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1. Background and Objective

As per international trends (Basis the IPCC 2018 report https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/), countries and cities are chasing carbon neutrality now. A carbon neutrality plan for Pune Metropolitan Region prepared by Pune International Centre (PIC) (http://puneinternationalcentre.org/publication/pathway-taking-pune-carbon-neutrality-2030/) has been endorsed by the Government of Maharashtra. Carbon neutrality means

(A) Minimize greenhouse gas emissions to the best extent possible, and

(B) Create a sink (the most popular approach being tree plantation) for the residual GHG emissions.

This approach has the simple advantage of improving energy efficiency and shifting to renewables in key sectors (for Pune these are housing and transport) and reducing the pressure of land acquisition for sequestration. Both of these have co-benefits - higher energy efficiency and shift to renewables is also typically accompanied by reduction in pollution. If we know exactly what area is needed for sequestering carbon, there will be relatively less conflict between land area needed for inevitable expansion and infrastructure building of the city and land area needed for carbon sequestration.

The approach for part A will focus on reducing greenhouse gas emissions (and pollution too as a co-benefit) through mobility interventions, and part B will focus on sequestration through tree plantation. In this case, the scenarios are linked with each other - Part A will tell you how much emission is to be sequestered, and then part B will tell you how much land is needed, what species are needed etc., for sequestering that much emissions. Separate programmatic plans are needed for each of the parts A and B simply because the two parts require different expert and knowledge inputs. But implementation of the simulations to build various scenarios must go hand in hand. The current document details the scope and objective for part B.

1.1. Pune Tree Cover

Rapid urbanization and growth has resulted in increased particulate matter and carbon footprint of the Pune city. Urban tree cover can have a significant effect in contributing to the reduction of atmospheric CO_2 levels as well as particulate matter. Given a population CAGR of 3.05%, (Current population estimated at ~43lakhs) and assuming 1 tree per person being a healthy number, there is a need to plant at least 1 lakh saplings every year.

Pune Municipal Corporation (PMC) has recently completed a tree census, of approximately 40 lakh trees, using GIS and GPS technology. The data on 25+ attributes of each tree has been captured in this process. This big dataset provides a good launch pad for this project which enables planning, impact measurement and sustenance for the tree plantation activity.

This tree census has been conducted by PMC in accordance with the Maharashtra (Urban Areas) Protection & Preservation of Trees Rules, 2009 and order passed by Hon'ble. High

Court, Bombay on 20th September, 2013. This project is in maintenance mode and the tree census can be viewed here.

The proposed project has identified areas of research related to the broad subject of trees, air quality and data analytics. It focuses on enriching the current tree census dataset through research inputs and descriptive as well as predictive analytics using other related datasets. The outcome of the project is expected to benefit the PMC in planning as well as impact measurement

The project takes a holistic view of the subject and proposes a technology enabled approach to increase the current tree cover and enhance carbon sequestration ability of Pune.

2. Project Overview

The project endeavors to leverage institutions of higher learning for the research and development components. It takes a holistic view on the subject. The key elements of the conceived project are given below.

a. Understand the characteristics of the existing tree cover (~50 lakh trees spread over PMC area of 331.26 sq km), through data mining, for tree density, native species etc.
b. Identify key species for plantation by type – Avenue, Parks & Gardens, Bio-Diversity Parks, in riparian zone, within housing societies, within commercial complexes etc. Create a tree plantation plan. PMC has a recommended list of 122 native varieties for plantation.
c. Identify plantation space. This is to be done by analyzing satellite images especially for public areas. Example: roads, riparian zone and bio-diversity parks.
d. Tree recruitment: Map saplings using participatory mapping exercise – mapathon. A framework for this data collection exercise will need to be created. Ground truthing of data will be needed.
e. Measure tree growth for a stratified sample. Build a growth model for trees and saplings. Tree mortality needs to be taken into account. Three sets of tree growth measurements are needed, in order to fit a data model for tree growth. The available tree census data being the first set, two rounds of data collection will be needed as part of the project
f. Build a Carbon sequestration model. Predict carbon sequestration capability (3-10 years). Apply this in conjunction with the growth model for saplings and trees.
g. Develop and run an Adopt-a-sapling program for Identification of sponsors. Saplings mapped through the mapathon exercise would form the superset available for adoption. Identify possible institutions / individuals who could be possible sponsors. Run campaigns – email / voice calling – with the ability to determine the best approach from campaign pilots - Reinforcement Learning.
h. Build a predictive model (3-10 years) for adsorption of particulate matter (PM2.5).
i. Other aspects: Leaf Fall modeling for planning waste collection. Birds, bees, butterflies and their population dynamics

2.1. Research Areas:

- CO_2 sequestration,
- Tree Growth Model,
- Data analytics & modeling,
- PM2.5 adsorption,

- Leaf Fall Model

2.2. Academic Collaborations:

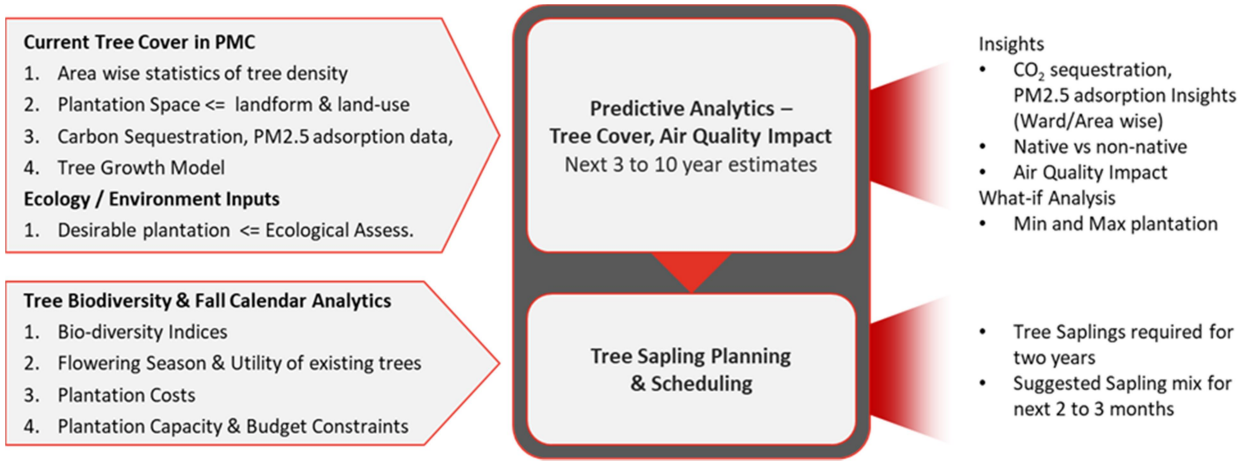
The following academic institutions have been approached and they have agreed to participate in the above-mentioned research areas

- Prof. R Sukumar, Centre for Ecological Sciences, IISc, Bangalore has agreed to be an advisor for this project
- Prof. Milind Sardesai, Department of Botany, SP Pune University
- Dr. Mandar Datar, Agharkar Research Institute, Pune
- Prof. Ankur Patwardhan, MES Garware College, Pune
- Geoinformatics, Statistics: Department of Statistics, SP Pune University, Flame University, Symbiosis International University,

3. Project Details

3.1. Conceptual Model of the Project

A conceptual model of the project is given in the Figure below. This model once developed could be used to improve the tree cover & diversity and measure the impact across other cities in India.



3.2. Key Stakeholders

- Pune Municipal Corporation
- Other Government Agencies – Forest Department, others to be named
- NGOs who are active in voluntary tree plantation and nurturing activities e.g. GreenHillsGroup, Vasundhara Abhiyaan, Nisarg Sevak and others to be named
- Funding Partners: To be identified
- Research / Knowledge Partners: Prof. R Sukumar, CES, IISc, Bangalore and Asian Nature Conservation Foundation. Others as detailed above
- Implementation Partners

Pune Knowledge Cluster (PKC): PKC is a program funded by the Office of the Principal Scientific Advisor (PSA) to Government of India. The program aims to foster collaboration between industry and academia. It focuses on key areas of social impact – Environment, Health, Electric Mobility, Big Data and Artificial Intelligence. The Principal Investigators of PKC are Prof. Ajit Kembhavi, Former Director, Inter-University Centre for Astronomy & Astrophysics (IUCAA) and Prof. L. S Shashidhara, IISER, Pune. PKC will anchor and support this project.

A Project Steering Group is proposed:

1. Chair, Municipal Commissioner (To be Decided)
2. Representatives from all the stakeholder groups
3. Distinguished Ecologists / Botanists
4. Principal Investigator

3.3. Project Approach

The approach for the different work streams of the project are detailed in this section. Multiple options are presented in some cases. The right approach will be chosen keeping in mind the timeline, budget and quality of outcomes.

3.3.1. Data Mining

- The data of 40 lakh trees that is available needs to be mined.
- Preliminary results from data mining are important for detailed planning of the project
- The data analysis and visualization requirements are detailed in the Appendix
- A geo-enabled visualization platform is recommended.

3.3.2. Identifying Space, Plantation Plan & Implementation

- Identifying plantation space is done as a manual activity, currently. Crowd sourcing has been used with the Corporator inviting citizens to come forward and suggest spots / spaces where plantation is required.
- Analysis of satellite images could be done to identify plantation space. This would especially apply for bio-diversity parks / forest area, roadsides and riparian zone.
- Crowdsourcing (technology enabled) is also important given the element of citizen participation. It complements the requirement 2.h adopt-a-sapling platform. The Pune Knowledge Cluster (PKC) has a platform to enlist volunteers. This platform could be tweaked and used for this project
- Coordinating the implementation activities (with the stakeholders) and data reporting.
- PMC has indicated support for preparation of saplings, digging etc. They have requested the project to budget for “tree guards” to protect existing and newly planted saplings. As a government body, they are unable to

3.3.3. Tree Recruitment

- Recruitment of new trees can be divided into two main components.
    a) Plantation
    b) Natural recruitment

- In an urban area like Pune, plantation will dominate the overall recruitment. There could be structured plantation, for example: plantation in parks, roadsides, schools. Such plantations in public places are relatively easy to track compared to plantations in personal properties.
- Natural recruitment is stochastic in nature and recruitment rates vary by species. Areas that have been undisturbed for the last 10-15 years need to be identified and natural recruitment studied in these areas
- Different approaches could be considered in estimating recruitment rates due to plantation activity.
    a) A full manual census only looking at new saplings
    b) A partial census, with sampling strategy covering different land classification types (to target natural recruitment). Additionally tracking of new plantation
    c) Using high resolution (sub-2m resolution) satellite imagery. (Ex: GeoEye, QuickBird, WorldView, IKONOS, Pléiades, KOMPSAT, TripleSat, Spot, Cartosat etc.) OR Use of Airborne-LIght Detection and Ranging (LIDAR)
- In the last three years i.e. 2017, 2018 and 2019 approximately 3 lakh saplings have been planted under the CM's drive for 50 Crore plantation in three years. Identifying "surviving" saplings, where required would be done as a part of the mapping.
- Saplings have been planted by a number of volunteer groups and NGOs too. It is important to map these saplings. As an example, Green-hills-group is active on Hanuman Tekdi, ARAI hill & Chaturshringi Hill; Vasundhara Abhiyan and a couple of other volunteer groups are active in the Baner-Sus Tekdi area.
- The surviving saplings are precious as they would sequester a good amount of carbon in 3 to 10 years.
- Tree mortality needs to studied too during the exercise for tree recruitment
- There are three work streams in this
    a) Designing a sampling strategy and creating a plan for the field work
    b) A platform for enrolling volunteers and supporting the mapping exercise for these saplings is needed. Open source tools like Epicollect5 (https://epicollect5.gitbooks.io/epicollect5-user-guide/content/) must be evaluated to support this data collection. Epicollect-5 can be adopted for use in Marathi and Hindi languages also. Doctor Vijay Edlabadkar, retired principal of Armori college in Gadchiroli district, and Prof. Madhav Gadgil have very successfully conducted such a campaign to collect information on forest resources of Gadchiroli district. Young men and women residing in very small villages scattered through Gadchiroli district contributed to this data collection exercise using Epicollect5 and did an excellent job. An Extract-Transform-Load layer may need to be built to upload this data into the database.

c) Onboarding volunteers and running the mapping exercise with these volunteers. Correct identification of species will be required. Therefore the volunteer groups need to be supported by persons from the Botany / Ecology stream who are knowledgeable about this aspect. A validation process may also be put in place.

- Multiple rounds of the mapping exercise are envisaged. A core team of volunteers who can conduct a mapping exercise would be groomed through these rounds. A mechanism for "tagging" the mapped saplings will need to be drawn up.
- The adopt-a-sapling team will use the saplings data collected through this exercise and offer selected saplings for adoption.

3.3.4. Carbon Sequestration Modeling including Tree Growth

- Estimating Carbon-sequestration rates requires measuring change in Carbon content of trees at different time intervals. Carbon content is difficult to measure directly, however, it is roughly half of the total biomass of the trees.
- Total biomass of a tree can further be divided into Above-ground Biomass (AGB) and Below-ground biomass. Below ground biomass is extremely difficult to measure, however it is shown to be proportional to the AGB, and sometimes equal to AGB.
- Majority (>95%) of the Above Ground Biomass is in the woody parts of the trees.
- Assuming AGB is a good proxy for the total carbon content of the tree, a city level tree Carbon-sequestration rate can be estimated by tracking AGB change over time.
- Modeling carbon-sequestration rate requires spatiotemporal modeling of change in AGB and its interaction with many factors (climate, disturbance, topography, and soils etc.).The academia would be leveraged to finalize both the approaches. Existing literature survey will be conducted.

3.3.4.1. AGB Estimation & Change in AGB

- AGB can be estimated non-invasively using the existing allometric relationship of AGB with variables such as Diameter at Breast Height (DBH), tree height, wood density. However, variables such as wood-density vary by species, hence species level identification is required.
- We are using a widely accepted and recognized global allometric equation (Chave et. al. 2014) to estimate AGB.
- J. Chave et al (2005) in their paper "Tree allometry and improved estimation of carbon stocks and balance in tropical forests" have provided allometric equations for estimating the Above Ground Biomass (AGB) across tropical forest types. These models are based on a large dataset of 2,410 trees (>= 5 cm) diameter, directly harvested in 27 study sites across the tropics. The paper identifies the most important predictors of AGB of a tree, in decreasing order of

importance, as, its trunk diameter, wood specific gravity, total height, and forest type (dry, moist, or wet).

- Major change in AGB is driven by two processes
    - Tree demography (recruitment and mortality)
    - Woody growth of existing trees
- Both demography and growth differ by species and depend on many factors such as (climate, disturbance, topography, and soils etc.).
- Modeling change in AGB requires modeling of underlying processes such as recruitment, mortality, and growth. Approaches to Tree recruitment are discussed above.

3.3.4.2. Estimating Mortality Rate

- Mortality of the trees are caused by following main factors
    - Senescence
    - Droughts/ Floods
    - Diseases (Pest, fungal, termite infection)
    - Manual Cutting
    - Windfall
    - Fire
    - Nutrient limitation
    - Herbivory (Insects, mammals)
    - Pollution
    - Tree-Injury
- Mortality rates, and mortality causes are species specific and depend on DBH. For example, senescence is higher in large DBH classes. Fungal and insect infestation could be highly species specific. Manual-cutting prevails during construction projects. Windfall is often associated with large trees having weaker mechanical strength, either due to poor root system and lower wood density or due to other comorbidities.
- Mortality in urban areas could be higher for trees located on the pavements, highly disturbed areas. While it can be lower for trees inside the personal properties or parks.
- Following are the different approaches which can be considered in estimating mortality rates
    a) A full manual census
    b) A partial census, with sampling strategy covering different land classification types. Additionally tracking of known tree-cutting

c) Using high resolution (sub-2m resolution) satellite imagery (Ex: GeoEye, QuickBird, WorldView, IKONOS, Pléiades, KOMPSAT, TripleSat, Spot, Cartosat etc) Or Use of Airborne-LIDAR

3.3.4.3. Estimating Tree Growth

- Woody growth is a key contributor to net carbon sequestration. The AGB increases by increase in the woody volume of the tree. It can be estimated by a repeated measurement of DBH and height. It is a relatively slow process. Studies, growth contributes roughly 0-2% increase in AGB), hence requires a high precision in measurements.
- Growth rates vary by species and DBH size class. Smaller DBH-classes grow faster but their contribution to change in AGB is lesser due to lower wood volume. On the other hand, relative growth of larger trees is lesser but change in AGB contribution is bigger.
- Growth rates highly depend on water and nutrient availability. Growth rates during a prolonged drought period can differ significantly from the rates after a period of good rainfall. Similarly, growth of trees in the parks could be very different from growth of trees located near highly concretized places. Natural variation in topography (valley vs hill), local ground-water tables also affect the tree growth rates.
- Research team from Centre for Ecological Sciences (CES) , Indian Institute of Science (IISc), Bangalore has examined tree growth rates in a large permanent plot at Mudumalai, southern India, for the influences of rainfall and three intrinsic factors (size, species and growth form) during three 4-year intervals over the period 1988–2000. The findings are published in a paper “Patterns of tree growth in relation to environmental variability in the tropical dry deciduous forest at Mudumalai, southern India”.
    - Growth measurements of over 14000+ stems spread over 61 species were used for analysis in this paper.
    - Among the species that are measured at Mudumalai, 36 species are present at Pune. Number of trees belonging to these species is ~1.7 lakhs
    - Possibility of obtaining this tree growth measurement data as well as data related to the environmental factors of Pune needs to be explored in order to apply machine learning techniques for projecting the GBH
- Here are the different approaches that could be considered for tree growth measurements
    a) A full manual census measuring only the DBH
    b) Species wise sampling (targeting ~1000 trees per species covering all DBH classes of major species)
    c) Sub-sampling the approach mentioned in b) above. Combine with Installation of dendrometers on selected trees
    d) Acquiring growth rates of species from literature

- Actual tree measurements (at least two more in a time series) are important. Measurements need to be done during the driest period i.e. from March to May. GBH needs to be measured and tree height too, if possible, using a clinometer.
- A tree growth and modeling expert would be needed to detail and finalize the approach. Prof. R Sukumar has mobilized resources for the same. Asian Nature Conservation Foundation would be the knowledge partner.

3.3.5. PM2.5 Adsorption modeling

- The academia would be leveraged to finalize the approach for modeling this. Existing literature survey will be conducted.
- This model would be built in the second Phase of the project

3.3.6. Adopt-a-Sapling

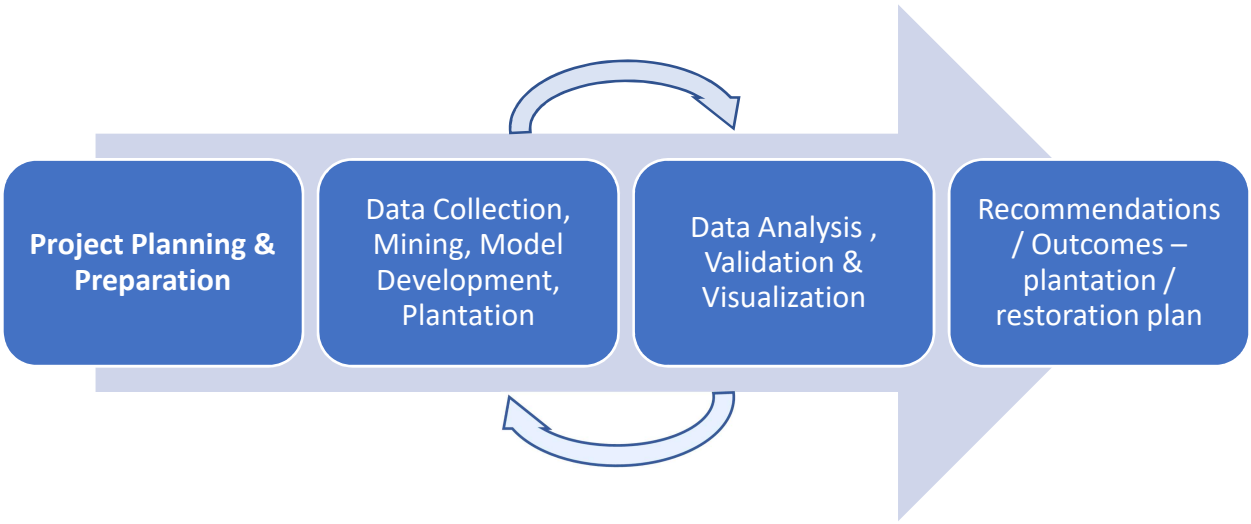
- For any tree-planting drive to be successful, it is important to ensure that the saplings that are planted grow up to become robust trees. Saplings need to be nurtured / watered for the first 5 years. This component assumes that a body like PMC provides nurturing for the saplings e.g. watering and a per year cost per tree is worked out. The sponsors contribute money towards the saplings / trees that they would like to adopt. Budget for "tree Guards" especially for road-side trees would need to be included in the sponsor's budget for the first year. This would be in addition to the yearly maintenance cost.
- The saplings planted by Green-hills-Group, Vasundhara Abhiyan and a few other volunteer groups are nurtured by them, respectively. These may be considered as "adopted" by them.
- This platform will build on the participatory mapping exercise for saplings. A small sample (2000 saplings in year 1 and 4000 saplings in year 2, of the native species) would be identified as candidates for adoption. These would be geo-tagged.
- Nurturing of saplings: The modalities and per tree cost for nurturing needs to be worked out. The possibility of PMC providing services for nurturing needs to be explored. Typically, PMC makes "water" available. A Maintenance partner for saplings / trees would need to be identified. Nisarg Sevak NGO has a "Smruti Vaan" project. They need to be approached too.
- Approach to identify sponsors needs to be detailed. The number of saplings being offered for adoption in year 2 may be increased basis the implementation experience in year 1
- Campaigns: Voice calling or email campaigns need to be run to onboard sponsors. Experience of Nisarg Sevak in running "Smruti Vaan" needs to be leveraged
- Campaign Analytics: Using Reinforcement Learning to identify and "train" the system for the best approach.

3.4. Project Phases and Timeline

1. **Phase 1**: The first phase of the project will consist of scope outlined in 2a through 2g. The expected timeline is ~3 years. It is proposed to start the project with a **Proof-of-Concept** (POC). The POC will include tree growth and modeling aspects. It will be completed during the first 8-9 months.
2. **Phase 2:** In this phase the scope of the project would be expanded to include the Pune Metropolitan Region. In additions items listed under 2h and 2i would be part of the phase 2 of the project.

3.5. Project Stages for the First Phase

The figure below shows the high-level components of the first phase of the project. It is envisaged that the first phase will be of 36 months duration. These will be refined basis inputs from Research partners / collaborators



3.6. Project Team for the First Phase

The project team for the first phase is detailed in the following table.

S No	Role	Role Details	Remarks
1	PMC Single Point of Contact	Responsible for enabling the connects within PMC	De Facto. Nominated by the MC or AMC
2	Principal Investigator (PI) /	Responsible for driving the project forward. Single point of contact for all the external stakeholders of the project	Anita Kane, Senior Advisor, PKC will be the PI

	Program Lead		for this project
3	Environment / Ecology Lead	Responsible for project coordination between the IT/Data Science team, Ecology Partner, Consultants and academia • Conceptualizing the sampling approach related field work and setting up the process with Epicollect5 • Training volunteers / team and Running mapathons • Training volunteers and supervising field work for tree recruitment, mortality, growth, wood density measurements etc • Work closely with IT team to deliver carbon sequestration capacity for PMC including predictive modelling. Engage academia for detail design / developing the Detailed Approach / Methodolgy for tree growth model and the Carbon Sequestration Model and then develop, test and validate	Ankur Shringi has been identified by Prof. R Sukumar. He will represent ANCF for the POC i.e. ~1year. Local lead and PKC PM / APM to work closely and acquire knowledge. Local Lead may be sourced from implementation partner - WRCS India
4	Environment / Ecology Team	Field work for Scope listed in 2.b , 2.c,2.d,2.e for ~10000 saplings. Also 3.3.3 b – Running mapathon • Mobilizing volunteers and Running mapathons, mortality assessments etc • Mobilizing volunteers and conducting tree growth measurements	Two Field staff from implementation partner Long-term interns / volunteers
5	Data Science / IT Lead also functions as a lead for the IT components	• Responsible for project management, and delivery of the IT & Data Science Components. • Requirements analysis and design of visualization and data mining requirements. Technology evaluation would also be needed. • Work closely with Ecology Lead for delivering carbon sequestration capacity for PMC including predictive modelling. Engage academia for detail design / developing the Detailed Approach / Methodolgy for tree growth model and the Carbon Sequestration Model and then develop, test and	

		validate. • Adopt-a-Tree campaign using reinforcement learning • Coordinating data dives / reviews with industry for leveraging expert inputs • Project Reporting to Steering Group & funding agencies.	
6	Data Science / IT /GIS Team	• Work closely with the Data Science / IT lead for development of: • Platform for enlisting volunteers • Evaluation of Epicollect5 & building integration layer • Adopt-a-sapling platform • Campaign Analytics • Data Analytics & Visualization • Reporting	IT Team + Data Science & GIS interns

7	GIS team	• Analysis of satellite imagery
		  ○ for identifying plantation space
		  ○ Sampling
			Prasad Pathak, Flame University mobilized

8	Campaign Lead	• Strategy for identifying sponsors, • Planning and execution of the campaigns	IT+Marketing analytics. WIDS / Sucheta Dhere is a possible partner
9	Outreach Team	• Asking for volunteers • Public outreach and awareness • Updating website, social media etc • Maintaing acknowledgement/ certification for interns • Adopt-a-Sapling campaign execution & management • Publishing Public Reports	1-2 team members + Interns

3.7. Key Project Partners

1. **Pune Knowledge Cluster**: The project will be anchored by the Pune Knowledge Cluster (PKC).
2. **Asian Nature Conservation Foundation (ANCF)**: http://www.asiannature.org/about-ancf/our-vision The ANCF will be the knowledge partners for the carbon sequestration capacity, tree growth measurements and modeling aspects of the project.

3. **Wildlife Research & Conservation Society (WRCS)**:
   https://www.wrcsindia.org/ The WRCS will be the implementation partners for the project. They will plan and conduct the field work.
4. **Savitribai Phule Pune University**:
   The Department of Statistics will partner on the stratified sampling & data modeling and the Department of Botany will partner for the ecology / taxonomy aspects.

4. Project Costs – Phase 1

The table below presents high level estimates for the project costs. Key assumptions are stated below

4.1. Assumptions

- PKC will contribute towards the hardware infrastructure requirements for the project.
- Open source software will be used.
- PMC will contribute towards the sapling / tree plantation activity.
- The Statistics & data modeling team will be housed in the Department of Statistics and the Ecology team will be housed in the Department of Botany, SP Pune University. Costs for office space have therefore not been budgeted

4.2. Cost Summary

- **Three year cost estimate is ~INR 2.22 Crores**
- Detailed breakup of costs is provided in the table below

S #	Item	Months	People	Yr 1 (INR Lakhs	Yr 2 (INR Lakhs)	Yr 3 (INR Lakhs
1	Ecology Leads	36	2	12	6.5	7
2	Ecology Team / Field Team	36	2	5	6	6.5
3	Data Science Lead	36	1	12	13	14
4	Data Science / IT Team	33	2	9	10.5	11.5
5	GIS Team	30	2	6	6.5	3.5
6	Hi Res Satellite Imagery, Tree tags, dendrometer bands, tools etc		-	10.5	5	1
7	Hardware / Server, Cloud, (if any) (n years)					
8	Software Costs - Year 1, Year 2, Yr 3					
9	Other Costs - Local Transport, Travel, Workshops, meetings, posters,website design, stationery			3	3.5	2.5

10	Adopt-a-Sapling – Campaign & Analytics	18	Lead + 1	9	18	3
11	Administrative Overheads			6.7	6.9	4.9
12	Project Interns	36	5	6	6	7
			Total	79.2	81.9	60.9
					Grand Total	222

5. Key References

5.1. Remote Sensing & Land Use

1. Agarwal 2013 - Mapping Urban Tree Species Using Very High Resolution Satellite Imagery: Comparing Pixel-Based and Object-Based Approaches; Shivani Agarwal, et al; Int. J. Geo-Inf. 2013, 2, 220-236;
2. Bhaskar 2012 - URBANIZATION AND CHANGING GREEN SPACES IN INDIAN CITIES (CASE STUDY – CITY OF PUNE), Padigala Bhaskar, Faculty of Sustainable Environment and Climate Change, Center for Environmental Planning & Technology, Ahmedabad-380009, India. International Journal of Geology, Earth and Environmental Sciences ISSN: 2277-2081 (Online)
3. Satellites could soon map every tree on Earth. Article in Nature. https://www.nature.com/articles/d41586-020-02830-3

5.2. Carbon Sequestration & Tree Growth Modeling

4. Nath 2006 - Patterns of tree growth in relation to environmental variability in the tropical dry deciduous forest at Mudumalai, southern India; CHERYL D NATH, H S DATTARAJA, H S SURESH, N V JOSHI and R SUKUMAR, Centre for Ecological Sciences, Indian Institute of Science, Bangalore 560 012, India; J. Biosci. 31(5), December 2006, 651–669, © Indian Academy of Sciences.
5. Chave 2005 - Tree allometry and improved estimation of carbon stocks and balance in tropical forests, J. Chave, C. Andalo, S. Brown, et al Oecologia (2005) 145: 87–99
6. Chave 2014 - Improved allometric models to estimate the aboveground biomass of tropical trees; J. Chave, M. Rejou, A. Burquez, et al; Global Change Biology (2014) 20, 3177–3190,

6. Interactions with Leaders

Meetings, workshops and brain storming sessions were conducted with a number of individuals and leading organizations in the formation of this proposal. The table below summarizes the details

Opinion Leader	Org. Category	Modality	Key Comments
Mayor Pune - Mukta tai Tilak	PMC	Went through the proposal in the context of Environment Week 2019	Showed tremendous interest in Adopt-a-Sapling program and wanted to get it off the ground immediately
Addl Municipal Commissioner - Rubal Agarwal	PMC	Meeting was a follow-up of the interest shown by Mayor	Budget for tree plantation is available.
Head, Garden Department, Head Tree Authority, Environment Officer	PMC	Multiple meetings individually and together	Budget for tree plantation is available. 10 lakh trees remain in Pune to be censused. Proposal must be presented to Tree Authority Committee
Aditya Malve, Corporator & Member Tree Authority Committee	PMC	Meeting sought	Extremely happy to support the project. Budget for tree plantation is available. Requested to provision for "tree guards" as a part of the project as the MC was not allowed to procure because of its scrap value
World Resources Institute represented by Ruchika Singh	NGO	Reviewed the proposal	Expressed interest in partnering for implementation. Provided a reference to their Cities4Forests platform
Sankalp	NGO	Reviewed the proposal	Offered to help with fund raising
Ecological Society	NGO	Reviewed the proposal	Suggested an exhaustive soil survey before any plantation activity. Keen topartner however reformation of the legal entity was in progress during Nov 2020
Tata Trusts - Shloka Nath, Anuj Gangwal	NGO	Reviewed the proposal	Positive feedback due to unique nature of the proposal. Keen to fund through its partners
Prof. R Sukumar, Centre for Ecological Sciences, IISc, Bangalore	Research	Reviewed the proposal	Participating as a key advisor. Co-PI (?). Data Collection must be included as a part of the project.

Prof. Milind Sardesai, Botany Department, SPPU	Research	Reviewed the proposal	Native classification of species. Collaborator for ecology aspects, tree growth etc measurements Briefed Dr. Aparna Watve
Prof. Ankur Patwardhan, Biodiversity, MES Garware College	Research	Reviewed the proposal	Agreed to have students participate in tree growth etc measurements.
Dr. Mandar Datar, Agharkar Research Institute	Research	Reviewed the proposal	Participating as a reviewer as a local ecologist / taxonomist aspects
Prof. Harini Nagendra, Azim Premji University	Research	Consulted for specific topics	Helping with details on work done using satellite imagery
Google Represented by Devaja Shah, Program Manager Outreach to NGOs and Govt.	Industry	Reviewed the proposal	- Offered to support with Maps API credits, Cloud credits in conjunction with GEE - Offered to check regarding credits for BigQuery, Visualize2030 in case required - GEE training every month where team could enroll and introduce to developer community - Environment Insights Explorer (a) The possibility of opening up the emissions data for Pune based on the request from the City (b) Tree Canopy Tool related enablement
Dr. Krishnakumar IFS Retd	Research	Reviewed the proposal	Expressed interest in being part of the Advisory Group.
WRCS India through Mr Jayant Kulkarni	NGO		Implementation partner for field work