Assessment of soil organic carbon in different land uses of scrub forest in Lehtrar, Pakistan

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A thesis submitted in partial fulfillment of the requirements for the degree of

Master of Science in Environmental Science

By

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THESIS ACCEPTANCE CERTIFICATE

It is certified that the contents and forms of the thesis entitled "Assessment of soil organic carbon in different land uses of scrub forest in Lehtrar, Pakistan" submitted by Mr. **Hamad Khalid Satti (Reg # 119957)** has been found satisfactory for the requirements of the degree of Master of Science in Environmental Science.

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It is certified that the contents and form of the thesis entitled

"ASSESSMENT OF SOIL ORGANIC CARBON IN DIFFERENT LAND USES OF SCRUB FOREST IN LEHTRAR"

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DEDICATION

Every challenging work needs self-efforts as well as the guidance of elders especially those who were very close to our hearts.

My humble effort I dedicate to my sweet and lovely

Father and Mother,

Whose affection, love, encouragement and prays of day and night make me able to such success and honor

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Hamad Khalid Satti

Table of Contents

List of Abbreviations

ArcGIS	Arc Geographic Information System
AFOLU	Agriculture, Forestry and other land uses
C-CARGO	Climate Change and Atmospheric Research Group
FAO	Food and Agriculture Organization
LCC	Land Cover Classification
LULUC	Land use and land use change
LULUCF	Land use, land use change and forestry
GHG	Green House Gas
GOP	Government of Pakistan
GIS	Geographic Information System
IPCC	Inter governmental Panel on Climate Change
NDVI	Normalized Difference Vegetation Index
NGO’s	Non-Government Organizations
PFD	Punjab Forest Department
REDD+	Reducing Emissions from Deforestation and Degradation
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United Nations Geological Survey

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The current study was conducted in the scrub forest of Lehtrarin region, Rawalpindi district of Punjab province. It was aimed to explore the potential of carbon storage in different land uses of scrub forest. Furthermore, the carbon stock, the growing stock and biomass of scrub forest along with the land use and land use change were also estimated. Carbon stock of scrub forest was assessed for the soil, below ground and above ground. The main species of tree in the study site of scrub forest were *Accaciamodesta*(Phulai) and *Olea ferruginea*(Kahu). Results indicate that the minimum carbon stock was recorded as 7.699 t/ha in soil and maximum carbon stock was recorded as 81.349 t/ha in above ground carbon. Total carbon stock assessed in study site was 818.85 t/ha. Further analysis reveals that there is a significant difference between carbon stocks of soil with different land uses of scrub forest in Lehtrar region. The maximum soil carbon was present in intact forest as 12.318 t/ha. However, the minimum soil carbon was present in land use agriculture converted from forest land as 4.65 t/ha. Total carbon stock present in scrub forest of study area is estimated as 818.85 t/ha. Results of classified maps showed that the land use class of forest land is changed into the other land use classes, as forest cover of study site was 39 % in year 1998 and decreased to 33 % in year 2017, while other land increased from 58 % in year 1998 to 64 % in year 2017.

Chapter 1

1. INTRODUCTION

Nowadays, one of the utmost pressing issue is considered to be of climate change. World average temperature is increasing due to increased greenhouse gas emissions. Rapid industrialization among all the anthropogenic activities is the leading cause for increased greenhouse gas emissions. Carbon dioxide contributes a major portion in elevating surface temperature (Malhi*et al*., 1999; Sharma *et al*., 2010). The concentration of CO_2 is on a constant rise since 1950's. Its atmospheric amount has increased from 315 ppm to 399.89 from 1959 until 2013 (NOAA, 2013). This rapid increase is attributed to burning of fossil fuel, production of cement (67%) and shift in land use patterns (33%). Two major sinks namely marine and forest tends to take in about 60% of these emissions while the rest of the 40% is recorded as an increase that has resulted from anthropogenic activities. Forests play an important role in minimizing and stabilizing CO_2 concentrations. They are considered as natural sinks of carbon dioxide as about 60 to 70% of carbon is trapped in the form of organic material in the soil (Janssen et al., 1999). In order to reduce the adverse effects of global warming, these sinks needs to be protected and enhanced (Lal.,2005).

The rising concern of greenhouse gases have forced international community to come into an agreement in 1997 in Kyoto (also known as Kyoto Protocol). The signatory states are dedicated to reducing GHG emissions into the atmosphere. Under this framework new guidelines and strategies have been devised for effective forestry and agricultural practices and their management of carbon sequestration in all types of soils. In specific these activities are listed under the clause 3.3 & 3.4 of Kyoto Protocol by the heading entitled as "Land-use, Land-use change and Forestry" (LULUCF) (IPCC, 2000).

Under the heading of Kyoto protocol, UNFCCC categorizes forests as a major sink to absorb CO_2 from the atmosphere (Masera*et al*., 2003; Tobin &Nieuwenhusis, 2007; Sohail*et al*., 2014). After proper management of these sectors, an optimistic impact will be witnessed in sequestering carbon in soil and plants. It will ultimately lead to high organic matter content, which is good for agricultural practices, cleaner environment and biodiversity growth. These natural improvements will ultimately result in fertile land which will increase the food production and to address food security and land degradation as well. In short it is a win-win situation for both mankind and the environment.

Plant biomass, debris, fallen leaves are all carbon pools in a forest ecosystem (The IPCC 2003;Richards and Evans 2004). Over a larger time period, as forest ages, the circle of these carbon pools increases and ultimately leads to a state of dynamic equilibrium where respirational losses, degradation and decomposition equals growth. In worst cases if a forest is burned or cut down, the release of CO2 occurs alongside some additional gases of greenhouse towards the atmosphere through the processes of decomposition or (IPCC 2003; Richards and Evans 2004;Schlesinger 1997).

Understanding of global carbon cycle in terrestrial zone is vital as its circulation from soil to atmosphere is key factor in releasing CO_2 into the atmosphere (Houghton et al., 2000). An important role in carbon cycle is played by soil carbon which makes it a significant part of the global climate models. On average a total of 90% of plant carbon content is stored in tree biomass. This signifies the importance of forests and the need to evaluate the carbon contained by forest accurately (Körner, 2006).

The rapid change in lifestyle have given rise to drastic change in land use, hence becoming a prominent cause of emissions from anthropogenic activities after the combustion of fossil fuels (Canadel, 2002). The shift in land use patterns largely effects the storage forms of carbon and biomass in soil. Hence,it impacts on the fertility of the soil (Power et al., 2004).The need to protect and conserve forests have been considered under Kyoto protocol guidelines. Afforestation schemes, carbon trading mechanisms, plantations campaigns are opted on international level to increase the forest security. Afforestation scheme is believed to have the most potential towards effective carbon stock management (Ritcher et al., 1999; Silver et al.,2000). To uphold these events, sustainable and cost-efficient measures to keep a record of changes and carbon pools are required. Management of native and exotic species in a forest ecosystem is lacking in Pakistan. To aggravate the situation, plant biomass and their densities vary widely depending on climatic, topographic, land use changes and the natural calamities. Based on these calculations of soil carbon, carbon markets are largely dependent. In order to meet the requirements of these markets, reliable, accurate and financially feasible methods are needed to calculate the forest carbon pools and fluxes.

According to the secretariat of the United Nation of Climate Change, the land use change, land use and forestry are defined as "The sector of Greenhouse Gas Inventory includes removal and emissions of Greenhouse Gases causing directly from human induced activities of land use such as settlements, forestry activates, commercial uses and land use changes." LULUCF (Land use, Land use change and Forestry). This causes a significant effect on Global Carbon cycle because these activities causes increase and decrease in the quantity of carbon dioxide in the atmosphere. LULUCF can be a factor for the atmospheric concentrations of carbon dioxide and ultimatelya contributor of global climate change. There are six land use categories according to UNFCCC that includes crop land, wetlands, forest land, settlements, grass land and other land types (bare soil, rock, ice etc.).

1.1. State of forests in Pakistan

At present forests of Pakistan are suffering from large-scale deforestation and degradation. And it is continuing unprecedentedly by 0.75 percent per year. In 1992 forested land was 4.242 Mha, which declined to 3.44 million hectares in 2001. Since independence in 1947, about 61,000 ha of forest land has transformed into various different types of land use. In Indus delta, the Mangrove forests have suffered highest rate of deforestation at 2.3 percent per year, followed by coniferous forests and riverine forests at 1.99 percent and 0.23 percent respectively. On provincial basis, forest land conversion to non-forest land is highest on Punjab with conversion of 977 ha of land, Sindh with 279 ha, Baluchistan with 137 ha, KP with 100 ha and lastly lowest in AJK 6 ha.

On the contrary government statistics show an increase in forest cover by 21.1 percent from 1947 to 1994. This increase is mainly attributed by afforestation and agro-forestry projects and strict control in illegal logging.

Some studies have reported significant deforestation mainly contributed by illegal timber extraction. Former Prime Minister of Pakistan lifted the ban from timber transportation which was imposed in the early nineties. As soon as the ban was removed 2.07 million cubic of timber was transported to different parts of the country. Timber mafia also benefitted from this opportunity by chopping trees worth Rs 8 billion.

1.1.1. Temperate coniferous forests in Pakistan

These forests, dominant in Pakistan, mostly grow in northern parts of the country at an elevation between 1000 and 3500 meters above sea level. They are abundant in places like Dir, Abbottabad, Malakand, Mansehra and Swat districts of KP along the district of Rawalpindi Punjab. Major species include fir, spruce, deodar, blue pine and Chir pine. Coniferous forests as a whole cover 1.93 Mha or 40.92 percent of total forests in Pakistan. Provincial distribution of these forests is highest in KP with 1073000 ha, AJK with 407000 ha, Northern Areas with 285000 ha, Baluchistan with 116000 ha and Punjab with 49000 ha. An important role is played by them in timber provision, protection of soil and land on slopes of steep mountains, medicinal plants, and supply of fuel wood and non-wood products, livestock grazing, moreover it supports the habitat of wildlife species. Some of the coniferous forests types are

1.1.2. Himalayan moist temperate forests

These forests, with limited undergrowth, includes evergreen and deciduous species. They grow at elevations between 1500m and 3000m above sea level. Specie distribution is based on lower an duper zone these forest. Dominant species in the lower zone are Cedrusdeodara, Pinus wallichiana, Piceasmithiana and Abiespindrow (Partal) while Abiespindrow and Q. semecarpifolia are overriding in upper region.

Himalayan dry temperate forests These types of forest consist of evergreen forest including open scrub brushwood, while some of area also show presence of coniferous and broad leaved species. This kind of species are most common at North West side of the study area and extended though the length of the area. Main Species are Pinus gerardiana (Chalghoza), Quercus ilex and dry zone Deodar. Blue pine is mostly dominated at innertrak region of the forest while locally found species also exist there which are; Juniperusmacropoda (Abhal, Shupa, Shur) and some Piceasmithiana.

1.1.3. Sub-alpine forests

Sub alpine forest species like broad-leaved trees and evergreen Conifers are mostly found within lower canopy side, typically along with deciduous shrubby undergrowth of Salix (Willow, Bed) and Viburnum (Guch). Such forest types are almost found in throughout Himalayas range at range of 3350 meter above sea level. Common species of these forest types are; Abiesspectabilis and Betula utilis (Birch, Bhuj). High level pine are mostly occurred at burnt sides and landslips.

1.1.4. Alpine scrub

This category mainly includes shrub formations 1 to 2 meter high but extending up to 150 meters. These forests are characterized by Lonicera (Phut), Cotoneaster with Juniperus, Salix, Berberis (Sumbul, Sumblue) and some rare species of Ephedra (Asmania) or Rhododendron.

1.1.5. Sub-tropical broad leaved evergreen forest

These types of forests includes the xerophytic forests comprising of evergreen species having thorny and small leaves. They occur on the lower slopes and foothills of the Salt Range, Sulaiman Rnage, Himalayas and Kalachitta.The main representative species are *Acacia modesta* (Phulai) and *Olea cuspidate* (Kau) which occur as either pure or mixed. The shrub i.e. *Dodonaea* (Sanatta) is mainly dominant in areas which are degraded. An estimated area of these forests is approximately 1,191,000 ha.

1.2. Forest mapping in Pakistan

For the assessment of the potential of a country for REDD+, quantification of the historic forest cover patterns and its emissions of CO_2 needs to be done. This will give a trend of possible future emissions if deforestation prevails. The use of remote sensing is a suitable method because satellites record the earth's land cover over the past decades. This data is archived and can be analysed to explore past changes in forest cover indicating the deforestation trends. There has to be a LULUC database in place for developing temporal and spatial records and assessing its variation over the years. In Pakistan forest cover assessment has been carried out on city or district level. Space and Upper Atmosphere Research Commission (SUPARCO) has carried out studies to assess the forest resources of Pakistan. Some of their research activities include mapping land cover of Swat, exploring the pattern of irrigated plantations in Changa Manga and mapping the Mangrove forest along the coastal areas and the Indus delta. Siddiqui et al evaluated the distribution of the Riverine forests along the river Indus plains. The results indicated 1042 ha loss of Riverine forests per year with a total loss of about 21,590 ha during the study's period of 1977 to 1998. In a similar study by Habibullah et al temporal changes in Riverine forest cover of Sindh between 1979 and 2009 were identified. Land cover of study area was classified as: forests, grassland/agricultural land, dry land/land use and water. By comparing land cover maps the annual ratio of depletion of forests came out to be 9.0%, with a total loss of 85% of forest cover from 1979 to 2009. Assessing the decline of Coniferous forests in all provinces of Pakistan was done by Ahmad et al using GIS applications. Their study, which showed an overall decrease in forests, detected forest cover change from 1992 to 2010.

A study was carried out in 2005 by Ali et al, in which he compared the Landsat images from time period of 1976 and 2002 for the evaluation of forest cover change. They also tried to determine the causes of forest loss with the help of surveys, workshops and interviews with forest department, forest contractors, Basho Development Organization and the local community. According to their results the major contributing factor towards deforestation is mismanagement of forest department and illegal harvesting instead of over population.

Forest cover assessment of Ayubia National park has been carried out by Abbas et al using high resolution imagery of Quick bird. Their study was successful in classifying land cover of Ayubia National Park into the following classes: Conifer Forest (Shadowed), Built up Area, Conifer Forest, Bare rocks/Soil and Mix forest grasses.

The area covered by Coniferous forest, as calculated in this particular study, came out to be 2100 ha.

Rizwan et al by using GIS techniques and Landsat Enhanced Thematic Mapper (ETM) extracted the forest cover of Toba Tek Singh, district of Punjab. Comparison made between the official forest area allotted to forest departments and the actual area covered by forests showed that the actual forest area (2140 ha) is less than the allotted area (5896 ha). Abbas et al assessed the distribution of mangrove forests along Makran coast of the Baluchistan Province and the entire Indus Delta within the Sindh Province. The study used images of ALOS-AVNIR-2, with a resolution of 10 m, for the year 2009. Multi-scale Object Based Image Analysis showed that mangrove cover spread to an area of 98,128 ha in Pakistan. Land cover maps developed had the following classes: dense mangrove, medium mangrove, sparse mangrove, algae, saltbush/ grasses, mudflats and water.

On small scale,the forest departments of respective provinces devised an appropriate work flows and strategies according to the type of forest, agricultural land and maintain forest inventories for research purposes. Despite all these efforts there are still gaps that needs to be bridged in order to have proper knowledge of carbon stocks in available forests.

1.3. Study Area

Lehtrar is located in the district Rawalpindi, Punjab, Pakistan, between latitude of 33" 42' 17 N or 33° 42' 00" and longitude of 26' 21 E or 73° 25' 59.87"(Pakistan Page-LehtrarBala, 2016; Geoview.info-LehtrarBala, 2017). While, the area under study i.e compartment 47 is positioned between a latitude of 33" 40' 13.88 N or 33°40' 00" while a longitude of 73" 21' 57.00 E or 73°21'00" having an elevation of 690 meter above sea level and contains a forest area of 497 acres. The climate of the area under discussion is quite mild with cold winters and mild summers.

The main tree species of the study area are*Acacia modesta* (phulai), Olea ferrugineae (Kahu), while the rare species being *PrinsepiaUtilis (Garanda)* and the most prominent shrub specie being *DeudonaeVisica* (Sanatha) (Sheikh, 1993).

Figure 1: Shape file of study area

1.4. Aims and objectives:

Objectives of the present study are as follows:

- Assessment of soil organic carbon in different land uses of scrub forest.
- Spatial and temporal analysis of study area

Chapter 2

2. LITERATURE REVIEW:

2.1. Climate Change

Pakistan's land is mostly comprised arid *and* semi-arid areas. The rivers are fed by the Himalayan glaciers, which are projected to be resending (CICERO, 2000-02). In past few years, extreme weather has been observed in Pakistan in over 78 years with the hottest day observed on 9^{th} June 2007 (CICERO, 2000-02). The country experiences higher risks of variability in extreme condition like 10 large floods, extended droughts and monsoon rains.By 2020, an increase of 0.9°C in temperature is expected whereas by 2050, an increase to 1.8°C is likely to be expected in Pakistan. The precipitation scenarios includes: (I) An increase of 20 cm by 2020, (II) An increase of 30 cm by 2050. An inundation of 0.2% area of Pakistan could occur due to a rise of 20 cm in sea level (CICERO, 2000-02).

LSE, 2002 suggested that less certainty is observed related to the relationship between occurrence of natural disasters and climate change. However there is an agreement that global warming will result in more intense floods and droughts. IPCC (2007) in Fourth Assessment Report found that intensity of events and its frequency such as droughts, floods and storms will increase because of climate changes. Currently, there is a significant evidence there exists close association between extreme climate events and climate change.An example of extreme climate events of high frequency has been observed since 1990's, showing recordings of highest temperature during the same period. This climatic variability will have major implications for water.

2.2. Forests

UNFCCC defines **Forests**as "A 0.05-1.0 ha of minimum area of land with more than 10-30% of tree crown cover (or equivalent stocking level) and tree potential to reach 2-5 m minimum height at maturity in situ". A forest may consists of closed forest formation which is identified as trees of various storey and under growth covering a high proportion of open or ground forest. Young natural stands and all plantations which have yet to reach a crown density of 10-30% or tree height of 2-5 m are included under forest, as are areas normally forming part of forest area which are temporarily un-stocked as a result of human interventions such as harvesting or natural causes but which are expected to revert to forest.

2.2.1. Forest Types of Pakistan

Pakistan has a deficiency of forest with approximately 4.6 million ha land of forests and forest plantation amount equivalent to 5.23% of the total land area (PFI, 2011). The distribution of forest vegetation is primarily governed by climatic and edaphically factors and is reflected in the diversity of forest types. Arid and semi-arid climate over more than 80% area is the major cause of low forest cover in Pakistan.

2.2.2. Climato-Silvicultural Classification of Forests

According to Sheikh M.I. the forests in Pakistan can be classified into following types on the basis of latitude, precipitation and vegetation types:

1. Swamp and Littoral Forest
2. Tropical Thorn Forest
3. Subtropical Pine Forest
4. Himalayan Dry Temperate Forest
5. Alpine Scrub Forest
6. Sub Alpine Forest
7. Himalayan Moist Temperate Forest
8. Subtropical Broad leaved Evergreen Forest
9. Tropical Dry Deciduous Forest

2.2.3. **Legal Classification of Forests**

Bajwa and Bukhari (2012) stated that forests in Pakistan can be classified on legal basis into 8 categories:

1. State Forests
2. Reserved Forest
3. Protected Forest
4. Un-classed Forests
5. Chaos Act Areas
6. Resume Lands
7. Guzara and Community Forests
8. Section 38 Areas

2.3. Forests and Climate Change

Davis and Botkin (1985) assesses that to bring a change in distribution and composition of tree species, a change as small as 1°C in mean annual temperature over a persistent time period is sufficient. Under a supposed doubling of atmospheric CO_2 concentration(a 2 * CO_2 climate), current global models estimate that a substantial fraction of prevailing forests will experience some new climatic conditions unlike their current conditions leading to the production of new types of vegetation.

2.4. **Soil carbon:**

According to study done by Sajjad and his colleagues in 2016 their results show that by observing the carbon pools of different types, upper story vegetation biomass stored maximum carbon whereas the under story vegetation biomass stored minimum carbon stock. Adnan and his friends in 2015 found in a study that perceived the storing of maximum amount of carbon in forest vegetation and soil followed by Rangeland. Conversion of forest land range land to agriculture land not only leads to loss of 56% due to forest land conversion and 37% due to range land conversion of soil carbon but also loss of valuable carbon sink.

Difference in SOC stocks were determined in part by rainfall, but more importantly by sand content. Managing soil erosion is the key strategy for reducing SOC loss.Vagen ., (2013). Soil organic carbon was significantly correlated with mean annual precipitation. No significant correlation with mean annual temperature. The results indicated considerable under stocking of trees, SOC depletion and a potential for sequestration of carbon (Alam ., (2013).

Ph decreased significantly by increase in age of rehabilitated forest regardless of depth. Soil organic matter and total carbon content increased with age. Forest rehabilitation by planting indigenous tree species at initial ages has shown signs of carbon sink. Ch’ng et al., (2013)

According to a study done by Nizami and his colleagues in 2009, results show that significant variation in means of carbon stocks in two forest sites.

Chapter 3

3. MATERIALS AND METHODS

The study area was stratified in different land uses i.e intact forest, forest land converted to agriculture land, forest land converted to grass land and intact forest converted to degraded forest as described in figure 2.

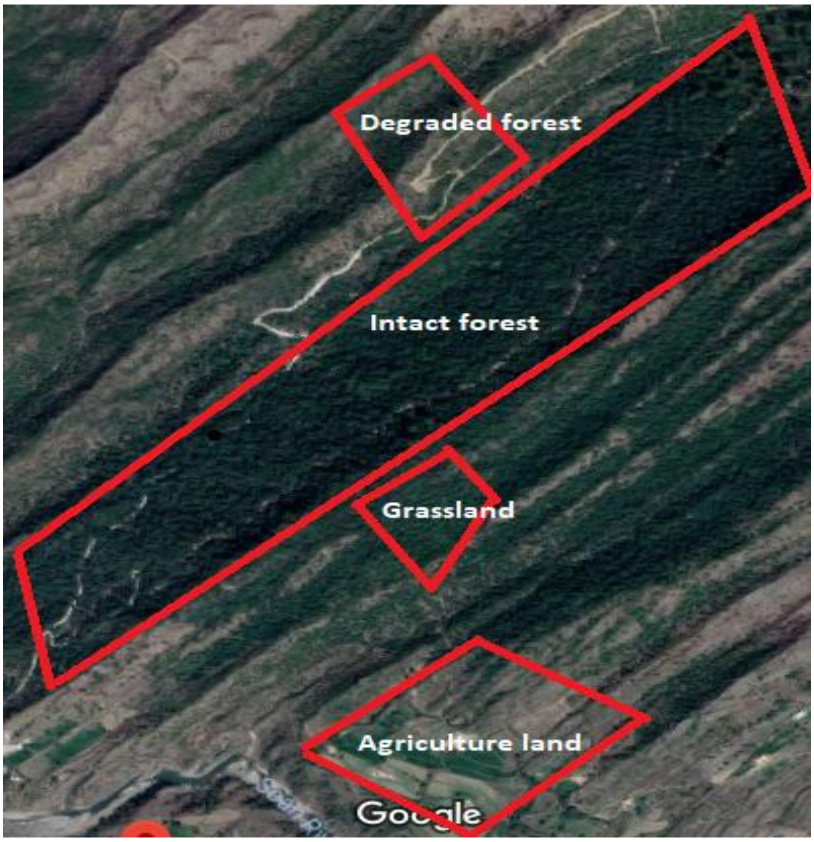

Figure 2: Stratified map of study area with different land uses identification

3.1. Field Enumeration:

A total of 10 nested co-centric plots of 17.84 m^2 each were laid out in the forest having two subplots. A small number of plots were taken keeping in view the very limited scope, time and budget constraint of the present project. Factors like tree diameter (cm) at breast height, tree height (m), geographical coordinates, slope, elevation and total stem density of every sampling plot were recorded. Tree height was measured using the instrument called Abney's level. Tree diameter was measured using dia tape. Basal area of tree in each sampling site was calculated as:

$$\textbf{Basal area} = (\prod/4 \times d^2)$$

Tree volume in each sampling site was calculated by multiplying the basal area with the height and form factor of the tree as:

$$V(m^3) = (\prod/4 \times d^2) \times h \times f \text{ (Phillips, 1994).}$$

Where,

V= Stem Volume,

h = Height of trees in meters,

d^2 = Square of DBH and

f = Form factor

Total stem biomass was obtained by multiplying the calculated volume (m^3/ha) with the specific wood density of each tree species. Specific density of wood for each specie of tree was obtained from different literature.

Stem Biomass = **SV x WD** (Nizami, 2012).

The resultant value was multiplied with the biomass expansion factor of each specie as devised from available literature (Haripriya, 2000). In order to calculate the biomass of shrubs, litter sub-plots of 5.64m^2 and 1 m^2 were laid out respectively. The vegetation and litter from these plots was harvested, freshly weighed, put in labelled bags and sent to the laboratory for dry weight examination.

3.1.1. Total Average Carbon Stock Measurement

It is generally considered that about half of the dry biomass consists of carbon. Thus the dry biomass can be converted to carbon stock by multiplying it with 0.47. In the current study the carbon stock was calculated by assuming that the carbon content is 47 % of total biomass, as described by IPCC (IPCC, 2003).

Total Carbon Stocks (tons/ha) = **Biomass** (tons/ha) **x0.47**

Below ground carbon was estimated by multiplying the above ground carbon with 0.25. As it is estimated that below ground carbon is about 25% of above ground carbon.

Below Ground Carbon Stocks (tons/ha) = **Aboveground Carbon Stocks** (tons/ha) **x 0.25**

3.1.2. Soil Carbon Stocks

Ten soil samples were collected at 30 cm depths using augar from each inventory plot, while 2 each from different land uses of forest i.e. degraded forest, forest land converted to cropland and forest land converted into grassland. In the field, weight (gm) of each soil sample was taken and they were placed in labelled bags and then brought to the laboratory for further analysis. Bulk density (g/cm^3) of each soil sample was calculated. Walkley-Black titration method was used for determination of soil carbon. The following formula was used to determine the soil carbon in t/ha (Persion et al., 2008).

[Soil carbon ($t\ ha^{-1}$) = Soil Bulk density (gm/cm^3) × SOC (%) × Thickness of horizon (cm) × 100]

3.1.3. Calculation of Total Carbon Stock

The total carbon stocks in scrub forest ecosystem (t/ha) in compartment no 47 of Lehtrar forest sub-division was calculated by adding total carbon stocks present in upper layer vegetation, below layer vegetation and carbon stored in soil.

3.2. Land Use and Land Use Change Assessment

To determine the Land Use/Land cover change, images of different temporal resolution of year 1998, 2007 and 2017 were downloaded from earthexplporer.usgs.gov/ of landsat 5, landsat 7 and landsat 8 respectively. The spatial resolution of these images is 30m. Bands of landsat image were stacked and then study area was clipped. Later supervised classification was done using ArcMap 10.3.1. Three classes were made i.e. forest land, water and other land. The class other land includes barren land, built up areas and roads.

Chapter 4

4. RESULTS

4.1. Growing Stock

The dominant tree species of scrub forest in Lehtrar areaare *Acacia modesta* (Phulai) and *Olea ferruginia* (Kahu). Basal area (m^2/ha), Tree height (m) and stem volume (m^2/ha) for every tree species were determined.

The mean height of *Acacia modesta* was found 7.45 m. The average stem volume recorded of *Acacia modesta* was 2863.05 m^3. Mean height and stem volume of *Olea ferruginia*was 7.46 m and 2582.57 m^3, respectively. To study the relationship between tree heights and stem diameter, various regression models for stem volume and basal area were developed.

Estimates of biomass of a forest sample arenot measured directly. Instead, estimates for individual trees were made and these were later added to give an estimate of total stand (Zianis*et al.,* 2005). The easiest way to calculate above-ground biomass at the single tree level is to use allometric equations.

4.1.1. Above Ground Carbon

The stem biomass in all tree species were calculated using volume (m3/ha) and basic wood density (kg/m3) of all particular tree species. The maximum average stem biomass was recorded in *Acacia modesta* (Phulai): 4794.688 kg in plot 2, however the minimum average biomass was recorded in *Olea ferruginia* (Kahu) : 1493.13 in plot 9.

Table 1 shows the plot wise specie specification of *Acacia modesta*. The highest number of trees of *acacia modesta* was present in plot no 8 and was 39, and minimum were present in plot no 2 and were 15. The highest average height was in plot 2 and that was 8.13 m. the highest avg diameter was 101.26 cm. The lowest Biomass was calculated in plot no 7 and that was 1824.8 kg, however the highest biomass was calculated in plot no 2 and that was 4794.7 Kg.

Table 1: Plot wise No. of trees, Avg Dia (cm), Avg Height (m), Avg. Basal ara(m^2/ha), and Avg. Volume (m3) of *Accaciamodesta*

Plot No.	No. of trees	Avg.dia (cm)	Average Height (m)	Average Basal Area (m^2/ha)	Average Volume (m^3)	Biomass (kg)
1	36	79.59	7.37	5849.50	3224.24	3095.3
2	15	101.26	8.13	8729.18	4994.47	4794.7
3	29	76.99	7.37	5266.21	2811.55	2699.1
4	23	78.30	7.33	5149.72	2728.73	2619.6
5	33	78.05	7.51	5562.06	3116.44	3991.8
6	37	75.65	7.50	4944.87	2683.22	2576.0
7	23	66.26	7.24	3696.65	1900.80	1824.8
8	39	71.84	7.43	4338.98	2286.37	2195.0
9	27	77.61	7.46	5206.12	2791.27	2679.6
10	38	66.37	7.13	3964.31	2093.46	2009.7

Table 2 shows the plot wise specie specification of *Olea ferruginea*. The highest number of trees of *Olea ferruginea* was present in plot no 2 and was 22 and minimum were present in plot no 9 and were 10. The highest average height was in plot 6 and that was 8.21 m. the highest avg diameter was 81.9 cm. The lowest Biomass was calculated in plot no 9 and that was 1493.1 kg, however the highest biomass was calculated in plot no 6 and that was 3976.8 Kg.

Table 2: Plot wise No. of trees, Avg Dia (cm), Avg Height (m), Avg. Basal ara(m^2/ha), and Avg. Volume (m3) of *Olea ferruginia*

Plot No.	No. of trees	Avgdia (cm)	Avg Height (m)	Avg basal area	Avg. Volume (m3)	Biomass (kg)
1	17	68.58	7.28	4917.04	3223.72	3626.7
2	22	68.70	7.54	4613.53	2934.88	3301.7
3	11	63.96	7.23	3736.22	2075.24	2334.7
4	11	75.74	7.65	5123.44	2916.02	3280.5
5	13	81.87	7.74	5879.11	3369.37	3790.5
6	12	80.22	8.21	5648.19	3534.97	3976.8
7	13	68.58	7.46	3765.27	1935.69	2177.7
8	18	76.06	7.88	4760.92	2620.14	2947.7
9	10	58.42	6.77	2776.36	1327.22	1493.1
10	17	56.78	6.74	2829.57	1445.55	1626.2

4.1.2. Below Ground Carbon

The highest below ground carbon was recorded as 20.337 tonnes in plot 1 however the minimum value for below ground carbon was 8.26tonnes recorded in plot 7.

4.2. Soil Carbon

The mean of soil carbon stock was estimated from the relation of depth of horizon, soil bulk density (gm/cm^3) and total organic carbon (%) as described in section 3.1.2. The minimum soil carbon stock was recorded in the land use of scrub forest which was converted from forest land to agriculture land and it was 3.78 t/ha, however the maximum soil carbon stock was calculated in the plot 1 of intact forest and it was 12.318 t/ha. The average soil carbon stock of 10 plots of intact forest was 10.13 t/ha, however average soil carbon stock of the grass land which was converted from forest land was 5.11 t/ha and of agriculture land which is converted from forest was 4.65 t/ha. The average soil carbon stock of the land use which is degradedforest was 8.71 t/ha. P-value obtained was less than 0.05 illustrates that there is significant difference between the soil carbon stocks present in different land uses of scrub forest in Lehtrar area.

Figure 2 shows the graphical presentation of soil organic carbon of different land uses of scrub forest. The graphs illustrate that minimum soil organic carbon was found in the land use which was converted from forest land to the agriculture land. Main reason for this decrease in amount of soil organic carbon in agriculture land is due to the absence of humus layer in the agriculture land which is made up of organic material and also the continuous usage of land could have been the reason of less amount of soil organic carbon in the agriculture land. In these graphs, the blue color shows the land use of intact forest, grey color shows the land use of grassland converted from forest land however yellow and brown color shows the land use agriculture land and degraded forest converted from forest respectively.

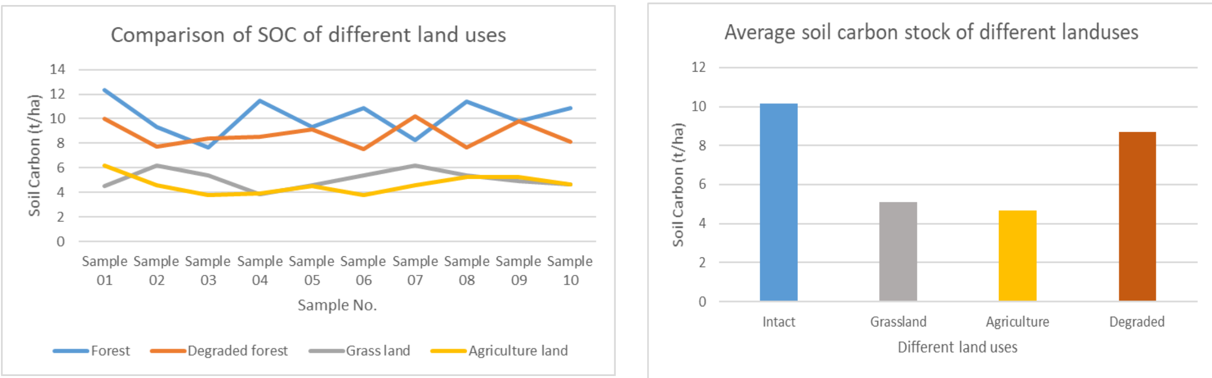

Figure 1: Comparison of soil carbon stocks of different land uses

Sample No.	Intact forest	Degraded forest	Agriculture land	Grass land
1	12.32	10.01	6.16	4.54
2	9.31	7.71	4.62	6.19
3	7.65	8.42	3.79	5.39
4	11.50	8.52	3.91	3.84
5	9.30	9.10	4.50	4.62
6	10.84	7.54	3.78	5.39
7	8.29	10.21	4.61	6.22
8	11.40	7.66	5.29	5.39
9	9.81	9.81	5.23	4.92
10	10.89	8.14	4.64	4.63
Average	**10.13**	**8.71**	**4.65**	**5.11**

Table 3: Soil carbon (t/ha) in different land uses of scrub forest in Lehtrar, Rawalpindi

Table 3 explains about the soil organic carbon in ton per hectare in different land uses of scrub forest in the study area. Different land uses which were studied are intact forest, degraded forest, land use converted to agriculture land from forest land and land use converted from forest land to grass land.

4.3. Determination of Total Carbon Stock

By adding the carbon existing in respective carbon pools, the total carbon stock was calculated. For the present study, the carbon stock was calculated in aboveground, soil and below ground. The minimum Carbon Stock was recorded as 7.699 t/ha in soil and maximum carbon stock was recorded as 81.349 t/ha in above ground carbon. Total carbon stocks present in our study site is about 818.85 t/ha.

To study the relationship between basal area and stem biomass, regression models were developed for all tree species.

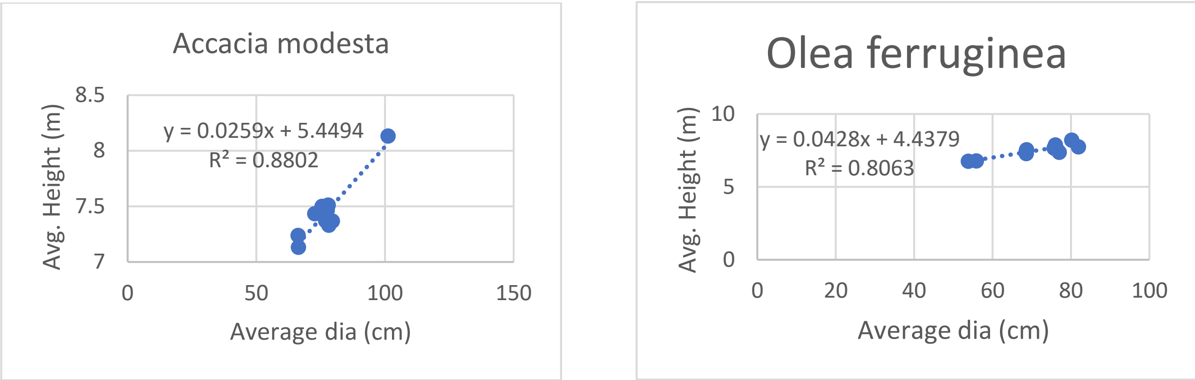

Figure 3: Relationship between average diameter and height of *Accaciamodesta* and *Olea ferruginea*

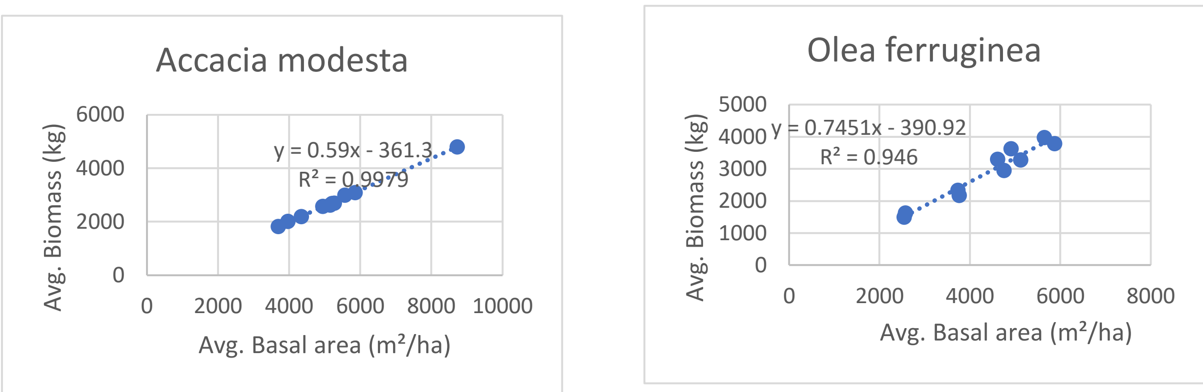

Figure 4: Relationship between average basal area and average biomass of *Accaciamodesta* and *Olea ferruginea*

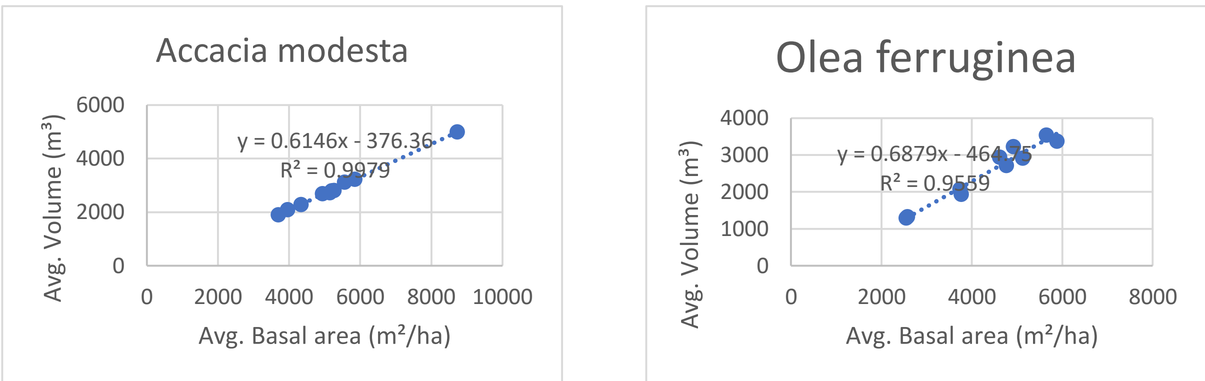

Figure 5: Relationship between average basal area and average volume of *Accacia modesta* and *Olea ferruginea*

4.4. Land Use and Land Use Change

Supervised classification was performed on the images of Landsat 5, Landsat 7 and Landsat 8 of the years 1998, 2007 and 2017 respectively. The minimum vegetation was 33 % in the year 2017, however the maximum forest cover was in year 2007. The other land class increased from 57 % to 64 % from year 2007 to year 2017.

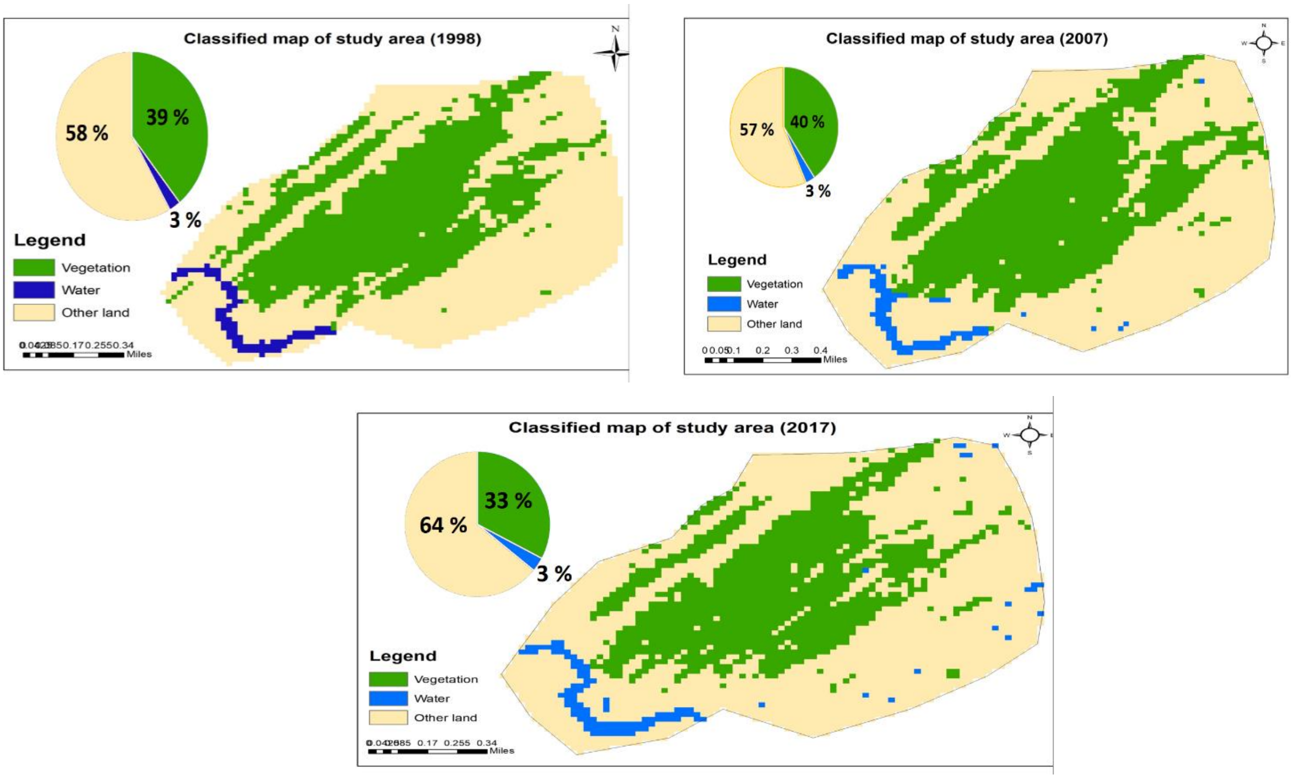

Figure 6: Classified maps of study area of years 1998, 2007 and 2017

4.5. Conclusions:

The vital carbon pool present in the forest is the soil organic carbon. The results showed that there is a significant difference between the soil carbon stocks of different land uses of scrub forest in Lehtrar area, which are; Intact forest, degraded forest, Grass land converted from forest land and Agriculture land converted from forest land. P-value obtained from ANOVA test was less than 0.05 which means there is significant difference among different land uses mentioned above. The soil organic carbon stocks were less in the land uses other than the intact forest which is because of lack of trees. No humus will be accumulated due to the absence of leaves shed by trees, thus decrease in level of carbon stocks ashumus is main source of soil organic carbon is expected. The highest carbon stock was calculated in above ground biomass i.e 81.349 t/ha however the minimum was recorded in soil i.e 7.699 t/ha.

The results of classified maps of study area show decrease in forest area and increase in other land. This may be attributed to increased population, more demand of fuelwood, increased urbanization, and lack of natural gas in the area, poverty and lack of awareness towards the importance of forest.

Chapter 5

5. RECOMMENDATIONS

- Policy makers and decision makers must take in account the soil carbon while making decisions about forest management.
- More trees must be grown as soil carbon stocks are more in the soil under forest area than other land uses.
- Soil carbon must be studied in future research.
- The conversion of forest area in other land uses should be minimized and discouraged.
- Other forest types should also be studied.
- This research should be extended on larger scale.
- Natural gas could be an alternative of fuelwood, should be provided to minimize the use of fuelwood.
- Awareness campaigns must be launched about the importance of forest.
- More employment options should be provided to reduce the dependence on forest.
- Heavy fines must be imposed on the offenders for illicit felling.

Chapter 6

5. Refrences:

Sajjad Saeed, M. Irfan Ashraf, Adnan Ahmad and Ziaur Rahman. The bela forest ecosystem of district Jehlum, A potential carbon sink. *Pak. J. Bot*. **2016**, 48(1): 121-129, DOI.

ADNAN, A. and S.M. NIZAMI. Carbon stocks of different land uses in the Kumrat valley, Hindu Kush region of Pakistan. J. Forestry Research **2015**, 26(1): 57-64

ADNAN, A., S.N. MIRZA and S.M. NIZAMI. Assessment of biomass and carbon stocks in coniferous forest of Dir Kohistan, KPK. Pak. J. Agric. Sci. **2014**, 51(2): 35-350.

Douglas W. Pribyl. A critical review of the conventional SOC to SOM conversion factor. Geoderma. **2010**, 156 (2010) 75–83.

Syed Moazzam Nizami, Sarwat N. Mirza, Stephen Livesley, Stefan Arndt, Julian C. Fox, Irshad A.Khan, Tariq Mehmood. Estimating carbon stocks in sub-tropical pine (*Pinus roxburghii*) Forests of Pakistan. Pak. J. Agri. Sci., **2009**, Vol. 46(4).

Chhabara, A., S. Palriab and V.K. Dadhwala. Growing stock-based forest biomass estimate for India. *Biomass andBioenergy*, **2002**, 22: 187-194.

Gairola, S., C.M. Sharma, S.K. Ghildiyal and S. Sarvesh. Live tree biomass and carbon variation along altitudinal gradient in moist temperate valley slopes of Garhwal Himalaya India. *Curr. Sci*. **2016**, 100: 1862-1870.

Haripriya, G.S. Estimates of biomass in Indian forests. *Biomass and Bioenergy **2000***, 19: 245-258.

Nizami, S.M. The inventory of the carbon stocks in sub tropical forest of Pakistan for reporting under Kyoto Protocol. *J. For. Res*. **2012**, 23(2): 377-384.

Pearson, T R., S.L Brown and R.A. Birdsey. Measurement guidelines for the sequestration of forest carbon, general technical report, USAD forest service **2008**.

Philip, M.S. Measuring trees and forests, 2nd edn. CAB. International, Wallingford **1994**.

Walkley, A. and J.B. Black. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic titration method. *Soil Sci*. **1934**, 37: 29-38.

Lal, R. 2004. Soil carbon sequestration to mitigate climate change. Geoderma., 123(1–2):1–22.

Smith, P. 2004. Carbon sequestration in croplands: the potential in Europe and the global context. Eur. J. Agron., 20(3):229–236.

Mooney, H., J. Roy and B. Saugier. 2001. Terrestrial Global Productivity: Past, Present and Future. Academic Press, San Diego.

NOAA. 2010. Atmospheric CO2 Mauna Loa Observatory (Scripps / NOAA / ESRL).Monthly& Annual Mean CO2 Concentrations (ppm). Washington, DC (http://co2now.org).

White, A., M. G. R. Cannell and A. D. Friend. 2000. The high-latitude terrestrial carbon sink: a model analysis. Global Change Biology., 6(2): 227–245.

IPCC. 2001b. International Panel on Climate Change: Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. J. T. Houghton, Y. Ding, D. J. Griggs, M. Noguer, P. J. van der Linden, X. Dai, K. Maskell and C. A. Johnson Eds. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA,, Cambridge, UK.

Schlesinger, W. H. 1997. Biogeochemistry: An Analysis of Global Change (Second Edition). Academic Press, San Diego, California.