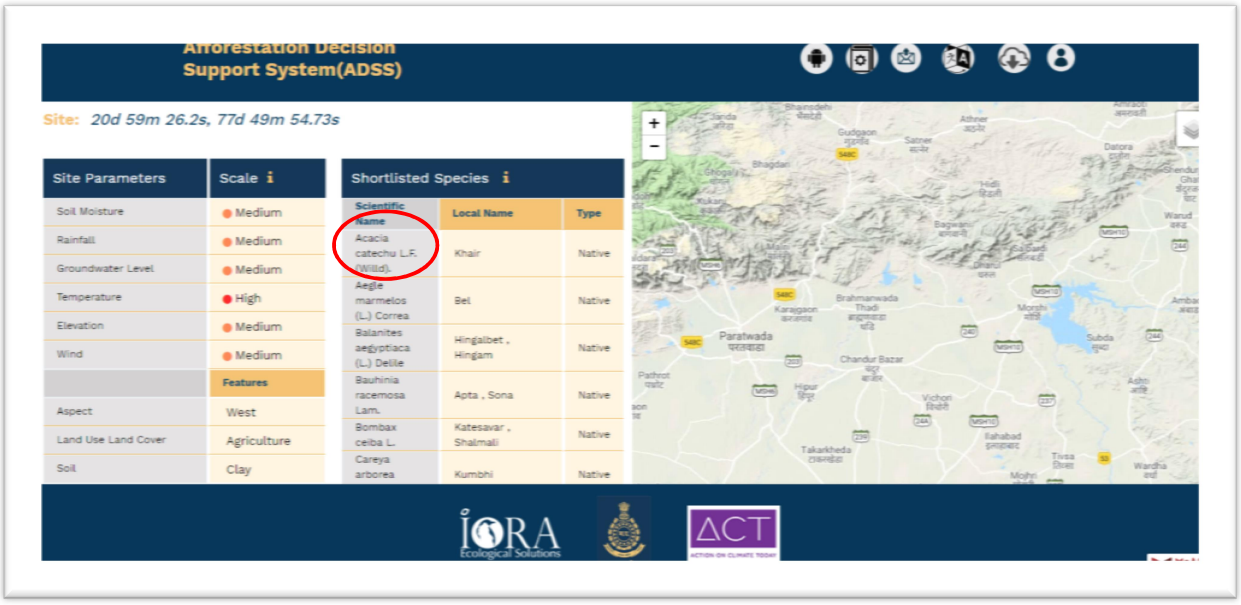
Step 5:

Click on the Draw a Marker icon upper right side of the ADSS window to select the location of interest and click **Submit:**

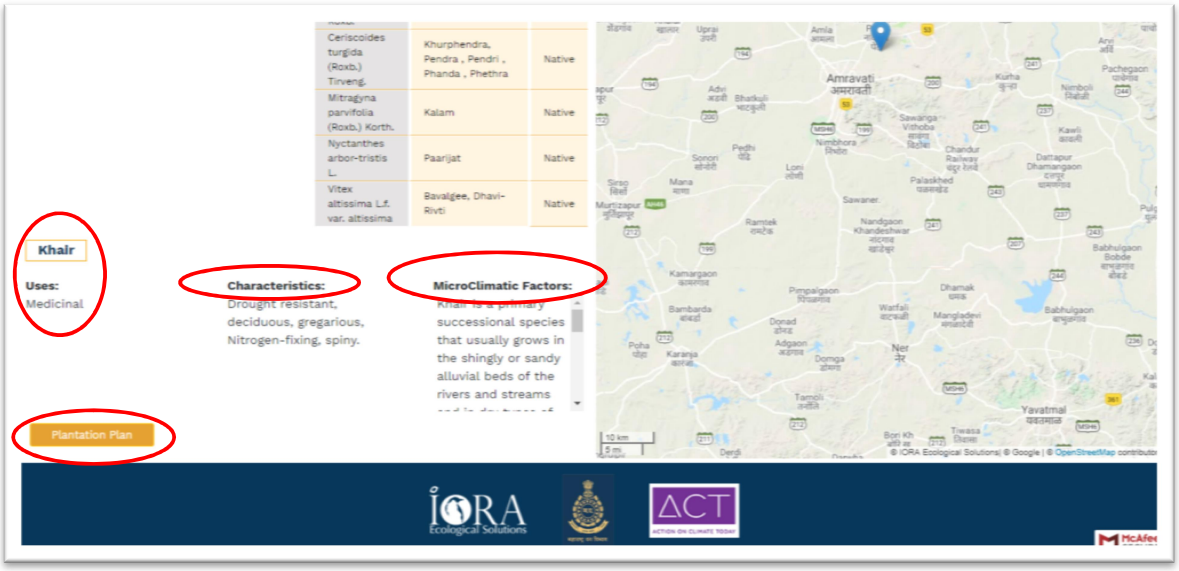


After submitting the query, detailed information viz. *site coordinate, site parameters together with its scale and list of species* appears on the ADSS window. Hover over the scale to see the values of the parameters in that area of interest

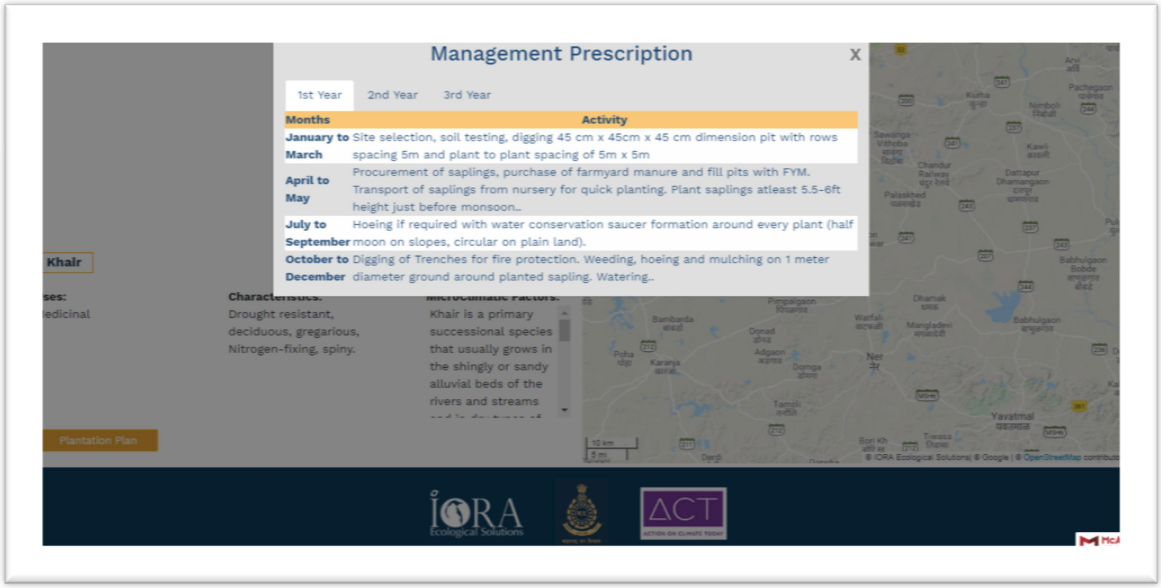
Step 6:
From the species list, select the preferred species:



A pop up with information viz: *local name; uses; characteristics and preferred microclimatic information together with Plantation Plan* appears at the bottom of the window.



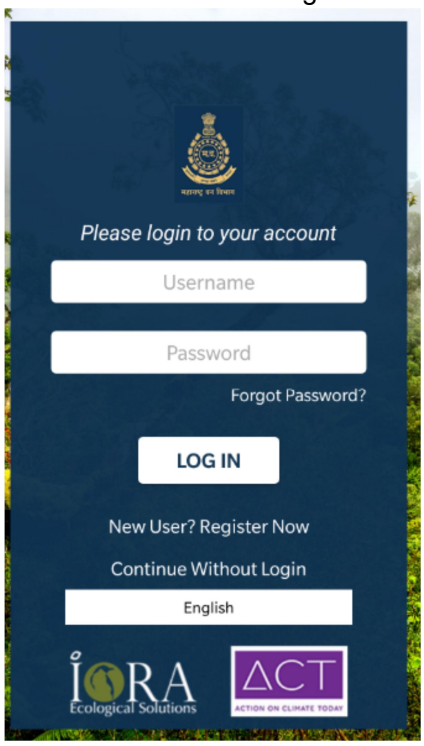
Step 7:
Click on the Plantation Plan icon to see the details of the Plantation Management and Prescription:



Manual for ADSS (Mobile version)

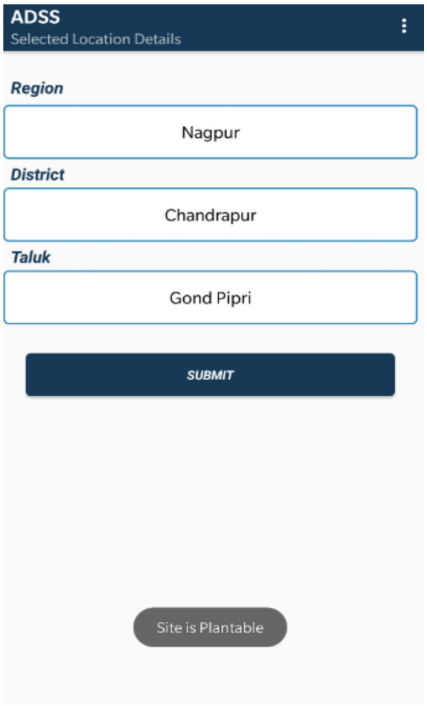
Step1:

Enter registered **Username** and **Password** to login



Step 2:

Select the **Region** to get the details of location and **Submit:**

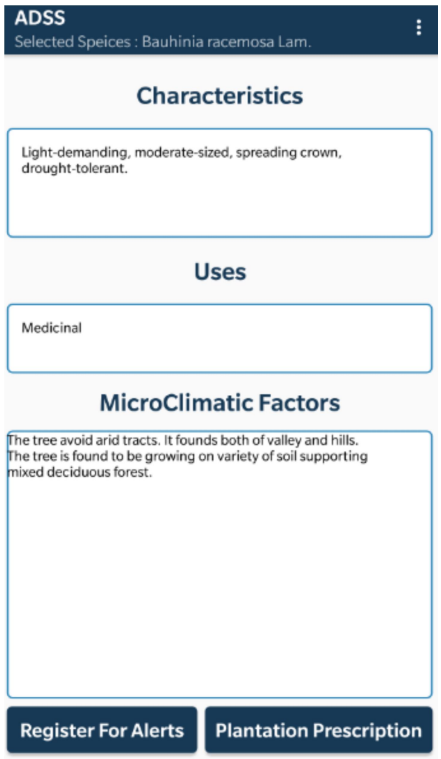


Step 3:
The location get selected in the map. Click **Submit** to continue

A new window pops up with visual scales spatial and climatic characteristics for species.

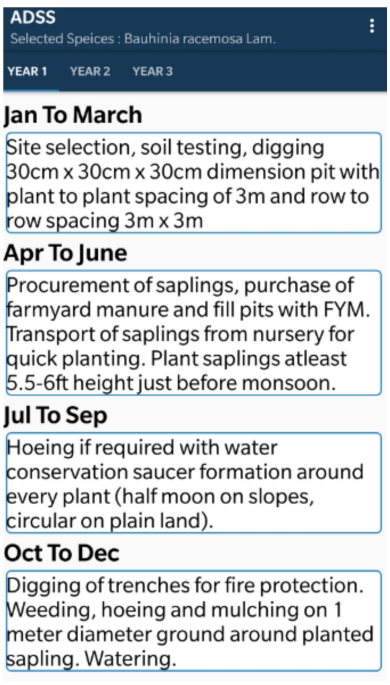
Step 4:
Select the desired species from the **Species list**

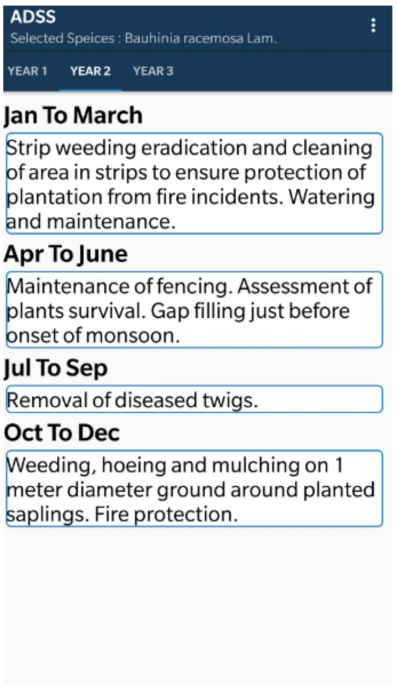
Step 5:
Once the species is selected, detailed information on the characteristics, uses and preferred micro-climate of the chosen species pops up:



Step 6:

Click on the Plantation Prescription, detailed information on the Plantation and Management for respective years pops up:





Environmental Finance • Climate Policy • Clean Technology • Ecosystem Conservation

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