

**IMPACTS OF LAND USE CHANGE ON SOIL RESPIRATION AND ELEMENTAL
CARBON IN THE FORESTS OF KARASU DISTRICT**

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BOĞAZİÇİ UNIVERSITY

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CARBON IN THE FORESTS OF KARASU DISTRICT**

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ABSTRACT

In recent years, expansion of agricultural activities in the Karasu region which is located in northwest Turkey has led to significant deforestation. As a result, deforestation in this region is one of the most critical in Turkey. The purpose of this study is to evaluate the impact of land use change on soil respiration, soil elemental carbon in the Karasu District. The study also assess the potential seasonal changes on these three key parameters. To achieve this purpose, field trips were carried out over four seasons in 2008-2009. In total 900 soil samples from forested and deforested lands were collected. Geographical Information Systems (GIS) Remote Sensing Technologies (RST) were employed in conjunction with in situ measurements, laboratory experiments and statistical analyses. Soil respiration was measured in situ while soil samples were collected for the laboratory determination of soil elemental carbon (C) and nitrogen (N), C:N ratio, microbial respiration, soil organic matter (SOM), electrical conductivity, gravimetric moisture content, pH and soil textural structure. Analysis of the collected data indicated that the differences in mean soil respiration and elemental carbon due to land use and seasonal variations were statistically significant. The average annual soil respiration and elemental carbon in forested lands was about 27% and 34% higher than that from deforested lands. The statistical analyses also showed that the clay content exhibited high correlations with soil respiration and, particularly, with elemental carbon. Geostatistical analysis was conducted to calculate the spatial average values of soil respiration, surface elemental carbon. The data analyses and interpretation methods developed in this study can serve as an example for future studies in other geographical regions involving the evaluation of soil carbon content and emissions.

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

ÖZET

Karasu Bölgesi son yıllarda yoğun olarak tarım üretimi yapabilmek amacıyla ormansızlaştırılmaya maruz kalmaktadır. Bu bölge ormansızlaştırılmış alanlar içerisinde Türkiye’de en önemli ve hassas yörelerden bir tanesidir. Bu çalışmanın amacı Karasu Bölgesi’ndeki arazi kullanım değişiminin toprak solunumu ve elemental karbon üzerine olan etkisini belirlemektir. Ayrıca, mevsimsel değişimlerin bu parametreler üzerine olabilecek etkilerinin belirlenmesi bu projenin diğer bir amacıdır. Bu nedenle proje süresi boyunca dört ayrı mevsimi kapsayacak şekilde 2008 ve 2009 yıllarında saha çalışmaları yapılmıştır. Koordinatları belirlenmiş ormanlık ve ormansızlaştırılmış noktalardan toplam 900 toprak numunesi alınarak ölçümler yapılmıştır. Çalışmanın kapsamında coğrafi bilgi sistemleri ve uzaktan algılama teknikleri, arazi ve laboratuvar çalışmaları ile birlikte kullanılmış ve çıkan sonuçlar İstatiksel olarak değerlendirilmiştir. Yapılan saha çalışmalarında toprak solunumu ölçülmüş ve bu çalışmalar esnasında alınan toprak örnekleri üzerinde de laboratuvar çalışmaları yürütülerek, toprak elemental karbon, karbon / azot oranı, mikrobiyal solunum, pH, elektriksel iletkenlik, toprak organik maddesi, toprak gravimetrik nemi ve toprak tekstür yapısı belirlenmiştir. Arazi kullanımı değişimi ile mevsimsel değişimin toprak solunumu ve elemental karbon ortalama değerleri arasında anlamlı istatistiksel farklar oluşturduğu gözlenmiştir. Genel olarak, arazi kullanımındaki değişim sonucunda ormanlık alanlardaki elemental karbonun %27, ve toprak solunumunun %34 oranlarında ormansızlaştırılmış alanlardaki değerlerden daha yüksek olduğu istatistiksel olarak bulunmuştur. Ayrıca, toprakta bulunan kil mineralleri ile toprak solunumu ve özellikle elemental karbon değerleri arasında yüksek korelasyon bulunmuştur. Jeostatistik analizler kullanarak Karasu Bölgesi için elemental karbon ve toprak solunumu uzaysal ortalama değerleri hesaplanmıştır. Bu çalışma kapsamında geliştirilen veri analizi ve değerlendirme metotları farklı bölgelerde yapılacak toprak karbonu ve emisyonu konulu başka çalışmalarda örnek olarak kullanılabilir.

Anahtar Kelimeler: Arazi Kullanım Değişimi, Toprak Solunumu, Elemental Karbon, Coğrafi Bilgiler Sistemi (CBS), Jeostatistik Analiz

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LIST OF SYMBOLS/ABBREVIATIONS

AC	: Air inlet
Ag ₂ SO ₄	: Silver sulfate
AN	: Analysis
ASTM	: American Standard Technical Methods
AVHRR	: Advanced Very High Resolution Radiometer
BaCl	: Barium chloride
BEF	: Biomass expansion factor
C	: Carbon
C ₃ plants	: Use enzym ribulosodiphosphatcarboxylase to accept CO ₂ from the air
C ₄ plants	: Use phosphoenolpyruvatcarboxylase to accept CO ₂ from the air
⁰ C	: Celcius
CEC	: Cation exchange capacity
CL	: Clay loam
C:N	: C:N ratio
Clear Cut Pines	: Clear Cut Pines
Ca ²⁺	: Calcium
CO	: Carbon Monoxide
CO ₂	: Carbon Dioxide
CH ₄	: Methane
CIRAS	: Portable Photosynthesis System
DOC	: Dissolved Organic Carbon
E	: East
EC	: Electrical conductivity
ETM+	: Enhanced Thematic Mapper
FeSO ₄	: Ferrous Sulfate

$\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$	: Ferrous sulfate heptahydrate
FRA	: Forest Resources Assessment
G	: Granite parent materials
GP	: Grazed mixed-grass prairie
GCP	: Ground control points
GPP	: Gross per production
GPS	: Global Positioning System
GIS	: Geographic Information System
GHG	: Green House Gases
HCl	: Hydrochloric Acid
H_2SO_4	: Sulfuric acid
H_3PO_4^-	: Phosphoric acid
IDW	: Inverse Distance Weighted
IPCC	: Intergovernmental Panel on Climate Change
IRGA	: Infrared Gas Analysis
IVS	: In vitro soil-less
K^+	: Potassium
K	: Khat statistic
KCl	: Potassium chloride
$\text{K}_2\text{Cr}_2\text{O}_7$	: Potassium chromate
LUCC	: Land Use Change Cover
MBC	: Microbial Biomass Carbon
Mg^{2+}	: Magnesium
Mmhos/cm	: Millimhos/cm
MTC	: Million tonnes carbon
MSS	: Multispectral Sensor
NOAA	: National Oceanic and Atmospheric Administration
N	: Nitrogen
NGP	: Non-grazed mixed-grass prairie

NaCl	: Sodium chloride
NaOH	:Sodium hydroxide
NDVI	:Normalized Difference Vegetation Index
N ₂ O	:Nitrous Oxide
NO ₃ ⁻	:Nitrate
NOAA	:National Oceanic and Atmospheric Research
NO _x	:Nitrogen Oxides
NR	:Non-Reactive carbon atoms
N ₂ O	:Nitrous Oxide
NH ₄ ⁺	:Ammonium
NH ₃	:Ammonia
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
REF	:Reference
RST	:Remote Sensing Technology
RMSE	:Root Mean Square Error
RGB	:Red Green Blue Bands
SAR	:Synthetic aperture radar
STP	:Standard Temperature and Pressue
SL	:Sandy Loam
SO ₂	:Sulfur Dioxide
SOM	:Soil organic matter

SIR-C	:Supervised classification
T	:Tertiary
TM	:Thematic Mapper
tC ha	:Tonnes carbon hectares
UCCP	:Uncut Clear Cut Pines
USDA	:United States Department of Agriculture

1. INTRODUCTION

Atmospheric CO₂ concentrations have increased by almost 100 ppm in comparison to its preindustrial level, reaching 379 ppm in 2005, with mean annual growth rates in the 2000–2005 periods that were higher than those in the 1990s according to the Intergovernmental Panel on Climate Change (IPCC, 2007) and the annual mean temperature of the Earth's surface has increased by 0.3 to 0.6°C over the last century (IPCC, 2001). The largest temperature increases on land are observed in the northern high latitudes, while lower increases are recorded near the tropics and in regions with strong oceanic influences. These changes are primarily due to increased atmospheric concentrations of greenhouse gases (mainly CO₂) and sulfate (SO₄⁻²) aerosols. Same study also suggests that, since the industrial revolution, the CO₂ concentration in the atmosphere has increased 1.27 times (from ~290 parts per million by volume (ppmv) to more than 370 ppmv today). This increase is mainly attributed to human activities (e.g. fossil fuel combustion, cement manufacture and tropical deforestation). It is also predicted that atmospheric CO₂ levels will continue to rise and could exceed 500 ppmv during the 21st century (IPCC, 2001). For 2030, Green House Gas (GHG) emission projections consistently show a 25–90% increase compared to 2000, with more recent projections being higher than earlier ones (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 which 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).

All human activities, such as industrial production, transportation of goods or people, or daily household routines, as well as field activities such as deforestation cause gas emissions (in particular carbon dioxide) in increasing quantities into the atmosphere. These emissions add several billion tons of carbon dioxide to the atmosphere annually and much of this carbon is likely to remain in the atmosphere for a period of hundred years or more. Carbon dioxide is a good absorber of heat radiation coming from the Earth's surface and increased carbon dioxide acts like a blanket over the surface, keeping it warmer than it would otherwise be. With the increased temperature the amount of water vapor in the atmosphere increases as well, providing a further blanket-like effect and causing the surface to be even warmer (Houghton, 2004).

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 IPCC Report 2000, land-use change is the main reason about 136 (+55) Gt C emission from 1850 to 1998. This resulted in an increase in the atmospheric carbon dioxide to 176 (+10) 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).

This study analyzes results of land use change on soil in Karasu District in northwestern Turkey. Remote sensing technologies (RST) were used in conjunction with in-situ measurements and laboratory experiments to obtain and evaluate data. This study also determines effects of deforestation on soil CO₂ efflux and statistically analyzes the relationship between soil parameters and land use change. Some of the

data used in this study were obtained through direct field measurements from 2008 (Winter and Summer) and 2009 (Spring and Fall) from Karasu District.

In Chapter 2, a detailed literature review is provided on the carbon cycle and its relationship with climate change, land use change studies, soil respiration and measurement methods. Materials and methods for in-situ measurements, laboratory experiments and satellite image techniques employed in study are explained in Chapter 3. Chapter 4 introduces the statistical and geostatistical evaluation of the results and discussion and Chapter 5 presents conclusions.

2. LITERATURE REVIEW

The literature review is grouped into three sections: (1) The carbon cycle and the relationship with climate change; (2) Land use change studies; (3) Soil respiration and measurement methods.

2.1 The Carbon Cycle

According to Houghton, (2004) the carbon cycle involves all living things on Earth. This cycle can be considered as an atmospheric cycle because most of the carbon that passes through the biosphere comes from the air. 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. The units of the pool can be defined with mass (e.g., t C) (National Resources Canada, 2009).

CO₂ is removed from the atmosphere by various mechanisms in carbon cycle. Carbon sinks can be defined as mechanisms that take away carbon from the atmosphere. Forests and oceans are the largest carbon sinks on Earth. Deforestation is simply reducing the size of a sink, allowing greater amounts of CO₂ to be remain in the atmosphere. Approximately 0.03 to 0.04% of the air is CO₂ and this minute percentage is the main source of carbon for all living things and it is this reservoir from which plants withdraw carbon for photosynthesis. Through this reaction, green plants utilize carbon from the carbon dioxide in the air and through complex chemical processes they combine and rearrange these carbon atoms into carbon skeletons of various molecular shapes and sizes. Oxygen, nitrogen, phosphorus, sulfur, and other elements are attached to carbon to produce the substance of living matter—fats, carbohydrates, proteins and nucleic acids (Kupchella and Hyland, 1989).

Figure 2.1 illustrates the carbon movement between the atmosphere and its two important sinks: The land and the ocean (the units on the figure are Petagrams (Pg). 1Pg = 10¹⁵g.). Anthropogenic fluxes are shown in red and natural fluxes are shown in

black. Black numbers show the preindustrial sizes of the reservoirs and the red numbers denote the change resulting from human activities since preindustrial times (Sarmiento and Gruber, 2002).

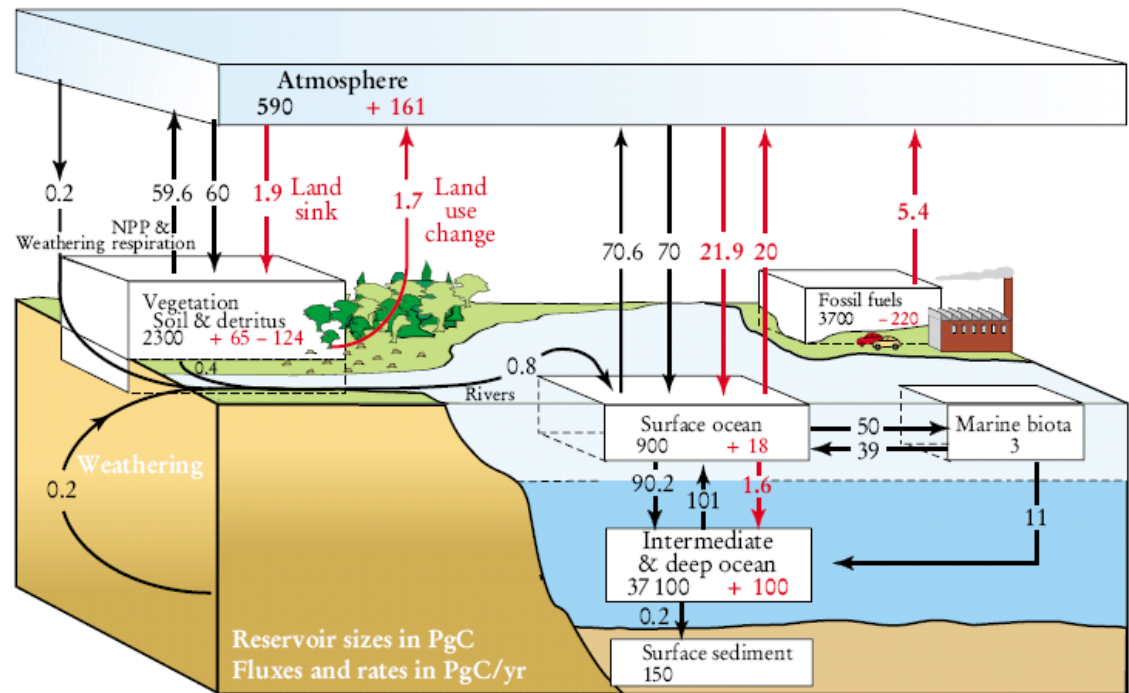


Figure 2.1. The Global Carbon Cycle (Sarmiento and Gruber, 2002)

Carbon on Earth is stored in three big reservoirs: Atmosphere, land and ocean. Vegetation contains about 600 giga tons 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 CO₂ only through surface layers. Carbon stored in soil is about 1600 Gt, twice as large as that 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). Soil is often defined as a mixture of dead soil organic matter, air, water, and weathered rock that supports

plant growth. As one key process of ecosystems, soil respiration is related to ecosystem productivity, soil fertility, and regional and global carbon cycles. Since the global carbon cycle regulates climate change, soil respiration is relevant to climate change, carbon trading, and environmental policy (Luo and Zhou, 2006). At high latitudes and in cooler climates, soil organic matter accumulates because it is produced faster than can be decomposed. At low latitudes, however, warmer temperatures encourage rapid decomposition of soil organic matter and subsequent recycling of nutrients (Dong, 2002).

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, 2004).

2.2 Climate Change

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 (CO₂), methane (CH₄), nitrous oxide (N₂O), 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.

Climate change can be defined as changes in the variability or average state of the atmosphere over long periods of time (from decades to millions of years). Normally, the greenhouse effect is essential for life on Earth (Houghton, 1991). Without the greenhouse effect, the Earth’s average temperature would be -17°C because of the energy absorbed by the atmosphere. The effect of this temperature would be devastating on natural vegetation and human. No essential life forms would exist on the Earth (Gurney, 1998). The greenhouse gases are more transparent to short-wave radiations. Since Sun’s energy is radiated in short-waves and re-radiated energy from the Earth is in long-waves, the equilibrium temperature of the Earth rises as the concentrations of these gases increase (Houghton, 1991).

“Global warming,” one measure of the climate change, is a phrase that refers to the effect of human activities on climate. These activities include the burning of fossil fuel (coal, oil and gas) and large-scale deforestation, which both cause emissions of large amounts of greenhouse gases – with the most important one being carbon dioxide – to the atmosphere (Houghton, 2005). Carbon dioxide can be found mainly in air, but also in water as a part of the carbon cycle. It is one of the most abundant gasses in the atmosphere and it plays an important part in vital plant and animal processes, such as photosynthesis and respiration (Miller, 2006). Houghton (2007) defines carbon dioxide as providing the dominant means through which carbon is transferred in nature between numbers of natural carbon reservoirs. Other greenhouse gases include water vapor, methane, nitrous oxide, and ozone. Fossil fuel combustion is responsible for

70% of total CO₂ 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 CO₂ 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, 1998).

2.2.1 The role of Forests in Climate Change

Forests potentially contribute to global climate change through their influence on the global carbon cycle. They store large quantities of carbon in vegetation and exchange carbon with the atmosphere through photosynthesis and soil respiration (Asan, 1998).

Trees, through photosynthesis, remove CO₂ from the atmosphere and store it as organic carbon until the tree dies and decays, or is burned, releasing the carbon back into the atmosphere as CO₂. Earth's vegetation and forests currently store about 610 Gt of carbon. Young, growing forests shift carbon from the atmosphere into temporarily stored organic biomass, but a mature old-growth forest is probably close to equilibrium, giving off as much carbon to the atmosphere (as trees die and decay) as it removes through photosynthesis. Planting a new tree could effectively offset some CO₂ emissions for the life of the tree, often 100 to 300 years, and large-scale reforestation could significantly reduce the rate of CO₂ buildup in the atmosphere (Hardy, 2003).

Respiration is the process by which chemical energy is released to do work in both plants and animals. This energy is used to drive anabolic reactions. The two metabolic reactions, photosynthesis and respiration are at the molecular “heart” of the mechanisms by which matter and energy are moved within ecosystems and responsible for the movement of carbon between land, ocean, and atmosphere (Kupchella and

Hyland, 1989). Photosynthesis by plants combines CO_2 from the atmosphere with water from the soil to produce carbohydrates which are organic molecules containing carbon (C), hydrogen (H), and oxygen (O) with an elemental ratio. In the process, O_2 is released into the atmosphere. The net reaction can be represented as



The macronutrients nitrogen (N) (as NH_4^+ and NO_3^-), phosphorus (P) (as H_3PO_4^-) and sulphur (S) (as SO_4^{2-}), together with calcium, magnesium and potassium ions are taken up through the plant roots from the soil. Small amounts of the micronutrients iron, manganese, zinc, copper, boron, molybdenum, cobalt and chlorine are also taken up. These elements are incorporated into plant materials. When the plant dies, Ca^{2+} , Mg^{2+} , and K^+ and the micronutrients are released rapidly into the soil. C, O, H, N, P, and S are bound in the organic molecules but are slowly released as the plant material is decomposed through the action of animals and microorganisms, which assimilate the elements they need, and release those not needed. Two processes are as follows (Rowell, 1996):

- i. In respiration, the organisms take in O_2 and CO_2 is released as formulated below.



- ii. Mineralization is the release of N, P, and S in the form of ammonium, phosphate and sulphate ions into the soil. The term “mineralization” is used because the inorganic (mineral) forms of these elements are produced from the organic forms.

Two activities are mainly responsible for the increased concentrations of CO₂ in the atmosphere: Emission of CO₂ from combustion of fossil fuels (Quadrelli and Peterson, 2007) and release of CO₂ (soil respiration) from deforestation (Asan, 1998).

2.3 Land use change

Land use change is an important measure for carbon storage. Deforestation is a subset of the bigger land use change problem. Deforestation is also known as forest degradation or forest clearance and can be defined as the conversion of forestland to non-forest land (IPCC, 2000). 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 CO₂, 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 Gton C/year release of CO₂ to the atmosphere. During combustion of any fossil fuel, carbon is oxidized and CO₂ is released. Fossil fuel combustion releases 5 Gton 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).

2.3.1 Satellite Image techniques

Land use change studies are 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. 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) have all studied land use change and deforestation. Forest carbon sequestration and carbon modeling on satellite images were studied by Turner *et al.* (2004), Feldpausch *et al.* (2006), Neef *et al.* (2005), Doraiswamy, (2007), Höhne, *et al.* (2007).

Sancar *et al.* (2009), investigated a land use change in province of Trabzon from 1987 to 2008. This province has the similar vegetation and climatic conditions with Karasu District. In the study, changes of landscape pattern from 1987 to 2008 were analyzed by a specific geostatistical software. The study showed that the percentage of urbanization in province of Trabzon increased from 4.72 % in 1987 to 6.27 % in 2008 based on supervised classification of images. As a result, they reported that cumulative urbanization accounted for 1.55% of the whole area of Trabzon (254 ha) and 32.8% of the settlement area of the province of Trabzon from 1987 to 2008. The authors also indicated that the diversity and landscape fragmentation are positively related to the degree of urbanization

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 higher results compared to other land use change results in Black Sea Region of Turkey.

Meadows and Hoffman (2003) studied the relationship between land degradation and climate change in South Africa. In that study, they proved that the carbon dioxide conditions are dependent on the land degradation and on extensive agriculture in South Africa.

Bruce *et al.* (2003) investigated the magnitude of the potential for carbon sequestration in the soil and in the forests as a means of reducing carbon dioxide (CO₂) in the atmosphere. They showed tools such as Remote Sensing and GIS could be used for this purpose.

Defries *et al.* (2002) investigated fluxes for 1980s and 1990s using subpixel estimates of percent tree cover derived from coarse (National Oceanic and Atmospheric Administration's—NOAA, Advanced Very High Resolution Radiometer—AVHRR) satellite data in combination with a terrestrial carbon model. They pointed out the net mean annual carbon fluxes from tropical deforestation and re-growth to average 0.6 (0.3–0.8) and 0.9 (0.5–1.4) petagrams (Pg)·yr⁻¹ for 1980s and 1990s, respectively. Compared with previous estimates of 1.9 (0.6–2.5) Pg·yr⁻¹ based on FRA national statistics of changes in forest soils, this alternative estimate suggests less “missing” carbon from the global carbon budget but increasing emissions from tropical land-use change.

Skole and Tucker (1993) published a research on the effects of deforestation on biodiversity. This research was based almost solely on interpretation of data obtained by the Landsat Thematic Mapper (TM) sensor. The study claims that massive extinction of species is the primary adverse effect of deforestation and classifies the consequences in biodiversity in three main points: destruction of habitat, isolation of forest fragments, and edge effect. The authors documented the extent and rate of deforestation through elaboration of a base map. They parted from 210 black and white, band 5 photos taken by the Landsat TM, at a large scale of 1:500,000, primarily from 1988. Through these images, deforested soils were detected using visual deforestation interpretation, including soils of secondary growth and pastures.

Westman *et al.*, (1994) published a report to show the ways of remote sensing-modeling approaches to predict regional C budgets. Land use scenarios that define different policy environments (e.g., government subsidies to support woody plant control, or carbon credit incentives that promote woody plant proliferation) are also investigated.

Lwin and Shibasaki (1998) demonstrated the combination of two-resolution satellite images (Landsat TM and NOAA AVHRR) in order to understand the causes of the deforestation process. This study can be considered as a pioneer one in 1998 to merge two different types of satellite images for understanding the land use change.

Mas *et.al* (2004) affirms generating a GIS database, describing the spatial distribution of land use/cover and allowing the quantification and spatial characterization of these changes. Their study presented the methods used to assess and improve the reliability of the database, along with a data analysis and an assessment of specific Land Use Change Cover (LUCC) processes such as deforestation.

Erasmi *et.al* (2004) published a study to show the transparent and reproducible processing and analysis work-flow for the land cover categorization in a tropical environment based on a multi-temporal Landsat data set (Landsat/MSS; Landsat/ETM+). They used geometric correction, radiometric calibration, land cover classification, and change analysis methods.

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.

Mas *et al.* (2004) investigated the spatial distribution of tropical deforestation. Landsat images dated 1974, 1986 and 1991 were classified in order to generate digital deforestation maps that locate deforestation and forest persistence soils. The deforestation maps were overlaid with various spatial variables such as the proximity to roads and to settlements, forest fragmentation, elevation, slope, and soil type to determine the relationship between deforestation and these explanatory variables. A multi-layer perception was trained in order to estimate the deforestation as a function of the explanatory variables and was used to develop deforestation risk assessment maps.

Mas (2004) utilized the nationwide multirate GIS database, which describes the spatial distribution of land use/cover and allows the quantification and spatial characterization of these changes. The study presented the methods used to assess and improve the reliability of the database, along with a data analysis and an assessment of specific LUCC processes such as deforestation.

Fallon *et al.* (1998) studied the changes in agricultural land use and climate and reported that these can lead to changes in the amount of carbon held in soils, thus, affecting the fluxes of CO₂ into and out from the atmosphere. Some agricultural management GIS-linked modeling is a useful tool for large-scale carbon cycle studies, allowing current estimates of regional carbon sequestration to be refined.

Naughton-Treves (2004) 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. Some economic reasons that allow the occurrence of deforestation in Peruvian forests were also defined.

Kanninen (2001) analyzed forests, based on case studies representative of different socio-economic, cultural, and biophysical conditions in Central America. For determining the carbon content of different ecosystems studied, he developed allometric equations. In order to evaluate the permanence of the stored carbon, farmers' decision-making on land use change was analyzed and modeled.

Apan and Peterson (1998) determined the significance and magnitude of the relationship between forest cover and some geo-referenced environmental factors of a given soils. They characterized and analyzed the deforested lands using GIS-based spatial analysis techniques and gained insights as to the causes of this deforestation. According to them, digital spatial data handling allows full and accessible archiving of data and information.

Mertens and Lam (1997) investigated the influence of the deforestation process on an empirical spatial model of deforestation and tested a remote-sensing-based methodology for defining the appropriate spatial entities for modeling deforestation. The initial steps included the production and integration in a geographic information system (GIS) of a database on land cover change and landscape attributes to support the development of a spatial model of deforestation for Southern Cameroon.

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. The collected data were analyzed using different software packages. The descriptive statistical parameters were calculated with Microsoft Office and SPSS. Maps were produced using Arc View software packages. 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 199,823km², respectively. According to the system, C stocks ranged from 9 tCha in degraded savannas in the north, to 113 tCha in the remnant forests of the Senegal River Valley.

This approach resulted in estimated total C stocks of 1019 and 727MTC between 1965 and 2000, respectively, indicating a loss of 292 MTC over 35 years.

Turkoglu and Goksel (1999) studied land use change in merli water Obasin in Istanbul, Turkey by using Remote Sensing and GIS data. Different types of data were collected from various sources. The satellite images, airborne photos, topographic maps and various thematic maps have been used.

Saatchi *et al.* (1996) investigated the potential use of space-borne polarimetric synthetic aperture radar (SAR) data in mapping land cover types and monitoring deforestation. A type of SAR views SIR-C L and C-Band were used and five major types of land cover were discriminated primary forest, secondary re-growth and pasture crops. Landsat TM satellite views were also compared with SIR-C views to examine the possible synergistic use of the optical and microwave systems for better classification accuracy.

Hudak and Wessman (2000) determined the deforestation in Mwanza District, Tanzania between 1981 and 1992 using Landsat MSS views. They calculated Normalized Difference Vegetation Index (NDVI) from MSS satellite views. Landsat MSS images were found to be more applicable to studies of vegetation structure given their higher spatial resolution (80 m) relative to AVHRR data. In the study it was shown that NDVI can be used to detect forest clearance.

Ochoa and Espinosa (2000) affirmed that deforestation rates and land use change are related to environmental factors (slope angle and soil type). Landsat MSS images were found to be exact sources of information to gather the accurate date. They found that soil properties were also important to affect the deforestation. According to their study, human population expansion is the driving force allowing the occurrence of deforestation.

Glenday (2006) investigated the carbon storage and emissions offset potential in an East African tropical rainforest. The study focused on GIS analysis to estimate carbon storage in the current landscape of the Kakamega national forest, Kenya to provide an assessment of the potential for further carbon sequestration based on observed carbon densities. They have found that the Kakamega national forest had an average aboveground biomass density (400 ± 72 Mg/ha). An Inverse Distance Weighted (IDW) nearest neighbor interpolation was used to estimate indigenous forest carbon stock.

Neeff *et al.* (2005) studied carbon budget estimation in Central Amazonia: The carbon budget resulting from the dynamics of forest vegetation was estimated spatially for a study region with intensive land use change in the Central Amazonia forest. Vegetation height was recovered from airborne SAR interferometry and was used along with an established relationship between forest height and age for mapping the successive stages of vegetation. A map of forest ages could be generated and validated (age RMSE was 3.5 years). The carbon budget was established based on limited input data, because a number of assumptions were made that deal with the expected forestland cover dynamics.

Defries *et al.* (2007) studied Earth observations for estimating greenhouse gas emissions from deforestation in developing countries. They assessed technical capabilities for estimating emissions from deforestation in developing countries as input to ongoing policy discussions. Their paper raised key issues that need to be addressed in further development of more detailed guidelines and protocols.

Van Laake and Azofeifa (2004) investigated a method that identified hot spots using an objective and reproducible approach. They used a method for identifying the hot spots and effects of separate analysis on the magnitude of indicators of deforestation and ways to improve land use policy development and management through location-specific actions. Digital image analyzing techniques were performed to determine the rate of deforestation and the yielded results were used to specify the hot spots location the study soils.

Hayes and Sader (2002) detected the reasons of deforestation in Guatemala as human mitigation and intensive agriculture activities. They used different dated Landsat TM images, where each image was acquired two years apart. The Landsat TM images were radiometrically normalized and pre-processed to remove clouds, water, and wetlands, prior to employing the change detection algorithm. They used three change detection methods and these can be listed as NDVI image differencing, principal component analysis, and RGB (Red Green Blue Bands)-NDVI change detection. They concluded that the highest overall accuracy was achieved with the RGB-NDVI method (85%). This method was also preferred for its simplicity in design and ease in interpretation.

Ballester *et al.* (2003) presented the results of an integrated analysis of the landscape characteristics of a tropical meso-scale river, soil properties in Western Amazonia. They demonstrated how a RS/GIS-based physical template can facilitate the understanding of complex environmental questions such as the effects of land-use changes in biogeochemistry of river systems. Some water quality parameters such as dissolved O levels, P, Ca and NO₂ concentrations are also examined and these parameters were evaluated with remote sensing and GIS data. They concluded that forest clearing modified water parameters respectively and allowed to increase soil temperature and erosion, which resulted in changes in the water balance and in the nutrient availability. Digital Elevation Model, a type of software application, was also created to model river basin characters in forest soils.

2.4. Soil respiration

Soil respiration is the main mechanism of C transfer from soil to the atmosphere and is a key component of the global C cycle (Schlesinger, 1991; Schimel, 1995). On a global scale, CO₂ release from soil is an order of magnitude larger than CO₂ release from burning fossil fuels and land-use change combined (Houghton *et al.* 1990; Gates, 1993). According to Nay and Bormann (2000), respiration of carbon dioxide from soil surfaces is one of the most important ecosystem processes.

Soil respiration balances net photosynthetic uptake of atmospheric CO₂ by plants, when storages of soil C are constant. This is an ecosystem process that releases carbon dioxide from soil via root respiration, microbial decomposition of litter and soil organic matter, and fauna respiration. The term usually accounts for the majority of ecosystem respiration, which is the sum of soil respiration and respiration of aboveground parts of plants (Figure 2.2). Soil respiration is defined as the production of carbon dioxide by organisms and the plant parts in soil. These organisms are soil microbes and fauna, and the plant parts are roots and rhizomes in the soil. Plants are the most important autotrophs contributing to CO₂ efflux from soil by root respiration. Other autotrophs: algae and chemolithotrophs are of minor importance. Algae cover only the upper 2–3 mm of the soil surface and are active mainly on hydromorphous and flooded soils (Kuz'yakov, 2004). Janssens *et al.* (2001) described the soil CO₂ efflux as the result of two main processes: the production of CO₂ in the soil and its transport from soil to the atmosphere (Figure 2.3). Soil respiration releases large amounts of CO₂ into the soil pore space. This leads to high soil CO₂ concentrations in soil air, where total storage may be equal or exceed the atmospheric CO₂ storage in forests.

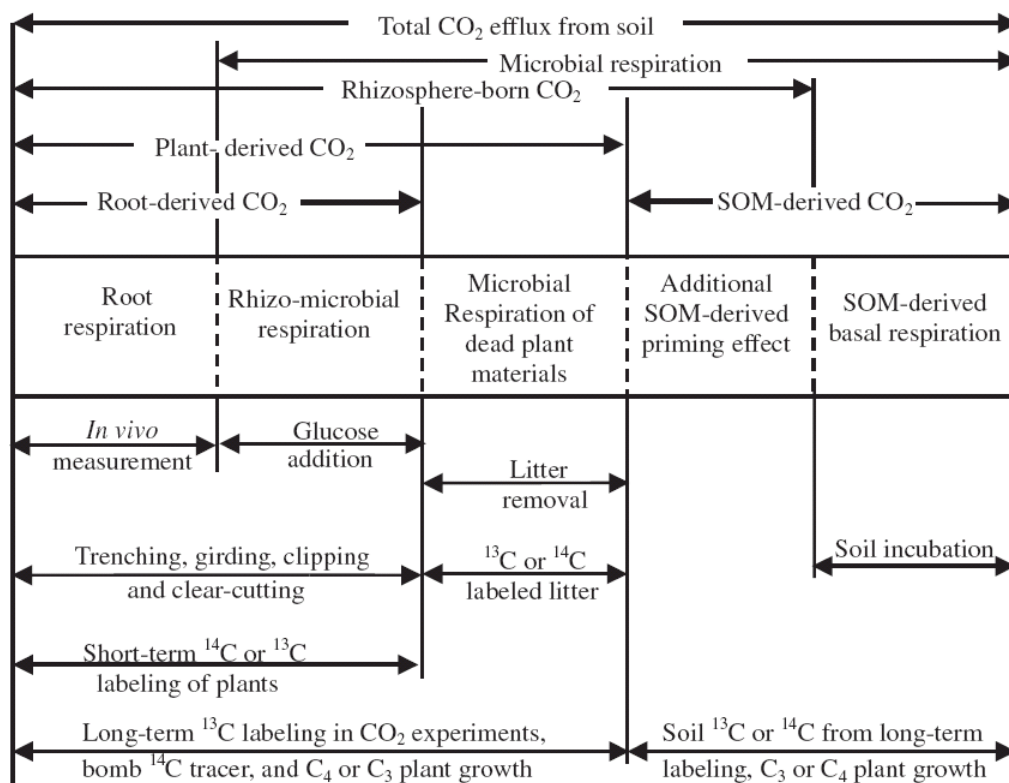


Figure 2.2. A Conceptual Scheme of Soil Respiration (Luo and Zhou, 2006)

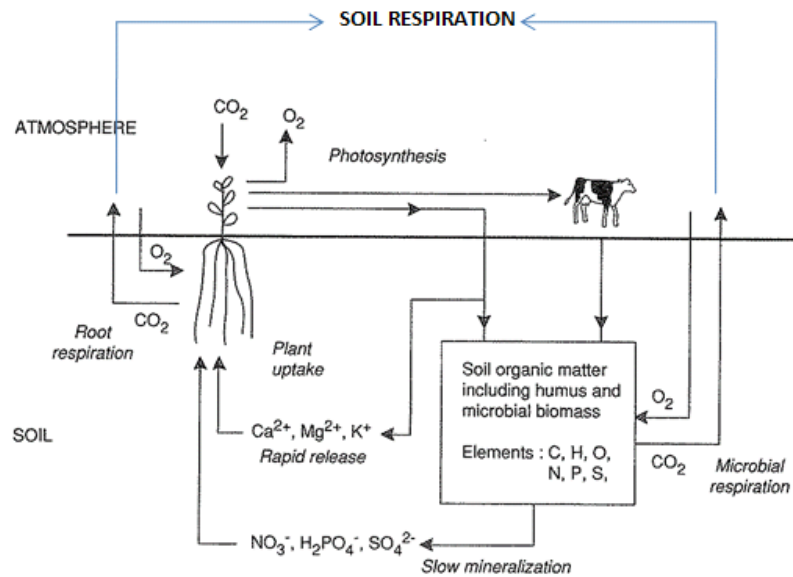


Figure 2.3. Carbon in the soil, plant and atmosphere (modified from Rowell, 1996)

Although soil respiration studies were made in Turkey before (Evrendilek *et al.* 2006; Evrendilek *et al.* 2004; Tufekcioglu *et al.* 2006; and Kizilkaya *et al.* 2004); there are few studies (Koçyiğit, 2008, Kara and Bolat, 2008, Akfırat, 2009) in the literature regarding effects of land conversion from forest to agriculture on soil C and respiration. Moreover, no specific studies have been found on conversion of forests to hazelnut plantations around the world.

Asan (1998) defined the locations of carbon sinks in Turkish forests. He reported that the amount of carbon stocks in the Turkish forest soils could be estimated as the total rate of 58% of the total biomass. He calculated this rate using empirical equations that are based on the calculations of tree trunks, branches and leaves.

Evrendilek *et al.* (2006) quantified the net carbon budget of the Mediterranean forest ecosystems in Turkey. The carbon stock of aboveground biomass, aboveground litterfall, and leaf litter decomposition of four indigenous tree stands (*Pinus brutia*, *Pinus nigra*, *Cedrus libani*, and *Juniperus excels*), and a mixed stand of *Abies cilicica*, *P. nigra*, and *C. libani* was measured in the southern forests of Turkey.

Numerous researchers have studied soil respiration detection depending on land use change since 1950s. In last decade, this research field became more popular after the emerging Global Climate Change issues. Kim (2008), Wang *et al.* (2007), Lou *et al.* (2004), Tedeschi *et al.* (2006), Larionova *et al.* (1998), Frank *et al.* (2002), Lee and Jose, (2003), Teklay *et al.* (2006), Jia *et al.* (2005), Popescu (2001), Van der Molen *et al.* (2004), Tufekcioglu and Raich (2001), Trettin *et al.* (2001), Nay and Bormann, (1999), Epron *et al.* (2006), Sanchez *et al.* (2003), Van Laake *et al.* (2004), Ochoa-Gaona, S *et al.* (2000), Miglietta *et al.* (2007), Dawson and Smith (2007) investigated the soil respiration and carbon balance. Physical and chemical soil analyses were investigated by Schumacher, (2001), Rowell, (1996), Luo and Zhou, (2006), Nelson and Sommers, (1982). They quantified that the physical and chemical parameters of soil affect the soil respiration.

Deng *et al.* (2010), assessed the main and interactive effects of elevated (CO₂) and Nitrogen addition on soil respiration by growing tree seedlings in ten large open-top chambers under CO₂ (ambient CO₂ and 700 µmol/mol) and nitrogen (ambient and 100 kgN/ha/year) treatments in subtropical regions of China. They found that mean value of annual soil respiration was 5.32±0.08, 4.54±0.10, 3.56±0.03 and 3.53±0.03 kg CO₂ m²/yr in the chambers exposed to elevated (CO₂) and high N deposition.

Zemanova *et al.* (2008), conducted soil respiration study on three wet meadow ecosystems in the Czech Republic. They reported that soil respiration rates were significantly affected by soil temperature, although they differed among the sites, just as nutrient availability differed on each sampling sites. They also figured out that The highest CO₂ emissions rates in situ were measured in June, when the soil temperature was 19°C. The rates reached up to 10.31 µmol CO₂ /m²/s¹ at eutrophic site, at peaty oligotrophic site 7.03 µmol CO₂ /m²/s¹, and 8.38 µmol CO₂ /m²/s¹ at mineral mesotrophic site.

Elberling and Brandt (2003) worked on seasonal trends in the production and release of CO₂ from soil. They quantified the temperature dependence of microbial soil respiration over the temperature range typically observed in the Arctic, to predict the actual site-specific winter soil respiration and to evaluate to which extent the burst events observed during thawing can be explained by the release of CO₂ being produced and trapped during the winter.

Sivrikaya *et al.* (2007) proposed a satellite image processing methodology to produce spatially explicit estimates of the carbon storages (aboveground and belowground) depending on land use/cover changes in two different forest ecosystems in northeast forest region of Turkey.

Geoghan and Nelson (2002) described the methods to use spatial analysis on land use/cover for deforestation. They discussed basic remotely-data information and analyzing processes.

Kim (2008) carried out a study in South Korea to determine the effects of clear-cutting on soil CO₂ efflux in a 42-year-old pine stand (*Pinus densiflora*). He found high soil CO₂ efflux rates in Clear Cut Pines (CCP) were attributed to the change of soil temperature, soil pH, and soil organic C and soil moisture content following canopy removal. In addition, soil temperature in CCP was significantly higher than in Uncut Pines (UCP) except during winter ($P < 0.05$). Soil pH was also significantly higher (0.1–0.5 units) in CCP than in UCP ($P < 0.05$), suggesting a better environment for microbial or root growth activity.

Kuzyakov (2006) claimed that there are five main biogenic sources of CO₂ efflux from soils and he described each due to their turnover rates and the mean residence time of carbon. These sources are known as root respiration, rhizomicrobial respiration, decomposition of plant residues, the priming effect induced by root exudation or by addition of plant residues, and basal respiration by microbial decomposition of soil organic matter. In his study, he mentioned that plants are the most important autotrophs contributing to CO₂ efflux from soil by root respiration.

Yunsheng *et al.* (2004), determined the rates of CO₂ emissions from subtropical arable soils of China. According to results of the study, the average annual fluxes were estimated 2.84, 2.13 and 1.41 kg CO₂ m⁻² year⁻¹ from red soils derived from granite parent materials (G), tertiary (T) red sandstone, and quaternary (Q) red clay. Soil temperature strongly affects the seasonal variability of soil CO₂ flux (85.0 – 88.5% of the variability), followed by DOC (55.8 – 84.4%) and rainfall (43.0 – 55.8%). The differences in soil CO₂ flux among the three red soils were partly explained by MBC (33.7 – 58.9% of the variability) and DOC (23.8 – 33.6%). The results showed that soil CO₂ flux had clear seasonal fluctuations with the maximum value in summer, the minimum in winter and intermediate in spring and Fall. Significant differences in soil CO₂ flux were found among the three red soils, generally in the order of G > T > Q.

Tüfekcioglu *et al.* (2001) quantified the rates of soil respiration among sites within an agricultural landscape in Iowa, USA. The study was conducted in riparian cool-season grass buffers, in re-established multispecies riparian buffers and in adjacent crop (maize and soybean) fields. Soil respiration was measured approximately monthly over a two-year period using the soda-lime technique. Mean daily soil respiration across all treatments ranged from 0.14 to 8.3 g C m⁻² d⁻¹. They found no significant differences between cool-season grass buffers and re-established forest buffers, but respiration rates beneath switch grass were found to be significantly lower than those beneath cool-season grass.

The in situ soil respiration measurement technique was first proposed by Parkinson (1981). After that, an infrared gas analysis in-situ measurement equipment namely, CIRAS was used by Medlyn, *et al.* (2005); Jones *et al.* (1999); Maestre and Cortina, (2003) ; and Carrasco, *et al.* (2007). This study follows a similar methodology to these.

Parkinson (1981) investigated a method for measuring soil respiration in the field where a chamber of known volume is placed on the soil and the rate of increase in CO₂ within the chamber is monitored. He described the way of air samples were withdrawn at one minute intervals and separately analyzed at the equipment. In the study it was

explained that the air is continuously sampled in a closed circuit through the respiration equipment, and the soil respiration rate is calculated, displayed and recorded by the instrument. As a result, the air within the chamber is carefully mixed to ensure representative sampling without generating pressure differences which would affect the evolution of CO₂ from the soil surface.

Kolari et al., (2006) prepared a study titled “Forest floor vegetation plays an important role in photosynthetic production of boreal forests”. They found that the contribution of forest floor vegetation to the ecosystem gross photosynthetic production in boreal Scots pine forests is significant. Mosses especially can utilize efficiently the low irradiances in the shade of the tree canopies. The seasonal pattern of GPP measured with the automated soil chambers was similar to that predicted with the temperature-driven phenology model and the manual chamber measurements. During the study, light responses of photosynthesis in the dwarf shrub and moss species were measured in July and August 2003 with a portable photosynthesis measuring device CIRAS 2.

Pumpanen *et al.*, (2004) investigated the different chamber techniques for soil CO₂ efflux. They have found that the fluxes generated with the calibration system were stable and appeared to be spatially homogeneous, allowing conversion factors for different chambers to be produced. Reliability of the chamber systems was not related to the measurement principle. Good results can be achieved with both-steady state and non steady state chambers. CIRAS-2 was categorized as non-steady state measurement equipment which uses through-flow chambers.

Fernandez *et al.*, (2007) investigated seasonal variations of soil CO₂ emissions from deciduous forests. In-situ carbon dioxide flux measurements were performed using CIRAS IRGA soil gas analyzer. They found that potential soil CO₂ emissions from both forest types were quite similar, despite their notably different soil organic matter contents.

Newell (2006) explained the gas exchange measurements were made with an infrared gas analyser (Qubit S151[®] IRGA) connected to an AC gas pump and flow meter. The rate of CO₂ uptake or production (R_{CO_2}) of rooted microcuttings was recorded using a Lab Pro[®] interface and Logger Pro[®] software. Metabolic heat production and respiration values from microcuttings were calculated and plot.

Goins *et al.*, (1997) quantified meteorological variables and characterized an existing CO₂ and temperature gradient along a rural-urban transect. The aim of the study was to determine if such gradient could simulate short-term (50 year) climate projections regarding atmospheric CO₂ and air temperature and to quantify associated changes in vegetative productivity associated with first year re-growth from Fallow farmland. CO₂ analyses were performed using Qubit S151[®] IRGA.

Maclain and Martens (2006) measured the potential mineralization, nitrification, and denitrification of N compounds representing successive steps in microbial steps in microbial N metabolism. They also partitioned N₂O production into fungal and bacterial components by the use of cycloheximide and streptomycin, inhibitors of fungal and bacterial activity, respectively. In-vitro CO₂ concentrations were determined by flushing the gas from the incubation flasks through a Qubit S151[®] IRGA.

Albrecht and Kandhji, (1999) studied the relationship between soil organic matter and carbon emission. They showed that agriculture, deforestation and reforestation are the main sources of CO₂ emissions to atmosphere.

Jia *et al.*, (2005) demonstrated the partition root and microbial activities to soil respiration by greenhouse experiment using two approaches. They used inferred and observed methods. The inferred approach in the study used a regressive relationship between soil respiration rates and root biomass at different observation times. The authors employed a method that was based on the difference between soil respiration rates of planted and unplanted treatments.

Michelsen *et al.*, (2004) investigated the seasonal changes and spatial distribution of soil total, dissolved organic carbon and microbial biomass C during 18 months, quantified the soil CO₂ emission in the beginning of the rainy season, and related these variables to the fire frequency in important dry vegetation types grassland, woodland and dry forest in Ethiopia. They found that in woodland and woodland–wooded grassland C_{mic} and SIR increased in the dry season and gradually decreased during the following rainy season, confirming previous suggestions that microbes may play an important role in nutrient retention in the dry season

Aka *et al.*, (2005) determined how carbon and nitrogen mineralization of carob soil (*Ceratonia siliqua* L.) are affected by the addition of Aleppo pine (*Pinus halepensis* Mill.) leaf, Kermes oak (*Quercus coccifera* L.) leaf, and their mixtures (containing 2.5% total organic carbon) under the same laboratory conditions (30 days at 28 °C). They collected the carob soils from two different sites in the eastern Mediterranean region of Turkey. Carbon mineralization of all soils was determined using CO₂ respiration method. Nitrogen (N) mineralization was measured in vitro both in no leaf added soils and plant leaf added soils. They presented that addition of plant leaves in both sites clearly increased microbial activities. No added soils were significantly different from the plant leaf added soils in respect to carbon (C) mineralization at the end of the incubation period, while no statistical difference was observed among the three treatments in which plant leaves were added. They also concluded that ratios of nitrogen mineralization declined with additions of leaves in both sites.

Frank *et al.*, (2002) studied soil CO₂ flux measurements over a 5-year period for the entire growing season with 2 years of over winter measurements for a Northern Great Plains semiarid mixed-grass prairie. They suggested that soil CO₂ flux is a significant contributing factor to the annual carbon budget of northern semiarid grasslands. The objectives were to quantify soil CO₂ fluxes for grazed mixed-grass prairie (GP), non-grazed mixed-grass prairie (NGP), and grazed western wheatgrass [*Pascopyrum smithii* (Rybd) Love] sites, and to evaluate the relationship between soil temperature,

air temperature, soil water content, and soil CO₂ flux for purposes of developing a predictive model.

Arnold *et al.*, (2004) examined the net greenhouse gas exchange at the soil surface in deciduous forests on soils with high organic contents. Fluxes of CO₂, CH₄, and N₂O were measured using dark static chambers for two consecutive years in three different forest types; (i) a drained and medium productivity site dominated by birch, (ii) a drained and highly productive site dominated by alder and (iii) an un-drained and highly productive site dominated by alder. Although the drained sites had shallow mean groundwater tables (15 and 18 cm, respectively) their average annual rates of forest floor CO₂ release were almost twice as high compared to the un-drained site (1.9G0.4 and 1.7G0.3, compared to 1.0G0.2 kg CO₂ mK2 yrK1). The average annual CH₄ emission was found to be almost 10 times larger at the un-drained site (7.6G3.1 compared to 0.9G0.5 g CH₄ mK2 yrK1 for the two drained sites). The average annual N₂O emissions at the un-drained site (0.1G0.05 g N₂O mK2 yrK1) were shown to be lower than at the drained sites, and the emissions were almost five times higher at the drained alder site than at the drained birch site (0.9G0.35 compared to 0.2G0.11 g N₂O mK2 yrK1). The temporal variation in forest floor CO₂ release was explained by the authors to a large extent by differences in groundwater table and air temperature, but little of the variation in the CH₄ and N₂O fluxes could be explained by these variables. The measured soil variables were only significant to explain for the within-site spatial variation in CH₄ and N₂O fluxes at the un-drained swamp, and dark forest floor CO₂ release was not explained by these variables at any site. The between-site spatial variation was attributed to variations in drainage, groundwater level position, productivity and tree species for all three gases. Their results indicated that N₂O emissions are of greater importance for the net greenhouse gas exchange at deciduous drained forest sites than at coniferous drained forest sites.

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⁻¹, 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%.

3. MATERIALS AND METHODS

3.1 Study Area

The study was conducted in the Karasu District, located at $41^{\circ} 05' 08.53''$ N latitude and $30^{\circ} 41' 58.46''$ E longitude in the Marmara Region of Turkey (Figure 3.1). Karasu is a recent settlement of the Province of Sakarya with a population of 47,900. The surface soils of the village are 450 km². The geography of the region covers the northern part of the Anatolia and Thrace. The southern boundary of this region follows the upper part of the southern flanks of the Northern Anatolian Mountains (Atalay, 2000).

This area was chosen since 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 soils (13,784 ha) as of 2004 (Forest Service, 2003). During the preliminary field trips it was observed that these soils were converted from forest to hazelnut plantations and corn fields.

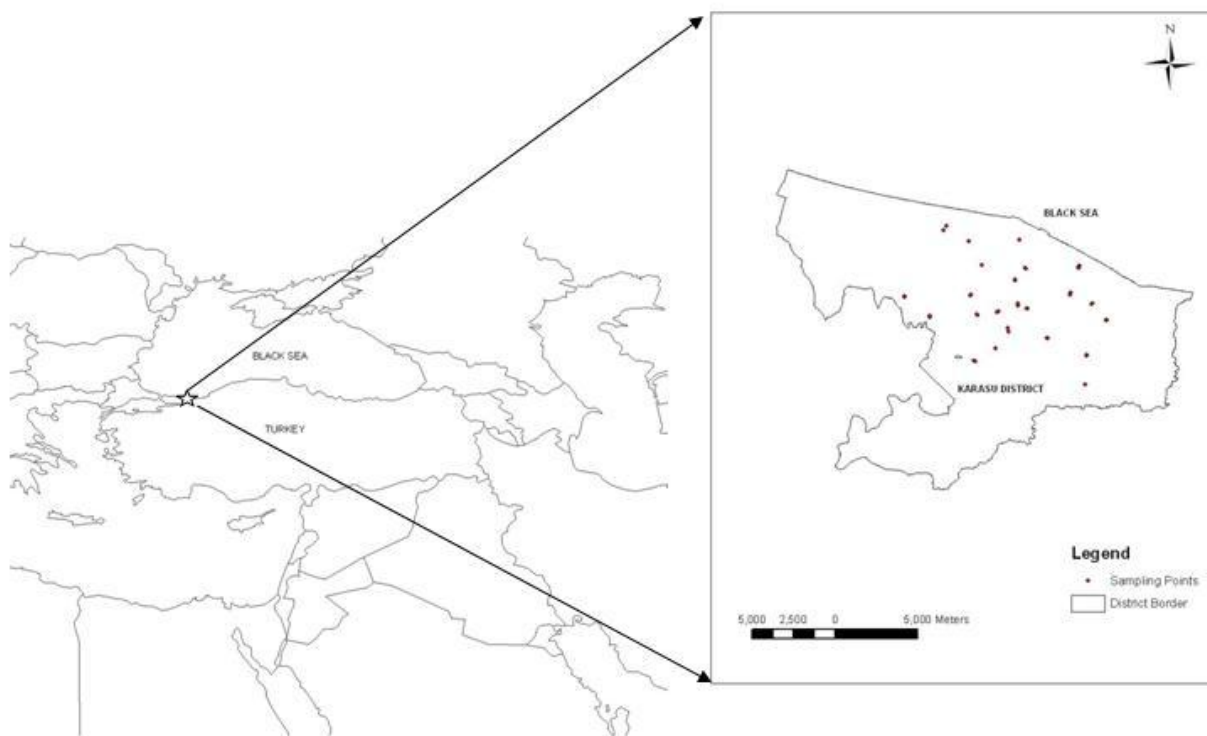


Figure 3.1. Study Area

3.1.1 Topography

The region is located within the Northern Anatolian Mountains extending across the East -West direction. These mountains divide the district into few branches, 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).

3.1.2. 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.

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

3.1.3 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 (*Castanea 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,2004).

3.2 Land Use in Karasu District

The majority of the agricultural lands in the District are used for hazelnut and corn cultivation. Favourable 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).

This study covers different methodologies for presenting the effect of land use change on soil. The in situ soil respiration measurements were performed during the field trips. Then, the soil samples were brought to the laboratory for experimental analysis. Environmental parameters such as soil moisture and texture, pH, bulk density, soil electrical conductivity, soil organic matter, and elemental carbon were determined by experimental analysis. Microbial respiration experiments were ran simultaneously with these analyses. The GIS and Remote Sensing technologies were employed to detect land use change from 1987 to 2008. Results of

both laboratory experiments and satellite image processing were the main data entries to statistical analyses. These methodologies were presented in Figure 3.2.

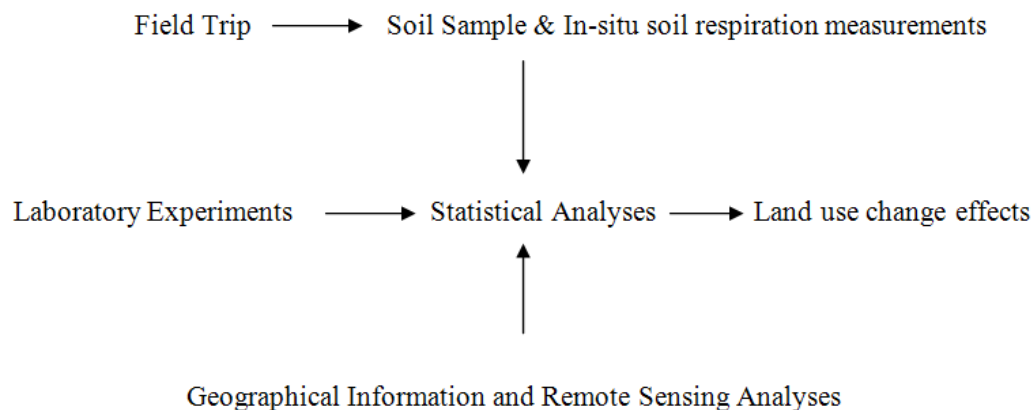


Figure 3.2 . Study plan

3.2.1. Field Trips

Four field trips were carried out during the study (Table 3.1). The first one was in February 2008, the second was in July 2008, the third one was in April 2009, and the last one was in November 2009. These dates were chosen to determine and understand the impact of the seasonal changes on soil respiration, and soil carbon.

Table 3.1. Dates of the field trips

Dates	Season
7-8-9-10 February 2008	Winter 2008
11-12-13-14-15 July 2008	Summer 2008
5-6-7-8-9 April 2009	Spring 2009
4-5-6 November 2009	Fall 2009

3.2.2. Soil Sampling and Selected Parameters

45 soil samples from previously selected locations were analyzed for soil organic matter (SOM), 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 points were selected from degraded forest soils such as the hazelnut agriculture fields.

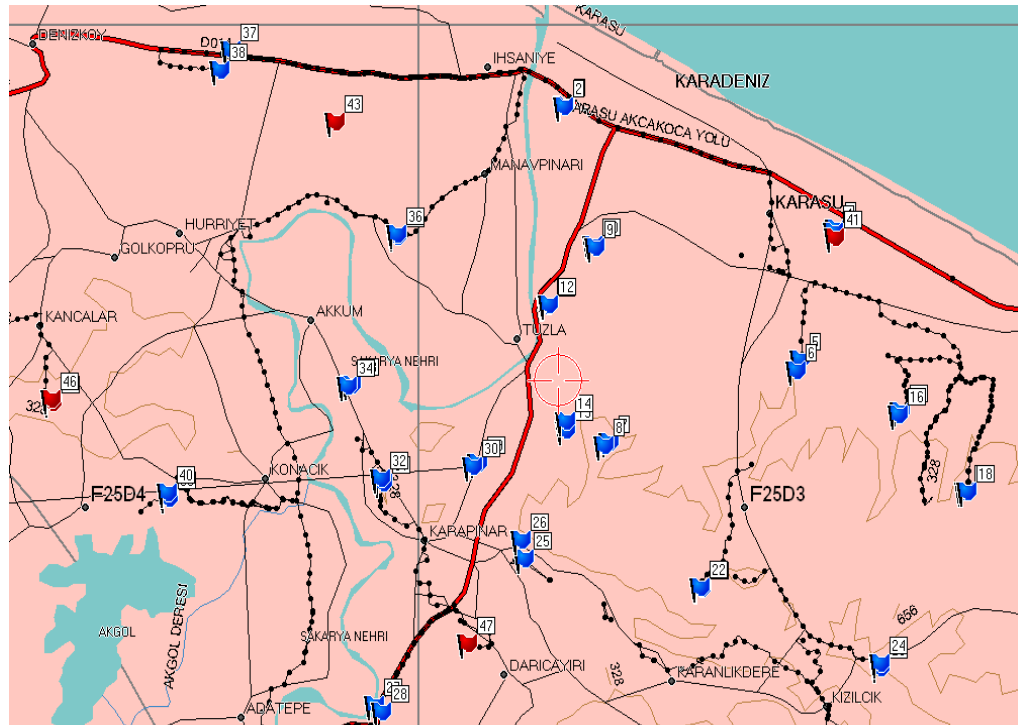


Figure 3.3. The sampling locations

The undisturbed soil samples were taken from four different soil depths 0-5, 5-20, 20-45 and 45-100 cm to measure the bulk density and gravimetric soil moisture, similar to the methodology used in Jones et al., (1999) and Kizilkaya et al., (2005) (they both used a soil auger (Eijelkamp Agrisearch) as shown in Figure 3.4). The disturbed samples, to measure the elemental carbon were taken from the soil surface between 0-20 cm depth. This portion of the soil is the most cultivated zone that is normally tilled and contains the major portion of the

crop's roots (Soil Fact Sheet, 2003). The top layer of soil was removed before inserting the soil auger to collect samples and to prevent the biological activity during the laboratory experiments. The auger was screwed into the ground then lifted out. Soil is retained on the blades of the auger and kept for testing. The soil sampling using this method was labeled “disturbed” by Hodgsdon (Hodgsdon, 1978). Triplicate soil sampling was done to obtain the mean values during the soil experimental analyzes as recommended by Rowell and Carter (Rowell, 1996, Carter, 2007).

Table 3.2.The parameters measured in the study

Parameter	Analysis	Method
In-situ soil respiration	On site	IRGA
Soil temperature	On site	Raich and Tufekcioglu, 2000
Elemental carbon	Laboratory	Walker and Desanker,2004
C:N ratio	Laboratory	Walker and Desanker,2004 & Vose,2005
Soil organic matter	Laboratory	Modified Walkley-Black
Soil gravimetric moisture	Laboratory	Loss on ignition
pH	Laboratory	U.S. Salinity Laboratory Staff, 1954
Electrical conductivity	Laboratory	Conklin,2005
Microbial respiration	Laboratory	Isermayer,1952 and Rowell, 1996
Soil texture	Laboratory	ASTM 152
Bulk Density	Laboratory	ASTM D2937

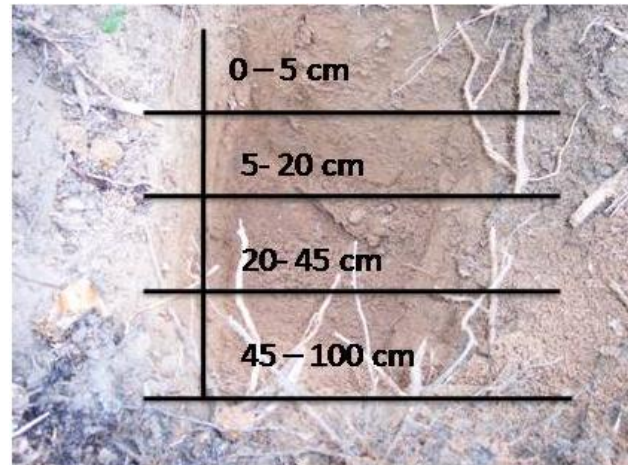


Figure 3.4. Soil sampling depth intervals

3.2.3 In-situ Soil Respiration Measurements

Among various methods available in literature such as closed dynamic chamber, isotopic and soda lime methods, CIRAS which works with infrared gas analyzer (IRGA) was selected due to its easy response to soil carbon dioxide and allowing mobility during the field trips in the study as used by Kolari et al., (2006), Pumpanen et al.,(2004), Fernandez et al.,(2007), Carroasco et al.,(2007).

3.2.3.1.CIRAS-2 and Soil Respiration Chamber (SRC). The method of measuring soil respiration is that described by Parkinson, (1981) where a chamber of known volume is placed on the soil and the rate of increase in CO₂ within the chamber is monitored. In the original method used by Parkinson, (1981), air samples were withdrawn at one-minute intervals and separately analyzed. With this system, the air is continuously sampled in a closed circuit through the CIRAS (Figure 3.5) and the soil respiration rate is calculated, displayed and recorded by the analyzer. The air within the chamber is carefully mixed to ensure representative sampling without generating pressure differences, which would affect the evolution of CO₂ from the soil surface (PP Systems, 2007). The amount of CO₂ absorbed by

soda lime in a chamber over the soil surface is determined by the gain in soda-lime dry weight during the sampling period. The increase in weight is directly related to the absorption of CO₂ with a correction factor (Luo and Zhou, 2004). CIRAS-2 employs a non-dispersive infrared measurement, coupled with microprocessor-based signal processing, to achieve very good stability and specificity to make accurate of CO₂ and water vapour concentrations. The analyser measures the absolute concentration of one gas sample referred as REF. It also measures the difference in concentration to a second sample which is referred as AN. With gas exchange measurements, REF and AN are defined as the air entering and leaving the leaf cuvette, respectively (PP Systems, 2007). Table 3.3 shows the system parameters used by Soil Respiration Chamber



Figure 3.5. The CIRAS and Soil Respiration Chamber (PP systems, 2007)

Table 3.3. CIRAS system parameters (PP systems, 2007)

System volume	Soils of exposed soil	CO₂ change	Time	System temperature
1170 cm ³	78 cm ²	60 ppm	60 seconds (adjustable to 120 seconds)	25 ⁰ C

The assimilation is measured by placing a closed chamber on the soil and monitoring the CO₂ concentration increase rate inside the chamber. Then, assuming a well-mixed sealed system, the following formula can be generated:

$$R = \frac{(C_n - C_o)}{T_n} \times \frac{V}{A} \quad (3.1)$$

where ,

R , is the assimilation rate (Flux of CO₂ / unit soils/ unit time),

C_o , is the CO₂ concentration at $t = 0$,

C_n , is the concentration at time t_n ,

A , is the soils of the exposed soil,

V , is the total system volume.

Thus

$$R = b \times \frac{P}{1000} \times \frac{273}{273 + T_a} \times \frac{44.01}{22.41} \times \frac{V}{A} \quad (3.2)$$

where ,

R is the CO₂ flux in kg.m⁻².s⁻¹,

V is the system volume (largely the chamber volume) in m³,

A is the soil soils exposed in the chamber in m²,

P is the atmospheric pressure in mb,

T_c is the temperature of the system volume (chamber) in °C.

The CIRAS measures

DC/DT = b (the difference between CO₂ flux) as ppm/second,

V in cm³,

A in m²,

R is expressed as g.m⁻².hr⁻¹.

To convert the CO₂ flux from (g.m⁻². hr⁻¹) to (micro-mol.m⁻².s⁻¹), 6.312 coefficients were used (PP systems, 2003). CIRAS measures CO₂ flux using the units volume/volume ratio (= ppm by volume = micro – litre/litre = micro-bar/bar = micro-mol/mol). One kg mol of gas (44.01 kg of CO₂) at STP occupies 22.41 m³.

3.3 Definition Primary Parameters

The in situ soil respiration measured by CIRAS and the elemental carbon content of the soil determined by the laboratory experiments were classified as the primary parameters (Lal, 1995, Risk, et al., 2008, Li et al., 2009). The In situ soil respiration represents the overall respiration activities from the top 20 cm of the soil and the elemental carbon content relates with the soil organic carbon content and the degradability ratio of the organic materials in the soil yields the C:N ratio.

3.4 Pre-treatment of the samples

Field moist soil samples were gently sieved through a 2 mm mesh to remove stones, roots, and large organic residues and stored in a polyethylene bag for 1 week (Islam and Weil, 2000). The polyethylene bags were loosely fold to allow access of air and shaken to aerate the soil each day (Soil Fact Sheet, 2003). The samples were left to dry in the air then they were crushed using a mortar and passed through a 2 mm sieve to remove the roots and stones (Rowell, 1996).

3.5 Laboratory Experiments

Laboratory experiments were conducted on soil samples for the following parameters: Soil organic matter (SOM), soil gravimetric moisture, soil elemental carbon, C: N ratio, soil temperature, the microbial respiration, soil texture, pH, and electrical conductivity.

3.5.1 Environmental Parameters (Abiotic and Biotic Factors)

A range of biotic and abiotic factors, such as temperature, soil water content, aboveground vegetation structure, photosynthetic activity, or plant phenological development (Subke et al., 2006) control soil respiration. Luo and Zhou, (2006), reported that temperature, soil moisture, and texture, pH, bulk density, soil electrical conductivity and soil organic matter (SOM) affect the rate of soil respiration. Laboratory experiments were conducted to determine the influences of these parameters.

3.5.1.1. Soil Texture Analysis. Sand, silt, and clay are the three components of soil texture. These components were determined by Bouyoucos hydrometer and the ASTM 152 method. Various relative compositions, expressed on percentage bases, are used in the experiments to give soil a textural name such as sandy loam or loamy clay. For soil containing significant amounts of silt, the term loam is used, although with high levels (>88% silt, < 20% sand, and 12% clay), the soil is called silt. Thus, a soil containing high amounts of sand would be sand, sandy loam, loamy sand, or sandy clay, and clay soils would be designated as clay, clay loam, sandy clay, and silt soils as silt loam. The textural name of a soil is established by determining the soil's relative percentage of sand, silt, and clay and then locating this percentage on a textural triangle (as shown in Figure 3.6). Sandy soils are the easiest to extract and analyze while clay soils are the hardest. Drying, crushing, and sieving will aid in extraction and analysis, although it may not be necessary to crush very sandy soils. Clayey soils may retain small amounts of contamination even after extensive extraction. In all cases extraction and analysis procedures must be robust enough to handle all textures containing all clay types (Conklin, 2005).

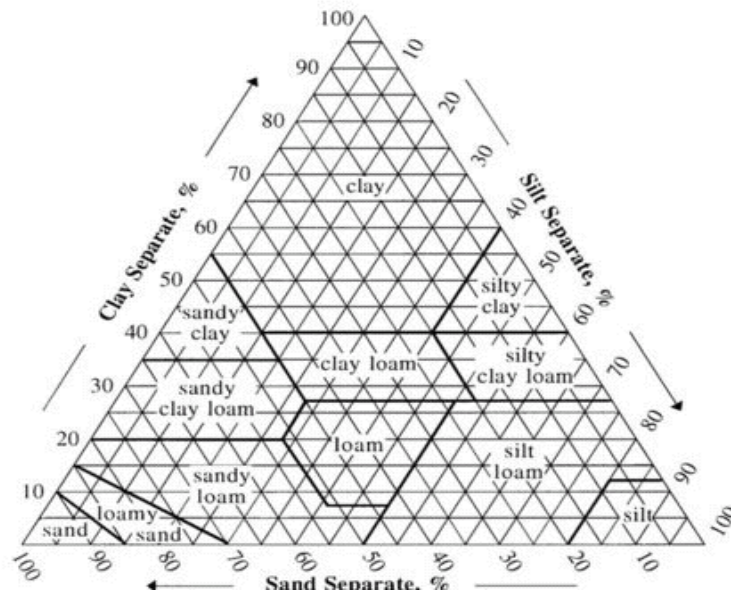


Figure 3.6. Soil Texture Triangle (USDA, 1938)

This method quantitatively determines the physical proportions of three sizes of primary soil particles as determined by their settling rates in an aqueous solution using a hydrometer. The hydrometer method of estimating particle size analysis (sand, silt and clay content) is based on the dispersion of soil aggregates using a sodium hexametaphosphate solution and subsequent measurement based on changes in suspension density. The utilization of the ASTM 152 H-Type hydrometer is based on a standard temperature of 20°C and a particle density of 2.65 g/ cm³. Corrections for temperature and for solution viscosity were made by taking a hydrometer reading of a blank solution. The method has a detection limit of 2% sand, silt and clay (dry soil basis) and is generally reproducible within 8% (relative). Bouyoucos hydrometer, thermometer, Humboldt mixer and dispersion cup, stop watch and clock, glass graduated cylinders capable of containing 1200 ml of solution and 250 ml beakers were used for the texture analysis (Sheldrick and Wang, 1993).

3.5.1.2. Soil Organic Matter. SOM is determined by potassium dichromate reduction of organic carbon and subsequent spectrophotometric measurement (modified Walkley-Black) (Nelson and Sommers, 1982). The primary source of soil organic matter (SOM) is plant material and its composition reflects. Decomposition through animals and microorganisms causes changes in composition to produce humus in the form of highly complex and very large organic molecules. Soil organic matter is therefore a mixture of plant and animal material in various stages of decomposition together with humus (Rowell, 1996). SOM also consists of humic and non-humic substances. The non-humic materials are unrecognizable organic residues of plants, animals, and microbes. They usually account for up to 20% of SOM. The remaining 80% or more of SOM are humic substances (*i.e.*, humus), which are formed by secondary synthesis reactions. As litter undergoes biochemical alterations, microorganisms synthesize additional compounds, some of which polymerize or condense through either chemical or enzymatic reactions. A key mechanism of humus formation appears to be through enzymatic or autooxidative polymerization reactions involving phenolic compounds (Luo and Zhou, 2006).

The modified Walkley-Black method quantifies the amount of oxidizable organic matter in which OM is oxidized with a known amount of chromate in the presence of sulfuric acid. The remaining chromate is determined spectrophotometrically at 600 nm wavelength.

3.5.1.3 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.

3.5.1.4. 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°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 ($\text{g}_{\text{soil}}/\text{g}_{\text{water}}$) or on volumetric basis ($\text{cm}^3_{\text{water}}/\text{cm}^3_{\text{soil}}$). The mass of oven-dry soil in a 10g air-dried soil sample was used in the analysis (Rowell, 1996).

3.5.1.5. 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.

3.5.1.6. Soil pH. U.S. Salinity Laboratory Staff, (1954) measurement method was followed 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.

3.5.1.7. 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).

3.5.1.8. 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 C⁰ 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).

3.5.1.9 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 is. This parameter shows the decomposition rate in the soil (Vose et al., 1995).

3.5.1.10 The laboratory determination for measuring the microbial respiration. Carbon dioxide release from soil is an indicator of microbial and root activity and essential component of carbon budget system. The soda lime technique has been used extensively for more than 30 years to measure carbon fluxes from soil under field conditions (Monteith et al., 1964). The CO_2 is the end product of respiration within soil. The organic materials are degraded due to biological activity. As a result CO_2 that is produced by respiration in a moist soil is trapped by absorption in a NaOH or BaOH solution. The amount of remaining NaOH after a known time period is determined by titration with standard acid (Isermayer, 1952 and Rowell, 1996). A 250 ml conical flask with a rubber was prepared the respirometer as shown in Figure 3.7.

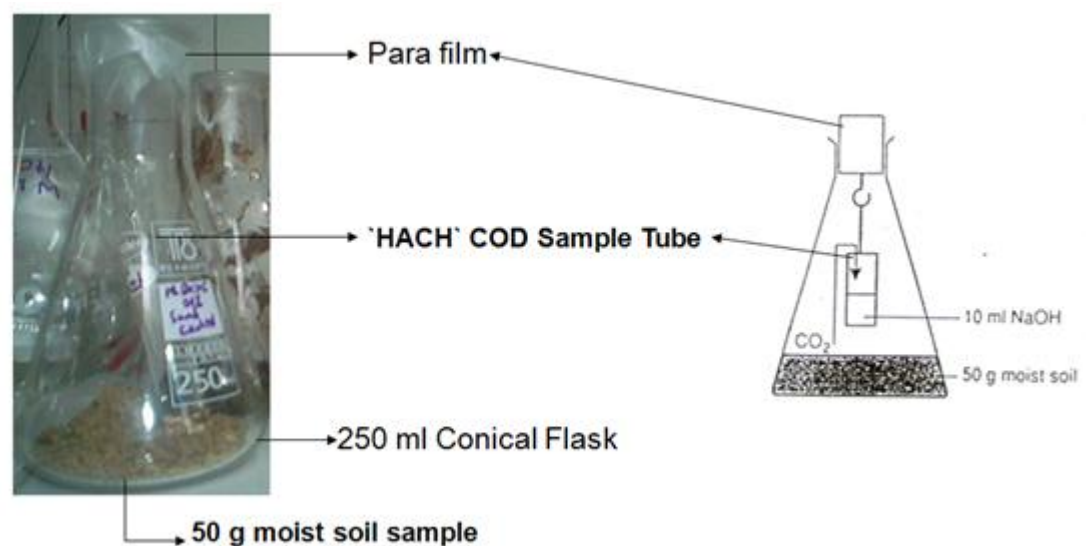


Figure 3.7 Microbial Respiration Layout (Rowell, 1996)

The flasks were sealed with Para film and a blank “HACH” COD sample tube was inserted into the flask. Sodium Hydroxide (NaOH) 0.3M, Hydrochloric Acid (HCl) 0.1 M, Barium chloride (BaCl) 1M, Phenol phthalein indicator reagents were used to obtain the CO₂. The amount of CO₂ yielded at this experiment was calculated using the following formula

$$\text{CO}_2 - \text{C } (\mu\text{g g}^{-1} \text{ soil}) = \frac{((B-S) \times (M) \times (E))}{\text{DOW}} \quad (3.3)$$

where,

- B is the amount of the standart acid to measure the blank NaOH solution (μl),
- S is the amount of the standart acid to measure the NaOH at soil samples (μl),
- M denotes Molarity of HCl,
- E is 6 (equivalent weight to figure out the amount of Carbon),
- DOW denotes dry oven soil weight (g).

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, the in-situ soil carbondioxide respiration and laboratory measurements were linked with Global Positioning System (GPS) coordinated sampling points. Two Landsat 5 – Thematic Mapper (TM) images of 1987 and 2007 were used to extract land use maps. The sources, path and row specifications of the images were shown on Table 3.4.

Table 3.4. Data sources of the study

Satellite Images	In situ and Laboratory measurements in 2008 and in 2009	Maps	GPS Data	Statistical Data	Hardware and Software
Landsat TM 1987 (30m X 30m)- Global Land Cover Facility Landsat TM 2007 (60mX60m)- European Space Agency	In-situ soil carbondioxide respiration measurements Laboratory Measurements	Topographical Map of Karasu region Scale 1:25.000 (Digital Format) Thematic Forest Stand Map 2004 (1:25.000) Land Use Maps	GPS coordinated In-situ soil carbondioxide respiration measurements	Thematically Layers In-situ soil carbondioxide respiration measurements Laboratory Measurements	PC ERDAS Imagine 9.3 Version ArcGIS 9.3 Version with Spatial and Geostatistical Analyst Extension

Both images were imported using ERDAS Imagine software. Landsat 5 – TM of 1987 was geo-referenced to the 1:25.000 topological map. The intent of image rectification and restoration is to correct image data for distortions or degradations that stem from the image acquisition process. The nature of such procedures varies considerably with such factors as the digital image acquisition type (digital camera, along-track scanner, across-track scanner),

platform (airborne versus satellite), and total field of view. Georeferencing correction process is normally implemented as a two-step procedure. First, those distortions that are systematic, or predictable, are considered. Second, those distortions that are essentially random, or unpredictable, are considered. Random distortions and residual unknown systematic distortions are corrected by analyzing well-distributed ground control points (GCPs) occurring in an image GCPs are features of known ground location that can be accurately located on the digital imagery (Lillesand, et al., 2004). Landsat TM satellite image is used due to higher spatial, spectral, and radiometric resolution than types of Landsat images.

The Universal Transverse Mercator Coordinate System, Zone 36, International 1909 Spheroid and European 1909 Datum were inserted as the background image information onto Landsat Images. Landsat 5- TM of 2007 was geo-referenced in image-to-image format with Landsat 5 – TM of 1987 (Jensen, 1996). The root mean standard error (RM.S.E) was yielded less than 0.56 m. The nearest neighbor re-sampling method is the simplest method and basically makes the pixels bigger, the color of a pixel in the new image is the color of the nearest pixel of the original image, was employed during georeferencing (Lillesand, *et al.* 2004). Radiometric normalization was not applied as each image was classified independently (A.Etter *et al.*, 2006). The image subsetting was performed for a way of reducing the extent of an image to include just the soils that is of interest. The 6th thermal band on the satellite images were excluded during the subsetting. The objective of the training process is to assemble a set of statistics that describe the spectral response pattern for each land cover type to be classified in an image (Lillesand, et al. 2004). The quality of the training data set used is of fundamental importance to a classification and a major determinant of classification accuracy. The training stage seeks to provide descriptive statistics for each class in the image that may be used to direct the accurate determination of class membership by the selected classifier. The typical approach to training adopted involves the acquisition of a sample of pixels of known class membership from the image to characterize the classes. These selected pixels represent the training set upon which the remainder of the classification analysis is based. Typically, the descriptive statistics derived from the training pixels are used to characterize the classes and ultimately convey the information needed to partition feature space so that class membership may be determined for all image pixels. Obtaining an accurate description of each class is seen as fundamental to the derivation of an accurate classification

(Foody and Mathur, 2006). A supervised classification technique using ERDAS Imagine software was applied to differentiate 4 classes: forest, urban-pasture & meadows – abandoned soils, water and agricultural production. Supervised classification involves the use of GCPs. In the study, 45 ground-control points were collected using a Global Positioning System (GPS). These points help to identify the true land use (Etter et al., 2006).

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

- a. 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.
- b. 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 then recorded in the corresponding cell of an interpreted data set.
- c. Output Stage: The results are presented at this section.

Gaussian maximum likelihood method was applied in supervised classification technique. The method evaluates both the variance and covariance of the category spectral response patterns when classifying an unknown pixel. To do this an assumption is made that the distribution of the cloud of points forming the category data is Gaussian (normally distributed) (Lillesand, *et al.* 2004). In the computation of digital number distributions, determining the means and covariances for the classes that fall within the training sites, a statistical (Bayesian) Probability Function is also calculated for the class data (NASA, 2008).

3.6.1 Land Use Change Detection

Change detection involves the use of multitemporal data sets to discriminate soils of land cover change between dates of imaging. The types of changes that might be of an interest can range from short term phenomena such as snow cover or floodwater to long term phenomena such as urban fringe development or desertification. The reliability of the change detection process may also be strongly influenced by various environmental factors that might change between image dates. In addition to atmospheric effects, such factors as lake level, tidal stage, wind, or soil moisture condition might also be important. Even with the use of anniversary dates to imagery, such influences as different planting dates and season-to-season changes in plant phenology must be considered. In this study, the temporal image differencing method was employed to detect the land use change from 1987 to 2007. In the image differencing procedure, digital numbers from one date are simply subtracted from those of the other. The difference in soils of no change will be very small (approaching zero), and soils of change will manifest larger negative or positive values. If 8-bit images are used, the possible range of values for the difference image is -255 to +255, so normally a constant is added to each difference image value for display purposes (Lillesand, et al. 2004).

3.6.1.1. Accuracy Assessment. The number of reference pixels is an important factor in determining the accuracy of the classification. More than 250 reference pixels are needed to estimate the mean accuracy of a class to within plus or minus five percent. Accuracy assessment is also known as to construct an “error matrix.” This is a square matrix in which the rows and columns represent the land cover classes from the classified image. So, if you have 5 classes, you will have an error matrix with five rows and five columns. The matrix is filled with counts taken from a sample. For every point in the sample you determine the “ground truth” and you know the image classification. In many situations the “ground truth” is determined from higher resolution air photos. Because the sample is not always acquired from the ground, it is often called “reference data” and it is assumed to be correct. Even if the reference data points are found by actual field visits, it is rarely done at the same time the satellite is flying overhead. KAPPA analysis was performed to run accuracy assessment on error matrix. This analysis is based on descriptive statistics technique; overall accuracy is

computed by dividing the total correct by the total number of pixels in the error matrix (Congalton, 1991). Jensen, 1996 and Congalton, 1991 defined that KAPPA analysis is a discrete multivariate technique used in accuracy assessment. The *Khat* statistics is taken place under KAPPA analysis. A *Khat* statistic ($\hat{K}$) which is the best estimate of the *kappa*, can be calculated. The *Khat* statistic is derived from the entire error matrix. The *kappa* is a discrete multivariate technique, which takes into consideration the off diagonal elements of the matrix (the error of omission and commission) as a product of the marginal totals (Cohen, 1960).

The *kappa* analysis generates a *Khat* ($\hat{K}$) statistic with a range from zero to one. It is described by Verbyla (1995) as follows:

$$\frac{\text{overall classification accuracy} - \text{expected classification accuracy}}{1 - \text{expected classification accuracy}}$$

More specifically it is computed in terms of the rows, columns and marginals of the error matrix as follows:

$$\hat{K} = \frac{N \sum_{i=1}^r X_{ii} - \sum_{i=1}^r (X_{i+} * X_{+i})}{N^2 - \sum_{i=1}^r (X_{i+} * X_{+i})} \quad (3.4)$$

Where r is the number of rows in the matrix, X_{ii} is the number of observations in row i and column i , X_{i+} are the marginal total of row i , X_{+i} are the marginal totals of column i , and N is the total number of observations (sample stations).

3.7 Statistical Analyses

SPSS 17 Statistical Software Package was employed to evaluate the field and laboratory data. Specifically, the aim was to assess (i) the correlation between primary (in-situ soil respiration and elemental carbon) and environmental parameters (soil temperature, gravimetric soil moisture, soil organic material, soil pH, soil clay content, and electrical conductivity), (ii) the influence of seasonal variations and land use change on the primary parameters, and (iii) develop regression models to explain the variability of the primary parameters

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

Pearson's Correlation analysis was used to show the correlations between soil parameters affecting the soil respiration and the elemental carbon (Cox et. al., 2006).

The equation of the correlation analysis is shown below;

$$r = \frac{\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})}{(n-1)S_X S_Y} \quad (3.5)$$

where,

- X and Y are the variables,
- S_X and S_Y are the standard deviations,

The value for a Pearson's correlation can fall between 0.00 (no correlation) and 1.00 (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 derived from these values as follows (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)

The mean value comparison tests, also known as the paired-samples T test, were run on the parameters affecting the soil respiration to compare the results from different seasons and land use types and to observe the significance levels. The paired-samples T test procedure compares the means of two variables for a single group. The procedure computes the differences between values of the two variables for each case and tests whether the average differs from 0 (SPSS 17, 2008). The following results can be obtained from this test

- Descriptive statistics for each test variable
- The Pearson correlation between each pair and its significance
- A confidence interval for the average difference (95% or a value you specify)

For each variable: Mean, sample size, standard deviation, and standard error of the mean are computed. For each pair of variables: correlation, average difference in means, t test, and confidence interval for mean difference and standard deviation and standard error of the mean difference is calculated.

The paired samples t-test is also used to test the hypothesis related with the samples. The first is null hypothesis, which assumes that the mean of two paired samples are equal. The second hypothesis in the paired sample t-test will be an alternative hypothesis, which assumes that the means of two paired samples are not equal. The next step is to determine the level of significance. In most of the cases in the paired sample t-test, significance level is taken as 5%. taken as 5%. The equation of the test is shown below;

$$t = \frac{\bar{d}}{\sqrt{s^2/n}} \quad (3.6)$$

where,

$\bar{d}$, is the mean difference between two samples,

s^2 , is the sample variance,

n , is the sample size

t , is a paired sample t-test with $n-1$ degrees of freedom.

Trend analysis was conducted to monitor the influence of land use change and seasonal changes on primary parameters. The parameters were grouped into deforested and forested land use types. Each land use types consist of 83 samplings locations that were monitored over four seasons. For seasonal effects, the mean comparison analysis was conducted on the parameters but they were not grouped into two main land use types.

Finally, step-wise linear regression analysis was performed to evaluate the correlation between primary 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 will continue for other steps.

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

$$Y = a + bX + e \quad (3.7)$$

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

3.7.1 Geostatistical analyses

Geostatistical analyses were employed 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). IDW, kriging and co-kriging, spline are the interpolation methods that are used in geostatistics.

Kriging was selected to apply for exploring the geostatistical relationships between sample values. Kriging uses statistical models that allow a variety of map outputs including predictions, prediction standard errors and probability. It is assumed the data come from a stationary stochastic process (Arc GIS, 2008). The aim of kriging is to estimate the value of an unknown real function f at a point x , given the values of the function at some other points. Kriging was selected to apply on primary parameters because main advantage of this method over other contouring techniques is its ability of quantifying the estimation variance, which will lead to define the precision of the resulting estimates. Also, Kriging incorporates the spatial correlation of the data, while all the other classical statistical procedures do not (Largueche, 2006). The kriging equation is shown at below.

$$F(x,y) = \sum_{i=1}^n W_i f_i \quad (3.8)$$

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 kriging method is to calculate the semivariogram. The characterization of spatial correlation in geostatistical methods can be described using semivariogram analysis. 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 3.8.

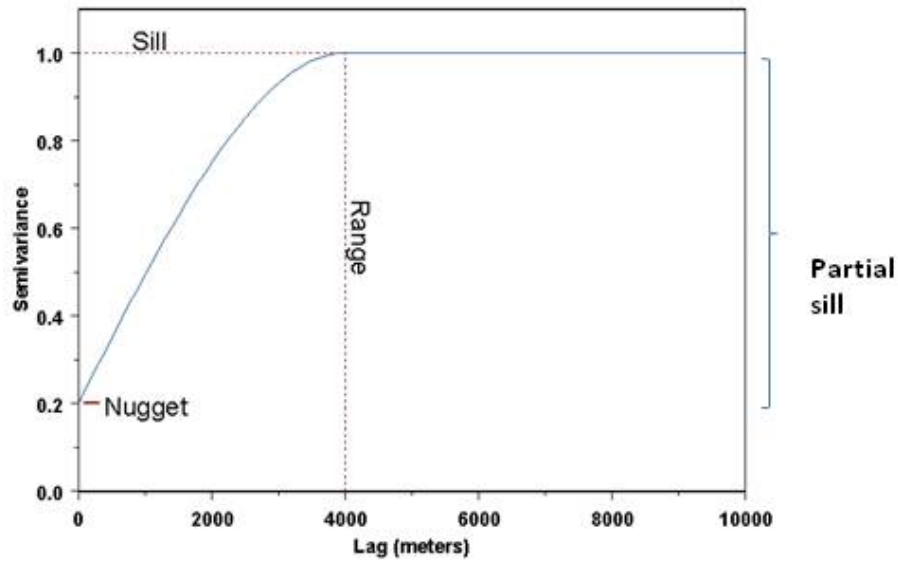


Figure 3.8. The characteristics of semivariogram analysis (modified from Bohling, 2005)

Sill refers to the “amplitude” of a certain component of the semivariogram and, 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. Nugget represents variability at distances smaller than the typical sample spacing, including measurement error (Bohling, 2005). The semivariogram of the sample values is calculated using the following equation.

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} [f(x_i) - f(x_i + h)]^2 \quad (3.9)$$

where;

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

$N(h)$, is the number of experimental pairs separated by vector h ,

$f(x_i)$ ve $f(x_i+h)$; are the positions in two dimensions.

The semivariograms were fitted with various theoretical models like spherical, exponential, gaussian, and linear and power by the weighted least square method.

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 winter, summer 2008 and spring, fall 2009 seasons. The diagram below shows the steps of obtaining geostatistical maps.

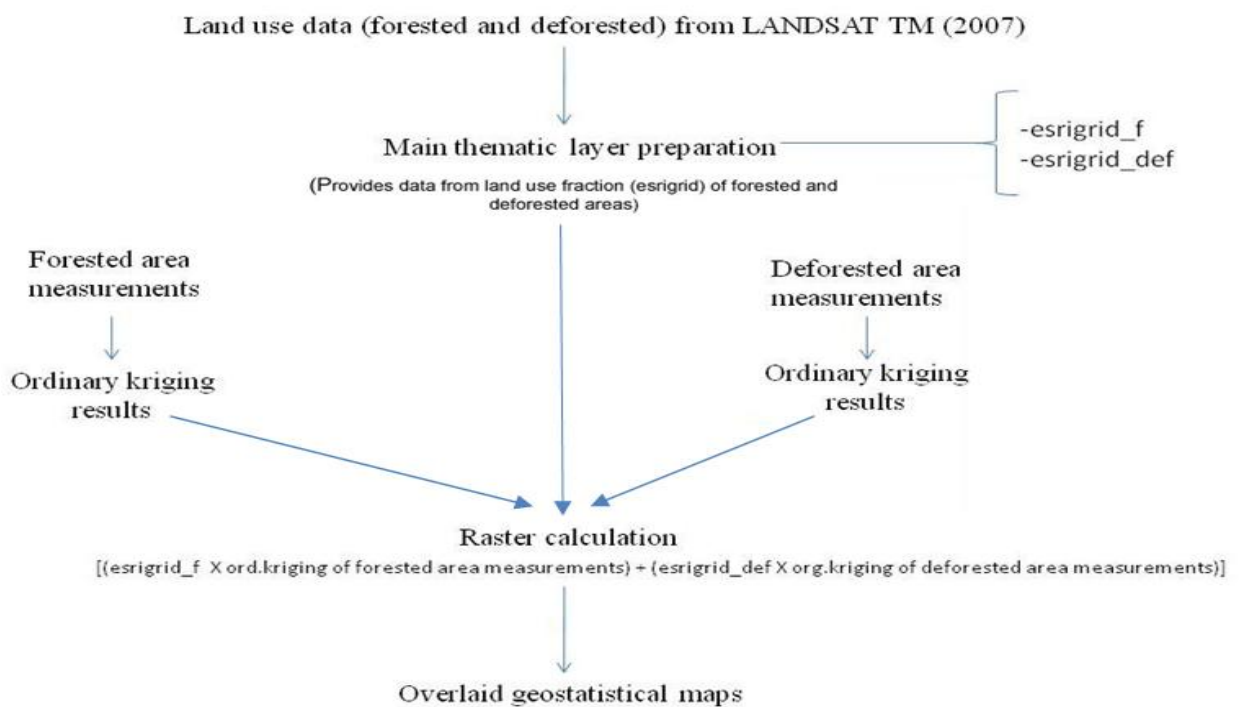


Figure 3.9. Flow diagram of the steps used to generate overlaid geostatistical maps.

For main thematic layer preparation, grids were generated to characterize the spatial and temporal patterns of seasonal measurements of in situ soil respiration and elemental soil carbon. To calculate the land use ratio from forested and deforested areas, the grids were exported and renamed as “EsriGrid”. The forested, deforested land use maps were also

reclassified. Reclassifying means replacing input cell values with new output cell values. It was applied for to reclassify the values in land use maps to a common scale and to group certain values from land use maps together and to get specific values to “NoData”. These “NoData” were excluded using the “Set null” function at spatial analyst tool.

In ordinary kriging, variogram parameters were calculated automatically. Lag size was entered 1000 meter and search radius type was set to “Fixed”. The distance value, which equals to twice the specified RADIUS {r} distance, or the maximum distance between pairs of input sample points, was entered “9000 meter”. The output of the analysis was saved as “Raster” format to use at raster calculator (Figure 3.09).

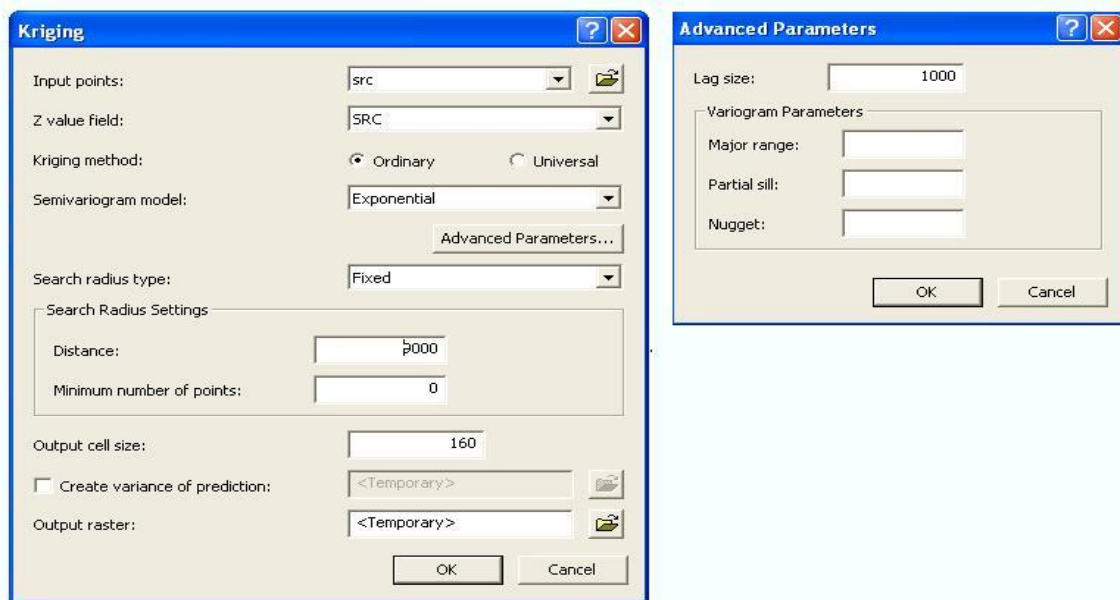


Figure 3.10. The Raster calculator tool in spatial analyst

Raster calculator use 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 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.

4. RESULTS and DISCUSSIONS

Field measurements and laboratory results of primary (in situ soil respiration and elemental carbon) and environmental parameters, as well as land use change obtained from satellite image analyses are presented in this section. SPSS17.00 software was used for statistical analysis. Trend analyses of primary parameters, correlations between primary and environmental parameters, and regression analyses of primary parameters are also presented.

4.1 Statistical Description of Primary parameters

In situ soil respiration and elemental carbon of the soil can be classified as primary parameters (Lal, 1995; Risk, et al.,2008; Li et al., 2009), as described in the Materials and Methods Section. Sections 4.1.1 and 4.1.2 present the measurements and analysis results of these two primary parameters.

4.1.1 In situ soil respiration measurements

Four field trips were made in winter 2008, summer 2008, spring 2009, and Fall 2009 seasons. In situ soil respiration measurements were conducted between 09:00 and 16:00 at each field trip as can be seen in Table 4.1.

Table 4.1. The in situ soil respiration

In situ soil respiration (g/m ² /h)									
Forested Soils					Deforested Soils				
No	Summer 08	Winter 08	Spring 09	Fall 09	No	Summer 08	Winter 08	Spring 09	Fall 09
2	0.96	0.99	0.67	0.88	1	0.47	0.81	0.65	0.35
4	0.92	1.81	1.84	0.98	3	0.50	0.45	0.54	0.55
6	0.52	0.26	0.92	0.89	5	0.43	0.16	0.42	0.38
8	0.79	0.39	0.81	0.83	7	0.23	0.10	0.71	0.51
10	0.22	1.09	0.93	0.78	9	0.23	0.92	0.52	0.35
12	0.52	0.32	0.83	0.87	11	0.23	0.45	0.26	0.55
14	0.44	0.28	0.85	0.88	13	0.12	0.40	0.55	0.34
16	1.18	0.11	0.65	0.78	15	0.18	0.51	0.34	0.44
18	0.68	0.31	0.96	0.85	17	0.43	0.12	0.47	0.59
20	0.57	0.86	0.88	0.83	19	0.44	0.50	0.54	0.51
22	0.47	0.26	0.86	0.73	21	0.31	0.24	0.56	0.56
24	0.47	0.44	0.77	0.86	23	0.23	0.76	0.52	0.36
26	0.38	0.22	0.89	0.80	25	0.30	0.42	0.46	0.52
28	1.65	0.22	1.09	0.82	27	0.92	0.23	0.50	0.57
30	0.34	1.70	0.90	0.81	29	0.40	1.35	0.45	0.48
32	0.53	0.00	0.93	0.88	31	0.54	0.06	0.54	0.42
34	0.15	0.55	1.18	0.79	33	0.27	0.03	0.43	0.43
36	0.62	0.36	0.93	0.77	35	0.23	0.51	0.45	0.55
38	0.47	0.37	0.94	0.99	37	0.19	0.25	0.42	0.45
40	0.36	0.29	1.08	0.76	39	0.24	0.51	0.47	0.42
46	0.37		0.52	0.86	41	0.64		0.50	0.52
					43	0.21		0.54	0.48
					45	0.53		0.51	0.42
					47	0.36		0.43	0.50

Figure 4.1 demonstrates average values of in situ soil respirations for all seasons for forested and deforested soils. Based on these results, it was concluded that the soil respiration rates were high during spring and fall, while minimum values were observed in winter and summer seasons.

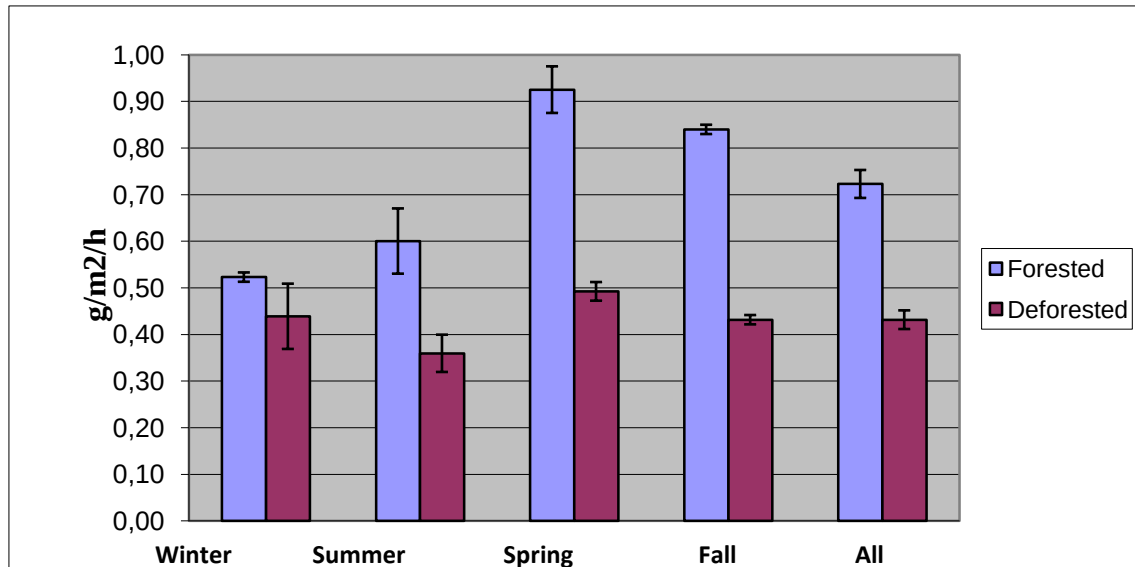


Figure 4.1. The in situ soil respiration results from four seasons for forested and deforested soils.

Soil respiration overall mean values can be listed from highest to the lowest as: Fall 2009 > Spring 2009 > (Summer 2008 and Winter 2008). The detailed statistical evaluation of the in situ soil respiration measurements depend on four seasons and different type of land use change were given in the statistical evaluation section.

4.1.2 Soil Elemental Carbon Analysis

The elemental carbon analysis was performed on soil samples obtained from 0 to 20 cm depth from the surface. Table 4.2 presents results for four seasons.

Table 4.2. Elemental carbon content

Elemental Carbon (%)									
Forested Soils					Deforested Soils				
No	Summer 2008	Winter 2008	Spring 2009	Fall 2009	No	Summer 2008	Winter 2008	Spring 2009	Fall 2009
2	1.99	1.20	1.50	1.58	1	0.80	0.70	1.00	0.87
4	1.83	2.70	2.70	2.00	3	0.90	0.70	0.90	0.85
6	2.05	1.60	2.50	2.10	5	2.50	1.50	1.70	1.61
8	2.14	2.50	3.90	2.11	7	1.60	1.70	1.70	1.93
10	2.31	1.50	3.40	1.70	9	1.20	1.20	1.30	1.38
12	1.26	1.30	2.20	1.27	11	0.90	0.70	1.90	1.55
14	1.77	1.70	1.40	1.79	13	1.00	0.90	0.80	0.69
16	0.90	1.40	0.80	1.07	15	1.50	1.20	1.20	0.91
18	2.69	3.10	2.30	2.27	17	2.20	1.90	1.70	1.70
20	1.80	1.30	1.30	1.04	19	1.30	1.20	1.10	1.55
22	1.88	1.50	1.50	1.11	21	1.70	1.40	1.30	1.12
24	1.20	1.40	1.60	1.21	23	1.50	1.30	1.30	0.95
26	1.88	1.70	2.60	1.44	25	1.40	0.80	1.00	0.87
28	1.70	1.80	1.90	2.49	27	2.70	2.50	1.60	1.62
30	2.08	1.90	2.30	1.43	29	1.80	1.40	1.80	1.46
32	1.45	1.20	1.10	1.04	31	2.10	1.90	1.00	1.07
34	1.82	2.50	1.80	1.74	33	1.10	1.30	1.70	1.32
36	1.83	1.80	3.10	2.28	35	2.40	2.30	3.60	2.10
38	1.28	1.10	1.10	0.66	37	0.90	1.40	1.20	1.18
40	2.67	2.10	2.50	2.62	39	2.60	1.70	1.40	2.49
46	2.14		1.70	1.52	41	1.50		1.50	1.59
					43	0.80		0.60	1.09
					45	1.20		0.90	1.34
					47	2.20		2.80	0.90

Laboratory analysis showed that elemental carbon percentages of forested soils is generally greater than the deforested soils because of litter, char and humus presence on the soil surface (Bhat and Wani, 2003 and Lal, 2008). Figure 4.2 shows mean values with standard errors for four seasons of forested and deforested soils.

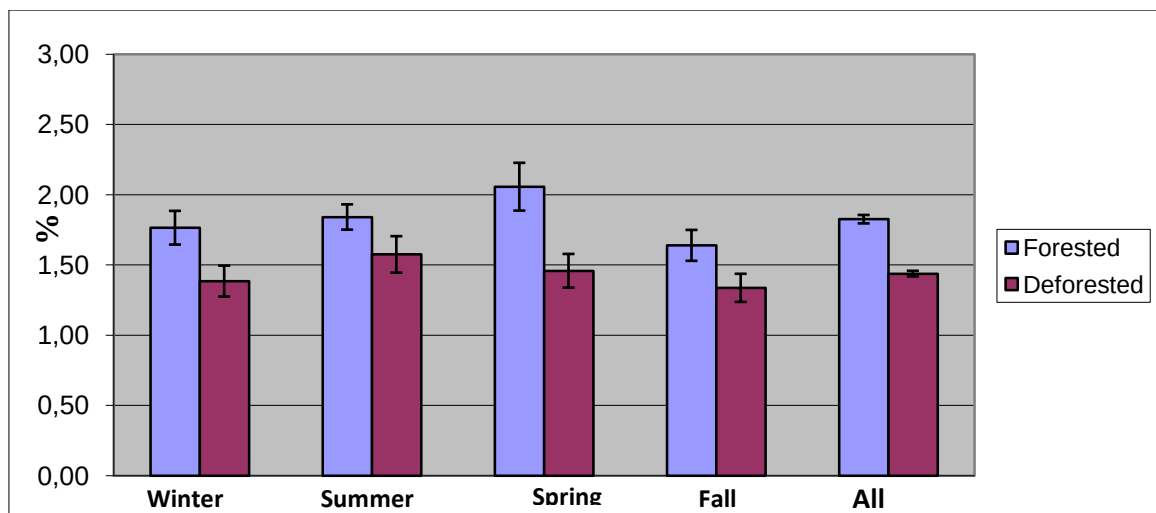


Figure 4.2. Elemental carbon content of soil samplings

The differences in mean values of soil elemental carbon from forested and deforested soils are found to be significant ($t=4.445$, $p=0.000$). 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 lost its natural vegetation layer on top, elemental carbon tends to decrease, due to enhanced mineralization and lower carbon inputs. As a result, soil carbon may decline immediately following conversion.

In this study, elemental carbon is used to detect carbon to nitrogen (C:N) ratios of the soil samples (Table 4.3). 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.

Table 4.3. The C:N ratios of the soil samples from four seasons

CN ratio									
Forested Soils					Deforested Soils				
No	Summer 2008	Winter 2008	Spring 2009	Fall 2009	No	Summer 2008	Winter 2008	Spring 2009	Fall 2009
2	7.96	5.71	5.00	4.51	1	8.00	7.00	1.00	8.70
4	9.15	9.64	13.50	8.69	3	9.00	7.00	9.00	5.66
6	20.50	17.77	25.00	16.15	5	12.50	15.00	17.00	14.63
8	21.40	15.62	19.50	17.58	7	16.00	17.00	17.00	17.54
10	11.55	10.71	11.33	15.45	9	12.00	12.00	13.00	10.61
12	12.60	14.44	11.00	14.11	11	9.00	7.00	9.50	17.22
14	17.70	11.33	14.00	19.88	13	10.00	9.00	8.00	8.62
16	9.00	14.00	8.00	13.37	15	15.00	12.00	12.00	11.37
18	17.93	17.22	23.00	17.46	17	11.00	9.50	17.00	13.07
20	12.80	11.81	13.00	10.40	19	13.00	12.00	11.00	15.50
22	18.80	18.75	15.00	11.10	21	17.00	14.00	13.00	11.20
24	12.00	15.55	16.00	12.10	23	15.00	13.00	13.00	9.50
26	18.80	14.16	13.00	7.20	25	14.00	8.00	10.00	8.70
28	17.00	9.47	19.00	16.60	27	13.50	12.50	16.00	16.20
30	20.80	17.27	23.00	14.30	29	18.00	7.00	18.00	14.60
32	14.50	17.14	11.00	10.40	31	21.00	19.00	10.00	10.70
34	18.20	11.90	18.00	17.40	33	11.00	13.00	17.00	13.20
36	18.30	13.84	15.50	11.40	35	12.00	11.50	12.00	8.40
38	12.80	9.16	11.00	6.60	37	9.00	14.00	12.00	11.80
40	26.70	13.12	12.50	17.46	39	13.00	17.00	14.00	24.90
46	21.40		17.00	15.20	41	15.00		15.00	13.25
					43	8.00		6.00	10.90
					45	12.00		9.00	13.40
					47	11.00		9.33	9.00

Under ratios below 15:1, nitrogen has a slower decaying rate than carbon in the soil (Griffin, 1972). Martin et al., (2005) reported that lower C:N ratios generally correlate with higher rates of root turnover and soil respiration. Table 4.3 shows that the forested sampling locations 2, 4 and 16 have the lowest C:N ratio (7.96, 9.15, and 9.00, respectively) for summer 2008. In situ soil respiration measurements at these locations were 0.96 g/m²/h, 1.83 g/m²/h and 1.18 g/m²/h, respectively. Similar with summer 2008 for the locations 2 and 4 in winter 2008, the soil measurements were 0.99 g/m²/h and 1.81 g/m²/h, respectively, and C:N ratios were 5.71 and 9.64, respectively. In Fall 2009, C:N ratios of the same locations were observed as 4.51 and 8.69 and recorded in-situ soil respiration measurements were 0.88 g/m²/h and 0.98 g/m²/h. For spring 2009 ratios of these locations were not as low as compared to other seasons. C:N ratios from sampling locations 1 and 3 have the lowest ratios, 8.00 and 9.00, respectively. In situ soil respiration at these locations was 0.47 g/m²/h and 0.50 g/m²/h in summer 2008. These measurements are the highest values for this season. For the winter 2008, same locations have a C:N ratio of 7.00 and the soil respiration measurements were 0.81 g/m²/h and 0.45 g/m²/h. The ratios in spring 2009 were also low (1.00 and 9.00) and the respiration measurements were 0.67 g/m²/h and 0.56 g/m²/h. The overall mean value of C:N ratios from forested soils for all seasons is slightly higher than the deforested soils (14.46 ± 4.5, 12.21 ± 3.61). The land use change showed significant difference between C:N ratios from forested and deforested soils (p<0.05). It can be said that land use change has an effect on C:N ratios. As a result, the difference between the means of C:N ratios from two types of land use was found significant (p<0.05).

4.2 Environmental Parameters

This section presents results of laboratory and correlation analysis conducted on environmental parameters from forested and deforested soils over extent seasons. Enviromental parameters can be listed as microbial respiration, soil texture, temperature, electirical conductivity, pH, gravimetric moisture, and soil organic matter. The analyses were conducted on soil samples obtained from field trips.

Table 4.4. Correlation factors between parameters soils from forested lands (* Indicates the correlation at significant level 0.001, **Indicates the correlation at significant level 0.005)

	Microbial respiration Corr./Sig.	Soil texture Corr./Sig.	Soil temp. Corr./Sig.	Electrical cond. Corr./Sig.	Log_pH Corr./Sig.	Grav.Moist. Corr./Sig.	SOM Corr./Sig.
Microbial respiration	1 0.45	-0.08 0.45	0.06 0.57	0.25** 0.02	0.13 0.23	0.42* 0.00	0.19 0.07
Soil texture	-0.08 0.45	1	0.02 0.80	0.18 0.08	-0.22** 0.04	0.04 0.69	0.26** 0.01
Soil temperature	0.06 0.57	0.02 0.80	1	-0.24** 0.02	-0.16 0.14	-0.50* 0.00	-0.09 0.37
Electrical conductivity	0.25** 0.02	0.18 0.08	-0.24** 0.02	1	0.44* 0.00	0.41* 0.00	0.13 0.21
Log_pH	0.13 0.23	-0.22** 0.04	-0.16 0.14	0.43* 0.00	1	0.21 0.05	-0.13 0.21
Grav.Moist.	0.42* 0.00	0.04 0.68	-0.50* 0.00	0.41* 0.00	0.21 0.05	1	0.10 0.33
SOM	0.19 0.07	0.26** 0.01	-0.09 0.37	0.13 0.21	-0.13 0.21	0.106 0.33	1

Table 4.5. Correlation factors between parameters for the deforested soils (* Indicates the correlation at significant level 0.001,** Indicates the correlation at significant level 0.005)

	Microbial respiration Corr./Sig.	Soil texture Corr./Sig.	Soil temp. Corr./Sig.	Electrical cond. Corr./Sig.	Log_pH Corr./Sig.	Grav.Moist. Corr./Sig.	SOM Corr./Sig.
Microbial respiration	1	0.23** 0.02	0.11 0.29	0.19 0.06	0.15 0.15	0.23** 0.02	0.25** 0.01
Soil texture	0.23** 0.02	1	0.01 0.90	0.43* 0.00	-0.04 0.69	0.31* 0.00	0.53* 0.00
Soil temperature	0.11 0.29	0.01 0.90	1	-0.07 0.49	0.11 0.27	-0.39* 0.00	-0.04 0.66
Electrical conductivity	0.19 0.06	0.43* 0.00	-0.07 0.49	1	0.21** 0.04	0.27* 0.00	0.32* 0.00
Log_pH	0.15 0.15	-0.04 0.69	0.11 0.27	0.21** 0.04	1	-0.03 0.75	-0.01 0.882
Grav.Moist.	0.23** 0.02	0.31* 0.00	-0.33* 0.00	0.27* 0.00	-0.03 0.75	1	0.21** 0.04
SOM	0.25** 0.01	0.53** 0.00	-0.04 0.66	0.32* 0.00	-0.01 0.88	0.21** 0.04	1

4.2.1 Soil Gravimetric Moisture

Laboratory analyses showed that the winter 2008 soil gravimetric moisture was between 16% and 61.7% (average is $30.71\% \pm 13.66$). The summer soil gravimetric moisture was found between 6% and 42% (average is $15.1\% \pm 7.34$). Spring 2009 soil gravimetric results were observed to be similar with winter results, while the highest spring 2009 moisture content was lower than the winter 2008 moisture content. The spring 2009 soil gravimetric moisture was measured in the range from 12.15% to 32.55% (average is $19.87\% \pm 4.53$). 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 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).

The descriptive statistics showed that mean values of gravimetric moisture from forested soils are greater than the deforested soils, which is attributed to forest soils receiving less sunlight than the agricultural soils and their ability to retain more moisture due to differences in soil structure (more humus observed) (forested soils 21.17 ± 9.83 , deforested soils 19.95 ± 7.95).

The correlation analysis between gravimetric soil moisture and other environmental parameters gave the following results (Tables 4.4 and 4.5). There is a moderate correlation with microbial respiration for forested soils ($r=0.42$, $p<0.01$). Microbial respiration has a low correlation with gravimetric moisture ($r=0.23$, $p<0.05$) for deforested soils. This type of respiration is an indicator of microbial activity in the soil and this activity needs suitable moisture and temperature conditions to occur.

Low correlation was observed with clay content in deforested soils ($r=0.31$, $p<0.01$). Soils with high clay content are called clayey soils and clay has a strong affinity to hold the water molecules due to chemical structure. Deforested soils are used mainly for agricultural purposes and agricultural managements such as plowing and cultivating which do not alter clay content of soils (Lal, 2001 and Rowell, 1996). Soil temperatures of four seasons for forested and deforested soils yielded a negative correlation at significant levels with gravimetric soil moisture. Correlations were found for forested soils ($r= -0.50$, $p<0.00$), as well as for deforested soils ($r= -0.33$, $p<0.00$). Gravimetric moisture and electrical conductivity are correlated in forested ($r=0.41$, $p<0.01$) and deforested soils ($r= 0.27$, $p<0.01$). It is concluded that gravimetric soil moisture content has an effect on electrical conductivity in forested and deforested soils. Electrical conductivity measures the dissolved salt content. The salt content is related with cation exchange capacity (CEC) of the soils. CEC is highly dependent upon soil texture and organic matter content and these affect the ratio of the soil respiration. Figures 4.3 and 4.4 present the measured soil gravimetric moistures in this study for four seasons from forested and deforested areas, respectively.

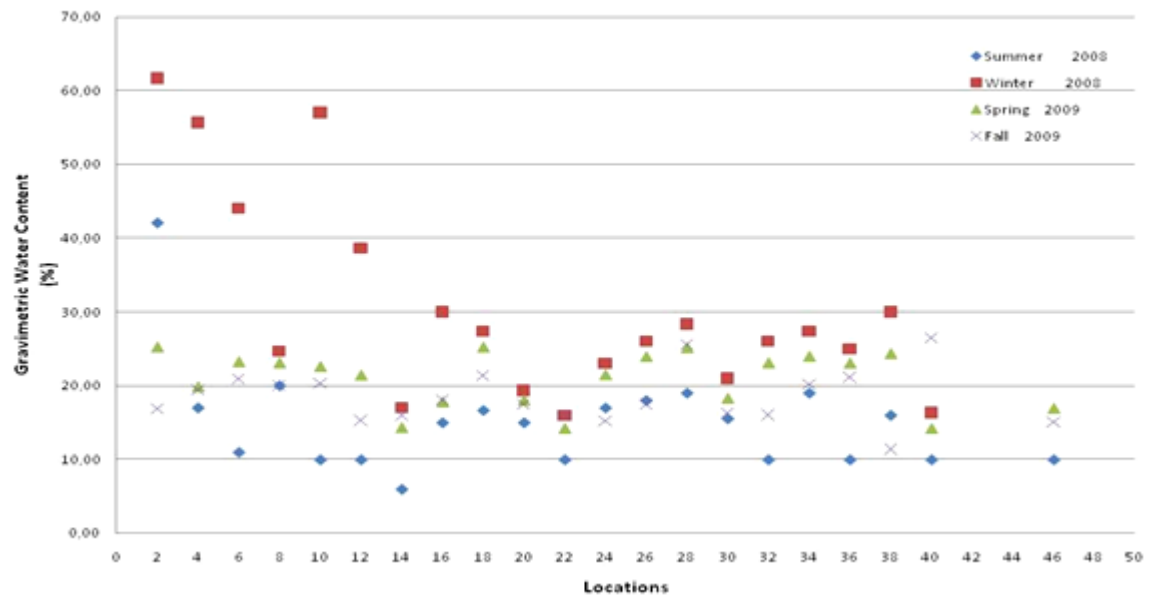


Figure 4.3. Gravimetric water content from forested soils

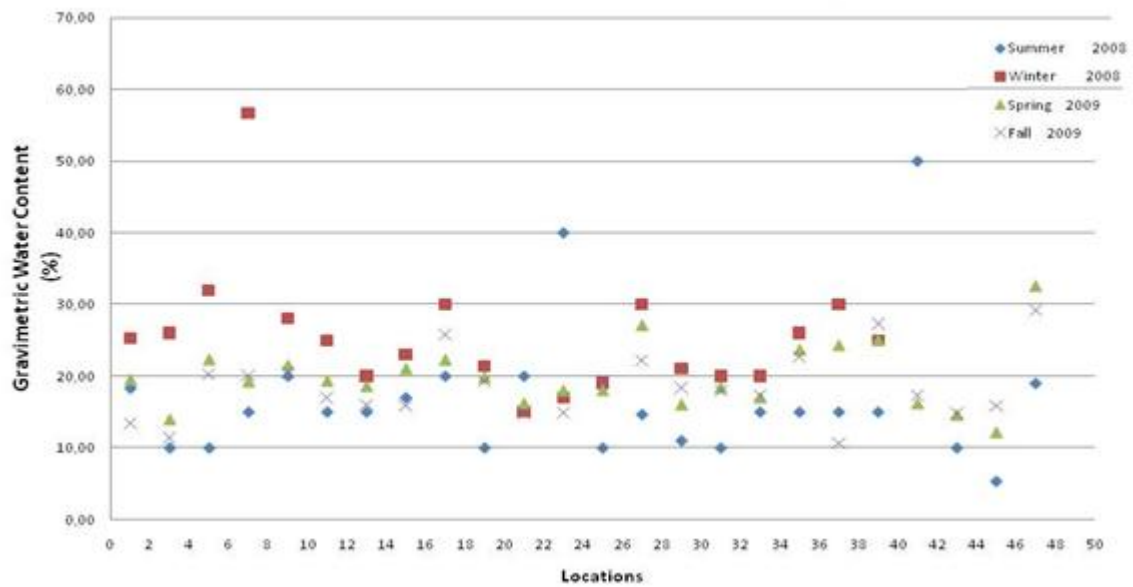


Figure 4.4. Gravimetric water content from deforested soils

4.2.2. Soil pH.

Figures 4.5 and 4.6 show observed pH values for four different seasons from forested and deforested soils. Winter soil pH values ranged between 3.60 and 6.70, while summer 2008 soil pH values were 4.01 to 6.51, for forested area. The alkalinity difference between these two seasons can possibly be attributed to the soil temperature differential between winter and summer 2008 seasons. The laboratory results showed that spring 2009 values were between 4.20 and 6.61 and Fall 2009 soil pH values ranged from 4.66 to 6.93. These values indicate that forested soils have a slightly acidic composition. For deforested soils, winter 2008 pH values were between 4.50 and 7.10, while for summer 2008, these were between 4.47 and 6.86. In spring 2009, soil pH ranged from 4.51 to 6.53 and for Fall 2009 from 4.68 to 7.35. 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. For forested soils, winter 2008 and summer 2008 pH values are moderately correlating ($r=0.49$, $p<0.05$), and an almost perfect correlation was found between spring 2009 and fall 2009 ($r=0.98$, $p<0.05$) seasons. As for deforested soils, a moderate correlation was found between winter 2008 and summer 2008 seasons ($r=0.44$, $p<0.05$). Spring 2009 and fall 2009 results have a higher correlation compared to other seasons ($r=0.78$) and differences are also very significant ($p<0.05$). pH is considered as one of the main contributors of soil respiration (Luo and Zhuo, 2006, and Kim 2008). However, the correlation between soil respiration and soil pH is fluctuating due to seasonal changes. For instance, a high correlation found between soil respiration and pH ($r=0.51$, $p<0.05$) for forested soils for the summer 2008 season.

However, a correlation was not observed for the winter 2008 season for forested soils. Smith and Doran, (1996) reported that soil electrical conductivity and pH indicate soil anion and cation levels. These two parameters are occasionally correlated with each other. It was found that, there is a correlation between soil electrical conductivity and pH ($r=0.21$, $p<0.05$) in deforested soils for all four seasons in study soils (Tables 4.4 and 4.5). In forested soils, this

correlation was found to be moderate ($r=0.43$, $p<0.05$) at significant level. Soils formed under high rain fall conditions are more acidic than those formed under arid (dry) conditions.

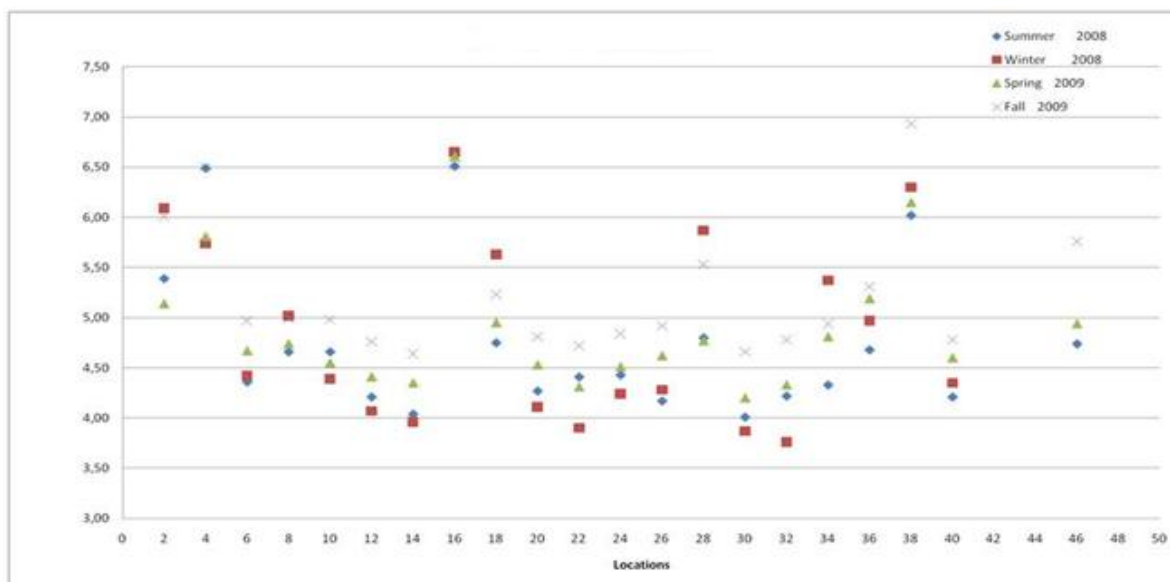


Figure 4.5. The soil pH laboratory results from forested soils

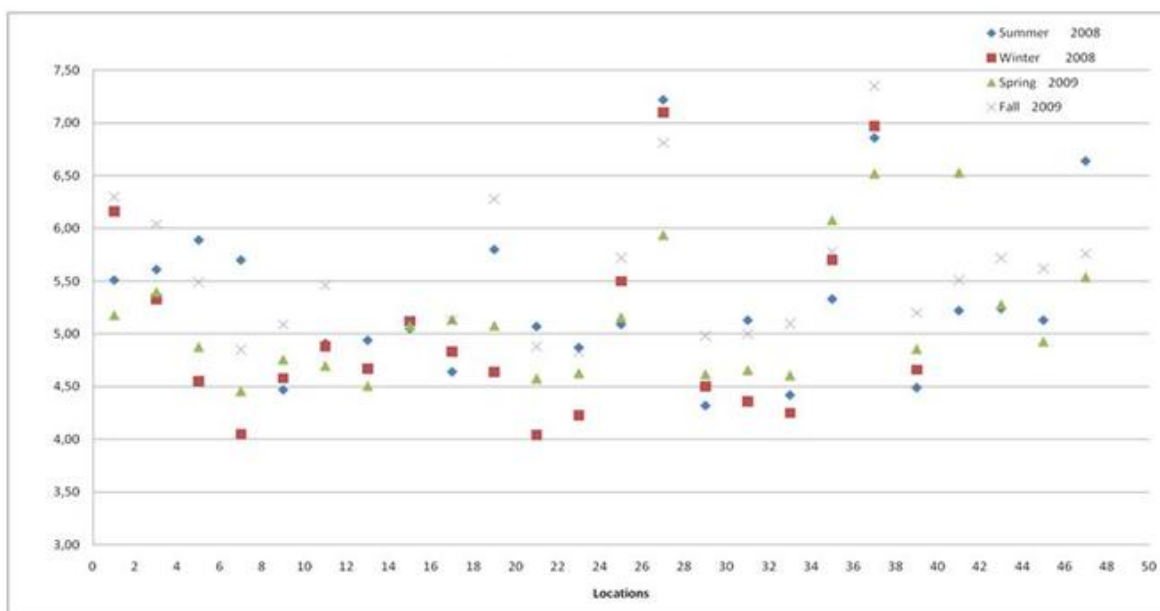


Figure 4.6. The soil pH laboratory results from deforested soils

4.2.3. Soil Organic Material

The laboratory results showed that soil organic material (SOM) content of deforested soils was lower than forested soils, which can be attributed to land use change. The percentage of SOM in forested soils is generally greater than deforested soils because of the availability of litter on the soil surface (Bhat and Wani, 2003). Deforested soils are mainly used for agricultural purposes such as hazelnut and corn planting. Agricultural management practices, such as fertilizing and liming may have played important roles for decreasing the SOM content (Küçüker, et al., 2009). SOM decomposition was significantly enhanced by rhizosphere carbon additions, a process described as a priming effect, which was defined as rhizosphere-stimulated or suppressed microbial respiration using SOM as the substrates. Input of labile substrates in the rhizosphere may significantly accelerate SOM decomposition as a result of the priming effect (Li et al., 2009). Figures 4.7 and 4.8 present SOM content measured for four seasons from deforested and forested soils. The highest SOM content was detected in sampling location 35 (SOM 3.5%) in winter 2008 for deforested soils. In summer 2008, SOM ranged from 0.5% to 3%. The highest content was found at sampling location 17 (32%). Meanwhile, clay contents of location 35 in winter 2008 for deforested soils were 35% and for sampling location 17 it was 39%.

There is a correlation ($r=0.26$, $p<0.05$, $r=0.53$, $p<0.05$) between soil texture and SOM for deforested and forested soils (Walker and Desanker, 2004). This correlation was also observed for each season. A high correlation ($r=0.73$, $p<0.05$) exists between SOM and clay content of deforested soils for the Fall 2009 season. In spring 2009 and summer 2008, this correlation was found as moderate ($r=0.45$, $p<0.05$), ($r=0.48$, $p<0.05$). In winter 2008, the correlation between SOM and clay content was again observed as moderate ($r=0.52$, $p<0.05$). In forested soils for the Fall 2009 season, a high correlation was observed between SOM and clay content ($r = 0.59$, $p<0.05$). However, for other seasons, correlations are weak and the differences are insignificant. (Spring 2009: $r=0.16$; summer 2008: $r= 0.19$; winter 2008: $r=0.16$). It was found that SOM has correlated ($r= 0.24$, $p<0.05$) with microbial respiration for deforested soils. Electrical conductivity of soil revealed a correlation with SOM ($r= 0.32$,

$p < 0.01$) for deforested soils. Added to that, SOM has a correlation ($r = 0.21$, $p < 0.05$) with gravimetric moisture content for deforested soils.

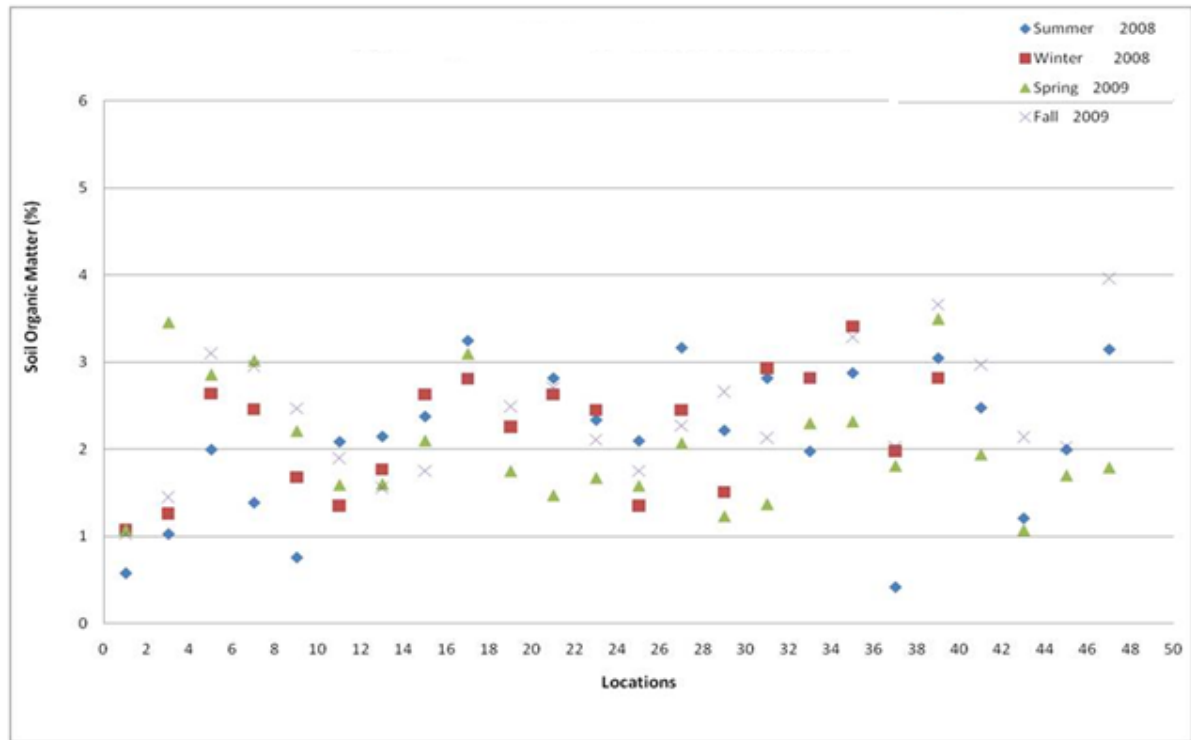


Figure 4.7. Soil organic matter in deforested soils

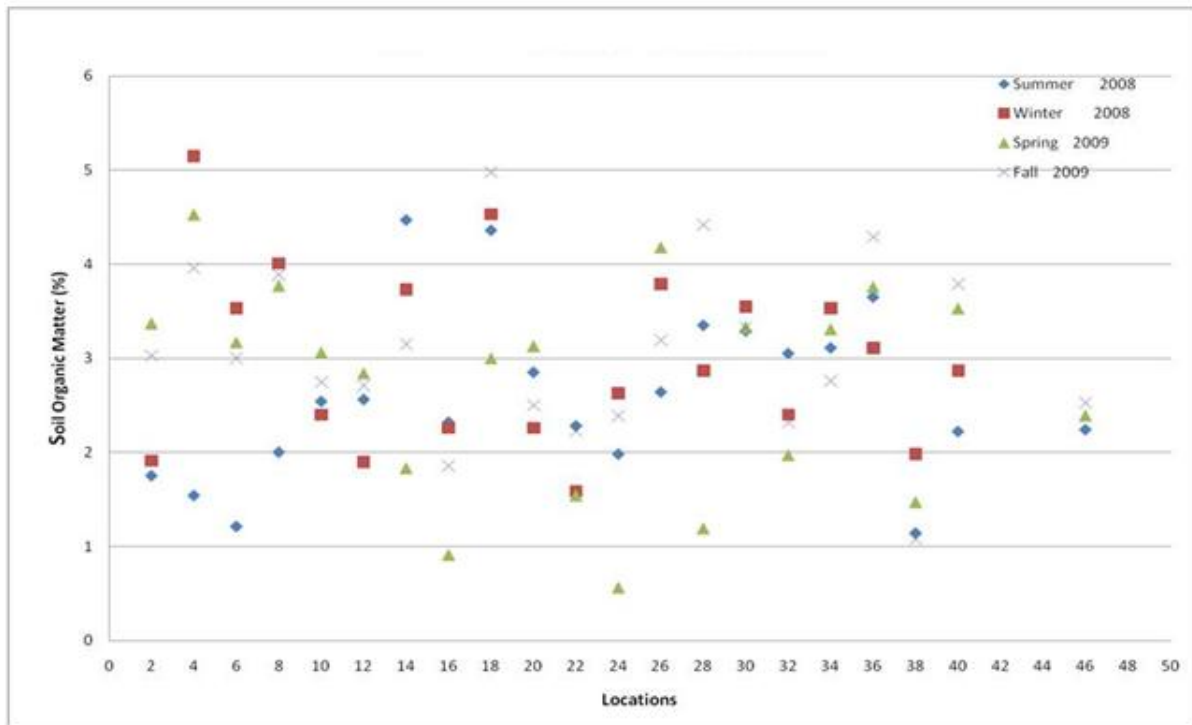


Figure 4.8. Soil organic matter in forested soils

4.2.4. 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), accordingly with 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 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).

TABLO

The clay content of the soil revealed a low correlation with SOM ($r=0.26$, $p<0.001$) for forested soils and a high correlation ($r=0.53$, $p<0.01$) for deforested soils (Table 4.5). The correlation in deforested soils is almost two folds of forested soils. 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.

The correlation between the clay content and electrical conductivity was high ($r=0.62$, $p<0.01$) for deforested soils. The moisture content showed a moderate correlation ($r=0.31$, $p<0.01$) with the clay content. 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.

4.2.5. Soil microbial respiration

Microbial respiration is the result of basal respiration. It is an indicator for transformation of soil carbon pools in various ecological scenarios (Koçyigit, 2008, Isermeyer,1952). The laboratory experiment to investigate microbial respiration rate was performed at in-vitro. Adequate amount of water was added to sample flasks and they were exposed to moderated climatic conditions, which altogether is similar to the methodology used by Rowel (Rowell, 1996).

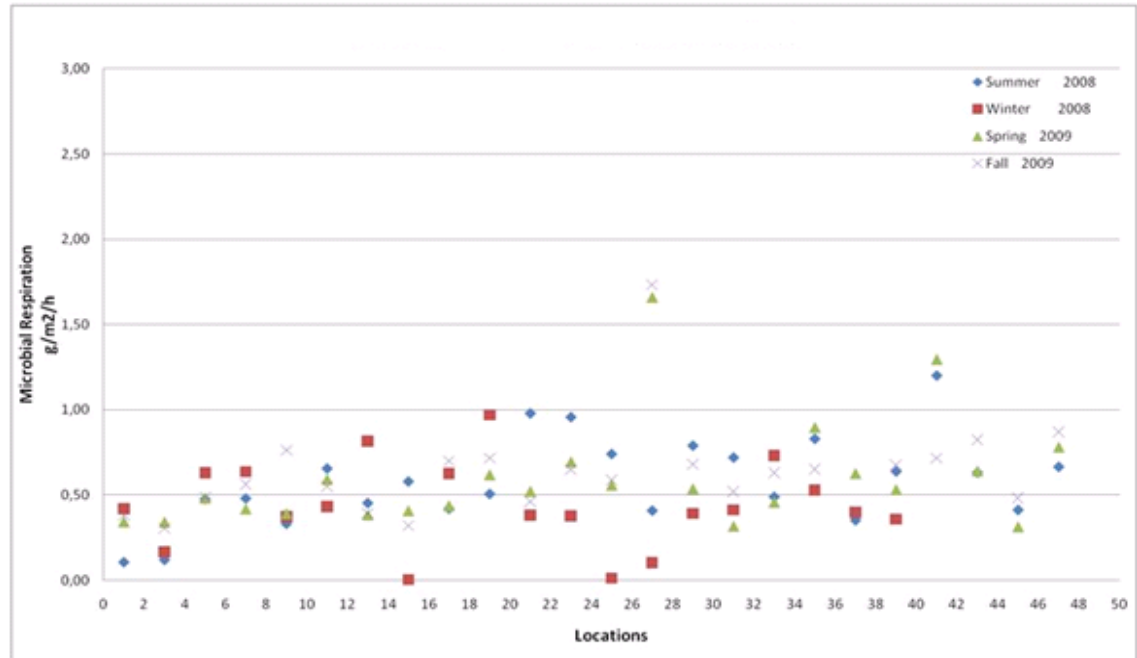


Figure 4.9. The microbial respiration results from deforested soils

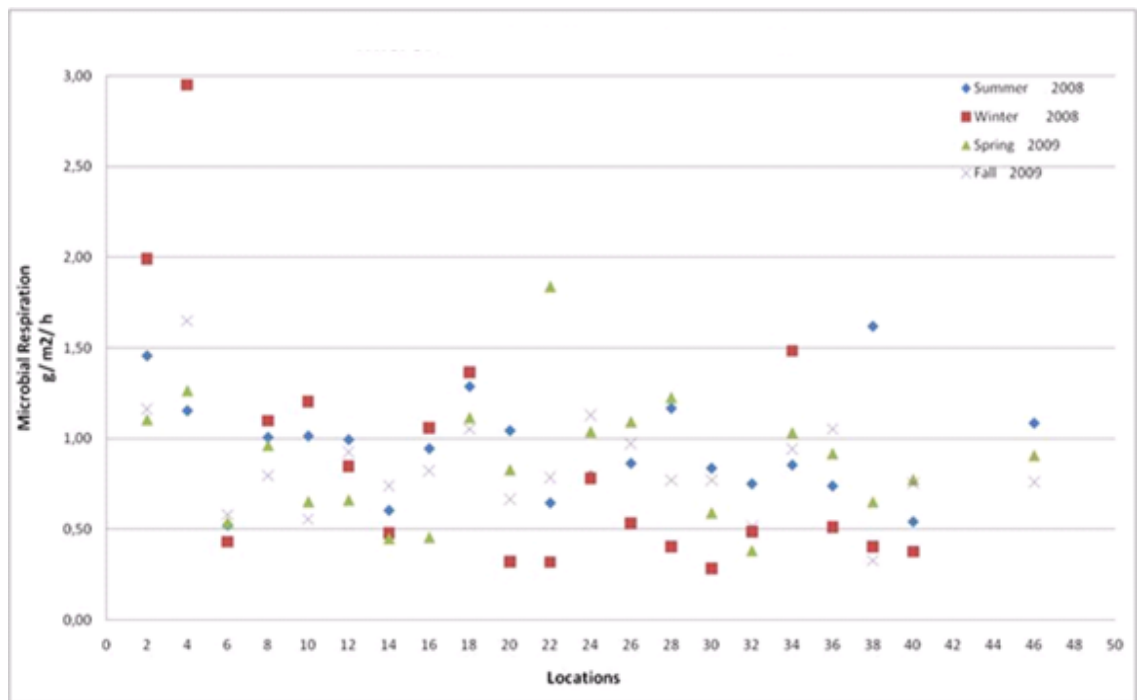


Figure 4.10. The microbial respiration results from forested soils

It was observed that the mean value of microbial respiration from forested soils is always higher compared to deforested soils, for all four seasons ($0.88 \text{ g/m}^2/\text{h} \pm 0.42 - 0.55 \text{ g/m}^2/\text{h} \pm 0.28$). The mean value of microbial respiration indicated that the microbial activity potential in deforested soils are nearly halved compared to forest soils (Figures 4.9 and 4.10). The aboveground litter and organic matter decomposition on the forest floor can be associated with this finding.

The mean value of the microbial respiration of forested soils is higher than deforested soils (forested soils: $0.88 \text{ g/m}^2/\text{h} \pm 0.42$; deforested soils: $0.55 \text{ g/m}^2/\text{h} \pm 0.29$). Available seasonal conditions and soil temperatures may have accelerate the biological activity in deforested soils. There is a moderate correlation between microbial respiration results and soil temperature ($r=0.41$, $p<0.05$) measured from deforested soils for the Fall 2009 season

The difference between mean values is significant between forested and deforested soils for the summer 2008 season ($p<0.01$). This can be explained by soil homogeneity or heterogeneity, the degradability of the substrates present in soils, or differences in soil structural properties (Ingram, et al., 2005). Soil microbial activity also responds differently to soil management systems and soil environmental factors (Koçyigit, 2008).

4.2.6. Electrical Conductivity

Electrical Conductivity (EC) is related to the amount of dissolved salts in the soil. These salts can be classified as soil minerals and they stabilize the soil, similar to the clay content. Soil stabilization is also related with turnover of long residence time of the organic carbon (Torn et al., 1997).

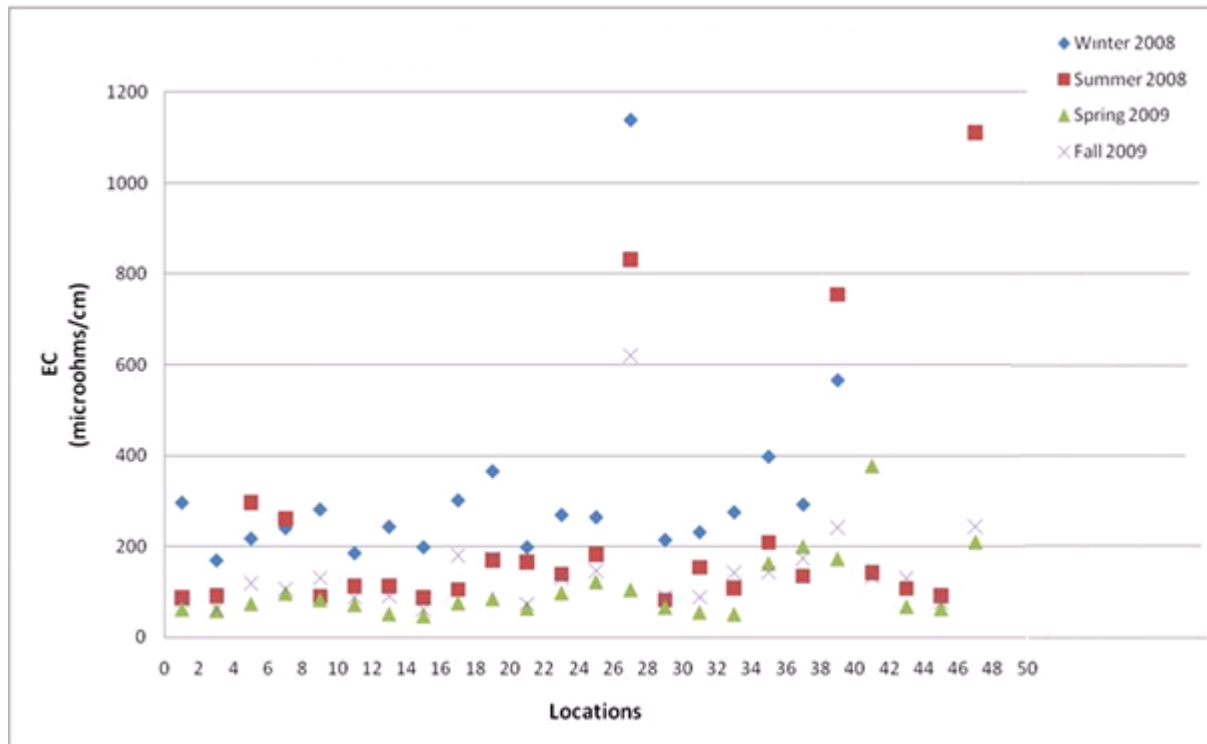


Figure 4.11. The electrical conductivity results from deforested soils

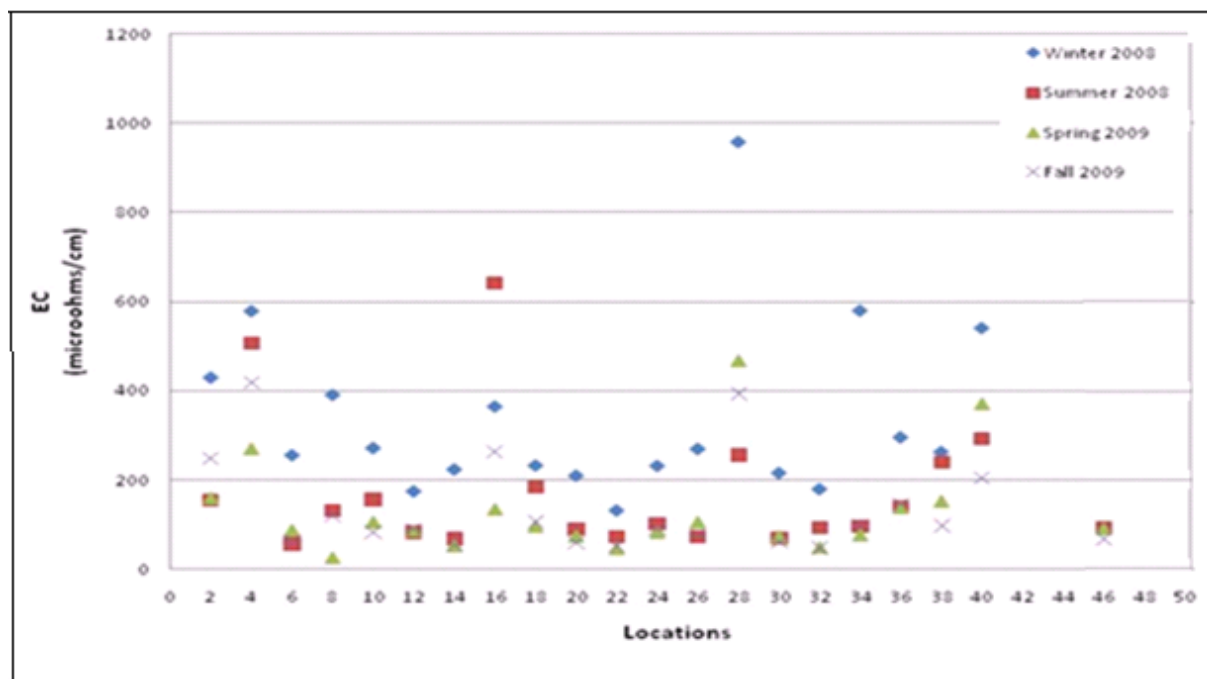


Figure 4.12. The electrical conductivity results from forested soils

The laboratory results demonstrated that highest EC results were observed in winter and summer 2008 seasons in deforested soils (1138 $\mu\text{mhos/cm}$ and 1111 $\mu\text{mhos/cm}$, respectively). For forested soils highest results were also observed in winter and summer 2008 seasons (958 $\mu\text{mhos/cm}$ and 641 $\mu\text{mhos/cm}$, respectively). Figures 4.11 and 4.12 present these results. The evaporation from the soil surface could be a reason for these higher results, as suggested by Grisso et al., (2009). A moderate correlation was observed between electrical conductivity (EC) readings obtained from forested and deforested soils (Table 4.12). The differences are significant ($p < 0.05$). The mean value of EC of deforested soils is slightly greater compared to forested soils (4.99 $\mu\text{mhos/cm}$ vs. 4.96 $\mu\text{mhos/cm}$) and there is a significant difference between two types of land use ($p < 0.01$). This can be explained with the clay content of the soil. The EC has a moderate correlation with clay content ($r = 0.62$, $p < 0.05$) for all deforested soils. Corwin and Lesch, (2005) reported that electrical conductivity is influenced by clay content of the soil. It was found that the clay content of soils for Fall of 2009 of deforested soils is highly correlated ($r = 0.62$, $p < 0.01$) with EC. In summer 2009, the clay content is also highly correlated ($r = 0.68$, $p < 0.01$) with EC for deforested soils. In addition, same correlation was observed ($r = 0.566$, $p < 0.01$) for deforested soils for the winter 2009 season. In spring 2009, for forested soils, a moderate correlation ($r = 0.42$, $p < 0.05$) was observed between electrical conductivity and clay. The relationship between soil pH and electrical conductivity may be explained by the correlation between clay and electrical conductivity. Soil pH is also the indicator of anion and cation content of the soil (Rowell, 1996) and as a result, EC has a correlation with pH ($r = 0.21$, $p < 0.05$) for all deforested soils. The difference in the mean value of soil pH under the land use change revealed a significant correlation ($p < 0.01$).

4.2.7. Soil temperature

Soil temperature was measured at each field trip (four in total). Figures 4.13 and 4.14 present these measurements. The land use change has an effect on soil temperature. The difference of mean value is significant ($p < 0.05$). The soil temperature of forested soils is lower compared to deforested soils. The natural vegetation in forest floor enhances the penetration of

solar radiation to the top (0-20 cm) of the soil. As a result, the soil temperature in deforested soils remains lower than forested soils.

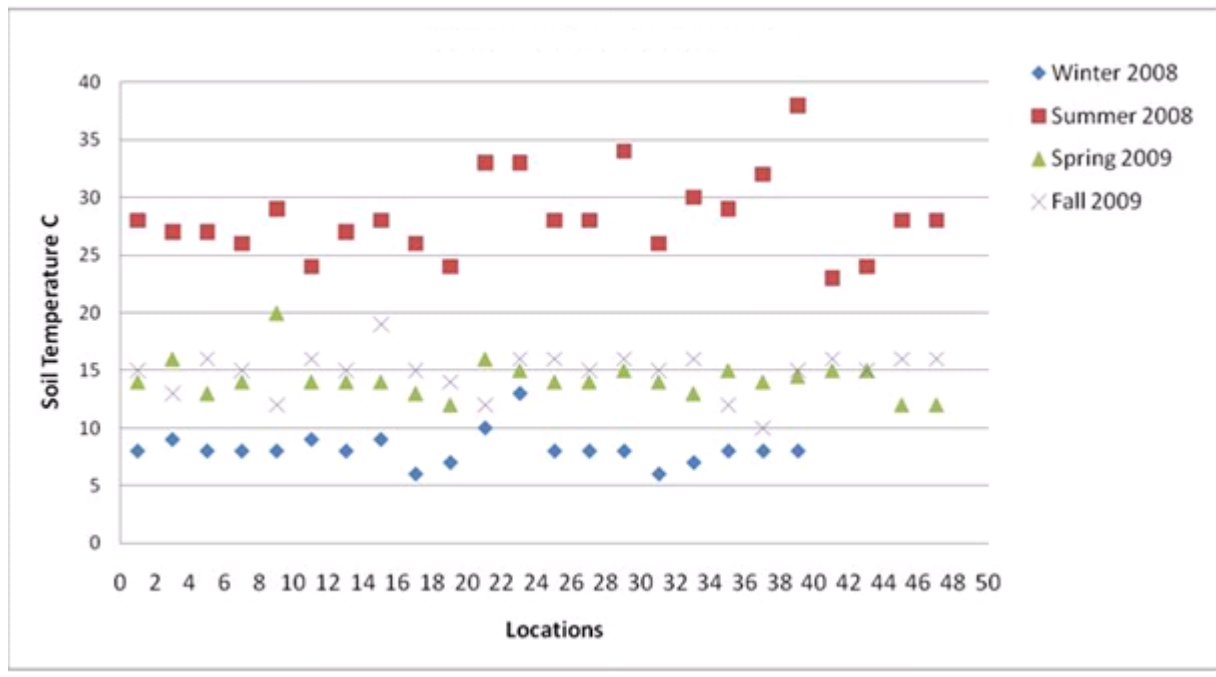


Figure 4.13. Soil temperature measurements from deforested soils

The mean value of winter season's soil temperature for forested soils is higher compared to deforested soils (by 0.1 units (8.3 ± 0.92 , and 8.2 ± 1.47 , respectively). The Fall 2009 season also exhibited a similar trend to the winter season. The mean value for the forested soils is 15.1 ± 1.42 and 14.8 ± 1.88 for deforested soils.

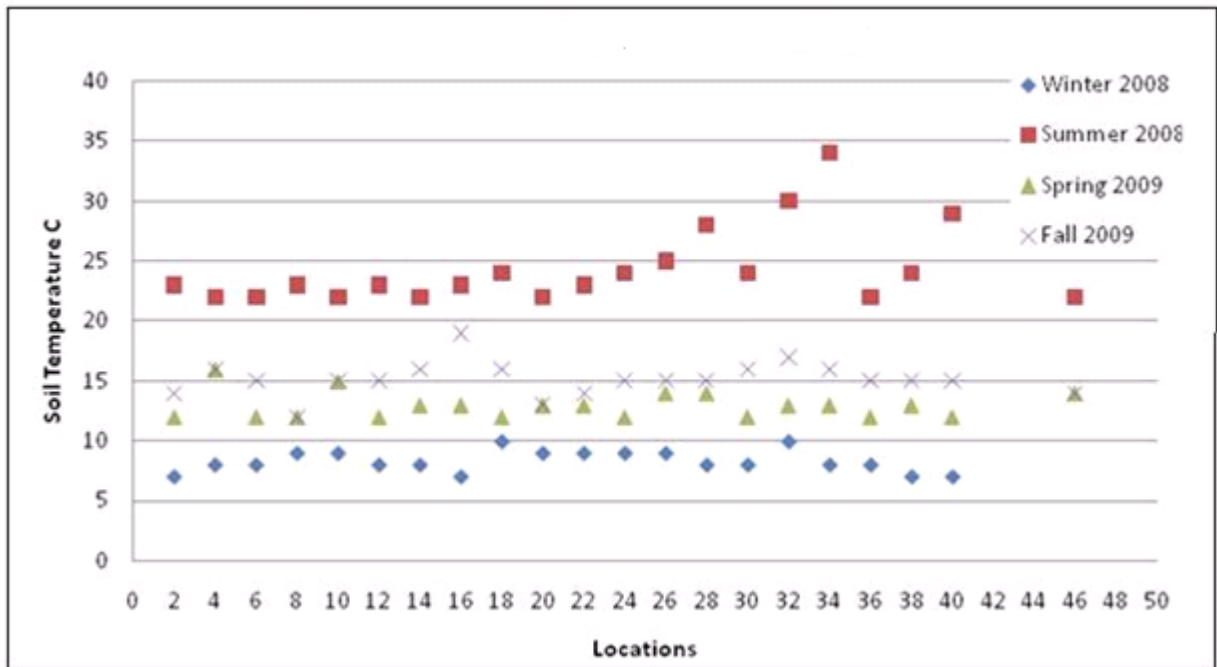


Figure 4.14. Soil temperature measurements from forested soils

Summer 2008 and spring 2009 mean values for deforested soils are higher compared to forested soils. This is due to thick vegetation cover in the forested floor, which limits the exposure to the sunlight. On contrast, there is no vegetation cover in deforested soils therefore the sunlight directly reaches the top layer of the soil increasing the soil temperature.

The soil surface temperature varies depending on sampling point locations (especially in shadowy locations). Also, some measurements were performed in morning hours while some were performed in the afternoon, which introduced a temporal measurement difference. Direct exposure to the solar radiation in summer caused low gravimetric moisture retention capacities in sampling locations, which also affected the soil temperature.

4.3 Satellite Image Analyses

Satellite images (dated 1987 and 2007) were used to compare land use change in the study area .Table 4.7 shows land use change from 1987 to 2007.

Table 4.7. The land use change values from 1987 to 2007

Land Use Types	Soils (1987) Hectares(ha)	Soils (2007) hectares (ha)	Increase (+)/ Decrease(-)	Change
Agricultural Production	14,193	15,400	(+) 1207 ha	8,5% (+)
Forests	5362,8	4758	(-) 604,8 ha	11% (-)
Urban soils, Pasture & meadows, abandoned soils	4536	3907	(-) 629 ha	13% (-)
Water (Akgol Lake, Sakarya River and Black Sea)	2854,36	2886,17	(+)31,81 ha	0,1 % (+)
Total	26951.17	26951.17		

The forest surface area of the soils has decreased from 5362, 8 ha to 4758 ha from 1987 to 2007 as can be seen in figures 4.15 and 4.16. The rate of the decrease is 11%. When compared with the literature, it was observed that Güler et al., (2007) found the decrease rate in the Province of Samsun (located in the Black Sea coast) to be 28%. They defined 8 land use types and listed them as: open forests, dense forests, hazelnut plantations, degraded forests, agricultural production, abandoned soils, urban, and water. However, in this dissertation, no detailed species classification in forest vegetation was presented, therefore the rate was calculated in Güler et al., (2007) is greater than the one calculated in this study for the Karasu forests.

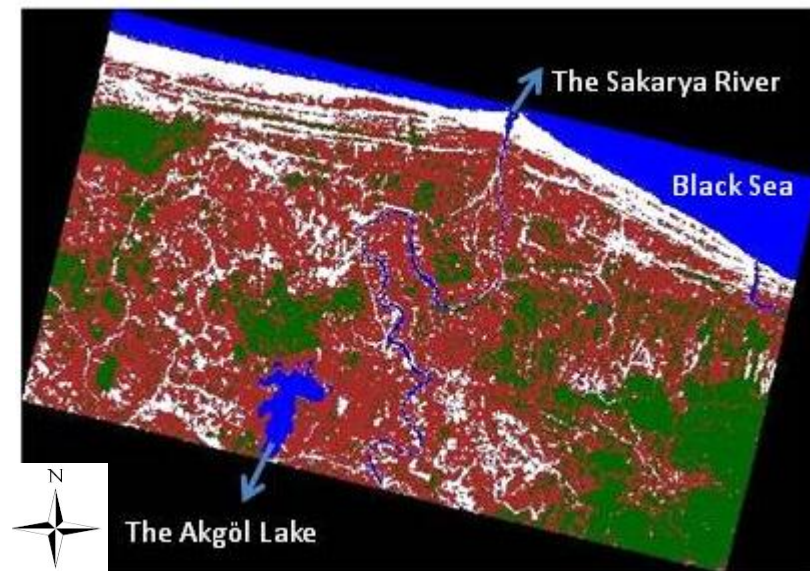


Figure 4.15 The land use maps on satellite images dated 1987

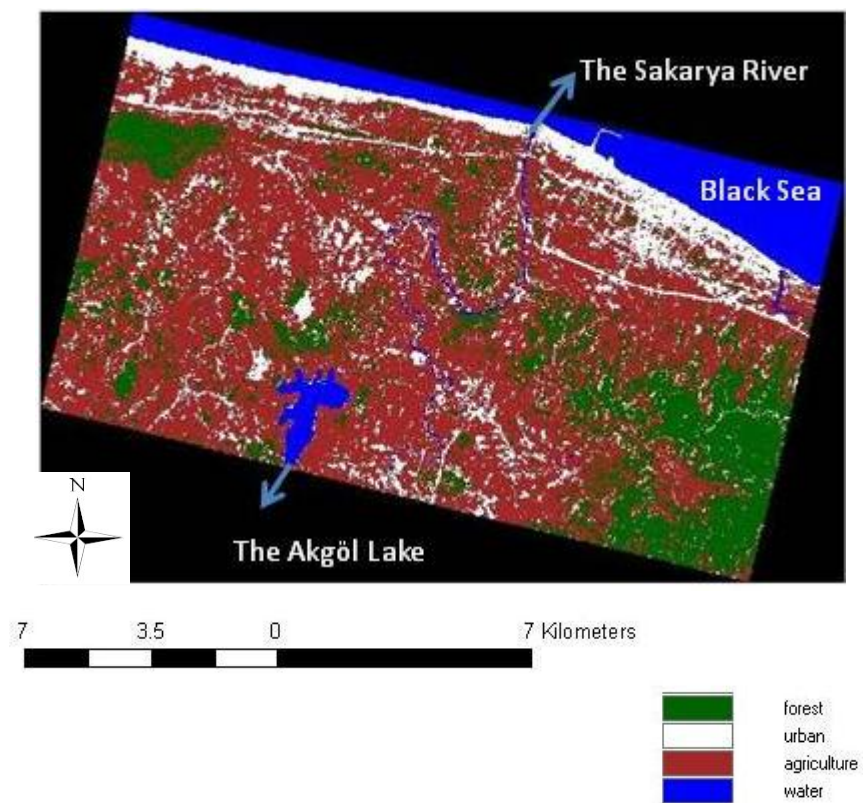


Figure 4.16 The land use maps on satellite images dated 2007

Ozdemir and Ozkan, (2003) presented land use change from 1992 to 2001 in the Armutlu forests, in Istanbul. They found that the forested area had decreased by 318, 41 ha within nine years (with an annual decrease rate of 1,96%). Yildirim et al., (2001) investigated land use change in forests of Kocaeli Peninsula (located in the Northwestern Turkey) from 1986 to 1998. Their results showed that the surface areas of forest soils have diminished by 4,1% in the peninsula.

In the study area, the increase in agricultural soils such as hazelnut and corn are calculated as 1207 ha. The rate of the increase is 8,5%. Guler et al., (2007) reported that the soils of open forest and hazelnut increased by 5,5% in the province of Samsun.

It was observed that surface areas urban soils, pasture and meadows, abandoned soils were decreased by 13%. Uncontrolled population expansion in urban soils forced people to look for other locations for running agricultural activities as financial income. Therefore, the pastures and abandoned soils were converted into the hazelnut plantations in the Karasu District

4.3.1. Accuracy Assesment Results

Accuracy assessment determines the quality of the information derived from remotely sensed data (Congalton and Green, 1999). The ground truth control data collected from field trips were overlaid and matched onto classified images of 1987 and 2007. The accuracy threshold of the defined classes on the satellite images is preferred to be greater than 80%. Results below this percentage shows that the manual classification made by the user is incorrect (Cohen, 1960). 95% accuracy was obtained in the classified images of 2007 for forested soils and for deforested soils (agricultural production soils) it is 97%.

For forested soils an 89% accuracy assesment value was obtained through analysis of 1987 classified images. For deforested soils it is 93%. Pietroniro and Soulis (2000) reported the accuracy assesment value of the forest classification as 91.9% in the Mackenzie Basin, Canada. This value is lower than the value calculated in Karasu District, because Pietroniro

and Soulis (2000) grouped 14 types of land use instead of 4, as it is done in this study. Güler et al., (2007) indicated the assessment value of deforested soils 89%, where they detected land use change in province of Samsun on forested and hazelnut soils (based on 8 defined land use types). Sancar et al., (2009) reported an overall classification assessment value of 92% where they used 4 types of land use, similar to the method preferred in this study.

4.4. Statistical Evaluation

SPSS 17.00 software package was employed to evaluate the results and the correlation between primary 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 soil respiration, elemental carbon, and factors affecting the soil respiration.

Table 4.8. Descriptive Statistics from forested soils

Parameters	N	Minimum	Maximum	Mean	Std. Deviation
In situ soil respiration	83	0,12	1,84	0,72	0,35
Soil Organic Material	83	0,56	5,15	2,83	0,97
Soil temperature	83	7,00	34,0	15,2	6,14
Electrical Conductivity	83	25,0	958,0	192,3	166,3
Gravimetric Moisture	83	6,00	61,67	21,1	9,83
pH	83	4,96	7,10	4,96	0,75
Microbial respiration	83	0,28	2,95	0,88	0,42
Elemental Carbon	83	0,66	3,90	1,82	0,61
Clay	83	5,00	53,0	23,2	13,3

Table 4.9. Descriptive Statistics from deforested soils

Parameters	N	Minimum	Maximum	Mean	Std. Deviation
In situ soil respiration	92	0,00	1,35	0,43	0,18
Soil Organic Material	92	0,42	3,96	2,18	0,73
Soil temperature	92	6,00	38,0	16,76	7,70
Electrical Conductivity	92	47,0	1138,0	195,8	196,6
Gravimetric Moisture	92	5,33	56,6	19,88	7,76
pH	92	5,22	7,35	3,76	0,76
Microbial respiration	92	0,00	1,73	0,56	0,28
Elemental Carbon	92	0,60	3,60	1,441	0,55
Clay	92	4,00	49,0	22,53	12,98

4.4.1 Transformation of the parameters

This process is conducted on the data when they do not follow a normal distribution with uniform variance. There are three commonly used transformations for quantitative data as follow:

- a. The logarithm transformation,
- b. The square root transformation,
- c. The reciprocal transformation

These transformations are called variance-stabilizing because the purpose is to make variances the same (Switzer and Nelson, 1972).

Soil pH and electrical conductivity did not meet the normal distribution criteria. Therefore, the Shapiro-Wilk normality tests and Kolmogorov-Smirnov statistical tests were conducted (Geissen et al., 2009). The results are given in the Appendix Section. Log transformation was then applied on electrical conductivity and pH to obtain the normal distribution (Korsaeth, 2005).

4.4.2. Trend analyses

This section presents mean comparison and correlation analyses performed to monitor effects of land use change, four seasons, and soil texture content (by means of clay percentage) on primary parameters. The mean value comparison tests were ran on factors affecting the soil respiration to compare results for different seasons and land use types. In this section the following issues will be addressed:

- a. Trend analyses of the primary parameters (Soil respiration and Elemental Carbon) with land use change
- b. Trend analyses of the primary parameters with seasonal trends
- c. Trend analyses of the primary parameters with clay content of the study soils

4.4.2.1 Land use change. The parameters were grouped into deforested and forested land use types. Each land use types consist of 83 samplings locations that were monitored over four seasons. The significant differences between means were presented with bold font.

Table 4.10. Pair sample test parameters of the primary parameters

Pairs	<i>t</i> values	Significance
In situ soil respiration_forested In situ soil respiration _deforested	8.711	0.00
Elemental Carbon_forested Elemental Carbon_deforested	5.468	0.00

The overall in situ soil respiration measurements from forested soils are higher compared to deforested soils (Table 4.10). The differences between the means of in situ soil respiration from forested and deforested soils are statistically significant. As a result, a trend was observed between land use change and in-situ soil respiration measurements.

In situ soil respiration can be affected by degradation of SOM in the soil (Carlisle, et al., 2006). Larionova et al., (1998) reported that deforestation and subsequent conversion to agriculture reduces SOM content of the soil and as a result the soil respiration is affected. Forestation of agricultural soil or natural vegetation on topsoil can also increase the SOM content.

Microbial respiration is one of the important factors that affect in-situ soil respiration (Rowell, 1996, Luo and Zhou, (2006), and Lou et al., (2004). Differences in situ soil respiration for forested and deforested soils might be due to soil microbial respiration.

The t-test showed that the elemental carbon differences between means of forested and deforested lands are significant ($t=4.45$, $p=0.00$). However, the correlation between elemental carbon compositions from two land use types is weak ($r=0.10$) (Figure 4.17).

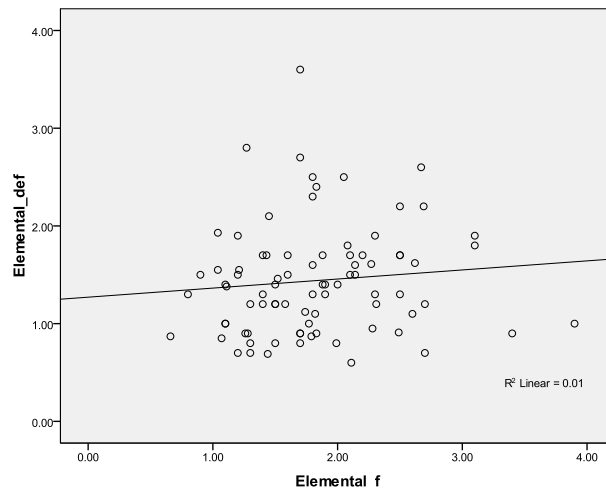


Figure 4.17. Correlation between elemental carbon from deforested and forested soils

It was also found that the elemental carbon accumulation in forested soils is higher compared to the deforested soil (Table 4.8).

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 forested soils. These plantations were defined as deforested soils in the study. Li et al., (2005), reported that fertilizer application allows a chemical stabilization of the soil (injection of chemicals into a soil to improve its strength and decrease its permeability). For this reason, fertilizer application may also influence the accumulation of elemental carbon in the soil (Paul et al., 2001). The cultivation of the soil and removal of the natural vegetation on topsoil decreases the elemental carbon due to enhanced mineralization and lower carbon input in deforested soils (Nobili et al., 2008 and Lou and Zhou, 2006).

Type of forest species and previous land uses in soils subject to this study, can also be associated with the finding. Former land use had a significant effect on change in soil carbon at less than 30 cm soil depth. 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). Bhat and Wani (2003), and Lal, (2008) concluded that the availability of litter, char, and humus on the soil surface increase the percentage of elemental carbon in forested soils. For these results it can be said that the amount of elemental carbon in forested soils are greater than the deforested soils.

4.4.2.2 Seasonal trends. For seasonal effects, the mean comparison analysis was conducted on the parameters. Each seasonal measurements consist of 21 samplings locations that were monitored from individual seasons. Only winter season consist of 20 sampling locations both from forested and deforested areas. The significant differences between means were presented with bold font

Table 4.11. Pair samples test parameters

Parameter	Pairs	<i>t</i> values	Significance
In situ soil respiration (forested)	2008 Winter- 2008 Summer	-0.512	0.614
	2008 Winter- 2009 Spring	-4.464	0.000
	2008 Winter -2009 Fall	-2.862	0.010
	2008 Summer- 2009 Spring	-3.659	0.002
	2008 Summer- 2009 Fall	-3.195	0.005
	2009 Spring- 2009 Fall	1.592	0.127
In situ soil respiration (deforested)	2008 Winter- 2008 Summer	0.861	0.400
	2008 Winter- 2009 Spring	-1.048	0.308
	2008 Winter -2009 Fall	-0.696	0.495
	2008 Summer- 2009 Spring	-3.377	0.003
	2008 Summer- 2009 Fall	-3.081	0.005
	2009 Spring- 2009 Fall	0.876	0.390
Elemental carbon (forested)	2008 Winter- 2008 Summer	-0.591	0.561
	2008 Winter- 2009 Spring	-1.929	0.069
	2008 Winter -2009 Fall	1.156	0.262
	2008 Summer- 2009 Spring	-1.487	0.153
	2008 Summer- 2009 Fall	2.192	0.040
	2009 Spring- 2009 Fall	3.021	0.007
Elemental carbon (deforested)	2008 Winter- 2008 Summer	-2.910	0.009
	2008 Winter- 2009 Spring	-0.630	0.536
	2008 Winter -2009 Fall	0.249	0.806
	2008 Summer- 2009 Spring	0.946	0.354
	2008 Summer- 2009 Fall	2.247	0.035
	2009 Spring- 2009 Fall	0.984	0.335

Overall mean values of soil respiration for four seasons were compared using paired samples statistical analysis. According to the results in Table 4.12, the differences in mean of soil respiration from summer - winter seasons and forested - deforested soils, are statistically significant. The computed *t* values are in order as follow: winter-spring pairs (-4,464), summer-spring pairs (-3,659).

The mean values of in situ soil respiration rates from forested soils were higher compared to deforested soils in winter of 2008. These values were also different for the summer season ($t = -3.659$, $p = 0.00$). The mean rates for the forested soils in the spring season were almost two folds compared to deforested soils rates. Table 4.12 shows 95% confidence intervals of difference levels between soil respirations results (measured at four seasons).

In winter 2008 from forested and deforested soils, soil respiration was reduced because of low topsoil temperatures and presence of anaerobic organisms (Vincent et al., 2006) as a result, the differences in mean soil respiration from winter and summer 2008 due to seasonal variations were statistically not significant. It was also monitored that the respiration was higher in summer 2008 compared to winter 2008, which was attributed to low content of gravimetric moisture content of the soil.

The elemental carbon content does not have a seasonal trend in winter 2008 for forested soils but it shows a trend in winter 2008 from deforested soils. The Table 4.12 indicated that the differences in mean soil elemental carbon from summer 2008 and spring 2009 due to seasonal variations were statistically significant ($t = 2.192$, $t = 0.040$).

There was a significant difference between the mean value of elemental carbon in forested and deforested soils in spring and fall 2009 seasons. Hazelnut planting takes place in fall season and the elemental carbon content in deforested soils tends to decrease gradually. Other agricultural management practices such as cultivating, airing the soil, fertilizing, and liming decreased the soil organic matter and the carbon content of the soil in spring and fall 2009 seasons (Lou and Zhou, 2006). The elemental carbon showed a high correlation with the clay content and the gravimetric water content both in spring and fall 2009 seasons for forested and deforested soils. This correlation could account for the difference between mean values of elemental carbon in forested and deforested soils in spring and fall 2009.

4.4.2.3 Soil texture type trends. The mean comparison analysis was conducted on the parameters. Clay measurements consist of 21 samplings locations that were monitored from individual seasons. The correlation between the clay content, in situ soil respiration and elemental carbon from forested and deforested soils were investigated in this part.

For the clay content - in situ soil respiration from forested soils, in-situ soil respiration measurement from fall 2009 for forested soils has a negative correlation with clay content (Table 4.12). Figure 4.18 presents this correlation.

Table 4.12. The correlation factors between In situ soil respiration and clay content (*: indicates the correlation at significant level 0.005)

	Winter	Summer	Spring	Fall
	Cor.- Sig	Cor.-Sig	Cor.- Sig	Cor.-Sig
Clay –in situ soil respiration (forested soils)	-0.23- 0.32	0.05-0.80	0.09-0.69	-0.46-0.03*
Clay –in situ soil respiration (deforested soils)	-0.29- 0.20	0.11-0.59	0.04-0.84	0.10-0.63

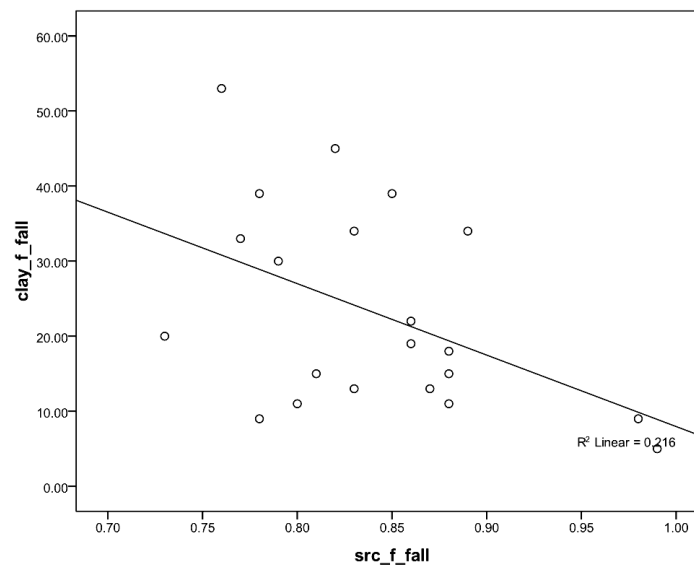


Figure 4.18. The in situ soil respiration and clay content for Fall 2009 for the forested soils

Nobili, (2008) argued that the reverse correlation between two parameters is related to the chemical stabilization of SOM. This occurs as a result of chemical or physico-chemical binding to soil mineral surfaces and reversible sorption of labile substrates. These substrates also decrease the concentration of SOM in the soil solution and slow up decomposition. As a

result, a lower CO₂ evolution observed in clay soil. Added to that, Yang, et al., (2008) also figured out the fine texture of clay soil reduced the amount of carbon mineralization, which contributed to accumulation of the soil organic carbon.

According to the Table 4.12, no correlation was found between in situ soil respiration and clay content over extent seasons from deforested soils. This could be the lack of water content and greater nutrient availability due to less physical protection of the organic matter in coarse-textured soils. The microorganism in aggregates of fine textured soils cannot access inter-aggregate substrates therefore the in situ soil respiration does not take place (Wang, (2003), Müller and Höper,(2004).

For the clay content elemental carbon from forested soils, Table 4.11 presents effects of the soil clay content in forested soils on elemental carbon. A trend was not observed between clay content and elemental carbon for winter 2008. However, a trend is observed for summer 2008 and spring and fall of 2009. Results stated by the following figures (4.20, 4.21, and 4.22) have been already given in Table 4.13.

Table 4.13. The correlation factors between Elemental Carbon and clay content
(*: indicates the correlation at significant level 0.001)

	Winter	Summer	Spring	Fall
	Cor.- Sig	Cor.-Sig	Cor.- Sig	Cor.-Sig
Clay - Elemental Carbon (forested Soils)	0.43- 0.05	0.64-0.00*	0.52-0.01*	0.79-0.00*
Clay - Elemental Carbon (deforested Soils)	0.65-0.00*	0.74-0.00*	0.60-0.00*	0.52-0.00*

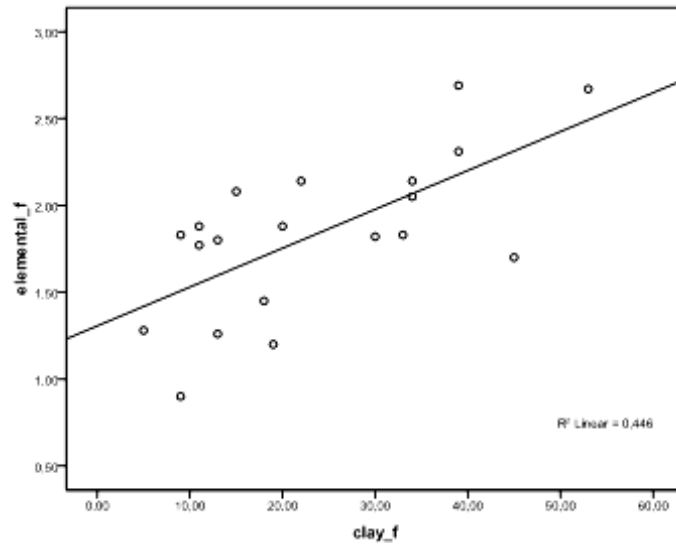


Figure 4.19. Elemental Carbon and clay content for the summer 2008 season for the forested soils

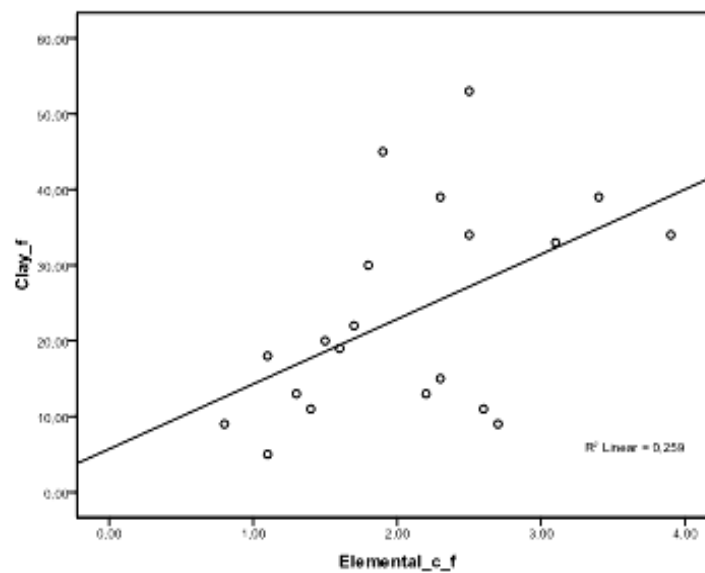


Figure 4.20. Elemental Carbon and clay content for the spring 2009 season for the forested soils

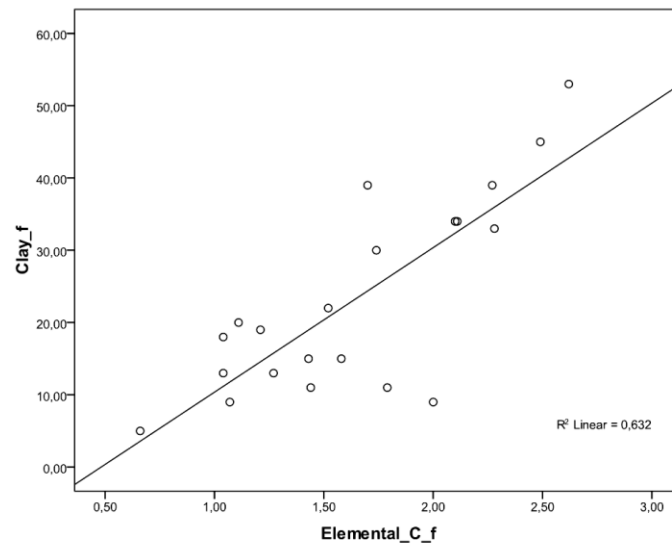


Figure 4.21. Elemental Carbon and clay content for the Fall 2009 season for the forested soils

Schimel et al., (1994) quantified this trend in forested soils as “clay content lead to more stabilization of soil organic carbon.”

For the clay content and elemental carbon from deforested soils, Table 4.11 shows there is a trend between clay content and elemental carbon for deforested soils. According to Lal, (2001) this high correlation can be explained by the removal of the natural vegetation and conversion of these forests into any other types of land use, which increases the carbon holding capacity of clay minerals in the soil. The correlation between the clay content and elemental carbon content form deforested soils can be seen in figures 4.22, 4.23, 4.24, and 4.25.

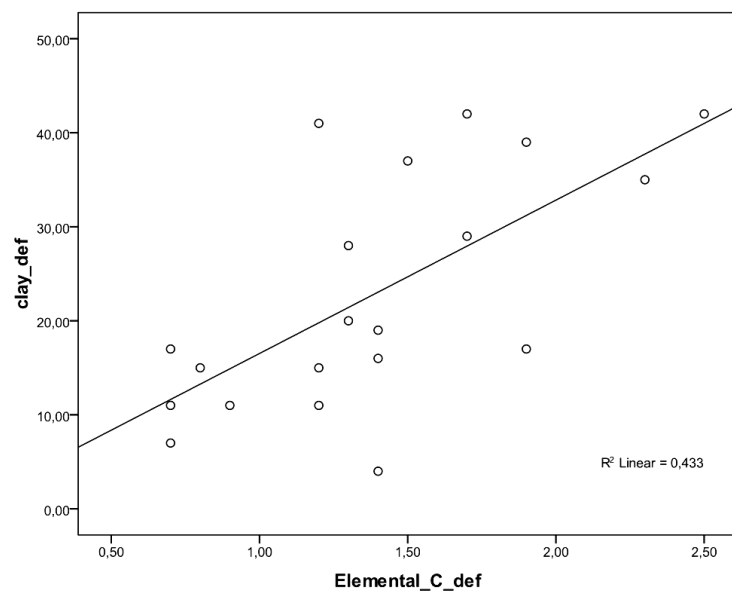


Figure 4.22. Elemental Carbon and clay content for the winter 2008 season for the deforested soils

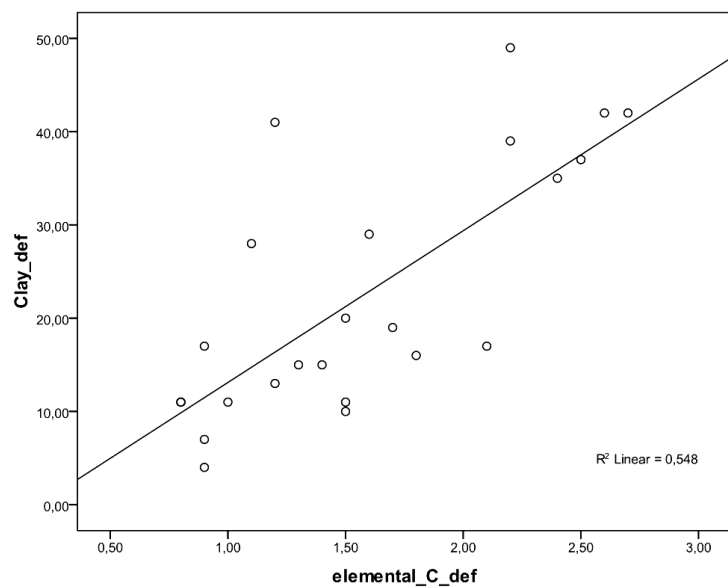


Figure 4.23. Elemental carbon and clay content for the summer 2008 season for the deforested soils

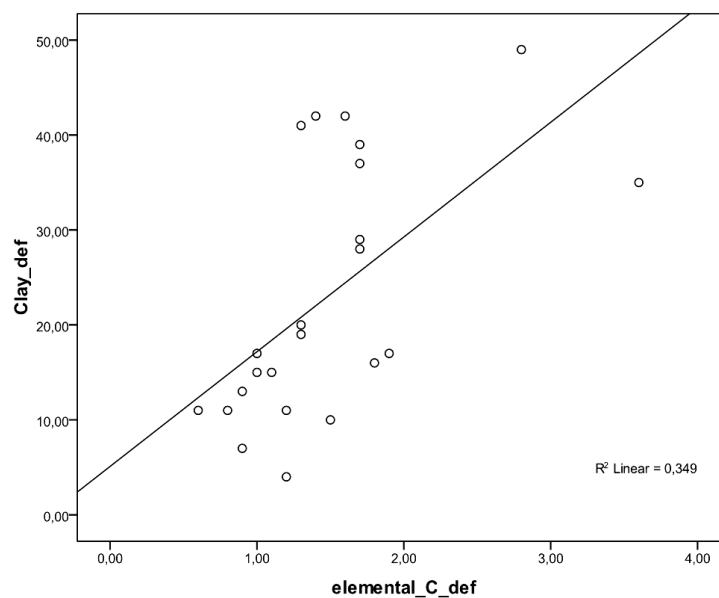


Figure 4.24. Elemental carbon and clay content for the spring 2009 season for the deforested soils

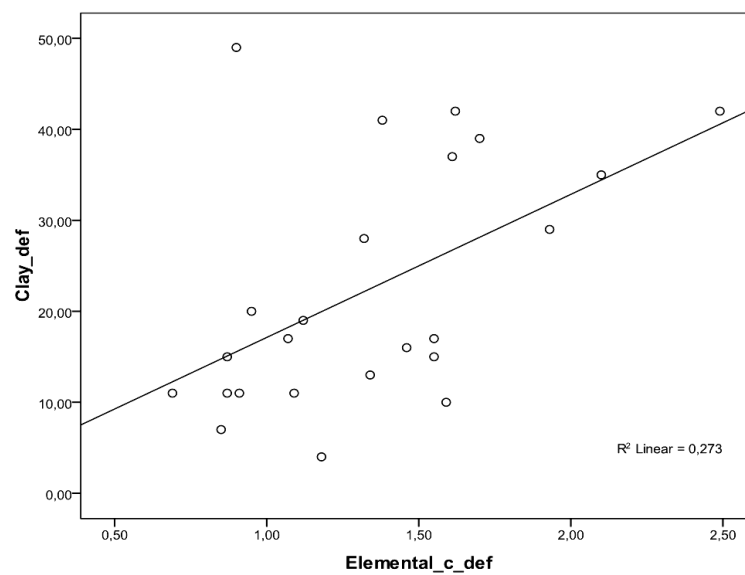


Figure 4.25. Elemental carbon and clay content for the fall 2009 season for the deforested soils

4.5. Correlations

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

- 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.

The bivariate correlation procedure was applied on parameters because the significance levels were used to assess relations between variables and rank orders. Table 4.14 shows the Pearson correlation coefficients (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 4.14. Pearson correlation coefficients

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, infinite

The primary parameters, soil, and other environmental parameters were grouped as deforested and forested depending on two main land use types. Each land use type consists of 83 samplings that extend over four seasons.

In this section the following issues will be addressed:

- a. Correlations between primary parameters among each other for different seasons
- b. Correlation of the primary parameters to the other soil and environmental parameters (soil temperature, electrical conductivity, pH, gravimetric moisture, soil organic matter)
 - All seasons
 - Seasonal variations

4.5.1. Correlation of the primary parameters among each other for different seasons.

No correlation was found between in situ soil respiration and elemental carbon for four seasons and two different types of land uses. However, low correlation was monitored at significant levels ($p < 0.05$) in spring and fall 2009. The correlation parameters are shown in Table 4.15, and Table 4.16.

Table 4.15. Correlation results between primary parameters for four seasons

Pairs	N	Correlation	Significance
In situ soil respiration - Elemental Carbon (Forested)	83	0.12	0.25
In situ soil respiration – Elemental Carbon (Deforested)	83	-0.02	0,78

Table 4.16. Correlation results between primary parameters in individual seasons
(*Indicates the correlation at significant level 0.005)

Pairs	N	Winter 2008 Corr./ (Sig)	Summer 2008 Corr./ (Sig)	Spring 2009 Corr./ (Sig)	Fall 2009 Corr./ (Sig)
In situ soil respiration (Deforested)- Elemental Carbon (Forested)	45	0.10/(0.53)	0.11/(0.45)	0.38/(0.01)*	0.297/(0.04)*

Having no correlation between in situ soil respiration and elemental carbon can be explained as: Elemental carbon is obtained by a process called “dry combustion” in a furnace and in situ soil respiration is measured from forest floors using a process of differentiating the air inside a closed chamber supported by the IRGA technology. As a result, no correlation was observed between two parameters. Vanhala et al., (2005) also agreed with this result and they reported that in situ soil respiration measurements were not correlated with soil parameters or with soil elemental carbon.

The deforestation process alters the amount of retained carbon in soil and forest soils store a substantial amount of carbon, often more than other types of vegetation. This stored amount of carbon can only be detected at laboratory conditions (Peltoniemi et al., 2004).

Former land use had a significant effect on change in soil carbon in less than 30 cm soil depth (Paul et al., 2002). According to 1993 forest stand data of study soils in Karasu District, some locations classified currently as deforested were natural forests just 14 years ago. This previous land use is probably the reason why no correlation was observed between in situ soil respiration and elemental carbon.

The correlation between in situ soil respiration and elemental carbon in Fall and spring 2009 seasons can be associated with gravimetric moisture, SOM, and clay content of the soil.

4.5.2. Correlation of primary parameters to other soil and environmental parameters. The correlation between primary parameters and other soil and environmental parameters were investigated for seasonal variation and for all seasons.

4.5.2.1. All seasons

The analysis showed a correlation between in situ soil respiration and microbial respiration. Table 4.17 presents correlation results.

Table 4.17. Correlation results between in situ soil respiration and other environmental parameters for all four seasons for the forested soils (Indicates the correlation at significant levels 0.01 and 0.05)

Pairs	N	Correlation	Significance
In situ soil respiration - SOM	83	0.17	0.10
In situ soil respiration Soil Temp.	83	-0.04	0.68
In situ soil respiration - Electrical Cond.	83	0.00	0.95
In situ soil respiration – Grav.Moisture	83	0.14	0.20
In situ soil respiration - pH	83	0.19	0.07
In situ soil respiration - Microbial Resp.	83	0.32*	0.00
In situ soil respiration - Elemental C.	83	0.11	0.28
In situ soil respiration - Clay	83	-0.06	0.55

A moderate correlation ($r = 0.32$, $p < 0.001$) was observed between in-situ soil respiration and microbial respiration from forested soils. In situ soil respiration is controlled by microbiological activities in soil, and these biotic activities are moderating in-situ respiration (Kuzakov, 2006 and Rowell, 1996). Figure 4.26 shows the correlation between in-situ soil respiration and microbial respiration.

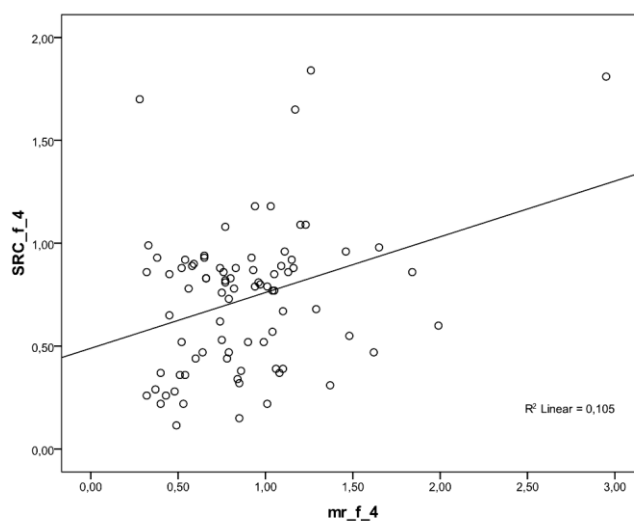


Figure 4.26. Correlation between in situ soil respiration and microbial respiration from the forested soils.

Table 4.18. Correlation results between In situ soil respiration and other environmental parameters from all seasons, deforested soils (Indicates the correlation at significant levels 0.01 and 0.05)

Pairs	N	Correlation	Significance
In situ soil respiration – SOM	83	-0.00	0.96
In situ soil respiration - Soil Temp.	83	-0.17	0.09
In situ soil respiration - Electrical Cond.	83	-0.05	0,63
In situ soil respiration - Gravimetric M.	83	-0.07	0.49
In situ soil respiration - pH	83	0.02	0.82
In situ soil respiration - Microbial Resp.	83	-0.03	0.76
In situ soil respiration - Elemental C.	83	-0,02	0.78
In situ soil respiration - Clay	83	-0,05	0.59

A significant correlation was not observed between in situ soil respiration and other environmental parameters in deforested soils (Table 4.18). It was expected to monitor correlations, however soil respiration is influenced and varied by type of vegetation, physical, and chemical property of soil, and season of the year (Jiabin et al., 2005) and soil homogeneity or heterogeneity, and the degradability of the substrates present in soils. Differences in soil structural properties such as clay content are also affecting rates of in-situ soil respiration (Ingram, et al., 2005). This result means that the in situ soil respiration from deforested soils from all seasons, in Karasu District is not correlated with the environmental parameters.

For soil elemental carbon, significant correlations were found between elemental carbon and other environmental parameters for forested and deforested soils (Tables 4.19 and 4.20). For instance, there is a high correlation between elemental carbon and soil organic matter ($r = 0.59$, $p < 0.05$) as shown in Figure 4.30. According to Lal, (1988) the experimental analysis methods of these parameters may be one of the reasons for a high correlation. Elemental carbon is obtained by dry combustion method using oxygen or metal oxides under high temperature to convert organic carbon. Soil organic matter is found by dichromate oxidation method or Walkley-Black method that use chromic acid to measure the oxidizable organic carbon in a soil (Nelson and Sommers, 1982).

Table 4.19. Correlation results between elemental carbon and other environmental parameters for all seasons from the forested soils (Indicates the correlation at significant levels 0.01 and 0.05)

Pairs	N	Correlation	Significance
Elemental Carbon - SRC	83	0.12	0.28
Elemental Carbon - SOM	83	0.59*	0.00
Elemental Carbon – Soil Temp.	83	0.00	0.94
Elemental Carbon - Electrical Cond.	83	0.07	0.51
Elemental Carbon- Grav. Moist.	83	0.07	0.50
Elemental Carbon – pH	83	0.11	0.26
Elemental Carbon - Microbial Resp.	83	0.22**	0.33
Elemental Carbon – Clay	83	0.55*	0.00

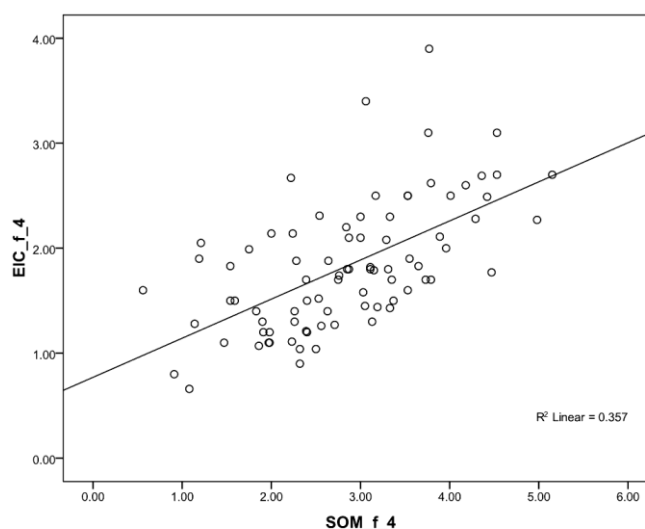


Figure 4.27. Correlation between elemental carbon and soil organic matter

There is a negative correlation between elemental carbon and pH ($r=-0.23$, $p<0.01$). Soil pH values in the study range between 4.5 and 7.5. This range is classified as “neutral” or “slightly acidic” (Soil Survey, 1950). Nsabiana, et al., (2008) reported that under low pH conditions, the SOM is difficult to mineralize and therefore, soil elemental organic carbon levels are not enhanced.

The correlation between elemental carbon and microbial respiration was monitored low ($r=0.22$, $p<0.01$) (Figure 4.29). Kocyigit, (2008) concluded that the microbial biomass and respiration are closely related with the transformation of soil carbon storage. Soils are covered under different types of vegetations have different potential to accumulate the soil organic matter and nutrients. Also, low level of organic matter in soil may alter the biological activities in soil, as well.

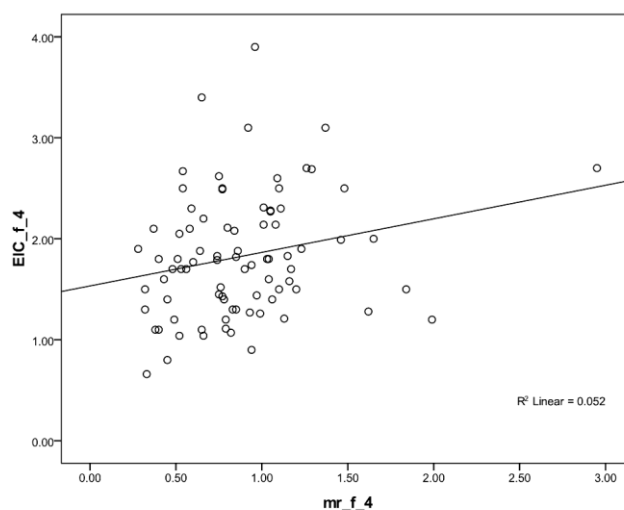


Figure 4.28. Correlation between elemental carbon and microbial respiration

One of the highest correlations was detected between elemental carbon and clay content ($r=0.55$, $p<0.01$) (Figure 4.29). Clay in the soil is used as a stabilizing agent and for that purpose it has an affinity to soil organic content (Lal, 2001). Soils with high clay content lead to more stabilization of soil organic carbon (Schimel et al., 1994). In addition, clay offers chemical protection to organic matter through adsorption onto clay surfaces.

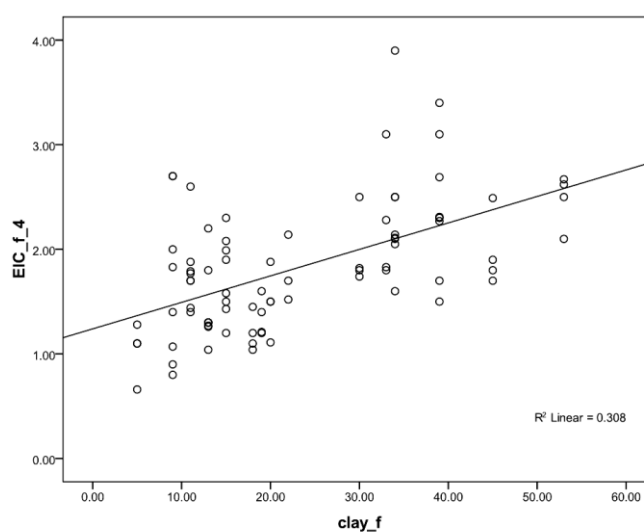


Figure 4.29. Correlation between elemental carbon and clay content

For both forest and deforested soils correlations were observed with elemental carbon, SOM, microbial respiration, and clay (Table 4.19). However, a significant correlation was not detected with elemental carbon and pH at this type of land use. The correlation between elemental carbon and SOM is high ($r=0.52$, $p<0.05$), while the correlation between microbial respirations is low ($r=0.25$, $p<0.05$) and with clay the correlation was high ($r=0.62$, $p<0.05$). According to Lal, (2001) this high correlation can be explained by the removal of natural vegetation and conversion of these forests into any other types of land use, which in overall, increases the carbon holding capacity of clay minerals in the soil. Also, a moderate correlation was found ($r=0.43$, $p<0.05$) between elemental carbon and electrical conductivity as shown in Figure 4.30.

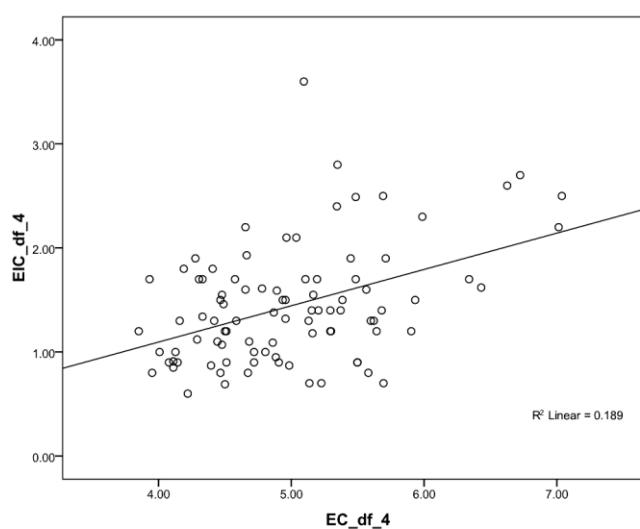


Figure 4.30. Correlation between elemental carbon and electrical conductivity

Gleason, et. al., (2002) found that soil electrical conductivity is positively correlated with soil carbon in micronesian mangrove forest. They reported that there is a high correlation ($r=0.55$; $p<0.05$) between the two parameters. The hydrological factors of the forest soil such as the precipitation, moisture content may control the conductivity and carbon relationships. Electrical conductivity is closely related with cation exchange capacity (CEC) of the soils and

CEC is highly dependent upon soil texture and organic matter content and this affect the ratio of the soil respiration.

Table 4.20. Correlation results between elemental carbon and other environmental parameters for all seasons from the deforested soils (Indicates the correlation at significant levels 0.01 and 0.05)

Pairs	N	Correlation	Significance
Elemental Carbon - In situ soil respiration	83	-0.02	0.78
Elemental Carbon - SOM	83	0.52*	0.00
Elemental Carbon – Soil Temp.	83	0.14	0.17
Elemental Carbon - Electrical Cond.	83	0.43*	0.00
Elemental Carbon- Gravimetric M.	83	0.19	0.06
Elemental Carbon – pH	83	0.11	0.26
Elemental Carbon - Microbial Resp.	83	0.25**	0.01
Elemental Carbon – Clay	83	0.62*	0.00

4.5.2.2. Seasonal variation

In this part, observed correlations between primary parameters, soil and other environmental parameters taken from individual seasons are presented. The correlations are shown in tables 4.21, 4.22, 4.23, and 4.24.

Table 4.21. Correlation results between in-situ soil respiration and other environmental parameters from forested soils (*Correlation is significant at 0.001 level (2-tailed) and **Correlation is significant at 0.005 level (2-tailed))

	Environmental parameter	Winter	Summer	Spring	Fall
		Corr./(Sig.)	Corr./(Sig.)	Corr./(Sig.)	Corr./(Sig.)
In situ soil respiration	SOM	0.33/ (0.14)	-0.01/(0.94)	0.42/(0.05)	-0.16/ (0.46)
	Soil Temp.	-0.09 / (0.69)	-0.08/(0.70)	0.51 [*] /(0.01)	0.02/(0.90)
	Electrical Cond.	0.12/(0.59)	0.58 [*] /(0.00)	0.41/(0.06)	0.10/(0.66)
	Grav. Moist.	0.31/ (0.09)	0.34/(0.07)	0.08/(0.70)	-0.43/(0.05)
	pH	-0.05 / (0.80)	0.53 ^{**} /(0.14)	0.15/(0.49)	0.50 ^{**} /(0.02)
	Microbial Resp.	0.48 ^{**} / (0.03)	0.36/(0.10)	0.25/(0.27)	0.11/(0.63)
	Clay	-0.23 / (0.32)	0.05/(0.80)	0.09(0.69)	-0.46 ^{**} /(0.03)

Table 4.22. Correlation results between in-situ soil respiration and other environmental parameters from deforested soils. (*Correlation is significant at 0.001 level (2-tailed) and **Correlation is significant at 0.005 level (2-tailed))

	Environmental parameter	Winter	Summer	Spring	Fall
		Corr./(Sig.)	Corr./ (Sig.)	Corr./ (Sig.)	Corr./ (Sig.)
In situ soil respiration	SOM	-0,39/(0,08)	0.24/(0.29)	0.08/(0.74)	0.19/(0.41)
	Soil Temp.	0.36/(0.11)	-0.22/(0.34)	0.14/(0.54)	-0.13/(0.57)
	Electrical Cond.	-0.11/(0.62)	0.38/(0.09)	-0.05/(0.82)	0.21/(0.36)
	Grav. Moist.	-0.29/(0.21)	-0.26/(0.27)	-0.25/(0.28)	0.20/(0.37)
	pH	-0.17/(0.47)	0.54/(0.03)	-0.30/(0.19)	0.250/(0.37)
	Microbial Resp.	-0.14/(0.54)	-0.26/(0.26)	-0.23/(0.31)	0.31/(0.16)
	Clay	-0.29/(0.20)	0.22/(0.33)	0.01/(0.94)	0.06/(0.79)

Table 4.23. Correlation results between soil elemental carbon and other environmental parameters from forested soils (*Correlation is significant at 0.001 level (2-tailed) and ** Correlation is significant at 0.005 level (2-tailed)

	Environmental parameter	Winter	Summer	Spring	Fall
		Corr./ (Sig.)	Corr./ (Sig.)	Corr./ (Sig.)	Corr./ (Sig.)
Elemental Carbon	SOM	0.83*/(0.00)	0.20/(0.37)	0.68*/(0.00)	0.44*/(0.04)
	Soil Temp.	0.21/(0.35)	0.01/(0.95)	0.07/(0.76)	-0.12/(0.58)
	Electrical Cond.	0.400/(0.08)	-0.12/(0.60)	-0.03/(0.89)	0.46**/(0.03)
	Gravimetric Moist.	-0.05/(0.81)	-0.01/(0.93)	0.23/(0.31)	0.87*/(0.00)
	pH	-0.20/(0.39)	-0.32/(0.15)	-0.19/(0.40)	-0.13/(0.53)
	Microbial Resp.	0.45**/(0.04)	-0.92/(0.69)	0.13/(0.57)	0.30/(0.18)
	Clay	0.43/(0.05)	0.64*/(0.00)	0.52**/(0.01)	0.79*/(0.00)

Table 4.24. Correlation results between soil elemental carbon and other environmental parameters from deforested Soils (*Correlation is significant at 0.001 level (2-tailed) and ** Correlation is significant at 0.005 level (2-tailed)

	Environmental parameter	Winter	Summer	Spring	Fall
		Corr./ (Sig.)	Corr./ (Sig.)	Corr./ (Sig.)	Corr./ (Sig.)
Elemental Carbon	SOM	0.77*/(0.00)	0.74*/(0.00)	0.26/(0.21)	0.64*/(0.00)
	Soil Temp.	-0.26/(0.26)	0.29/(0.18)	-0.03/(0.88)	0.12/(0.56)
	Electrical Cond.	0.63*/(0.00)	0.73*/(0.00)	0.32/(0.13)	0.40**/(0.04)
	Gravimetric Moist.	0.28/(0.22)	0.02/(0.99)	0.42**/(0.04)	0.55*/(0.00)
	pH	0.08/(0.71)	0.78/(0.72)	0.21/(0.32)	-0.01/(0.93)
	Microbial Resp.	0.03/(0.87)	0.27/(0.19)	0.33/(0.12)	0.30/(0.14)
	Clay	0.65*/(0.00)	0.73*/(0.00)	0.51**/(0.01)	0.52*/(0.00)

Four seasons from forested soils. The seasonal in situ soil respiration measurements and soil elemental carbon laboratory results from forested soils are presented in this section.

In winter 2008 there is a low correlation ($r = 0.48$, $p < 0.05$) between in situ soil respiration and microbial respiration from forested soils. Table 4.23 and Figure 4.32 show the correlation.

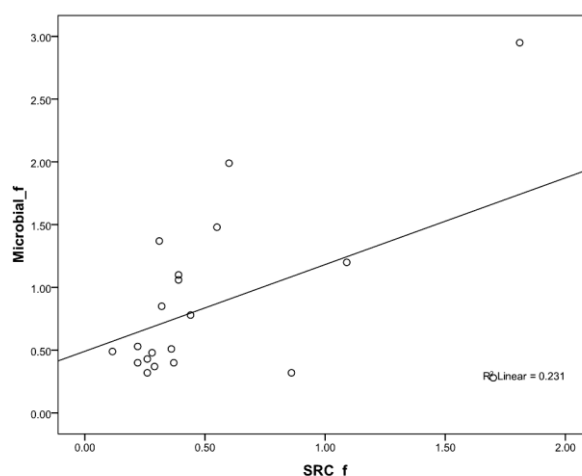
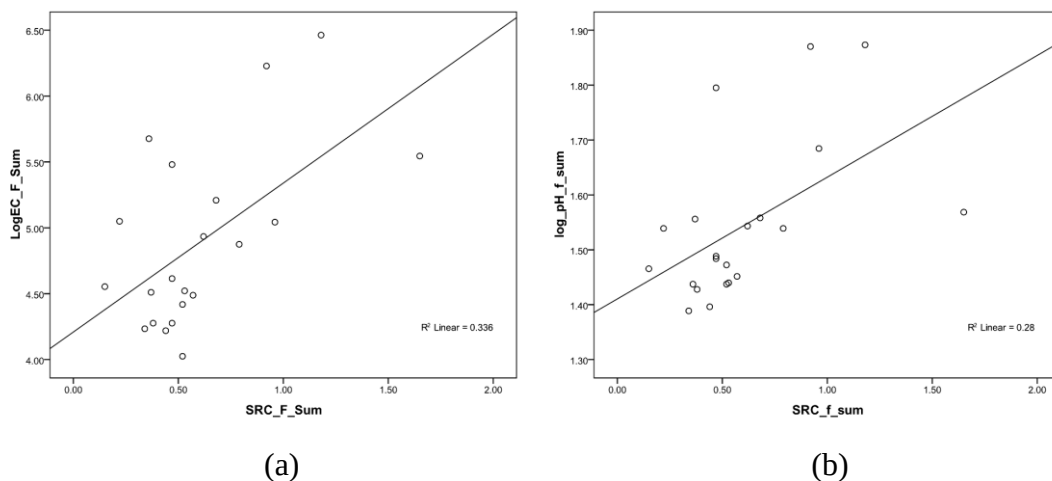


Figure 4.31. Correlation between in situ soil respiration and microbial respiration for the winter season, forested soils.

In Summer 2008 electrical conductivity and pH are highly correlated with in-situ soil respiration for forested soils for the summer 2008 season (Figure 4.33). Tüfekçioğlu and Küçük, (2004) investigated the soil respiration in spruce stands with adjacent grasslands in the East Black Sea Region of Turkey. They reported that seasonal changes in soil respiration were strongly related with soil pH ($r = 0.60$, $p < 0.05$). Reth, et al., (2005) concluded that soil pH variation and soil respiration showed a positive correlation ($r^2 = 0.24$, $p < 0.01$). The correlation analysis also showed that the electrical conductivity has a high correlation with pH ($r = 0.82$, $p < 0.00$) and in situ soil respiration has the same correlation with pH. It can be stated that the pH is a common parameter, which might be related with in-situ soil respiration and the electrical conductivity.



Figures 4.32. Correlation between in situ soil respiration, (a) electrical conductivity and (b) pH for the summer season, forested soils.

For spring 2009 In situ soil respiration is highly correlated with soil temperature (Table 4.20 and Figure 4.36) in the spring season. Luo and Zhou, (2006) considered the soil temperature as one of the significant biotic factors that control the soil respiration. This factor accelerates the microbiological activity in the soil, as the outcome CO_2 is released from soil surface and the in situ respiration can be measured. Maddock, et al.,(2004) investigated relationship of soil respiration and soil temperature. They reported that there is a good correlation ($r^2=0.71$) between two parameters and figured out that CO_2 emission rates vary as a function of soil temperature due to the dependence of the density of microorganisms on these soil physico-chemical conditions.

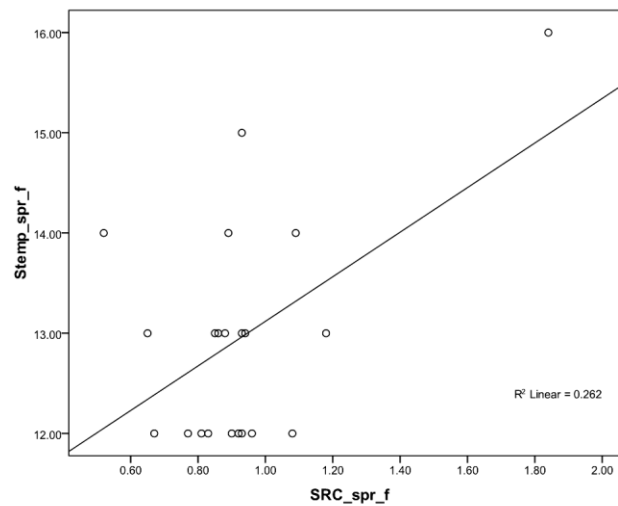
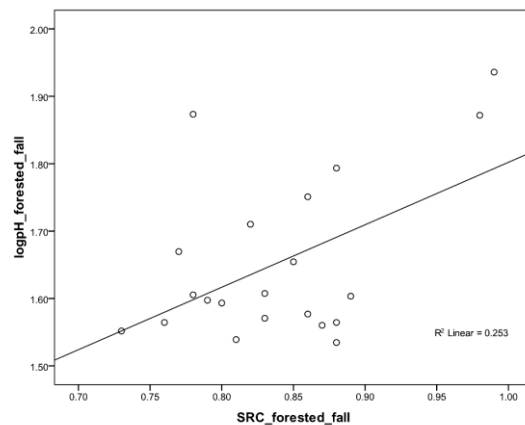
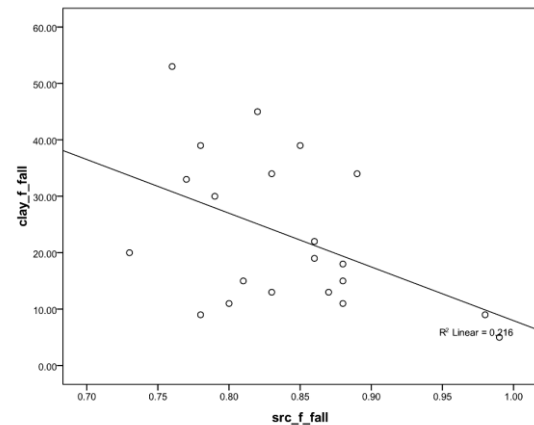


Figure 4.33. Correlation between in situ soil respiration, and soil temperature for the spring season for the forested soils.

There is a negative correlation between in situ soil respiration and clay content for the Fall 2009 season (Table 4.21). Figure 4.34 shows the negative correlation. The soil texture influences the root systems of the vegetation and this indirectly affects the soil respiration (Luo and Zhou, 2006). Yang, et al., (2007) defined the respiration as a function of carbon decomposition and such that a negative correlation between clay content and the rate of carbon decomposition was observed. They also reported that the fine texture of clay soil reduced the amount of carbon mineralization, which contributed to accumulation of the soil organic carbon. Dilustro et al., (2005) quantified the soil respiration and the relationship with clay content. According to these results, there was no correlation between soil respiration and clay content in the clayish sites of mixed pine forest in Southeastern Georgia.



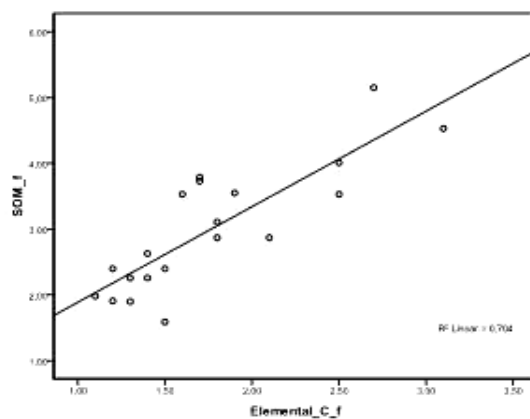
(a)



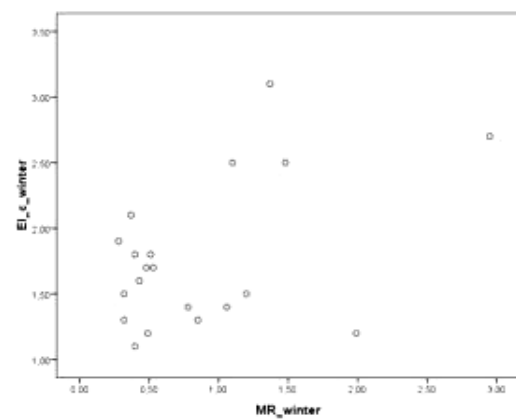
(b)

Figures 4.34. Correlation between in situ soil respiration,(a) pH and (b) clay for the fall season for the forested soils

In winter 2008 Elemental carbon measures the recalcitrant organic carbon (Vasques, 2009) and soil organic matter is an inhomogeneous mixture of compounds of different chemical stabilities (Aranoa and Mozos, 2008). The environmental factors in forests allow decaying of organic materials on the forest floors. The decayed materials are the main component of SOM and these can exist in different morphological patterns. A high correlation was detected between elemental carbon and soil organic material and microbial respiration in forested soils (Table 4.23 and Figure 4.35).



(a)



(b)

Figure 4.35: Correlation between elemental carbon, (a) soil organic material and (b) microbial respiration

In summer 2008 correlation between elemental carbon and clay was detected high (Table 4.24 and Figure 4.36). 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.

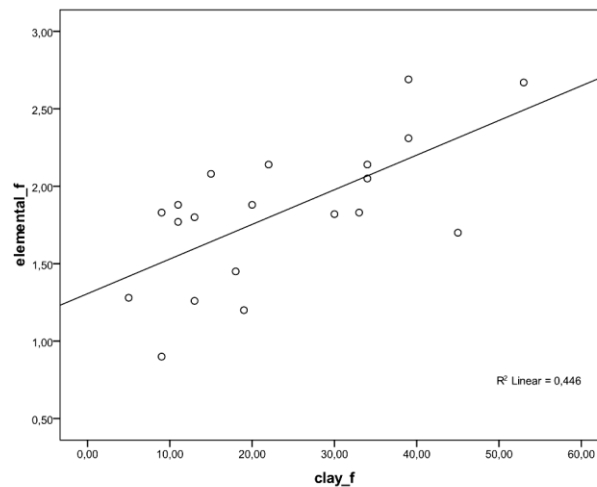
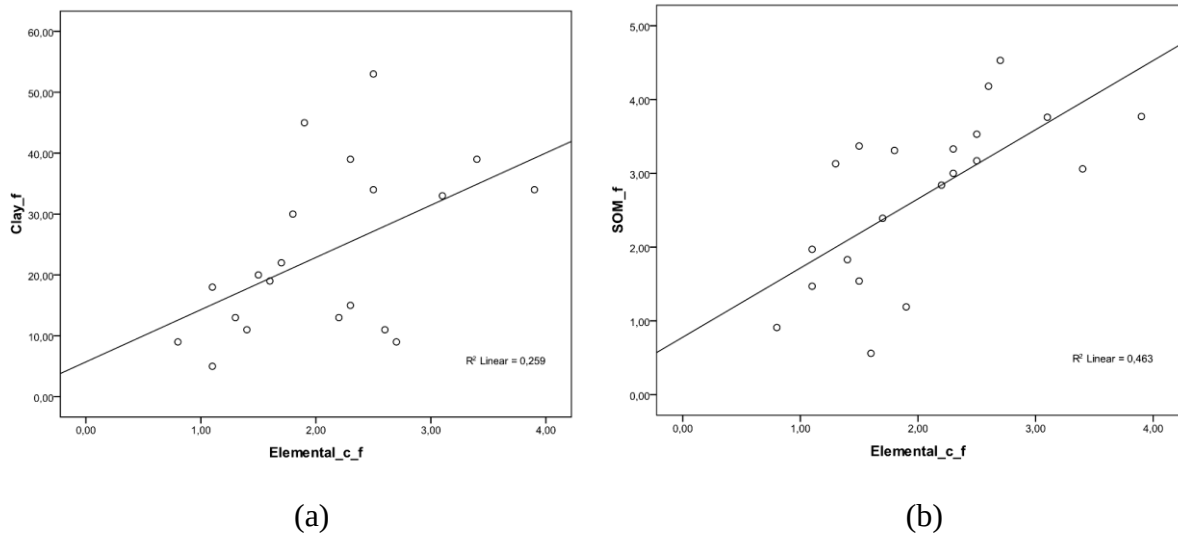


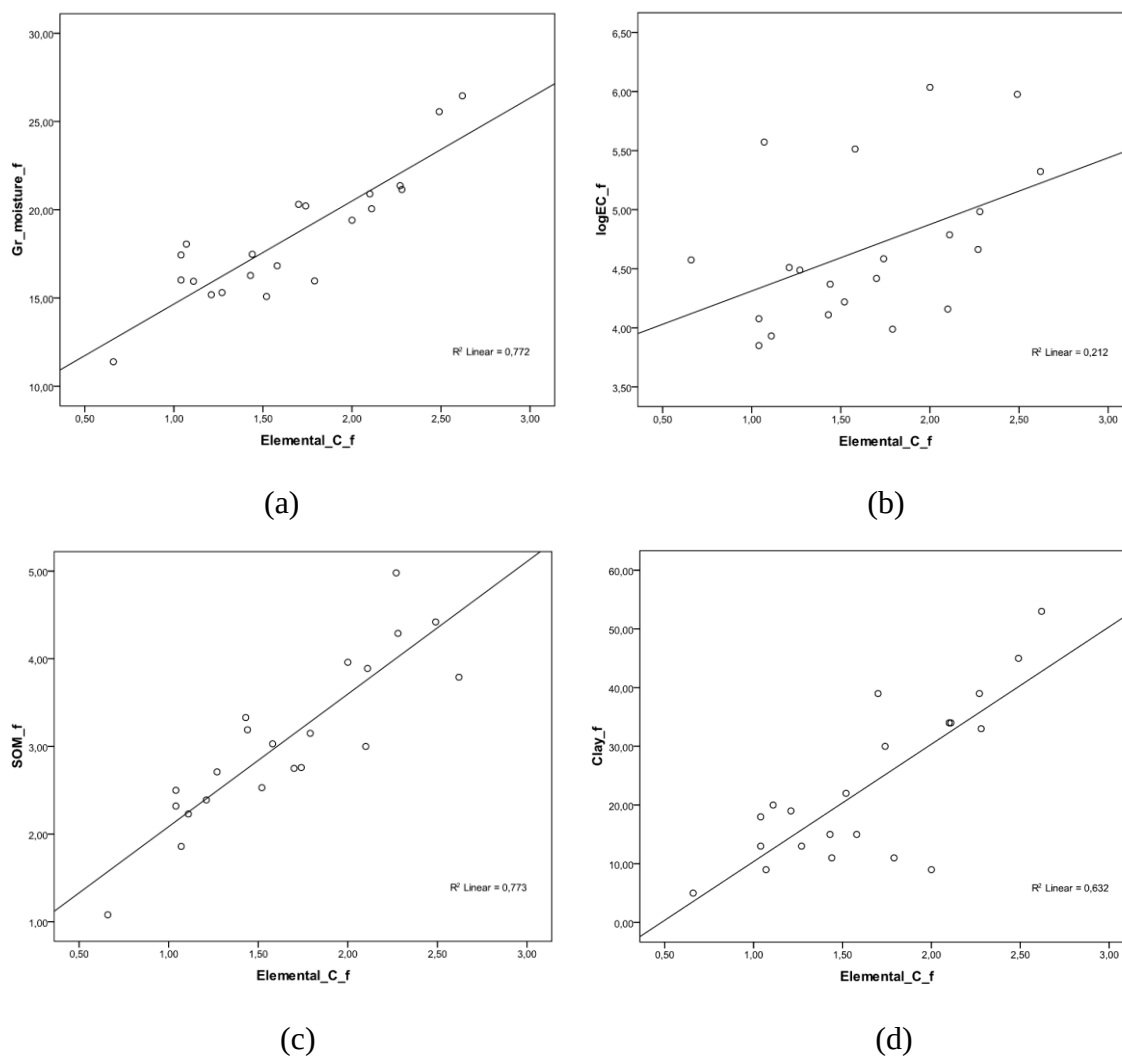
Figure 4.36. Correlation between elemental carbon and clay

In spring 2009, similar to winter and summer 2008 seasons, correlations between clay and soil organic material were high. Table 4.23 shows correlation parameters and Figure 4.37 presents the correlation between clay and soil organic material.



Figures 4.37: Correlations between (a) clay and (b) SOM

For the fall 2009 season, similar to spring 2009, correlations between EC, SOM, and clay were observed. Between elemental carbon and gravimetric moisture almost perfect correlation was detected (Table 4.23 and Figure 4.38). Stoyan, et al., (2000) also quantified the moderate correlation between elemental carbon and moisture content ($r=0.49$, $p<0.05$).

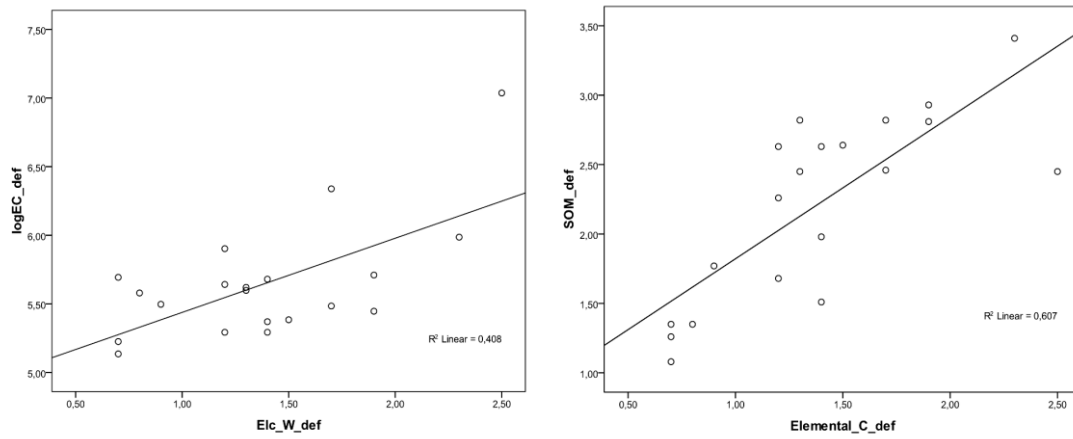


Figures 4.38. Correlations between (a) gravimetric moisture, (b) electrical conductivity, (c) SOM, and (d) Clay

Four seasons from deforested soils No correlation observed between in situ soil respiration and other environmental parameters for all four seasons from deforested soils. Sampling locations were selected as close pairs within tens of meters (one being in the forest and other in converted soils) of each other. This may be the reason of no-correlation between in situ soil respiration and other environmental parameters. Different textural types of soils, and micro climatic conditions during measurements could also support this finding.

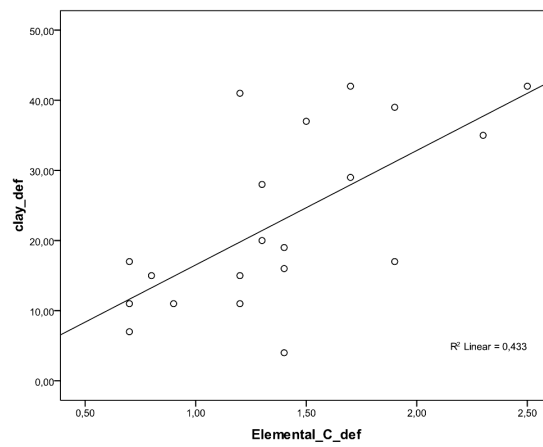
A high correlation between elemental carbon and electrical conductivity, soil organic material, and clay content of the soil was observed for winter and summer 2008 seasons (Tables 4.23 and 4.24). Correlation analysis showed that clay is a key parameter due its high correlation with electrical conductivity and SOM for both seasons (for winter, clay-soil organic matter: $r=0.52$, $p<0.05$ and clay-electrical conductivity: $r=0.56$, $p<0.01$). As discussed in the “Laboratory analysis for environmental parameters” Section, clay is a stabilizing agent in soil, and it traps the soil organic matter as well as in carbon in the soil. The total mineral content of the soil, which can be described as the electrical conductivity or salinity, correlates with the amount of moisture held by soil textural particles. Therefore, clay has a strong affinity to electrical conductivity of the soil.

For winter 2008_Figure 4.39 demonstrates the correlation between elemental carbon content and electrical conductivity, soil organic material, and clay.



(a)

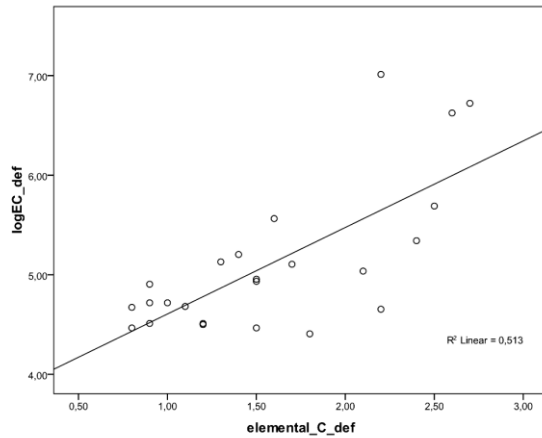
(b)



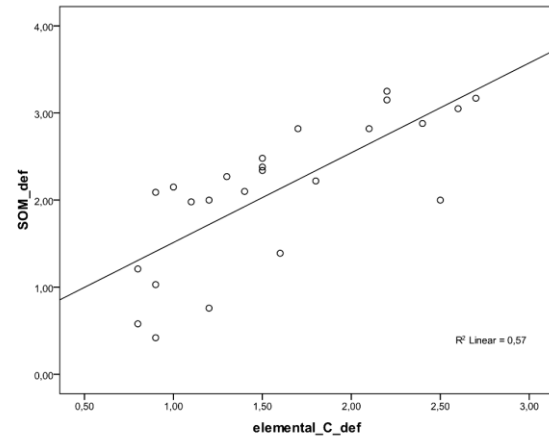
(c)

Figures 4.39. Correlation between elemental carbon content (a) electrical conductivity, (b) SOM, and (c) clay

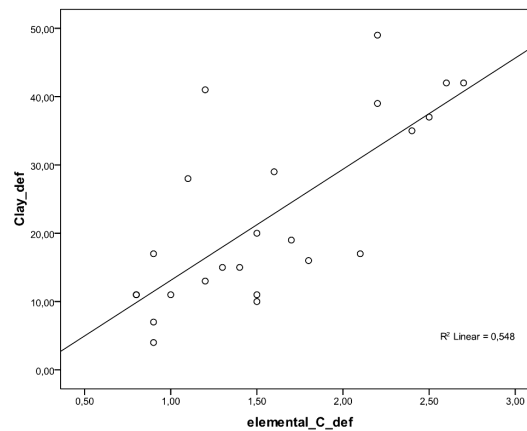
For summer 2008 Figure 4.40 demonstrates the correlation between elemental carbon content and electrical conductivity, soil organic material, and clay.



(a)



(b)



(c)

Figures 4.40. Correlation between elemental carbon content (a) electrical conductivity, (b) SOM and (c) clay.

In spring 2009 the elemental carbon revealed a high correlation with soil gravimetric moisture and clay content for the spring 2009 season (Table 4.23 and Figure 4.41). This correlation was also observed in Fall 2009 season (Table 4.24 and Figure 4.45). Muniafu and Kinyamario (2007) observed that soil carbon has high correlation with moisture in spring and Fall, in Kenya ($r=0.66, 0.65, p<0.05$).

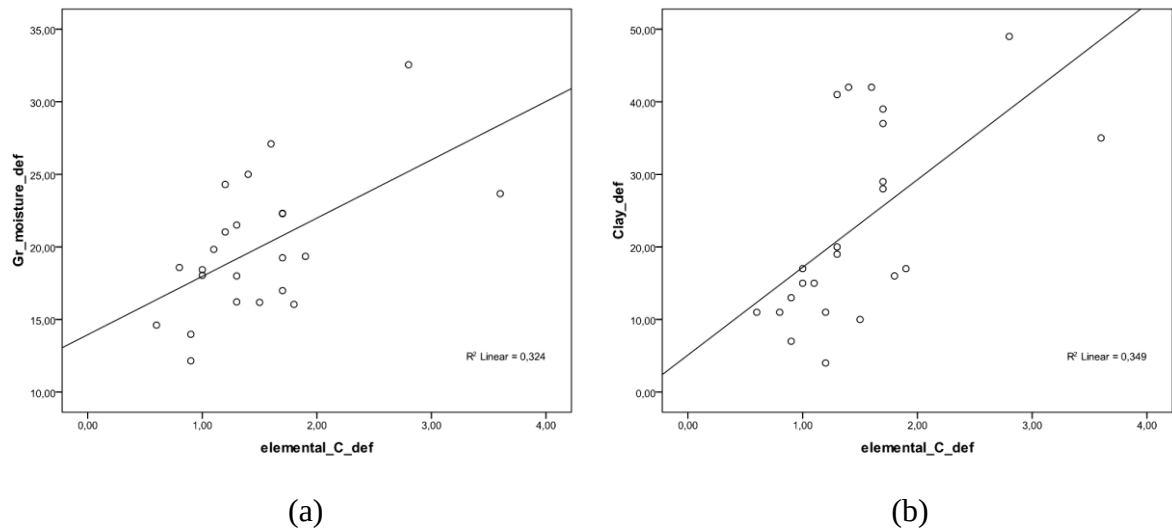


Figure 4.41. Correlation with (a) soil gravimetric moisture and (b) clay content

For fall 2009 Figure 4.42 shows the correlation between elemental carbon content, SOM and clay.

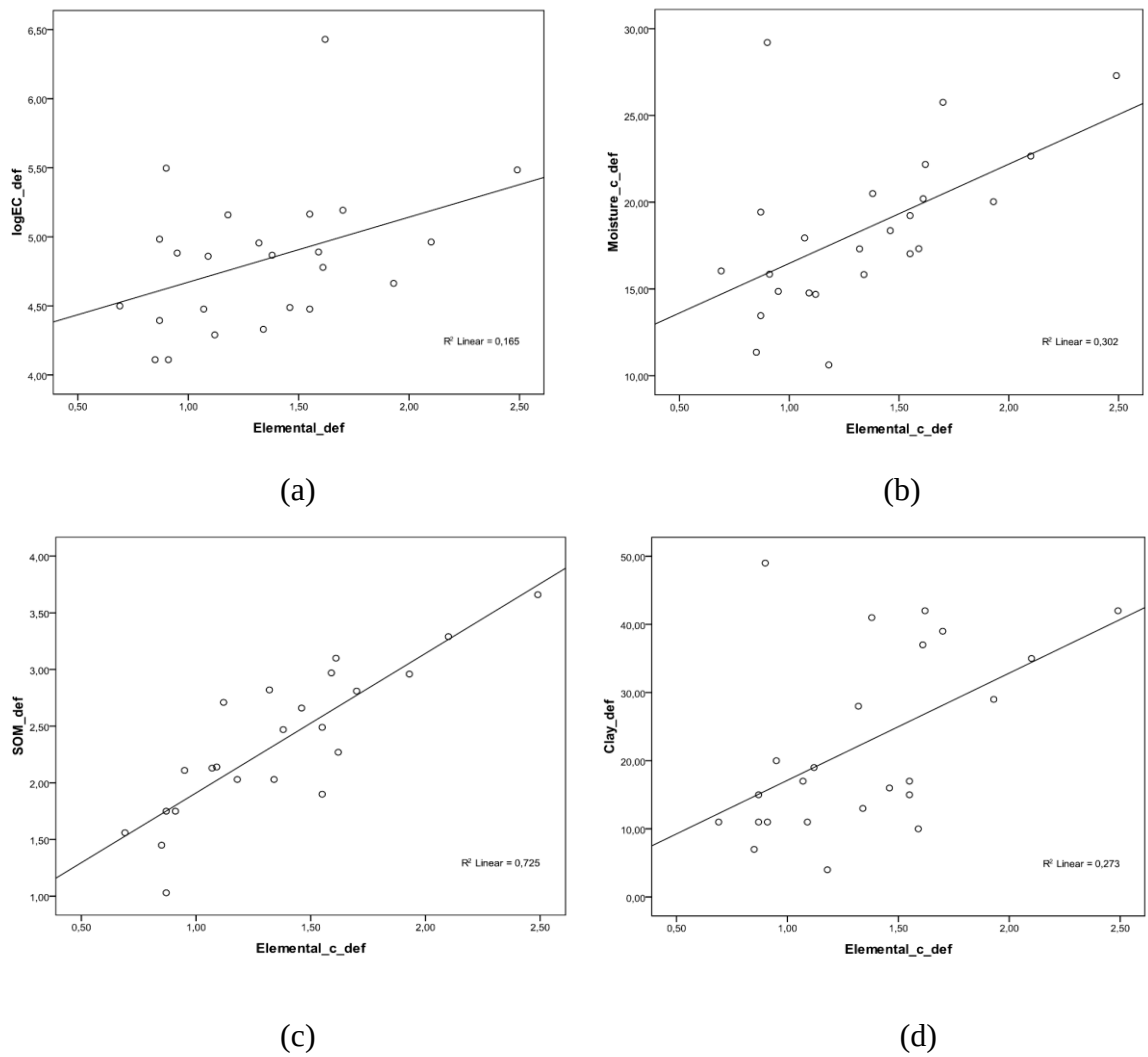


Figure 4.42. Correlation between elemental carbon content,(a) Electrical conductivity
(b) gravimetric moisture, (b) SOM, and (c) clay

4.6. Regression Analyses

In this section the results of regression analyses are presented. This statistical analysis is used to observe the relationships between variables for the purpose of predicting future values.

Stepwise linear regression was used to construct soil carbon model functions for different land uses and to explain soil carbon in terms of other parameters. The analyses were conducted on parameters between dependent and independent variables. The dependent variables were defined as elemental carbon and independent variables were clay, SOM, EC, and MR. 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 elemental carbon as a function of parameters to show correlation with the elemental carbon:

1. Elemental C = $0,027 \times \text{Clay} + 0,818$
2. Elemental C = $0,020 \times \text{Clay} + 0,261 \times \text{SOM} + 0,418$
3. Elemental C = $0,017 \times \text{Clay} + 0,243 \times \text{SOM} + 0,138 \times \text{EC} - 0,171$

Table 4.25 shows the R^2 -values of the equations.

Table 4.25. R^2 values of the regression models from deforested soils

Model	R	R Square	Adjusted R Square	Standard Error of the Estimate
1	0.681 ^a	0.463	0.457	0.37820
2	0.750 ^b	0.563	0.553	0.34335
3	0.769 ^c	0.591	0.577	0.33384

a. Predictors: (Constant), clay_def

b. Predictors: (Constant), clay_def, SOM_df_4

c. Predictors: (Constant), clay_def, SOM_df_4, EC_df_4

Table 4.26 shows that clay explains 46% of the variance in elemental carbon from forested soils. Introduction of SOM to the model explains additional 16% of the variance and further introduction of electrical conductivity explains 4% of the model.

This indicated that SOM was the most important determinant of elemental carbon in deforested soils. The following Figure shows the variances of clay, SOM and electrical conductivity in the models.

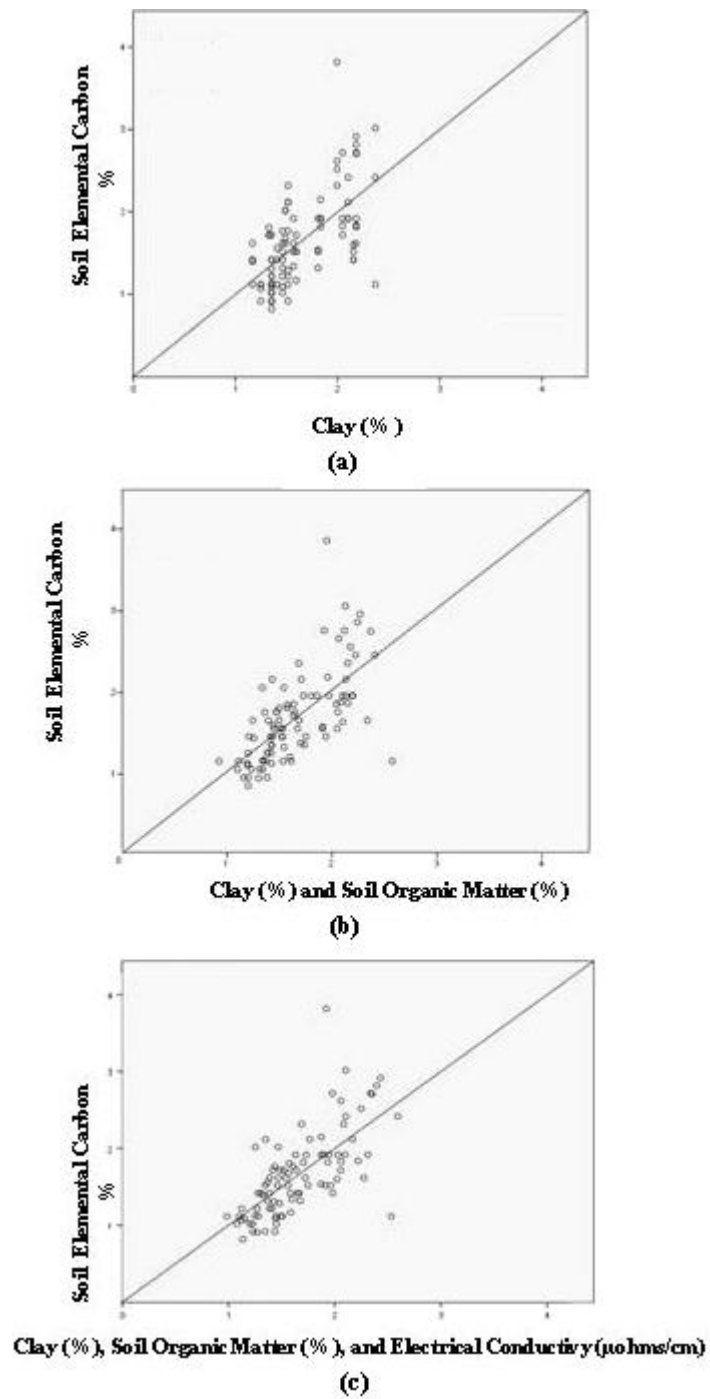


Figure 4.43. To compare the measured and predicted soil elemental carbon measurements using regression models a) clay %, b) clay % and soil organic matter, (%) c) clay(%), soil organic matter (%), and electrical conductivity ($\mu\text{hms/cm}$)

Elemental carbon regression equations for the forest soils are as follows:

1. Elemental C = $0,372 \times \text{SOM} + 0,77$
2. Elemental C = $0,302 \times \text{SOM} + 0,01 \times \text{Clay} + 0,521$
3. Elemental C = $0,275 \times \text{SOM} + 0,021 \times \text{Clay} + 0,26 \times \text{pH} + 0,339$

The R-values of these equations are given in Table 4.26.

Table . 4.26. R^2 values of the regression models from forested soils

Model	R	R Square	Adjusted R Square	Standard Error of the Estimate
1	0.629 ^a	0.396	0.388	0.42543
2	0.749 ^b	0.561	0.550	0.36498
3	0.777 ^c	0.604	0.588	0.34885

a. Predictors: (Constant), SOM_f_4

b. Predictors: (Constant), SOM_f_4, clay_f

c. Predictors: (Constant), SOM_f_4, clay_f, pH_f_4

As can be seen in Table 4.27 SOM alone explains 40% of the variance in elemental carbon from forested soils. Introduction of clay to the model explains additional 16% of the variance and further introduction of microbial respiration explains 4% of the model. The following Figure shows the variances of SOM, clay and pH in the models.

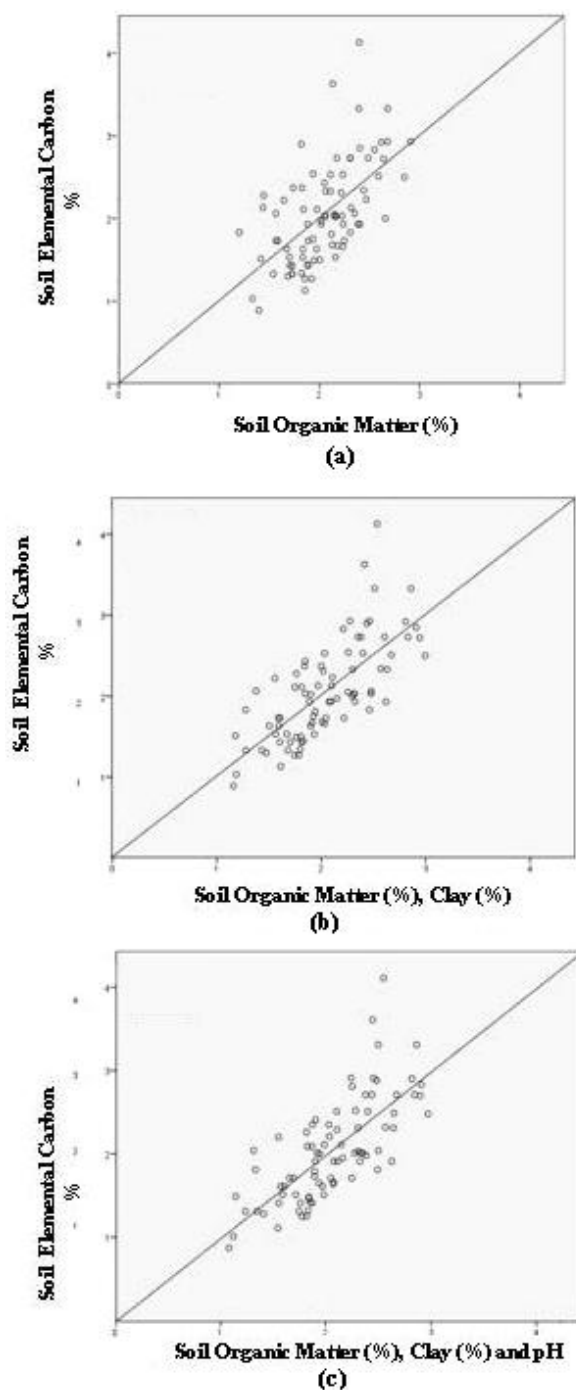


Figure 4.44 To compare the measured and predicted soil elemental carbon measurements using regression models a) soil organic matter (%) b) soil organic matter (%), and clay % c) soil organic matter (%), clay (%) and pH

As can be seen from the Figures 4.43 and 4.44, a predictive model to measured and predicted soil elemental carbon measurements fit on the graphs using other parameters.

4.7 Geostatistical Analyses

In this section, the results of the geostatistical analyses are presented and spatial averages of in situ soil respiration and soil elemental carbon are computed. Geostatistical maps were plot using the ordinary kriging method. The analyses were conducted on primary parameters in all seasons. The raster calculator tool of the spatial analyst 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 4.45), 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. The Figure 4.46 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 map were used to calculate the spatial average of primary parameters. The overall computed value inserted into all grid cells were divided to number of grid cells,1040. Therefore, the spatial average of each grid cell was obtained.

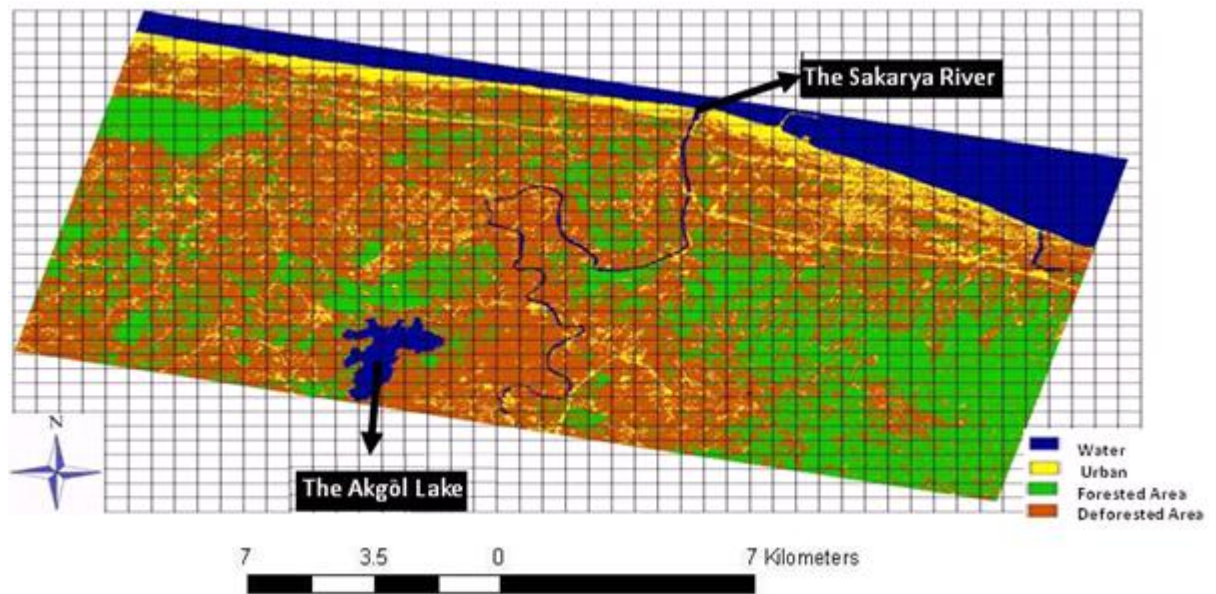
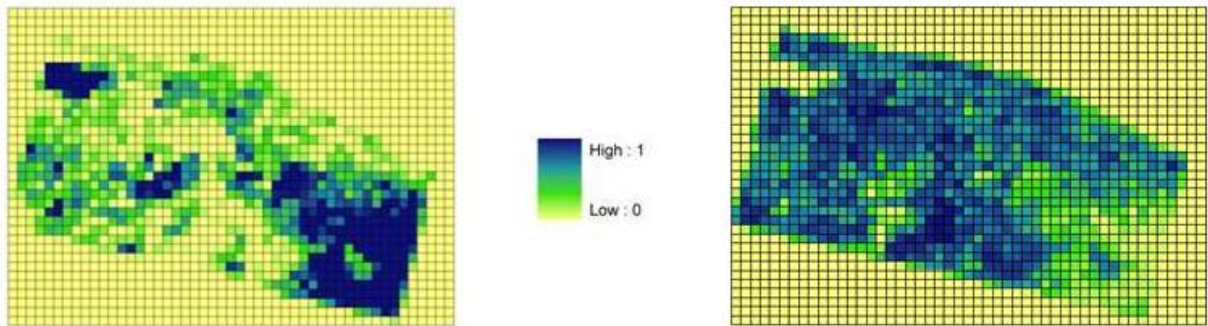


Figure 4.45 The land use map of Karasu District



4.7.1. In situ soil respiration

In this part, the in situ soil respiration kriging maps are presented that were plot from two different land use types and four seasons using the land use fraction maps (Figures 4.47-4.58).

As can be seen from the overlaid kriging maps of in situ soil respiration, only the forested and deforested land use fractions were employed with kriging estimates. Therefore, the urban development and water bodies were categorized as zero value symbolized with the yellow color/

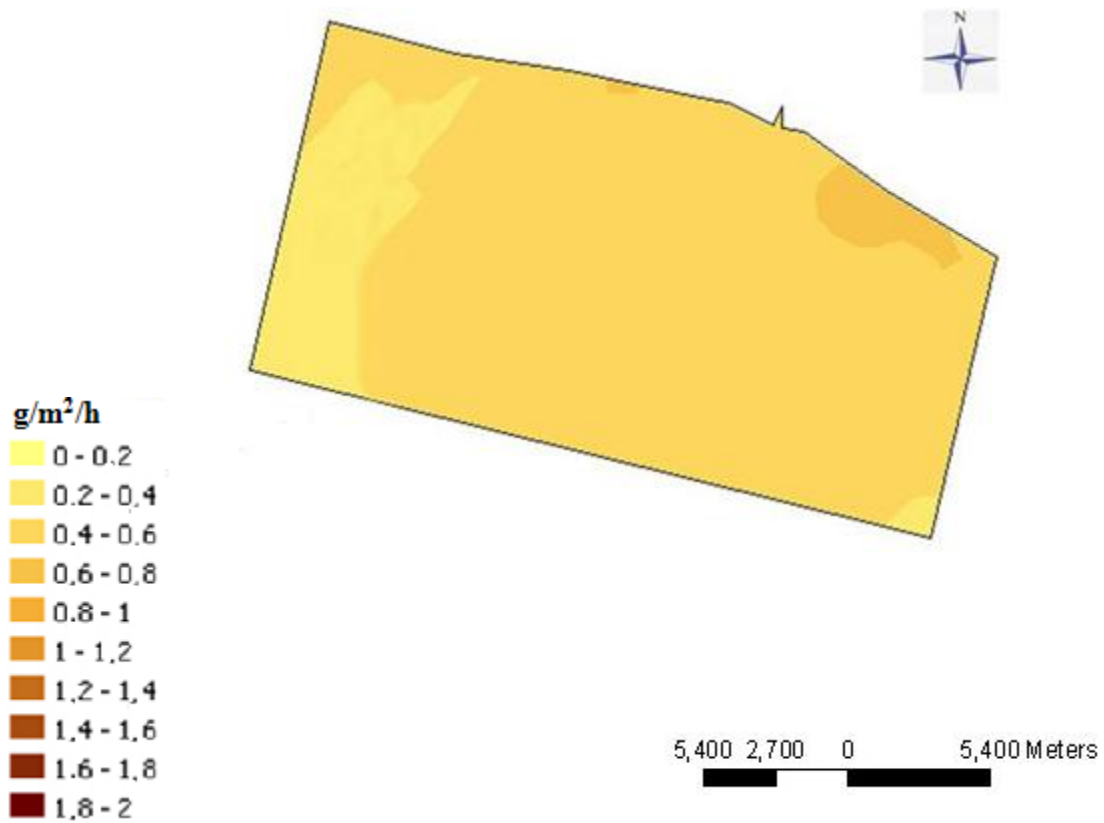


Figure 4.47. Ordinary kriging map of in situ soil respiration from forested area

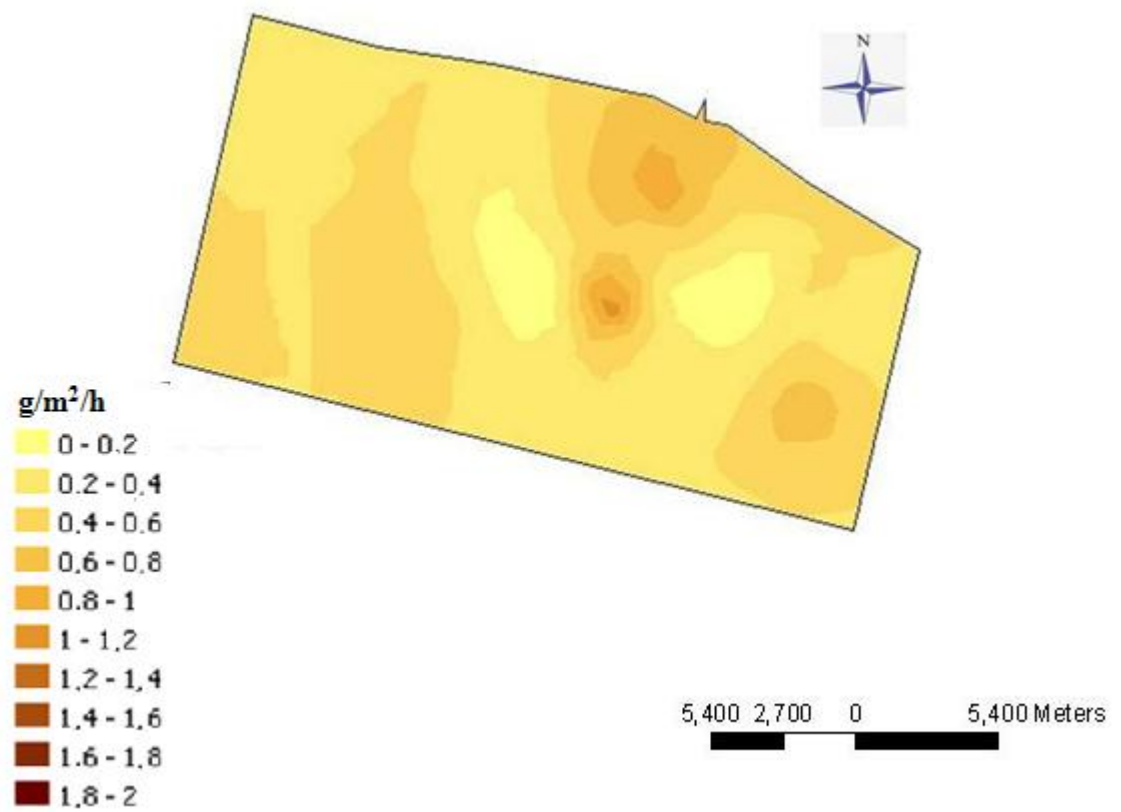


Figure 4.48 Ordinary kriging map of in situ soil respiration from deforested area

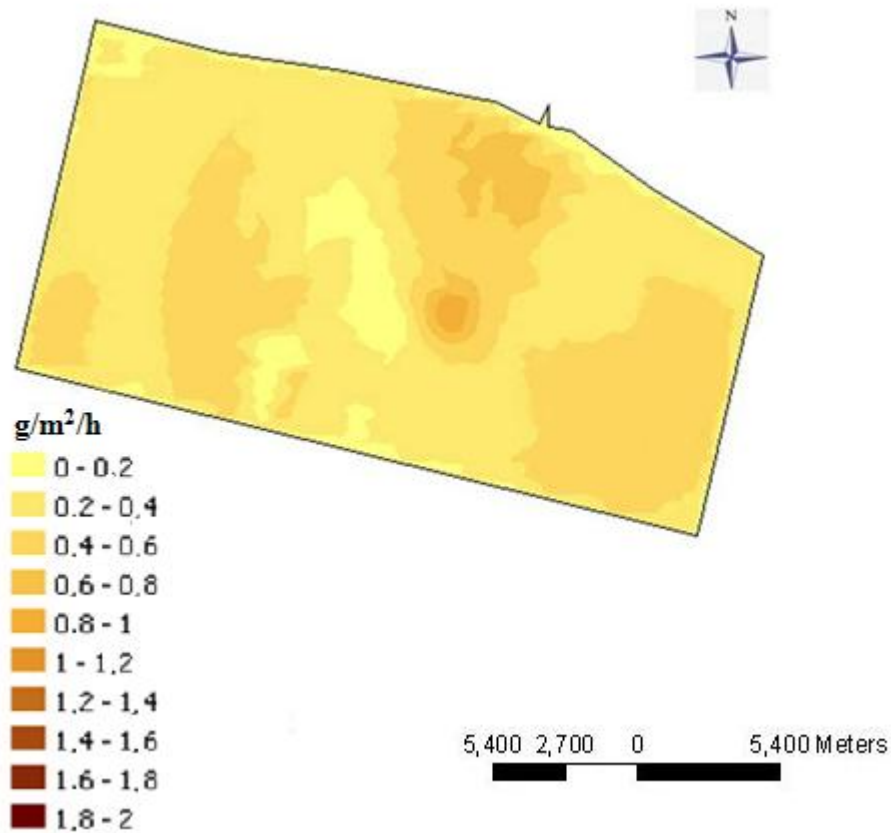


Figure 4.49 Overlaid kriging map of in situ soil respiration in Winter 2008

For winter 2008 the variability in both seasons from forested and deforested areas created a constant color distribution in the maps. The land use fractions were employed to produce the overlaid kriging maps of in situ soil respiration values in winter 2008. As can be seen from the figure, lower in situ soil respiration values were observed between the Akgol lake and Sakarya River water catchment area in south direction of the study area (Figure 4.49). The spatial average of winter 2008 was computed $0.34 \text{ g/m}^2/\text{h}$.

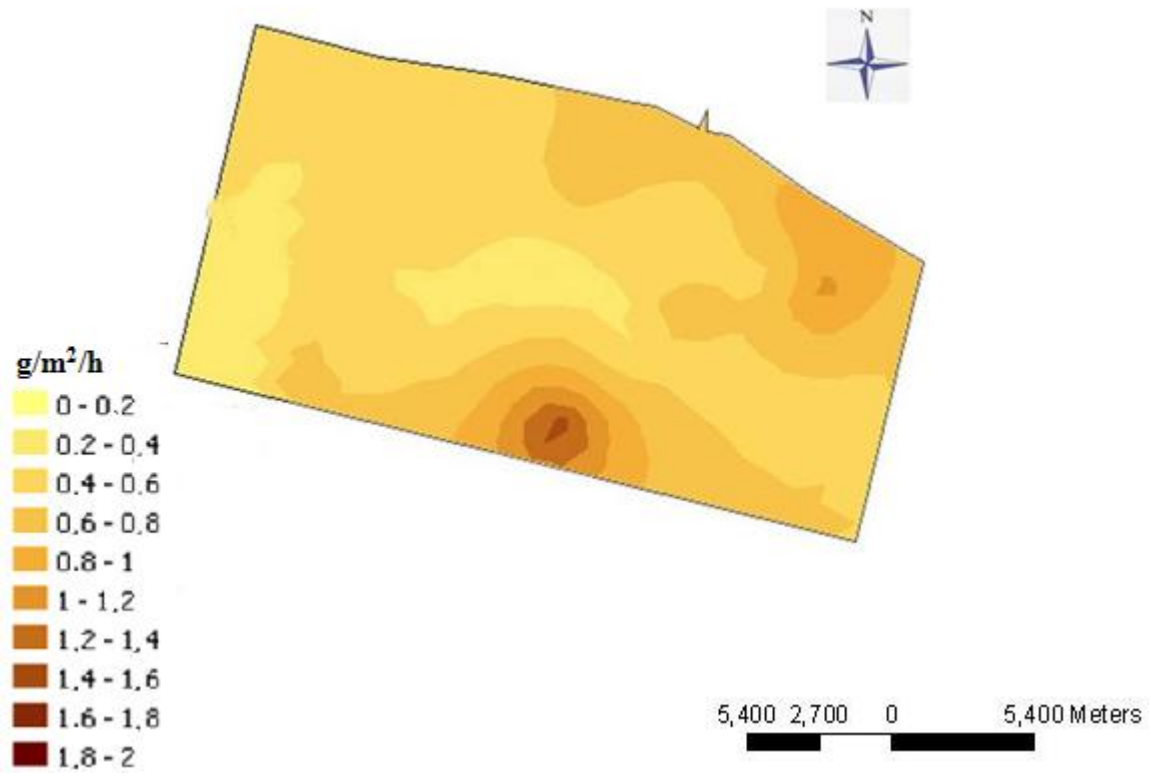


Figure 4.50 Ordinary kriging map of in situ soil respiration from forested area

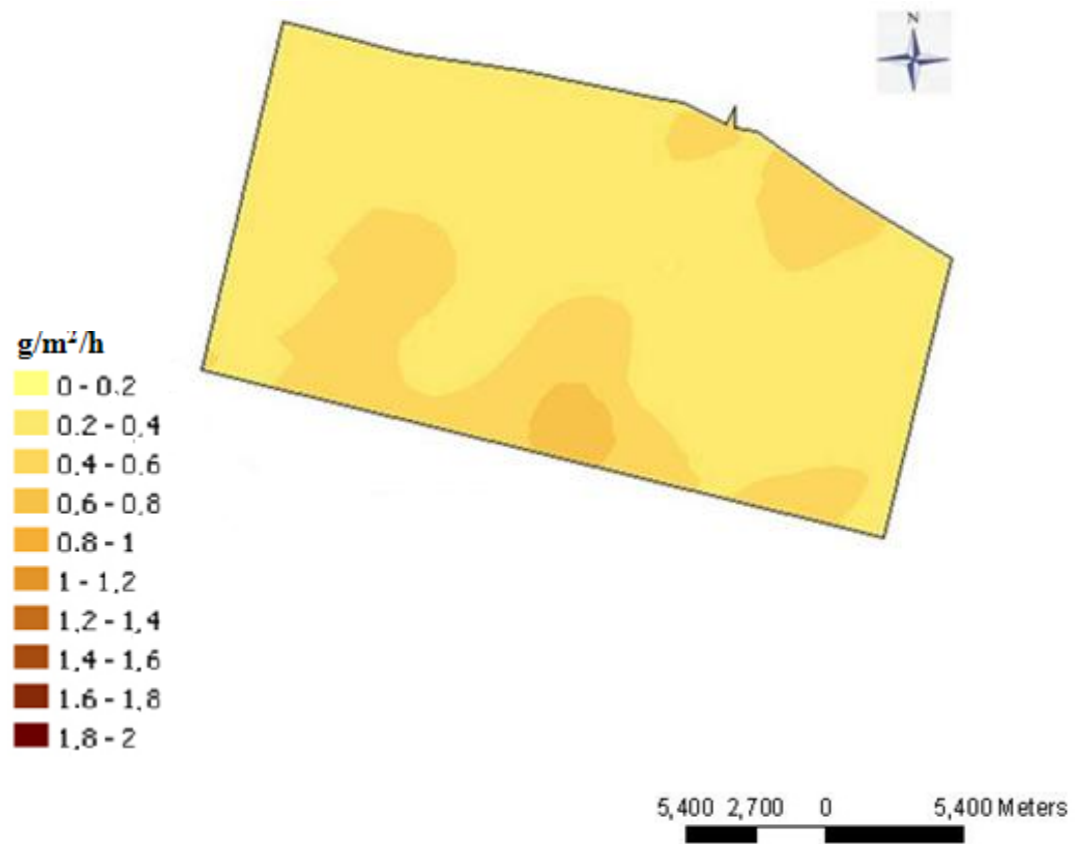


Figure 4.51. Ordinary kriging map of in situ soil respiration from deforested area

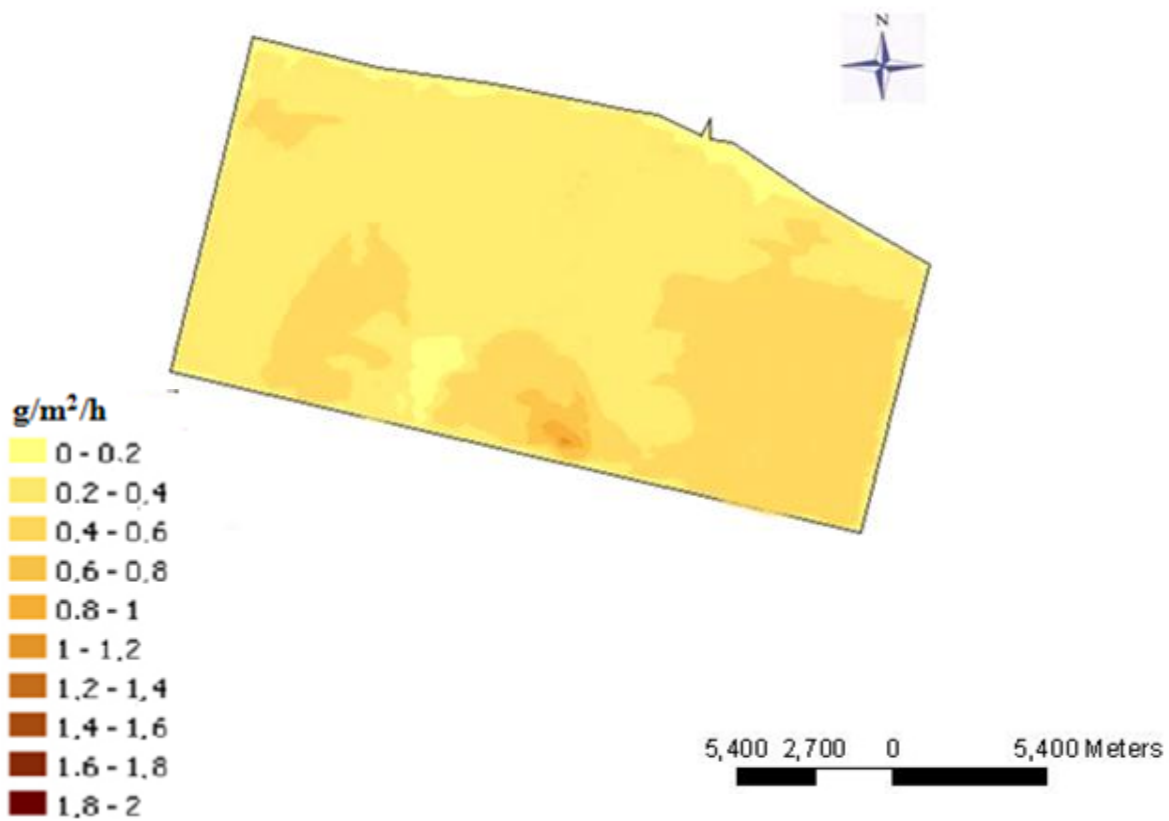


Figure 4.52 Overlaid kriging map of in situ soil respiration in summer 2008

For summer 2008, it was found that the soil respiration values vary from 0.40 to 1.20 g/m²/h in south direction of the study area, between the Akgol Lake and the Sakarya River. On the field trips, it was observed that the agricultural planting is extensive in this region. The spatial average of summer 2008 was computed 0.34 g/m²/h.

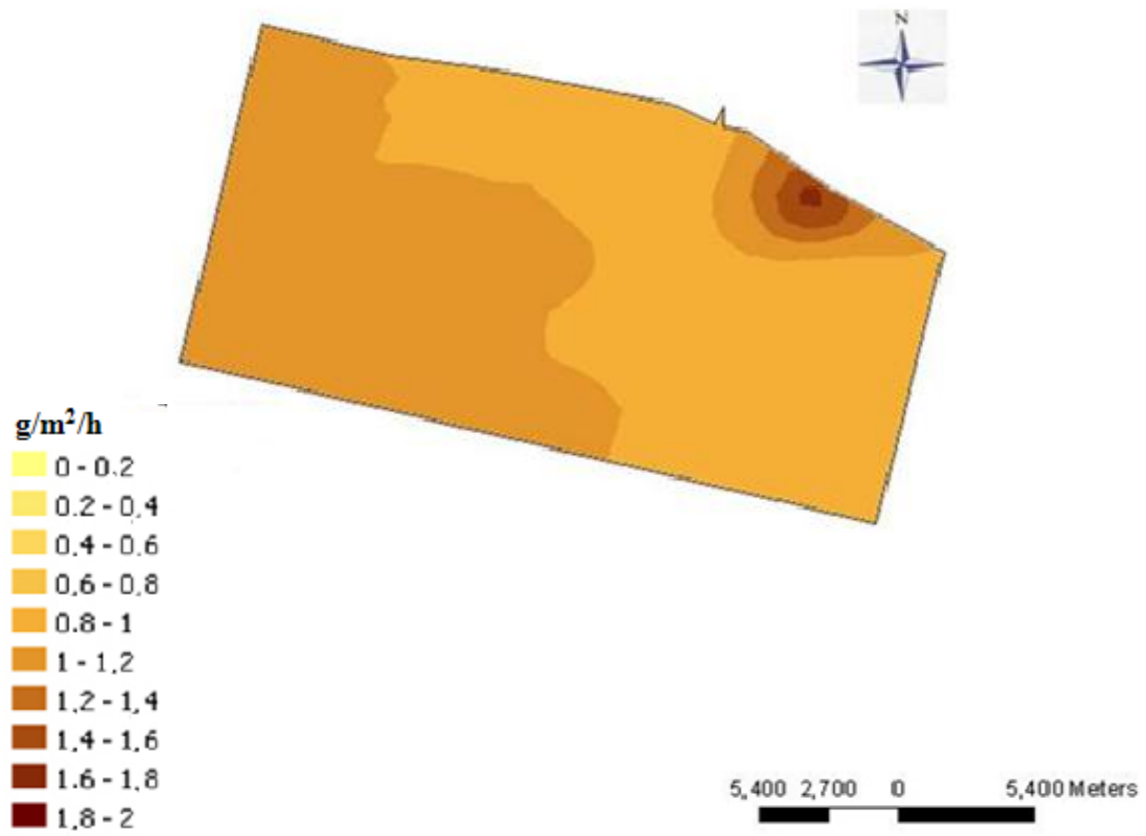


Figure 4.53 Ordinary kriging map of in situ soil respiration from forested area

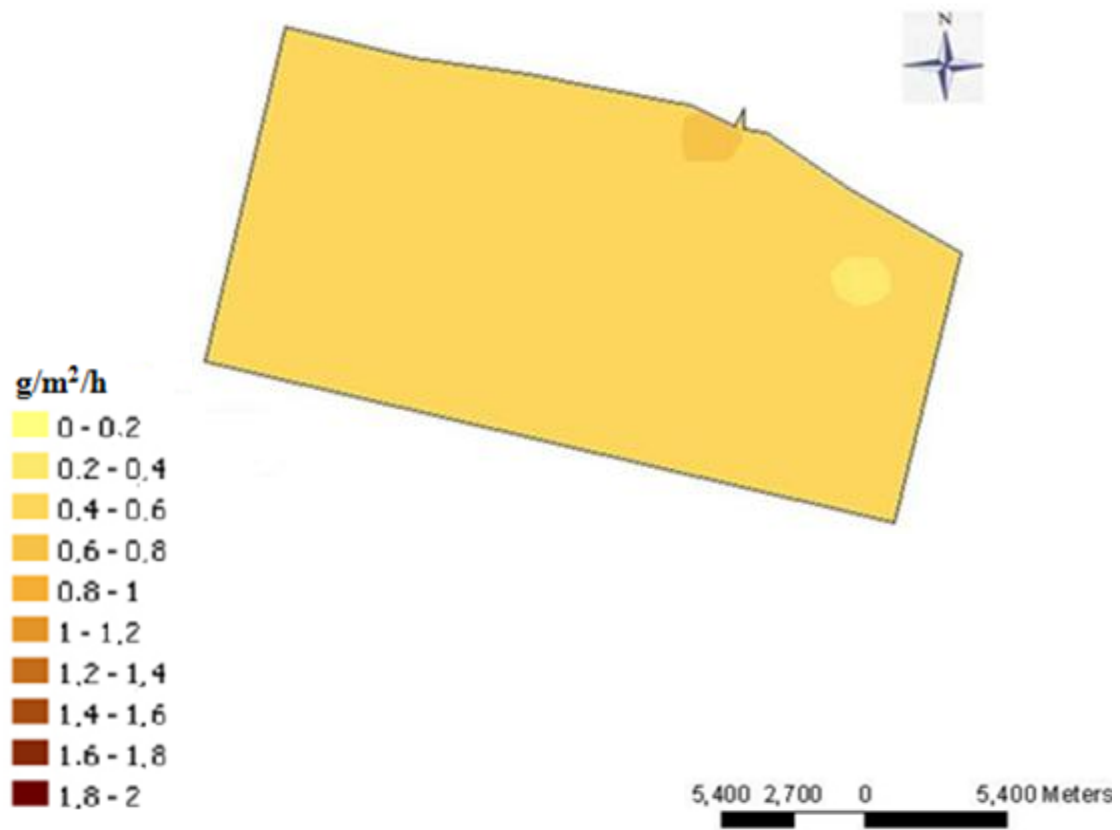


Figure 4.54 Ordinary kriging map of in situ soil respiration from deforested area

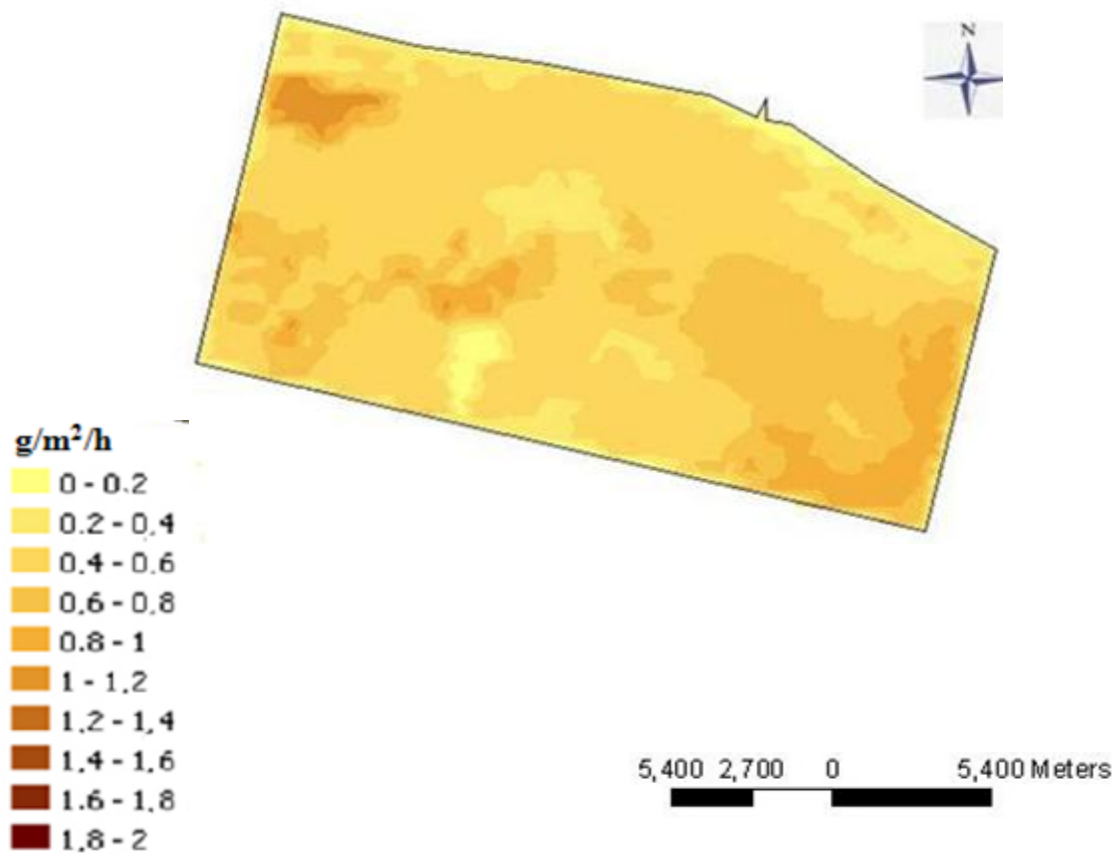


Figure 4.55 Overlaid kriging map of in situ soil respiration in Spring 2009

In Spring 2009, similar for winter 2008 due to the low variability of in situ soil respiration measurement values in winter 2008 and spring 2009 seasons from forested and deforested areas created a constant color distribution in the maps. The map legend shows that the in situ soil respiration measurement values are varying from 0.80 to 1.2 $\text{g/m}^2/\text{h}$ in northwest and southeast directions of the study area. These calculated values are greater than the computed spatial average (0.51 $\text{g/m}^2/\text{h}$).

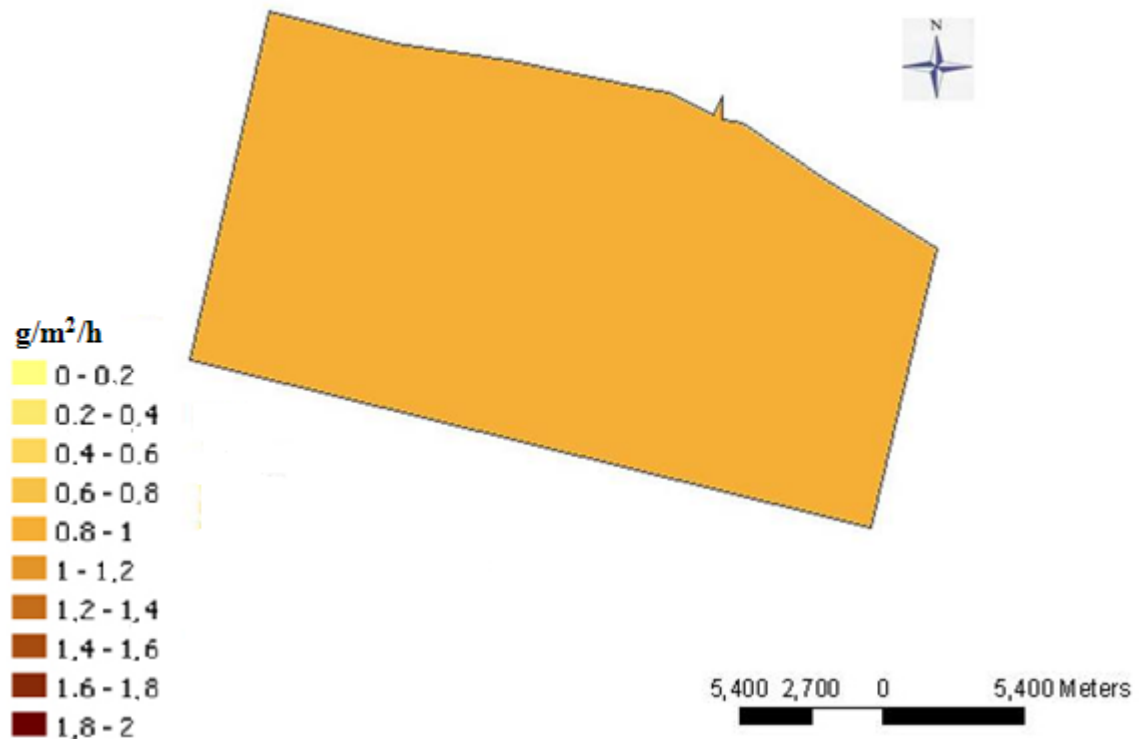


Figure 4.56 Ordinary kriging map of in situ soil respiration from forested area

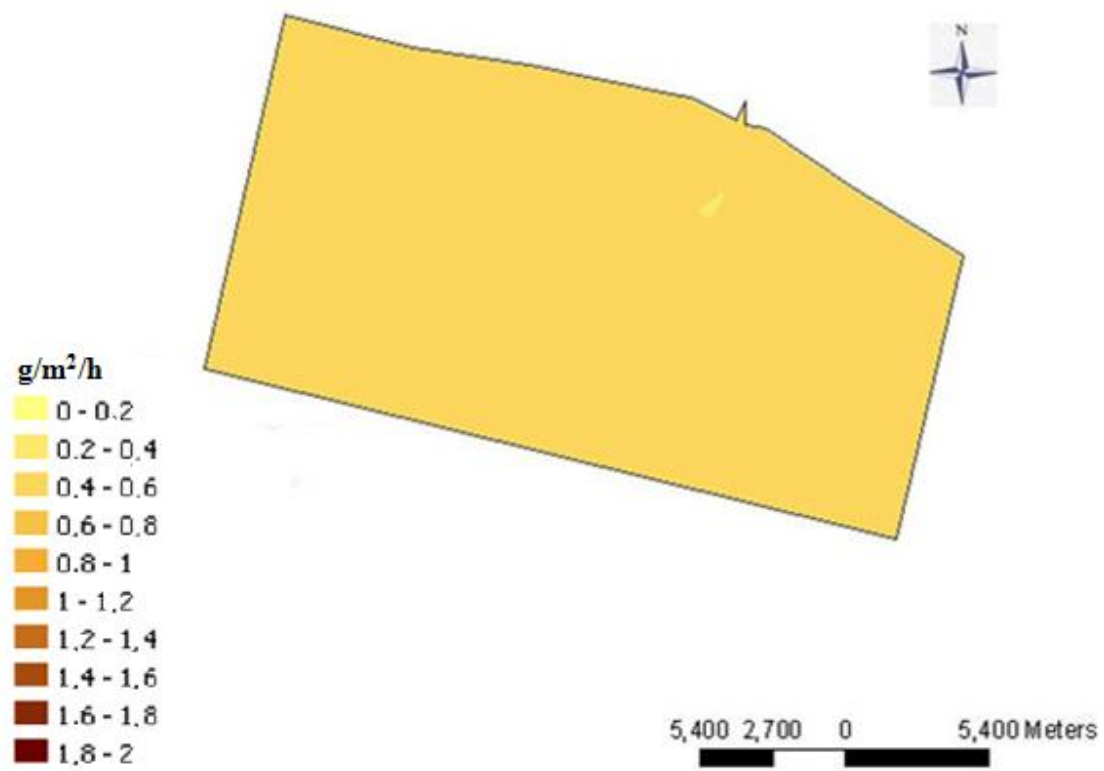


Figure 4.57 Ordinary kriging map of in situ soil respiration deforested area

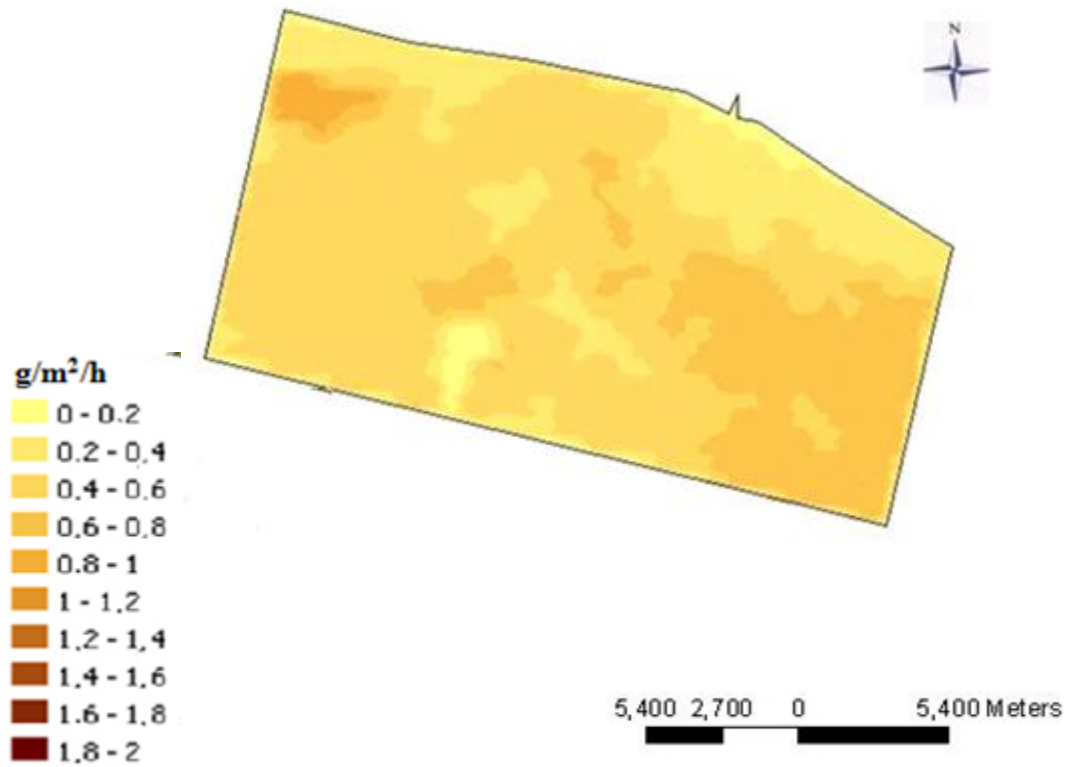


Figure 4.58 Overlaid kriging map of in situ soil respiration in Fall 2009

In fall 2009 season, due to the low variability of in situ soil respiration measurement values in both seasons from forested and deforested areas created a constant color distribution in the maps. The in situ soil measurement values are varied from 0.6 to 1 g/m²/h in the northwest and southeast of the study area. These values are higher than the computed spatial average (0.47 g/m²/h).

4.7.2 Soil Elemental carbon

In this part, the elemental carbon kriging maps are presented that were plotted from two different land use types and four seasons using the land use fraction maps (Figures 4.59-4.70).

As can be seen from the overlaid kriging maps of soil elemental carbon, only the forested and deforested land use fractions were employed with kriging estimates. Therefore, the urban development and water bodies were categorized as zero value symbolized with the yellow color.

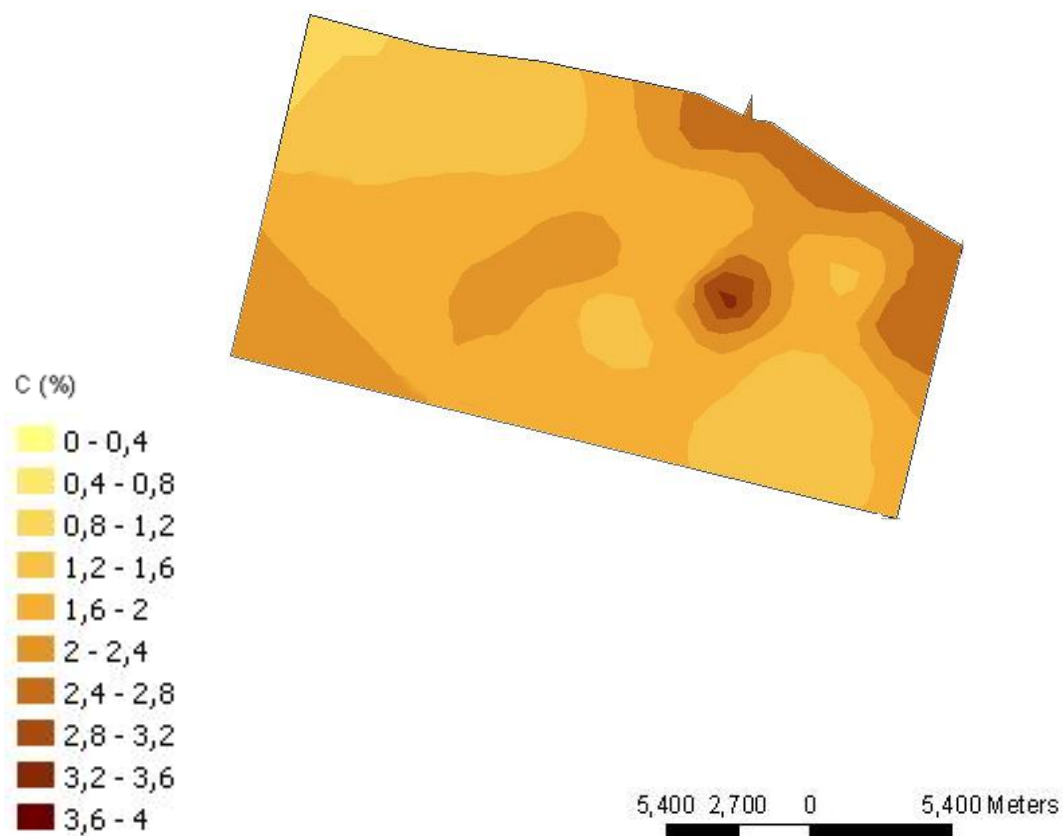


Figure 4.59 Ordinary kriging map of soil elemental carbon from forested area

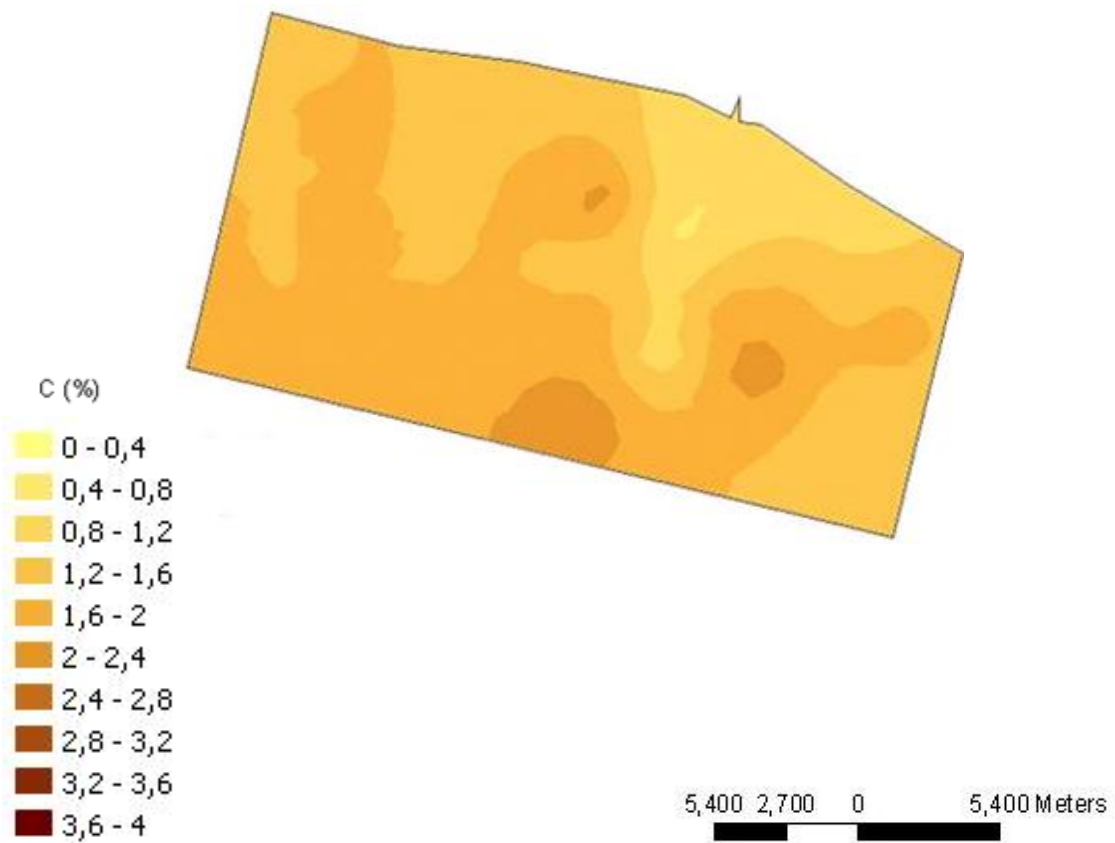


Figure 4.60 Ordinary kriging map of soil elemental carbon from deforested area

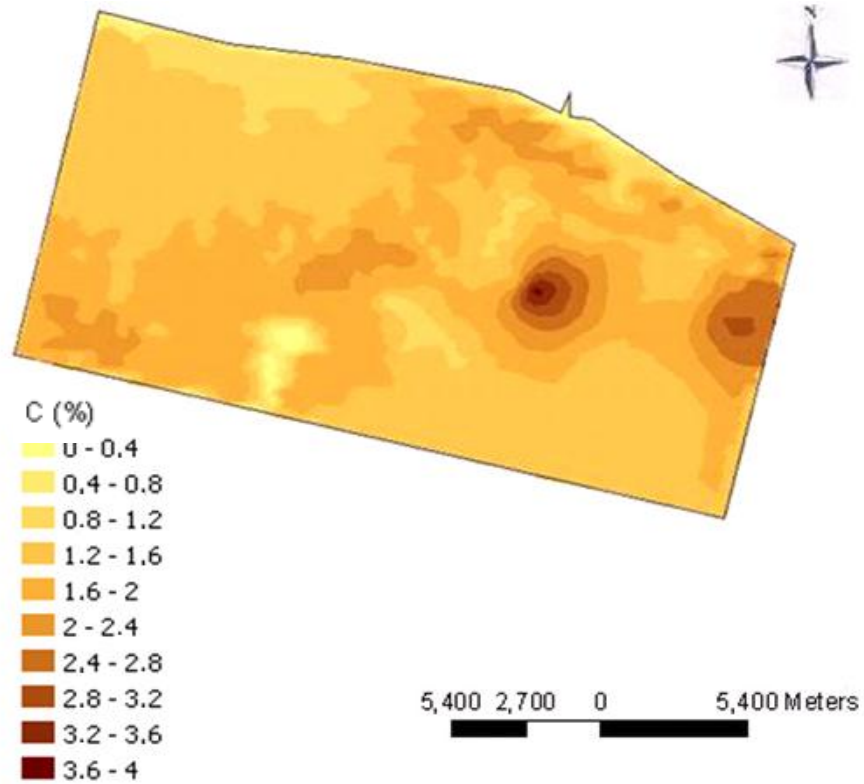


Figure 4.61 Overlaid kriging map of elemental carbon in winter 2008

In winter 2008, the soil elemental carbon measurement values are varied between 0.8 % and 0.4 %. These values are found using the land use fractions. The spatial average of the soil elemental carbon in this season is %1.48.

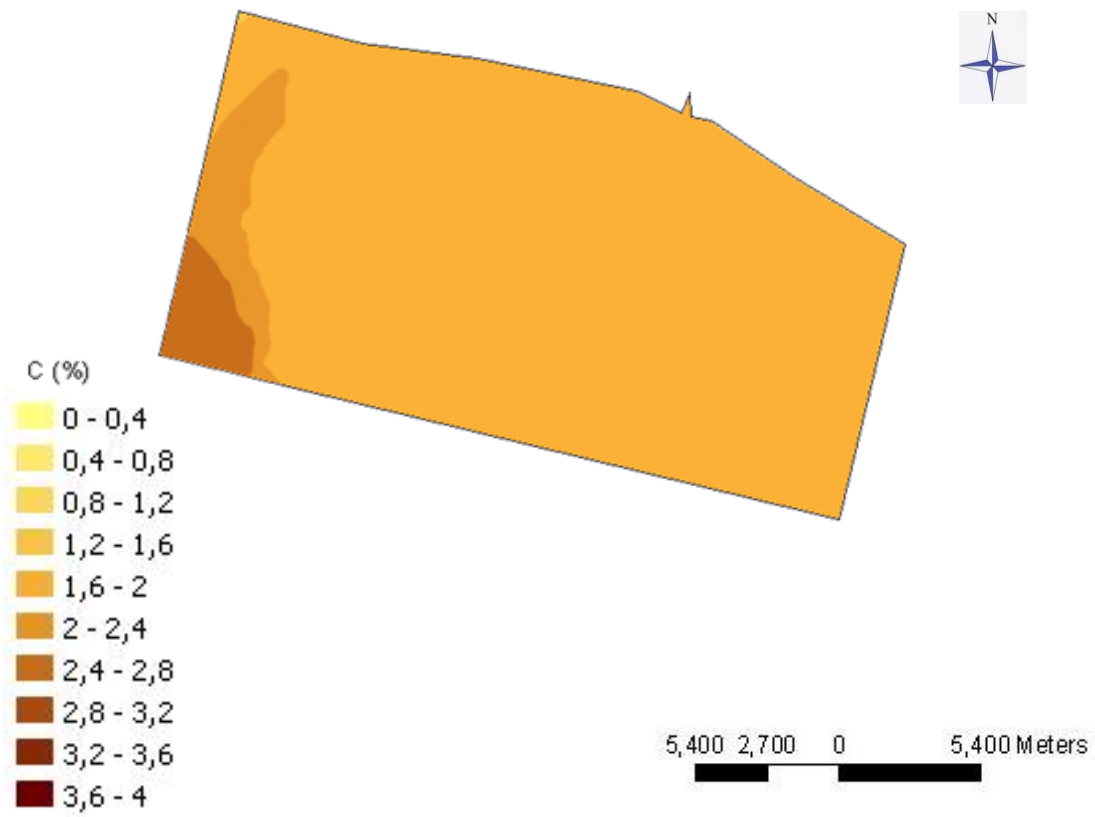


Figure 4.62 Ordinary kriging map of soil elemental carbon from forested area

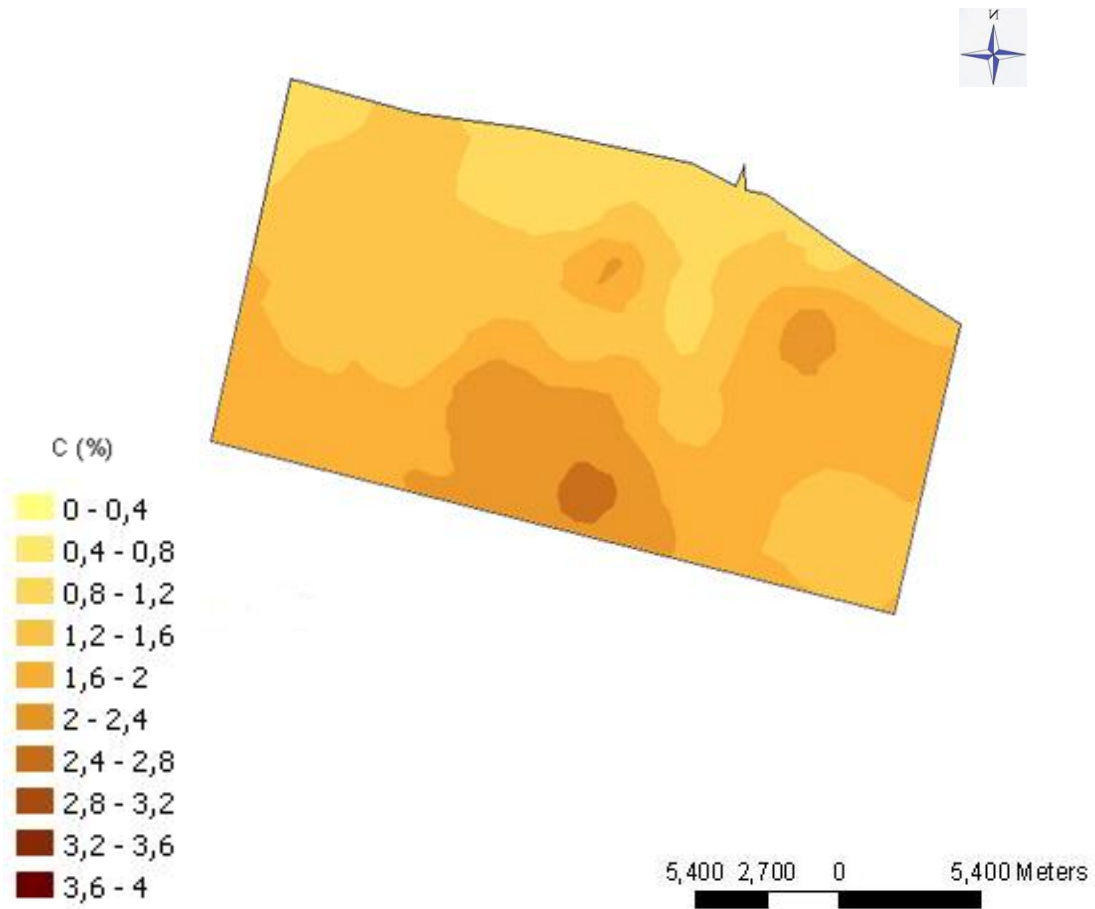


Figure 4.63 Ordinary kriging map of soil elemental carbon from deforested area

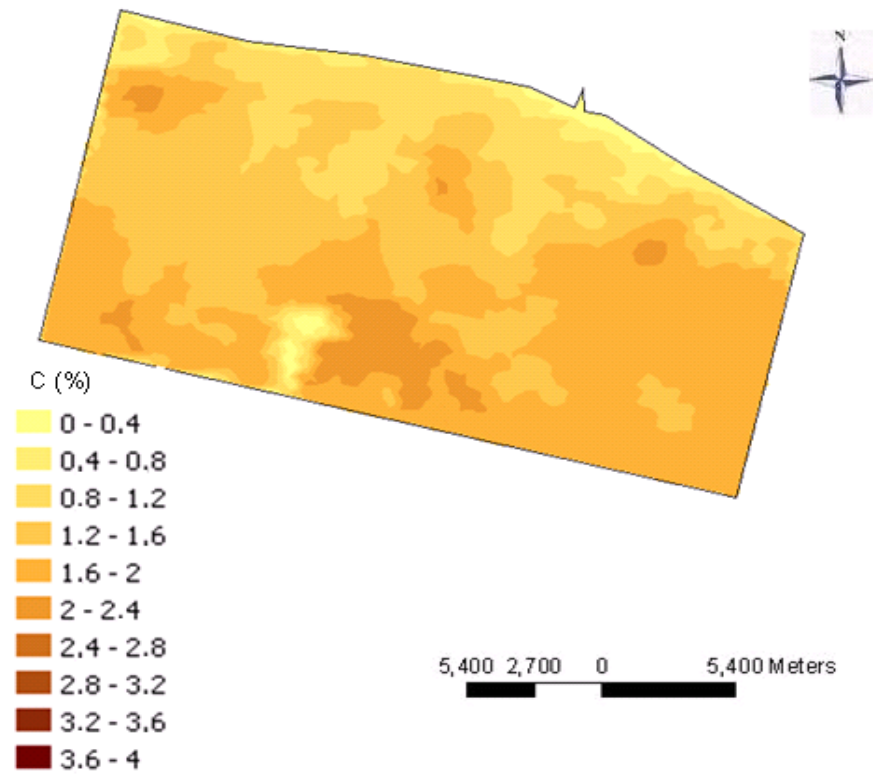


Figure 4.64 Overlaid kriging map of soil elemental carbon in summer 2008

As can be seen from the overlaid kriging maps in summer 2008, the soil elemental carbon measurements from forested lands are higher than the deforested lands in the study area. The final kriging map also indicated that the elemental carbon measurements were definitely higher compared to other regions in nearby area of the Akgol Lake. The spatial average of summer 2008 is computed 1.37%. This result represents the spatial average value of each grid cells in the study area.

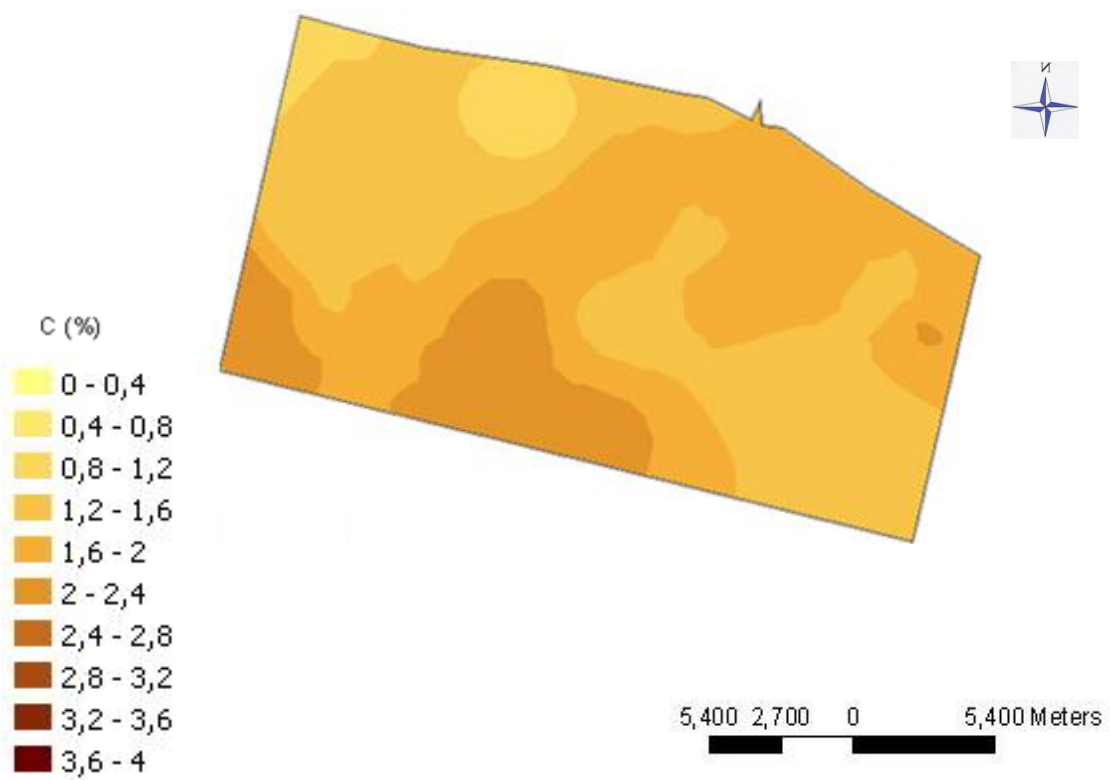


Figure 4.65 Ordinary kriging map of soil elemental carbon from forested area

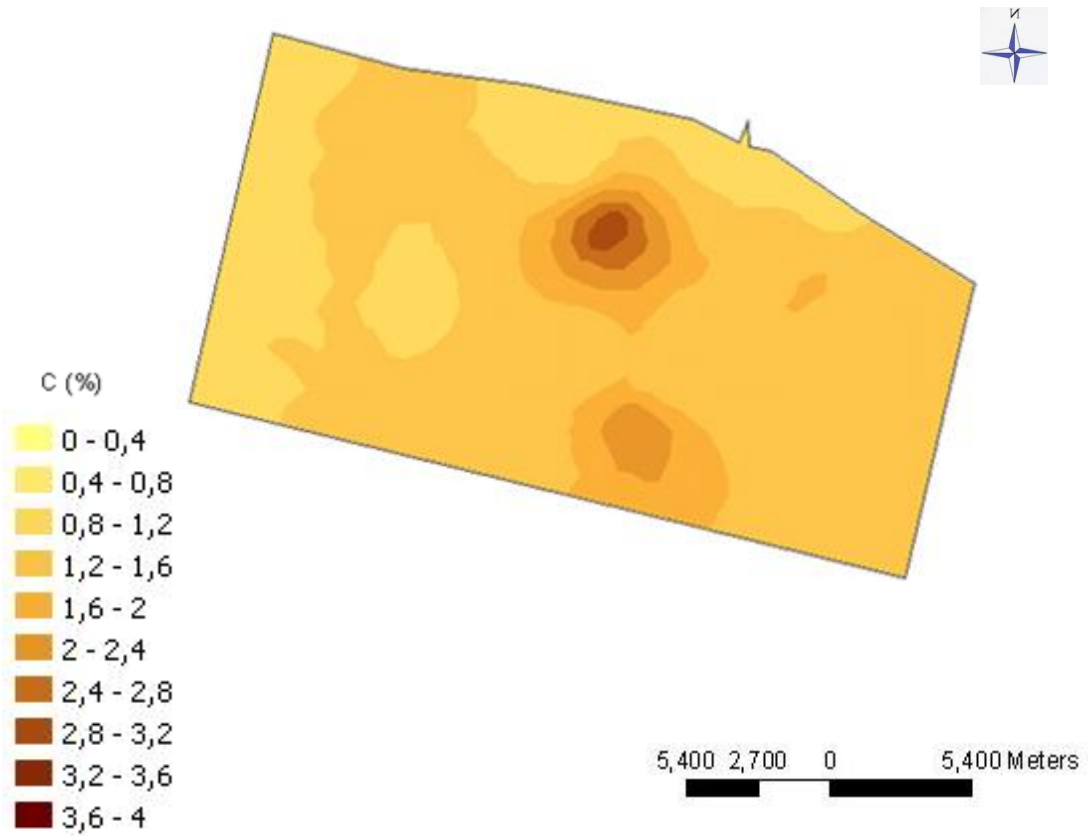


Figure 4.66 Ordinary kriging map of soil elemental carbon from deforested area

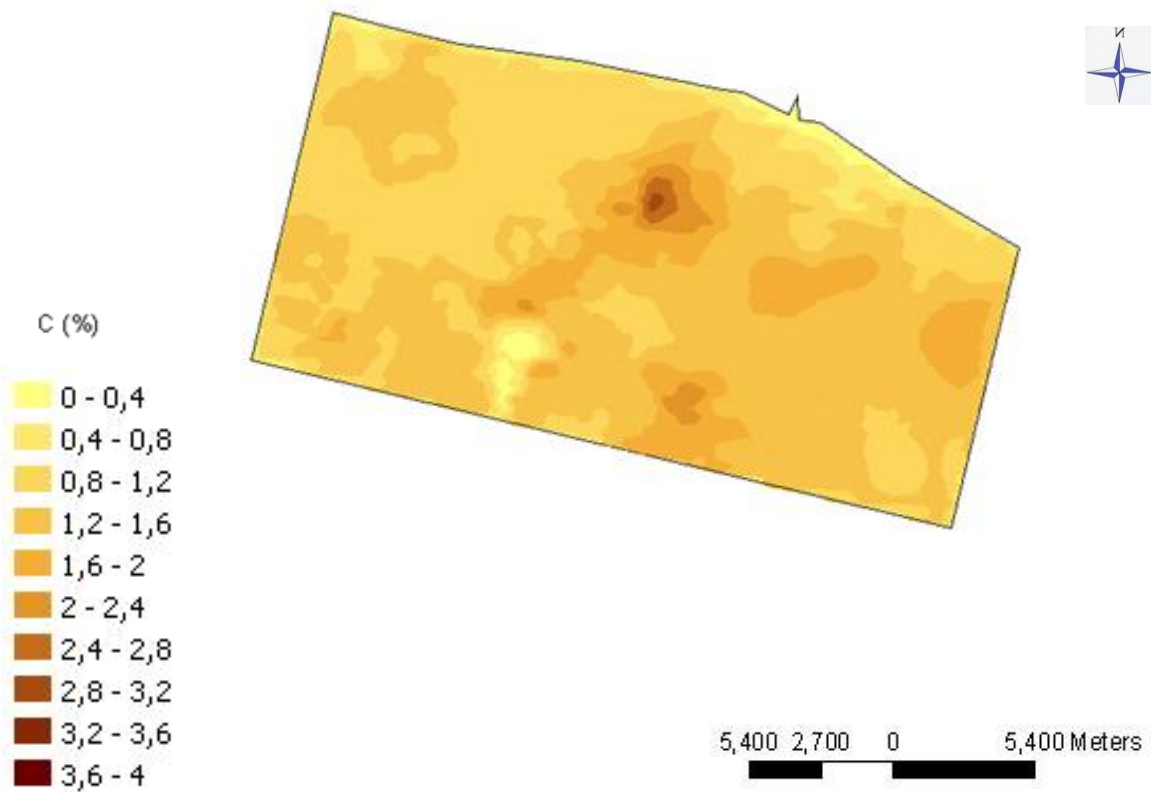


Figure 4.67 Overlaid kriging map of soil elemental carbon in spring 2009

According to overlaid kriging map results, the spatial distribution of elemental carbon measurements were monitored high in the north and northeast of the study area. The spatial average of soil elemental carbon in spring 2009 is 1.18 %. The map also showed that the low results (0–0.4 %) were found on the coastline of the study area for categorizing the urban development and water bodies as zero value. As a result, this region is symbolized with the yellow color.

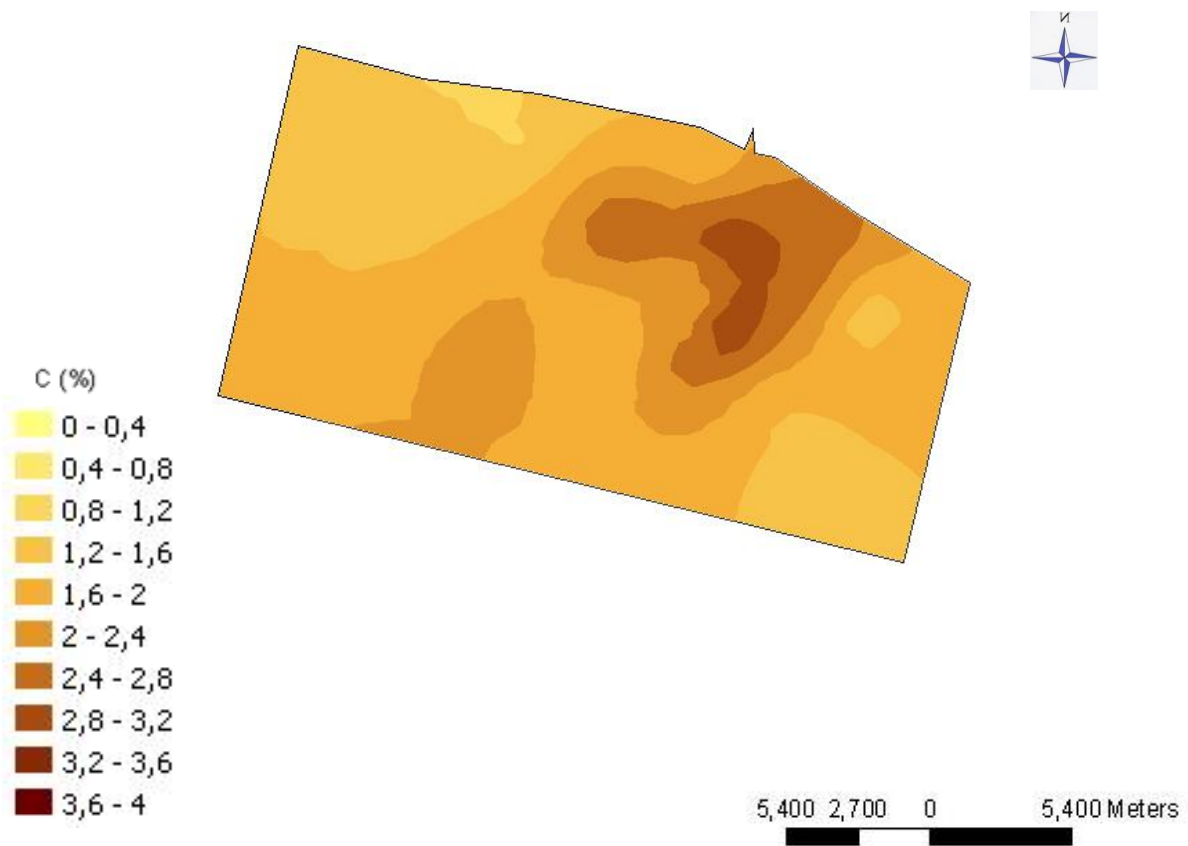


Figure 4.68 Ordinary kriging map of soil elemental carbon from forested area

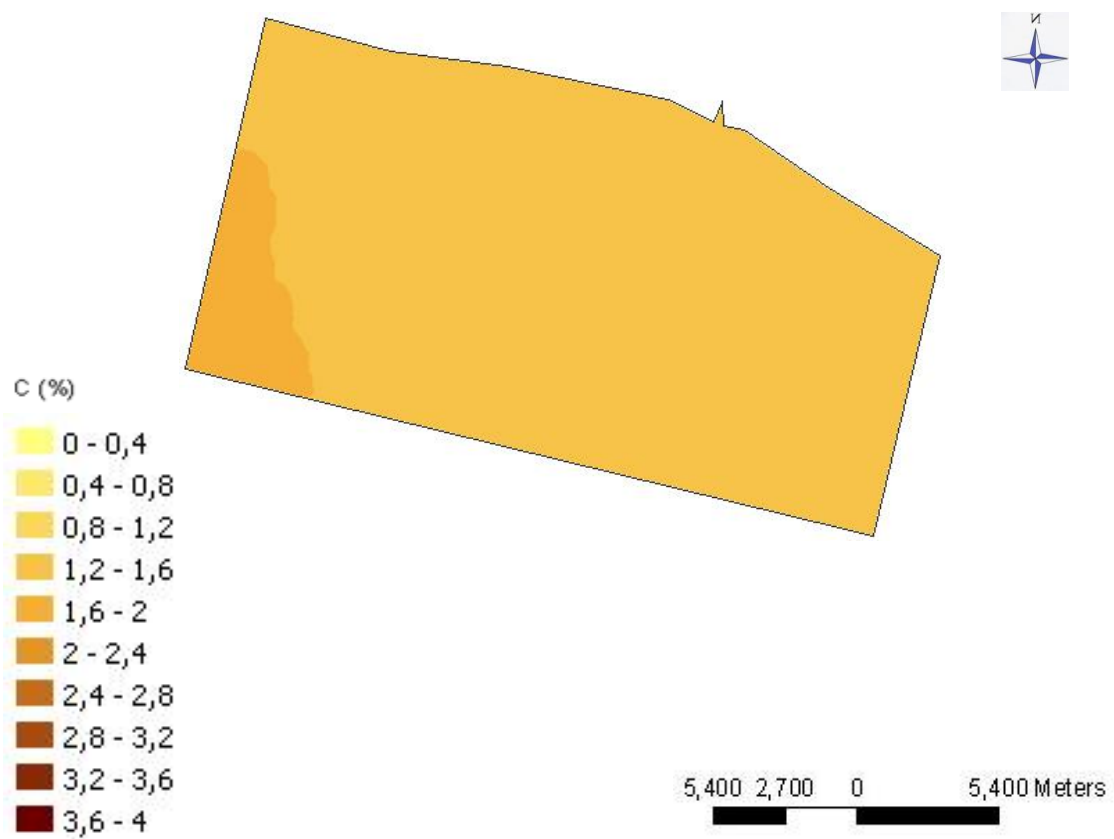


Figure 4.69 Ordinary kriging map of soil elemental carbon from deforested area

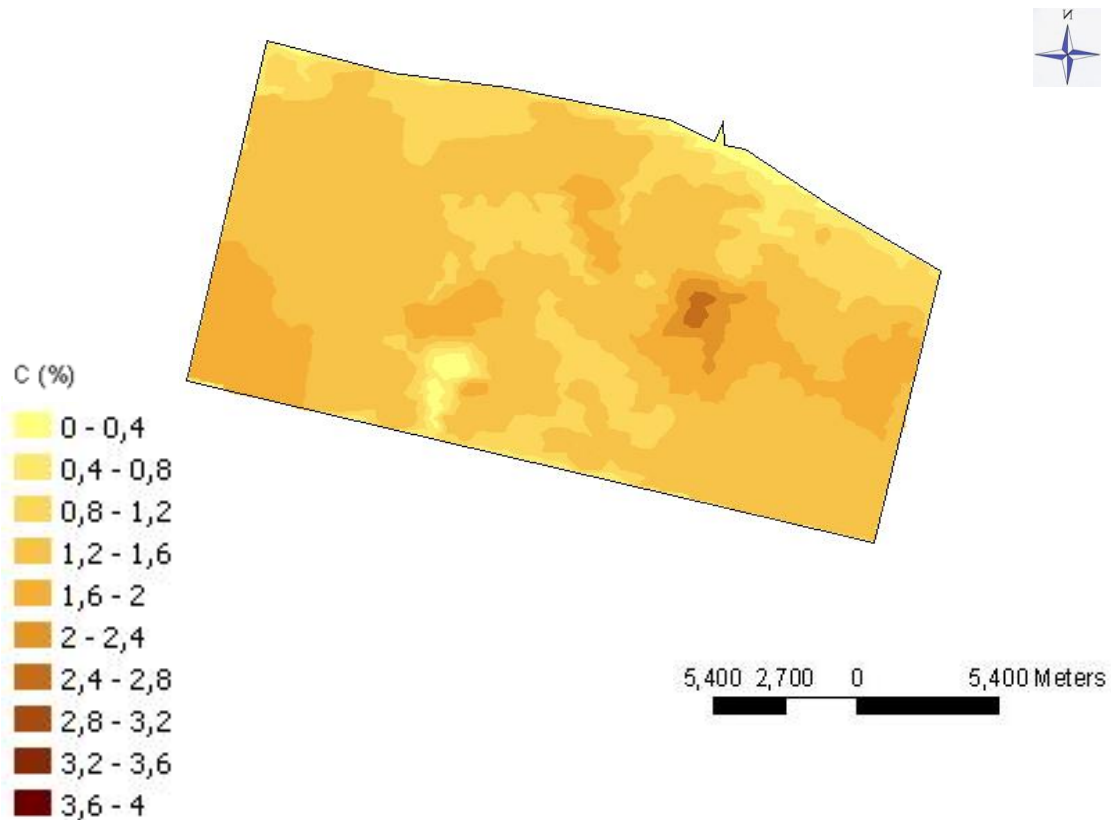


Figure 4.70 Overlaid kriging map of elemental carbon in fall 2009

The spatial average of fall 2009 is computed 1.24 %. Due to the low variability of soil elemental carbon measurement values from forested and deforested areas created a constant color distribution in the maps. The spatial distribution of the soil elemental carbon in fall 2009 varies from 1 to 2.8 %.

Table 4.27 presents the results of the spatial averages of the primary parameters. These values were found using the raster calculator function in spatial analyst and the sum up function represents in the local estimate of the attribute taking into account the land use distribution at that location.

Table 4.27 Computed spatial average values of in situ soil respiration and soil elemental carbon

Parameters-Season	Spatial Average
In situ respiration - Winter 2008	0.34 g/m ² /h
In situ respiration - Summer 2008	0.34 g/m ² /h
In situ respiration - Spring 2009	0.51 g/m ² /h
In situ respiration - Fall 2009	0.47 g/m ² /h
Soil elemental carbon - Winter 2008	1.48 %
Soil elemental carbon - Summer 2008	1.37 %
Soil elemental carbon - Spring 2009	1.18 %
Soil elemental carbon - Fall 2009	1.24 %

The discussions for the results of this study can be stated as follow:

The land use change affected in situ soil respiration measurements. The statistical evaluation suggests that overall in situ soil respiration measurements from forested soils are higher compared to deforested soils. The differences between the means of in situ soil respiration measurements from forested and deforested soils ($p < 0.05$) were statistically significant. According to Carlisle et al., (2006) this result can be explained by the SOM degradation. Furthermore, it was also observed that SOM content of deforested soil to be lower compared to forested soils. Küçüker, et al., (2009) quantified that agricultural management practices, particularly fertilizing and liming, may have played an important role for decreasing the SOM content in the soil. Bhat and Wani, (2003), concluded that the availability of litter on the forest floor may be the another reason.

Larionova et al., (1998) and Kuzyakov, (2006) concluded that deforestation and subsequent conversion to agriculture reduces SOM content of the soil and as a result, the soil respiration is affected. Rowell, (1996), Luo and Zhou, (2006), and Lou et al., (2004) confirmed that differences in in situ soil respiration for forested and deforested soils may be caused by soil microbial respiration and this difference may affected in situ soil respiration.

The seasonal trend affected in situ soil respiration. It was observed that the mean value of in situ soil respiration rates from forested soils was higher than the deforested soils for winter of 2008. Vincent et al., (2006) confirmed this result and they reported soil respiration was reduced because of low topsoil temperatures. The respiration was higher in summer 2008 compared to winter 2008, which was attributed to the low content of gravimetric moisture content of the soil (Orchard and Cook 1983, Davidson et al., 1998, and Wang et al., 2008).

Soil respiration overall mean values can be listed from highest to the lowest as: Fall 2009 > Spring 2009 > (Summer 2008 and Winter 2008). For forested soils, the values can be listed as follow: Spring 2009 ($0,92 \pm 0,06 \text{ g/m}^2/\text{h}$) and Fall 2009 ($0,84 \pm 0,01 \text{ g/m}^2/\text{h}$), Summer 2008 ($0,60 \pm 0,08 \text{ g/m}^2/\text{h}$) and Winter 2008 ($0,54 \pm 0,11 \text{ g/m}^2/\text{h}$). In situ soil respiration

measurements from forested soils for the Fall season in Karasu District, $0.84 \text{ g/m}^2/\text{h} \pm 0.06$, was similar to findings of Blanke (1996). Tang et al., (2005) also reported that the average soil respiration in the Sierra Nevada Mountains of California as $0.56 \text{ g/m}^2/\text{h}$ for the fall season.

For deforested soils, the mean values were found in order as follow: Fall 2009 ($0.89 \pm 0.02 \text{ g/m}^2/\text{h}$) and Spring 2009 ($0.49 \pm 0.02 \text{ g/m}^2/\text{h}$), Winter 2008 ($0.42 \pm 0.07 \text{ g/m}^2/\text{h}$) and Summer 2008 ($0.36 \pm 0.04 \text{ g/m}^2/\text{h}$). These values are compared with the literature. Mantlana et al., (2009) reported that the in situ soil respiration varies from $1.40 - 1.29 \text{ g/m}^2/\text{h}$ in Africa. Kim, (2008) quantified the in situ soil respiration measurements $0.52 \text{ g/m}^2/\text{h}$ deforested soils in Korea. Tedeschi et.al., (2006) reported the in situ measurements from degraded forested soils in Central Italia from $0.26 \text{ g/m}^2/\text{h}$ to $1.23 \text{ g/m}^2/\text{h}$. Soil homogeneity or heterogeneity, the vegetation, the degradability of the substrates present in soils, or differences in soil structural properties (Ingram et al., 2005) might be the main reason to observe various in situ measurements from different regions.

The difference between the means of soil elemental carbon from forested and deforested soils are statistically significant ($t=4.45$, $p=0.00$). It can be stated that land use change has significant effect on soil elemental carbon from forested and deforested soil. According to Paul et al., (2002) the previous land use, climate, and forest types could be the reason. Li et al., (2005) reported that the fertilizer application on agricultural production soils may improve strength of the soil, as well as decreasing the permeability. Descriptive statistical results showed that the elemental carbon accumulation in forested soil was higher than deforested soil. The cultivation of the soil and removing the natural vegetation on topsoil decreases the elemental carbon due to enhanced mineralization. This process also lowers the carbon input in deforested soils (Nobili et al., 2008 and Lou and Zhou, 2006). Dundar and Altundag, (2004) and Li et al., (2005) concluded that agricultural management practices on deforested soils reduce the elemental carbon accumulation in the soil. Kucuker et al., (2009) concluded that fertilizer application might also influence the accumulation of elemental carbon in the soil. Paul et al., (2002) reported that type of forest species and previous land use types might also be associated. They concluded the former land use of locations had a significant effect on change in soil carbon at less than 30 cm soil depth. Availability of litter, char, and

humus on the forest surface also increase the elemental carbon accumulation in forested soils according to Bhat and Wani (2003) and Lal, (2008).

As for the seasonal trends, it was observed that there was a significant difference between the mean values of elemental carbon in forested and deforested soils in spring and fall 2009 seasons but the mean value comparison analysis showed no significant difference between winter and summer 2008 seasons, for forested and deforested soils. The statistical significances were monitored between the mean differences of winter 2008 and spring 2009 ($t=-4.644$, $p=0.000$) from forested lands, summer 2008 and spring 2009 ($t=-3.377$, $p=0.003$) from deforested lands. Huang et al., (2008) found a similar result and they quantified that soil elemental carbon pools are not static but instead they are dynamic entities such as temperature changes may moderate the elemental carbon over time. According to Lou and Zhou, (2006), other agricultural management practices such as cultivating, airing the soil, fertilizing, and liming decreased the soil organic matter and the carbon content of the soil and this might be the reason of observing the statistically differences in spring and fall 2009 seasons. It can be also said that hazelnut planting takes place in fall season and the elemental carbon content in deforested soils tends to decrease gradually.

The trend analysis of soil texture (clay content) suggested that the in situ soil respiration measurement for the winter 2008 and fall 2009 season for the forested soils has a negative correlation with the soil texture. The soil texture influences the root systems of the vegetation and this indirectly affects the soil respiration (Luo and Zhou, 2006). Yang et al., (2007) concluded that the clay content in soil might reduce the amount of carbon mineralization, which contributes to accumulation of the soil organic carbon. Nobili, (2008) argued that the reverse correlation between two parameters is related with the chemical stabilization of SOM. This stabilization occurs as a result of chemical or physico-chemical binding to soil mineral surfaces. Müller and Höper, (2004) explained that clay dependent capacity of soils to protect microbial biomass in the soil, therefore negative statistical relationship could be detected between soil clay content and metabolic quotient (qCO_2) as an indicator of specific microbial activity and in situ soil respiration. Güner et al. (2010) investigated the land use type and slope position effects on soil respiration in black locust

plantations in Artvin. They reported that in situ soil respiration correlated negatively with mean surface soil clay and silt contents.

The soil textural trend and elemental carbon content of the soil for all seasons for forested and deforested soil showed a trend (Schimel et al., 1994). The correlation between these two parameters was high for all seasons for two types of land use. According to Walker and Desanker, (2004), carbon levels tend to increase with respect to clay content because carbon is often captured within small pores of clay particles that are bound in the inter-layers of silicate clays. Lal, (2001) reported that converting forests into any other types of land use increases the carbon holding capacity of the clay minerals in the soil.

The pH level of the soil in study soils was detected as slightly acidic. Janick and Paul (2008) reported that the slightly acidic soils are ideal for hazelnut production. The soil pH level mean value from forested soils was found higher than the deforested soils with a significance of $p < 0.05$. Bhat and Wani (2003) concluded similarly and they reported that the pH of forest floor is affected by basic cations, which is influenced by litter composition.

For selected correlation analysis from seasonal variation between in situ soil respiration and environmental parameters, it was observed that electrical conductivity and pH are highly correlated in summer 2008 season from forested soils. Similar result found by Tüfekçioğlu and Küçük, (2004) in the East Black Sea Region of Turkey. They reported that seasonal changes in soil respiration were strongly related with soil pH ($r = 0.60$, $p < 0.05$). Reth et al., (2005) also concluded that soil pH variation and soil respiration exhibited a positive correlation ($r^2 = 0.24$, $p < 0.01$).

No correlation observed between in situ soil respiration and other environmental parameters for all four seasons from deforested soils. Sampling locations were selected as close pairs within tens of meters (one being in the forest and other in converted soils) of each other. This may be the reason of no correlation between in situ soil respiration and other environmental parameters. Different textural types of soils, and micro climatic conditions during measurements could also support this finding.

The elemental carbon revealed a high correlation with soil gravimetric moisture and clay content for the spring and fall 2009 season for deforested soils. According to Muniafu and Kinyamario (2007) soil elemental carbon has a high correlation with moisture at different seasons. They observed a similar finding in Kenya. High correlation ($r=0.66, 0.65, p<0.05$) was reported in Kenya between soil elemental carbon and moisture at spring and fall seasons.

Satellite image analyses indicated that the forest surface area of the soils has decreased 11% from 1987 to 2007 in Karasu Forests. Güler et al., (2007) found the decrease rate of forest surface area in the Province of Samsun to be 28%. However, they defined 8 land use types and listed them as: open forests, dense forests, hazelnut plantations, degraded forests, agricultural production, abandoned soils, urban, and water. In this dissertation, land use types were categorized under 4 classes, therefore the rate was calculated in Güler et al., (2007) is greater than the one calculated in this study for the Karasu Forests. Özdemir and Özkan, (2003) presented land use change from 1992 to 2001 in the Armutlu forests, in Istanbul. They found that the forested area had decreased by 318,41 ha within nine years (with an annual decrease rate of 1,96%). Yildirim et al., (2001) investigated land use change in forests of Kocaeli Peninsula (located in the Northwestern Turkey) from 1986 to 1998. Their results showed that the surface area of forest soils have diminished by 4,1% in the peninsula. Günlü et al. (2009), reported that the forested lands in the Province of Rize, where is located on Black Sea Coast, decreased 2.30%.

Land use change results also showed that the increase in agricultural soils such as hazelnut and corn are calculated as 1207 ha in Karasu Forests. The rate of the increase is 8,5%. Güler et al., (2007) reported that the soils of open forest and hazelnut increased by 5,5% in the province of Samsun.

The spatial averages of the primary parameters (in situ soil respiration and soil elemental carbon) were computed employing the ordinary kriging method in geostatistical analyses. The averages of in situ soil respiration from winter and summer 2008 are 0.34 g/m²/h, spring 2009 is 0.51 0.34 g/m²/h, and the fall 2009 is 0.47 g/m²/h. The spatial average values of winter and summer 2008 can be explained by soil hardness of the A horizon in winter, altitude and topographic relief index (slope position) in summer season. Limiting

factors of soil respiration could vary from season to season, leading to various spatial patterns. This suggests that multi-measurements are important when trying to understand the spatial dynamics of soil respiration (Ohashi et al., 2009). According to Herbst et al., (2007) the spatial variability that affects on the spatial average of soil respiration is mainly moderated by variability in soil water content.

The spatial averages of elemental carbon were computed as follow: Winter 2008 is 1.48%, summer 2008 is 1.37%, spring 2009 is 1.18%, and fall 2009 is 1.24%. Wang et al. (2007) suggested that the variation of spatial averages in elemental carbon might be related with root-density and root distribution in the surface soil. Relative contributions from C_3 and C_4 vegetation, leaf litter on the ground could be other reasons of the variability. Slope position and land use types in Karasu District could be other factors for the spatial variability of elemental carbon.

5. CONCLUSIONS

In this dissertation, the impacts of land use change on primary parameters (in situ soil respiration and soil elemental carbon content) in the Karasu forests are investigated. The relationship of these two primary parameters to environmental parameters is also examined.

The statistical evaluation of results is conducted using 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 primary parameters.

Geographical Information Systems (GIS) Remote Sensing Technologies (RST) was employed in conjunction with in situ measurements, laboratory experiments and statistical analyses. Satellite image analysis was conducted to monitor the land use changes from 1987 to 2007 in the study area. The data obtained from the analysis was used in geostatistical analyses to explore the spatial relationships between the primary parameters.

A statistical trend was observed between land use change and in situ soil respiration measurements. It was found that the average annual soil respiration in forested soils was about 27% higher than from deforested lands.

The in situ soil respiration rates were maximum during spring and fall 2009 seasons and minimum during winter and summer 2008 seasons. A moderate correlation was detected between winter 2008 forested and deforested soil respiration results. Soil respiration overall mean values can be listed from highest to the lowest as: Fall 2009 > Spring 2009 > (Summer 2008 and Winter 2008).

In situ soil respiration measurement from fall 2009 forested soils have a trend with soil texture type and no correlation was observed between in situ soil respiration and clay content in deforested soils for four seasons. A similar result, having no correlation between in situ soil respiration and other environmental parameters for four seasons, was observed for deforested soils.

The correlation analysis of in situ soil respiration measurements and environmental parameters for all seasons revealed the following: There is a moderate correlation between in situ soil respiration and microbial respiration for forested soils. No correlation was observed between in situ soil respiration and elemental carbon for four seasons and two different types of land uses, and the correlation between soil respiration and soil pH is moderated due to seasonal fluctuations.

The seasonal variations with in situ soil respiration and other environmental parameters were investigated by the correlation analysis method. It was found that, in the winter season in situ soil respiration has a correlation with microbial respiration from forested soils, while in the summer season in situ soil respiration has a correlation with electrical conductivity and soil pH for forested soils. The in situ soil respiration is highly correlated with the soil temperature in spring for forested soils and in fall season in situ soil respiration has a correlation with electrical conductivity and soil pH for forested soils. A significant correlation was not found between in situ soil respiration and other environmental parameters for deforested soils.

Soil elemental carbon content is denoted as another primary parameter. The laboratory analysis showed that percentages of elemental carbon in forested soils are generally larger than deforested soils because of the availability of litter, char, and humus on the soil surface. It was calculated that the average annual soil elemental carbon in forested soils was about 34% higher than from deforested lands.

The C:N ratio can be calculated from the elemental carbon and nitrogen content of the soils. The overall mean value of C:N ratios for forested soils for all seasons are slightly higher than deforested soils.

The descriptive statistical analysis showed that forest soils had 36% more SOM in winter and 25% more SOM in summer on average (organic matter percentages up to 5.15% in winter and 4.47% in summer, differences significant), however, when the spring and summer seasons are added to the analysis, the degradation of the SOM is slowly halted and inverse correlation ($r=-0.16$) is observed.

It was concluded that the land use change affects the elemental carbon content in forested and deforested soils. The clay content of forested soils has a significant correlation with the elemental carbon in summer 2008, spring 2009, and fall 2009 seasons. A similar result was observed with the clay content of deforested soils. Moreover, this environmental parameter has a significant correlation with the elemental carbon content for all seasons.

Significant correlations were found between elemental carbon and other environmental parameters for forested and deforested soils however, a negative correlation was observed between elemental carbon and pH for forested soils.

The correlation analysis with elemental carbon content of the soil and other environmental parameters in seasonal variations yielded the following results: A high correlation was detected between elemental carbon and soil organic material in winter 2008 for forested soils. A similar result was observed with the clay content in summer 2008 for forested soils. The elemental carbon content of the soil has a correlation with soil organic material and clay content in spring 2009 for forested soils. There is a high correlation between elemental carbon and electrical conductivity, soil organic material, and clay content of the soil in winter and summer 2008 seasons. A high correlation was also detected with the gravimetric moisture and clay content of the soil in spring and fall 2009 seasons.

Statistical evaluations between environmental parameters were performed using the correlation analysis method and mean difference tests. The evaluations indicated that a strong relationship can be observed with soil texture and SOM in deforested soils. Soils of forests and agricultural sites were in slightly acidic range with no samples with high acidity or alkalinity. The points in pairs of sampling locations in forested and deforested soils were very close to each other, as a result, many soil parameters had very close values and/or had strong correlations (microbial respiration, elemental carbon, C:N, ambient and soil temperature, and pH).

The statistical evaluations also suggested that microbial respiration is one of the important factors that affect the in situ soil respiration and the overall mean values of microbial respiration from forested soils is higher than the deforested soils.

In this dissertation, Landsat TM satellite images, dated 1987 and 2007, were used to monitor land use change within the last 20 years. The surface area of soils of forests decreased 604.8 ha from 1987 to 2007. The rate of decrease is 11%. The increase in agricultural production soils, such as hazelnut and corn plantations, was calculated as 1207 ha. The rate of increase is 8.5%. Surface areas of urban soils, pasture and meadows, and abandoned soils were decreased by 13%. Uncontrolled population expansion in urban soils forced people to look for other locations for running agricultural activities as a financial income. Therefore, the pastures and abandoned soils were converted into hazelnut and corn plantations in the Karasu District.

The stepwise regression results showed that 46%, 16%, and 4% variations in soil elemental carbon could be explained by clay content, SOM, and electrical conductivity. This indicated that SOM was the most important determinant of elemental carbon in deforested soils. For forested soils, 40%, 16 %, and 4% variations in soil elemental carbon could be explained by clay content, SOM, microbial respiration, respectively.

Overall, it is observed that land conversion in the Black Sea Karasu region from forests to agricultural lands, resulted in a significant decrease in situ soil respiration, soil elemental carbon, soil microbiological activity, and also in a significant loss of SOM, and differentiation in soil textural characteristics, which also reflected in differences in soil carbon model functions.

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APPENDICES

Appendix A Satellite Image Characteristics

Table A.1 Characteristics of Landsat-1 to -7 Missions (Lillesand, 2004)

Table A.2 Sensors used on Landsat-1 to -7 missions (Lillesand, 2004)

Appendix B Soil respiration

Figure B.1. Soil Carbon Dioxide monitoring methods (Luo and Zhou,2006)

Figure B.2. CIRAS Soil Respiration Measurement System

Figure B.3. Air Supply in CIRAS-2 (PP Systems, 2007)

Appendix C. Statistical Evaluation

Table C.1 Normality test results of soil pH

Table C.2 Normality test results of soil electrical conductivity

Table C.3 Primary and Environmental Parameters from deforested soils (based on land use type)

Table C.4 Primary and Environmental Parameters from forested soils (based on land use type)

Table C.5 In-situ Soil Respiration Measurements from Seasons

Table C.6 Soil Elemental Carbon Measurements from Seasons

Appendix A

Table A.1 Characteristics of Landsat-1 to -7 Missions (Lillesand, 2004)

Satellite	Launched	Decommissioned	RBV Bands	MSS Bands	TM Bands	Orbit
Landsat 1	July 23, 1972	January 6, 1978	1-3 ^c	4- 7	None	18 days/ 900km
Landsat 2	January 22, 1975	February 25, 1982	1-3 ^c	4-7	None	18 days/ 900km
Landsat 3	March 5, 1978	March 31, 1983	A -D	4-8 ^a	None	18 days/ 900km
Landsat 4	July 16, 1982 ^b		None	1-4	1-7	16 days/705km
Landsat 5	March 1, 1984		None	1-4	1-7	16 days/705km
Landsat 6	October 5, 1983	Failure upon launch	None	None	1-7 plus ETM	16 days/705km
Landsat 7	April 15, 1999		None	None	1-7 plus ETM	16 days/705km

^a **Band 8 (10.4 12.6 μ m) failed after launch**

^b **TM data transmission failed in August,1993**

^c **Simultaneous images**

Table A.2 Sensors used on Landsat-1 to -7 missions (Lillesand, 2004)

Sensor	Mission	Sensitivity (µm)	Resolution (m)
RBV	1,2	0.45 -0.575 0.580 -0.680 0.690-0.830	80 80 80
	3	0.505 – 0.750	30
MSS	1-5	0,5-0,6 0.6 – 0.7 0.7-0.8 0.8-0.11	79/82 ^a 79/82 ^a 79/82 ^a 79/82 ^a
	3	10.4 -12.6 ^b	240
TM	4,5	0.45-0,52 0.52-0.60 0.63-0.69 0.76-0.90 1.55 – 1.75 10.4 -12.5 2.08 – 2,35	30 30 30 30 30 120 30
ETM	6	Above TM bands Plus 0.50 – 0.90	30(120 m thermal band) 15
ETM	7	Above TM bands Plus 0.50 – 0.90	30(120 m thermal band) 15

^a 79m for Landsat-1 to -3 and 82m for Landsat-4 and -5

^b Failed shortly after launch (band 8 f Landsat-3)

^c Landsat-6 launch failure

Appendix B

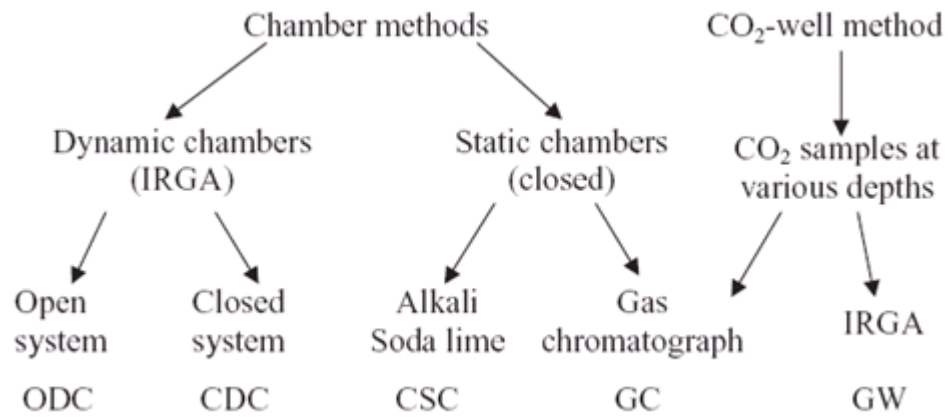


Figure B.1. Direct measurement methods of Soil Respiration (Luo and Zhou, 2006).



Figure B.2. CIRAS Soil Respiration Measurement System

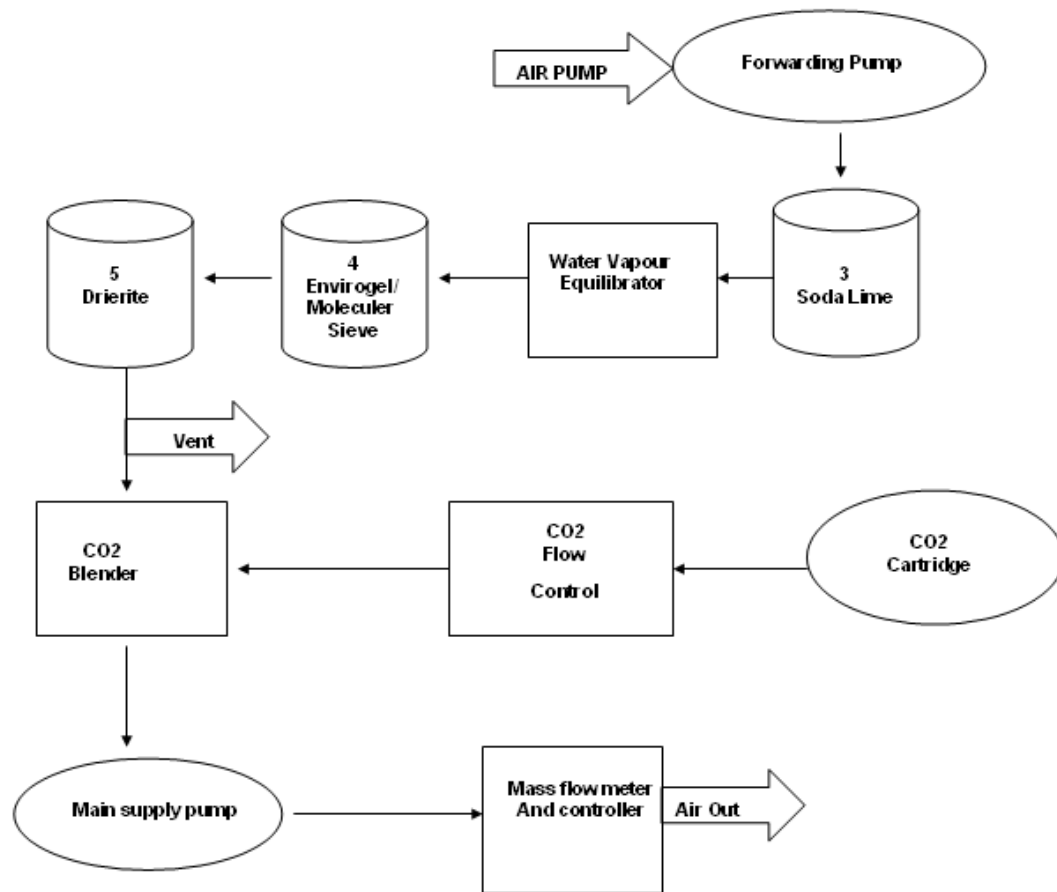


Figure B.3. Air Supply in CIRAS-2 (PP Systems, 2007)

Appendix C

Table C.1. Normality test results for Soil pH

		ph W def	ph S def	pH spr def	pH fall def	pH W for	pH S for	pH spr for	pH fall for
N		20	24	24	24	20	21	21	21
Normal Parameters ^{a,b}	Mean	4.8495	5.3146	5.1304	5.5296	5.0060	4.7314	4.8662	5.2652
	Std. Deviation	.91701	.75236	.60279	.66126	.88599	.74811	.62552	.68397
Most Extreme Differences	Absolute	.230	.164	.176	.149	.207	.273	.209	.275
	Positive	.230	.164	.176	.149	.207	.273	.209	.275
	Negative	-.117	-.093	-.133	-.103	-.138	-.167	-.143	-.180
Kolmogorov-Smirnov Z		1.030	.806	.860	.731	.924	1.251	.956	1.262
Asymp. Sig. (2-tailed)		.240	.535	.450	.659	.361	.087	.320	.083

Table c.2 Normality test results for Soil Electrical Conductivity

		Sum f EC	Spr f EC	Fall f EC	Win def EC	Sum def EC	Spr def EC	Fall def EC
N		21	21	21	20	24	24	24
Normal Parameters ^{a,b}	Mean	170,8571	130,1905	135,2857	317,8500	234,1667	105,0833	146,7083
	Std. Deviation	150,88018	110,44574	108,91655	212,64779	268,07570	74,62598	112,55046
Most Extreme Differences	Absolute	,254	,257	,273	,330	,329	,250	,259
	Positive	,254	,257	,273	,330	,329	,250	,259
	Negative	-,223	-,173	-,209	-,243	-,285	-,218	-,223
Kolmogorov-Smirnov Z		1,162	1,177	1,249	1,474	1,612	1,227	1,267
Asymp. Sig. (2-tailed)		,134	,125	,088	,026	,011	,099	,081

Table C.3 Primary and Environmental Parameters from deforested soils (based on land use type)

Seasons	SRC_df_4	SOM_df_4	Stemp_df_4	EC_df_4	Grm_df_4	L_ph_df_4	mr_df_4	ElC_df_4	clay_def
1	0.81	1.08	8.00	5.69	25.33	1.81	0.42	0.70	11.00
1	0.45	1.26	9.00	5.14	26.00	1.75	0.17	0.70	7.00
1	0.45	2.64	8.00	5.38	32.00	1.49	0.63	1.50	37.00
1	0.10	2.46	8.00	5.48	56.67	1.61	0.64	1.70	29.00
1	0.17	1.68	8.00	5.64	28.00	1.48	0.37	1.20	41.00
1	0.45	1.35	9.00	5.23	25.00	1.40	0.43	0.70	17.00
1	0.40	1.77	8.00	5.50	20.00	1.38	0.82	0.90	11.00
1	0.51	2.63	9.00	5.29	23.00	1.89	0.00	1.20	11.00
1	0.12	2.81	6.00	5.71	30.00	1.73	0.63	1.90	39.00
1	0.50	2.26	7.00	5.90	21.33	1.41	0.97	1.20	15.00
1	0.24	2.63	10.00	5.29	15.00	1.36	0.38	1.40	19.00
1	0.76	2.45	13.00	5.60	17.00	1.44	0.38	1.30	20.00
1	0.42	1.35	8.00	5.58	19.00	1.45	0.01	0.80	15.00
1	0.23	2.45	8.00	7.04	30.00	1.77	0.10	2.50	42.00
1	1.35	1.51	8.00	5.37	21.00	1.35	0.39	1.40	16.00
1	0.06	2.93	6.00	5.45	20.00	1.32	0.41	1.90	17.00
1	0.00	2.82	7.00	5.62	20.00	1.68	0.73	1.30	28.00
1	0.51	3.41	8.00	5.99	26.00	1.60	0.53	2.30	35.00
1	0.25	1.98	8.00	5.68	30.00	1.84	0.40	1.40	4.00
1	0.51	2.82	8.00	6.34	25.00	1.47	0.36	1.70	42.00
2	0.47	0.58	28.00	4.47	18.33	1.71	0.11	0.80	11.00
2	0.50	1.03	27.00	4.51	10.00	1.72	0.12	0.90	7.00
2	0.43	2.00	27.00	5.69	10.00	1.77	0.48	2.50	37.00
2	0.23	1.39	26.00	5.56	15.00	1.74	0.48	1.60	29.00
2	0.23	0.76	29.00	4.50	20.00	1.50	0.33	1.20	41.00
2	0.23	2.09	24.00	4.72	15.00	1.59	0.66	0.90	17.00
2	0.12	2.15	27.00	4.72	15.00	1.60	0.45	1.00	11.00
2	0.18	2.38	28.00	4.47	17.00	1.62	0.58	1.50	11.00
2	0.43	3.25	26.00	4.65	20.00	1.53	0.42	2.20	39.00
2	0.44	2.27	24.00	5.13	10.00	1.76	0.51	1.30	15.00
2	0.31	2.82	33.00	5.11	20.00	1.62	0.98	1.70	19.00
2	0.23	2.34	33.00	4.93	40.00	1.58	0.96	1.50	20.00
2	0.30	2.10	28.00	5.20	10.00	1.63	0.74	1.40	15.00
2	0.92	3.17	28.00	6.72	14.67	1.98	0.41	2.70	42.00
2	0.40	2.22	34.00	4.41	11.00	1.46	0.79	1.80	16.00
2	0.54	2.82	26.00	5.04	10.00	1.64	0.72	2.10	17.00

2	0.27	1.98	30.00	4.68	15.00	1.49	0.49	1.10	28.00
2	0.23	2.88	29.00	5.34	15.00	1.67	0.83	2.40	35.00
2	0.19	0.42	32.00	4.91	15.00	1.93	0.35	0.90	4.00
2	0.24	3.05	38.00	6.63	15.00	1.50	0.64	2.60	42.00
2	0.64	2.48	23.00	4.96	50.00	1.65	1.20	1.50	10.00
2	0.21	1.21	24.00	4.67	10.00	1.66	0.63	0.80	11.00
2	0.53	2.00	28.00	4.51	5.33	1.64	0.41	1.20	13.00
2	0.36	3.15	28.00	7.01	19.00	1.89	0.67	2.20	49.00
3	0.65	1.07	14.00	4.13	19.52	1.64	0.34	1.00	11.00
3	0.54	3.46	16.00	4.08	13.98	1.69	0.34	0.90	7.00
3	0.42	2.86	13.00	4.30	22.32	1.59	0.48	1.70	37.00
3	0.71	3.02	14.00	4.57	19.25	1.50	0.42	1.70	29.00
3	0.52	2.21	20.00	4.42	21.51	1.56	0.39	1.30	41.00
3	0.27	1.59	14.00	4.28	19.35	1.55	0.59	1.90	17.00
3	0.54	1.60	14.00	3.95	18.58	1.51	0.38	0.80	11.00
3	0.34	2.10	14.00	3.85	21.03	1.63	0.41	1.20	11.00
3	0.46	3.10	13.00	4.33	22.29	1.64	0.44	1.70	39.00
3	0.54	1.75	12.00	4.44	19.83	1.63	0.62	1.10	15.00
3	0.59	1.47	16.00	4.16	16.21	1.52	0.52	1.30	19.00
3	0.53	1.67	15.00	4.58	18.00	1.53	0.69	1.30	20.00
3	0.44	1.58	14.00	4.80	18.04	1.64	0.56	1.00	15.00
3	0.46	2.07	14.00	4.65	27.10	1.78	1.66	1.60	42.00
3	0.46	1.23	15.00	4.19	16.04	1.53	0.54	1.80	16.00
3	0.53	1.37	14.00	4.01	18.43	1.54	0.32	1.00	17.00
3	0.47	2.30	13.00	3.93	16.99	1.53	0.46	1.70	28.00
3	0.42	2.32	15.00	5.09	23.67	1.81	0.90	3.60	35.00
3	0.42	1.81	14.00	5.30	24.30	1.87	0.63	1.20	4.00
3	0.54	3.50	14.50	5.15	25.00	1.58	0.53	1.40	42.00
3	0.49	1.94	15.00	5.93	16.18	1.88	1.29	1.50	10.00
3	0.43	1.07	15.00	4.22	14.61	1.66	0.64	0.60	11.00
3	0.54	1.70	12.00	4.14	12.15	1.60	0.31	0.90	13.00
3	0.51	1.79	12.00	5.35	32.55	1.71	0.77	2.80	49.00
4	0.35	1.03	15.00	4.39	13.46	1.84	0.38	0.87	11.00
4	0.55	1.45	13.00	4.11	11.35	1.80	0.31	0.85	7.00
4	0.38	3.10	16.00	4.78	20.20	1.70	0.49	1.61	37.00
4	0.51	2.96	15.00	4.66	20.03	1.58	0.56	1.93	29.00
4	0.35	2.47	12.00	4.87	20.50	1.63	0.76	1.38	41.00
4	0.55	1.90	16.00	4.48	17.03	1.70	0.55	1.55	17.00
4	0.34	1.56	15.00	4.50	16.04	1.54	0.39	0.69	11.00
4	0.44	1.75	19.00	4.11	15.85	1.64	0.32	0.91	11.00
4	0.59	2.81	15.00	5.19	25.76	1.64	0.70	1.70	39.00
4	0.51	2.49	14.00	5.16	19.23	1.84	0.72	1.55	15.00
4	0.56	2.71	12.00	4.29	14.69	1.59	0.46	1.12	19.00
4	0.36	2.11	16.00	4.88	14.86	1.57	0.65	0.95	20.00

4	0.52	1.75	16.00	4.98	19.43	1.74	0.59	0.87	15.00
4	0.57	2.27	15.00	6.43	22.18	1.92	1.73	1.62	42.00
4	0.48	2.66	16.00	4.49	18.36	1.61	0.68	1.46	16.00
4	0.42	2.13	15.00	4.48	17.94	1.61	0.52	1.07	17.00
4	0.43	2.82	16.00	4.96	17.31	1.63	0.63	1.32	28.00
4	0.55	3.29	12.00	4.96	22.66	1.75	0.65	2.10	35.00
4	0.45	2.03	10.00	5.16	10.62	1.99	0.40	1.18	4.00
4	0.42	3.66	15.00	5.48	27.30	1.65	0.68	2.49	42.00
4	0.52	2.97	16.00	4.89	17.32	1.71	0.72	1.59	10.00
4	0.48	2.14	15.00	4.86	14.77	1.74	0.82	1.09	11.00
4	0.42	2.03	16.00	4.33	15.83	1.73	0.48	1.34	13.00
4	0.50	3.96	16.00	5.50	29.21	1.75	0.87	0.90	49.00

Table C.4 Primary and Environmental Parameters from forested soils (based on land use type)

Seasons	SRC_f_4	SOM_f_4	Stemp_f_4	Log_EC_f_4	Grm_f_4	log_pH_f_4	mr_f_4	ElC_f_4	clay_f
1	0.60	1.91	7.00	6.06	61.67	1.82	1.99	1.20	15.00
1	1.81	5.15	8.00	6.36	55.67	1.67	2.95	2.70	9.00
1	0.26	3.53	8.00	5.55	44.00	1.52	0.43	1.60	34.00
1	0.39	4.01	9.00	5.97	24.67	1.40	1.10	2.50	34.00
1	1.09	2.40	9.00	5.61	57.00	1.52	1.20	1.50	39.00
1	0.32	1.90	8.00	5.16	38.67	1.59	0.85	1.30	13.00
1	0.28	3.73	8.00	5.41	17.00	1.54	0.48	1.70	11.00
1	0.39	2.26	7.00	5.90	30.00	1.63	1.06	1.40	9.00
1	0.31	4.53	10.00	5.45	27.33	1.57	1.37	3.10	39.00
1	0.86	2.26	9.00	5.35	19.33	1.53	0.32	1.30	13.00
1	0.26	1.59	9.00	4.88	16.00	1.40	0.32	1.50	20.00
1	0.44	2.63	9.00	5.45	23.00	1.44	0.78	1.40	19.00
1	0.22	3.79	9.00	5.60	26.00	1.70	0.53	1.70	11.00
1	0.22	2.87	8.00	6.86	28.33	1.96	0.40	1.80	45.00
1	1.70	3.55	8.00	5.38	21.00	1.50	0.28	1.90	15.00
1	0.12	2.40	10.00	5.19	26.00	1.47	0.49	1.20	18.00
1	0.55	3.53	8.00	6.36	27.33	1.45	1.48	2.50	30.00
1	0.36	3.11	8.00	5.69	25.00	1.74	0.51	1.80	33.00
1	0.37	1.98	7.00	5.57	30.00	1.94	0.40	1.10	5.00
1	0.29	2.87	7.00	6.29	16.33	1.54	0.37	2.10	53.00
2	0.96	1.75	23.00	5.04	42.00	1.68	1.46	1.99	15.00
2	0.92	1.54	22.00	6.23	17.00	1.87	1.15	1.83	9.00
2	0.52	1.21	22.00	4.03	11.00	1.47	0.52	2.05	34.00
2	0.79	2.00	23.00	4.88	20.00	1.54	1.01	2.14	34.00
2	0.22	2.54	22.00	5.05	10.00	1.54	1.01	2.31	39.00
2	0.52	2.56	23.00	4.42	10.00	1.44	0.99	1.26	13.00
2	0.44	4.47	22.00	4.22	6.00	1.40	0.60	1.77	11.00
2	1.18	2.32	23.00	6.46	15.00	1.87	0.94	0.90	9.00
2	0.68	4.36	24.00	5.21	16.67	1.56	1.29	2.69	39.00
2	0.57	2.85	22.00	4.49	15.00	1.45	1.04	1.80	13.00
2	0.47	2.28	23.00	4.28	10.00	1.48	0.64	1.88	20.00
2	0.47	1.98	24.00	4.62	17.00	1.49	0.79	1.20	19.00
2	0.38	2.64	25.00	4.28	18.00	1.43	0.86	1.88	11.00
2	1.65	3.35	28.00	5.55	19.00	1.57	1.17	1.70	45.00
2	0.34	3.29	24.00	4.23	15.52	1.39	0.84	2.08	15.00
2	0.53	3.05	30.00	4.52	10.00	1.44	0.75	1.45	18.00
2	0.15	3.11	34.00	4.55	19.00	1.47	0.85	1.82	30.00
2	0.62	3.65	22.00	4.93	10.00	1.54	0.74	1.83	33.00
2	0.47	1.14	24.00	5.48	16.00	1.80	1.62	1.28	5.00
2	0.36	2.22	29.00	5.68	10.00	1.44	0.54	2.67	53.00

2	0.37	2.24	22.00	4.51	10.00	1.56	1.08	2.14	22.00
3	0.67	3.37	12.00	5.07	25.24	1.64	1.10	1.50	15.00
3	1.84	4.53	16.00	5.60	19.88	1.76	1.26	2.70	9.00
3	0.92	3.17	12.00	4.47	23.26	1.54	0.54	2.50	34.00
3	0.81	3.77	12.00	3.22	23.12	1.56	0.96	3.90	34.00
3	0.93	3.06	15.00	4.65	22.62	1.52	0.65	3.40	39.00
3	0.83	2.84	12.00	4.45	21.47	1.48	0.66	2.20	13.00
3	0.85	1.83	13.00	3.95	14.35	1.47	0.45	1.40	11.00
3	0.65	0.91	13.00	4.90	17.84	1.89	0.45	0.80	9.00
3	0.96	3.00	12.00	4.55	25.24	1.60	1.11	2.30	39.00
3	0.88	3.13	13.00	4.29	18.05	1.51	0.83	1.30	13.00
3	0.86	1.54	13.00	3.81	14.25	1.46	1.84	1.50	20.00
3	0.77	0.56	12.00	4.41	21.50	1.51	1.04	1.60	19.00
3	0.89	4.18	14.00	4.65	23.95	1.53	1.09	2.60	11.00
3	1.09	1.19	14.00	6.15	25.12	1.56	1.23	1.90	45.00
3	0.90	3.33	12.00	4.29	18.32	1.44	0.59	2.30	15.00
3	0.93	1.97	13.00	3.87	23.12	1.47	0.38	1.10	18.00
3	1.18	3.31	13.00	4.33	24.00	1.57	1.03	1.80	30.00
3	0.93	3.76	12.00	4.93	23.06	1.65	0.92	3.10	33.00
3	0.94	1.47	13.00	5.02	24.35	1.82	0.65	1.10	5.00
3	1.08	3.53	12.00	5.92	14.23	1.53	0.77	2.50	53.00
3	0.52	2.39	14.00	4.50	16.98	1.60	0.90	1.70	22.00
4	0.88	3.03	14.00	5.51	16.83	1.79	1.16	1.58	15.00
4	0.98	3.96	16.00	6.04	19.41	1.87	1.65	2.00	9.00
4	0.89	3.00	15.00	4.16	20.90	1.60	0.58	2.10	34.00
4	0.83	3.89	12.00	4.79	20.06	1.61	0.80	2.11	34.00
4	0.78	2.75	15.00	4.42	20.31	1.61	0.56	1.70	39.00
4	0.87	2.71	15.00	4.49	15.31	1.56	0.93	1.27	13.00
4	0.88	3.15	16.00	3.99	15.97	1.53	0.74	1.79	11.00
4	0.78	1.86	19.00	5.57	18.06	1.87	0.82	1.07	9.00
4	0.85	4.98	16.00	4.66	21.37	1.65	1.05	2.27	39.00
4	0.83	2.50	13.00	4.08	17.44	1.57	0.66	1.04	13.00
4	0.73	2.23	14.00	3.93	15.95	1.55	0.79	1.11	20.00
4	0.86	2.39	15.00	4.51	15.19	1.58	1.13	1.21	19.00
4	0.80	3.19	15.00	4.37	17.48	1.59	0.97	1.44	11.00
4	0.82	4.42	15.00	5.98	25.56	1.71	0.77	2.49	45.00
4	0.81	3.33	16.00	4.11	16.28	1.54	0.77	1.43	15.00
4	0.88	2.32	17.00	3.85	16.02	1.56	0.52	1.04	18.00
4	0.79	2.76	16.00	4.58	20.22	1.60	0.94	1.74	30.00
4	0.77	4.29	15.00	4.98	21.15	1.67	1.05	2.28	33.00
4	0.99	1.08	15.00	4.57	11.39	1.94	0.33	0.66	5.00
4	0.76	3.79	15.00	5.32	26.46	1.56	0.75	2.62	53.00
4	0.86	2.53	14.00	4.22	15.09	1.75	0.76	1.52	22.00

Table C.5 In-situ Soil Respiration Measurements from Seasons

Winter08 SRCForested	Summer08 SRCForested	Spring09 SRCForested	Fall09 SRCForested	Winter08 SRCDeforested	Summer08 SRCDeforested	Spring09 SRCDeforested	Fall09 SRCDeforested
0.60	0.96	0.67	0.88	0.81	0.47	0.65	0.35
1.81	0.92	1.84	0.98	0.45	0.50	0.54	0.55
0.26	0.52	0.92	0.89	0.16	0.43	0.42	0.38
0.39	0.79	0.81	0.83	0.10	0.23	0.71	0.51
1.09	0.22	0.93	0.78	0.92	0.23	0.52	0.35
0.32	0.52	0.83	0.87	0.45	0.23	0.27	0.55
0.28	0.44	0.85	0.88	0.40	0.12	0.54	0.34
0.12	1.18	0.65	0.78	0.51	0.18	0.34	0.44
0.31	0.68	0.96	0.85	0.12	0.43	0.46	0.59
0.86	0.57	0.88	0.83	0.50	0.44	0.54	0.51
0.26	0.47	0.86	0.73	0.24	0.31	0.59	0.56
0.44	0.47	0.77	0.86	0.76	0.23	0.53	0.36
0.22	0.38	0.89	0.80	0.42	0.30	0.44	0.52
0.22	1.65	1.09	0.82	0.23	0.92	0.46	0.57
1.70	0.34	0.90	0.81	1.35	0.40	0.46	0.48
0.00	0.53	0.93	0.88	0.06	0.54	0.53	0.42
0.55	0.15	1.18	0.79	0.03	0.27	0.47	0.43
0.36	0.62	0.93	0.77	0.51	0.23	0.42	0.55
0.37	0.47	0.94	0.99	0.25	0.19	0.42	0.45
0.29	0.36	1.08	0.76	0.51	0.24	0.54	0.42
	0.37	0.52	0.86		0.64	0.49	0.52
					0.21	0.43	0.48
					0.53	0.54	0.42
					0.36	0.51	0.50

Table C.6. Soil Elemental Carbon Measurements from Seasons

Winter 08 Elemental Carbon Forested	Summer 08 Elemental Carbon Forested	Spring 09 Elemental Carbon Forested	Fall_09 Elemental Carbon Forested	Winter 08 Elemental Carbon Deforested	Summer 08 Elemental Carbon Deforested	Spring 09 Elemental Carbon Deforested	Fall 09 Elemental Carbon Deforested
1.20	1.99	1.50	1.58	0.70	0.80	1.00	0.87
2.70	1.83	2.70	2.00	0.70	0.90	0.90	0.85
1.60	2.05	2.50	2.10	1.50	2.50	1.70	1.61
2.50	2.14	3.90	2.11	1.70	1.60	1.70	1.93
1.50	2.31	3.40	1.70	1.20	1.20	1.30	1.38
1.30	1.26	2.20	1.27	0.70	0.90	1.90	1.55
1.70	1.77	1.40	1.79	0.90	1.00	0.80	0.69
1.40	0.90	0.80	1.07	1.20	1.50	1.20	0.91
3.10	2.69	2.30	2.27	1.90	2.20	1.70	1.70
1.30	1.80	1.30	1.04	1.20	1.30	1.10	1.55
1.50	1.88	1.50	1.11	1.40	1.70	1.30	1.12
1.40	1.20	1.60	1.21	1.30	1.50	1.30	0.95
1.70	1.88	2.60	1.44	0.80	1.40	1.00	0.87
1.80	1.70	1.90	2.49	2.50	2.70	1.60	1.62
1.90	2.08	2.30	1.43	1.40	1.80	1.80	1.46
1.20	1.45	1.10	1.04	1.90	2.10	1.00	1.07
2.50	1.82	1.80	1.74	1.30	1.10	1.70	1.32
1.80	1.83	3.10	2.28	2.30	2.40	3.60	2.10
1.10	1.28	1.10	0.66	1.40	0.90	1.20	1.18
2.10	2.67	2.50	2.62	1.70	2.60	1.40	2.49
	2.14	1.70	1.52		1.50	1.50	1.59
					0.80	0.60	1.09
					1.20	0.90	1.34
					2.20	2.80	0.90

Table 4.6. Soil texture percentages

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