KRIGING-BASED ESTIMATION OF THE CHANGE IN SOIL CARBON STOCK IN THE KARASU COASTAL BLACK SEA REGION OF TURKEY

MEHMET ALİ KÜÇÜKER

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By

MEHMET ALİ KÜÇÜKER

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ABSTRACT

KRIGING-BASED ESTIMATION OF THE CHANGE IN SOIL CARBON STOCK IN THE KARASU COASTAL BLACK SEA REGION OF TURKEY

In this study the effects of deforestation and land-use changes in Karasu Forests located within the provincial borders of Sakarya on elemental carbon and carbon stock were analyzed. The specific goals of this study are 1) to predict and map soil carbon stocks as a function of depth from the ground surface up to 1 m depth for the Karasu region using a weighted ordinary kriging approach that takes into account the land use spatial distribution; 2) to evaluate the impact of the land use pattern in the study area (primarily forested and deforested areas) on soil carbon stock; 3) to reveal the relationship between the soil carbon stock and soil parameters in the study area. For this purpose, 360 soil samples were collected over the Spring and Fall 2009 seasons from a total of 45 different locations covering the entire study area (21 points within the forest areas, 24 points within defrosted areas). At each location, undisturbed soil samples were taken from depths of 0-5, 5-20, 20-45 and 45-100 cm. The carbon content of the soil samples were analyzed in the laboratory by dry combustion using an automatic CHNS analyzer. The spatial distribution of the soil carbon stocks from the surface to a depth of 1 m was estimated using profile depth distribution functions and a modified ordinary kriging procedure that honors the observed C stock data, their statistical spatial structure as well as the land use pattern at each location. As a result of geostatistical analysis, spatial average values of carbon stocks were 9.96 kg/m^2 in spring 2009 and 10.84 kg/m^2 in fall 2009. It was observed that the impact of deforestation on carbon content within the study area during the last two decades was limited to the upper most 0-5 cm layers. However, deforestation did not caused a significant change in the amount of total carbon sequestered in soil up to a depth of 1 m.

Key Words: Land Use Change, Soil Carbon Stock, Geographic Information System (GIS), Geostatistical Analysis

ÖZET

KARADENİZ BÖLGESİ KARASU KIYILARINDA TOPRAK KARBON STOK DEĞİŞİMİNİN KRİGİNG METODUNA DAYALI TAYİNİ

Bu projede Sakarya İl sınırları içerisinde yer alan ve Karasu Ormanları’nda görülen arazi kullanım değişikliklerinin ormansızlaştırma başlığı altında elemental karbon ve karbon stoku üzerine olan etkileri araştırılmıştır. Bu çalışmanın başlıca amaçları, 1) toprak yüzeyinden 1 m derinliğe kadar olan kısımda “Ordinary Kriging” metodu kullanılarak Karasu Bölgesi için karbon stok miktarı tayini ve harita çizimi yapılmasıdır; 2) Karasu Bölgesi’ndeki arazi kullanım değişiminin karbon stok miktarı üzerindeki etkileri incelenmesidir; 3) çalışma alanında toprak karbon stoku ile diğer toprak parametreleri arasındaki ilişkinin araştırılmasıdır. Bu amaçlar doğrultusunda, İki farklı sezonda (ilkbahar ve sonbahar 2009), 45 örnekleme noktasından, 4 farklı derinlikten (0-5, 5-20, 20-45, 45-100 cm) toplamda 360 adet toprak örneklemesi yapılmıştır. Araziden alınan toprak örneklerinin analizleri sonucunda toplam karbon yüzdesi ve kuru hacim ağırlığı belirlenmiştir. Elde edilen numunelerde elemental karbon ve kuru hacim ağırlığı analizleri gerçekleştirilmiştir. Topraktaki karbon miktarı kuru yakma prensibine dayanan otomatik CHNS cihazı kullanılarak gerçekleştirilmiştir. Dört farklı derinlikten alınan örneklerin verilerine göre yüzeyden 1 m derinliğe kadar olan her bir örnekleme noktasının toplam karbon stoku hesaplanmış ve bu hesaplamaya göre kriging yöntemi kullanılarak çalışma alanın karbon stok haritası yapılmıştır. Jeoistatistik analiz sonucunda karbon stok uzaysal ortalama değerleri ilkbahar 2009’da 9,96 kg/m^2 sonbahar 2009’da 10,84 kg/m^2 olarak bulunmuştur. Çalışma alanında son 20 yılda gerçekleşen ormansızlaştırılmanın toprağın derinliklerindeki karbon miktarını etkilemediği gözlenmiş böylece ormansızlaştırılmanın toprakta tutulan toplam karbon miktarının da anlamlı bir değişikliğe neden olmadığı saptanmıştır.

Anahtar Kelimeler: Arazi Kulanım Değişimi, Karbon Stok, Elemental Karbon, Coğrafi Bilgiler Sistemi (CBS), Jeoistatistik Analiz

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LIST OF SYMBOLS/ABBREVIATIONS

Symbol	Explanation	Units Used
a	Intercept	
AN	Analysis	
ASTM	American Standard Technical Methods	
b	Slope or regression coefficient	
C	Carbon	
C	Mean content of carbon of the ith horizon	
C_s	Carbon stock of each profile	
$C_{s,i}(x, y)$	Carbon stock at location (x,y) for horizon i	
^0C	Celcius	
CEC	Cation exchange capacity	
CL	Clay loam	
C:N	C:N ratio	**%**
Ca^{2+}	Calcium	
CH_4	Methane	
CO	Carbon Monoxide	
CO_2	Carbon Dioxide	
e	Error term	
E	East	
EC	Electrical conductivity	µS/cm
ETM	Enhanced Thematic Mapper	
FRA	Forest Resources Assessment	
G	Granite parent materials	
GCP	Ground control points	
GHG	Green House Gases	
GIS	Geographic Information System	
GP	Grazed mixed-grass prairie	

GPP	Gross per production	
$K_2Cr_2O_7$	Potassium chromate	
LUCC	Land Use Change Cover	
MBC	Microbial Biomass Carbon	
Mg^{2+}	Magnesium	
MSS	Multispectral Sensor	
MTC	Million tonnes carbon	
n	Number of scatter points in the set	
N	Nitrogen	
N(h)	Number of experimental pairs separated by the lag distance h	
NaCl	Sodium chloride	
NaOH	Sodium hydroxide	
NGP	Non-grazed mixed-grass prairie	
NH_3	Ammonia	
NH_4^+	Ammonium	
NO_3^-	Nitrate	
NOAA	National Oceanic and Atmospheric Administration	
NO_x	Nitrogen Oxides	
NR	Non-Reactive carbon atoms	
N_2O	Nitrous Oxide	
P	Phosphorus	
Pg	Petagram	
pH	Soil pH	
PPM	Part per million	
PPMV	Parts per million by volume	
Q	Quaternary	
(qCO_2)	Metabolic quotient	
R	Root-to-shoot	
RM	Stone percent	**%**
REF	Reference	

SIR-C	Supervised classification
SL	Sandy Loam
SOM	Soil organic matter
SO_2	Sulfur Dioxide
STP	Standard Temperature and Pressue
S_X	Standart deviations for X
S_Y	Standart deviations for Y
T	Tertiary
tC ha	Tonnes carbon hectares
TM	Thematic Mapper
UCCP	Uncut Clear Cut Pines
USDA	United States Department of Agriculture
W_i	Weights assigned to each scatter point
X	Independent variable (or covariate)
Y	Dependent variable
Z_i	Depth of the i^{th} horizon
ϵ	Sm of all the coefficients
μ	Overall mean of Y
ρ_b	Mean bulk density of the i^{th} horizon (kg/m^3)
$\gamma(h)$	Estimated value of the semivariance for lag h

1. INTRODUCTION

Soil quality, food production and mitigating the net rate of greenhouse gas emission depend on several parameters; one of the most important parameters is soil carbon (Bruce et al., 1998; Post and Kwon, 2000). Forests are the most significant component of terrestrial carbon, containing 77% of all carbon stored in vegetation and storing roughly twice as much as the atmosphere (Mantlana et al., 2009). Forests also remove carbon dioxide (CO_2) from the atmosphere and store it in the organic matter of soil and trees. The current carbon stock in tree biomass comprises half of the atmospheric storage and is continuing to grow despite deforestation, albeit at a decreasing rate. The amount of carbon stored in a forest stand depends on its age and productivity. Destroying the world’s forests, mainly for agricultural purposes, releases large amounts of carbon to atmosphere (up to 2×10^{15} g/yr), much of which arises from cultivation which causes an accelerated decomposition of soil organic matter (Han et al., 2009). Owing to the slow soil organic matter turnover rates, as compared to aboveground vegetation, soil carbon levels do not react as quickly to changes in land use. Therefore, soil carbon levels measured through time can establish the long-term productivity and possible sustainability of that land use system. The Intergovernmental Panel on Climate Change’s (IPCC) default assumption is that the mineral soil carbon pool reaches a steady-state 20 years after any land use change involving substantial change in soil carbon, and/or in litter inputs to the soil carbon pool (IPCC, 2007).

The dynamics of terrestrial ecosystems depend on interactions between a numbers of biogeochemical cycles: the carbon cycle, nutrient cycles, and the hydrological cycle. All of these can be modified by human actions. Carbon is retained in live biomass in terrestrial ecological systems. Such systems include decomposing organic matter and soil and these play an important role in the global carbon cycle. Carbon is naturally exchanged between these systems and the atmosphere through photosynthesis, respiration, decomposition, and combustion. Human activities such as land use, land-use change, and forestry as well as others, alter the amount of carbon stocks in these pools and also the exchanges between these and the atmosphere. Substantial amounts of carbon have been released from forest clearing at high and middle latitudes over the last several centuries and in the tropics during the later part of the 20th century (IPCC, 2000).

Land use change is an important measure for carbon storage (Lou and Zhou, 2006). It is responsible for emitting large carbon fluxes in and out of the terrestrial biosphere and can be described as the total of arrangements, activities, and inputs undertaken in a certain land cover type (a set of human actions). According to the 2000 IPCC Report, land-use change is the main reason for the emission of 136 Gt of carbon between 1850 and 1998. This resulted in an increase in the atmospheric carbon dioxide to 176 Gt C. Soils have historically played the roles of both source and sinks of carbon associated with changes in land management including forest management (Schlesinger, 1997).

As a result of international negotiations surrounding implementation of the Kyoto Protocol, many countries are beginning to develop methods to quantify both current and future carbon stocks. While defining system for forestry activities are well developed, techniques to quantify current and future C stock in soils at large scales are poorly developed. Soils are particularly important, as they are the largest reservoir of carbon in the terrestrial biosphere.

This research work is part of broader project titled Land use change from forestry to agriculture in Karasu, Turkey: Impact on soil carbon and in situ respiration. This is project is part of the COST Action 639 “Greenhouse-gas budget of soils under changing climate and land use”. The specific purpose of the current study is assess the effects of conversion of forest lands to agriculture and the changes to the carbon stock of the soil due to deforestation.

In a recent study that focused on the Karasu region, Oral (2010) examined the impact of land use change from forest to agricultural lands on soil respiration. Specifically the study investigated the differentiation of various field parameters between forest and agricultural lands, evaluated the seasonal variations on *in situ* soil respiration in the study area for the two different land uses. However, no studies have been conducted in Turkey to quantify soil carbon stock variability at different depth intervals using geostatistics. Hence, the objectives of this study are; 1) to predict and map soil carbon stocks as a function of depth from the ground surface up to 1 m depth for the Karasu region using weighted ordinary kriging approach that takes into account the land use spatial distribution; 2) to evaluate the impact of the land use pattern in the study area (primarily forested and deforested areas) on soil carbon stock; 3) to reveal the relationship between the soil carbon content and soil parameters in the study area.

In Chapter 2, a detailed literature review is provided on the carbon cycle and its relationship with climate change, land use change studies, soil carbon stock and measurement methods. The materials and methods used for in-situ field measurements, laboratory experiments and satellite image techniques employed in the study are described in Chapter 3. The geostatistical approach used to estimate the carbon stocks are also described in Chapter 3. Chapter 4 presents the statistical and geostatistical evaluation of the results and discussion and Chapter 5 concludes with a brief summary and suggestions for future research.

2. LITERATURE REVIEW

The literature review is grouped into three sections: (1) The carbon cycle and its relationship to with climate change; (2) Land use change studies and their impact on carbon stock; (3) Soil carbon stock and measurement methods.

2.1. The Carbon Cycle and Climate Change

Carbon is exchanged among the biosphere, pedospehere, geosphere, hydrosphere and atmosphere of the Earth. It is one of the most important cycles of the earth and allows for carbon to be recycled and reused throughout the biosphere and all of its organisms (Hwang, 2008). The cycle is closely related with the carbon pool which has the capacity to accumulate or release carbon. Examples of carbon pools can be listed as forest biomass, wood products, soils, and the atmosphere.

Carbon exists in the Earth's atmosphere primarily as $CO_{2(g)}$. Although it is a small percentage of the atmosphere (approximately 0.04% on a molar basis), it plays a vital role in supporting life. Other gases containing carbon in the atmosphere are methane and chlorofluorocarbons (the latter is entirely anthropogenic).

Trees and other green plants such as grass convert carbon dioxide into carbohydrates during photosynthesis, releasing oxygen in the process (Sedjo, 1993).

Carbon is an essential part of life on Earth. About half of the dry weight of most living organisms is carbon. It plays an important role in the structure, biochemistry, and nutrition of all livingcells. Living biomass holds about 575 gigatons of carbon, most of which is wood. Soils hold approximately 1500 gigatons, mostly in the form of organic carbon, with perhaps a third of that inorganic form of carbon such as calcium carbonate (Lal, 2008).

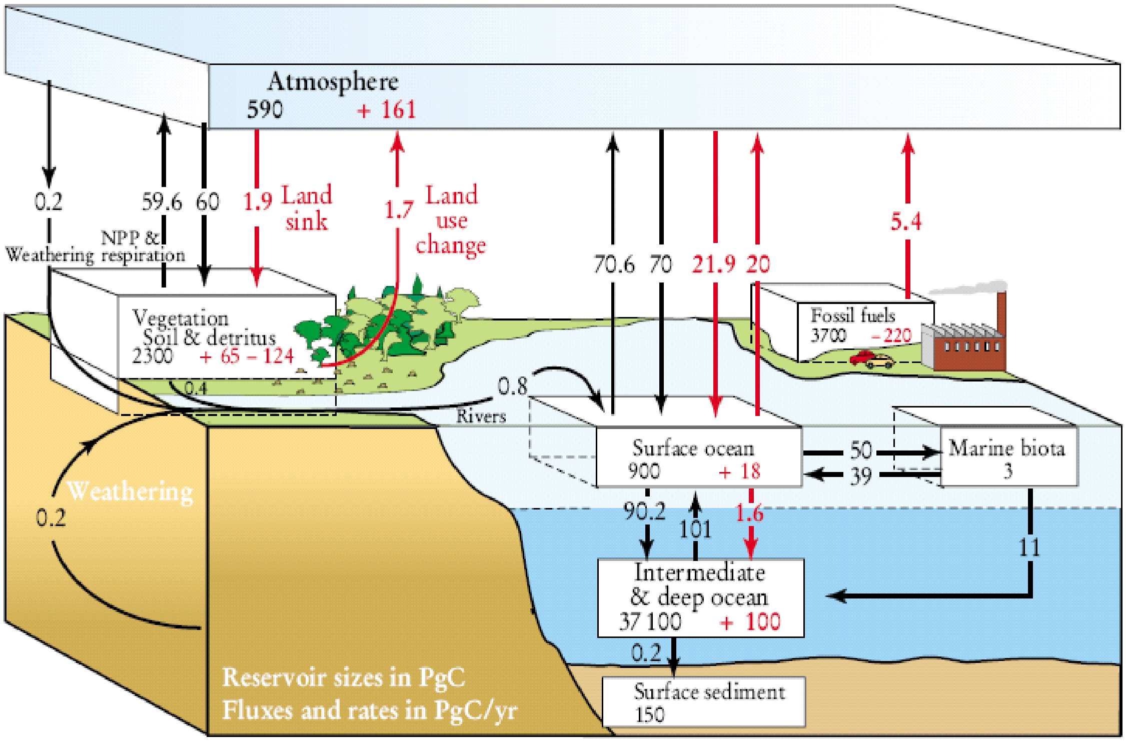


Figure 2.1. The global carbon cycle (Sarmiento and Gruber, 2002)

Figure 2.1 illustrates the carbon cycle between the atmosphere and its two important sinks: The land and the ocean (the units on the figure are Petagrams (Pg). 1Pg = 10^{15}g.). Carbon (C) on Earth is stored in three big reservoirs: Atmosphere, land and ocean. Vegetation contains about 600 gigatons of carbon (Gt C), comparable to the amount in the atmosphere (750 Gt C) and is approximately equal to 60% of the carbon in surface ocean layers (1000 Gt). The deeper ocean layers contain significant amounts of carbon, (about 38,000 Gt), but they can interact with the atmospheric CO_2 only through surface layers. Carbon stored in soil is approximately 1600 Gt, twice large as the one in the vegetation. The carbon stored in the soil and litter of forest ecosystems also makes up a significant proportion of the total carbon pool. Globally, soil carbon represents more than half of the stock of carbon in forests. More than 80% of the carbon in the boreal ecosystems is stored in the form of soil organic matter, whereas in tropical forests the carbon is fairly equally distributed between the vegetation and soil (Dong, 2002).

In a nutrient poor system, soil organic matter (SOM) can play an important role in the stability, quality, and fertility of the soil. Farmers and land use planners are therefore interested in land use management that will enhance soil carbon levels. In most ecosystems worldwide the conversion of land to agriculture will drastically change the natural internal nutrient cycling and nutrient loss will exceed nutrient gain. In agricultural areas, biomass litter inputs become minimal and tillage will split up soil aggregates, increasing decomposition (Walker and Desanker, 2004).

Humans basically contribute to carbon cycle via breathing. Using the oxygen taken from the atmosphere, we burn the carbon stored in our food and turn into carbon dioxide. This process is analogous to fires, rotting of wood, and decomposition of organic material in the soil and elsewhere. To offset these respiration processes where carbon is turned into carbon dioxide, there are processes involving photosynthesis in plants and trees, which works in the opposite way; in the presence of light, plants and trees take up carbon dioxide, use the carbon for growth and return the product oxygen back to the atmosphere. Both respiration and photosynthesis also occur in oceans (Houghton, 2007).

Climate change is one of the most important environmental problems of the world. It is closely related to changes in the atmospheric concentration of some gases such as water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), which are also called the greenhouse gases. Increased rate of fossil fuel burning is one of the biggest contributors to the increased atmospheric concentration of green house gases (Oral, 2010).

Houghton (2007) defines carbon dioxide as providing the dominant means through which carbon is transferred in nature between numbers of natural carbon reservoirs. Fossil fuel combustion is responsible for 70% of total CO_2 emission from the Earth to the atmosphere and deforestation for 30% of the total emissions and a continuing trend of increased use of solar energy will help to reduce the growth of anthropogenic fossil-fuel-based CO_2 emissions (Pan, 2004). The reason for the release of carbon following deforestation is that forests hold 20 to 100 times more carbon per unit soils than agricultural lands (Houghton, 1991). Clearing of land and forest for agriculture also results in the loss of organic carbon from soil (Asan, 2002).

Carbon dioxide is constantly exchanged between the atmosphere, the oceans and terrestrial ecosystems. Vegetation and soils can accumulate carbon, thus reducing the rate of CO_2 build-up in the atmosphere that is responsible for climate change (IPCC, 2000). Over time forests accumulate carbon through the growth of trees and the increase of soil organic carbon unless major disturbances occur. Immature forests sequester carbon at high rates, while in mature forests carbon sequestration eventually equals decomposition; that is, the carbon balance of the ecosystem reaches a steady state. The forest is a carbon reservoir, but no longer acts as a carbon sink. This means that whether forests act as reservoirs, sinks for carbon from the atmosphere, or sources of GHGs depends on several factors such as the age of the forest, the management regime, other biotic and abiotic disturbances (e.g. insect pests, forest fires, etc.) and human-induced deforestation (IPCC, 2000).

There are two fundamental reasons for the increased concentrations of CO_2 in the atmosphere: the first reason is emission of CO_2 from combustion of fossil fuels (Quadrelli and Peterson, 2007) and the second reason is release of CO_2 (soil respiration) from deforestation (Asan, 2002).

2.2. The Land Use Change Studies

Land management is among the important determinants of soil carbon stocks because land use influences the input and output of organic matter to the soil (Guo and Gifford, 2002). Deforestation results from human activities that partially remove forest carbon stocks without regeneration in a reasonable time frame (on the order of a decade). That is, the rate of biomass carbon removal is greater than the rate of re-growth resulting in a gradual decline in overall biomass carbon stocks (DeFries et al., 2007).

Deforestation releases CO_2, known as soil respiration, to the atmosphere because carbon stored in the organic matter of trees and soils is oxidized during the processes of removing the forests. Carbon dioxide fluxes from deforestation are highly uncertain components of the contemporary carbon budget, due to changes in forest soils. Deforestation frequently occurs in the tropics, and accounts for about 2 Gt C/year release of CO_2 to the atmosphere. During combustion of any fossil fuel, carbon is oxidized and CO_2 is released. Fossil fuel combustion releases 5 Gt C/year and this value is rising exponentially with time, driven by population growth and economic growth. Both processes release carbon to the atmosphere at a rate of about 7 Gton C/year (Archer, 2007).

Land use change studies are often performed using satellite images. The types of satellites and sensors, remotely sensed data source issues, converting reflectance data to metadata, vegetation indices, clustering and classification techniques can be considered together with the issue of land use change. Studies that focused on land use change and deforestation include Woodbury et al. (2006), Fisher et al. (2004), Neill et al. (1997), Walker and Desanker, (2004), Fearnside et al. (1998), Zaehle et al. (2007), Reithmaier et al. (2006), Guler et al. (2007), Islam and Weil (2000), Riezebos and Loerts (1998), Forest carbon sequestration and carbon modeling on satellite images were studied by Turner et al. (2005), Feldpausch et al. (2006), Neef et al. (2005), Doraiswamy (2007), Höhne et al. (2007), Han et al. (2010), Mishra et al. (2009).

Bruce et al. (1998) investigated the magnitude of the potential for carbon sequestration in the soil and in the forests by means of reducing carbon dioxide (CO_2) in the atmosphere. They showed tools such as Remote Sensing and GIS could be used for this purpose.

Günlü et al. (2009), conducted a land use change study in the vicinity of Rize province. They indicated that 1.98 % of expansion in urban development was detected in the province from 1987 to 2007. The forested lands decreased 2.30%. This rate is equal to 12.506 ha of the surface area. They concluded that this value is one of the highest rates of land use change in Black Sea Region of Turkey.

Sancar et al. (2009), investigated land use change in the province of Trabzon from 1987 to 2008. The study showed that the percentage of urbanization in the province of

Trabzon increased from 4.72 % in 1987 to 6.27 % in 2008 based on supervised classification of images. The authors also indicated that the diversity and landscape fragmentation are positively related to the degree of urbanization.

Liu et al. (2004) claimed that land use change such as vegetation removal and agricultural activities are closely related with carbon sequestration in Senegal. In their study, land cover maps were produced by using spatially explicit geographic information system (GIS) databases of climate and soil and used these maps and databases to support biogeochemical modeling. Grids were generated at a resolution of 10-km-length scale to characterize the spatial and temporal patterns of monthly precipitation from 1961 to 1996.

Naughton-Treves (2005) used the Landsat TM satellite images and made field observations to estimate the carbon emitting based on the deforestation in Peru. He formulated the predictable carbon emission by adding and subtracting the forest types from each other. Economic reasons that allow the occurrence of deforestation in Peruvian forests were also identified.

Zhang and McGrath (2004) carried out geo-statistical and GIS analyses on soil organic carbon concentrations in grasslands. They quantified the spatial and temporal changes in soil organic carbon. Mean values of the study, spatial structure of soil organic carbon, and factors related to changing soil organic carbon levels were compared and analyzed, respectively. Their results showed that a combination of geostatistics and GIS map calculation provides a useful tool for the study of spatio-temporal changes in environmental sciences.

Woomer et al. (2004) determined Senegal’s terrestrial carbon stocks in 1965, 1985, and 2000 using an inventory procedure involving satellite images revealing historical land use change, and recent field measurements of standing carbon stocks occurring in soil and plants. Senegal was divided into eight ecological zones containing 11 land uses. In 2000, savannas, cultivated lands, forests, and steppes were the four largest land uses in Senegal, occupying 70, 22, 2.7, and 2.3 percent of Senegal’s 199,823km^2, respectively. According to the system, C stocks ranged from 9 tC/ha in degraded savannas in the north, to 113 tC/ha in the remnant forests of the Senegal River Valley.

Mishra et al. (2009) predict and map soil carbon stocks in different land uses in Indiana, USA. A total of 98 samples were randomly selected from the whole data set, dividing the data set into calibration and validation data sets. This was done using the Create Subset function of Geostatistical Analyst in ArcGIS 9.2. The parameters of the functions were interpolated for the entire study area using ordinary kriging on 81% of the data points.

2.3. The Soil Carbon Stock Studies

Soil carbon stock is an important soil component is farming system. It is essential for improving soil and water quality and hence sustains food production. Habitat loss and soil organic carbon (SOC) stock variations linked to land cover change were estimated over two decades in the most populated biodiversity hotspot all around the world for assessing the possible influence of conservation practices on the protection of SOC (Seen et al., 2010).

Han et al. (2009), conducted a soil carbon storage study in China. They indicated that the SOC content per area in the grassland and farmland was higher than the other classes and the shrub land was similar to the woodland while the Aeolian sandy soil and gully were the lowest. The SOC storage in the catchment of farmland, grassland, shrub land, woodland, gully, and Aeolian sandy soil was estimated as 3.32×10^6 kg, 9.45×10^6 kg, 1.023×10^7 kg, 2.73×10^6 kg, 5.76×10^6 kg, and 2.94×10^6 kg, respectively. The total SOC storage up to 100 cm depth in the catchment is 3.443×10^7 kg.

Meersmans et al. (2010), developed a quantitative model in order to evaluate the distribution of SOC with depth by applying an empirical modeling approach between 1960 and 2006 in the northern Belgium. They indicated that land management practices seriously affect the SOC status of the soil.

Mishra et al. (2009), estimated the spatial variation of the soil organic carbon storage by means of a geographically weighted regression (GWR) approach. They claimed that the amount of C stored in the sol per unit of land area is highly variable. The magnitude of the soil carbon stock at a location depends on various factors such as soil type, land use, annual input of biomass, topographic features and climatic conditions. The prediction accuracy of this SOC pool map was compared with the multiple linear regression (MLR) and regression kriging (RK) approaches. A relative improvement of 22% over MLR and 2% over RK was observed in SOC prediction. The results suggest that the GWR approach is a promising tool for regional-scale SOC prediction.

Stevens et al. (2008), measured the SOC in croplands at regional scale using airborne imaging spectroscopy. SOC maps of bare agricultural fields were produced using the best calibration model. Two map excerpts were shown, which display intra and inter-field variability of SOC contents possibly related to topography and land management.

Green et al. (2007), investigated the above and belowground biomass measurements in an un-thinned stand of Sitka spruce (Picea sitchensis (Bong) Carr.). Ten trees were destructively sampled to develop aboveground and tree component biomass equations. The roots were excavated and a root-to-shoot (R) ratio developed to estimate belowground biomass. Application of the total aboveground biomass function yielded a C stock estimate for the stand of 74 tones C/ha, with an uncertainty of 7%. The R ratio was determined to be 0.23, with an uncertainty of 10%. The C stock estimate of the belowground biomass component was then calculated to be 17 tones C/ha, with an uncertainty of 12%. The equivalent C stock estimate from the biomass expansion factor (BEF) method, applying Ireland’s currently reported default values for BEF (inclusive of belowground biomass), wood density and C concentration and methods for estimating volume, was found to be 60 tones C /ha, with an uncertainty of 26%.

Schulp et al. (2008) investigated the effect of tree species on carbon stocks in first floor and mineral soil and implication for soil carbon inventories in Netherlands. Results indicated that forest soil organic carbon and forest floor carbon (FFC) stocks are highly variable. The sampling effort required to assess SOC and FFC stocks is therefore large, resulting in limited sampling and poor estimates of the size, spatial distribution, and changes in SOC and FFC stocks in many countries. At managed locations, carbon stocks were lower than at unmanaged locations. The carbon inventory currently overestimates FFC stocks. Differences in carbon stocks between conifer and broadleaf forests were significant.

Scott et al. (2002) designed a soil carbon monitoring system for New Zealand using country specific land use and soil carbon information. The system stratifies the country by soil type, climate and land use. This system quantifies equilibrium changes in soil carbon associated with land use change if land use is updated periodically.

3. MATERIALS AND METHODS

3.1. Study Plan

This study encompasses several steps to determine the effect of land use change on soil. Field trips were conducted and soil samples were brought to the laboratory for experimental analysis. Environmental parameters such as soil moisture, soil texture, pH, bulk density, soil electrical conductivity, and elemental carbon were determined by experimental analysis. Results of these experiments and satellite image processing were the main data entries to statistical analyses. A geostatitical approach was used to estimation the spatial distribution of the carbon stock as a function of soil depth. The analyses conducted in this study are presented in Figure 3.1 and are discussed in more detail in the following subsections.

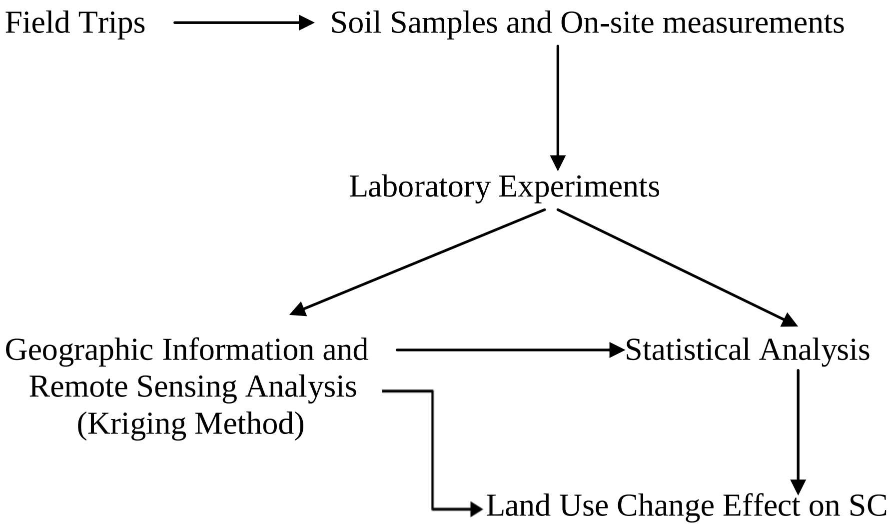


Figure 3.1. Study plan

3.2. Study Area

The selected site for the study is in the Karasu District of Sakarya, Turkey. The study area is located on 41 05' 08.53" N latitude and on 30 41' 58.46" E longitude, and in the Marmara Region of Turkey (Figure 3.2), with a population of 53,275 inhabitants. The surface area of the Karasu region is 450 km^2. Between 1935 and 2008, population of the village increased double fold, with the greatest rise occurring mostly in the coastal zone. The rise in the population, combined with the lack of disincentive and inadequate enforcement of existing laws, led to extensive illegal land conversion.

This area was chosen in this study because it had the highest rate of deforestation in Turkey, as reported by the Forest Service of Turkey, among other districts (Forest Service, 2007). The area of forest clearance has been 26,343 ha between 1994 to 2003, which is almost two times greater than the actual forest areas (13,784 ha) as of 2004 (Forest Service, 2003). During preliminary field trips it was observed that these soils were converted from forest to mostly hazelnut plantations and corn fields.

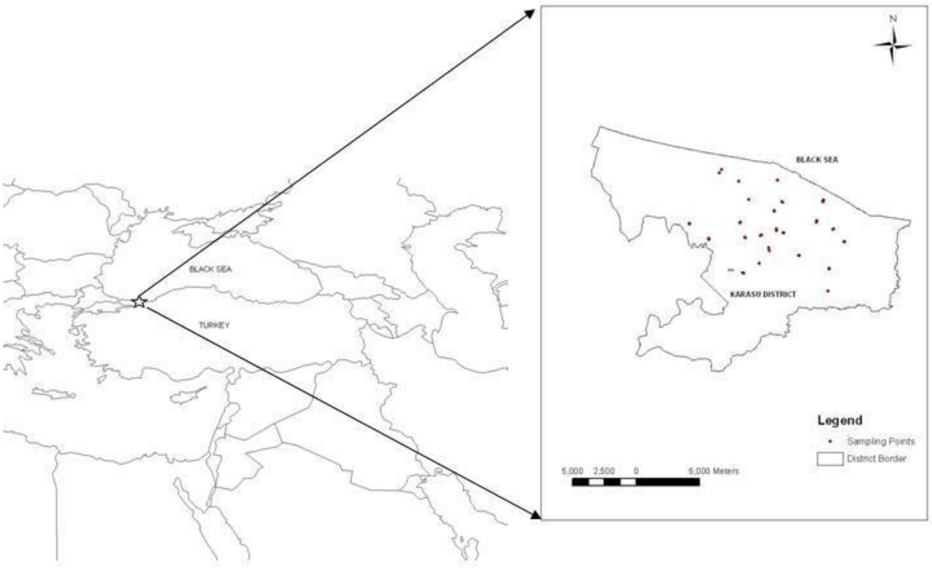


Figure 3.2. The study area (Oral, 2010)

3.2.1. Topography

The region is located within the Northern Anatolian Mountains extending across the east-west direction. These mountains divide the district into several subregions, which are separated from each other by the river valleys and tectonic grabens. The coastal mountains abruptly rise on the seashore of the Black Sea. The main chains from the coast to the west are Karçal, Kaçkar, Giresun, Canik, Küre in the Anatolian section, and the Yıldız Mountains in Thrace (Atalay, 2002).

3.2.2. Climate

Oceanic climate prevails on the coastal belt of Black Sea in the northern part of the region. The mean annual precipitation is over 1000 mm; the northern slopes of the coastal belt mountains receive abundant precipitation as a result of the intercepting fronts coming from the northern direction. Precipitation decreases and can be as low as 500 mm towards the southern section of the region, notably along the deep and wide valley floor (Oral, 2010).

The mean annual temperature of the Black Sea coastal belt is 14–15 ^{o}C, this figure drops to 8–10 ^{o}C at an elevation of 1000 m and 4–5 ^{o}C at 2000 m. The average temperature is 17 ^{o}C and precipitation is 805.7 mm per year (Bayar, 1996). The mean temperature in July is around 21–23 ^{o}C along the coastal belt, but this figure increases inland due to the increase of continentality. The mean temperature in January is 4–5 ^{o}C along the coastal belt. But this temperature decreases towards the southern direction (Atalay, 2002).

3.2.3. Vegetation

The Black Sea region contains different forest types and/or vegetation communities in accordance with the climatic and edaphic factors. Deciduous broad leaf forests are common on the coastal belt and coniferous forests are found on the upper part of the mountains. Shrubby vegetations containing Mediterranean plant elements appear along the deep valley and the tectonic corridor. Alpine meadows are common on the natural timberline of the mountains (Atalay, 2002). The dominant types of species in forests of the Karasu District is as follows: Beech (*Fagus sylvatica)*, Hornbeam (*Carpinus betulus)*, Oak (*Quercus sp.)*, Populus *(Populus sp.)*, Larch – (*Pinus nigris)*, Chestnut *(Castenea sp.)*, Linden *(Tilia sp.)*, Sycamore *(Platanus sp.)*, Maple (*Acer negundo*), European ash species *(Fraxinus sp.)*, and bushes are the Bay Laurel *(Laurus nobilis)*, the Strawberry tree (*Arbutus unedo L.*), Rock rose *(Cistus sp.)* (Forest Service, 2007).

3.3. Land Use in Karasu District

The majority of the agricultural lands in the Karasu district are used for hazelnut and corn cultivation. Favorable soil and climatic conditions are the main reasons of establishing agricultural fields along the study soils. The high financial income for planting hazelnut agriculture accelerated the land conversion from forest to agricultural soils from 1980 to 1995 (Bayar, 1996).

3.3.1. Field Trips

Two field trips were carried out during the study to assess the impact of the seasonal changes on soil carbon stock, the first field trip was in the spring (April 2009), while the second was in the fall (November 2009).

3.3.2. Soil Sample and Selected Parameters

45 soil samples distributed over the study area were collected and analyzed in the laboratory for soil elemental carbon, gravimetric soil moisture, soil texture, pH, and electrical conductivity. A hand-held Global Positioning Device was used to fix the sampling points (Figure 3.3). The sampling point pairs were selected from forest soils as well as the hazelnut agriculture fields.

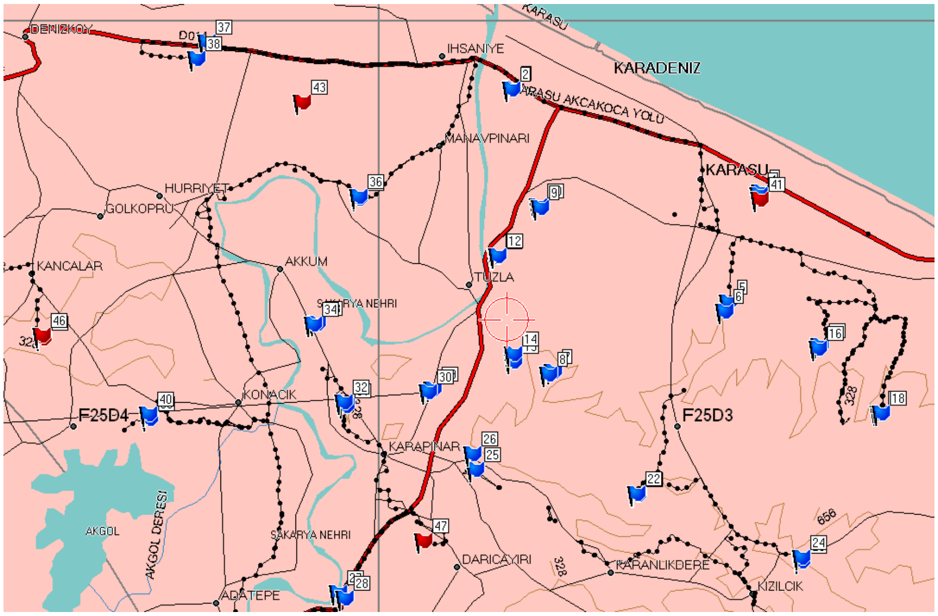


Figure 3.3. The sampling location

Undisturbed soil samples were taken from four different soil depths 0-5, 5-20, 20-45 and 45-100 cm in order to measure the bulk density and elemental carbon and their variability with depth (Figure 3.4). The samples were collected using a soil auger (Eijelkamp Agrisearch) and a method similar to that described in Jones et al. (1999) and Kizilkaya et al. (2004) At each sampling point four profiles with depth extending to 100 cm was developed based on the measured bulk density and carbon content data.

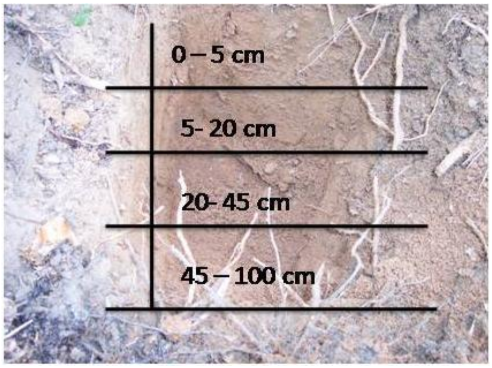


Figure 3.4. Soil sampling depth intervals

The analytical protocols that were applied in this study are given in Table 3.1.

Table 3.1.The parameters measured in the study

Parameter	**Analysis**	**Method**	**Instrument**
Ambient Temperature	On site	On line	Digital Thermometer
Soil Temperature	On site	On line	Digital Soil Thermometer
pH	Laboratory	4500-HB Method Electrometric (APHA,AWWA-WEF-1998)	ORIAN SA520 pH meter
Elemental Carbon	Laboratory	TSE 12089 EN 13137 TURKISH STANDARD	Costech Elemental Analysis
C:N Ratio	Laboratory	TSE 12089 EN 13137 TURKISH STANDARD	Costech Elemental Analysis
Conductivity	Laboratory	2510 B Method (APHA,AWWA-WEF-1998)	WTW LF 320 Conductivity meter
Soil gravimetric Moisture	Laboratory	Loss on ignition	-
Soil texture	Laboratory	ASTM 152	-
Bulk Density	Laboratory	ASTM D2937	-

3.4. Laboratory Experiments

3.4.1. Environmental Parameters

Environmental parameters examined in this study are: soil texture, bulk density, soil gravimetric moisture, elemental analysis, C:N ratio, soil and ambient temperature, pH, and electrical conductivity. Each of these analysis methods are briefly described below.

<u>3.4.1.1. Soil Texture Analysis.</u> Soil texture describes the size (diameter) of the soil particles. Where larger mineral particles predominate, the soil is gravelly (d > 2mm), or sandy (0.05 < d < 2 mm); where smaller, colloidal mineral particles are dominant, the soil is claylike (d < 0.002 mm). These components were determined by Bouyoucos hydrometer and the ASTM 152 method. Soils can have any combination of gravel, sand, and clay and a textural chart is used to describe the soil textures from the soil's particle size distribution as shown in Figure 3.5.

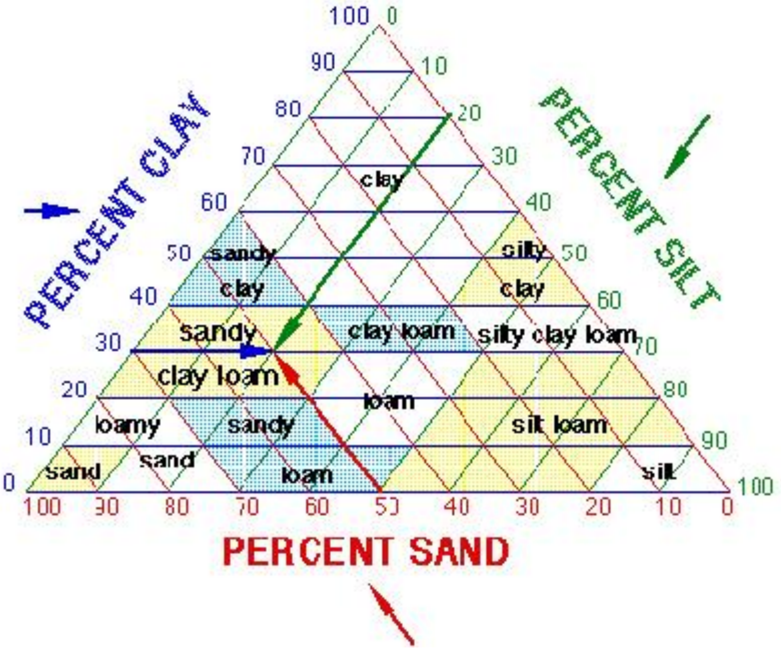


Figure 3.5. Soil Texture Triangle (USDA, 1938)

Any soil composed of all three particle sizes and not exhibiting the physical properties of any one of them is referred to as a loam. Texture influences plant growth by its direct effect on soil aeration, water infiltration, cation exchange capacity, and erodibility. Infiltration and permeability are rapid in sandy soils, very slow in clay soils, and intermediate in loam soils. Soils that are granular, with a large diversity in particle size, have many large and small pores a desirable characteristic for plant growth.

Soil texture can be estimated in the field by experienced soil scientists. While a set of sieves can be used to separate out the sand fraction, a sedimentation procedure is usually used to determine the amounts of silt and clay. Soil particles are denser than water and they tend to sink. Depending on their size, they will settle at different velocities with larger particles settling faster. By measuring the amount of soil still in suspension after various amounts of settling time (using a pipette or hydrometer), the percentages of each size fraction can be determined, ultimately identifying the soil textural class. The size of the particles can be determined because settling time can be related back to the diameter of a particle by Stoke's Law (Brady and Weil, 1999).

3.4.1.2. Dry Bulk Density. Bulk density is a measure of the weight of the soil per unit volume (g/cc), usually given on an oven-dry (110° C) basis. Variation in bulk density is attributable to the relative proportion and specific gravity of solid organic and inorganic particles and to the porosity of the soil (Birkeland, 1984). ASTM D2937 method was used to find out the bulk density.

3.4.1.3. Soil Gravimetric Moisture. The gravimetric measurement method of the air-dry water content was used to determine the parameter. Soil samples were dried at 105^{o}C until mass constancy is reached. The differences in masses before and after drying are a measure for the water content for soils. The water content was calculated on gravimetric (gsoil/gwater) and on volumetric basis (cm^{3}water/cm^{3}soil). 10g air-dried soil sample was used for the determination of the soil gravitational moisture (Rowell, 1996).

3.4.1.4. Soil and Ambient Temperature**.** Soil temperature was measured at 5 cm (Raich and Tufekcioglu, 2000) depth using a soil thermometer probe (WINLAB). Ambient temperature was measured using a digital thermometer.

3.4.1.5. Soil pH. U.S. Salinity Laboratory Staff, (1954) measurement method was used to determine the soil pH in the laboratory. The method is most applicable to soils with a pH ranging from 4.0 to 9.0 (Rowell, 1996). A pH meter equipped with pH electrodes (for indicating and reference) and primary standard buffers, pH 4.00, 7.00, and 10.0 were used (Rowell, 1996 and U.S. Salinity Laboratory Staff, 1954). A saturation paste was prepared. The pH meter was standardized and calibrated for the measurement.

3.4.1.6. Electrical Conductivity. The electrical conductivity (EC) of soil or water depends on the amount of salts present. In humid regions, they are at low concentration and do not affect plant growth, while in semiarid and arid regions and near salt lakes or oceans they may be at high concentration and have detrimental effects on plant growth. In all these cases the electrical conductivity is simply measured by determining the amount of electricity passing through a cell of known dimensions and configuration when it contains a salt solution. In the case of soil, the electrical conductivity of a soil paste or solution extracted from soil is related to the soil's salt content (Conklin, 2005).

3.4.1.7. Elemental Analysis. Elemental analyzers, which are able to analyze the elements, require a small sample of very finely ground material. In this study, elemental analyzer COSTECH ECS 4010 was used to determine the elemental ratio of carbon in the soil (Walker and Desanker, 2004). This ratio was used to calculate the amount of carbon stored in different depths of soil.

The reliability of the results is linked with the fine-grounded matter. In practice, high-precision planetary grinders are used for preparing samples for C, H, and N analyzers. Small subsamples (usually in the range of 50–500 mg) of the finely ground material are enclosed in silver or aluminum cups, fed to the analyzer by automatic sampler, and burned at around 1000 ^{o}C in oxygen. The resulting gas is carried through a set of absorption columns and analyzed for heat conductivity, which is strictly related to the composition of the gas obtained from the burned samples. The results are compared against calibration curves obtained with a standard material of precisely known concentrations of C, H, and N (plus O and S for CHNO-S analyzers) and recalculated to concentrations of elements in the sample (Caswell, 2003).

3.4.1.8. C:N Ratio. The C:N ratio of organic matter stands for the amount of carbon relative to the amount of nitrogen present. There is always more carbon than nitrogen in organic matter. The carbon to nitrogen ratio is usually designated by C:N and is a single number, because it expresses how much more carbon than nitrogen there exists. This parameter shows the decomposition rate in the soil (Vose et al., 1995).

3.5. Carbon Stock Calculation

The sampling area was classified according to the land use and soil type. The area of the different classes was calculated using the ArcGIS software. The soil carbon stock of each horizon was computed as follows:

$$C_{sp,i} = \frac{C\rho_b Z_i (1-RM)}{100} \tag{3.1}$$

where;

$C_{sp,i}$, carbon stock of i^{th} horizon (kg/m^2),

C, mean content of carbon of the i^{th} horizon (%),

ρ_b, mean bulk density of the i^{th} horizon (kg/m^3),

Z_i, depth of the i^{th} horizon (m),

RM, stone percent (%).

The soil carbon stock was estimated in each profile by summing the carbon stock of each horizon from the surface to 1 m depth using;

$$C_s = \sum_{i=1}^{n} (C_{sp,i}) \tag{3.2}$$

where;

C_s , carbon stock of each profile (kg/m^2).

All calculations and presentation of results was performed within the ArcGIS 9.3 software package.

3.6. Remote Sensing Technology

Remote sensing is the gathering of information about objects from the Earth's surface and observing them from space or air. In the study, laboratory measurements were linked with Global Positioning System (GPS) coordinated sampling points. The Landsat 5 – Thematic Mapper (TM) images of 2007 was used to extract land use maps. The sources, path and row specifications of the images were shown on Table 3.2.

Table 3.2. Data sources of the study

Images	Laboratory Experiments in 2009	Maps	GPS Data	Statistical Data	Hardware and Software
Landsat TM 2007 (60mX60m)- European Space Agency	Laboratory Measurements	Land Use Maps	GPS coordinated for sampling points	Thematically Layers Laboratory Measurements	ERDAS Imagine 9.3 Version ArcGIS 9.3 Version with Spatial and Geostatistical Analyst Extension

There are three basic steps involved in a typical supervised classification technique and they can be listed as follows (Lillesand et al., 2004):

(i) Training Stage: The analyst identifies representative training soils and develops a numerical description of the spectral attributes of each land cover type of interest in the scene.

(ii) Classification Stage: Each pixel in the image data set is categorized into the land cover class it most closely resembles. If the pixel is insufficiently similar to any training data set, it usually labeled ―unknown.‖ The category label assigned to each pixel in this processes in then recorded in the corresponding cell of an interpreted data set.

(iii) Output Stage: The results are presented at this stage.

3.7. Data Analysis

3.7.1. Statistical Analysis

The data analysis was performed by SPSS 17.00. The goal was to assess (i) the correlation between carbon stock and environmental parameters (bulk density, soil and ambient temperature, gravimetric soil moisture, soil pH and electrical conductivity), (ii) the influence of land use change on the parameters, and (iii) developing regression models to explain the variability of the carbon stock.

Descriptive statistics were computed to reveal the overall characteristics of the data. The following statistical parameters of the data were computed: number of samples (N), range, minimum, maximum, mean, standard deviation, variance, skewness, and kurtosiss.

Pearson’s Correlation analysis was used to show the correlations between soil parameters affecting the soil carbon stock and soil parameters (Cox et al., 2003).

The equation of the correlation analysis is shown below;

$$r = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(Y_i - \overline{Y})}{(n-1)S_X S_Y} \tag{3.3}$$

where;

X and Y are the variables,

S_X and S_Y are the standart deviations,

$\overline{X}$ and $\overline{Y}$ are the means of X and Y, respectively.

The value for a Pearson's correlation can fall between 0 (no correlation) and 1 (perfect correlation). Other factors including group size will determine if the correlation is significant. Generally, correlations above 0.80 are considered high. The correlation coefficient may take any value between -1.0 and +1.0 and the following assumptions can be reproduced from these values : (SPSS 17, 2008):

- There is a linear relationship between X and Y
- The variables X and Y must be independent of each other

Both variables in the analysis must be normally distributed. The normal distribution is a pattern for the distribution of a set of data which follows a bell shaped curve. In this study, Shapiro-Wilk normality tests and Kolmogorov-Smirnov statistical tests were used to assess whether the data are close to normal. When the variables do not meet the normal distribution criteria, the data were transformed (such as log transformation) prior to the statistical analysis.

In statistics, analysis of variance (ANOVA) is a collection of statistical models, and their associated procedures, in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form ANOVA provides a statistical test of whether or not the means of several groups are all equal, and therefore generalizes *t*-test to more than two groups. ANOVAs are helpful because they possess an advantage over a two-sample t-test. Doing multiple two-sample t-tests would result in an increased chance of committing an error. For this reason, ANOVA is useful in comparing two, three or more means.

Observations of a dependent variable Y, and each observation is associated with an independent categorical variable X that has i different "levels" (possible values). The ANOVA equation that represents this situation is:

$$y_{ij} = \mu + \alpha_i + \epsilon_{ij} \tag{3.4}$$

where;
y_{ij} is the j'th observation of Y_i , the group that has the i'th level of X,
μ is the overall mean of Y,
α_i is the deviation from that mean that comes from being in the i'th level of X,
ϵ is the sum of all the coefficients.

Finally, step-wise linear multivariate regression analysis was performed to evaluate the correlation between carbon stock and environmental parameters. In this analysis, a list of several potential explanatory variables is available and this list is repeatedly searched for variables which should be inserted into the equation. The best explanatory variable is used first, then the second best comes after the first and it continued for other steps.

The variables in the equation of step-wise linear regression analysis are as follow:

$$Y = a + bX + e \tag{3.5}$$

where ;

Y is the dependent variable,
a is the intercept,
b is the slope or regression coefficient,
X is the independent variable (or covariate),
e is the error term.

3.7.2. Geostatistical Analysis

Geostatistical analyses were conducted to estimate the spatio temporal relationships between the sample values. Geostatistics is a class of statistical methods that considers the interrelationship between a dependent univariate variable and the independent variables of position (x, y, z or time). Inverse distances weighting (IDW), kriging and co-kriging, spline are the interpolation methods that are used in geostatistics.

A modified kriging procedure was used to explore the geostatistical relationships between sample values. The modification takes into account the fraction of land use types at each grid point within the study area. Kriging uses statistical models that allow a variety of map outputs including predictions, prediction standard errors and probability. It is assumed that the data come from a stationary stochastic process (Arc GIS, 2008). The biggest advantage of the kriging technique over many classical statistical procedures is that kriging incorporates the spatial correlation of the data, while all other classical statistical procedures do not (Largueche, 2006).

The modified kriging equation is shown below.

$$F(x, y) = \sum_{i=1}^{n} (W_i f_i) \tag{3.6}$$

where;

n is the number of scatter points in the set,

f_i are the values of the scatter points,

W_i are weights assigned to each scatter point.

The first step in the kriging method is to calculate the semivariogram. A semivariogram is a measure of the spatial correlation of the variable (e.g., carbon stock). Semivariogram analysis assumes that the differences between sample values are related but the values themselves are spatially indeterminate (Houlding, 2000). The characteristics of semivariogram analysis are shown in Figure 3.6.

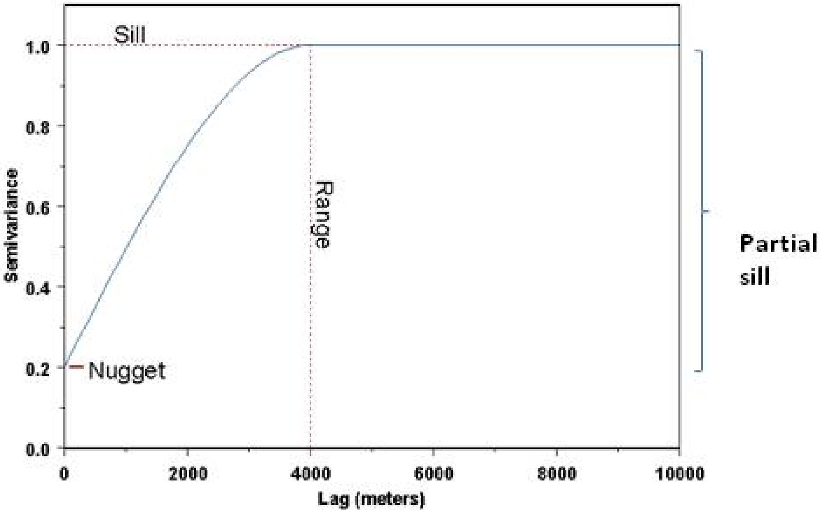


Figure 3.6. The characteristics of semivariogram analysis (Bohling, 2005)

In the above figure, the term sill refers to the amplitude of a certain component of the semivaryogram. Nugget represents variability at distances smaller than the typical sample spacing, including measurement error (Bohling, 2005**)**. Range is the lag distance at which the semivariogram (or semivariogram component) reaches the sill value. Partial sill is the subtraction of the nugget from the sill. The semivariogram of the sample values were calculated using the following equation.

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[f(x_i) - f(x_i + h) \right]^2 \tag{3.7}$$

where;

$\gamma(h)$ is the estimated value of the semivariance for lag *h*,

$N(h)$ is the number of experimental pairs separated by the lag distance *h*,

$f(x_i)$ and $f(x_i + h)$ are the values of the parameter (in our case carbon stock) at two locations separated by the lag distance, *h*.

The semivariograms is next fitted with various theoretical models like spherical, exponential, gaussian, and linear and power by the weighted least square method. Separate semivariograms are developed for the forested and agricultural lands.

Once the semivariogram is determined, ordinary kriging is applied to the forested and deforested lands. Ordinary kriging expresses the value of a parameter at any unsampled point as a linear weighted average of adjacent data points (Equation 3.8). The weights are dependent on the semivariogram model.

Kriging is applied separately for the forested and deforested lands and the soil carbon stock distribution for horizon *i* is finally determined as a weighted average of the local the forested and deforested kriging estimates:

$$\mathrm{C}_{s,i}\ (x, y) = \mathrm{w}_f\ \mathrm{F}_f(x, y) + \mathrm{w}_d\ \mathrm{F}_d(x, y) \tag{3.8}$$

where;

$\mathrm{C}_{s,i}\ (x, y)$ is the carbon stock at location (x,y) for horizon I,

$\mathrm{F}_f(x, y)$ is the forested kriging estimate at location (x,y),

$\mathrm{F}_d(x, y)$ is the deforested kriging estimate at location (x,y).

w_f and w_d weights taken equal to the fraction of forested/agricultural lands at any particular location (x,y):

The spatial analysis extension was employed to plot the geostatistical maps. This tool includes the transformations, manipulations, and methods that can be applied to geographic data to convert them into useful information for geostatistical analyses (ARCGIS, 2008). Geostatistical analysis applied on two different seasons' data. The diagram below shows the steps of obtaining geostatistical maps (Figure 3.8).

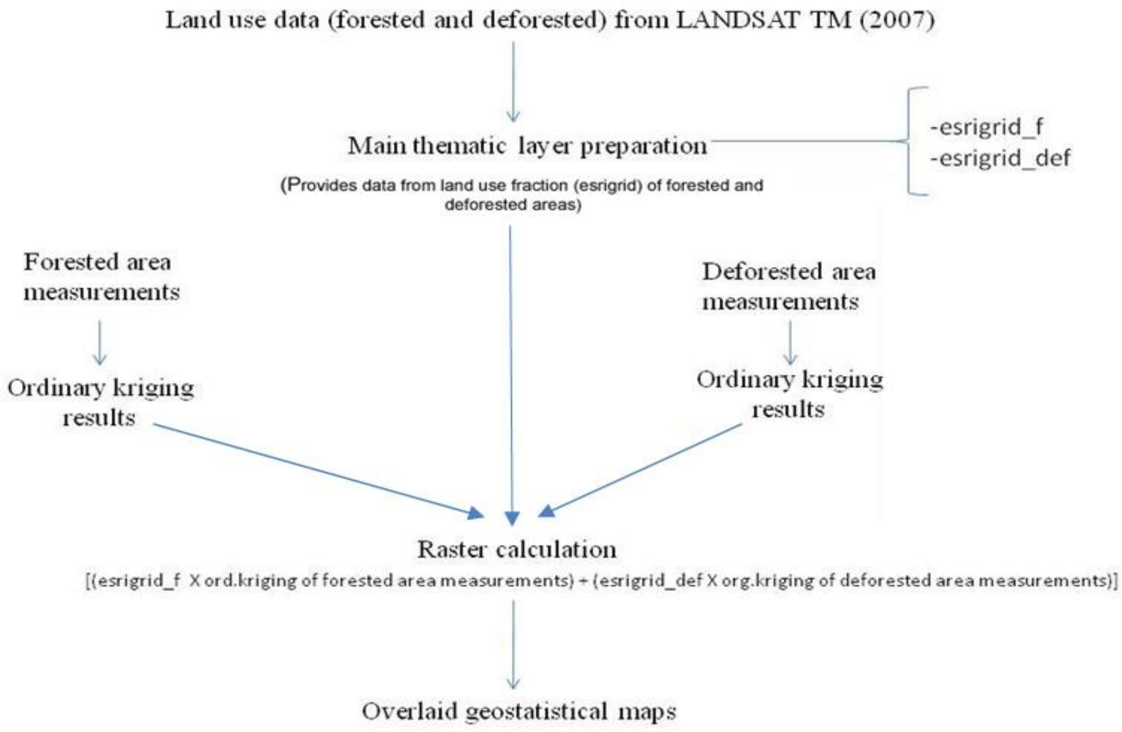


Figure 3.7. Flow diagram of the steps for generating overlaid geostatistical map

4. RESULTS AND DISCUSSION

This chapter presents the field measurements and the results of the laboratory experiments , as well as land use change obtained from satellite image analyses. SPSS17.00 software was used for statistical analysis which includes Trend analyses of parameters, correlations between carbon stock and environmental parameters, and regression analyses. The geostatisitcal analyses culminating into seasonal maps of the carbon stock within the study area are also presented.

4.1. Soil Elemental Carbon Analysis

In order to determine the effects of land-use change on carbon stocks in the Karasu district, the average carbon content of the soil samples taken from 45 sampling locations (forested and deforested) and from 4 different depths over 2 seasons (Spring and Fall 2009) are given in Table 4.1.

Table 4.1. Elemental carbon content of each depth intervals

Forested Area									Deforested Area								
No	**Spring 2009 Carbon Content (%)**				**Fall 2009 Carbon Content (%)**				**No**	**Spring 2009 Carbon Content (%)**				**Fall 2009 Carbon Content (%)**			
	P1	**P2**	**P3**	**P4**	**P1**	**P2**	**P3**	**P4**		**P1**	**P2**	**P3**	**P4**	**P1**	**P2**	**P3**	**P4**
2	4.75	1.05	0.30	1.15	3.72	1.52	0.79	0.62	**1**	1.05	0.65	0.45	0.15	1.40	0.63	0.44	0.18
4	2.25	0.95	0.40	0.15	2.26	0.95	0.62	0.16	**3**	1.15	1.10	0.70	0.40	1.60	0.89	0.83	0.54
6	2.45	1.20	0.65	0.30	2.48	1.18	0.89	0.34	**5**	3.70	1.25	0.65	0.50	3.47	0.85	0.79	0.34
8	4.35	2.05	0.85	0.45	3.85	3.31	1.20	0.78	**7**	1.70	2.05	0.75	0.50	1.74	1.48	1.36	0.68
10	1.70	2.40	1.30	0.70	3.93	1.41	0.74	0.52	**9**	1.30	1.50	0.75	0.25	1.72	1.27	0.42	0.45
12	1.20	1.75	0.90	0.40	2.22	1.17	0.42	0.33	**11**	1.15	1.55	1.75	1.60	2.55	0.96	0.41	0.29
14	1.55	2.20	1.20	0.55	2.46	0.62	0.62	0.50	**13**	0.95	1.15	0.90	0.55	1.88	0.73	0.52	0.77
16	0.95	1.25	0.80	0.45	1.61	1.12	0.35	0.10	**15**	0.65	1.60	1.70	0.65	1.81	0.71	0.16	0.07
18	2.85	2.95	1.40	0.90	2.94	1.55	0.74	0.69	**17**	1.25	1.55	1.00	0.45	1.99	1.12	0.45	0.30
20	1.50	1.55	0.70	0.45	3.00	1.32	0.83	0.39	**19**	1.80	2.10	0.90	0.55	2.22	1.41	0.77	0.66
22	1.20	1.45	0.70	0.50	2.13	1.20	0.37	0.37	**21**	1.50	1.70	0.65	0.35	2.66	1.14	0.66	0.57
24	1.15	1.90	2.45	0.75	2.48	0.79	0.69	0.61	**23**	0.45	1.95	0.60	0.65	1.71	1.60	0.91	0.53
26	1.80	3.15	2.85	1.95	3.38	2.02	1.33	0.66	**25**	0.90	0.95	0.55	0.40	2.13	1.02	0.57	0.39
28	2.00	2.95	1.60	0.60	3.35	2.51	1.19	0.82	**27**	1.75	2.50	1.90	1.15	3.33	2.84	2.82	1.61
30	1.50	1.85	0.90	0.45	2.74	1.88	0.86	0.62	**29**	1.20	1.90	0.95	0.60	2.26	1.10	0.67	0.37
32	1.05	1.40	0.65	0.35	2.58	0.85	0.79	0.54	**31**	0.60	0.90	0.60	0.55	2.29	1.47	0.71	0.32
34	1.25	1.55	0.90	0.50	2.89	1.60	0.59	0.46	**33**	1.35	0.65	0.35	1.25	1.87	1.24	0.54	0.56
36	3.10	3.50	1.10	0.60	4.33	1.47	0.57	0.39	**35**	2.30	3.10	1.40	0.65	3.49	1.66	1.03	1.10
38	1.45	1.15	0.95	1.00	0.79	0.72	0.46	1.25	**37**	0.80	1.25	1.05	1.40	1.58	1.34	0.52	0.63
40	1.90	2.45	1.80	1.15	3.54	1.41	0.94	1.41	**39**	1.95	2.05	1.10	0.75	3.93	1.95	0.91	0.35
46	0.50	0.80	1.20	3.65	2.83	1.59	0.42	0.32	**41**	1.80	1.85	0.90	0.45	1.85	1.30	0.65	0.27
									43	0.80	1.25	0.70	0.35	1.77	0.59	0.42	0.31
									45	0.90	1.20	1.00	0.55	3.32	1.14	0.75	0.34
									47	4.65	2.70	1.65	3.40	5.30	3.59	2.15	1.65

Laboratory analysis showed that elemental carbon content of forested soils is generally larger than the deforested soils because of litter, char and humus presence on the soil surface (Bhat and Wani, 2003; Lal, 2008). Table 4.2 shows the spatial averages of elemental carbon (as a percent) for different land uses and for different soil depth intervals.

Table 4.2. Elemental carbon average values for different depth and land uses

Depth	Spring 2009 Average Carbon Values (%)		Fall 2009 Average Carbon Values (%)	
	Forested Area	Deforested Area	Forested Area	Deforested Area
(0-5 cm)	2.91	2.20	2.83	2.41
(5-20 cm)	1.44	1.40	1.44	1.33
(20-45 cm)	0.89	0.73	0.86	0.73
(45-100 cm)	0.45	0.49	0.56	0.58

These results show that the C content decreases with depth for both forested and deforested soils. At all sites soil organic carbon is greatest at the surface and then declines rapidly with depth. This is especially true for the 0-5 cm and 5-20 cm intervals with a mean difference of 1.47% for forested soils and 0.80% in deforested soils in spring season. The corresponding values for the fall season are 1.39% and 1.08% respectively. These differences become lower in the samples between 5-20 cm and 20-45 cm intervals (0.55% for forested, 0.67 for deforested in spring and 0.58% for forested, 0.60 for deforested in fall).

The results of this study show that land use change in the Karasu District has a strong influence on the amount of the carbon sequestered in the uppermost soil horizons (Figure. 4.1). The change in the quantity of carbon within the 0 to 20 cm depths for both land use types in the study area was found to be approximately 50%. As a joint result of more than 100 studies conducted worldwide, the amount of carbon in soil is found to be directly associated with the land use change. In these studies where the land use change determined by the age of vegetation within the working site, it was reported that change in carbon stock in forested areas consisting of trees of 0-40 year old varied between 30% and 40% on average (Peoplau et al., 2010) which is consistent with the values observed in this study.

Han and others (2010), examined the amount of carbon as a function of soil depth depths on 6 different types of land and 169 soil profile in Northwest China. They found the type of land use to have a strong influence on organic carbon in soil and soil bulk density. They observed a decrease in the amount of soil carbon with depths in all forms of 6 different land uses.

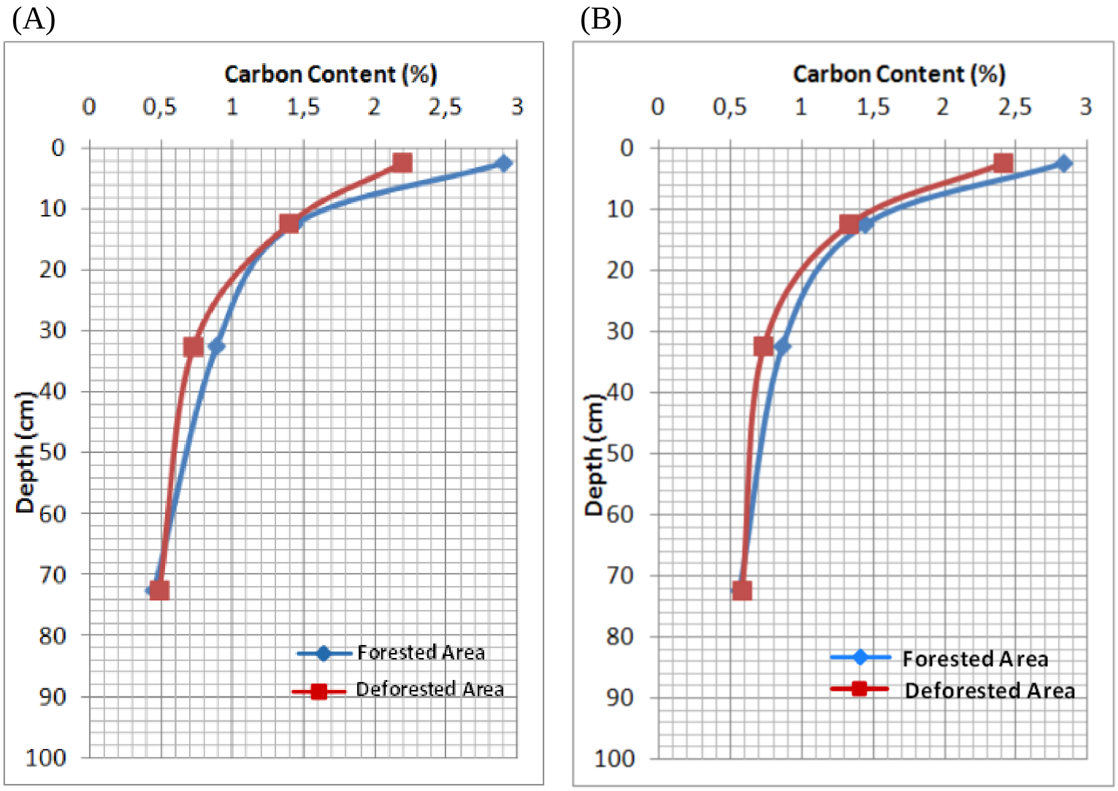


Figure 4.1. Soil organic carbon content as a function of depth in (A) Spring 2009 and (B) Fall 2009 seasons.

The difference in C content for forested and deforested lands was found to be statistically significant only at 0-5 cm soil sampling depth intervals. This could be due the change in ionic strength of soil media by fertilization and liming which are both applied within the study area. These agricultural management practices modify the solubility of metal humus compounds within uppermost soil layer (Osher, et al, 2003).

Such land use changes and agricultural management practices may result in the release of metals complexes by organic functional groups at soils (Osher et al, 2003). As a result, the deforestation in the study area for the planting of hazelnuts may not have affected the carbon content at deeper soil depth intervals. In addition, this might be due to the previous land use, climate and type of forests in the study soils (Paul et al., 2002). Fertilizer application triggers chemical stabilization of the soil, which can be defined as the injection of chemicals into a soil to improve its strength and decrease its permeability (Li et al., 2005). Nobili et al. (2008) indicated that when a soil is cultivated or losses its natural vegetation layer on top, elemental carbon tends to decrease, due to enhanced mineralization and lower carbon inputs.

According to Dundar and Altundag, (2004) the intensive application of fertilizer in hazelnut and corn plantations in the Black Sea Region might have caused higher elemental carbon accumulations in deforested soils. These plantations were defined as deforested soils in the study. Type of forest species and previous land uses in soils investigated in this study, can also influence the sequestration of carbon. Long term soil management regimes such as slash and burn, stocking, weed control, and thinning in plantations are other reasons of soil elemental carbon degradation in deforested soils (Paul et al., 2002).

According to the results obtained within the scope of the project, in Western Black Sea region in general, the soil carbon percentage in soil in forest areas is higher when compared to those deforested areas.

The carbon to nitrogen (C:N) ratios calculated for the carbon and nitrogen contents of the collected soil samples is shown in Figure 4.2. The C:N ratio of soil organic matter is related to patterns of nitrogen immobilization and mineralization during organic matter decomposition (Nakamura,1990), which is linked with the rate of organic matter decaying in soil.

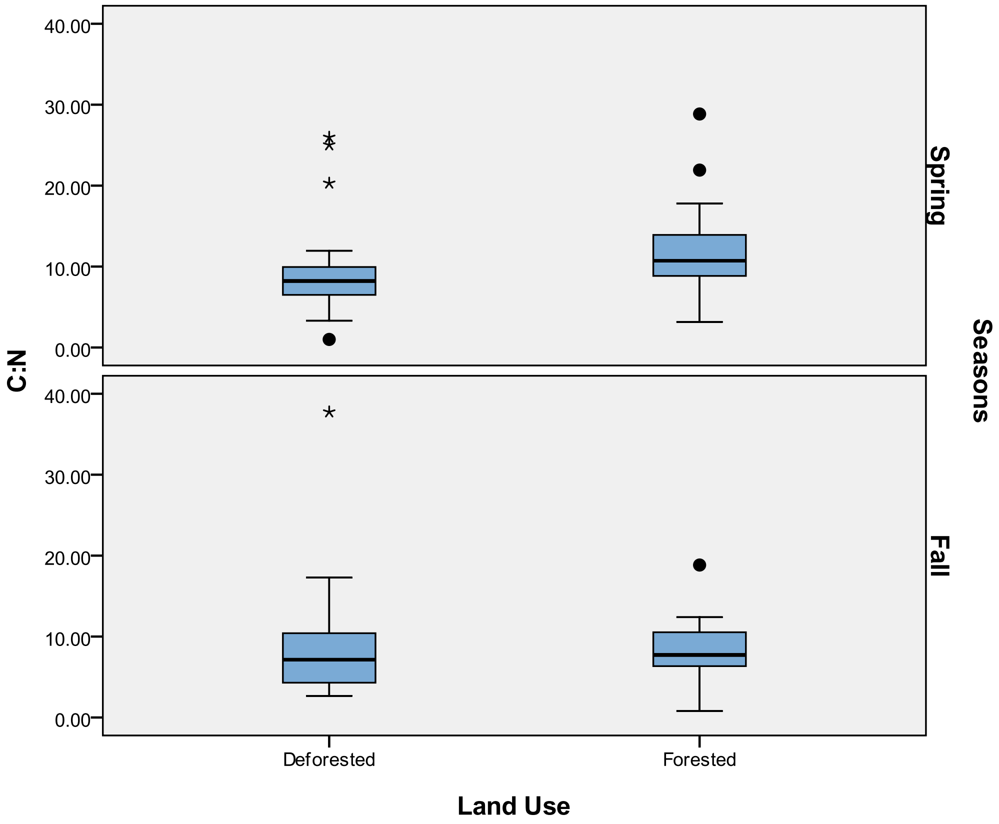


Figure 4.2. Descriptive statistics of C:N ratio in box plots graph.

4.2. Soil Carbon Stock Analysis

The Carbon stock was calculated according to the results of elemental carbon from soil profile samples and equation 3.1. Table 4.3 shows the carbon stock values for all the collected samples for the two land use types. Determining the carbon stocks is one of the most important step for evaluating the impact of land use change on the carbon-cycle.

Table 4.3. Carbon stock results according to type of land use.

Carbon Stock (kg/m^2)					
Forested Area			**Deforested Area**		
No	**Spring 2009**	**Fall 2009**	**No**	**Spring 2009**	**Fall 2009**
2	9.64	14.15	**1**	5.70	6.63
4	6.87	8.14	**3**	9.94	11.91
6	9.32	9.13	**5**	12.72	11.06
8	15.26	19.48	**7**	11.92	14.32
10	13.48	12.56	**9**	7.19	10.49
12	10.28	8.18	**11**	9.63	9.05
14	11.19	12.20	**13**	10.75	11.46
16	7.02	5.03	**15**	11.96	4.29
18	14.42	14.16	**17**	9.29	7.79
20	7.23	11.06	**19**	12.99	13.65
22	10.47	11.53	**21**	8.44	12.49
24	18.01	12.32	**23**	10.76	12.13
26	23.86	17.33	**25**	8.38	10.33
28	12.73	18.47	**27**	18.66	33.66
30	8.60	12.94	**29**	13.18	10.49
32	6.06	12.50	**31**	7.92	10.62
34	9.20	12.19	**33**	8.34	12.20
36	11.62	11.03	**35**	13.68	18.30
38	13.72	15.15	**37**	20.83	12.63
40	19.22	20.02	**39**	14.27	11.60
46	12.74	10.72	**41**	8.75	9.73
			43	7.34	7.65
			45	10.31	13.04
			47	25.55	27.50

As indicated in Equation 3.1, the calculation of the carbon stock is directly related to the bulk density of the soil. General statistical analysis of the carbon stocks are given in Table 4.4.

Table 4.4. Descriptive statistics of carbon stock data

	Spring 2009		**Fall 2009**	
	Forested Area	**Deforested Area**	**Forested Area**	**Deforested Area**
Number of Samples	21	24	21	24
Mean	11.9	11.6	12.8	12.6
Maximum	23.9	25.6	20.0	33.7
Minimum	6.1	5.7	5.0	4.3
S. Deviation	4.5	4.6	3.8	6.3

When the soil profile (0-1 m) were evaluated in terms of carbon stocks in forested and deforested area, the differences in the carbon stock in the forested and deforested soils were observed as 0.34 kg/m^2 in spring season and 0.15 kg/m^2 fall season, respectively. These results show that the carbon stock of fall season is higher than the spring season and in the forest area, soil carbon stock is greater than the deforested area for both seasons. In the Speulder- and Sprielder forest (Veluwe, Netherlands), soil carbon stocks varied between 53.3 Mg C/ha (beech) and 97.1 MgC/ha (larch). At managed locations, carbon stocks were lower than at unmanaged locations (Schulp et al, 2008).

4.3. Environmental Parameters

This section presents results statistical evaluation of the environmental parameters determined from laboratory analyses on the collected samples from forested and deforested soils over the spring and fall seasons. Environmental parameters examined are: bulk density, soil pH, soil gravimetric moisture, soil texture, soil and ambient temperature, electrical conductivity. The analyses were conducted on soil samples obtained from field trips.

4.3.1. Dry Bulk Density

Dry Bulk density values are needed for the calculation of total quantities of carbon sequestered at a particular time and soil depth. Table 4.5 shows the bulk density values for all the collected samples for different land use types.

Table 4.5. Dry bulk density values

Bulk Density (kg/m^3)					
Forested Area			**Deforested Area**		
No	**Spring 2009**	**Fall 2009**	**No**	**Spring 2009**	**Fall 2009**
2	1358	1487	**1**	1651	1789
4	1570	1632	**3**	1609	1661
6	1480	1287	**5**	1570	1624
8	1549	1375	**7**	1394	1403
10	1540	1435	**9**	1539	1670
12	1581	1433	**11**	1690	1706
14	1477	1330	**13**	1734	1517
16	1680	1300	**15**	1667	1574
18	1442	1503	**17**	1504	1430
20	1563	1442	**19**	1546	1556
22	1724	1504	**21**	1749	1598
24	1563	1641	**23**	1708	1445
26	1249	1489	**25**	1702	1690
28	1333	1430	**27**	1475	1542
30	1529	1331	**29**	1511	1623
32	1304	1668	**31**	1625	1551
34	1521	1561	**33**	1710	1700
36	1291	1395	**35**	1267	1423
38	1291	1603	**37**	1485	1672
40	1290	1432	**39**	1402	1283
46	1424	1624	**41**	1495	1636
			43	1522	1695
			45	1624	1834
			47	1227	1223

Laboratory analyses showed that the spring 2009 soil bulk density values ranged between 1227 and 1749 kg/m^3 (average is 1514.78 kg/m^3 ± 144.13). The fall soil bulk density was found between 1223 and 1834 kg/m^3 (average is 1527.71 kg/m^3 ± 143.58). The descriptive statistics showed that mean values of bulk density from deforested soils are greater than the forested soils (Figure 4.3), which is attributed to forest soils receiving less sunlight than the agricultural soils.

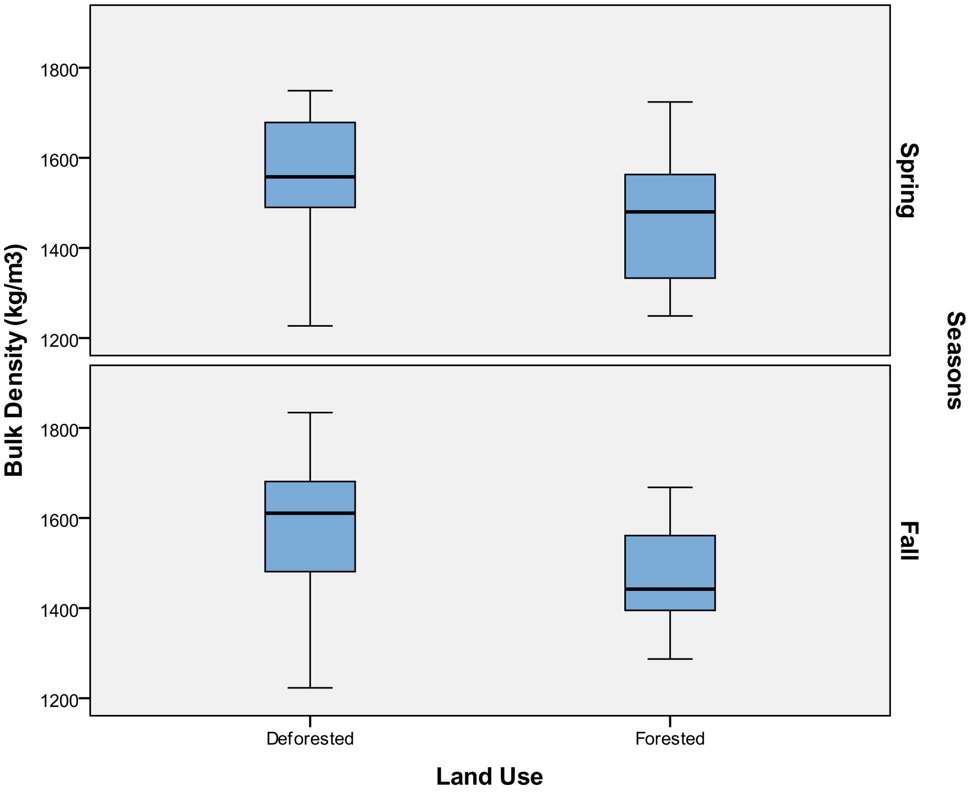


Figure 4.3. Box plots of the dry bulk density.

4.3.2. Soil pH

Soil pH is an important parameter governing most of the environmental processes. It plays a major role in the transportation of nutrients and ions. Laboratory analysis show that pH values for the two seasons from forested and deforested soils. Spring season soil pH values ranged between 4.20 and 6.61 (average is 4.87 ± 0.63), while for fall season soil pH values were 4.64 to 6.93 (average is 5.23 ± 0.68), for forested area. For deforested soils, spring pH values were between 4.46 and 6.53 (average is 5.13 ± 0.60), while for fall season, these were between 4.68 and 7.35 (average is 5.53 ± 0.66) (Figure 4.4). The alkalinity difference between these two seasons can possibly be attributed to the soil temperature differential between spring and fall 20009 seasons. These results showed that deforested soils also have a slightly acidic composition. Such acidic soil is used for agricultural purposes, such as hazelnut production in areas subject to this study. Janick and Paul (2008) stated that a soil pH of 6.5, which is slightly acidic, is ideal for hazelnut production. Forested and deforested soils were in slightly acidic range with no samples with high acidity or alkalinity.

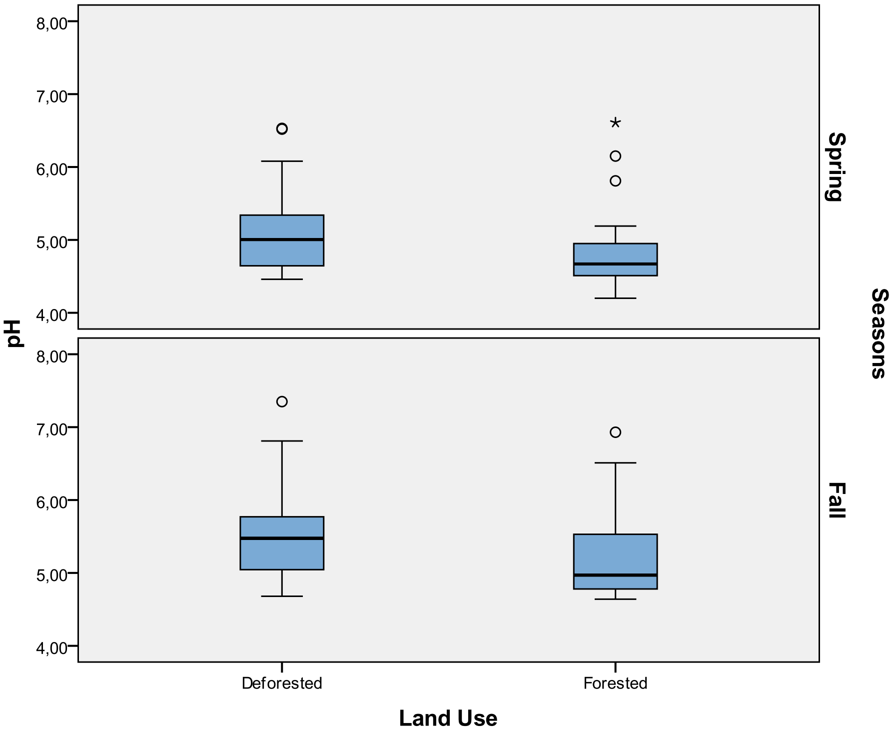


Figure 4.4. Box plots of the pH

4.3.3. Soil Gravimetric Moisture

Laboratory analyses showed that the spring season soil gravimetric moisture was in the range of 14.23 to 25.24 % (average is 20.95 % ± 3.76), while fall season soil gravimetric moisture values were 11.39 to 26.46 % (average is 18.40 % ± 3.58), for forested area. For deforested soils, spring soil gravimetric moisture values were between 12.15 and 32.55 % (average is 19.87 % ± 4.53), while for fall season, these were between 10.62 and 29.21 % (average is 19.87 % ± 4.62) (Figure 4.5). Luo and Zhuo, (2006) observed a similar trend in their study and they explained it as follows: When large amounts of water are added to soil, soil moisture contents are recharged to high levels, but soil respiration rates are not very high. The low respiration rates at the high soil water contents are probably attributable to inhibition of gaseous movement in water-saturated soil soon after precipitation (Luo and Zhuo, 2006).

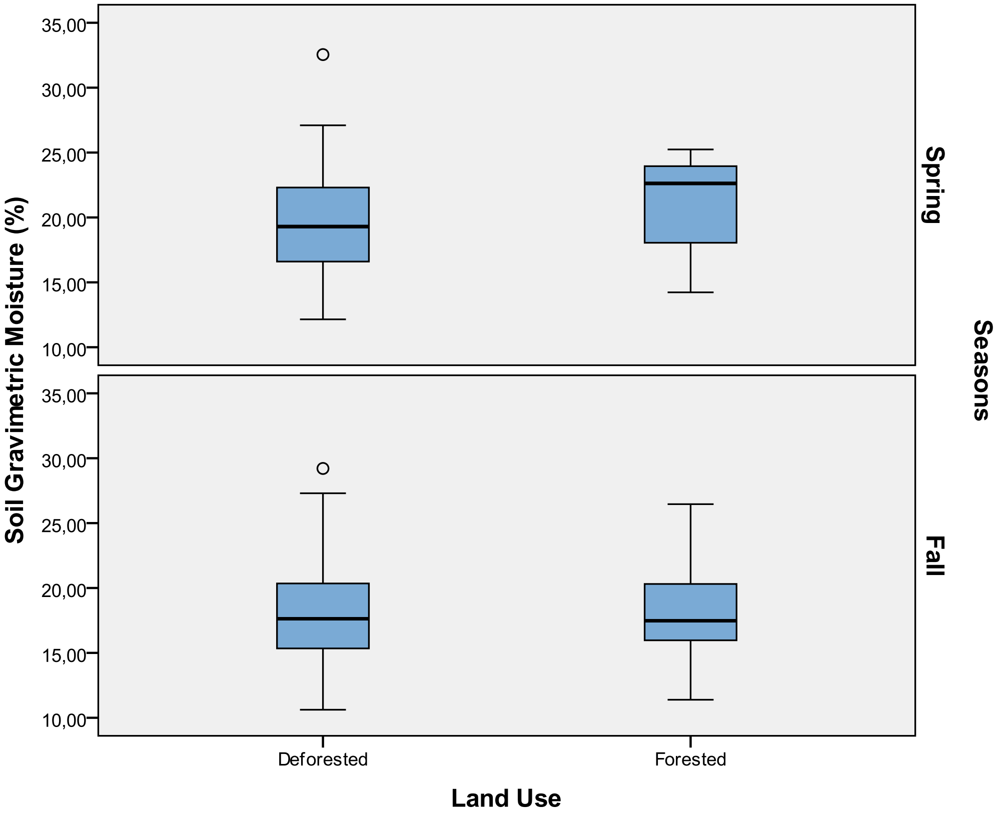


Figure 4.5 Box plots of the soil gravimetric moisture

4.3.4. Soil Texture

Soil texture is related to minerals in the soil and does not change with land use management or agricultural activities. The texture requires a careful analysis for better understanding the degree of carbon loss expected from conversion to agriculture or the possibility of carbon sequestration (Walker and Desanker, 2004). Table 4.6 shows the percentage ratios of clay, silt, and sand of the soil samplings examined in this study. The soil texture classes of 19 sample locations were classified as Sandy Loam (SL), based on the USDA soil particles size triangle (1938). The soil texture of 5 sample locations was classified as clay (C), while 11 locations was clay loam (CL). The highest percentages of clay were measured at sampling locations 9, 17, 18, 28, 39, and 47. Majority of these locations are in the deforested soils and they were categorized as agricultural production soils. Hazelnut is the dominating plant species in the agricultural production soils and the clay content in these locations is measured high because the ideal and suitable soil type is clay or clay loam for hazelnut (Adiloglu, 2004).

According to Milne (2008) organic matter can be trapped in very small spaces between clay particles making them inaccessible to microorganisms and therefore slowing the decomposition in soil. Broge et al. (2004) confirmed the correlation with the electrical conductivity and Molin et al. (2005) quantified that electrical conductivity depends on soil moisture and chemical composition of the soil solution and soil exchangeable ions, soil clay content, and the interaction between non-exchangeable and exchangeable ions in the soil.

Table 4.6. Soil texture percentages

Forested Area					Deforested Area				
Sampling Points	**Clay (%)**	**Sand (%)**	**Silt (%)**	**Texture Class**	**Sampling Points**	**Clay (%)**	**Sand (%)**	**Silt (%)**	**Texture Class**
2	15	67	18	SL	**1**	11	75	14	SL
4	9	69	22	SL	**3**	7	81	12	LS
6	34	24	42	CL	**5**	37	24	39	CL
8	34	30	36	CL	**7**	29	25	46	CL
10	39	24	37	CL	**9**	41	27	32	C
12	13	62	25	SL	**11**	17	47	36	L
14	11	63	26	SL	**13**	11	67	22	SL
16	9	77	14	SL	**15**	11	69	20	SL
18	39	24	37	CL	**17**	39	26	35	CL
20	13	68	19	SL	**19**	15	62	23	SL
22	20	59	21	SL	**21**	19	60	21	SL
24	19	58	23	SL	**23**	20	56	24	SL
26	11	66	23	SL	**25**	15	51	34	L
28	45	22	33	C	**27**	42	26	32	C
30	15	63	22	SL	**29**	16	65	19	SL
32	18	62	20	SL	**31**	17	61	22	SL
34	30	30	40	CL	**33**	28	41	31	CL
36	33	32	35	CL	**35**	35	27	38	CL
38	5	88	7	S	**37**	4	90	6	S
40	53	19	28	C	**39**	42	25	33	C
46	22	54	24	SCL	**41**	10	75	15	SL
					43	11	79	10	SL
					45	13	65	22	SL
					47	49	29	22	C

4.3.5. Soil and Ambient Temperature

Soil and ambient temperature was measured at at each sampling location during both field trip. Figures 4.6 and 4.7 present the descriptive statistics concerning with soil and ambient temperature, respectively. The measured spring 2009 soil temperatures were in the range from 12 to 16 ^{o}C (average is 12.95 ^{o}C ± 1.12), while fall soil temperature were from12 to 19 ^{o}C (average is 15.14 ± 1.42), for forested area. For deforested soils, spring soil temperature were between 12 and 20 ^{o}C (average is 14.27 ^{o}C ± 1.65), while for fall season, the soil temperatures were between 10 and 19 ^{o}C (average is 14.83 ^{o}C ± 1.88). As a result, the soil temperature in forested soils remains lower than deforested soils.

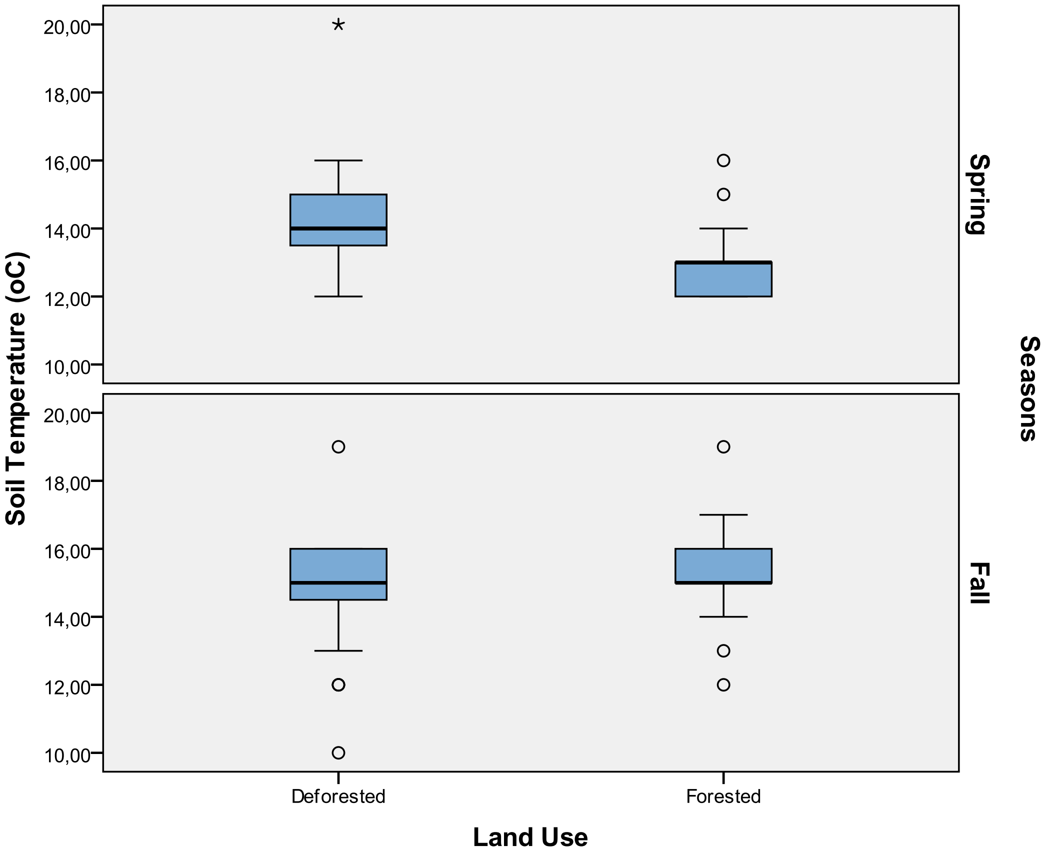


Figure 4.6. Box plots of the soil temperature

The spring 2009 ambient temperature was measured in the range from 9 to 21.10 ^{o}C (average is 14.58 ^{o}C ± 3.35), while fall ambient temperature values were from 13.90 to 21.50

^{o}C (average is 18.21 ± 2.03), for forested area. For deforested soils, spring ambient temperature values were between 10 and 26.80 ^{o}C (average is 15.26 ^{o}C ± 4.27), while for fall season, these were between 14.60 and 22.50 ^{o}C (average is 19.30 ^{o}C ± 1.99) (Figure 4.7). The land use change has an effect on soil and ambient temperature. The ambient temperature of forested soils is lower compared to deforested area. The natural vegetation in forest limits the penetration of solar radiation. As a result, the ambient temperature in forested remains lower than deforested.

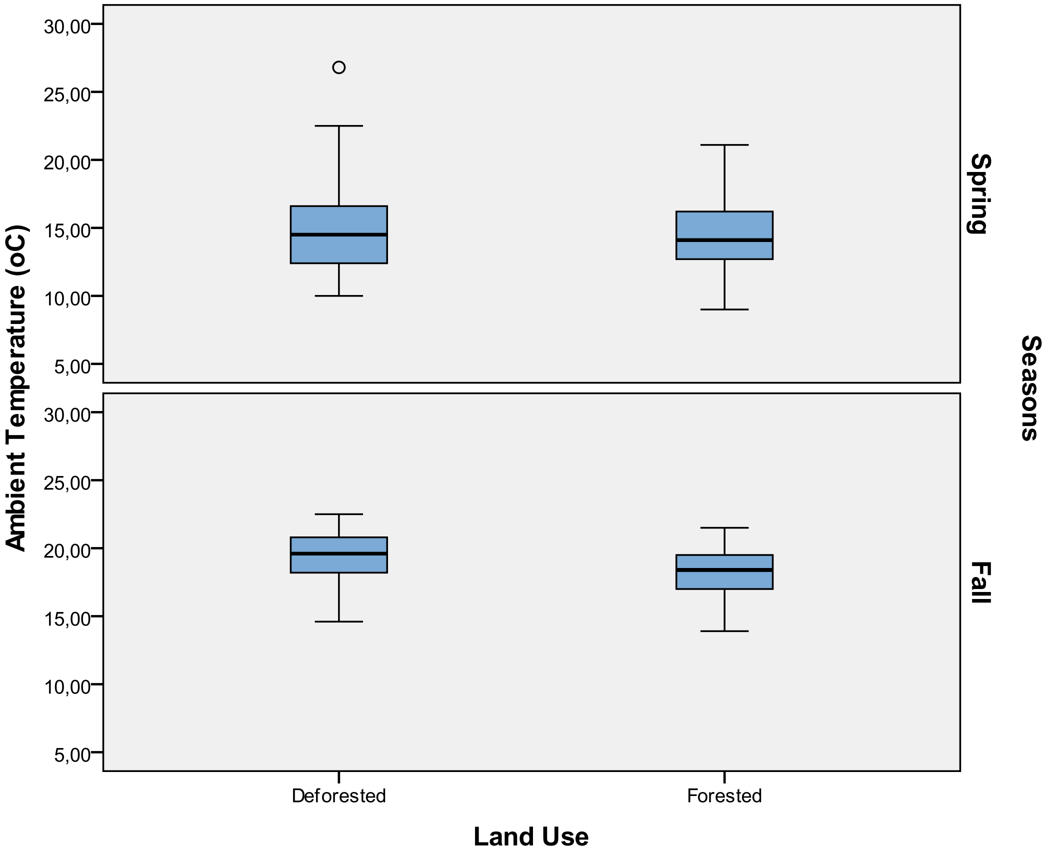


Figure 4.7. Box plots of the ambient temperature

4.3.6. Electrical Conductivity (EC)

The electrical conductivity of soils varies depending on the amount of moisture held by soil particles. Sands have a low conductivity, silts have a medium conductivity, and clays have a high conductivity. Consequently, EC correlates strongly to soil particle size and texture (Grisso et al., 2009). The laboratory results demonstrated that the highest EC results was observed in the fall season in deforested soils (620 µS/cm). For forested soils the highest results were also observed in the spring season (468 µS/cm). The mean value of EC of forested soils is slightly greater compared to deforested soils (132.7 µS/cm vs. 125.9 µS/cm). This may be due to the higher clay contents in the forested soils.

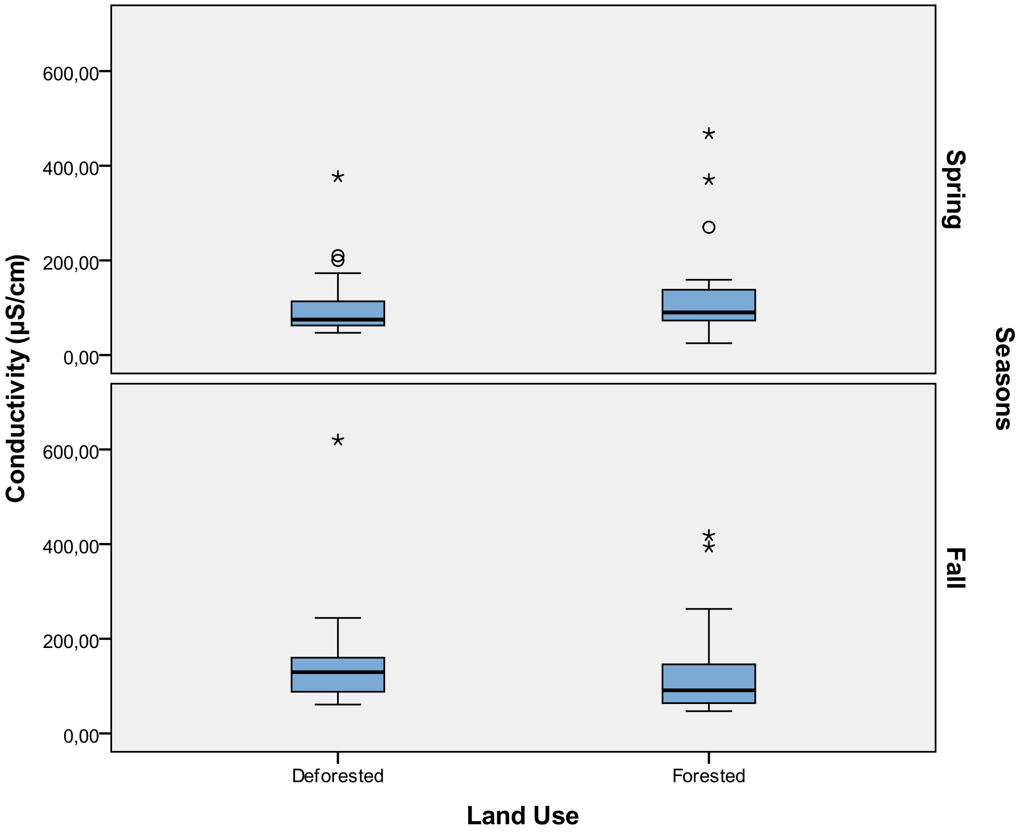


Figure 4.8. Box plot of the soil electrical conductivity

4.4. Satellite Image Analyses

Satellite image (dated 2007) was used to evaluate the spatial distribution of land use types in the study area (Table 4.8). The land use types of the soils can be seen in Figure 4.9. Table 4.7 shows land use types in 2007.

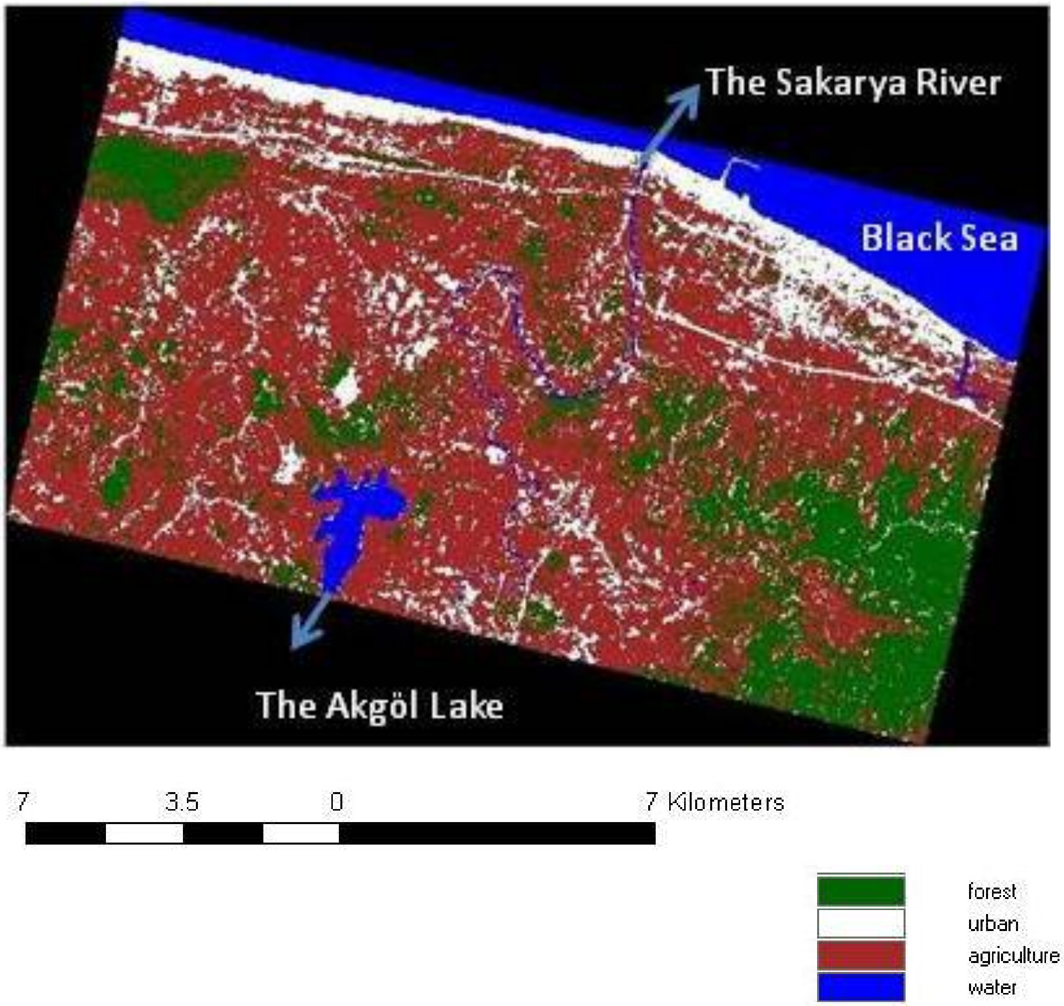


Figure 4.9. The land use maps on satellite images dated 2007 (Oral, 2010)

Table 4.7. Land use types values in 2007

Land Use Types	Soils (2007) hectares (ha)
Agricultural Production	15,400
Forests	4,758
Urban soils, Pasture & Meadows, Abandoned soils	3,907
Water (Akgol Lake, Sakarya River and Black Sea)	2,886.17
Total	26,951.17

Uncontrolled population expansion in urban soils forced people to look for other locations for conducting agricultural activities . Therefore, the pastures and abandoned soils were converted into the hazelnut plantations in the Karasu District.

4.5. Statistical Evaluation

The SPSS 17.00 software package was employed to evaluate the results and the correlation between carbon stocks, bulk density and environmental parameters from forested and deforested soils in Karasu District. Descriptive statistics (shown in tables 4.8 and 4.9) were computed to reveal the overall characteristics of the data. Pearson correlation analysis was performed to indicate the possible relationships between carbon stocks, bulk density, and factors affecting the soil elemental carbon.

Table 4.8. Descriptive statistics for different land use types (both seasons)

		Carbon Stock (kg/m^2)		Bulk Density (kg/m^3)		C:N		Electrical Conductivity (µS/cm)		Clay Content (%)	
		Forested	Deforested	Forested	Deforested	Forested	Deforested	Forested	Deforested	Forested	Deforested
GENERAL	Mean	12.363	12.115	1468.12	1567.73	132.74	125.90	10.09	9.11	23.19	22.46
	St. Dev.	4.117	5.455	125.154	143.59	108.37	93.50	5.23	6.58	13.38	13.22
	Min.	5.03	4.29	1249	1223	25.00	47.00	0.80	1.00	5	4
	Max.	23.86	33.66	1724	1834	468.00	620.00	28.85	37.75	53	49

		Ambient Temperature (°C)		Soil Temperature (°C)		Moisture Content (%)		pH	
		Forested	Deforested	Forested	Deforested	Forested	Deforested	Forested	Deforested
GENERAL	Mean	16.40	17.28	14.05	14.55	5.07	5.33	19.68	19.14
	St. Dev.	3.30	3.88	1.68	1.77	0.678	0,658	3.85	4.59
	Min.	9.00	10.00	12.00	10.00	4.20	4.46	11.39	10.62
	Max.	21.50	26.80	19.00	20.00	6.93	7.35	26.46	32.55

Table 4.9. Descriptive statistics for different land use types in spring and fall (combined)

		Carbon Stock (kg/m^2)		**Bulk Density (kg/m^3)**		**C:N**		**Electrical Conductivity (µS/cm)**		**Clay Content (%)**	
		Forested	**Deforested**	**Forested**	**Deforested**	**Forested**	**Deforested**	**Forested**	**Deforested**	**Forested**	**Deforested**
SPRING	**Mean**	11.95	11.60	1464.71	1558.58	11.78	9.61	130.19	105.08	23.19	22.46
	St. Dev.	4.47	4.60	136.40	140.17	6.03	6.01	110.45	74.63	13.54	13.36
	Min.	6.06	5.70	1249	1227	3.16	1	25	47	5	4
	Max.	23.86	25.55	1724	1749	28.85	25.98	468	377	53	49
FALL	**Mean**	12.78	12.63	1471.52	1576.87	8.40	8.60	135.29	146.71	23.19	22.46
	St. Dev.	3.80	6.25	116.10	149.37	3.71	7.20	108.92	112.55	13.54	13.36
	Min.	5.03	4.29	1287	1223	0.80	2.67	47	61	5	4
	Max.	20.02	33.66	1668	1834	18.84	37.75	418	620	53	49

		Ambient Temperature (°C)		**Soil Temperature (°C)**		**Moisture Content (%)**		**pH**	
		Forested	**Deforested**	**Forested**	**Deforested**	**Forested**	**Deforested**	**Forested**	**Deforested**
SPRING	**Mean**	14.58	15.26	12.95	14.27	20.95	19.87	4.87	5.13
	St. Dev.	3.35	14.50	1.12	1.65	3.76	4.53	0.63	0.60
	Min.	9	10	12	12	14.23	12.15	4.20	4.46
	Max.	21.10	26.80	16	20	25.24	32.55	6.61	6.53
FALL	**Mean**	18.21	19.30	15.14	14.83	18.41	18.41	5.27	5.53
	St. Dev.	2.03	1.20	1.424	1.88	3.58	4.46	0.68	0.67
	Min.	13.90	14.60	12	10	11.39	10.62	4.64	4.68
	Max.	21.50	22.50	19	19	26.46	29.21	6.93	7.35

There was a little difference between the mean value of carbon stocks in forested and deforested soils. The mean value of carbon stocks in the forest area is higher than in the deforested area.

Prior to conducting significance testing, the parameters that do not follow a normal distribution with uniform variance were transformed. The three most commonly used transformations for quantitative data are (Geissen et al., 2009):

(i) The logarithm transformation,
(ii) The square root transformation,
(iii) The reciprocal transformation

These transformations are called variance-stabilizing because the purpose is to make variances the same (Switzer and Nelson, 1972). Results of the Shapiro-Wilk normality tests and Kolmogorov-Smirnov statistical tests (Geissen et al., 2009) indicated that Carbon stock, soil pH, electrical conductivity, gravimetric moisture content and C:N ratio did not meet the normal distribution criteria. The results of these tests are given in the Appendix. Therefore, Log transformation was applied to Carbon stock, soil pH, electrical conductivity, gravimetric moisture content and C:N ratio to obtain the normal distribution (Korsaeth, 2005).

4.5.1. Trend analyses

This section presents mean comparison and correlation analyses performed to monitor effects of land use change, seasonal variation, and soil texture content (by means of clay percentage) on carbon stock and bulk density. The analysis of variance (ANOVA) and the mean value comparison tests were ran on factors affecting the soil carbon stock to compare results for different seasons and land use types. Specifically, the following issues will be addressed:

- Trend analyses of the parameters (soil carbon stock and bulk density) with land use change
- Trend analyses of the parameters with seasonal trends
- Trend analyses of the parameters with clay content of the study soils

4.5.1.1. Land Use Changes. The parameters were grouped into deforested and forested land use types, there were 48 and 42 sampling locations, respectively. Based on ANOVA results, the significant differences were presented in Table 4.10 with bold font.

Table 4.10. The results of variance analysis for land uses (data from both seasons are combined together)

Parameter	**F value**	**Significant (p value)**
Carbon Stock	0.308	0.580
Bulk Density	12.138	**0.001****
C:N Ratio	1.353	0.248
Ambient Temperature	1.342	0.250
Soil Temperature	1.904	0.171
G. Moisture Content	0.573	0.451
pH	4.088	0.046*
E. Conductivity	0.016	0.900

* significant (p) ≤ 0,05
** significant (p) ≤ 0,01, with bold font.

The overall bulk density measurements from deforested soils are higher compared to forested soils (Table 4.8). The differences between the means of bulk density from forested and deforested soils are statistically significant.

The differences in the average carbon stock (calculated over a depth of 1m) between forested and deforested soils was $0.35\ kg/m^2$ in the spring of 2009 and $0.15\ kg/m^2$ in the fall of 2009. Based on the ANOVA results, the difference in the carbon stock for forested and deforested soils when combining data from both seasons where not significant (F = 0.450, significance (p)= 0.580), suggesting that direct effect of land use on carbon stock does not exist.

Deforestation realized in the last two decades within the study area was observed to have a some effect in the change of carbon content after 0 - 30 cm of the earth. However, this difference was offset by the difference in the dry bulk density which was observed to be significantly higher for deforested soils, thus no statistically significant change caused by deforestation in the total amount of carbon sequestered in soil was determined.

4.5.1.2. Seasonal Trends. For seasonal effects, the analysis of variance was conducted on the parameters. The significant differences between means were presented with bold font (Table 4.11).

Table 4.11. The results of variance analysis for seasonal changes

Parameter	**F value**	**Significant (p value)**
Carbon Stock	0.837	0.363
Bulk Density	0.181	0.672
C:N Ratio	3.451	0.067
Ambient Temperature	35.089	**0.000****
Soil Temperature	15.058	**0.000****
G. Moisture Content	5.276	0.024
pH	9.445	**0.003**
E. Conductivity	2.642	0.108

* significant (p) ≤ 0,05
** significant (p) ≤ 0,01, with bold font.

Results of the statistical tests suggest that carbon stock does not have a seasonal trend. Table 4.11 indicated that the differences in mean carbon stock from spring and fall 2009 due to seasonal variations were not statistically significant (F=0.837, p=0.363). In addition, there was no significant differences between the mean value of bulk density in forested and deforested in spring and fall 2009 seasons (F=0.181, p=0.672).

The ANOVA results showed that the ambient and soil temperature differences between means of forested and deforested lands on the days that field campaigns were conducted are significant (for ambient temperature F=35.089, p=0.00, for soil temperature F=15.058, p=0.00).

4.5.1.3. Soil Texture Type Trends. The correlation between the clay content, carbon stock and bulk density from forested and deforested soils were investigated in this part (Table 4.12).

Table 4.12. Correlation between clay content, carbon stock and bulk density

	Carbon Stock & Clay Content				**Bulk Density & Clay Content**			
	Forested		**Deforested**		**Forested**		**Deforested**	
	Corr.	**p**	**Corr.**	**p**	**Corr.**	**p**	**Corr.**	**p**
All seasons	0.347	0.025	0.320*	0.027	-0.155	0.327	-0.498**	0.000
Spring	0.301	0.185	0.190	0.374	-0.128	0.582	-0.421*	0.041
Fall	0.403	0.070	0.433	0.034	-0.188	0.413	-0.572**	0.003

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

There is a significant correlation between clay content and bulk density for deforested soils for the all seasons (correlation factor (Corr.), -0.498, significant value (p), 0.00). The bulk density diminishes while the clay content increases, so there is an inverse proportionality between the clay content and bulk density in deforested area (Figure 4.10). High correlation can be explained by the bulk density decreased while air content increased in soil with increasing organic matter content. The compression index in the field was virtually unaffected by soil texture and organic matter content, while the compression index obtained in the uniaxial test was positively correlated to the clay content. On the other hand, there is an unexpected results showing the increased in soil organic carbon (SOC) content increased with precipitation and clay content and decrease with temperature. The importance of these parameters changed with depth, climate dominating in shallow layers and clay content dominating in deeper layers, possibly due to increasing percentages of slowly cycling SOC fractions at depth (Jobbágy and Jackson, 2000).

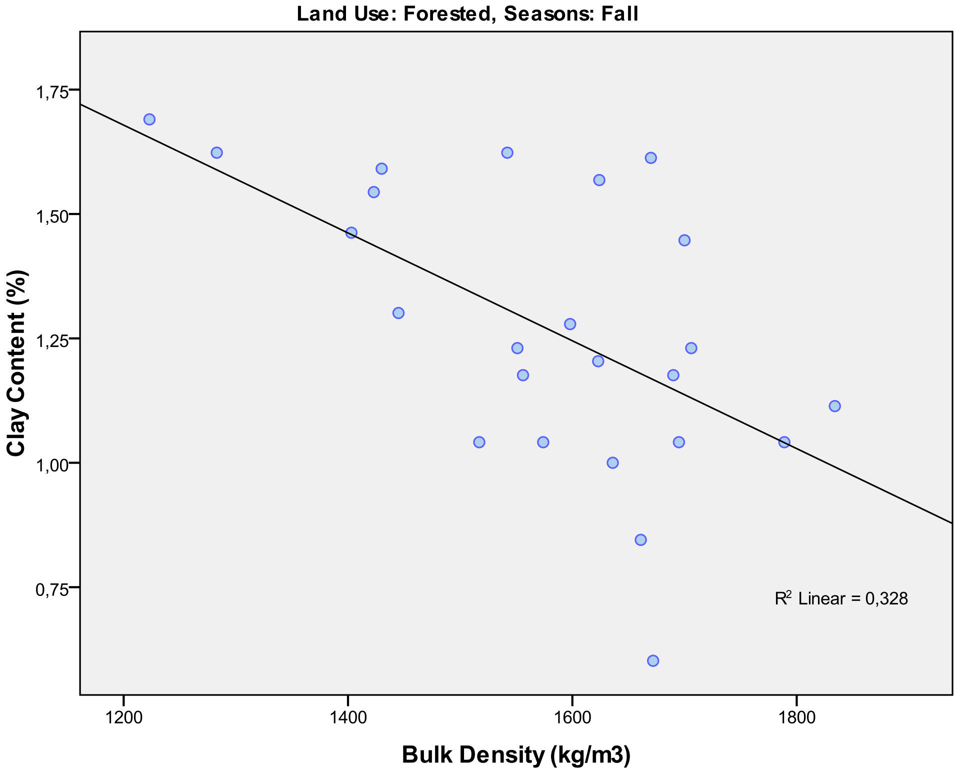


Figure 4.10. Correlation of dry bulk density and clay content for deforested soils

The significant correlation at 0.05 significant levels between the clay content and carbon stock from deforested soils can be seen in Figure 4.11 (correlation factor (Corr.), 0.320, significant value (p), 0.027). According to Lal (2001) this high correlation can be explained by the removal of the natural vegetation and conversion of these forests to other types of land use, which increases the carbon holding capacity of clay minerals in the soil. A positive correlation between soil organic carbon stock and clay content is observed in Flanders, Belgium (Meersmans et al., 2008). Schimel et al. (1994) found a similarly high correlation and they reported that soils with high clay content lead to more stabilization of soil organic carbon.

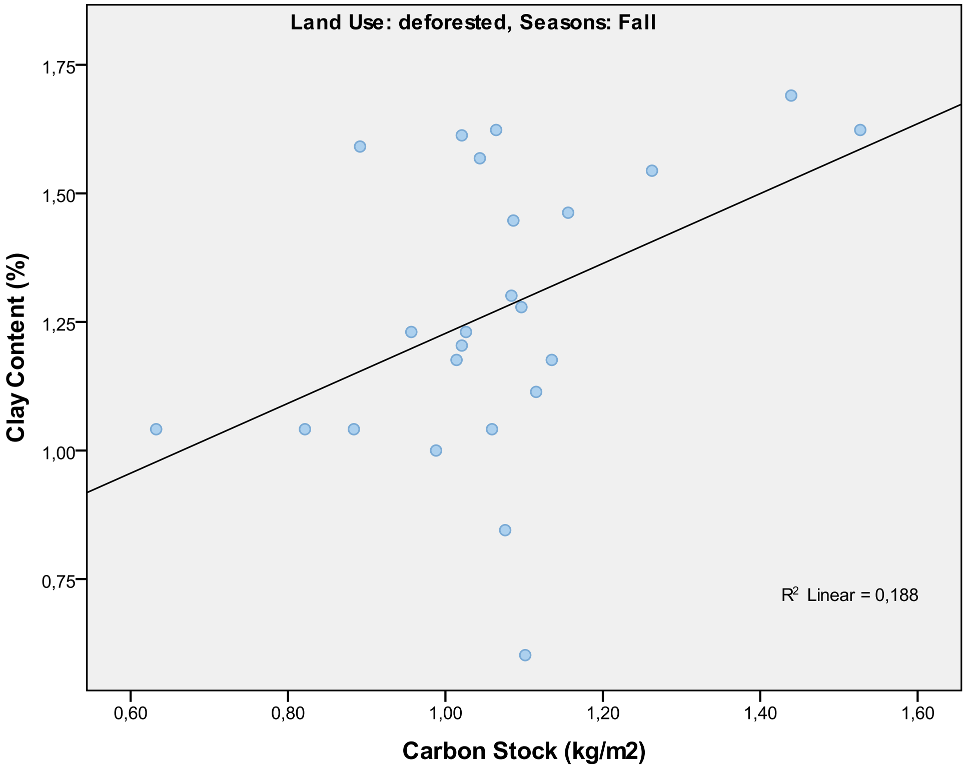


Figure 4.11. Correlation of carbon stock and clay content for deforested soils

4.5.2. Correlation of the Parameters

The statistical correlation computes the simultaneous change in value of two numerically valued random variables. There are two types of correlations:

(i) Bivariate correlation
(ii) Partial correlation

The bivariate correlation procedure computes Pearson's correlation coefficient. This coefficient obtains information about the degree of correlation as well as the direction of the correlation.

Partial correlation determines the relationship between two variables while controlling for a third variable. The aim is to find the unique variance between two variables while eliminating the variance from a third variable.

In this study, the bivariate correlation were computed to assess relations between variables . Table 4.13 shows the a qualitative description of different levels of correlation (Cohen, 1988). Correlation coefficients significant at the 0.05 are identified with a single asterisk, and those significant levels at 0.01 are identified with two asterisks.

Table 4.13. Pearson correlation coefficients (Cohen, 1988)

Correlation Coefficient	Descriptor
0.0 – 0.1	Trivial, very small, insubstantial, tiny, practically zero
0.1 – 0.3	Small, low, minor
0.3 – 0.5	Moderate, medium
0.5 – 0.7	Large, high, major
0.7 – 0.9	Very large, very high, huge
0.9 – 1.0	Nearly, practically, or almost perfect, distinct, inifinite

The specific goal of this section is to assess the Correlations between carbon stock, bulk density and other parameters when taking data from all seasons together as well as for each season. Separate correlat’ons are computed for data from forested and deforested soils.

The correlation parameters and results are shown in Table 4.14, and Table 4.15.

Table 4.15. Correlation results between parameters in all and individual seasons for deforested areas.

Season	Pair			Correlation
All Seasons	Carbon Stock	-	Bulk Density	-0.491*
	Carbon Stock	-	pH	0.340*
	Carbon Stock	-	Soil Temperature	-0.318*
	Carbon Stock	-	E. Conductivity	0.557**
	Carbon Stock	-	Ambient Temperature	0.048
	Carbon Stock	-	G. Moisture Content	0.466*
	Carbon Stock	-	C:N ratio	0.489*
	Carbon Stock	-	N Content	0.328*
	Carbon Stock	-	Clay Content	0.320*
	Bulk Density	-	pH	-0.078
	Bulk Density	-	Soil Temperature	0.029
	Bulk Density	-	E. Conductivity	-0.495**
	Bulk Density	-	Ambient Temperature	0.058
	Bulk Density	-	G. Moisture Content	-0.630**
	Bulk Density	-	C:N ratio	-0.363*
	Bulk Density	-	Clay Content	-0.498*
Spring	Carbon Stock	-	Bulk Density	-0.610**
	Carbon Stock	-	pH	0.377
	Carbon Stock	-	Soil Temperature	-0.372
	Carbon Stock	-	E. Conductivity	0.465*
	Carbon Stock	-	Ambient Temperature	0.027
	Carbon Stock	-	G. Moisture Content	0.634**
	Carbon Stock	-	C:N ratio	0.428*
	Carbon Stock	-	N Content	0.405*
	Carbon Stock	-	Clay Content	0.190
	Bulk Density	-	pH	-0.492*
	Bulk Density	-	Soil Temperature	0.084
	Bulk Density	-	E. Conductivity	-0.643**
	Bulk Density	-	Ambient Temperature	0.094
	Bulk Density	-	G. Moisture Content	-0.580**
	Bulk Density	-	C:N ratio	-0.459*
	Bulk Density	-	Clay Content	-0.421*
Fall	Carbon Stock	-	Bulk Density	-0.411*
	Carbon Stock	-	pH	0.300*
	Carbon Stock	-	Soil Temperature	-0.309*
	Carbon Stock	-	E. Conductivity	0.652**
	Carbon Stock	-	Ambient Temperature	-0.021
	Carbon Stock	-	G. Moisture Content	0.379*
	Carbon Stock	-	C:N ratio	0.574**
	Carbon Stock	-	N Content	0.266
	Carbon Stock	-	Clay Content	0.433*
	Bulk Density	-	pH	0.251
	Bulk Density	-	Soil Temperature	-0.035
	Bulk Density	-	E. Cconductivity	-0.448*
	Bulk Density	-	Ambient Temperature	-0.096
	Bulk Density	-	G. Moisture Content	-0.671**
	Bulk Density	-	C:N ratio	-0.262
	Bulk Density	-	Clay Content	-0.572**

**Correlation is significant at the 0.01 level (2-tailed), with red font

*Correlation is significant at the 0.05 level (2-tailed), with blue font

Table 4.16. Correlation between parameters from forested areas for each individual season and for both seasons together

Season	Pair			Correlation
All seasons	Carbon Stock	-	Bulk Density	-0.156
	Carbon Stock	-	pH	-0.171
	Carbon Stock	-	Soil Temperature	-0.170
	Carbon Stock	-	E. Conductivity	0.056
	Carbon Stock	-	Ambient Temperature	0.095
	Carbon Stock	-	G. Moisture Content	0.105
	Carbon Stock	-	C:N ratio	0.331*
	Carbon Stock	-	N Content	0.151
	Carbon Stock	-	Clay Content	0.347*
	Bulk Density	-	pH	0.098
	Bulk Density	-	Soil Temperature	0.022
	Bulk Density	-	E. Conductivity	-0.234
	Bulk Density	-	Ambient Temperature	0.301*
	Bulk Density	-	G. Moisture Content	-0.357*
	Bulk Density	-	C:N ratio	0.002
	Bulk Density	-	Clay Content	-0.155
Spring	Carbon Stock	-	Bulk Density	-0.388*
	Carbon Stock	-	pH	-0.166
	Carbon Stock	-	Soil Temperature	-0.126
	Carbon Stock	-	E. Conductivity	0.126
	Carbon Stock	-	Ambient Temperature	0.161
	Carbon Stock	-	G. Moisture Content	0.085
	Carbon Stock	-	C:N ratio	0.497*
	Carbon Stock	-	N Content	0.085
	Carbon Stock	-	Clay Content	0.301
	Bulk Density	-	pH	-0.026
	Bulk Density	-	Soil Temperature	0.058
	Bulk Density	-	E. Conductivity	-0.405*
	Bulk Density	-	Ambient Temperature	0.391*
	Bulk Density	-	G. Moisture Content	-0.374*
	Bulk Density	-	C:N ratio	0.030
	Bulk Density	-	Clay Content	-0.128
Fall	Carbon Stock	-	Bulk Density	0.135
	Carbon Stock	-	pH	-0.284
	Carbon Stock	-	Soil Temperature	-0.528**
	Carbon Stock	-	E. Conductivity	-0.035
	Carbon Stock	-	Ambient Temperature	-0.202
	Carbon Stock	-	G. Moisture Content	0.232
	Carbon Stock	-	C:N ratio	0.287
	Carbon Stock	-	N Content	0.210
	Carbon Stock	-	Clay Content	0.403*
	Bulk Density	-	pH	0.233
	Bulk Density	-	Soil Temperature	-0.044
	Bulk Density	-	E. Conductivity	-0.027
	Bulk Density	-	Ambient Temperature	0.268
	Bulk Density	-	G. Moisture Content	-0.363*
	Bulk Density	-	C:N ratio	-0.009
	Bulk Density	-	Clay Content	-0.188

** Correlation is significant at the 0.01 level (2-tailed), with red font

* Correlation is significant at the 0.05 level (2-tailed), with blue font

High correlation with at least 0.05 significance among parameters are presented in scatter graphics and discussed below.

- In all seasons for deforested areas, a moderate negative correlation was found between carbon stock and bulk density (corr.=-0.491, $p<0.05$) (Figure 4.12). A high correlation (corr.= 0.557, $p<0,01$) was observed between carbon stock and electrical conductivity from deforested soils. Figure 4.13 shows the correlation between carbon stock and electrical conductivity. Between bulk density and gravimetric moisture content high negative correlation was also observed (corr.=-0.630, $p<0,01$) (Figure 4.14).

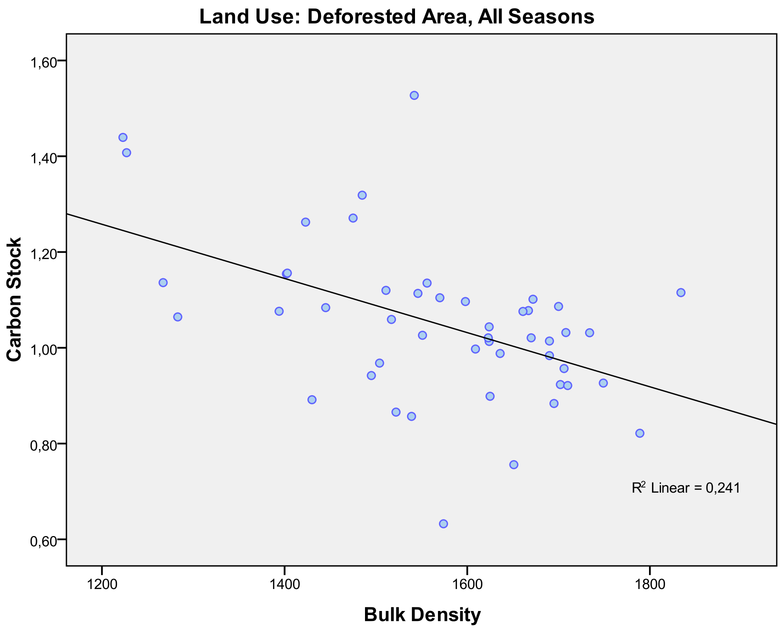


Figure 4.12. The carbon stock and bulk density for deforested soils

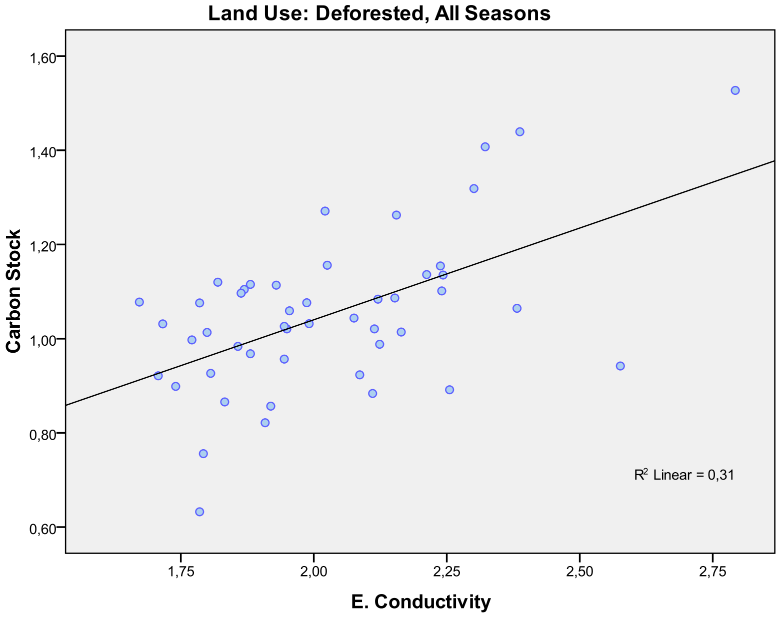


Figure 4.13. The carbon stock and electrical conductivity for deforested soils

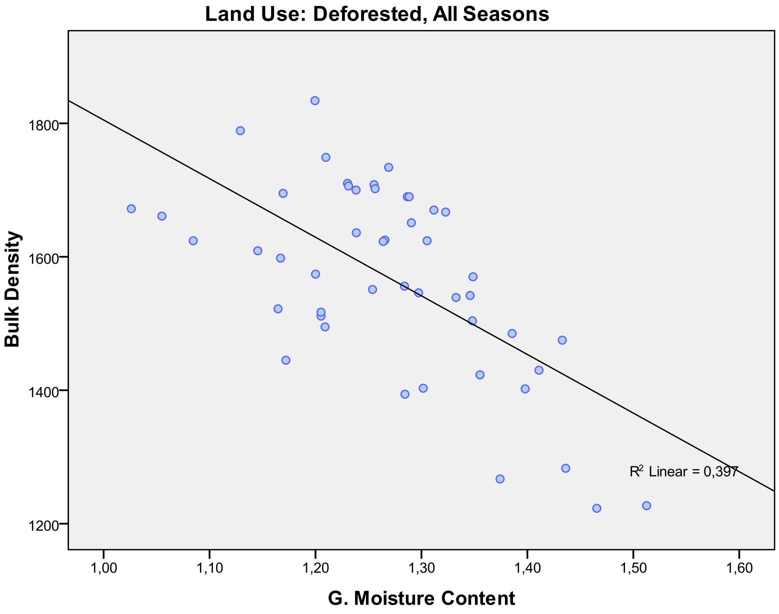


Figure 4.14. The bulk density and gravimetric moisture content for deforested soils

- In spring season for deforested areas, a high negative correlation was monitored between carbon stock and bulk density in deforested areas at significant levels (p<0.01), with a correlation coefficient of -0.610 (Figure 4.15). Between carbon stock and gravimetric moisture a high correlation (corr.=0.634, p<0,01) was observed (Figure 4.16). Stoyan, et al. (2000) also reported moderate correlation between elemental carbon and moisture content (r=0.49, p<0.05). There is a negative correlation (corr.=-0.580, p<0,01) between bulk density and gravimetric moisture content. Figure 4.17 shows this negative correlation. For spring 2009 bulk density is highly correlated with electrical conductivity (corr.=-0.643, p<0,01) as shown in Figure 4.18.

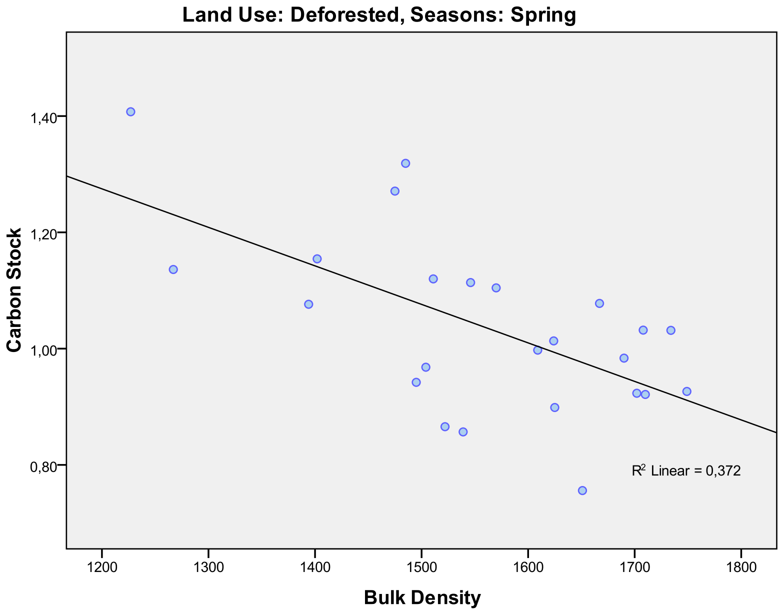


Figure 4.15. The carbon stock and bulk density for deforested soils in spring

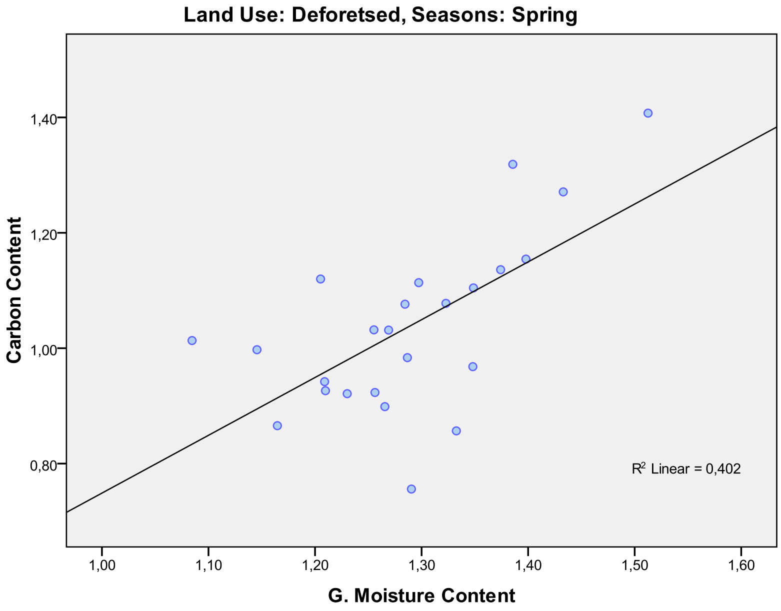


Figure 4.16. The carbon stock and gravimetric moisture content for deforested soils in spring season

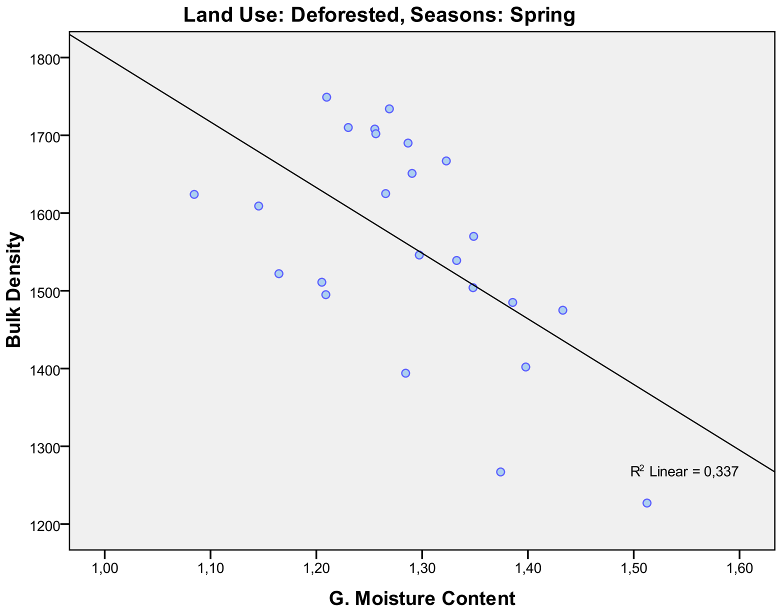


Figure 4.17. Bulk density and gravimetric moisture content for deforested soils in spring season

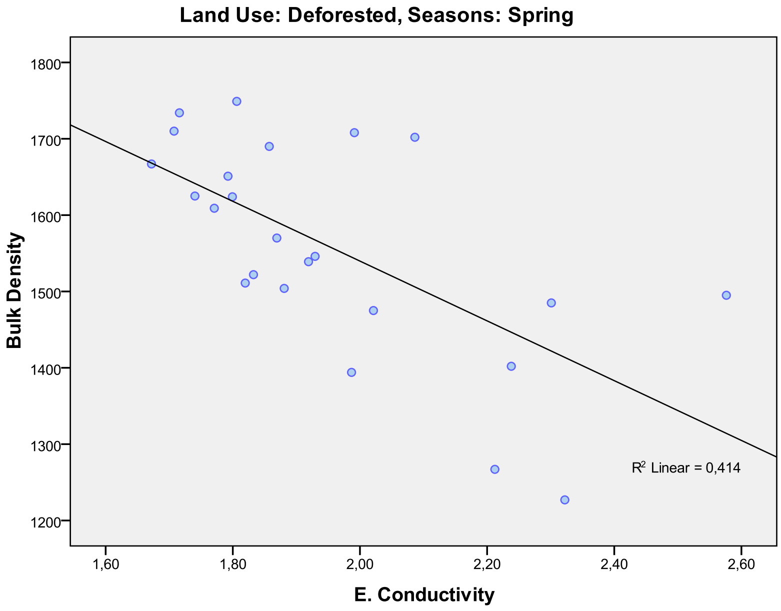


Figure 4.18. Bulk density and electrical conductivity for deforested soils in spring season

- In the fall season for deforested areas, a high correlation was found between carbon stock and electrical conductivity (corr.=0.652, p<0.01) (Figure 4.19). A high correlation (corr.= 0.574, p<0,01) was observed between carbon stock and C:N ratio from deforested soils. Figure 4.20 shows the correlation between carbon stock and soil temperature. Between bulk density and gravimetric moisture content a high negative correlation was detected (corr.=-0.671, p<0,01) (Figure 4.21). There was a similar trend for the spring season. A high negative correlation was monitored between bulk density and clay content at significant levels (p<0.01), correlation coefficient is -0.572. This correlation was given in Figure 4.9 at the section of soil texture types trends.

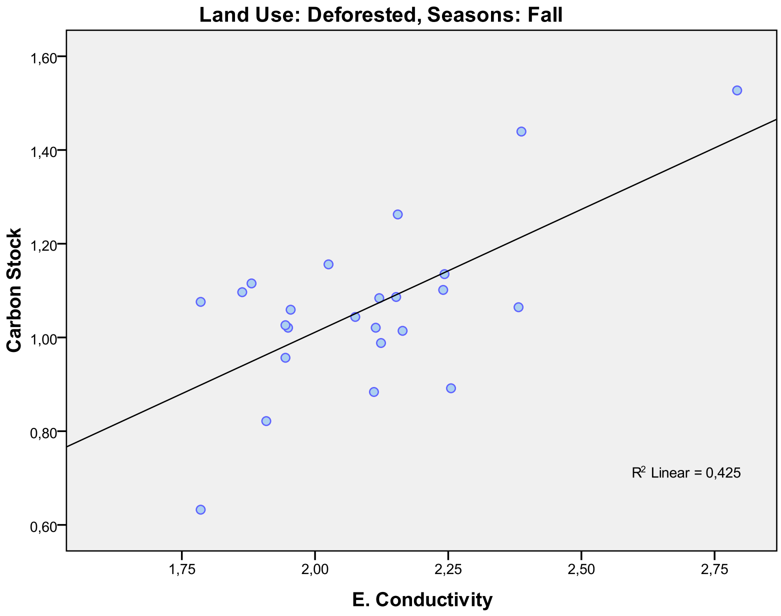


Figure 4.19. The carbon stock and electrical conductivity for deforested soils in fall season

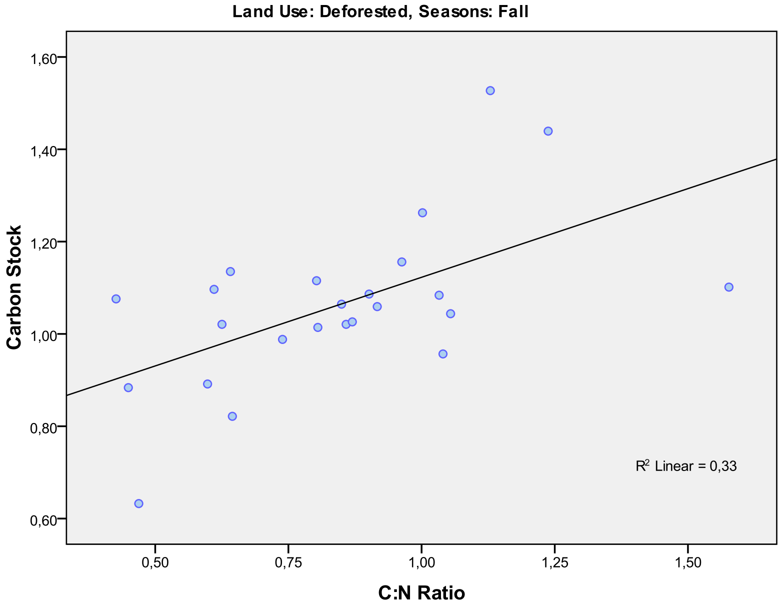


Figure 4.20. The carbon stock and C:N ratio for deforested soils in fall season

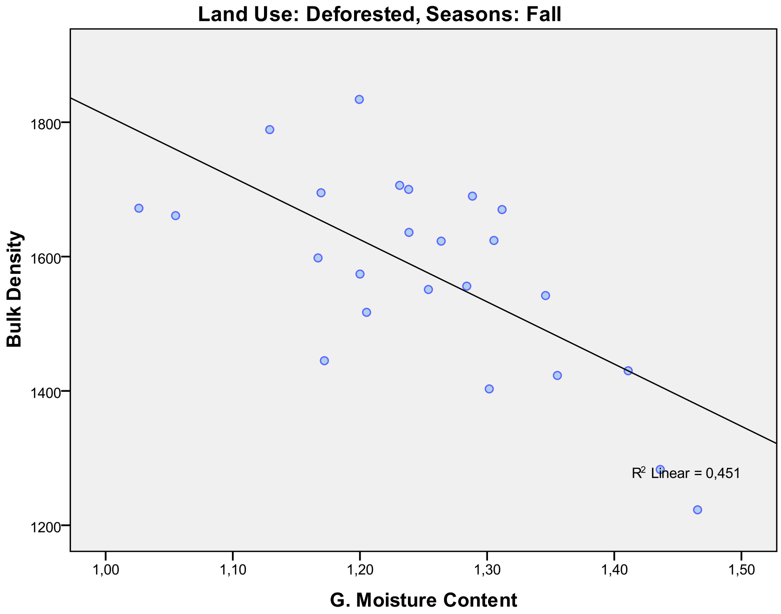


Figure 4.21. Bulk density and gravimetric moisture content for deforested soils in fall season

- In the forested areas there is not highly significant correlation for all seasons. The negative correlation between carbon stock and soil temperature was the only detected for the fall season (corr.=-0.528, p<0,01) (Figure 4.22).

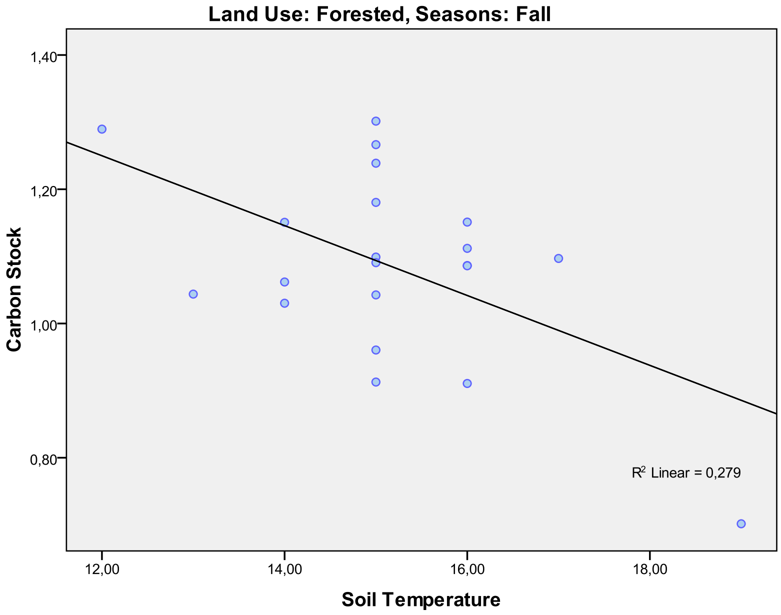


Figure 4.22. Carbon stock and soil temperature for forested soils in fall season

4.5.3. Regression Analyses

Stepwise linear regression was used to construct carbon stock model functions for different land uses and to explain carbon stocks in terms of other parameters. The analyses were conducted on parameters between dependent and independent variables. The dependent variables was defined as carbon stock and independent variables were bulk density, gravimetric water content, C:N ratio, electrical conductivity and soil temperature. Regression analysis estimate coefficients of a linear equation, involving one or more independent variables, those best predict the value of the dependent variable. The method of stepwise linear regression was conducted on parameters because variables incorporated in the model at every stage of the regression; then variables excluded from the equation were evaluated for entry.

For the deforested soils following equations were evaluated for the carbon stock as a function of parameters to show correlation with the carbon stock:

Model 1. Carbon Stock = 0.245 + 0.205 (C:N) + 0.309 (E.C)

Model 2. Carbon Stock = 0.637 + 0.186 (C:N) + 0.315 (E.C) - 0.027 (S.T.)

Model 3. Carbon Stock = 0.237 + 0.179 (C:N) + 0.232 (E.C.) - 0.028 (S.T.) + 0.471 (G.M.C)

Table 4.17 shows the R^2-values of the equations for deforested soils.

Table 4.17. R^2 values of the regression models from deforested soils.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.641[a]	0.411	0.385	0.12981
2	0.701[b]	0.492	0.457	0.12198
3	0.750[c]	0.562	0.521	0.11452

a. Predictors: (Constant), C:N Ratio, E.C.
b. Predictors: (Constant), C:N Ratio, E.C, Soil Temp.(S.T.).
c. Predictors: (Constant), C:N Ratio, E.C, Soil Temp.(S.T.), G. Moisture content.(G.M.C.)

Table 4.17 indicates that the C:N ratio and electrical conductivity explains 38.5 % of the variance in carbon stock from deforested soils. Introduction of soil temperature to the model explains an additional 7.2 % of the variance and further introduction of gravimetric moisture content explains 6.4 % of the model.

For forested soils the following equations were evaluated for the carbon stock:

Model 1. Carbon Stock = 0.892 + 0.187 (C:N ratio)

Model 2. Carbon Stock = 0.651 + 0.186 (C:N ratio) + 0.188 (Clay Content)

Table 4.18 shows the R^2-values of the equations for forested soils.

Table 4.18. R^2 values of the regression models from forested soils.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.331[a]	0.110	0.088	0.14076
2	0.478[b]	0.229	0.189	0.13271

a. Predictors: (Constant), C:N Ratio

b. Predictors: (Constant), C:N Ratio, Clay Content

c. Land Use = Forested

As can be seen from Table 4.18 C:N ratio alone explains 8.8 % of the variance in carbon stock from forested soils. Introduction of clay to the model explains an additional 10.1 % of the variance.

4.6. Geostatistical Analyses

In this section, the results of the geostatistical analyses are presented and spatial averages of soil carbon stock are computed. Geostatistical maps were developed using the ordinary kriging method. The analyses were conducted on carbon stock in spring and fall seasons.

The raster calculator tool of the spatial analyst of SPSS was employed to obtain the overlaid kriging maps. This tool uses map algebra to weight rasters, and make selections on the data in the form of queries with mathematical operators and Spatial Analyst functions. Forested and deforested land use fractions produced from land use types (Figure 4.23), at each grid point were multiplied by the kriging values individually and the results of the multiplication were summed up. The sum up function represents the local estimate of the attribute taking into account the land use distribution at that location and adjacent carbon stock data.

Figure 4.24 shows the results of fractions from forested and deforested areas. The dark blue color represents the forested; the light green represents the deforested areas. The land use fractions maps were used to calculate the spatial average of carbon stock. The overall computed value inserted into all grid cells were divided to number of grid cells. 41,796 (100m x 100m) grid cells are used in this study. Therefore, the spatial average of each grid cell was obtained.

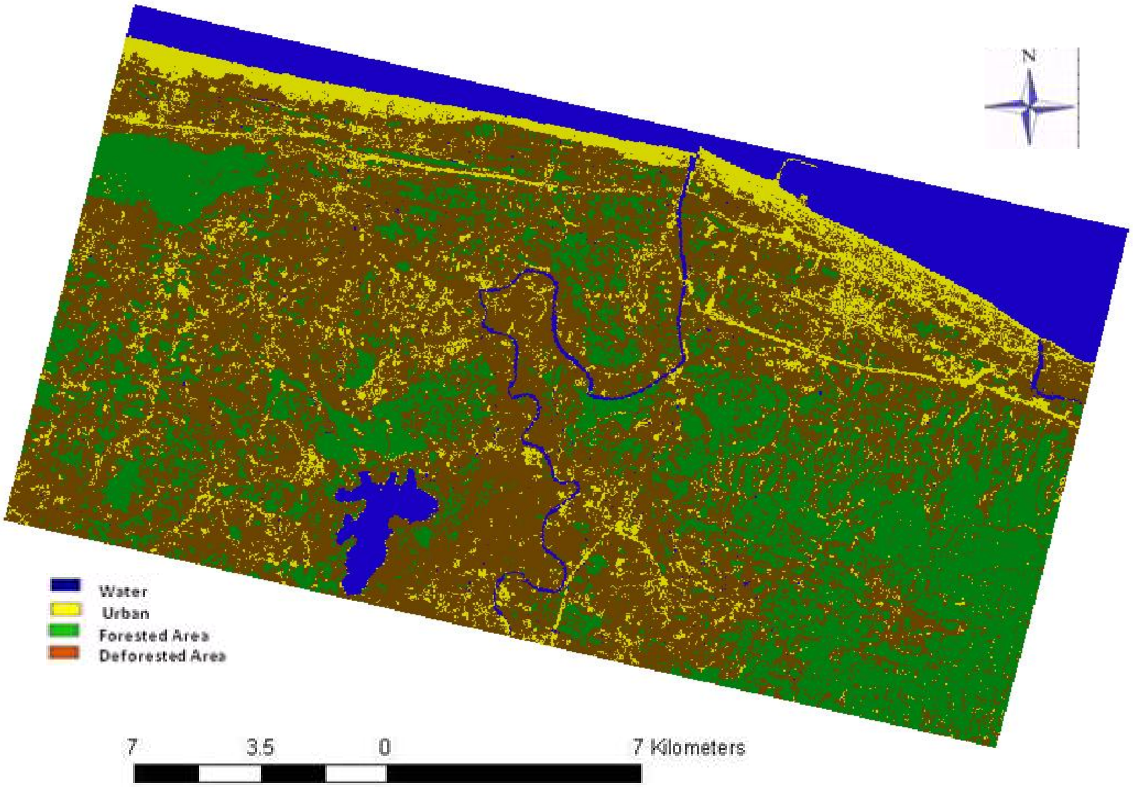
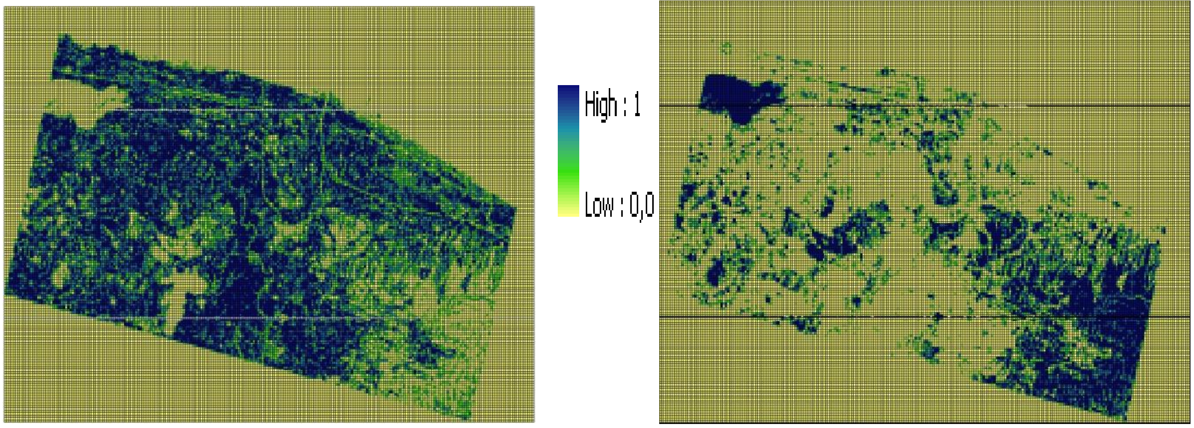


Figure 4.23. The land use map of Karasu District


(A)

(B)

Figure 4.24. Fraction of Deforested Areas (A), and Fraction of Forested Areas (B)

As also seen on the carbon stock kriging map, values which were calculated in forested area in spring 2009 and fall 2009 period, distribution of a solid colour can be observed in the large portion of the study area since the variability of carbon stock values (variation) is scarce.

As seen on the overlapped kriging map created by using the calculated carbon stocks and forested-deforested area ratios, as the agricultural activities take place in the region between Akgol and the Sakarya River are intensive, carbon stock values are higher than those of other parts of the study area (>10 kg/m^2). Spatial average of carbon stock values calculated in spring 2009 period, which falls to each of the grid areas in working site, is 10.0 kg/m^2.

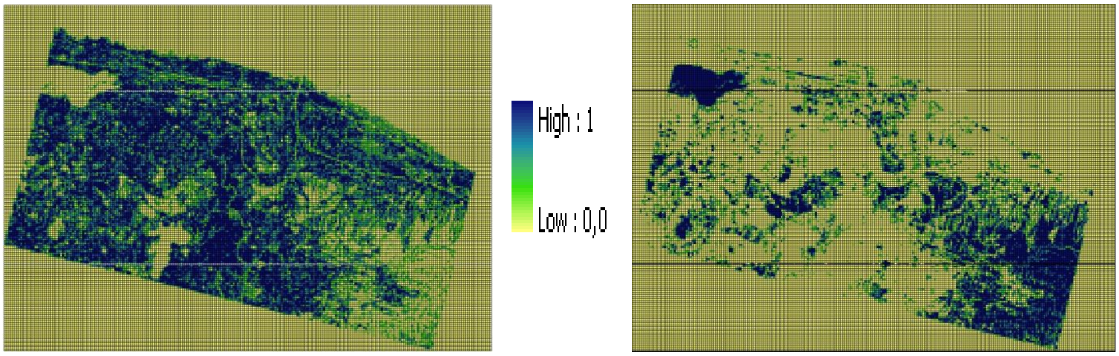
In the fall of 2009, carbon stock values in the region between Akgöl and the Sakarya River where agricultural activities are intensively engaged were high compared to other regions as well as Spring 2009 period (>13kg/m^2). Spatial average of carbon stock values calculated in autumn 2009 period, which falls to each of the grid areas in working site, is 10.8 kg/m^2.

Yu et al. (2011) mapped soil C storage and according to their results the carbon stock range is from 10 to 30 kg/m^2 in the coastal zone of Black Sea region in Turkey. This result is consistent with the outcome of our study, where the spatial averaged carbon stocks was found to be 10.4 kg /m^2.

Ordinary kriging and overlaid carbon stock maps are given in Figure 4.25 for spring and Figure 4.26 for fall.

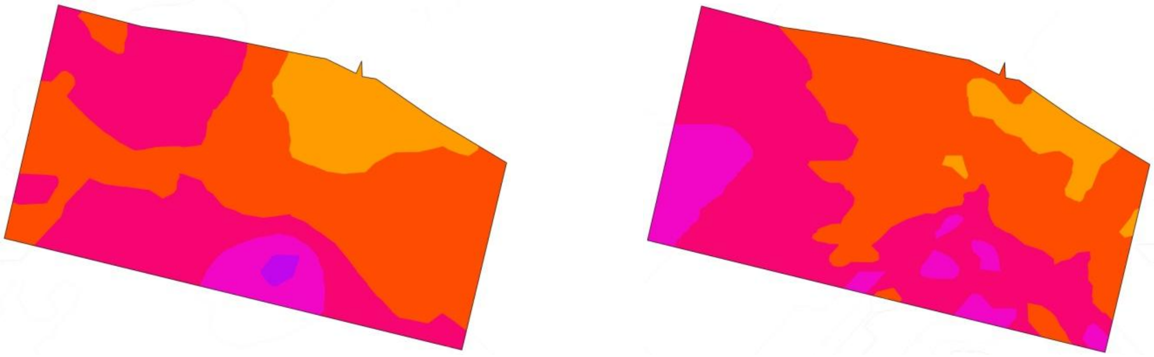
Table 4.19. Model summaries of the kriging maps

		Variogram	Number of Lags	Lag Size (m)	Nugget	Model Type	Range	Anisotropy	Partial Sill
Spring Season	Overlaid Kriging Map	Semivariogram	13	900	0	Exponential	11682.68	No	36.311
	Forested Kriging Map	Semivariogram	12	400	6.285	Exponential	1036.84	No	15.858
	Deforested Kriginig Map	Semivariogram	12	1100	10.874	Exponential	11906.79	No	14.192
Fall Season	Overlaid Kriging Map	Semivariogram	13	900	0	Exponential	11862.68	No	47.824
	Forested Kriging Map	Semivariogram	12	1000	9.362	Exponential	11853.27	No	7.160
	Deforested Kriginig Map	Semivariogram	12	1000	0	Exponential	11853/27	No	55.506



Fraction Of Deforested Area

Fraction of Forested Area



Ordinary Kriging of Carbon Stock in Deforested Area

Ordinary Kriging of Carbon Stock in Forested Area

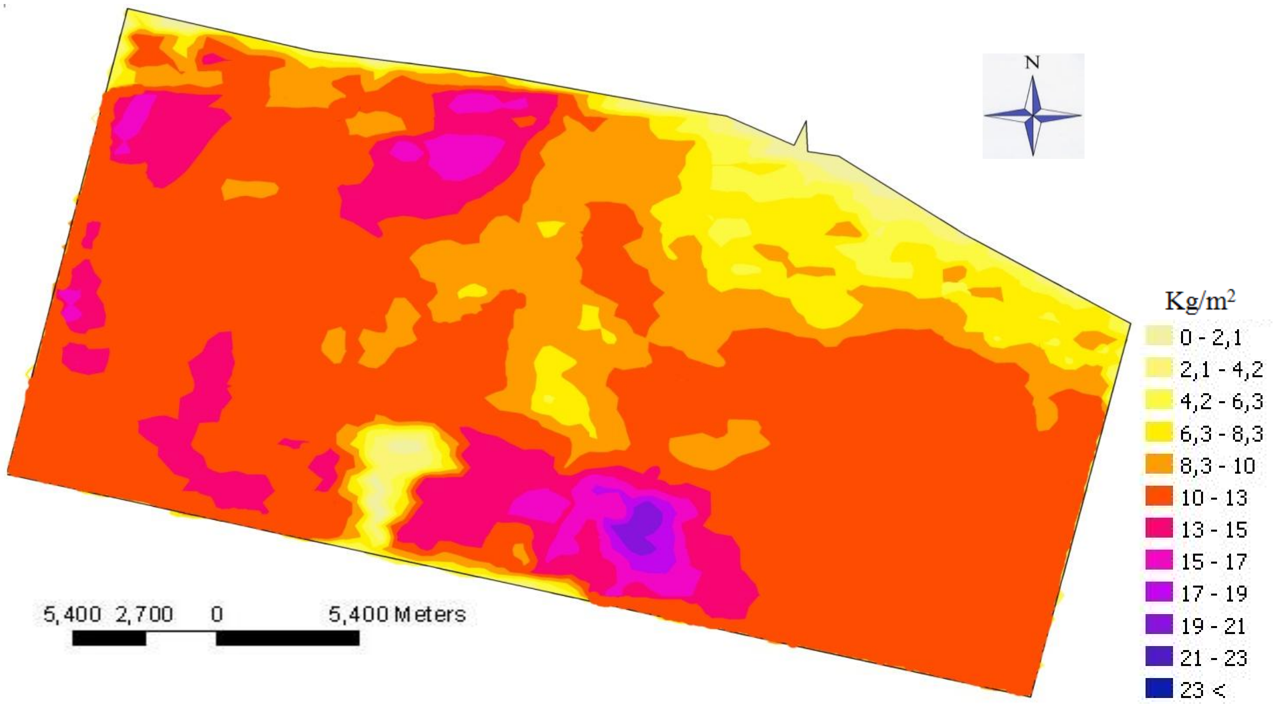
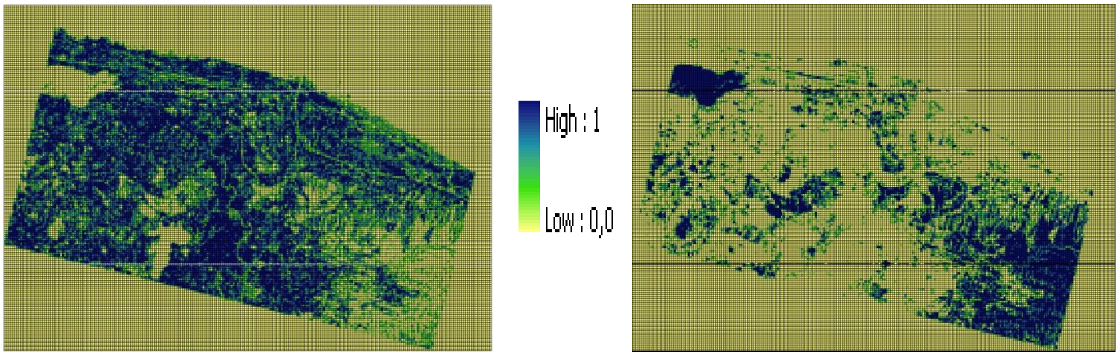
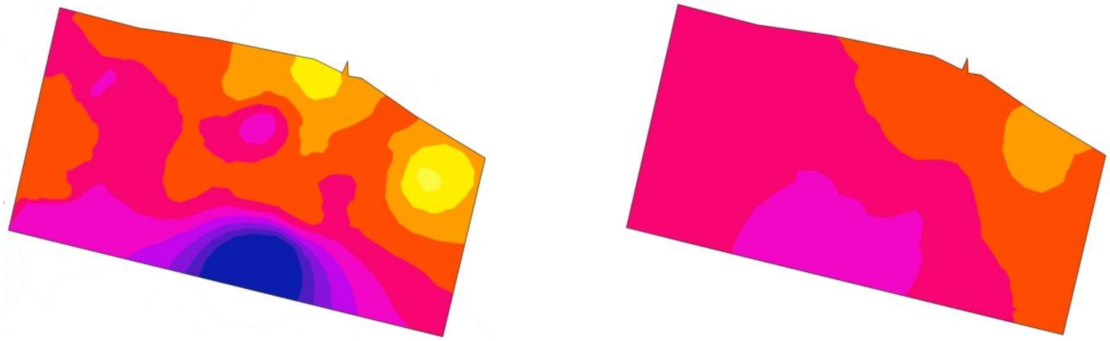


Figure 4.25. Overlaid geostatistics carbon stock map for the period of spring 2009



Fraction Of Deforested Area

Fraction of Forested Area



Ordinary Kriging of Carbon Stock in Deforested Area

Ordinary Kriging of Carbon Stock in Forested Area

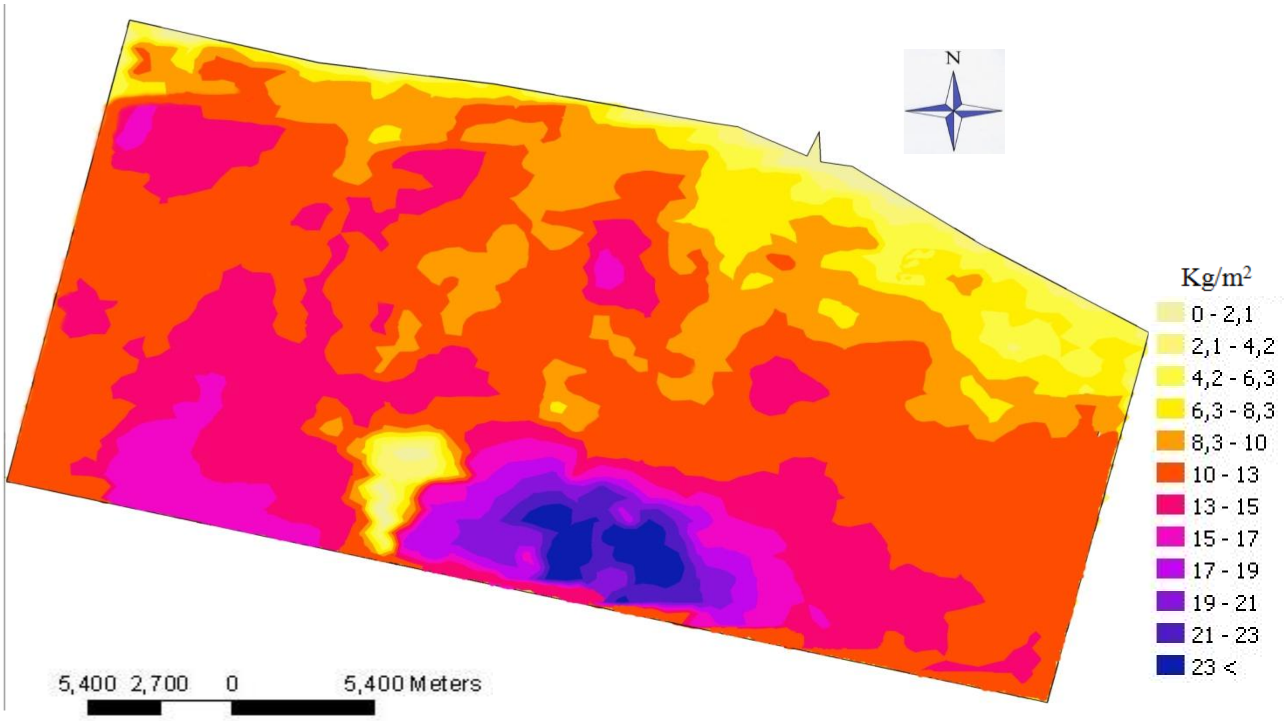


Figure 4.26. Overlaid geostatistics carbon stock map for the period of fall 2009

5. CONCLUSIONS

In this study the effects of land-use changes in Karasu Forests located within the provincial borders of Sakarya on elemental carbon and carbon stock were analyzed.

Field studies were conducted during spring and fall in 2009 so as to observe the effects of land use change on elemental carbon and carbon stocks in soil. Natural vegetation in large portions of the study area was converted to hazelnut farming which has a high economic return. Besides hazelnut gardens, maize cultivation has been observed in some areas. These agricultural activities carried out were examined and classified under the heading of "Deforestation".

This study encompasses several steps to determine the effect of land use change on soil. Field trips were conducted and soil samples were brought to the laboratory for experimental analysis. Environmental parameters such as soil moisture, soil texture, pH, bulk density, soil electrical conductivity, and elemental carbon were determined by experimental analysis. Results of these experiments and satellite image processing were the main data entries to statistical analyses. A geostatitical approach was used for the estimation the spatial distribution of the carbon stock as a function of soil depth.

Land use change analysis was made with the help of geostatistical analysis by utilizing LANDSAT TM 2007 satellite images. Within the field studies, soil samples taken from the soil surface and the depths of the specific profile were analyzed in the laboratoryfor elemental carbon, nitrogen and electrical conductivity, pH, and gravimetric soil moisture and texture analyses.

The statistical analyses of the data were conducted using SPSS to evaluate statistical trends, correlation, and regression analyses. Mean comparison analyses were performed to monitor the effects of land use change, seasonal changes, and soil texture content on carbon stock.

Geographical Information Systems (GIS) Remote Sensing Technologies (RST) was employed in conjunction with in situ measurements, laboratory experiments and statistical analyses. Satellite images of 2007of the study area was used to monitor and identity the land use patterns. The data obtained from the satellite image analysis was used in geostatistical analyses to explore the spatial relationships between the parameters.

The main findings of this study are summarized below:

- Carbon stock values in spring 2009 period were calculated as 11.9 kg/m^2 in forested areas and 11.6 kg/m^2 in deforested areas. On the other hand it was found to be 12.8 kg/m^2 in forested areas and 12.6 kg/m^2 in deforested areas in fall 2009.
- for deforested areas and for both seasons, a moderate negative correlation was found between carbon stock and bulk density (corr.=-0.491, $p<0.05$). A high correlation (corr.= 0.557, $p<0,01$) was observed between carbon stock and electrical conductivity from deforested soils.
- In the forested areas significant negative correlation was found between carbon stock and soil temperature in fall season only (corr.=-0.528, $p<0,01$).
- The stepwise regression results of deforested areas showed that 38.5%, 7.2%, and 6.4% variations in soil carbon stock could be explained by C:N ratio, electrical conductivity, soil temperature and gravimetric moisture content, respecitvely. For forested soils, C:N ratio alone explains 8.8 % of the variance in carbon stock from forested soils. Introduction of clay to the model explains an additional 10.1 % of the variance.
- As a result of geostatistical analysis, spatial average values of carbon stocks were 9,96 kg/m^2 in spring 2009 and 10,84 kg/m^2 in fall 2009. It was observed that deforestation realized within the study area during the last two decades had not had major effects on the amount of the carbon in the depths of the earth thus it was

determined that over the past two decades deforestation had not caused a significant change in the amount of total carbon sequestered in soil. The deforestation in the study area for the planting of hazelnuts may not have affected the carbon content at deeper soil depth intervals. Land use has an impact on the carbon stock in the uppermost soil. This is especially true for the 0-5 cm and 5-20 cm intervals with a mean difference of 1.47% for forested soils and 0.80% in deforested soils in spring season. The corresponding values for the fall season are 1.39% and 1.08% respectively. These differences become lower in the samples between 5-20 cm and 20-45 cm intervals.

- It has been observed that land use and seasonal changes do not carry out a statistically significant change on the carbon stock averages either in the study area.

Recommendation

When overall evaluation of the study was performed; any study related to the analysis of carbon cycle which occurs as a result of the destruction of the forested lands especially for hazelnut agriculture whose economic return is rather high or the calculation of carbon stocks has not examined previously in the literature. On the other hand, a study in which soil carbon stock is calculated using various methodologies to complement each other (Geographic Information Systems and remote sensing data, field and laboratory studies) has not previously been carried out across Turkey. In this study which was carried out for the first time in our country, carbon stock in Karasu Forests was calculated and the effects of land use change seen in this region in the past 2 decades on the environment were evaluated. However, such studies should be performed in the long run rather than short intervals. When worldwide studies are taken into consideration, within the scope of researches done in the districts having forested areas or others like vegetation especially in Europe and United States, there have been attempts to assess changes in the carbon stock over more than 100. In order to be able to conduct similar and long term studies in our country, the results and data gained from these experimental studies can serve as a starting point.

Acknowledgments

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APPENDIX A. STATISTICAL EVALUATION DATA

Table A1. Normality Test Results

Table A2. Parameters From Deforested Soils (Based on land use type)

Table A3. Parameters From Forested Soils (Based on land use type)

Table A.1. Normality test results

		Carbon Stock	**Carbon Stock-log**	**Bulk D.**	**Bulk D.-log**	**pH**	**pH-log**	**Soil Temp.**	**Soil Temp.-log**	**E. Cond.**	**E. Cond.-log**
N		90	90	90	90	90	90	90	90	90	90
Normal Parameters	Mean	12.2306	1.0586	1521.24	3.1802	5.2067	0.7132	14.3167	3.7769	129,0889	2.0219
	Std. Deviation	4.85157	0.15670	143.533	0.04173	0.67661	0.05364	1.73925	0.22871	101,82477	0.26128
Most Extreme Differences	Absolute	0.159	0.094	0.072	0.076	0.159	0.135	0.142	0.152	0.212	0.117
	Positive	0.159	0.094	0.061	0.063	0.159	0.135	0.122	0.120	0.212	0.117
	Negative	-0.080	-0.061	-0.072	-0.076	-0.085	-0.069	-0.142	-0.161	-0.193	-0.068
Kolmogorov-Smirnov Z		1.511	0.893	0.682	0.717	1.513	1.276	1.344	1.525	2.010	1.220
Asymp. (2-tailed)		0.021	0.402	0.740	0.683	0.021	0.077	0.054	0.019	0.001	0.170
		Ambient Temp.	**Ambient Temp.-log**	**G. Moisture Content**	**G. Moisture Content-log**	**C:N ratio**	**C:N ratio-log**	**Clay Content**	**Clay Content-log**	**N Content**	**N Content-log**
N		90	90	90	90	90	90	90	90	90	90
Normal Parameters	Mean	16.8678	4.0824	19.3918	1.2773	9.5647	0.9062	22.8000	1.2789	0.1133	-1.0690
	Std. Deviation	3.62667	0.45164	4.24360	0.096905	5.97503	0.26835	13.22510	0.27390	0.13419	0.31027
Most Extreme Differences	Absolute	0.066	0.070	0.068	0.042	0.194	0.106	0.184	0.120	0.314	0.142
	Positive	0.049	0.061	0.068	0.042	0.194	0.101	0.184	0.074	0.314	0.137
	Negative	-0.066	-0.070	-0.046	-0.041	-0.102	-0.106	-0.091	-0.120	-0.0221	-0.142
Kolmogorov-Smirnov Z		0.626	0.667	0.642	0.395	1.845	1.010	1.744	1.141	2.983	1.352
Asymp. (2-tailed)		0.828	0.765	0.805	0.998	0.002	0.259	0.005	0.148	0.000	0.052

Table A.2. Parameters from deforested soils (Based on land use type)

Season	Carbon Stock-log	Bulk Density	pH-log	Soil Temp.	E. Cond.-log	Ambient Temp.	G. Moisture Content-log	C:N ratio-log	Clay Content-log	N Content-log
Spring	0.98	1358	0.71	12.00	2.20	9.00	1.40	1.34	1.18	-0.96
Spring	0.84	1570	0.76	16.00	2.43	17.00	1.30	1.05	0.95	-0.75
Spring	0.97	1480	0.67	12.00	1.94	15.20	1.37	0.72	1.53	-1.28
Spring	1.18	1549	0.68	12.00	1.40	20.00	1.36	0.89	1.53	-1.03
Spring	1.13	1540	0.66	15.00	2.02	21.10	1.35	0.97	1.59	-1.08
Spring	1.01	1581	0.64	12.00	1.93	11.20	1.33	1.46	1.11	-0.80
Spring	1.05	1477	0.64	13.00	1.72	11.20	1.16	0.95	1.04	-0.27
Spring	0.85	1680	0.82	13.00	2.13	11.80	1.25	0.97	0.95	-1.76
Spring	1.16	1442	0.69	12.00	1.98	13.60	1.40	1.08	1.59	-1.03
Spring	0.86	1563	0.66	13.00	1.86	16.70	1.26	0.54	1.11	-1.03
Spring	1.02	1724	0.63	13.00	1.65	21.10	1.15	1.16	1.30	-0.79
Spring	1.26	1563	0.65	12.00	1.91	16.20	1.33	1.25	1.28	-1.08
Spring	1.38	1249	0.66	14.00	2.02	16.00	1.38	1.24	1.04	-1.07
Spring	1.10	1333	0.68	14.00	2.67	15.00	1.40	0.95	1.65	-1.06
Spring	0.93	1529	0.62	12.00	1.86	12.80	1.26	1.03	1.18	-0.89
Spring	0.78	1304	0.64	13.00	1.68	13.30	1.36	0.50	1.26	-1.19
Spring	0.96	1521	0.68	13.00	1.88	13.10	1.38	0.93	1.48	-0.96
Spring	1.07	1291	0.72	12.00	2.14	15.00	1.36	0.98	1.52	-0.98
Spring	1.14	1291	0.79	13.00	2.18	10.00	1.39	1.04	0.70	-1.35
Spring	1.28	1290	0.66	12.00	2.57	12.70	1.15	1.14	1.72	-0.98
Spring	1.11	1424	0.69	14.00	1.95	14.10	1.23	1.14	1.34	-0.86
Fall	1.15	1487	0.78	14.00	2.39	17.00	1.23	-0.10	1.18	0.05
Fall	0.91	1632	0.81	16.00	2.62	20.00	1.29	0.80	0.95	-0.85
Fall	0.96	1287	0.70	15.00	1.81	18.70	1.32	0.82	1.53	-1.00
Fall	1.29	1375	0.70	12.00	2.08	18.50	1.30	0.98	1.53	-0.83
Fall	1.10	1435	0.70	15.00	1.92	13.90	1.31	1.03	1.59	-0.95
Fall	0.91	1433	0.68	15.00	1.95	15.10	1.18	0.83	1.11	-1.11
Fall	1.09	1330	0.67	16.00	1.73	16.80	1.20	0.89	1.04	-0.89
Fall	0.70	1300	0.81	19.00	2.42	20.80	1.26	0.60	0.95	-1.08
Fall	1.15	1503	0.72	16.00	2.03	19.50	1.33	1.00	1.59	-1.04
Fall	1.04	1442	0.68	13.00	1.77	16.90	1.24	1.05	1.11	-1.19
Fall	1.06	1504	0.67	14.00	1.71	17.70	1.20	1.02	1.30	-1.10
Fall	1.09	1641	0.68	15.00	1.96	18.40	1.18	0.62	1.28	-1.35
Fall	1.24	1489	0.69	15.00	1.90	17.10	1.24	0.88	1.04	-0.84
Fall	1.27	1430	0.74	15.00	2.60	19.10	1.41	1.02	1.65	-0.93
Fall	1.11	1331	0.67	16.00	1.79	17.40	1.21	1.03	1.18	-1.05
Fall	1.10	1668	0.68	17.00	1.67	21.50	1.20	0.94	1.26	-1.08
Fall	1.09	1561	0.69	16.00	1.99	19.50	1.31	0.86	1.48	-1.01
Fall	1.04	1395	0.73	15.00	2.16	20.70	1.33	0.79	1.52	-0.95
Fall	1.18	1603	0.84	15.00	1.99	20.90	1.06	1.28	0.70	-1.19
Fall	1.30	1432	0.68	15.00	2.31	15.50	1.42	1.09	1.72	-0.95
Fall	1.03	1624	0.76	14.00	1.83	17.50	1.18	0.77	1.34	-0.98

Table A.3. Parameters from forested soils (Based on land use type)

Season	Carbon Stock-log	Bulk Density	pH-log	Soil Temp.	E. Cond.-log	Ambient Temp.	G. Moisture Content-log	C:N ratio-log	Clay Content-log	N Content-log
Spring	0.98	1358	0.71	12.00	2.20	9.00	1.40	1.34	1.18	-0.96
Spring	0.84	1570	0.76	16.00	2.43	17.00	1.30	1.05	0.95	-0.75
Spring	0.97	1480	0.67	12.00	1.94	15.20	1.37	0.72	1.53	-1.28
Spring	1.18	1549	0.68	12.00	1.40	20.00	1.36	0.89	1.53	-1.03
Spring	1.13	1540	0.66	15.00	2.02	21.10	1.35	0.97	1.59	-1.08
Spring	1.01	1581	0.64	12.00	1.93	11.20	1.33	1.46	1.11	-0.80
Spring	1.05	1477	0.64	13.00	1.72	11.20	1.16	0.95	1.04	-0.27
Spring	0.85	1680	0.82	13.00	2.13	11.80	1.25	0.97	0.95	-1.76
Spring	1.16	1442	0.69	12.00	1.98	13.60	1.40	1.08	1.59	-1.03
Spring	0.86	1563	0.66	13.00	1.86	16.70	1.26	0.54	1.11	-1.03
Spring	1.02	1724	0.63	13.00	1.65	21.10	1.15	1.16	1.30	-0.79
Spring	1.26	1563	0.65	12.00	1.91	16.20	1.33	1.25	1.28	-1.08
Spring	1.38	1249	0.66	14.00	2.02	16.00	1.38	1.24	1.04	-1.07
Spring	1.10	1333	0.68	14.00	2.67	15.00	1.40	0.95	1.65	-1.06
Spring	0.93	1529	0.62	12.00	1.86	12.80	1.26	1.03	1.18	-0.89
Spring	0.78	1304	0.64	13.00	1.68	13.30	1.36	0.50	1.26	-1.19
Spring	0.96	1521	0.68	13.00	1.88	13.10	1.38	0.93	1.48	-0.96
Spring	1.07	1291	0.72	12.00	2.14	15.00	1.36	0.98	1.52	-0.98
Spring	1.14	1291	0.79	13.00	2.18	10.00	1.39	1.04	0.70	-1.35
Spring	1.28	1290	0.66	12.00	2.57	12.70	1.15	1.14	1.72	-0.98
Spring	1.11	1424	0.69	14.00	1.95	14.10	1.23	1.14	1.34	-0.86
Fall	1.15	1487	0.78	14.00	2.39	17.00	1.23	-0.10	1.18	0.05
Fall	0.91	1632	0.81	16.00	2.62	20.00	1.29	0.80	0.95	-0.85
Fall	0.96	1287	0.70	15.00	1.81	18.70	1.32	0.82	1.53	-1.00
Fall	1.29	1375	0.70	12.00	2.08	18.50	1.30	0.98	1.53	-0.83
Fall	1.10	1435	0.70	15.00	1.92	13.90	1.31	1.03	1.59	-0.95
Fall	0.91	1433	0.68	15.00	1.95	15.10	1.18	0.83	1.11	-1.11
Fall	1.09	1330	0.67	16.00	1.73	16.80	1.20	0.89	1.04	-0.89
Fall	0.70	1300	0.81	19.00	2.42	20.80	1.26	0.60	0.95	-1.08
Fall	1.15	1503	0.72	16.00	2.03	19.50	1.33	1.00	1.59	-1.04
Fall	1.04	1442	0.68	13.00	1.77	16.90	1.24	1.05	1.11	-1.19
Fall	1.06	1504	0.67	14.00	1.71	17.70	1.20	1.02	1.30	-1.10
Fall	1.09	1641	0.68	15.00	1.96	18.40	1.18	0.62	1.28	-1.35
Fall	1.24	1489	0.69	15.00	1.90	17.10	1.24	0.88	1.04	-0.84
Fall	1.27	1430	0.74	15.00	2.60	19.10	1.41	1.02	1.65	-0.93
Fall	1.11	1331	0.67	16.00	1.79	17.40	1.21	1.03	1.18	-1.05
Fall	1.10	1668	0.68	17.00	1.67	21.50	1.20	0.94	1.26	-1.08
Fall	1.09	1561	0.69	16.00	1.99	19.50	1.31	0.86	1.48	-1.01
Fall	1.04	1395	0.73	15.00	2.16	20.70	1.33	0.79	1.52	-0.95
Fall	1.18	1603	0.84	15.00	1.99	20.90	1.06	1.28	0.70	-1.19
Fall	1.30	1432	0.68	15.00	2.31	15.50	1.42	1.09	1.72	-0.95
Fall	1.03	1624	0.76	14.00	1.83	17.50	1.18	0.77	1.34	-0.98