ABOVE-GROUND CARBON STOCK ASSESSMENT OF SHAKARPARIAN PARK AND THE CONSTRUCTION OF ITS CARBON BASE MAP

Submitted By

Sidra Adil

Nouma Hanif

Institute of Environmental Sciences and Engineering

School of Civil and Environmental Engineering

National University of Sciences and Technology

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own unique work and that no part of it has been presented for another degree in this university or other university.

Candidate's Signature: ……………………… Date: ………………………

Name: ………………………………………………………………

Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the National University of Sciences and Technology.

Principal Supervisor's Signature: ………………………. Date: ……………...

Name: …………………………………………………………….…

Co-Supervisor's Signature: ……………………………... Date: …………..…

Name: ……………………………………………………………..

ABSTRACT

Forests function as carbon sinks by absorbing the carbon dioxide in the atmosphere, to carry out the process of photosynthesis, and converting it into biomass. Carbon stored in the world's forest ecosystem is carbon-stock, it is largely in living biomass and soil, also in dead wood and litter but to a lesser extent. The objective of this study was to calculate the above-ground carbon-stock in Shakarparian. Altogether, 30 circular plots, each covering an area of 1/20th of a hectare, were laid out systematically in Shakarparian to carry out the forest inventory. Total above-ground biomass was estimated using allometric equations. Results indicated that Shakarparian has a total above-ground biomass of 2731 in tons of Carbon and a total basal area of 1240 m^2. It was also determined that Shakarparian Park, as of 2017, has a total tree population of 20,727 trees and a mean above-ground biomass of 2.64 tC/ha. Using imagery from the satellite Sentinel-02, a Land-Cover map for Shakarparian was also constructed in accordance with the six Land-Cover classes specified by IPCC, using ArcGIS. The NDVI values for Shakarparian were also determined, having a range of -0.01 to 0.64.

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It is with Allah's help and our parents' unflinching support that mobilized us to see this project through. We want to show our gratitude to our very dear supervisor Dr. Sofia Baig, who despite our newness to the subject, bore us with patience and guided us at every step of the way. Thank you for those amazing treats, Ma'am Sofia, those are memories to cherish!

We want to express the infinite gratitude we have for NFI Expert Kamran Hussain, who helped us design our field surveys and Miss Summaya Aleem who helped us gain fluency in the use of RS and GIS, thank you for your patience and constant support!

Lastly, to those people of UG-06, who helped us during the data collection surveys, we owe you and will remember to be there for you whenever you need us! Farhan, Shiza, Zahra, Ali, Rimsha, Shoaib, Hafsa, Aakasha, Kinza, Asad and Usama Fida, may you always find success wherever you go!

Dedication

We dedicate this effort to Pakistan and all those people who strive to make this world a better and an easy place to live, each day. Stay strong and keep smiling.

'Do unto others as you would have done unto you'-Prophet Jesus.

Contents

LIST OF TABLES FIGURES & EQUATIONS

LIST OF ACRONYMS

ABG	Above-Ground Biomass
DBH	Diameter at Breast Height
GHG	Greenhouse Gas
tC	Tons of Carbon
Ha	Hectare
IPCC	Intergovernmental Panel on Climate Change

CHAPTER 1: INTRODUCTION

1.1. Background of the study

Forest ecosystems provide a lot of facilities that are important to humans, and they are also responsible for maintaining important global biodiversity by supporting habitats (WWF, 2017). As forests store the most carbon in terrestrial ecosystems so they can play a significant role in global climate change reduction (Xinglong & Boyd, 2006).

Human activities have altered the natural exchange of carbon compounds between the atmosphere, oceans and terrestrial ecosystems which results in release of CO_2 from fossil fuel and through land use and land cover (LULCC) changes (Assefa et al., 2013). As a result, there is increase in CO_2 concentration in the atmosphere which has a significate greenhouse gas effects (Goetz et al., 2009). Among the GHGs, CO_2 is the most abundant (Brander, 2012). Trees decrease atmospheric greenhouse gas (GHG) accretion by absorbing carbon dioxide in the form of carbon from the atmosphere.

Solution to this challenge include the adoption of REDD+ which is Reducing emissions from deforestation and forest degradation, and enhancing forest carbon stocks. Forest ecosystems function as both source and sink to atmospheric carbon dioxide so they have been identified to play major roles in the climate change (Delux & Nguon, 2015). So assessment of carbon stock and its changes in various forest carbon pool is necessary (Assefa et al., 2013).

According to U.N. FAO, only 2.2% of Pakistan is forested. Pakistan has been losing 1.66% of forested land per year, dating from years 1990 to 2010 (Pakistan Forest Information And Data, 2000). This yearly decrease in forest cover indicates that Pakistan might be heading fast towards being struck by climate change induced impacts. Owing to this rapid deforestation rate and knowing that Pakistan is the 7^{th} most vulnerable country to climate change(Kreft et al., 2014), it is about time that a system of carbon accounting is devised. This can only be done if the country's forest carbon-stocks are documented for, giving way to policy makers to make more informed decisions on issues such as land-use change.

According to IPCC the amount of carbon stored in the world's forest, primarily in living biomass and soil, also in litter and dead wood but to some extent is Carbon stock. There are five core reservoirs or carbon pools in forests used for carbon stock assessment, which are biomass that is above the ground surface, biomass that is below the ground surface, dead wood, litter and organic matter of soil. Research was conducted on above ground carbon stock assessment of Shakarpariyan Islamabad, Pakistan

1.2. Problem Statement

Forest ecosystem can sequester large amount of carbon but they can be massive source of carbon emission, this hinders initiatives to reduce anthropogenic emission GHGs (GOFC-GOLD, 2009). The success of such initiatives are severely dependent on carbon storage information in various forests, and on conversion of these forests for other land use how much carbon may be released. Deforestation and degradation are results of land-use and land-cover changes leading to re-emission of large amount of sequestered carbon into the atmosphere (Nations, 2000).

It is very necessary to develop data files to compute carbon stocks by assessing carbon stocks of intact and modified forests. Filling these knowledge gaps will improve arguments for conservation of forest based on carbon stocks information in the long term.

1.3. Purpose of the Study

The purpose of this research was to undertake carbon stock assessments to evaluate the impact of environmental degradation on the ecosystems of above ground Biomass of Shakarpariyan, Islamabad, Pakistan and its Carbon base camp.

1.4. Research Objectives

The specific objectives were:

i. Determination of total carbon stock of Shakarparian.
ii. Construction of carbon base map of Shakarparian.

1.5. Significance of the Study

Findings of this research are expected to fill gaps for policy development, to inform local development authorities on AGB stock and to be added to database of forests of Pakistan.

1.6. Delimitations

The study was restricted to Shakarparian Park Islamabad, Pakistan only.

1.7. Limitations

Due to financial and time constraints, non-destructive sampling was done to estimate biomass.

1.8. Definition of Terms

- **Aboveground biomass AGB**: All woody stems, branches and leaves of living trees.
- **Allometric equations:** Equations used for approximating tree weight from variables such as tree diameter and height which are measureable in the field and are independent.
- **Biomass:** The mass of live or dead organic matter. It includes the entire mass of living organisms in a given volume or area. Biomass's quantity is expressed as dry weight
- **Carbon pool**: Carbon pool is a system which has the ability to collect or store carbon.
- **Carbon sequestration:** The long term storage of carbon in sinks (that is marine or terrestrial ecosystem) and its removal from the atmosphere.
- **Carbon sink**: A carbon pool from which more carbon flows in than out
- **Carbon source:** A carbon pool from which more carbon flows out than flows in
- **Climate change:** Due to increased levels of atmospheric carbon dioxide change in regional and global climate patterns.
- **Tree wood density:** It is the ratio of the mass of a wood section that is oven dried and the mass of water moved by its volume.

CHAPTER 2: LITERATURE REVIEW

2.1. Carbon pool

The place where carbon is deposited in nature is termed as carbon pool (University of New Hampshire, 2014). Primary pools of vigorously cycling carbon are CO_2 in the atmosphere, biota, organic matter of soil, and the seas or oceans.

Table 1: Types of carbon pools in forests (IPCC, 2006)

Pool		**Description**
Living Biomass	Above-ground Biomass	All biomass of living plants, both woody and herbaceous, above the ground including stems, stumps, branches, bark, seeds and foliage
	Below-ground Biomass	All biomass of live roots. Fine roots of less than 2 mm diameter (the suggested minimum) are often excluded because these often cannot be notable empirically from organic
Dead Organic Matter	Deadwood	All non-living woody biomass not contained in the emitter, either standing, lying on the ground, or in the soil. Deadwood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter
	Litter	All non-living biomass with a size greater than the limit for soil organic matter (the suggested minimum is 2 mm) and less than the minimum diameter chosen for deadwood (e.g. 10 cm) lying dead and in various states of decomposition above or within the mineral organic soil
Soil	Soil organic matter	Organic carbon in mineral soils to aspecified depth chosen and applied consistently through a time series. Live and dead fine roots within the soil (of less than the suggested minimum for below ground biomass) are included wherever they cannot be empirically distinguished from the soil organic

According to IPCC Guidelines (2006), there are 5 (five) major pools of carbon in forest, which include biomass which is above the ground surface, biomass which is below ground, wood which is dead, litter and organic matter of soil (Table 1). Carbon is used through the process of photosynthesis by vegetation for the purpose of growth. The results of photosynthesis process are carbohydrates, which are building blocks of life. Carbon is successively spread all over the plant body and ultimately stored in the body of plant (sequestration of carbon), signifying that carbon is deposited in live plants (biomass). Plants absorb this CO_2 from the atmosphere.

2.2. Tree Species

Islamabad has 162 plant species in total which represent 137 genera and 58 families. In green belts, *Pinus roxburghii* and *Grewia asiatica* are more common while *Dalbergia sissoo* and *Acacia nilotica* dominate native vegetation and are present in mostly uninterrupted green places. Around the drains/nullahs in the city *Broussonetia papyrifera* and *Populus euphratica* are widespread (Ali & Malik, 2010).

The research consisted of the assessment of above-ground carbon stock in Shakarparian and thus only tree species were considered for the study and shrubs were excluded. During data collection process in Shakarparian, 5 tree species were identified. *Pinus Roxburghii* along the green belts; *Populus Euphrates* and *Broussonetia Papyrifera* along the drains and nullahs present in Shakarparian, and *Acacia Nilotica* and *Dalbergia Sissoo* were present in plots surveyed at undisturbed green spaces. It was made sure that plots for data collection were spread evenly along the entire area to increase accurate.

Table 2: Tree species and their total numbers found in plots surveyed at Shakarparian (Ali & Malik, 2010)

Tree Species	Number In Total Plots Surveyed
Populus euphratica	30
Acacia nilotica	12
Dalbergia sissoo	104
Broussonetia papyrifera	315
Pinus Roxburghii	70

2.3. Allometric Equations

The allometric regression models use is rarely directly tested and is a critical step in estimating AGB (Chave et al., 2005). Owing to biodiversity in the forest ecosystem mixed tree species regression models of biomass must be used owing. Usually, published models of regression are based on directly harvested trees in a small number and include very limited trees with large diameter, thus forest is not well represented at large. This explains the reason of constructed models for the same forest that are more than one might result different Above Ground Biomass estimates, a difference aggravated for large trees, which executes a great uncertainty on tree level biomass estimates (Gibbs et al, 2007); (J. Chave et al., 2005). Few published research studies are available but it is difficult to acquire direct tree harvest data in the field. Therefore, independent assess the model's quality is often impossible (J. Chave et al., 2005).

Allometric equations are a method to assess AGB without the felling of trees and since our study consisted of non-destructive sampling, allometric equations were used to estimate carbon stock in Shakarparian.

Across different plant types when specific wood gravity, diameter of tree trunk, and total height of tree are available a single allometric equation, model 4 can be used to estimate tree AGB (Chave et al., 2014).

We used the model below, namely Model 4, to estimate biomass for *Broussenetia papyrifera, Populus Euphratica.* We used this model to estimate wet biomass for all tree species in our study area except for the *Pinus Roxburghii* as we were provided by a general equation for conifers in Pakistan by Gilgit-Baltistian Forest Department. We used the following equation for tree species other than *Pinus Roxburghii.*

$$\mathbf{AGB=0.0673(\rho D^2H)^{0.976}}$$

Equation 1: Chave et al. , 2014

Where D is in cm, H is in m, and q is in g cm^3. Across forests types and bioclimatic conditions this model performed well (Jérôme Chave et al., 2014). For tree species *Pinus Roxburghii*, the following equation, provided by the Gilgit-Baltistan Forest Department, was used to estimate dry-biomass directly:

$$\mathbf{AGB=0.1645(D^2H)^{0.8586}}$$

Equation 2: GB Forestry Dept. for Conifers

To approximate the volume of unique branches and stems, terrestrial LiDAR can be used for assembling whole-tree Above Ground Biomass estimation without reaping the tree. It should be probable to approximate tree Above Ground Biomass to a worthy accuracy without felling the tree with supplementary wood specific gravity measurements. Achievement of tree biometric data should speed up by this approach (Chave et al., 2014)

2.4. Tree wood density

Basically wood is organic tissue made of cells, which are also known as tracheides, and of walls made of lignin. The tracheides are filled of water and are similar to pipes that transfer the sap down the stem. Between the individuals of the same species, during the lifetime of a plant wood density is subject to change within the plant. The outer part of the tree trunk and its branches have a propensity to have a lighter wood in comparison to the pith (J. Chave, 2005).

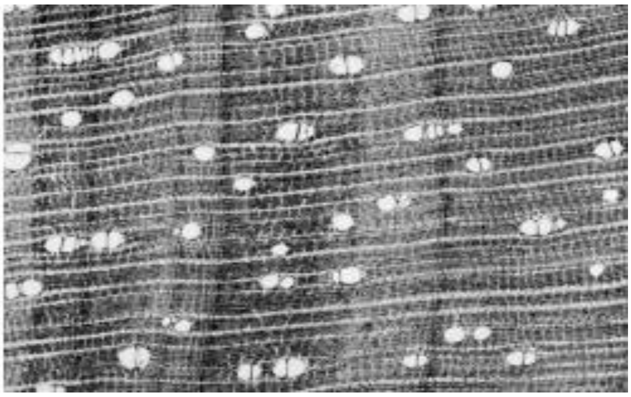

Figure 1: The tracheides are clearly visible in section of the wood.

Wood density has many definitions. Weight of a given volume of air-dried wood is measured by foresters. Air drying has different methods depending on the country: May be 12% or 15 % portion of water remain in the wood sample. Substantial difficulty in the literature is caused by this. Density of wood is in principle termed as the ratio of the mass of a wood sample that is oven dried and the mass of water moved by its green volume (wood specific gravity, or WSG). From measurements of oven-dry weight and the measurement of green volume this can be calculated (Chave et al, 2005).

Since tree wood density is one of the variables being used in the Model of allometric equations(Chave et al., 2014), wood densities were obtained from available literature for all tree species but *Pinus Roxburghii*, as the conifer equation provided to us by the GB forest department didn't require it.

Table 3: Wood densities of tree species in Shakarparian.

Tree Species	Tree Specific wood density(g/cm3)	Source
Populus Euphratica	0.70	FAO
Broussonetia Papyrifera	0.63	The Wood Database
Dalbergia Sissoo	0.6	FAO
Acacia Nilotica	0.6	FAO

2.5. NDVI

NDVI stands for normalized difference vegetation index. It assesses if the target being observed is comprised of live green vegetation or not. It is a simple indicator that is graphical and can be used to analyze remote sensing values, usually but not essentially from a space platform.

Red and near-infrared light waves reflected by land surfaces are measured by sensors carried abroad satellites. Scientists convert raw satellite data about these light waves into vegetation indices by using mathematical formulas and algorithms. Greenness, relative density and health of plants for each picture element, or pixel, in a satellite image is described by an indicator, vegetation index.

Normalized Difference Vegetation Index (NDVI) is one of the most commonly used vegetation indices. Its values are between +1.0 and-1.0. Areas of barren rock, sand, or snow usually show values of NDVI that are low (generally 0.1 or below). Values of NDVI that are moderate (approximately between 0.2 and 0.5) are shown by vegetation which is sparse such as bushes and plains or crops that are senescing. Values of NDVI that are high (approximately between 0.6 and 0.9) link to thick plantation such as that found in temperate and tropical forests or crops at their highest growth stage.

NDVI values are calculated by transforming raw satellite data, Images and other products that give a rough measure of type of plantation, number, and form on land surfaces all over the world can be created by researchers. For continental to global-scale vegetation monitoring

NDVI is very useful because it can compensate for conditions of illumination that are changing, slope of surface, and angle of viewing. Over plantation that is thick NDVI is able to saturate and is sensitive to primary colors of soil.

Values of NDVI that are obtained from sentinel-02 imagery for our area of study ranged from -0.01 to 0.64 and will be elaborated upon in the results sections.

CHAPTER 3: MATERIALS AND METHODS

3.1. Study Area

The research study was conducted in Shakarparian Park, which is situated in Islamabad, capital of Islamic Republic of Pakistan. Shakarparian Park is part of Margalla Hill National Park and is in protected area.

3.2. Shakarparian

Name Shakarparian has root from Potohari language in which Shakar means sweet and Parao means a place to rest. It is situated in Islamabad and is surrounded by three main High ways of Islamabad which are Kashmir Highway, Express Highway and Murree Road. Its geographical coordinates are 33° 41' 0" North, 73° 4' 0" East. It is mostly forest with a few hotels, park, museum and monument. Shakarparian is an area with variable topography there are several meters high hill at some points and a few meters deep depressions at other points. It has several natural Nalahs at some points while others are dry parts due to this diversity shakarparian is blessed with variety of species. It has *Pinus Roxburghi* at elevated points and species *Broussonetia Papyrifera* , *Dalbergia Sissoo, Acacia Nilotica* and *Populus Euphratica* at other points. It has humid subtropical climate with a lot of rainfall throughout the year. Temperature varies from below 0 degree in winter season and above 45 degree in summer season.

Figure 2: Google Earth Image of Shakarparian

Shakarparian was of interest because it is in the middle of Islamabad and represents almost all the forest type of Islamabad. Shakarparian is diverse in the terms of land-use, tree species, soil type and soil moisture so only a single research study can cover multiple aspects. Moreover, it was accessible and possible to cover with limitation of resources labor and money owing to small area. Following are some of the images of the area.

Figure 3: Shakarparian: A pictorial view of plots visited. The five species most abundant in these plots were *Pinus Roxburghii*, *Dalbergia Sissoo a*nd *Broussenitia Papyrifera.*

3.3. Materials and Equipment:

Material and equipment which was used during the research study include Measuring Tape, GPS and Clinometer. All the material and equipment was simple, easy to use and portable so it could be easily moved in the area of study.

Table 4: List of the equipment that were used for above-ground carbon stock assessment at Shakarparian

No.	Equipment	Function
1	Garmin GPS X	Navigation system
2	Digital Camera	To document study
3	Measuring tape	To measure circumference for DBH determination
4	Clinometer	To measure angle of elevation of tree

Tree species were identified with help of available literature and local knowledge using tree leaves and bark. Following five species were identified *Broussonetia Papyrifera, Pinus Roxburgi Dalbergia Sissoo, Acacia Nilotica* and *Populus Euphratica*. Data for DBH, crown diameter and canopy cover was collected with the help of measuring tape, for tree heights clinometer was used which gives angle of elevation and was converted into height by using trigonometric equations and data for plot coordinates that are longitude, latitude and elevation was taken with the help of GPS.

3.3.1. Satellite data:

Satellite imagery that was used during the research study was of Sentinel 02, having spatial resolution of 10 m, 20 m and 60 m, and 290 km field of view. It provides high accuracy and high image resolution. There are 13 bands which are from Multi-spectral data in Sentinel-2 mission in the visible (400-700 nm), near infrared (700-1100 nm), and short wave infrared (1100-3000nm) part of the spectrum. It systematically covers waters of coast, and full of the Mediterranean Sea and land surfaces between 56° S and 84° N. Under same viewing angles it revisits every 5 days so its accuracy is high. With different viewing angles Sentinel-2 swath overlap and in every 5 days some regions will be observed more than once at high altitudes. Its images and data can be used as it has free and open data policy.

Bands 5, 3 and 2 of Sentinel-02 were used for image processing and analysis through the course of this study. To obtain the NDVI values from Sentinel-02 imagery, bands 4 and 8 were used.

3.3.2. Software:

Software used for preprocessing, processing and analysis of data collected was ArcGIS and QGIS. ArcGIS was primarily used to construct the Land-Use Map and the Carbon Base-Map. NDVI values for the Sentinel 02 imagery was obtained through Q GIS and post-processing of the resultant image was done on ArcGIS.

3.4. Method

3.4.1. Sampling design:

A sampling design adapted from GB forest inventory was used. This study considered above-ground components to include trees with diameter at breast height (DBH) measuring ≥ 10 cm. Stratified random sampling was used but since there was no significant variation in strata based on height, we opted for simply random sampling. A circular plot design was adopted. Sampling plots of dimension 1/20th of hectare (radius was calculated using simple equation of circumference) were established using a measuring tape and the boundaries marked with ribbons. Each sampling plot was at least 50 m apart from other sampling plot. The sampling plots were designed to spread across entire Shakarparian to get a representative above-ground carbon stock estimate.

3.4.2. Data collection:

Primary and secondary data were collected during the dry season from December 2016 to April 2017. Existing baseline aerial maps of the study areas, capturing total tree coverage, were used along with Google maps. This provided a basis to account for total carbon stock at the location. A global positioning system (GPS) (Garmin) was used to determine the coordinates of the sites, plots. Notes based on existing literature were made on land-use types, tree species and coverage and validated by field observation. Carbon pools measured comprised biomass that is above the ground surface only. The AGB included live and dead or fallen (down) trees.

3.4.3. Parameters for calculation of above-ground biomass:

AGB refers to living and dead plant tissues above the surface of the soil. These include stems, stumps, branches, bark, seeds and foliage (Assefa et al., 2013) . However, this study restricted above-ground biomass to tree stems ≥ 10 cm. Tree species found were identified to species level using keys from available manuals and literature. Parameters for which data was collected included the tree species name, its height, DBH, canopy cover and crown diameter. The reason why these parameters were set is because they were a prerequisite for biomass estimation through allometric equations. The biomass of standing live trees was calculated using allometric equations to estimate total AGB of the trees (Chave et al., 2014). The most frequently occurring species and the most dominant species based on diameter at breast height were determined through field surveys to investigate their influence on the carbon storage in the forests. To obtain the most precise carbon stock estimates possible, the principle was to use well-established, relevant computational techniques from the literature which will be explained in the following section.

3.4.4. Allometric Equations

Biomass for tree species of all 30 plots was estimated using allometric equations. The Equation no 3 was used from Chave et. al 2014 for tree species *Broussonetia Papyrifera* , *Dalbergia Sissoo, Acacia Nilotica* and *Populus Euphratica*:

$$\mathbf{AGB=0.0673(\rho D^2\ H)0.976}$$

(**Equation 1**: **Chave et al.**, **2014**)

Where:

ρ= Tree-wood density

D= Diameter at breast height

H=Tree height

Tree-wood densities for biomass estimation by the ‘Chave Equation’ were obtained from available literature.

For tree species *Pinus Roxburghii*, the following equation, provided by the Gilgit-Baltistan Forest Department, was used to estimate dry-biomass directly:

$$\mathbf{AGB=0.1645(D^2H)0.8586}$$

(**Equation 2: GB Forest Dept. for Conifers**)

Where:

D=Diameter at breast height

H=Tree height

Once the biomass for each tree was calculated; dry biomass, carbon stock and carbon dioxide equivalent were also calculated.

Field measurements were recorded on field data sheets and then entered manually into spreadsheets. Data entry was done immediately after the completion of the field measurements. When data is entered into spreadsheets there is often a significant chance of error. Monitoring data is completed before the final analysis, communication between all persons involved in measuring and analyzing data is critical for resolving apparent differences. Special attention was paid to the units used in the field, IPCC guide lines and GB forest inventory techniques were used for the calculation and measurement of all tree DBH, height and crown diameter. All measurements contained in spreadsheets were clearly indicated. Errors were reduced through spot checks of the entered data. In addition, checking each value within an expected range identified any outlier trees.

3.5. Data Analysis

Estimation of Live Tree Carbon Stocks to estimate the stocks in Shakarparian was done as is outlined below:

The live biomass of sampled trees in each plot was predicted using the allometric equations obtained through literature. The biomass of all sampled trees is first estimated and then a plot-level estimate is calculated. A mean carbon stock is then calculated by taking the average of all plot estimates. The biomass estimated is then converted to tons of carbon. To approximate on a per hectare basis each tree biomass multiplies the biomass of tree by the factor for scaling that is correct on the basis of plot size or nest in which the tree was measured.

In allometric equations the units of biomass used are often kg dry biomass, in which to convert tons requires multiplication by 0.001. Sum the biomass of all trees in each plot.

Convert estimated biomass to carbon:

$$Cp = DM * CF$$

Equation 3: Estimation of Carbon Stock in a plot

Where: Cp = carbon stock in plot (t C ha^{-1})

DM = dry biomass in plot (t dry matter ha^{-1})

CF = carbon fraction (t C t-1 dry matter).

As it was free vegetation, the Carbon Fraction 0.47 tC H^{-1} dry matter or from the literature specific values of species (per IPCC 2006 GL, V4, Ch4, Table 4.38).

Finally, the confidence interval as well as mean of above-ground stock was calculated for Shakarparian.

Requirement for Allometric Equations:

- Wood density of tree
- Height of tree
- Diameter at Breast Height of the tree trunk

3.5.1. Scaling Factor Calculation:

A scaling factor is used to extrapolate the field measurements taken (e.g. mass of AG tree carbon within sampled plot) to a 'per hectare' basis. (This scaling factor is converting the area units from square meters to one hectare:

$$SF = 10{,}000/NA \quad (13)$$

Equation 4: Scaling Factor to convert to per hectare basis

Where:

SF = scaling factor to convert to per hectare basis (dimensionless)

10,000 = meters squared in one hectare

NA = horizontally projected area of nested plot (m^2)

CHAPTER 4: RESULTS

4.1. Above-Ground Carbon Stock Shakarparian:

These were the results that were obtained during data analysis:

Table 5: Population of trees and total above-ground carbon stock estimated for Shakaparian.

Project Area (Shakarparian) Level Analysis			
Construct	**Estimated Total For The Population**	**Relative Standard Error**	**95% Confidence Intervals**
AGB (tC)	2,730.90	1.54	2650.20-2811.60
No. of trees	20,727.00	0	20746.0- 20807.40

Table 6: Mean AGB per hectare estimated in Shakarparian.

Strata	Number of plots	Mean AGB (tC/ha)	Strata (Area in ha)
Shakarparian	30	2.64	1171.00

4.2. Carbon Stock Results

Shakarparian, as of 2017, as can be observed (Table 5: Results), has 2730 tonC AGB. The relative error, again, is very low and the confidence levels lie within a very narrow range.

- Finally, number of trees in Shakarparian have been estimated to be 20727.00. The mean AGB for every hectare was calculated to be 2.64. Forests being sinks for carbon are crucial in the mitigation of climate change. Carbon stock estimates not only aid policy makers in determining rate of sustainable land-use change but will also influence research to be carried out on future deforestation threats (Jantz, 2014) .

4.3. Shakarparian Land Use Map

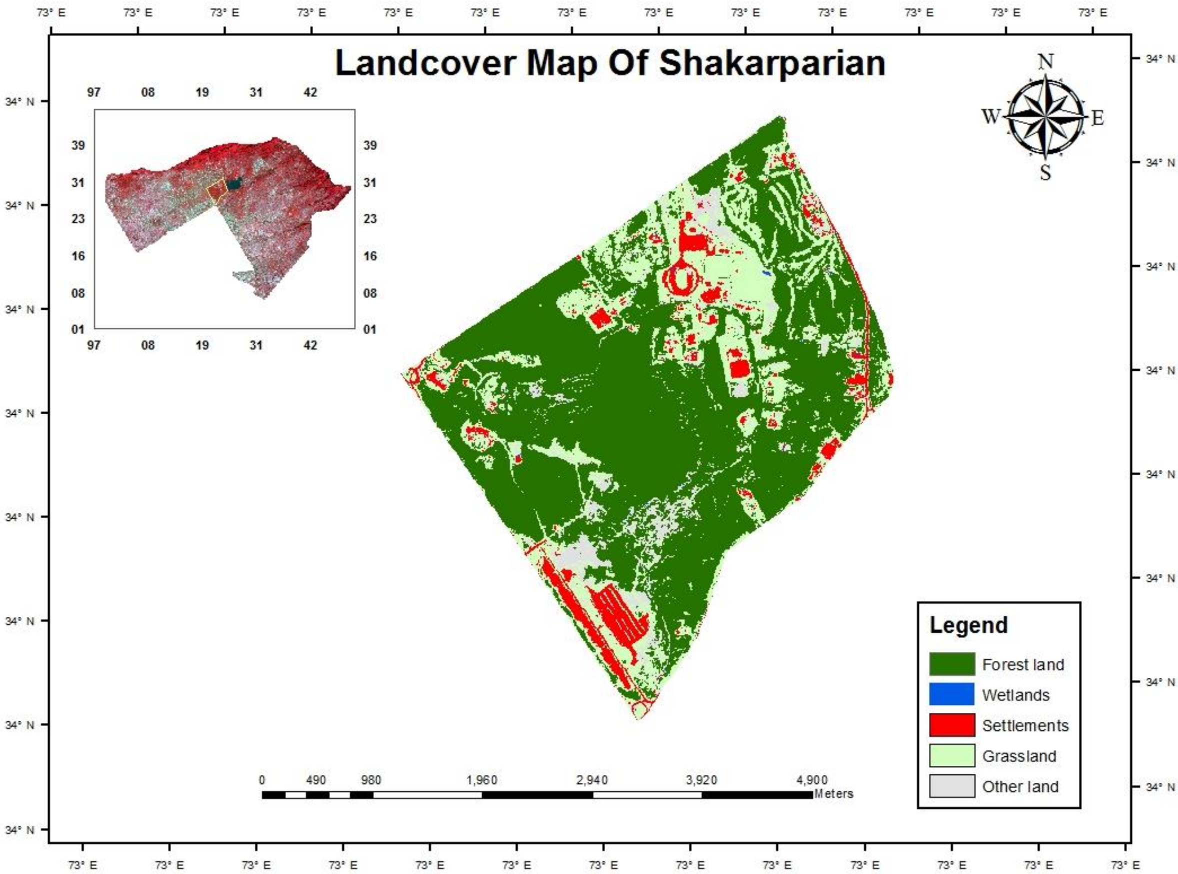

Figure 4: Land-Use Map of Shakarparian: Shakarparian was classified according IPCC 6 Land-Use classes, namely; Forest land, Wetland, Settlements, Grass land, Other Land and Crop Land. Since Shakarparian was completely devoid of Crop Land, the legend for Crop Land was removed.

The Land-Use map was constructed on ArcGIS software with the help of supervised classification operation. Classification was done according to IPCC Classification which comprises a total of 6 Land-Use types namely; Forest land, Wetland, Settlement, Grassland, Crop Land and other land. Since Shakarparian is completely devoid of any form of crop land, the crop land class was removed. The Land-Use map constructed was then compared to google imagery in order to ensure the precision of the classification done.

4.4. NDVI Map:

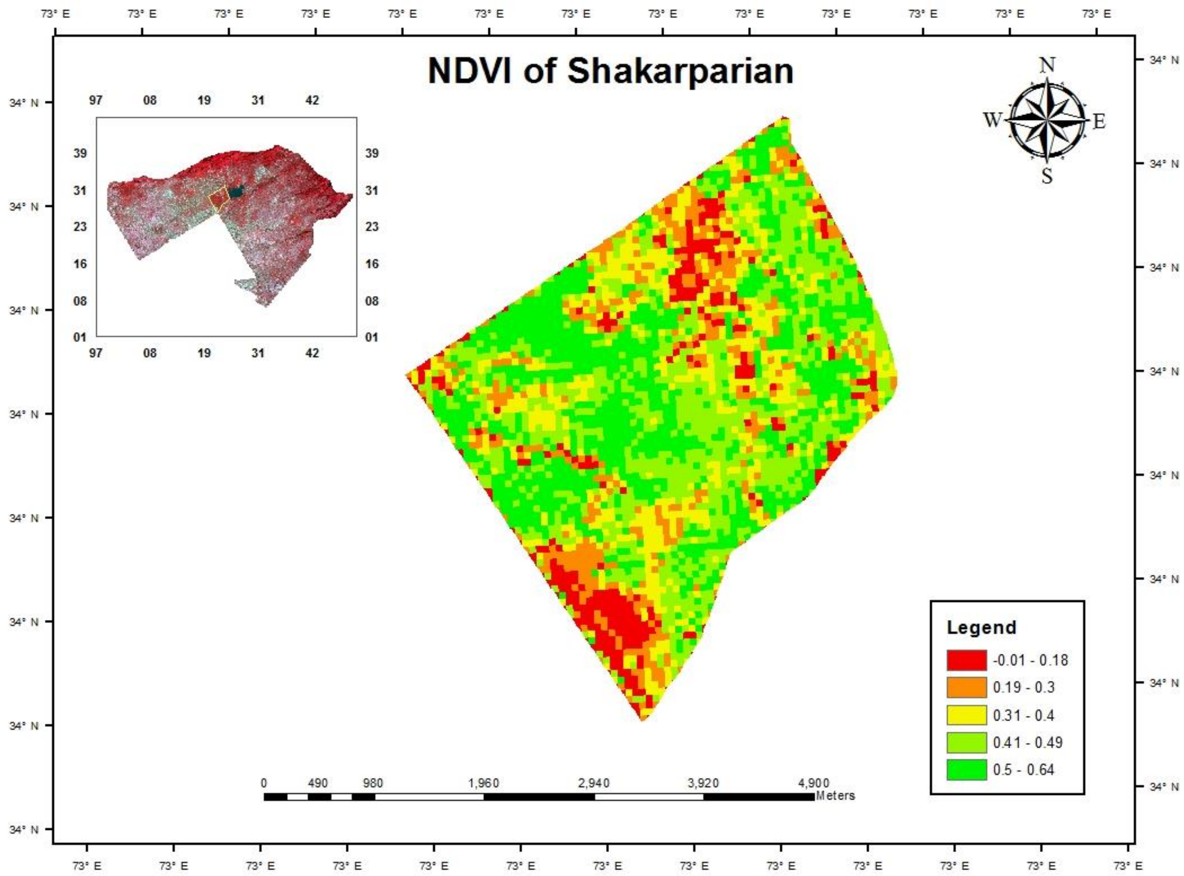

Figure 5: NDVI Map Of Shakarparian Derived From Sentinel 02 Image. The red extreme indicates barren rock, the yellow and orange areas indicate sparse vegetation while the greenish regions show us healthy vegetation.

Values of NDVI are between +1.0 and-1.0. Areas of barren rock, sand, or snow usually show values of NDVI that are low (generally 0.1 or below). Values of NDVI that are moderate (approximately between 0.2 and 0.5) are shown by vegetation which is sparse such as bushes and plains or crops that are senescing. Values of NDVI that are high (approximately between 0.6 and 0.9) link to thick plantation such as that found in temperate and tropical forests or crops at their highest growth stage. As can be observed from the NDVI map, its range is between -0.01 and 0.64. Value of 0.64 indicates that Shakarparian has dense vegetation.

4.5. Carbon Base Map of Shakarparian:

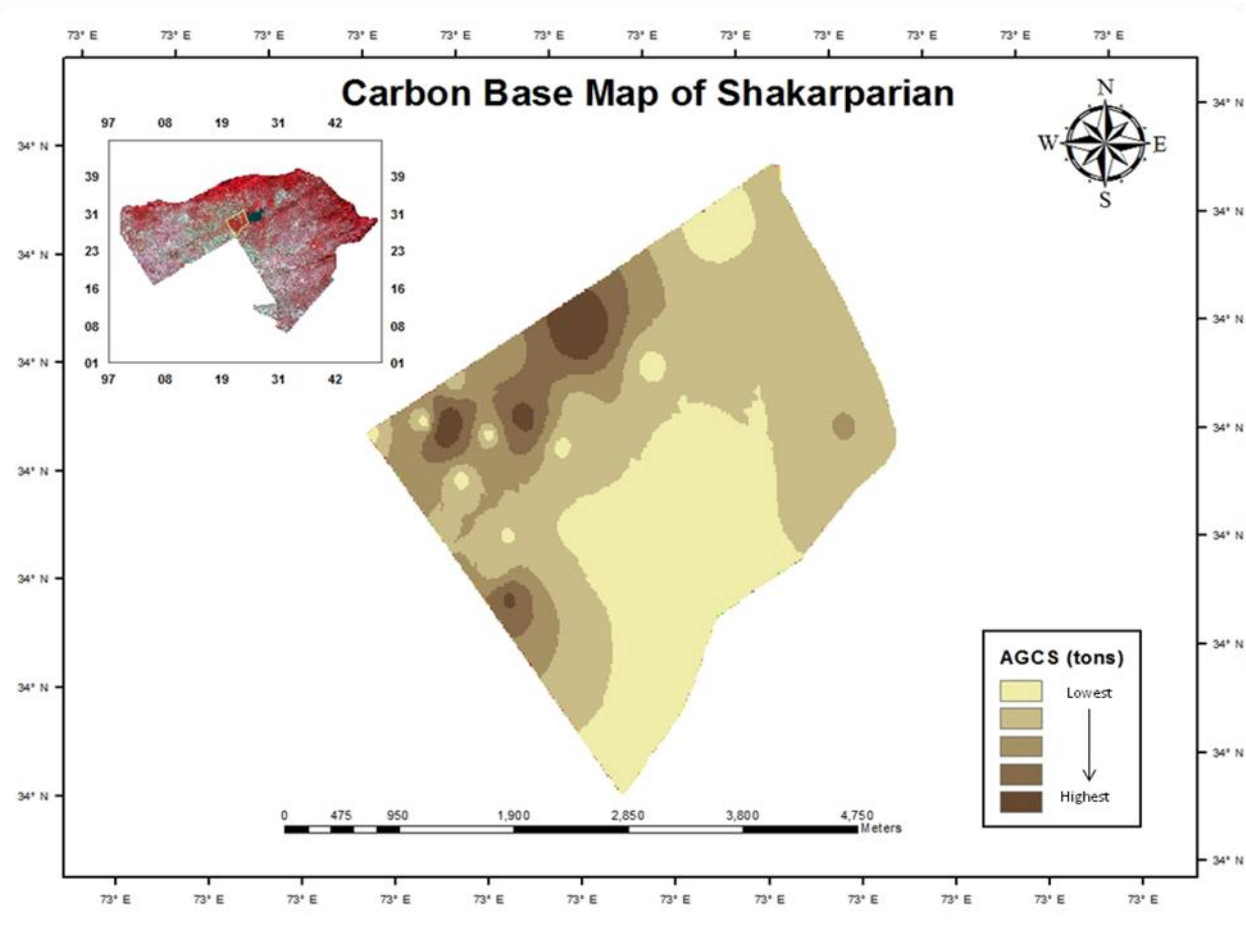

Figure 6: Carbon Base Map of Shakarparian. The lighter yellowish regions possess the lowest amount of Above Ground Carbon Stock. As the we move from light yellow to brown, the AGCS increases.

4.5.1. Observations made from carbon base map:

The darker brown colour on the carbon base map indicates the upper left Shakarparian region where vegetation was dense and comprised mostly of *Pinus Roxburghii*, this is where the Pakistan Monument and cafés like Yogi Haus are located. It is a tourist attraction site.

As the colour goes from brown to yellow, above-ground carbon stock decreases. Especially on both right and left regions.

The extreme right is where most of the drainage system of Shakarparian is located and thus species like *Populus Euphratica* and *Broussenetia Papyrifera* were the norm.As we head towards the extreme left, the colour begins to change to yellow which indicates the least carbon stock, the reason for this is that those areas come under Pakistan Defense and are mostly sites for army training.

Overall, it can be said that upper Shakarparian has dense vegetation while lower Shakarparian has relatively lesser carbon stock. Thus, lower Shakarparian is where reforestation efforts need to be made.

4.6. Variation of Carbon Stock with Tree Species:

The following graph shows the distribution of above-ground carbon stock according to tree species:

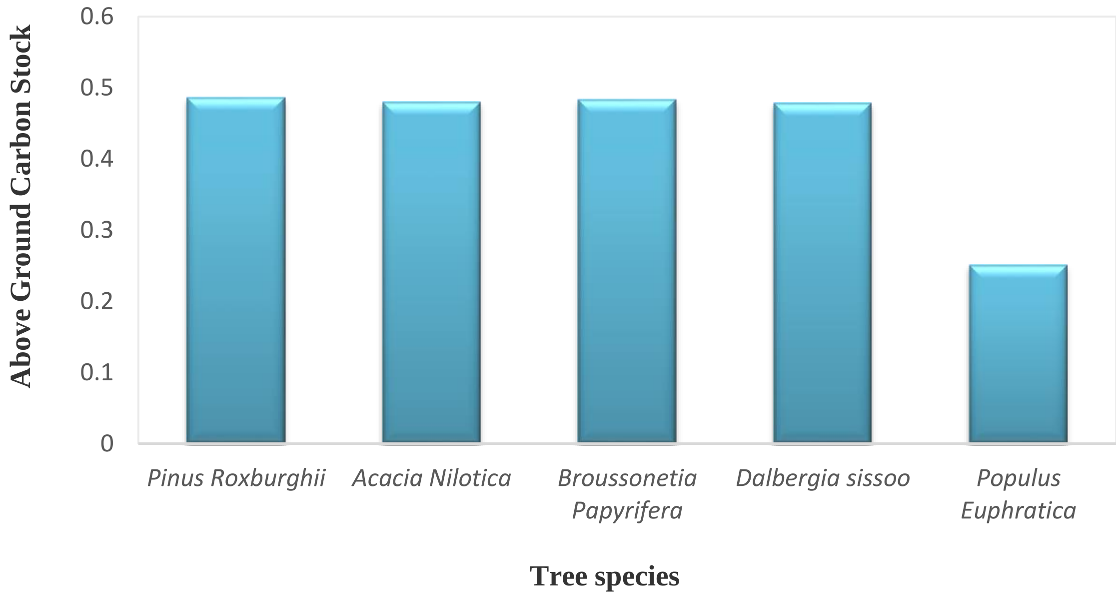

Figure 7: Relationship between ABG Carbon stock and tree species. Populus Euphratica has the least carbon stock while the other 4 species all contribute the same amount of carbon stock per hectare.

Above ground carbon stock remains relatively same in all species except for *Populus Euphratica* the reason for which will be explained through Figure 7.

Tree Species *Pinus Roxburghii, Acacia Nilotica, Broussonetia Papyrifera* all contribute to 0.5 tC/Ha while *Populus Euphratica* contributes half of that. After reviewing literature, the popular opinion was that carbon stock relationship with species biodiversity is not one that can be determined exactly and exhibits a very weak connection.

CHAPTER 5: CONCLUSION

From the study discussed above, we can conclude the following:

- Shakarparian has an AGB total of 2730 tC.
- Approximately, 21000 live trees stand in Shakarparian as of today.
- The successful construction of Land-Use, NDVI and Carbon Base Maps for Shakarparian has been achieved.
- Data obtained has high accuracy due to narrow confidence level range.

CHAPTER 6: RECOMMENDATIONS

The following recommendations can be made:

This data will be helpful to policy makers, especially when estimated carbon emissions due to Land-Use change. Studies for below-ground carbon stock assessment of Shakarparian need to be conducted as it was not a part of this project to get a more wholesome result.

These studies can be used to draw a correlation between emissions from vehicles and other activity surrounding Shakarparian area, to understand the relationship between the two variables.

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