# DATA VISUALIZATIONS AND MODELING OF ENVIRONMENTAL RISKS IN GREEN AREAS

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**Abstract**

Vegetation, more specifically forests and their comprising elements - trees, have been a product of consumption by mankind for as long as history can reveal. The industry, which is rapidly developing on a global level, in many of its aspects, is responsible for the increase in the demand for such natural resources. The destruction of forests leads to poor air quality, natural disasters and aggravation of climate. Cyprus, being the geographic location of interest for this project, is experiencing all of the mentioned consequences of deforestation. In order to reverse the situation and make a change, the level of awareness should be increased. The goal of this research project is to provide a solution for monitoring the status of vegetation through data visualizations and implement an easy process of initiation of new afforestation on the island, thus helping improve climate levels, reduce wildfires, and prevent further natural risks. To gain a better perspective as to how this could be achieved, a literature review is conducted where related projects are reviewed and proper implementation techniques are identified. Subsequently, actual design and implementation of the product is conducted, eventually delivering a final working prototype in the form of a web application.

# Contents

# Chapter 1

# Introduction

Despite undergoing massive destruction and decrease in area, forests are still taking up around thirty per cent of the planet's land mass[1]. Awareness behind the fact that this destruction leads to climate change is not uncommon to the general public. According to official data, on average, fourteen thousand hectares of forest land are being destroyed worldwide every day - both by natural disasters and human beings[2]. Nonetheless, the use of wood for numerous industrial purposes such as heating and furnishing is only sparsely regulated by governments, hence society, as well as nature, are forced to suffer the consequences. Fortunately, many non government organisations are attempting to help restrict the common practices of cutting trees. As a result of this, many afforestation initiatives have been conducted worldwide and the index of forest loss has decreased substantially since the beginning of the new millennium[3].

The ability to observe the current state of flora in populated or non-populated areas has gone through a huge transformation along the decades. Initially, it was highly reliant on foresters constantly inspecting its conditions and making sure it is safe and sound. In the contemporary world, the foresters' job is highly complimented by the innovative technology of satellites with forestry monitoring systems inside them. While observing land cover change and use was highly reliant on manpower in the past, it is currently performed by satellites, (e. g. Google Earth Engine)[4]. Classifying how forests respond to climate change or varying precipitation levels in past decades are all tasks that are precisely performed by satellites with integrated AI agents. An elaborate example of how such processes are executed is described by Li et al.[5] in whose experiment time series are used for analysing frequent satellite observations on forests in Eurasia. Such studies provide valuable information about the forests' current condition in different times of the year or specific climate conditions.

Thanks to technological advancements, geospatial information can be collected in numerous of ways. Concretely, afforestation can be observed by using either Agent-based modelling or real-time data from satellites. In the study of Manson and Evans[6] one can witness a discussion stating that using Agent-based modelling (a mixed-method approach, combining social, ecological, and information sciences) for afforestation practices can be inaccurate while conducting classification analysis and the need for real-time data, that can be provided by satellites, is the most appropriate solution for the case.

Afforestation is of crucial importance to stable well-being on both social, economic, and environmental levels. The report of the Millenium Ecosystem Assessment Framework states that '*deforestation of hillsides can expose downstream communities to the hazards of flooding*'[7, p. 73] - a detailed illustration of what the consequences could be if afforestation is not conducted in such areas. Preventing such disasters, as well as spreading the attention about the need for afforestation, by displaying and analyzing the current status of green lands on the territory of Cyprus is a key motivation for this project. It further aims to enhance the will of society to participate in restoring the vegetation of the island by allowing initiators to introduce such opportunities. The main research questions which will be answered in this study are formulated as:

- How to visualize satellite data for afforestation practices?
- How to create graphical interface that help policy-makers in making more informed decisions about reforestation actions?

# Chapter 2

# State of the Art

## 2.1 Impact afforestation has on local geographical level

On a local geographical level afforestation has a high impact on three main components. To begin with, climate and vegetation are highly affected by changes in the size of the area covered by forest lands. In the case of deforestation, anomalies can be caused and weather conditions may vary, and vegetation is put at high risk, while during afforestation the effect is the exact opposite, thus bringing more favorable conditions and natural balance. To illustrate, Prevedello et al.[8] state that afforestation has the ability to reverse the effects of deforestation and positively impact the local surface temperature, hence providing less space for climatic anomalies and risks of natural disasters, especially in tropical areas. Afforestation also decreases the albedo (amount of light that is reflected by the ground surface) in forests, which helps to improve the health of vegetation by absorption of radiation. There is a direct link between these two components since vegetation is the constituent element of forests and its mutual influence with climate change is highly dependent on the anthropogenic activities taken on forests.

Despite the aforementioned mutual causality, the third element - Greenhouse gas emissions is dependent mainly on the presence of green areas in a region. Houghton[9] also shows that afforestation can reverse the effects of deforestation and reduce greenhouse gas emissions and act positively on the carbon budget, which is further supported by Locatelli et al.[10]. Therefore, there appears to be a unanimous conclusion that afforestation brings a positive environmental impact on local geographical level.

## 2.2 Monitoring afforestation

Two are the major factors that bring the need for monitoring afforestation. The first of them is the need to observe the health conditions of vegetation. In the event of a disaster the caused damage can hardly be prevented on time if it encompasses large geographical areas. However, satellite monitoring can help human beings deal with such disasters in a timely manner. Thanks to trees having different shades of green, this feature of theirs can be used as a criteria for categorizing them more easily through AI classification algorithms[11]. According to Gerlein-Safdi et al.[12], this is a hard task in the remote sense, since traditional satellites, such as Landsat, are not optimized enough to classify plants with lower green index as such. In this study, an alternative approach is proposed. It involves the "use of active microwave remote sensing data from the QuickSCAT satellite and solar-induced chlorophyll fluorescence(SIF) from the Global Ozone Monitoring Experiment 2(GOME-2) satellite" - methods that prove successful in the measurement of photosynthesis and forest regrowth(SIF), and water status of plants and soil(microwave remote sensing).

Anthropogenic influence is the second factor bringing the need for satellite monitoring of afforestation that can be viewed from one specific perspective. Intuitively, mankind has been using wood for survival purposes, such as shelter building and heating, until recent days. An illustration of this is provided by Langer et al.[13] where major points of discussion are refugee camps and how people in them use forests in the aforementioned way, thus destroying them. Langer et al.[13] further describes the use of Landsat for monitoring the recovery process of forests. The experiment described in this paper has been conducted at an area close to the Equator(an area with a specific climate), which carries the statement that monitoring afforestation can be optimally applied during certain periods based on the geographical location.

Based on the literature findings, no direct correlation can be found between the two factors contributing to the need for afforestation monitoring systems.

## 2.3 Designing satellite data visualisations

Designing valuable visualizations based on the data that has been collected during satellite monitoring is highly reliant on two factors. First of all, due to the ability to visualize one data set in multiple ways, it should be clear what is the purpose of the visualization so as to choose the proper visualisation technique. This is discussed by Sibolla et al.[14] and initially stated in the study of Buja et al. [15] with supportive reasoning that proper visualization techniques lead to further development of the discipline of data visualization. Sibolla et al.[14] further discusses that technological advancements in the field of AI and Computer Vision lead to changes in the way visualizations are displayed for use by the general public. An example provided in their study describes the issue of intense changes in the land surface across time, with an innovative visualization technique (in the form of map video classification) being introduced to target this.

Nonetheless, the use of digital geospatial visualisation would invoke a form of interaction with it. According to Roth[16], interactions with data visualization consist of three components - visualisation, human and computing device. An important point of clarification for the further reasoning in this paper is to state that Geospatial visualizations are majorly displayed as maps containing information of different essence on them. Considering the specificity of this literature review, the discussion of this subtopic will be limited to the visualisation aspect. The study of Kraak[17] poses the a statement that geospatial maps can be optimally visualized on the World Wide Web thanks to the use of hyperlinks and the ability to store data separately from the map. Thankfully, since this study was conducted two decades ago, this technological limitation has been overcome, and indeed, examples of geospatial data visualizations can be witnessed on online platforms such as Google Earth, many weather tracking web applications, etc. Examples of how data can be visualised on a map are presented below. For the purpose information was taken from the website of Windy.com. The presented visualisations show how temperature can be visualised on a map by two separate techniques - either using a color-mapping technique or labeling the temperature data at the corresponding locations on the map.

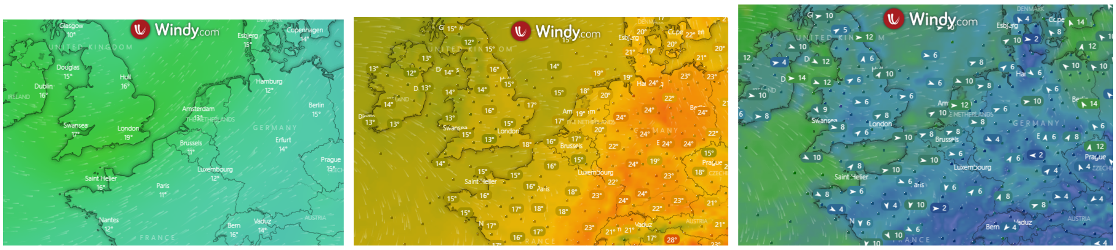


Fig 1: Windy.com - Map Visualisations

Overall, there is a correlation between interaction with geospatial data visualisations and their purpose. Due to the high demand for specific and accurate data, proper means of interaction need to be designed in accordance with the purpose of a given visualisation.

## 2.4 Related Work

The focus of this section is placed on the existing work and services that offer functionality similar to the one this projects aims to provide. The purpose of reviewing such products is to evaluate their usability and point out potential flaws that should be considered during the implementation phase.

### 2.4.1 Afforestation - Deforestation Monitoring Solution

**Company: CyberSwift**

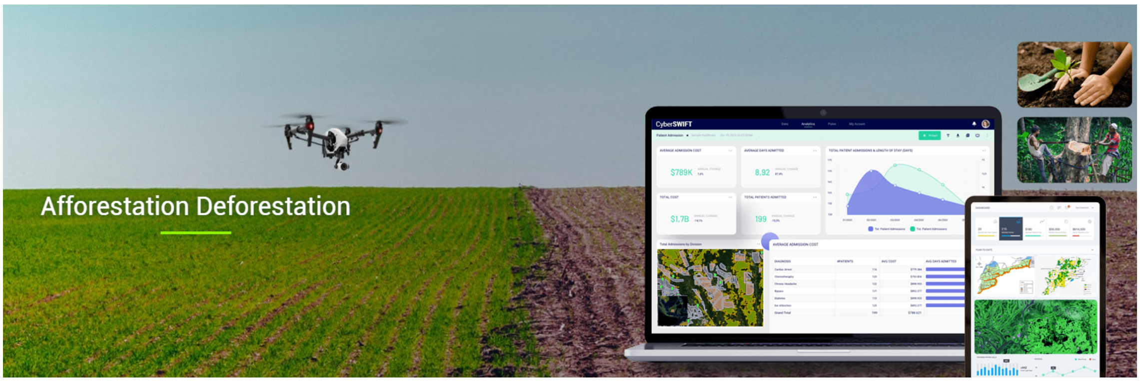



Figure 2: CyberSWIFT Afforestation Deforestation Monitoring Solutions

Provided by CyberSwift, the Afforestation Deforestation Monitoring Solutions serves as a monitoring system for observing areas which have undergone deforestation, collect necessary data from the given region and further analyse it in order to generate an appropriate plan for afforestation. The process happens thanks to remote sensing technology and collecting data from satellite images. The nature of the data collected includes soil type, climate conditions, slope, distance of water body, soil erosion intensity, land use, land cover, and forest aridity index. After analysis of the data, the tool identifies the regions where afforestation is the most needed. According to official website of CyberSwift[18], the validity of the collected data is best tested through field work for the sole purpose of improving accuracy.

### 2.4.2 Reforestation As A Service

**Company: DigitalHumani**

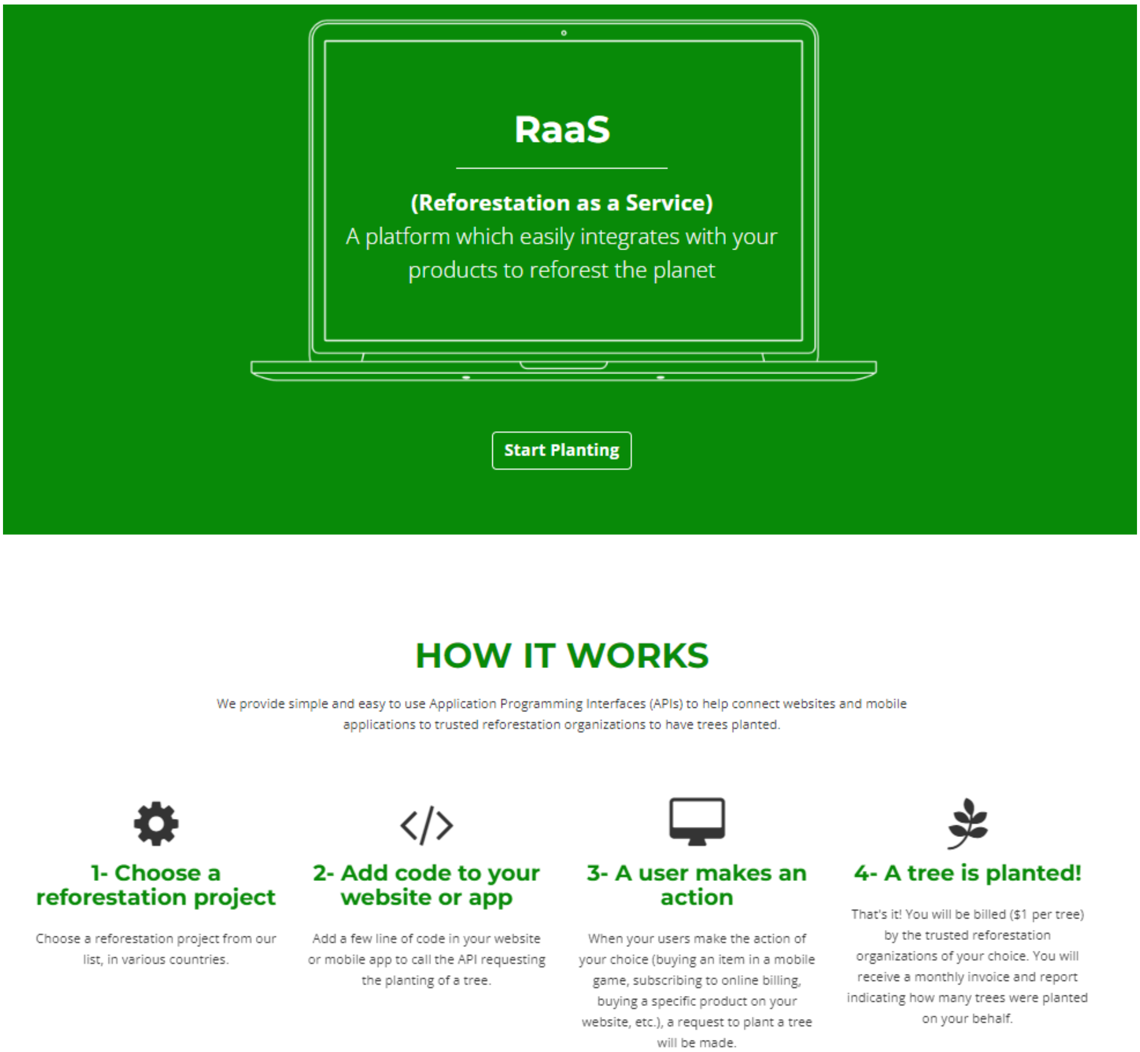



Figure 3: DigitalHumani - Reforestation As A Service

Developed by DigitalHumani, Reforestation As A Service (RaaS) is an Application Programming Interface (API), which provides the opportunity for spreading the awareness in terms of reforestation. This API can be used by any digital product that is found on the web. It enables the users of such a product to donate to reforestation initiatives while interacting with it. The API is programmed in a way that establishes direct communication between users and the initiatives to which they make donations. Thanks to the Graphical User Interface of the RaaS API, users can observe detailed information about the trees they have helped to be planted and make new requests for planting.

### 2.4.3 Forest Monitoring Germany

**Company: Remote Sensing Solutions - RSS**

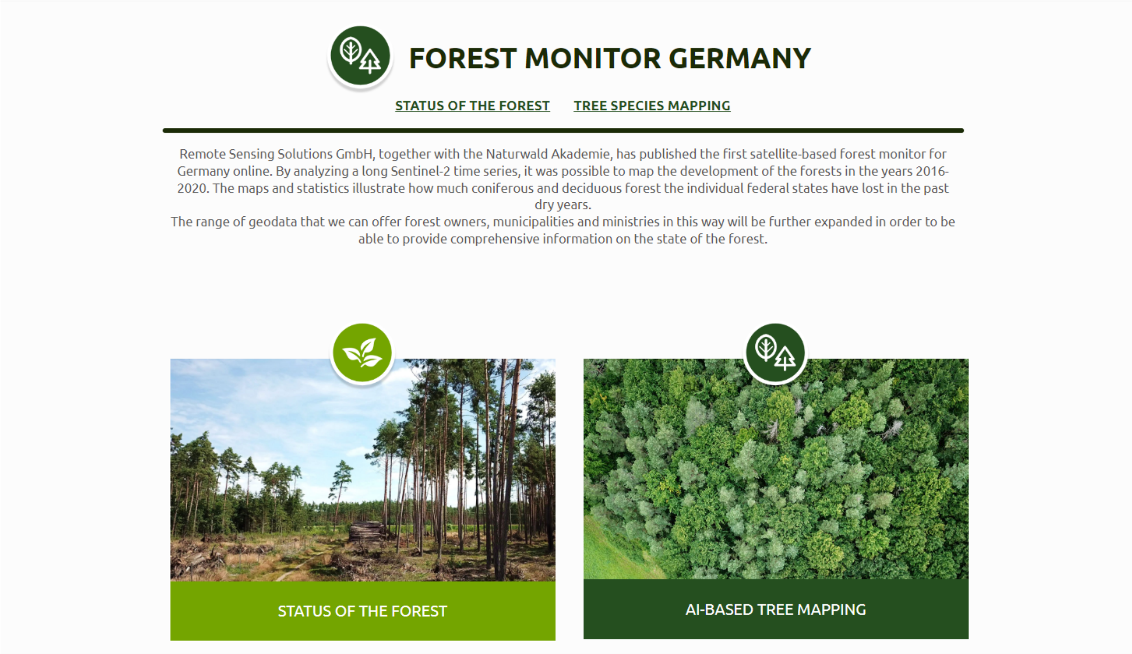



Figure 4: Remote Sensing Solutions - Forest Monitoring System

Remote Sensing Solutions collaborates with Naturwald Akademie in Germany in order to create a forest monitoring system that tackles all damages caused to vegetation by natural disasters such as wildfires, as well as pest attacks throughout the years 2018 - 2020[19]. Their software uses satellite observations in order to analyse vegetation losses and evaluate the status of forests. The integration of Artificial Intelligence in the form of predictive tree mapping is a helpful tool in forecasting future development of forests and help conduct optimal afforestation. The Graphical User Interface of the system is only presented in German without the option to switch languages and the data which is visualised includes only tree types and forest types. Another limitation is that considering the area of Germany, data visualisations are provided only for its eleven metropolitan regions, which does not provide concrete information about regions of a smaller scale.

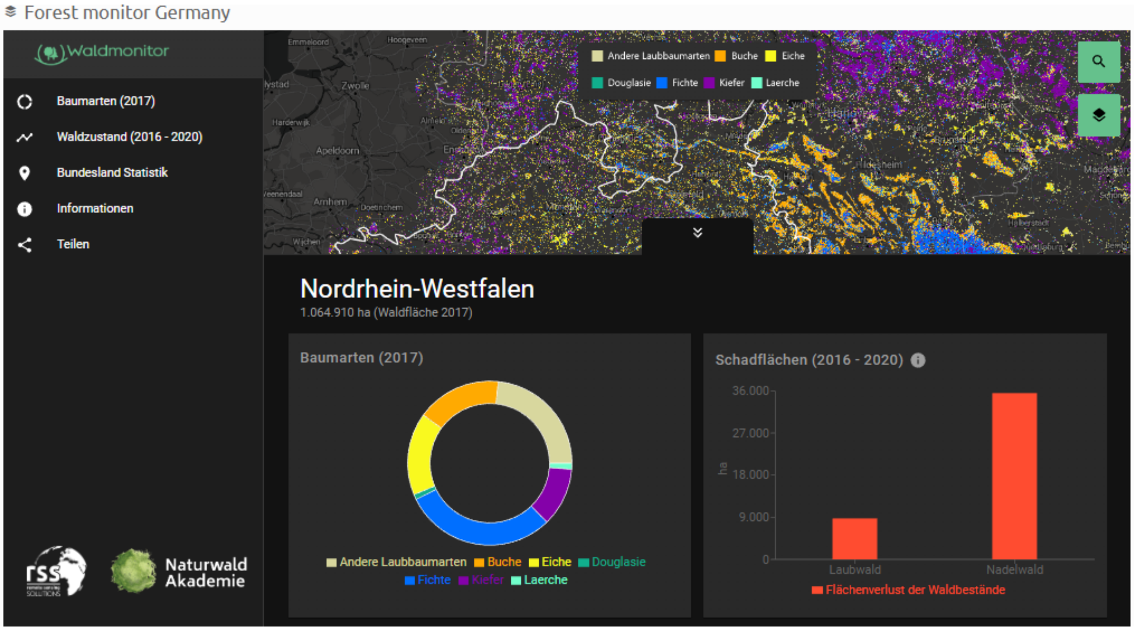



Figure 5: Remote Sensing Solutions - Forest Monitoring System

## 2.5 Conclusion

This literature review provides an overview of the factors that have lead to the need and opportunity to create web-based services for monitoring. In the first section, a description of the main elements that are influenced by the presence of forest is presented. This introduces a motive for the implementation of a technological solution in the presented situation.

Consequently, in the second part, different means of technology are reviewed with the sole purpose of finding the most efficient tool for monitoring afforestation. The QuickSCAT satellite provides a solution for observing details in the vegetation such as its health. This leads to a conclusion that a satellite with technological characteristics will be a viable tool to be used in monitoring afforestation.

Additionally, after observed reasoning about the deployment of geospatial visualizations on the internet[17] and all of the existing examples mentioned, a proper solution to the main Research Questions appears to be a web-based service. Specifically, the purpose of this project is to design a web application which is able to provide accurate data visualisations representing information of diverse essence about the current status of vegetation on the territory of Cyprus. This is done not only to provide a new tool for such observations but to establish a steady ground for future afforestation initiatives and offer everybody the opportunity to become a meaningful part of them.

Finally, existing products related to afforestation were identified and reviewed in terms of their functionality. One of them uses satellite data to analyse where it is beneficial to conduct afforestation, while the goal of this project is to also evaluate afforestation plans for any region of interest. The second product involves society in the process of afforestation by the implementation of an API which can be integrated on any web platform and provides a fast and easy method of donation. The last product has the purpose to provide information only about health of trees on a regional level and their diversity. What makes this research project different from the reviewed products is its motivation to combine the described services in one tool and further increase the number of possible use cases by introducing more, diverse and sophisticated functionality about analysing vegetation in Cyprus.

# Chapter 3

# Ideation

In this chapter, the focus is placed on establishing a solid ground for the vegetation status monitoring web application. This will be in the form of design principles and guidelines to which the development phase of this project will stick. In the first part of this chapter, general requirements collected from stakeholders can be found together with initially proposed mock-ups. Whereupon the same process will be repeated with the application of the feedback collected from a meeting with the stakeholders. Finally, the choice of technology will be discussed in order to emphasize the feasibility of the undertaken design choices.

## 3.1 General Requirements

Establishing the core functionalities of the web application is a result of a meeting with all stakeholders who are interested in the successful realization of this project. A list of the stakeholders is presented below:

- Feriha Tel (”Yesil Baris” citizens’ initiative)
- Liana Toumazou (Treedentity)
- Vijdan Sengor (Environmental Engineer)
- Elizabeth Kassinis (CYENS)
- Nikolay Pavlov (UTwente)
- Salih Gusel (Co-head of Environmental Technical Committee)
- Eleftheria Louka (300K Trees in Nicosia)
- Mary Athanasiou (Environmental Technical Committee)
- Andreas Kamilaris (CYENS, Supervisor of this research project)
- Savvas Karatsiolis (CYENS)
- Asfa Jamil (CYENS)

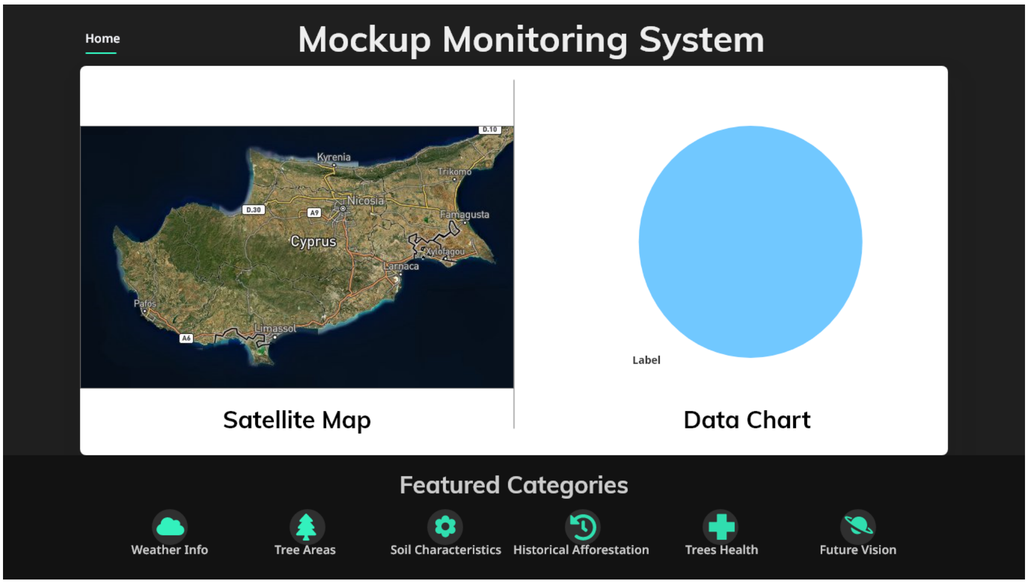
During this meeting, the following list of functionality requirements was composed. It stated that: The application must contain:

- Map of areas with trees, weather information, soil characteristics
  - Statistics after clicking on specific spots on the map
- Historical afforestation initiatives and overall health of trees
  - Including a 'before' and 'after' scenario
- Vision of 10 years from the current moment
  - Including a visualization of past situations vs future plans
- Indicate willingness of afforestation initiative where volunteers can join
- Declare diseases on trees so that others can receive notifications

## 3.2 Initial Design

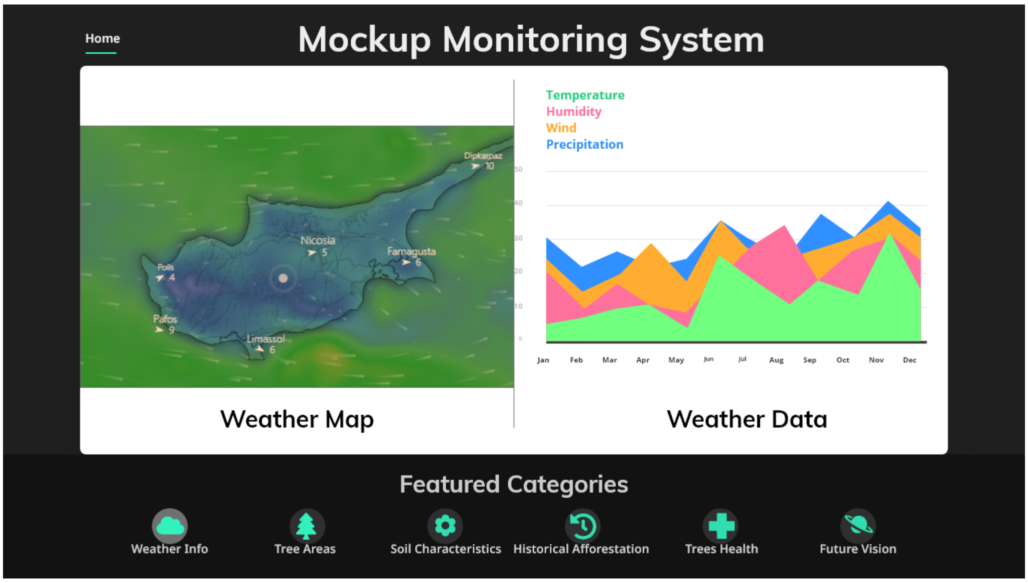
Based on the list of general requirements an initial mock-up was designed by incorporating all given criteria.

### Home page



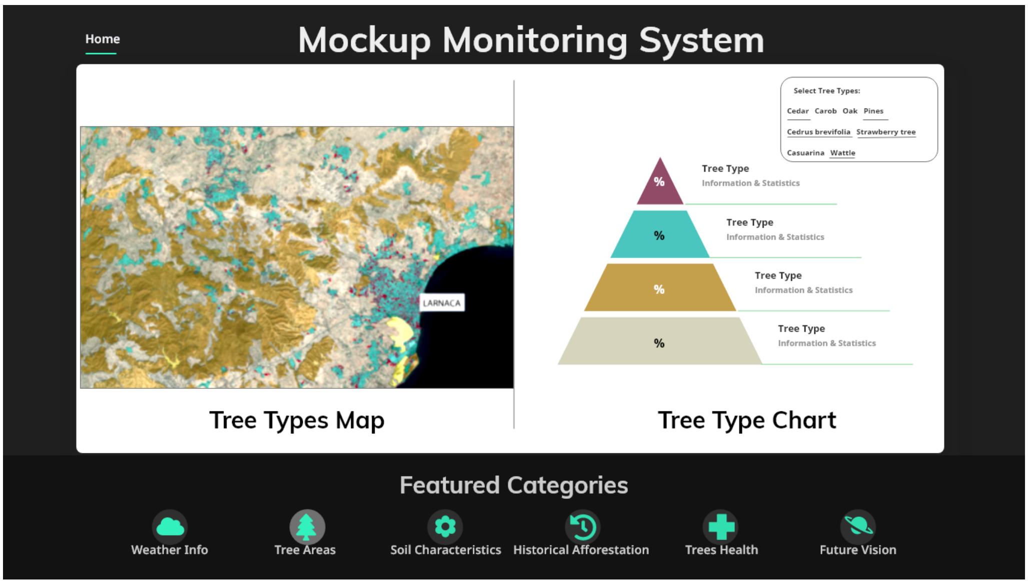

On the home page, one can witness all the services (located at the bottom part of the Graphical User Interface) that the application offers and reach any of them with one click. This list of services will be reachable from any state of the application for the convenience of the user and easier navigation. In the central-left part of the screen, the user can access a dynamic map of Cyprus which they can use to zoom in and view specific areas of the island. On the right-central part, the user will be able to see abstract data considering the island of Cyprus. In the left-upper part of the screen, there is a home button (present at all states of the application), which allows access to the home page.

### Weather Information



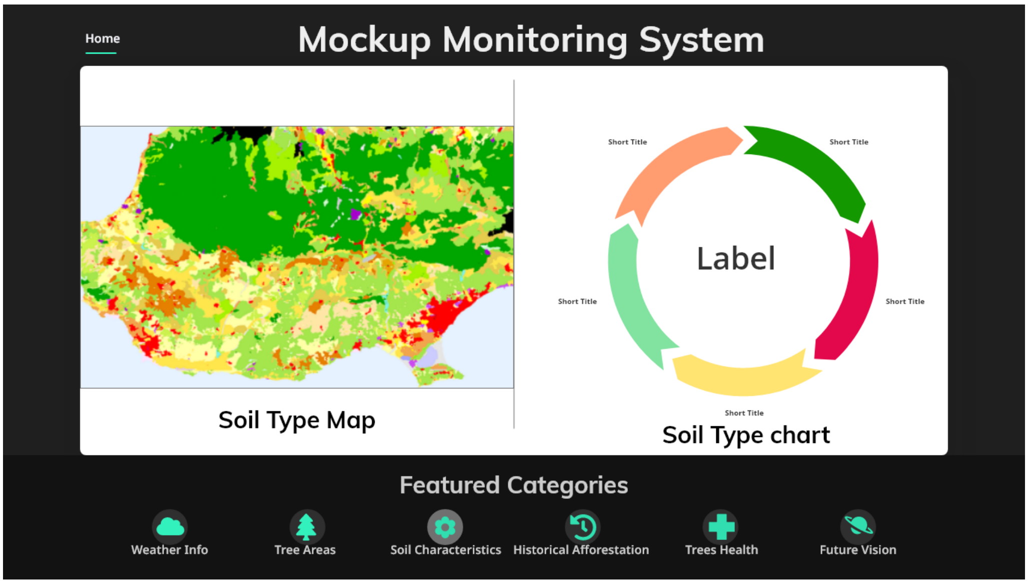

The above service of the web application provides visualization of the data about weather conditions in Cyprus such as temperature, humidity, wind, and precipitation on a yearly basis. This data will be presented on the right central part of the screen, while on the top left one, the user will be presented with a dynamic map of Cyprus, where they can see the visualized information for any given time of the year once they choose a date from the data chart by pressing on it.

### Tree Areas

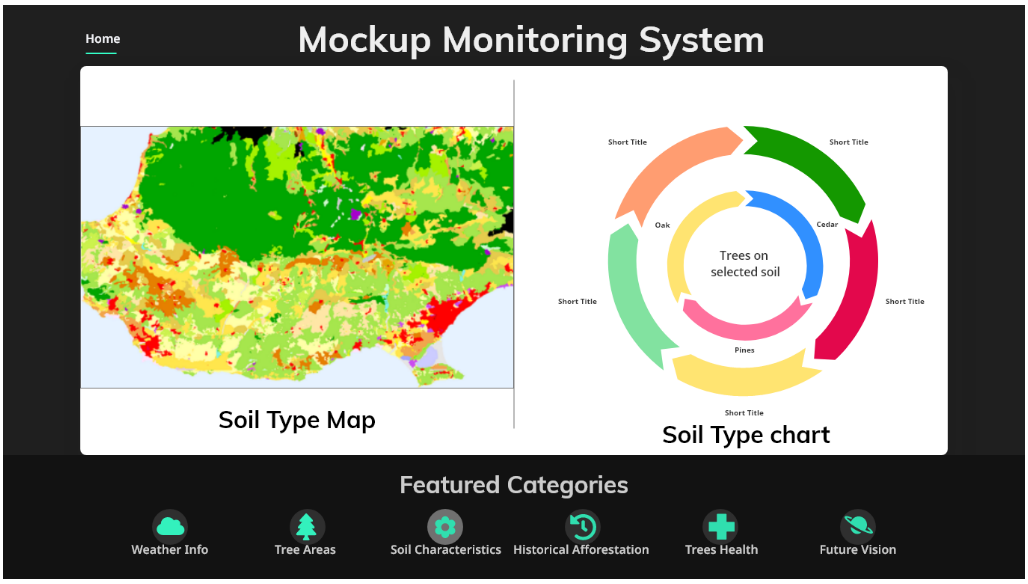


In the given service, the user is being presented with a dynamic map of Cyprus with the vegetation types growing on it. The user can choose a specific region of Cyprus and get the vegetation data automatically as they navigate along with the map. The data visualization presented at the central-right part of the screen provides an overview of tree types that grow in the given geospatial region together with information about them and statistics showing what percentage of green land those trees take and what percent of the vegetation they represent. The user can choose which tree types to observe by clicking on their names in the checkbox in the upper-right part of the screen.

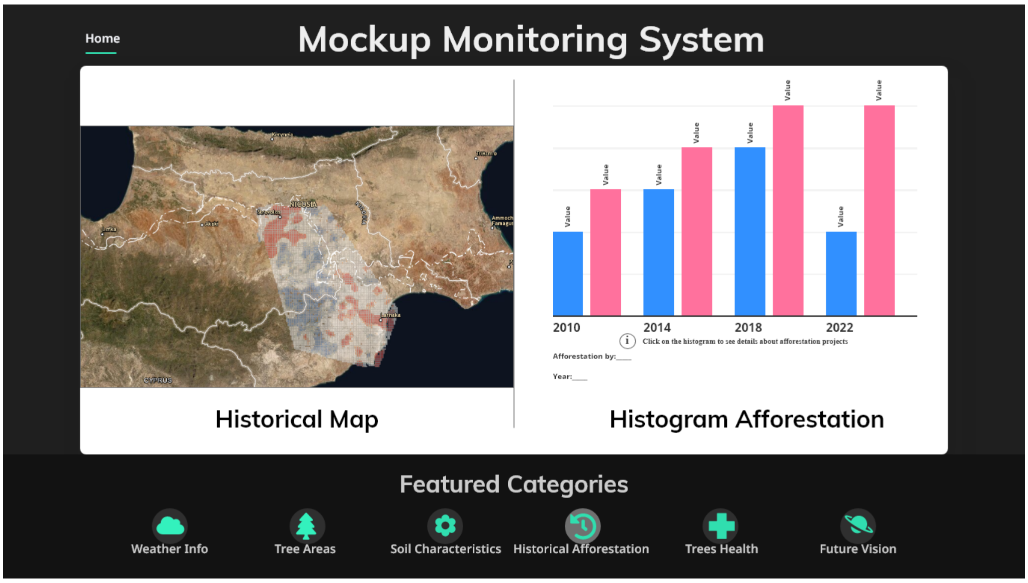
**Soil Characteristics**




This service provides the ability to observe the types of soil that can be found in any specific region in the territory of Cyprus. In the central-left part of the screen, the user is given a dynamic map of Cyprus in which they can choose to observe their desired region, and based on this they will be presented with the corresponding data visualization. The data visualization, being shown on the right central part of the screen, consists of a circular diagram that shows the soil types that can be found in the(chosen by the user) region. By clicking on any of the soil types, the user will see a smaller embedded circular diagram that contains information about what are the tree types that grow on the given soil type and what percentage of the total vegetation they represent. An example is provided below:

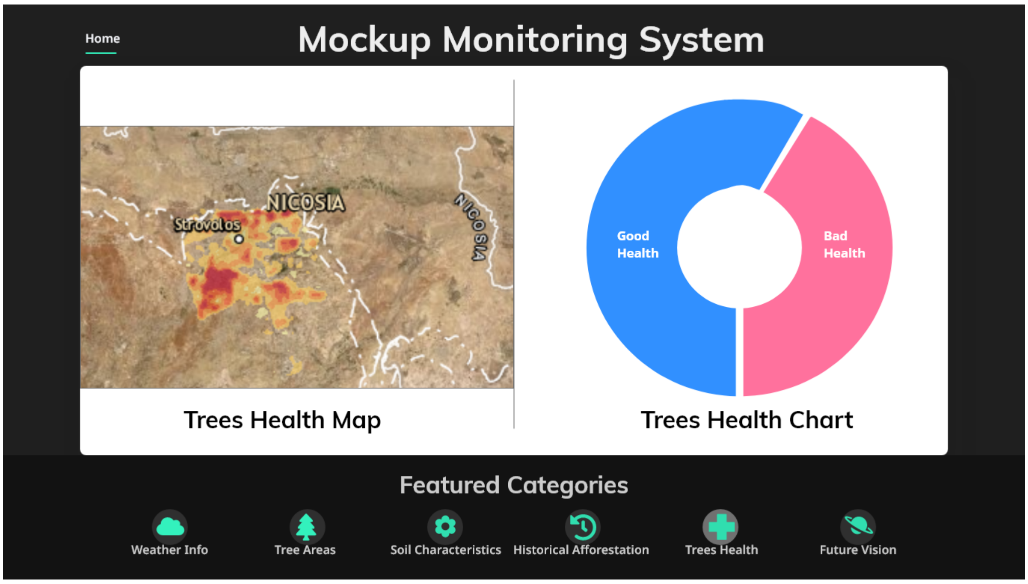



**Historical Afforestation**



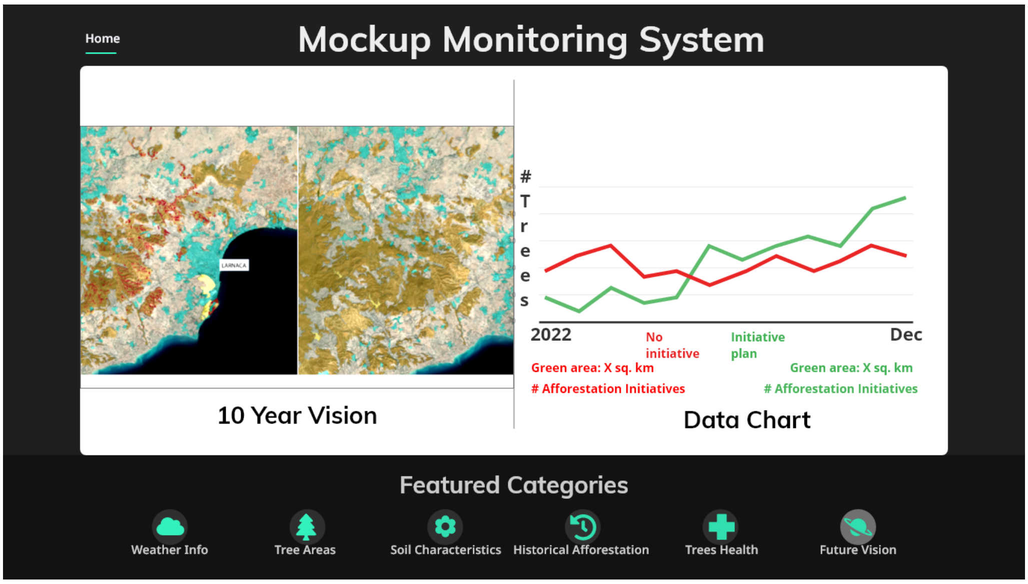

This service provides information about what afforestation initiatives have taken place on the territory of Cyprus in a period for which data can be collected. On the central-left part, there is a dynamic map that the user can use to choose a specific region and extract the historical afforestation data for it. An example of what could be represented as data in the given visualization is the budget of the initiative and the number of planted trees. Under the visualization, the user can see information about any afforestation initiative they choose such as the initiator of the afforestation process and the year of conducting it.

### Trees' Health




This service provides information about the current health state of the vegetation in different regions of Cyprus. On the central-left part of the screen, there is a dynamic map of Cyprus that shows the vegetation condition in a region specified by the user. On the central-right part of the screen is a diagram that represents the ratio of healthy vegetation vs damaged vegetation. Further updates in terms of functionality are highly likely to arise during development. An example is including information about the reason for the current state of the vegetation at a given point.

### Future Vision

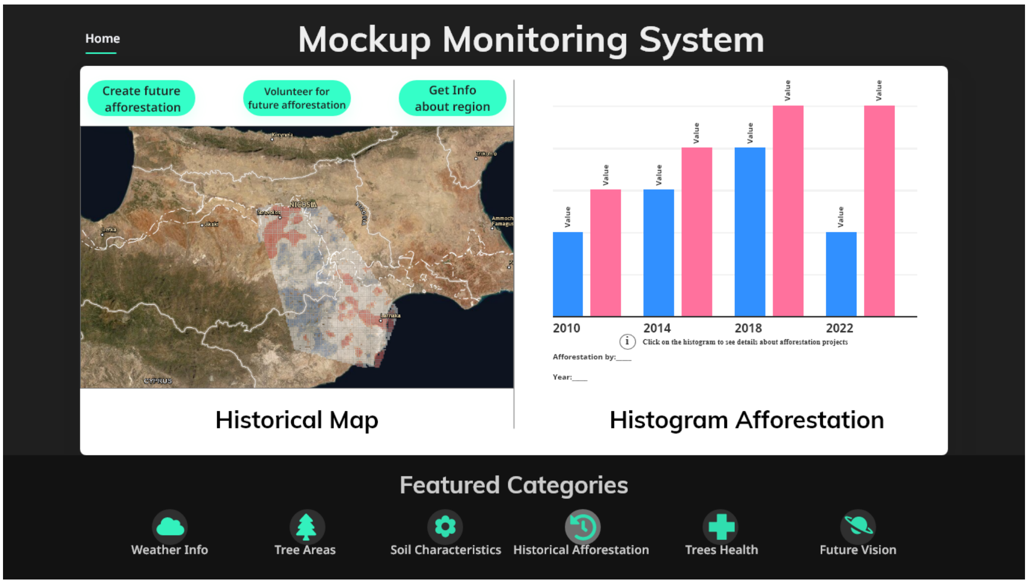



This service provides the 10-year plan of the project by visualizing what the current vegetation state of Cyprus is compared to what it will be in 10 years' time. The map that is presented on the left part is dynamic and the user can select different regions. The left map shows the current state of the vegetation in Cyprus, while the right one shows what it will look like in 10 years' time. The data visualization on the central-right part of the screen is a quantification of the final results. It provides a two-dimensional chart showing how the vegetation will change if the current project is not started and what it will look like if the project takes place. There is also a representation of what area vegetation will represent either globally for the scope of Cyprus, or in any region that the user is interested in. Data in the visualization is highly reliant on what the map shows.

## 3.3 Received Feedback

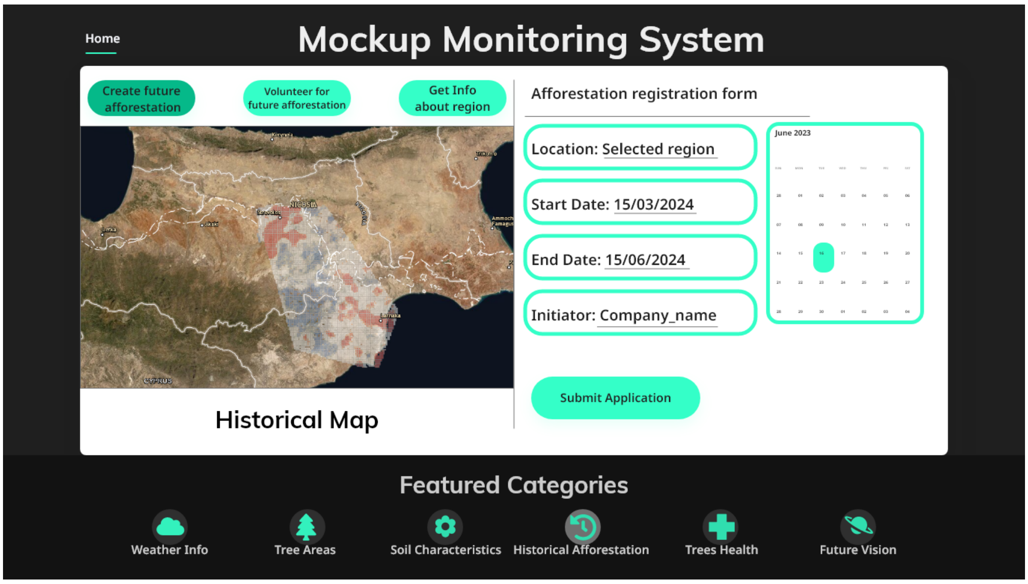
Upon presenting the mock-up to the stakeholders, a detailed discussion revealed existing flows in the current design, and suggestions for improvement were made. The particular services that were altered are presented below.

### Historical Afforestation



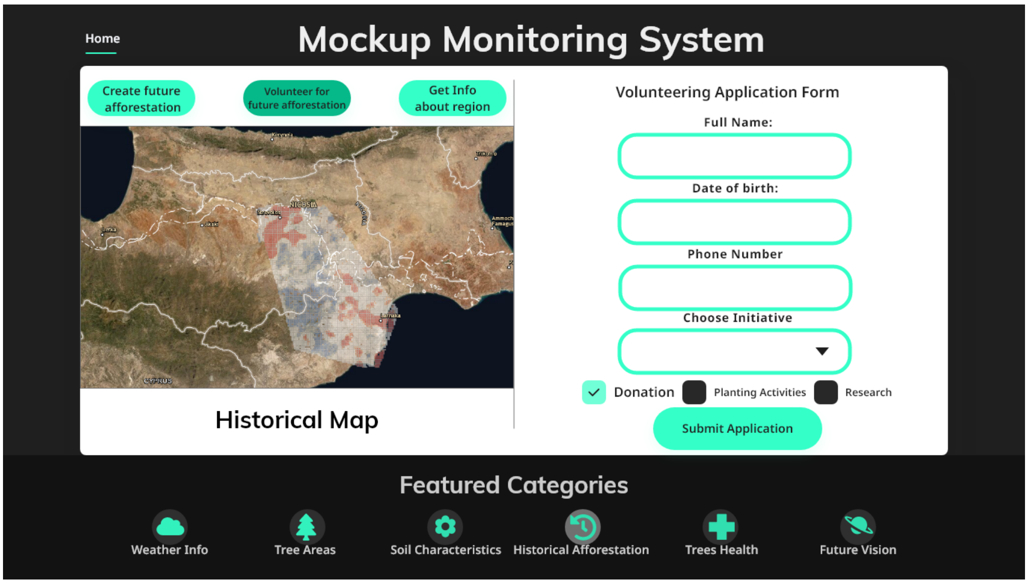

The service providing historical afforestation has been updated in accordance with the requirements of the stakeholders. One suggestion stated that the social aspect of the web application must not be neglected and an introduction of three new services was made.On the upper-left part of the screen, above the map, there are three buttons which provide the user with the ability to initiate a plan for future afforestation, volunteer for one or get all the necessary data of a specific region. On the central-left part, there is a dynamic map which the user can use to choose a specific region and extract the historical afforestation data for it. An example of what could be represented as data in the given visualisation is budget of the initiative and number of planted trees. Under the visualisation, the user can see information about any afforestation initiative they choose such as initiator of the afforestation process and year of conducting it.

**Historical Afforestation - Create future Afforestation Initiative**




In the above screen the user can create future afforestation by specifying the region it will encompass through a selection on the map as can be seen in the example. The user can provide the start and end dates of the initiative, as well as the company that is organizing the afforestation. This is further saved in the central database and future users can see it.

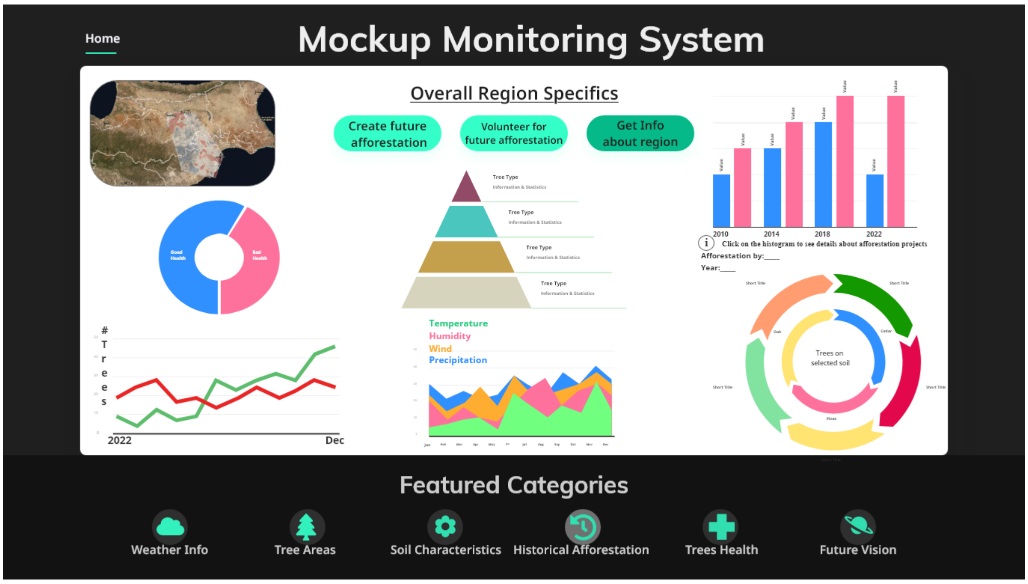
**Historical Afforestation - Volunteering for future Afforestation Initiative**




In this screen, users can choose to engage in a future afforestation initiative. As described in the previous screenshot, generating future initiatives opens space for other users to be willing to take part in it. Taking part can happen in multiples ways. The ones defined in the current design of the service are:

- Donation
- Participation in afforestation activities
- Participation in research for the successful conduct of afforestation

**Historical Afforestation - Information about specific region**




This service allows the users to see all the information that can be found on the website about a specific region in the territory of Cyprus. Information contained in this service encompasses the data visualization of trees' health, weather conditions in the region, soil type, planned future afforestation initiatives, historical afforestation, tree types growing in the region.

# Chapter 4

# Realization

This chapter presents a description of the development phase of this project. Its main goal is to elaborate on the important details behind all of the elements in the web application, the technology that has been used and the existing use cases. Procedures about how a user can interact with the web application on all services is presented in the Use Case section, while design discussion is present only in the Graphical User Interface section.

## 4.1 Web Application Development

The web application is developed using the python-based web development framework - Flask. The reason for this choice lies in the essence of the project. Development in the field of Data Science is mostly done in Python because this programming language provides all of the required tools and functionality[20]. The functionality, which Flask provides, contributes to the easy integration of JavaScript code on the front-end part of the project, proper use of web page building languages - HTML and CSS, and the integration of python scripting inside them. A detailed description of how this technology was used in order to achieve the final result is presented next.

## 4.2 Graphical User Interface

The Graphical User Interface(GUI) was built by mainly using HTML and CSS together with Bootstrap for improving the appearance of some of the elements inside it. As already mentioned, thanks to Flask, the use of python scripts inside the HTML files has enabled all web pages to inherit their structure from a main one, thus introducing a better code structure and reusability of massive blocks of code. There are two main elements in the GUI which were implemented in Python by using external libraries for their specific purposes.

### 4.2.1 Data Visualisations

The first of the two main constituting elements for the entire application are the data visualisations representing different aspects of the data in which a user of the application is interested. They have been implemented using the Plotly library. The choice to use this library was made as a result of its ability to dynamically filter and model the data that is being visualised in accordance with the user's needs. The visualisations which can be found across the GUI include information about:

- Vegetation Diversity - what are the types of trees growing at a specific location
- Vegetation Health - what is the health of trees at a location, depending on irrigation
- Soil Diversity - which soil types can be found at a specified region
- Elevation - ground elevation - useful information about
- Rain Volume - the average amount of rain at a specified region, which is an important indicator as it can serve as a supportive indicator when considering the health of vegetation
- Slope And Aspect - at what slope is vegetation growing at a specific region and which cardinal direction are they facing

### 4.2.2 Map Objects

The map objects were created using the library - Folium, which is the Python equivalent of the JavaScript library - Leaflet. It allows for plotting data on interactive maps and rendering them on web pages. Being displayed on a web page, a map object stores the data about any geographic location on the territory of Cyprus. However, instead of displaying this data directly on the map, a design decision was made to keep it hidden and not overburden the user with too much information. The alternative solution allows a user to see information about a specific area in which they are interested with one of the functionalities of the map - measure control.

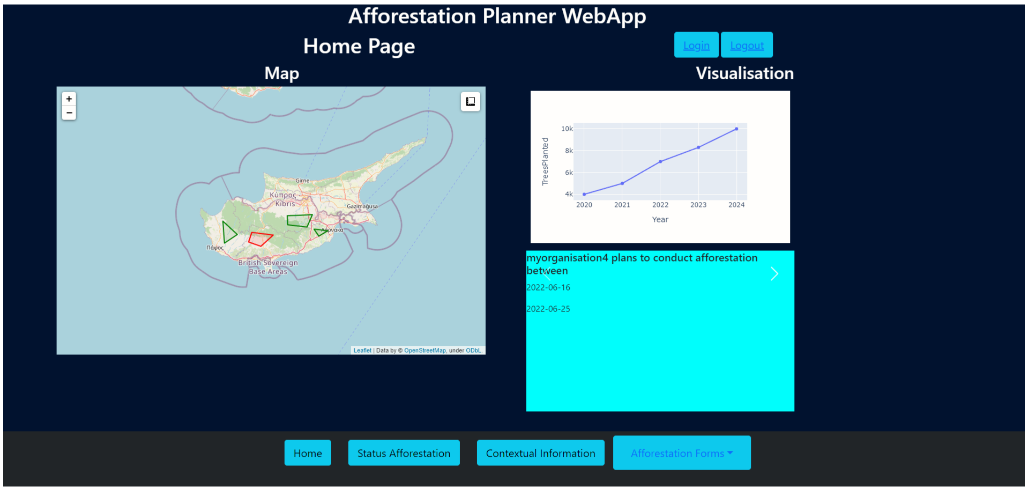
The Measure Control is a plugin which is part of the Folium library. It allows the user to select a specific region from the map and see basic information about it such as its perimeter and area. This plugin was further customised in order to allow the user to also see all data which is inside the polygon they have created. This is a key functionality as it provides the ability to avoid conflicts between users and gives them the opportunity to be accurate to the maximum extent with the regions they would like to choose and conduct afforestation on.

### 4.2.3 Design Changes

Comparing the layout and design of the Graphical User Interface from the ideation phase of the project and the implemented version, significant difference is evident. This transformation occurred due to the continuous iterative process of constant development and optimisation of the application and the way information is presented on it. The inspiration for this came from one of the services presented in the previous chapter - "Information about a specific region". There, multiple data visualisations are displayed on a single web page with the purpose to give the user a better overview of the entire situation in a specific afforestation. The design change encompasses the division of this service in two parts:

- Status of Afforestation - A service including data visualisations about the diversity of vegetation at a specific region and the vegetation's health.
- Contextual information about Afforestation - A service including data visualisations about the soil diversity, elevation, rain volume, slope and aspect.

The home screen was updated as well. Currently, when accessing it, the user can witness the map of Cyprus with all past and future afforestation initiatives on the left side of the screen. A past afforestation can be distinguished from a future one by the color each of them is assigned - a green polygon on the map represents a past afforestation, whereas a red one represents a future or an ongoing one. The reasoning behind this design decision is the idea to show which regions of Cyprus are already green and which are yet to become green(er). On the right side of the screen there are two separate blocks. On the upper one the user can see a diagram showing how many trees have been planted until the current year and how many are scheduled to be planted for a couple of years in the future. The lower block represents a news feed with information about the organisations which are planning upcoming or ongoing afforestation.



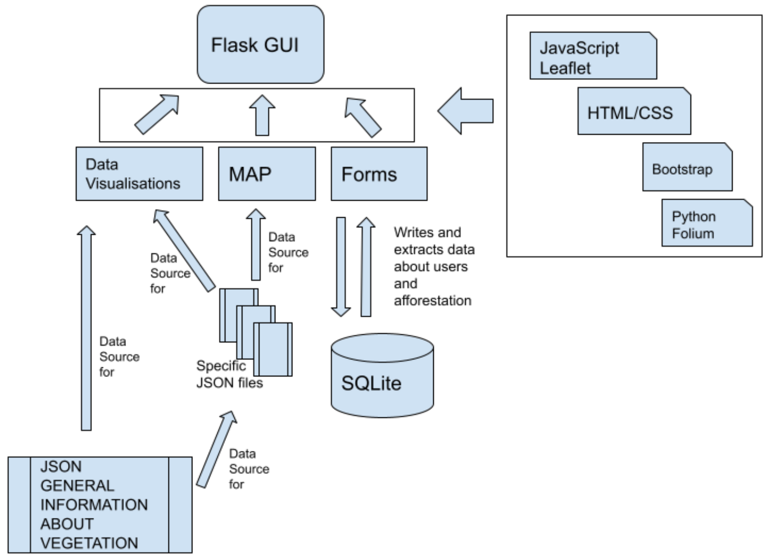

Further, the web pages where a user can submit an application for initiating or joining an afforestation have undergone slight transformations. Their structure has been kept the same in terms of layout, while the buttons for creating afforestation, joining one and seeing the details about one have been removed since they are present in the navigation bar at the bottom of the screen.

## 4.3 Web Application Architecture

The data source, where all information about the indicators used to represent vegetation status is stored, comes in the form of a static JSON file. The data inside it is structured in the form of dedicated JSON objects for each recorded coordinate on the map of Cyprus. The data visualisations which represent information on a global level for the entire island of Cyprus take direct use of this JSON file by extracting only the data for a given indicator (e. g. soil type and soil depth in order to visualize soil diversity).

In the event of a user attempting to see information about a specific region/ afforestation initiative in Cyprus, the corresponding data is being extracted from the general JSON file and written on a new one by taking only the JSON objects in which the points inside the given region are stored. Thus, data visualizations for specific regions operate in the same manner as the overall / national ones - by using a static file as a data source.

Since the web application allows users to operate with the static data by initiating afforestation or joining such initiatives, as well as being able to create an account, a database has been implemented. The database engine used in the application is SQLite3. The choice to use it was a result of understanding the scope of the entire application. The database only consists of tables for storing user accounts, storing afforestation initiatives (in the form of polygons together with all geographic points in order to extract the correct JSON objects during visualisation), and volunteers to afforestation initiatives. Therefore, even high usage of the web application would not overload the capacity of the database engine. The simplicity of this configuration allows for quick access to all required data on the back-end part of the system and easy integration on the front-end. Hence, for the current moment, the use of alternative and more advanced database tools is not required for optimal performance. To visualize and establish a better understanding of the entire configuration of the web application in terms of structure, a diagram of how the aforementioned tools interact is presented below:



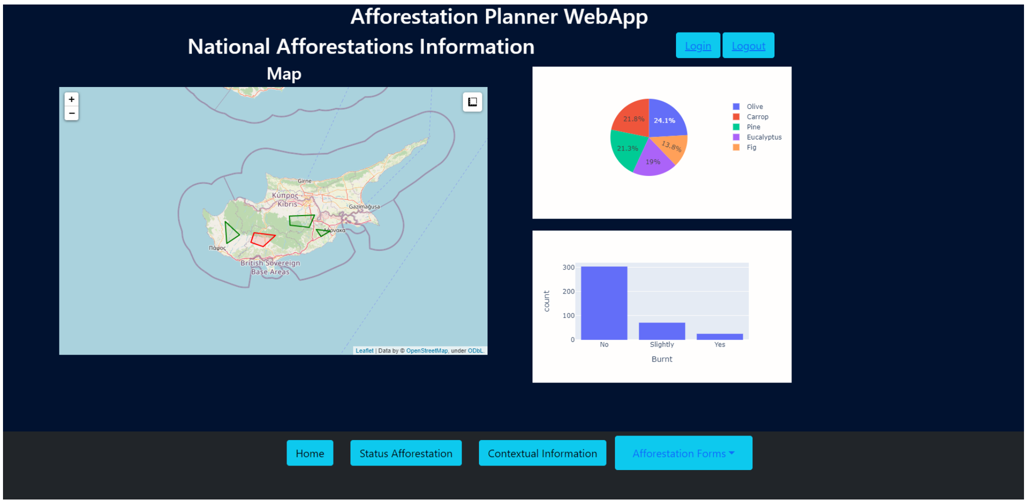

Finally, in order to achieve a fast and easy transition from using sample data to integration of an official Geospatial Application Programming Interface (Geo-API), the format of data and how it is stored was agreed on prior to actual development.

## 4.4 Use Cases

It is important to mention that all services in the web application present the use of one and the same map. The information it contains is not a subject to change except for the case when a user initiates a new afforestation through the "Afforestation Application" service. Hence, there will not be further referencing to this User Interface(UI) element. Information on what actions a user should take when they interact with any service is presented in this section.

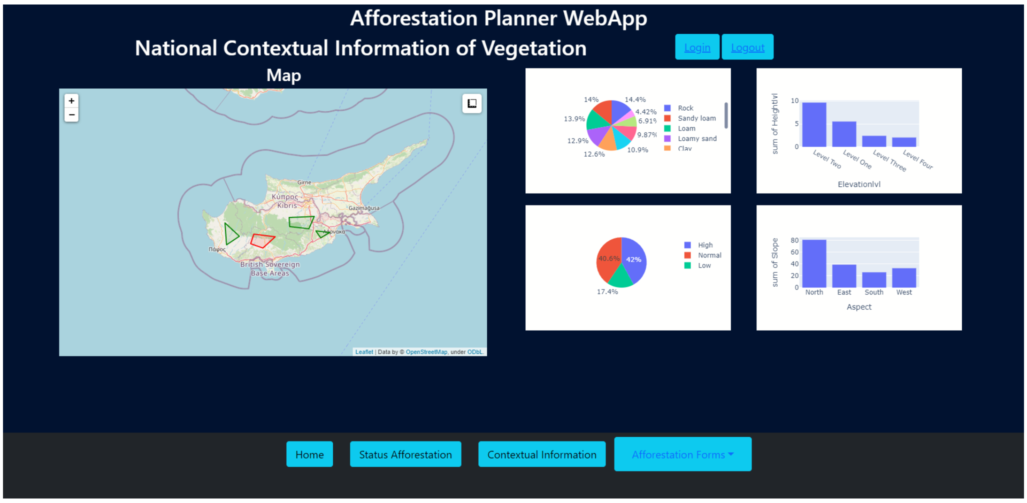
### 4.4.1 Overall status of afforestation

In the event that a user would like to inspect the status of afforestation on a national level in Cyprus, they can access this service through the button "Status Afforestation" in the navigation bar placed at the bottom of the screen. This service provides information about vegetation diversity and health of vegetation for the entire country.



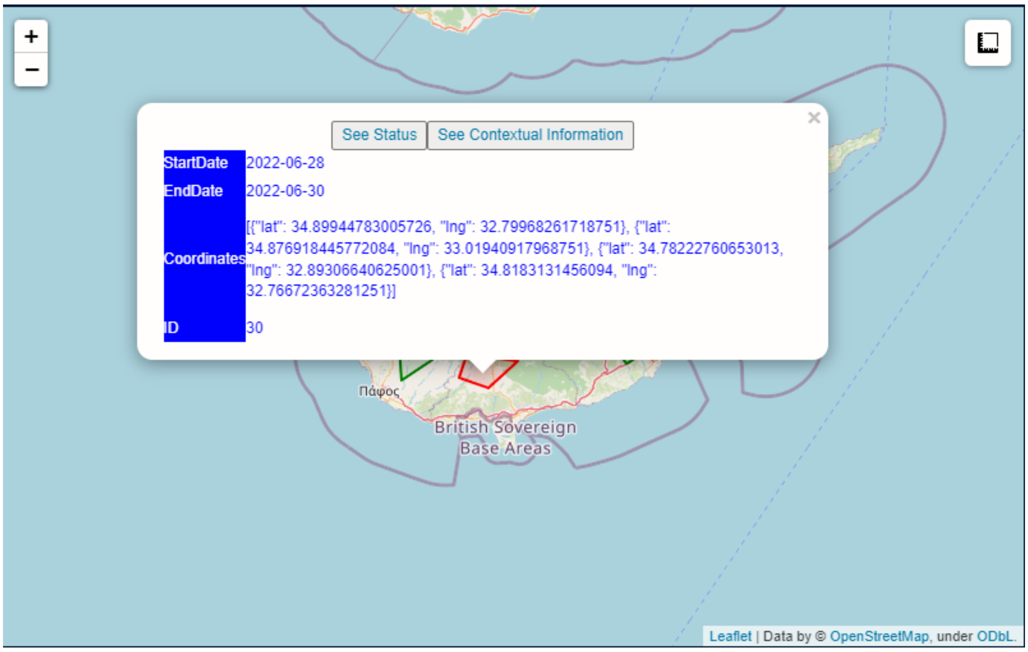

### 4.4.2 Overall contextual information about afforestation

This service can be accessed through clicking on the button ”Contextual Information” in the navigation bar. On the screen one can witness information on a national level about soil diversity, average rain volumes, elevation and slope.

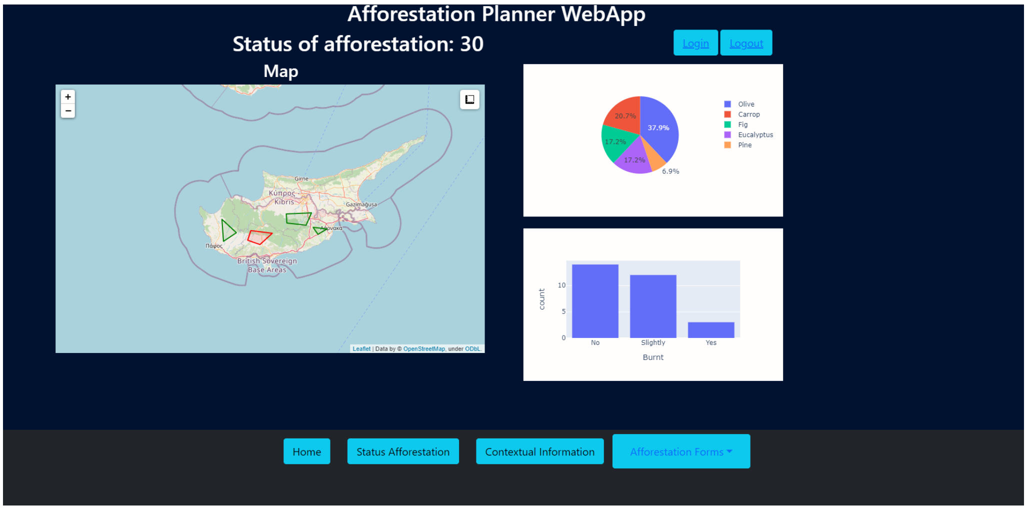



### 4.4.3 Status of a specific afforestation

This service is specific for each afforestation that has been initiated through the web application. Upon clicking on a specific afforestation polygon on the map, the user can see a pop-up window showing up.

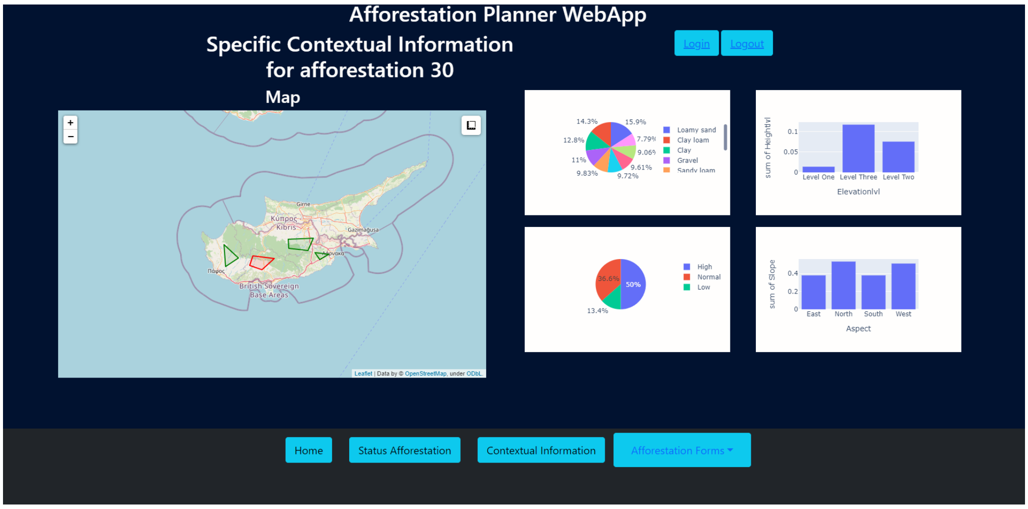



This window contains information about the general details of the afforestation - coordinates, start date, end date and identification number(ID). Apart from this information, on the pop-up window there are two buttons - "See Status" and "See Contextual Information". By clicking on "See Status", the user is presented with a screen which looks the same as the "Overall status of afforestation", but only contains information about this afforestation initiative.



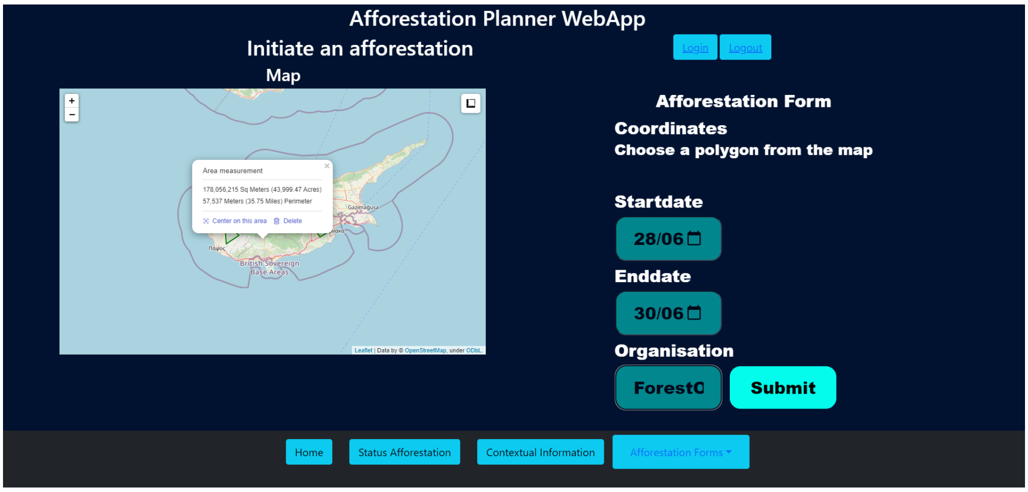

### 4.4.4 Contextual Information about a specific afforestation

The procedure for accessing this service follows the same steps as the previous use case with the only difference that the user should click on the button "See Contextual Information". The layout of this service is the same as the "Overall Contextual Information" service with the only difference that the visualisations represent the data for the specific afforestation initiative.



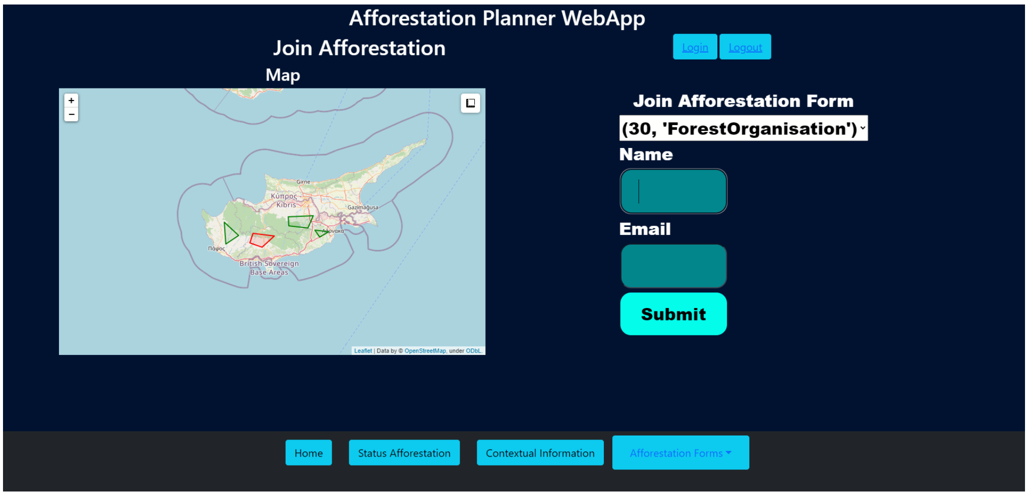

### 4.4.5 Initiate an afforestation

If a user wants to initiate an afforestation, they should click on the "Application Forms" drop-down button in the navigation bar and select the "Afforestation Application" option. The application will redirect the user to the web page with the form where the user should fill in the details of the afforestation. First they should create a polygon on the map by clicking on the measure control button(located in the upper-right part of the map) and draw by clicking on the coordinates where they would like to place the vertexes of the polygon. Consequently, they should select start and end dates of the afforestation, and fill in the name of the organisation they are representing. This information is then stored in the database and when the user reloads the page, they can see their afforestation initiative on the map.




### 4.4.6 Join an afforestation

The procedure for accessing this service resembles the "Initiate an afforestation" use case. When the user clicks on "Application Forms" drop-down menu, they should select the option "Afforestation Join Form". From this point, they will be redirected to the web page where they will need to fill in the necessary information. Firstly, the user needs to select an initiative from the drop-down list. Afterwards, they should fill in their name and email and submit the form. No further indication is displayed on the screen.



# Chapter 5

# Evaluation

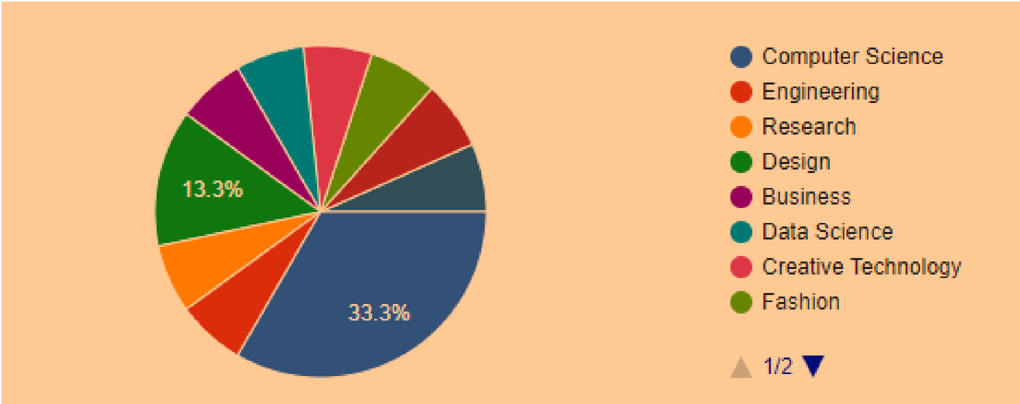
## 5.1 Methods Used

Deploying the web application on a server enabled the initiation of the evaluation phase. Considering the essence of this project and the information which is important for classifying the entire work as a success or failure, evaluation was conducted in the form of usability testing.

All usability tests were conducted in the same way. Two links were sent either via email or phone number to each user - one for the web application and the other for the form they had to fill in. Before a usability test, each user was informed about the essence of the test, the topic of the project and the purpose of the web application. As an initial step of the test, each user indicated that they agree to keep all information about the project private, as well as being aware that any personal data they reveal during the test will not be made public. The structure of the usability test follows the order of the use cases presented in Chapter 4.3. After signing the confidentiality agreement, all users had to perform six scenarios - one for each use case defined. The data that was collected includes information about the level of difficulty in accessing and performing any of the application's services, comprehension of the data visualisations, feedback about the overall experience of the users and suggestions for improvement.

## 5.2 Participants

Due to the signed confidentiality agreement, demographics cannot be specified. In order to properly evaluate the usability of the web application, the diversity in background among the users was important. The span of background fields of all participants is presented below:




As already mentioned, the primary stakeholders of the project are afforestation policy-makers. Since they are not expected to come from a highly technical background, the presence of people from non-technical disciplines helped establish validity in the final results.

## 5.3 Results

The statistics from the evaluation, provided in Appendix A and B, prove that the web application utilises high usability, easy navigation and delivers information in a comprehensive way. The evaluation also revealed issues with the design of the project, in the sense that the User Interface is designed in a non-responsive way, hence not offering users with mobile devices the ability to properly view any information they would like to, or initiate and join afforestation. A list of the most valuable and contextually accurate suggestions which were collected during feedback is provided below:

- **Scenario 1:** "The layout could be improved, especially the visualization since they are rather small, maybe widgets over the actual map?"
- **Scenario 2:** "Add labels and explain what the charts represent"
- **Scenario 2:** "The layout is better since you have more visualizations, however they are rather small"
- **Scenario 5:** "I don't receive any feedback if the afforestation form submit was successful so i would maybe add a popup for it"
- **Scenario 6:** "Improve the user interface of the form and add more guidance to the users"

After performing all user tests, review of the feedback was made and corresponding changes were added to the web application. In terms of the data visualizations, extra labels were added to each diagram in order to provide more information about the information presented on it. Increasing their size on the screen was also taken into account with the purpose to make the information more legible. At the scenarios where users had to fill in a form to either initiate or join afforestation, an extra feedback page was added in order to confirm all information they have entered and mark the form submission as successful.

Considering the changes made after the evaluation phase, to further confirm the validity of the web application, further usability tests will be conducted in the same form with the actual stakeholders.

# Chapter 6

# Discussion

The final goal of this project was to implement a web-based application for monitoring afforestation and vegetation status on the territory of Cyprus. This application serves as a tool for afforestation policy makers and external individuals whose main interest focuses on preserving and recreating the vegetation on this island country.

In terms of design, the nature of the stakeholders was taken into account. Having the main user persona be an individual with stronger expertise in natural sciences, such as Biology and Botany, rather than Information Studies, required paying more attention to designing for an appropriate User Experience. Therefore, the sole purpose was to design a user interface which does not require strong technical background on the user's side and delivers information in a comprehensive way.

## 6.1 Limitations

Multiple limitation factors have been identified throughout the lifespan of this project, as well as the existence of causality between two of them. During the development phase of the project, the tools that have been selected introduced technical limitations. A certain functionality required for the correct and successful execution of all services - the polygon drawing tool - was not a part of any extension or plugin in the programming tools which were reviewed. As a result of this, extra time resources were allocated to customise the functionality of an already existing plugin - Measure Control - which is a part of the Folium library. Solving this issue allowed for extraction and proper analysis of specific data from a geographical map, and generation of correct data visualisations. As a result of this, time constraints increased and the aesthetic design of the user interface was neglected in favor of functionality.

Another limitation was in the form of not being able to use real-world data during the implementation phase of the project. Instead, sample data was used for evaluation and testing purposes. Currently, the source of all data about vegetation comes in the form of a static JSON file. Therefore, users are not able to alter vegetation data and the services for overall status, and contextual information of afforestation in Cyprus, will present the same visualizations in terms of data. The solution of this problem will be made possible with integration of official data by putting all vegetation data in a database, together with an implementation of a new service in order to allow users to indicate changes in vegetation.

Finally, the web application allows users to initiate afforestation, while deleting one can only be done manually from within the database. Including such functionality could allow users to inspect different plans for afforestation before officially initiating one.

## 6.2 Future Work

This project, being fully functioning at the moment of speaking, lays the foundations for diverse future work. Taking the limitations into account, the first suggestion for future improvements of the project would be to polish up the User Interface in order to make it more engaging for the users.

Additionally, as illustrated in the first chapters of this paper, afforestation carries benefits on multiple levels in the contemporary world. Endorsing it on a global scale could help increase the empathy in the general public and spread the awareness. Therefore, in the event of high usability and successful afforestation of Cyprus, globalising this application appears to be an opportunity with a high likelihood of occurrence.

As stated in the beginning of this chapter, currently, the application only serves as data visualisation providing tool which can be used by policy makers in order to make informed decisions about afforestation. Despite this already facilitating their work significantly, another suggestion for future development in this project could be the integration of an AI Classification algorithm. Such update in the application could lead to turning the application from an informative monitoring tool to a forecasting one. This could bring the opportunity for optimised afforestation plans, better analysis of vegetation and its condition, and a more sustainable environment in Cyprus.

As a last suggestion, the integration of Reforestation As A Service (RaaS) could be reviewed since this would allow for subsidiary funding of afforestation initiatives. Having all businesses, which are polluting the environment, to take part in financing afforestation could not only accelerate the process of collecting resources but also help diminish many bad practices from the industry. thus making it more environmentally-friendly.

# Chapter 7

# Conclusion

The purpose of this project was to provide a solution that allows policy makers to make more optimal decisions while creating afforestation initiatives through visualising satellite data and presenting it in an informative manner. The research documented in this paper aimed to establish a strong argumentation as to why such a solution is necessary. To achieve this, the benefits of afforestation were outlined, as well as the need for a tool which serves as a way to monitor the status of vegetation. Inspiration has been gained during review of related projects, further followed by design and implementation of the desired product.

Throughout the design process, the main goal was to provide an answer to the research questions of this study:

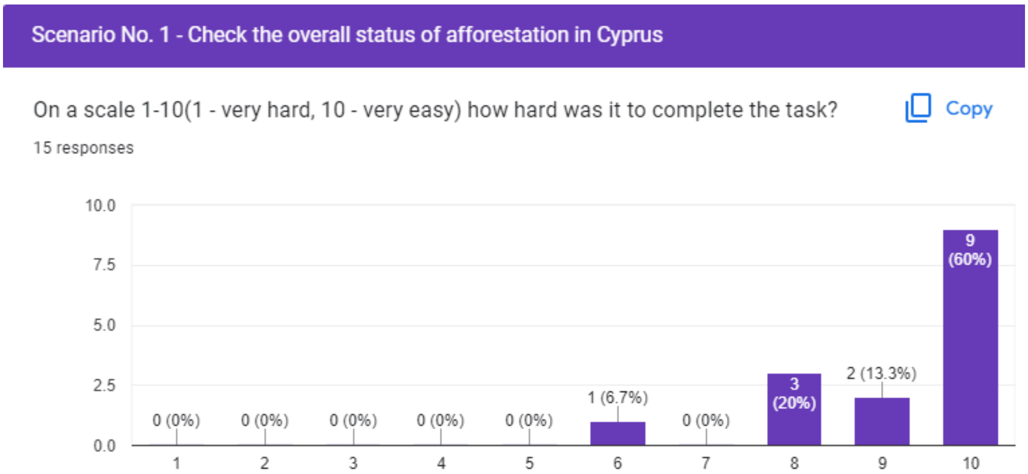
**How to visualise satellite data for afforestation practices?** As presented during literature review (Chapter 2.3), satellite data can be easily visualized on a geographic map by plotting it as a top layer and assigning proper labels to it in a numerical form. However, as witnessed during review of related work, as well as during design and implementation of the final product, satellite data can be visualised by quantification and representation in either numerical or categorical form. Choosing the latter option enabled the creation of easy-to-understand charts and diagrams, and avoid the use of overwhelming geographical maps filled with information whose essence is not directly described to the user.

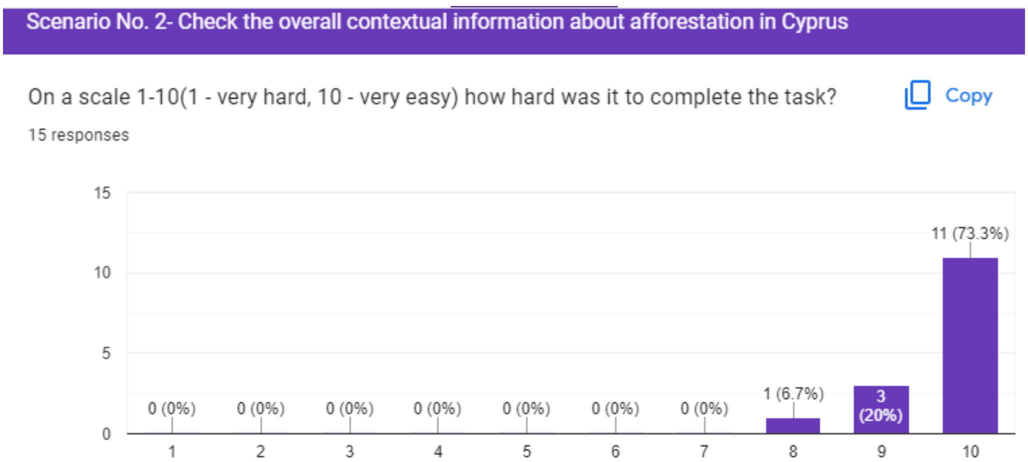
**How to create graphical interfaces that help policy-makers in making more informed decisions bout reforestation actions?** The answer to this question has mostly been answered in Chapters 3 and 4 during the description of the design and architecture of the final product. Implementing a web application which allows the integration of dynamically generated data visualizations serves as source of information for afforestation policy-makers during their work. Based on the presented information about vegetation (including all indicators discussed previously), they can evaluate how to structure an afforestation initiative that improves the environmental conditions in Cyprus.

With the implemented product, the provided information and the results from the evaluation until the present moment, a conclusion can be made that a graphical interface which has the ability to help policy-makers has been implemented and satellite data is successfully visualised in a comprehensible way.

# Appendix A

# Visualised Evaluation Results



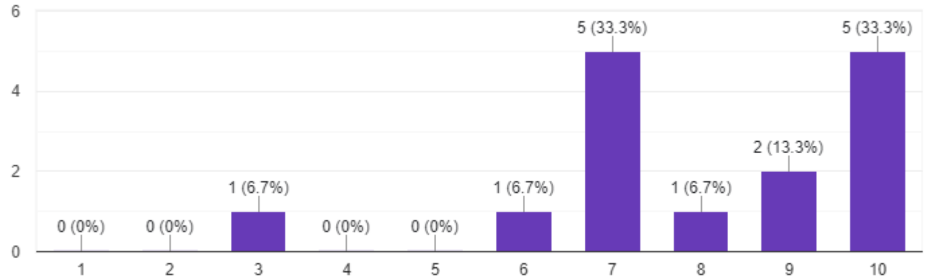



## Scenario No. 3 - Check the status of a specific afforestation

On a scale 1-10(1 - very hard, 10 - very easy) how hard was it to complete the task?

Copy

15 responses

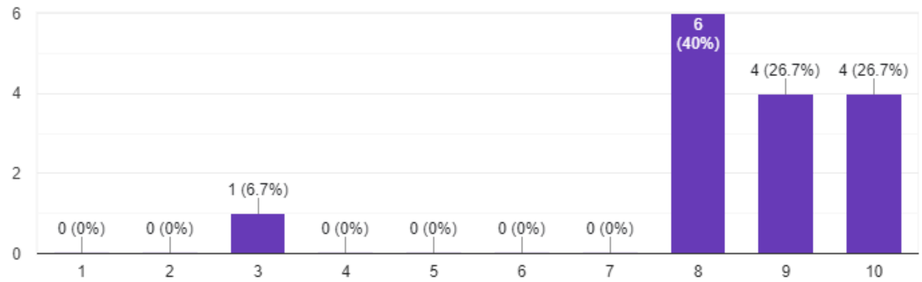



## Scenario No. 4 - Check contextual information about specific afforestation

On a scale 1-10(1 - very hard, 10 - very easy) how hard was it to complete the task?

Copy

15 responses

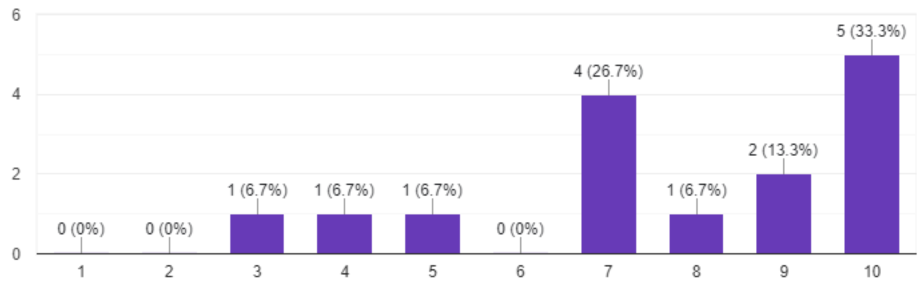


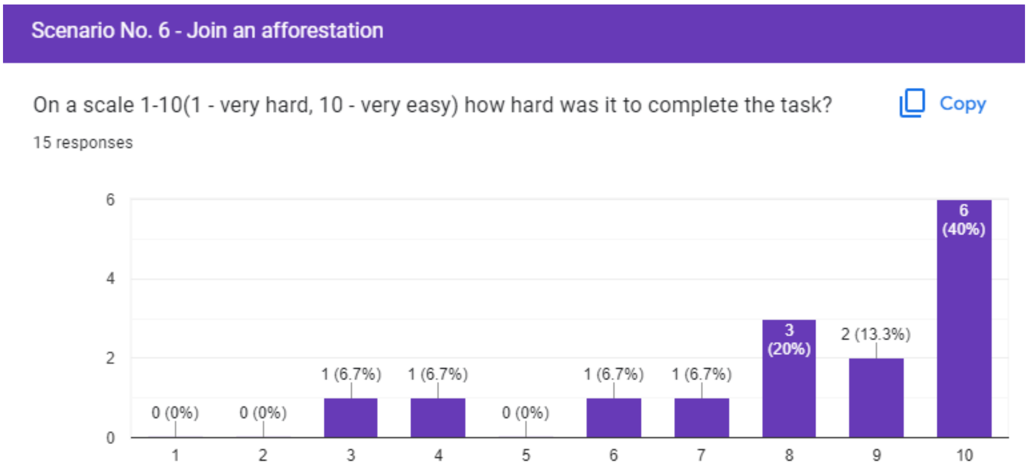

## Scenario No. 5 - Initiate an afforestation

On a scale 1-10(1 - very hard, 10 - very easy) how hard was it to complete the task?

Copy

15 responses




Scenario No. 6 - Join an afforestation
On a scale 1-10(1 - very hard, 10 - very easy) how hard was it to complete the task?
Copy
15 responses
0 (0%)
0 (0%)
1 (6.7%)
1 (6.7%)
0 (0%)
1 (6.7%)
1 (6.7%)
3 (20%)
2 (13.3%)
6 (40%)

# Appendix B

# Data Visualizations Comprehensibility


Fig. 1: Status of Afforestation

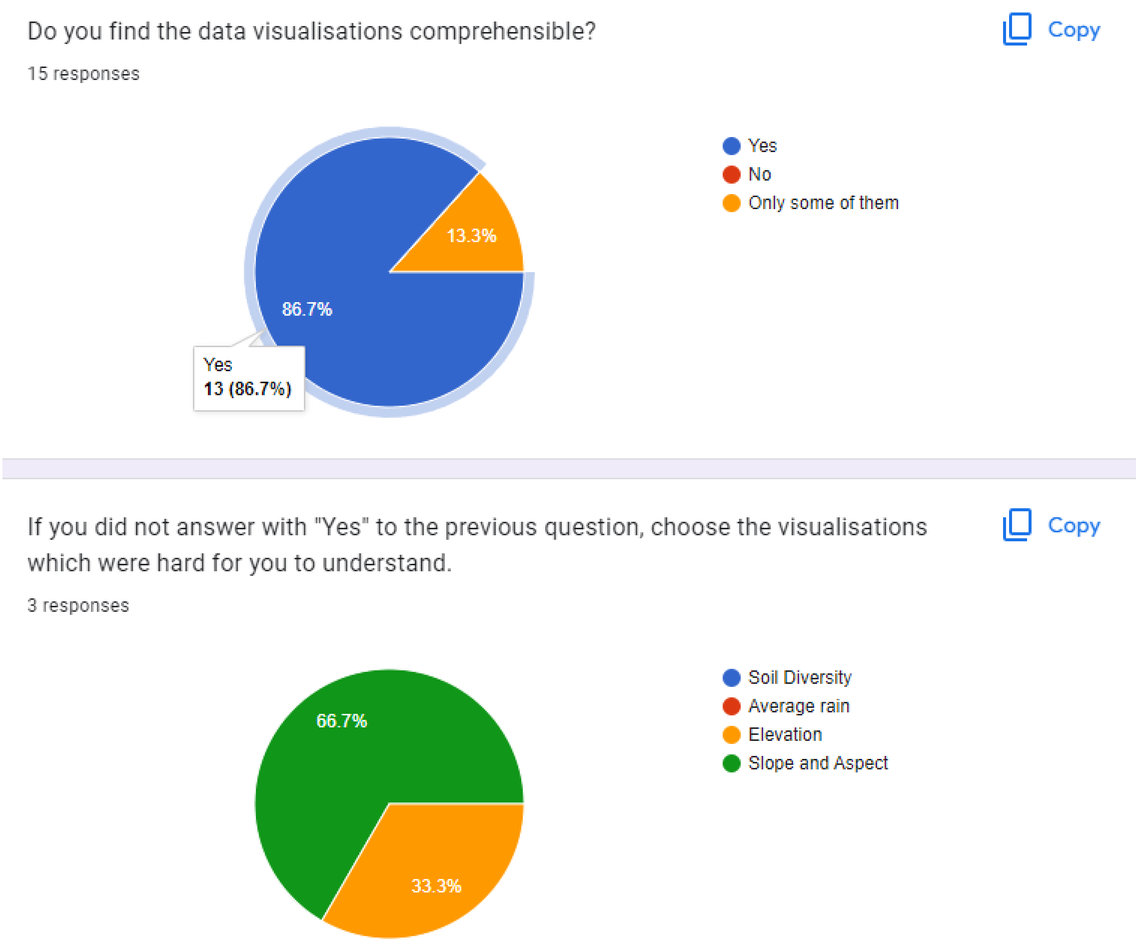



Fig. 2: Contextual Information

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