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ONDOKUZ MAYIS UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
DEPARTMENT OF SOIL SCIENCE AND PLANT NUTRITION**



**MULTI-CRITERIA DECISION ANALYSIS (MCDA) AND
ARTIFICIAL NEURAL NETWORK (ANN) FOR ASSESSING
SOIL QUALITY VARIATION UNDER DIFFERENT LAND USE
AND LAND COVER IN SAMSUN, TÜRKİYE**

Master's Thesis

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ACCEPTANCE AND APPROVAL OF THE THESIS

The study entitled “**MULTI-CRITERIA DECISION ANALYSIS (MCDA) AND ARTIFICIAL NEURAL NETWORK (ANN) FOR ASSESSING SOIL QUALITY VARIATION UNDER DIFFERENT LAND USE AND LAND COVER IN SAMSUN, TÜRKİYE**” prepared by **Endalamaw Dessie ALEBACHEW**, and supervised by **Prof. Dr. Orhan DENGİZ**, was found successful and unanimously accepted by committee members as Master thesis, following the examination on the date 14.8.2024.

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ÖZET

SAMSUN, TÜRKİYE'DE FARKLI ARAZI KULLANIMI VE ARAZI ÖRTÜSÜ
ALTINDA TOPRAK KALİTESİ DEĞİŞİMİNİN DEĞERLENDİRİLMESİ İÇİN ÇOK
KRİTERLİ KARAR ANALİZİ (MCDA) VE YAPAY SINIR AĞI (YSA)

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Toprak kalitesi, toprağın biyolojik üretkenliği sürdürmek, çevre kalitesini korumak ve bitki ve hayvan sağlığını geliştirmek için ekolojik kısıtlamalar dahilinde çalışabilme yeteneğidir. Halihazırda çeşitli arazi kullanım türlerine maruz kalmış topraklarda sq'nun değerlendirilmesi ve izlenmesi, bozulmuş toprakların özelliklerini tanımlamak ve sürdürülebilir arazi uygulamalarını ortaya çıkarmak için yararlı araçlar sunabilir ve arazi yöneticilerinin ve karar vericilerin sq tükenmesini önlemek için iyi bilgilendirilmiş önlemler almasına olanak sağlayabilir. . Bu araştırmanın amaçları, toprağın besin seviyeleri, biyolojik özellikleri, fiziksel ve kimyasal özellikleri gibi çeşitli arazi kullanım türleri genelinde toprak kalitesi göstergelerinin kapsamlı bir değerlendirmesini yapmak; ekili alanların, ormanların ve otlatma alanlarının toprak kalitesi üzerindeki spesifik etkilerini belirlemek; ve arazi kullanımı değişikliklerine tepki olarak toprak kalitesindeki mekansal değişiklikleri araştırmak. Üç farklı arazi kullanımından 54 toprak örneği alındı. Yani tarım, mera ve orman arazileri. 26 toprak kalite parametresi (toprağın fiziksel özellikleri, toprağın kimyasal özellikleri, verimliliği veya besin içeriği ve toprağın biyolojik özelliği) seçilip analiz edildi. Bu toprak kalite parametreleri, toprak kalitesine katkılarına göre daha iyi ve daha az iyi parametreler olarak sınıflandırılmıştır. Elde edilen sonucu normalleştirmek için standart puanlama fonksiyonu uygulandı. Standart puanlama fonksiyonunu takip eden ahp teknikleri her parametre ve dört ana grup için uygulandı. Daha sonra her bir toprak kalite parametresinin ağırlığı belirlendi. Son olarak standart puanlama fonksiyonu ile ahp teknikleriyle belirlenen parametrelerin ağırlıkları çarpılarak toprak kalite indeksi hesaplandı. Sonunda, toprak kalitesini belirlemek için matlab yazılımı kullanılarak yapay sinir ağı da uygulandı. Hesaplanan toprak kalite indeksi çok düşük, düşük, orta, yüksek ve çok yüksek olmak üzere beş gruba ayrıldı. Sonuç, toplam alanın 235,17 hektarlık alanını (%48,39) kapsayan alanın çoğunluğunun orta düzeyde toprak kalitesine sahip olduğunu ortaya koymaktadır. Toplam alanın %31'i yüksek ve çok yüksek düzeyde toprak kalitesi altındadır. Toplam alanın yalnızca %20,65'i düşük ve çok düşük düzeyde toprak kalitesine sahiptir. Toprak kalitesi ile arazi kullanımı arasındaki karmaşık bağları anlamak, başarılı arazi yönetimi, sürdürülebilir tarım ve ekosistemlerin korunması için kritik öneme sahiptir.

Anahtar Sözcükler; analitik hiyerarşi süreci, yapay sinir ağı, arazi kullanımı arazi örtüsü, toprak kalitesi, toprak kalite indeksi

ABSTRACT
**MULTI-CRITERIA DECISION ANALYSIS (MCDA) AND ARTIFICIAL
NEURAL NETWORK (ANN) FOR ASSESSING SOIL QUALITY
VARIATION UNDER DIFFERENT LAND USE AND LAND COVER IN
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Soil quality is the soil's ability to work within ecological constraints to maintain biological productivity, preserve environmental quality, and enhance plant and animal health. Assessing and tracking SQ in soils that have already been exposed to various land use types may offer useful instruments for identifying the characteristics of degraded soils and exposing sustainable land practices, allowing land managers and decision-makers to take well-informed measures to prevent SQ depletion. The objectives of this research are to conduct an extensive evaluation of soil quality indicators across various land use types, such as nutrient levels, biological properties, physical and chemical properties of soil; to identify the specific impacts of cultivated land, forest, and grazing land on soil quality; and to investigate spatial variations in soil quality in response to land use changes. 54 soil samples were taken from three different land uses. Namely, Agriculture, pasture and forest land. 26 soil quality parameters (Physical properties of soil, chemical properties of soil, fertility or nutrient content and biological property of soil) was selected and analyzed. Those soil quality parameters were classified as more better and less better parameters based on their contribution to soil quality. Standard scoring function was applied to normalize the result obtained. Following standard scoring function AHP techniques was applied for each parameter and for the main four groups. Then the weight of each soil quality parameters was determined. Finally soil quality index was calculated by multiplying standard scoring function with weight of parameters determined by AHP techniques. At the end, Artificial neural network also applied using MATLAB software to determine soil quality. The calculated soil quality index was classified into five groups as very low, low, moderate, high and very high. the result reveals that, the majority of the area falls in the moderate level of soil quality which cover 235.17 ha area (48.39%) of the total area. 31% of the total area is under high and very high level of soil quality. Only 20.65 %of the total area is low and very low level of soil quality. Understanding the complex links between soil quality and land use is critical for successful land management, sustainable agriculture, and preservation of ecosystems.

Key words; Analytical hierarchy process, Artificial Neural Network, Land use Land cover, Soil quality, Soil quality index

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SYMBOLS AND ABBREVIATIONS

AHP	: Analytical Hierarchical Process
ANN	: Artificial Neural Network
CI	: Consistency Index
CR	: Consistency Ratio
CV	: Coefficient of Variation
ENVI	: Environment for Visualizing Images
ISRIC	: International soil references information center
MCDA	: Multi-Criteria Decision Support System
RI	: Random Index
SPAW	: Soil-Plant-Air-Water
SQI	: Soil Quality Index
SSF	: Standard Scoring Function
USGS	: United state Geological Survey
WRB	: World Reference Base for Soil Resources

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1. INTRODUCTION

1.1 Background of the study

Soil quality is the inherent property of soil which is expressed as the ability of the soil to support plant and animal productivity, preserve or improve the quality of the water and air, throughout natural and managed ecosystems. It is crucial to create and implement a suitable approach for assessing soil quality since it will have a significant impact on the output of agriculture (Doran and Parkin, 1994; Cao and Zhou, 2008). According to Askari and Holden (2014) and Nakajima et al. (2015), soil quality plays an essential role for human health since it influences not just food production but also ecosystem diversity and function. Soil quality in general cannot be assessed directly on farms or in labs due to its complexity. However, it can be determined from the measurement of several characteristics of the soil regarded as indicators of soil quality (Cardoso et al., 2013; Zornoza et al., 2015). Soil Provides the most critical resources for food and habitat, an essential component of the terrestrial ecosystem, which are the foundations of the needs of life (Boudjabi and Chenchouni 2022). Since soil quality (SQ) simultaneously addresses sustainability and productivity, developing nations are finding SQ to be increasingly important (Mulat et al., 2021).

The physical, chemical, and biological Properties of soil are altered by land use type, and agricultural management practices experienced in the specific area can be taken to be the primary factors influencing soil quality (Caravaca et al. 2002). Turkey's fast-growing population and large-scale migration from eastern and southern countries make the sustainability of agriculture even more significant (Çelik et al., 2021). The country's ability to sustain its current level of soil quality and agricultural output is being challenged by issues with the soil, including nutrient deficiencies, salinity, compaction, and a decrease in organic matter content (Günel et al., 2015). Conservative agricultural practices must be closely monitored to assess their lasting effects on soil quality, and those that degrade soil quality should be avoided. In order to assess their soils' fertility status and potentially boost the yield of crops, farmers mostly analyze the chemical properties of the soil and different soil fertility parameters such as the presence of macro and micro nutrients in the soil. However, concentrating solely on soil pH, electrical conductivity, nitrogen, phosphorus, potassium, and occasionally zinc and iron levels, may make it easy

to disregard further limitations pertaining to the biological and physical characteristics of soils (Nunes et al., 2019). The issue of extensive or inappropriate land use leading to a decrease in soil quality or deterioration has long-standing roots. The process of degradation affects one or more of the functions of soil, either totally or partially (Blum and W.E, 2008). A significant and frequently severe impact on soil quality is caused by the over-exploitation of agro-habitats and the conversion of land uses, such as forests and pastures, to croplands (Rahmanipour et al., 2014).

There are different methods of assessing soil quality including soil card design and test kits (Ditzler and Tugel, 2002), soil quality index methods (Doran and Jones, 1996; Marzaioli et al., 2010a; Qi et al., 2009), and geostatistical methods (Sun et al., 2003). Since they are simple to use and have a wide range of quantitative applications (Qi et al., 2009), soil quality indicators are the most often used technique of soil quality assessment (Andrews et al., 2002). In the current study, both Multi-Criteria Decision Analysis (MCDA) Analytical Hierarchy Process (AHP) and Artificial Neural Network (ANN) was applied to determine soil quality index in the study area. According to Karlen et al., 2003, soil quality index starts with (1) identifying soil quality indicators (physical, chemical, biological and soil fertility parameters, (2) normalizing the indicators that are selected using standard scoring function, (3) Assigning weight for the selected parameters based on Analytical Hierarchy process (AHP) method (4) integrating indications into an index. Soil quality parameters are normalized to produce non-dimensional indicators, which are later combined by addition, multiplication, or weighted average method to produces Soil quality index (Dengiz, 2020; Andrews et al., 2002).

ANN is applicable in a wide range of situations (Mohammadi et al. 2020; Vaheddoost et al. 2020 and Köhler 2021). ANNs are mostly used for nonlinear pattern (Pacci et al., 2022). Artificial neural networks have produced remarkable effects, particularly when it comes to resolving problems in a variety of fields that are currently challenging and complex to manage. When the fundamental relationship remains a mystery, ANN can identify and learn several kinds of correlation between independent and dependent, allowing the dependent variants to be estimated using current independent variants data sets (Suo et al. 2010).

Although a number of academic studies have recently been published (Smith et al., 2017; Brown and Carter, 2019), they provide valuable information into the effects of specific land use activities, such as agriculture, forestry, and grazing land, on soil quality. However, there is an obvious absence of broad comparative studies across different land use types, which limits the understanding of the corresponding effects of different human activities on soil quality. Additionally, little is known about how different land use classes interact with one another and how spatial variation affects soil quality. Therefore, the aim of this study is to Execute an extensive assessment of soil quality indicators under various land use types, such as nutrient levels, biological properties, physical and chemical properties of soil; to identify the specific impacts of cultivated land, forest and grazing land on soil quality and to examine spatial variations in soil quality in responses to land use changes.

1.2. Statement of the problem

The primary concerns in environmental studies over the past fifty years have been the degradation of soil, climate change, and the security of water and food. In addition to these drawbacks, deforestation, land degradation, and changes in land use can exacerbate the problems associated with food and water security as well as climate change (Villarino et al., 2017). Soil quality is an essential factor in sustaining agricultural productivity and maintaining environmental health. The soil quality index (SQI) is the most frequently utilized technique, due to its ease of use and quantitative versatility (Andrews et al. 2002; Bhardwaj et al. 2011; Hammac et al. 2016). The properties of soil can be drastically changed by agricultural methods such as tillage, monoculture, and the application of agrochemicals (Kumar et al., 2017). Similarly, disruptions to natural ecosystems may result in changes in the quality of the soil (Li et al., 2019). Designing sustainable land management strategies requires an understanding of how various land use scenarios affect soil attributes such as microbial activity, organic matter, and nutrient content.

Despite the fact that Various scholarly literature now in publication (Smith et al., 2017; Brown and Carter, 2019) offers insightful information about the impacts of particular land uses activities, including forestry, grazing land, and agriculture on soil quality, there is a noticeable gap in detailed comparative studies across various land use types, restricting our understanding of the corresponding effects of various human

activities on soil quality. Furthermore, Spatial variation and the interactions between different land use classes on soil quality remain unexplored.

1.3. Objectives

1.3.1. General Objective

The main aim of this study is to determine Soil Quality under Different Land Use Types (Forest, Agricultural land and pasture) in Samsun, Turkey.

1.3.2. Specific Objectives

1. Executing an extensive assessment of soil quality indicators under various land use types, such as nutrient levels, physical and chemical properties of soil;
2. To identify the specific impacts of cultivated land, forest and grazing land on soil quality;
3. Examining spatial variations in soil quality in responses to land use changes.

1.4. Significance and Novelty

Several studies have indicated that difference in land use have a significant impact on soil attributes such as nutrient concentration, organic matter, microbial activity, and overall soil structure. However, The impact of different land uses on soil quality remains an extremely challenging and understudied component of soil science. The fundamental focus of the study is to investigate and understand how land management practices and human activities affect soil production and health in various contexts.

Understanding the complex interactions between land use and soil quality is critical for effective land management, agricultural sustainability, and ecosystem protection. The study intends to add to the current body of knowledge by providing an in-depth assessment that can inform policymakers, land managers, and researchers on the effects of land use changes on soil ecosystems. In addition, the findings will be useful for policymakers, land managers, and agricultural professionals looking to implement methods that reduce negative impacts on soil quality while promoting sustainable land use.

2. LITERATURE REVIEW

2.1 Soil Quality

According to Boudjabi and Chenchouni (2022) soil is the most vital resource for shelter and nutrition, which are the foundation of all living humans' needs. It is also a crucial component of the ecosystem of the earth. Soil quality is a term used to assess soil production potential and the functioning of ecosystems, and it can be defined by soil physical, chemical, and biological characteristics (Mamehpour et al., 2021). Soil quality is the ability of the soil to work within ecosystem limits in order to support biological productivity, preserve environmental quality, and advance the health of plants and animals (Doran and Parkin 1994). Evaluating and tracing SQ in soils that are already exposed to various land use types might offer useful instruments for identifying the characteristics of degraded soils and exposing sustainable land practices, enabling land managers and decision-makers to take well-informed measures to prevent SQ degradation (Brhane, 2014). High-quality soil benefits food production, human health, and long-term ecosystem growth (Li et al., 2018).

Soil quality has a significant impact on plant development and yield due to biological changes, organic matter degradation, the hydrological cycle, and chemical reactions in the soil (Dogan & Gülser, 2020). The ability of a soil that provides plant nutrients and water for plant development in order to provide food, fiber, and fuel for living things are referred to the productivity (Sanden et al., 2019). Because of the country's rapidly growing population and the large-scale migration from eastern and southern countries, Turkey needs to produce agricultural products sustainably (Çelik, et al., 2021). Furthermore, farmers unintentionally carry out traditional agricultural techniques such as flood irrigation, stubble burning, and conventional tillage (Korucu et al., 2009). Hence, the country's ability to sustain its current level of soil quality and output from agriculture is being threatened by soil issues such as nutrient deficiencies, salinity, compaction, and a decline in organic matter content (Günel et al., 2015).

In the majority of terrestrial ecosystems, increasing population and expansion of agriculture are two of the primary and widespread causes of the degradation of soil quality (Rahmanipour et al., 2014). As defined by Karlen et al. (2013), soil quality is the ability to carry out activities derived from soil properties within a certain ecosystem and

depending on its use under a specific management. This capacity must be determined through a multi-decision process that simplifies and weighs the effects of multiple interconnected and distinguishable aspects, including the soil's physical, chemical, fertility and biological factors (Mokarram & Mirsoleimani, 2018). According to Askari and Holden (2014) and Nakajima et al. (2015), soil quality is crucial for human well-being since it influences not just food production but also the variety of ecosystems and function. Evaluating SQ is critical for making sound decisions that will increase crop output while boosting the condition of the environment (Zahedifar, 2023). Although it is impossible to quantify perfectly, soil quality can be determined from an assessment of the physical, chemical, and biological characteristics of the soil (Bhardwaj et al. 2011; Obade and Lal 2016). Soil's chemical and physical characteristics are widely utilized for determining soil quality (Xia et al. 2015; Rojas et al. 2016). The biological properties of the soil as well as soil nutrient content (Soil Fertility parameters) are primarily utilized for small-scale purposefully ruined ecosystems, such grasslands and forest (Parisi et al. 2005; Ritz et al. 2009). preserving and enhancing soil quality is crucial for ensuring the health of ecosystems (Delelegn et al., 2017). Among numerous approaches for soil quality evaluation, the soil quality index (SQI) has been widely accepted and employed since it is not only easy to use but also represents the impacts of field management on soil quality (Serri et al., 2022; Taghipour et al., 2022).

2.2. Factors Influencing Soil Quality

2.2.1. Physical Factors

These are related with the physical structure of the solid components and pores, which includes soil texture, dry bulk density, porosity, aggregate stability and durability, soil crusting, compaction of the soil, and surface soil depth (Nortcliff, 2002). Soil quality is affected by different natural and anthropogenic factors. Soil erosion is one of the main factors affecting soil quality, since erosion modifies soil depth, it has a significant impact on crop productivity and the storage of nutrients and water, making it a crucial signal for soil quality. the depth of the soil surfaces affects nutrient storage, growth of roots, and entire resilience of ecosystems. Similar to this, differences in aggregate strength, size, and stability have a significant role in determining the structural quality of the soil as well as its capacity for preventing erosion (Blanco and Lal, 2008). The conversion of land uses

due to human activities highly affect the physical quality of soil. Li et al., 2007, stated that the conversion of natural land into cultivated land affect the infiltration capacity of soil as well as soil properties which accelerate the rate of soil erosion in the area. Which results in soil degradation and the reduction of organic matter content in the soil and decrease the stability of aggregate which affect the structure of soil (Wu and Tissen, 2002; Li et al., 2007).

Aggregate stability of the soil is affected by change in management practices which affects porosity, field infiltration, and saturated water capacity, is crucial to improve the absorption of water while preventing erosion (White, 2010; Oliver et al., 2013). Soil texture, the amount of sand, silt and clay has a significant impact on the retention of water, drainage, and availability of nutrients in the soil (Brady and Weil, 2008). The ratio of clay, silt, and sand influences drainage and the soil's ability to retain water. Sandy soils are drought-prone due to their rapid drainage and low water retention. Clayey soils, on the other hand, encourage waterlogging and decrease root oxygen supply due to their ability to store water but drain poorly (Guo, 2021).

2.2.2. Chemical Factors

Soil quality is also influenced by chemical factors such as pH, Electrical conductivity (EC), organic matter and calcium carbonate content. Soil pH is one of the chemical properties of soil which affect soil quality that is used to determine the soil reaction and it indicate the acidity and alkalinity of soil. Aluminum and manganese are more soluble within acidic conditions, which can be hazardous to plants, whereas phosphorus and molybdenum become less readily available (White, 2006; Brady & Weil, 2008). Soil with lower pH values has low macro nutrient content and high micro nutrients content. Acidic soil increases the solubility of mineral elements. The soil's ability to retain nutrients and be fertile is measured by the total exchangeable cations that it can absorb. This has a direct relationship to both clay and organic matter content of the soil. Cation exchange capacity is typically high in soil with high sand values (Javed et al., 2022). Soil organic matter is also one of the chemical factors affecting soil quality. The amount of organic matter present in cultivated land is much lower than the forest land and pasture land. Over a 12-year period, soil organic matter in cultivated soils decreased by 44 and

48% for the 0-10 cm layer and 48 and 50% for the 10-20 cm layer, respectively, when compared with soil organic matter in forest and pasture soils in a southern Mediterranean highland of Turkey (Celik, 2005). Agriculturalist primarily examine soil pH, electrical conductivity, nitrogen, phosphorus, potassium, and, on occasion, zinc and iron to figure out soil fertility, which may be useful in enhancing crop output. But focusing only on chemical soil indicators and nutrient content risks disregarding additional constraints associated with soil's physical and biological characteristics (Nunes et al., 2019). High CEC soils contain more nutrients for a longer duration of time and can gradually release them to plants, hence improving soil fertility (Sparks, 2003; Troeh & Thompson, 2005).

2.2.3. Biological Factor

Biological factors play an important part in determining the Soil Quality Index (SQI), which evaluates the productivity of soil, sustainability, and health. Soil quality is influenced by a wide range of biological factors, including soil microbial biomass, microbial diversity, soil organic matter, enzyme activity, mycorrhizal connections, and soil fauna. Soil microbial biomass plays a crucial role in the development of soil structure, organic matter breakdown, and the cycling of nutrients. Higher microbial biomass has a positive correlation with better soil fertility and structure, which in turn promotes plant production and development (Li et al, 2023).

The variety of soil microbes, including fungi, bacteria, and archaea, is essential for preserving the functions of soil ecosystems. Rich microbial populations support effective nutrient cycling and increase soil resistance to environmental impact. Microbially different soils are more resistant to adverse environmental conditions such heavy metal contamination soil erosion and drought. This diversity also supports a wider range of biochemical processes, improving SQI and promoting overall soil health (Singh et al., 2022).

Important measures of microbial activity and soil fertility are soil enzymes, such as urease, phosphatase, dehydrogenase, and β -glucosidase. These enzymes aid in important metabolic reactions include the release of nutrients and the breakdown of organic materials. Improved soil structure and nutrient availability have been associated with increased activity of enzymes, which increases SQI (Wang et al., 2023). Improved soil structure, a larger capacity for holding water, and enhanced microbial activity and

diversity are all connected with higher SOM levels. Together with one another, these elements improve the fertility of the soil and environmental sustainability which has an advantageous impact on soil quality index (Chen et al., 2023). The functions of soil fauna, especially worms and nematodes, in aeration, nitrogen cycling, and organic matter digestion, make them vital to soil quality. Enhanced soil fertility and structure are a consequence of higher microbial biomass and activity brought about by earthworm existence. Nematodes maintain a healthy microbial community by feeding on other soil organisms, which helps in the cycling of nutrients (Brown et al., 2023). Another significant component in soil health is the interactions that occur between plants and soil microbes. Root exudates from plants affect microbial populations by acting as growth substrates for microorganisms. Increased nutrient cycling and improved soil structure are two benefits of diverse plant-soil interactions which increase SQI (Garcia-Palacios et al., 2023).

2.3. Effects of Land use and Land Management on Soil Quality

Sustainable land use is the first step in soil quality management. Significant plant macronutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), have been reduced by industrial farming techniques in different regions of worldwide, which ultimately contribute to a decline in the quality of the soil (Lazarus, 2014). Pham et al. (2018) discovered notable differences in total nitrogen (TN) and soil organic matter (SOM) under several land-use types in central Vietnam as a result of long-term cultivation for the growth of agricultural enterprises farming and deforestation. Proper land use may both preserve and enhance the quality and health of the soil (Lal, 2015; Raiesi, 2017). According to several studies (Yu et al., 2014; Hall et al., 2017; Abdalla et al., 2018). Inequitable land uses or managements have been found to be the primary cause of a decline in soil quality due to ongoing declines of soil organic matter, nutrients, and soil physical structure.

The soil's characteristics influence how humans utilize the environment, which, in turn, influences the quality of the soil (Guo, 2021). According to Shukla et al. (2004), bulk density is the most effective measure of soil quality for tracking changes in soil characteristics over time resulting from land use and management. Understanding whether land management techniques that increase agricultural output are good for the

environment or, more likely, have a detrimental effect on the quality of the soil in both agricultural and grazing regions is necessary to find sustainable ways to feed the growing population (Karaca et al., 2021). Agricultural production has an enormous influence on decisions and judgments about soil quality, which are typically based on evaluations of soil quality based on crop yield (Tesfahunegn et al., 2013). Turkey's sensitive high-altitude ecosystems are under pressure due to overgrazing, deforestation, and excessive crop production (Evrendilek et al. 2004). When land is employed for human purposes, such as large-scale commercial or agricultural production, a substantial amount of natural vegetation must be removed, lowering soil quality as revealed by physical and biochemical characteristics (Veldkamp et al., 2020). Hydraulic characteristics can be greatly affected by changes in land management and use (Bormann and Klaassen, 2008; Zhou et al., 2008). Significant effects of land use on bulk density and saturation hydraulic conductivity (K_s) were noted by Bormann and Klaassen (2008). Bodhinayake and Cheng Si (2004) proved that a modification in land use altered the near-saturated hydraulic properties of surface soil. Pastures had higher infiltration rates and K_s than regularly farmed fields (Sonneveld et al., 2003).

3. MATERIALS AND METHOD

3.1. Descriptions of The Study Area

The study area is found in the southern coast of the Black Sea. The study area covers 486 ha. Geographically, the study area is located 41°20'15'' to 41°21'31''N latitude and 36°08'40'' to 36°11'0''E longitude. Based on international soil references information center (ISRIC) WRB soil classification system the majority of the area is covered with Haplic Cambisol, followed by Haplic Luvisols and Rendzic leptosol respectively. The elevation ranges from 127.6 to 565.2 m.a.s.l. (Figure 3.1).

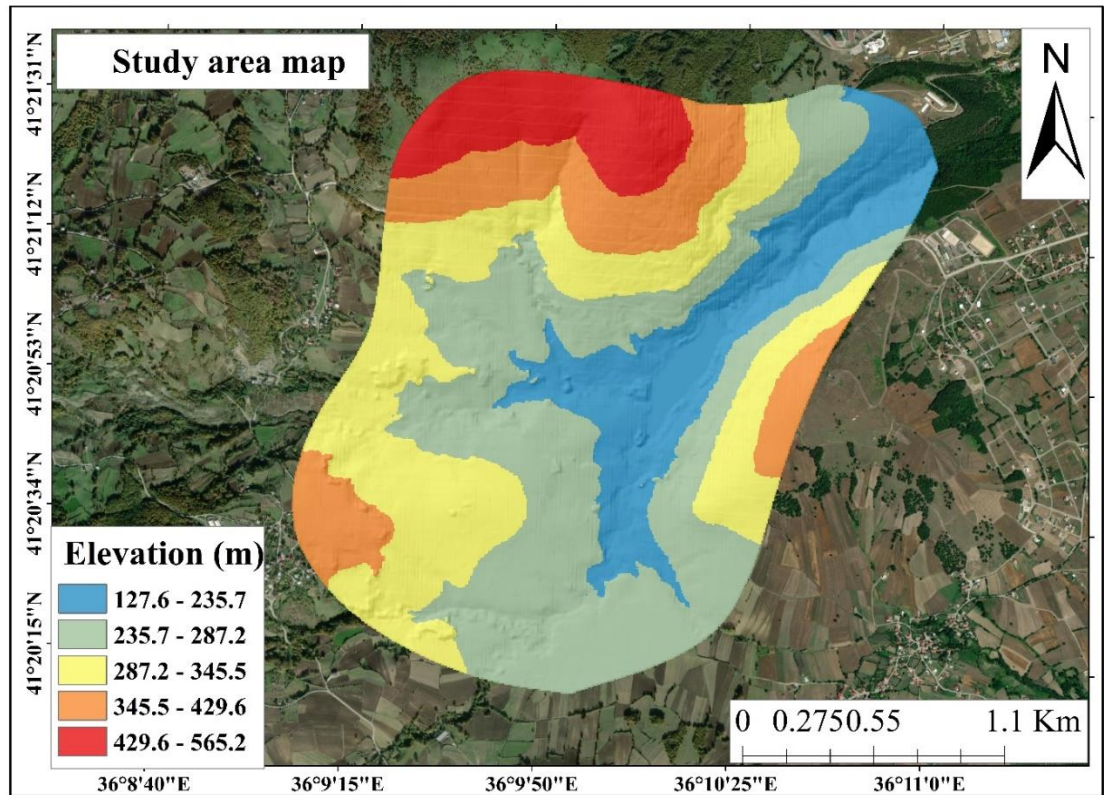


Figure 3.1. Study area map

3.2. Land Use

Landsat image with low cloud cover was obtained from USGS Earth explorer website (Landsat 8 2023), and image sharpening was performed using high resolution panchromatic image and low resolution multi spectral to increase the resolution of the image. Image classification was performed in "Environment for Visualizing Images (ENVI) software. A supervised image classification technique with maximum likelihood classification algorithm was applied. Once the image was successfully classified, the

classification accuracy was evaluated. To validate and cross-check whether the information produced by classification is consistent with what actually exists on the ground.

3.2. Soil Sampling

Using ArcGIS software, 54 sampling points were spread randomly throughout the study region. 25 sampling stations were on forest land, 16 were on cultivated land, and the remaining 13 were on pasture. A soil sample was collected from the top layer of these samples. After collecting soil samples 26 soil quality parameters such as soil textural classes, clay, silt and sand, organic matter content, bulk density, hydraulic conductivity, available water capacity, lime content (CaCO_3), moisture content, electrical conductivity, pH, aggregate stability, dispersion ratio, structural stability index, Calcium, magnesium, Nitrogen, phosphorus, potassium, sodium, iron, copper, zinc manganese, carbon dioxide, microbial biomass and microbial quotient, were selected and analyzed for each land uses based on the principles given in Table 3.1.

The collected soil samples were divided into More Better and Less Better based on their contribution to soil quality. More Better includes organic matter, clay, moisture content, nitrogen, phosphorus, potassium, calcium, magnesium, iron, copper, manganese, zinc, pH, lime content, aggregate stability. Less better parameters also include Bulk density, hydraulic conductivity, sand, silt, electrical conductivity, dispersion ratio, structural stability index, sodium, carbon dioxide and microbial quotients.

Table 3.1. Soil quality parameters

Parameters	Principles	References
Texture	Hydrometer method	Bouyoucos (1951)
Bulk density	SPAW Model	Soilwater characteristics
Available water content	SPAW Model	Soilwater characteristics
Aggregate stability	Wet Sieving	Kemper and Rosenau (1986)
pH	Soil water suspension	Soil Survey Laboratory (1992)
Electrical conductivity	Soil water suspension	Soil Survey Laboratory (1992)
Dispersion ratio	$\frac{A}{B} * 100$	Lal and Elliot (1994)
Structural Stability Index	$\sum A - \sum B$	Lal and Elliot (1994)
Moisture content		
Organic Matter	Walkley-Black wet digestion	Nelson & Sommers (1982)
Available Water Content	Difference of FC and PWP	Klute (1986)
CaCO ₃	Scheibler Calcimeter	Soil Survey Staff (1993)
CO ₂ , MBC,	Microbial induced respiration method	Anderson and Domsch (1978)
qCO ₂	Ratio of CO ₂ and MBC	
Total nitrogen	Kjeldahl	Bremner & Mulvaney (1982)
Phosphorus	Bray and Kurtz (Ph<7), Olsen (Ph>7)	Kacar (1994)
K, Ca, Mg, Na	Ammonium acetate extraction, flame spectrometry detection	Soil Survey Laboratory (1992)
Fe, Cu, Zn, Mn	DTPA extraction, AAS detection	Lindsay & Norvell (1978)

A represents the fraction of silt plus clay in suspension, while B represents the percentage of silt plus clay dispersed using a chemical agent.

To equalize the fluctuation in the units of the indicators, a standard scoring function (SSF) was employed and scores ranging from 0 to 1 were calculated using the methods below (Andrews et al., 2002).

$$SSF \text{ More Better} = \left((0.9) * \frac{(X - Min)}{(Max - Min)} \right) + (0.1) \quad \text{Equation 1}$$

$$SSF \text{ Less Better} = \left((1 - (0.9) * \frac{(X - Min)}{(Max - Min)}) \right) \quad \text{Equation 2}$$

Where X; Soil quality parameter. Min; Minimum Value. Max; Maximum Value. Mean; Average Value.

3.3. AHP Techniques for Weighting soil quality parameters

Following standard scoring functions, the selected soil quality parameters are further divided into four categories including Soil physical properties (clay, sand, silt, bulk density, available water content, moisture content and hydraulic conductivity), chemical properties (pH, Electrical conductivity, Organic matter and CaCO₃), fertility (N, P, K, Ca, Mg, Zn, Fe, Mn, Cu and Na) and Biological Factors (carbon dioxide, microbial biomass carbon and microbial quotient). In the analytical hierarchy technique, a pairwise comparison matrix is employed to calculate the weight of each soil quality indicator.

The ideal value of the parameters is established using various literatures, and different weights are assigned to each parameter. Weighting is used to highlight the importance or preference of each component in terms of soil quality in comparison to other factors. According to a Saaty (1980) scale Weights are calculated by comparing two elements at a time on ranging from 9 to 1/9 (Table 3.2).

Initially by Considering the effect of the criteria on soil quality, a comparison matrix (n x n dimensions) is produced between selected parameters (Eq. 3).

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{1n} \\ a_{21} & a_{22} & a_{23} & a_{2n} \\ a_{31} & a_{32} & a_{33} & a_{3n} \\ a_{n1} & a_{n2} & a_{n3} & a_{nn} \end{bmatrix} \quad \text{Equation 3}$$

All entries in this created matrix must have a positive value.

A: binary comparison matrix a_{ij} : the importance of element i compared with element J (i, J,.....n) properties of binary comparison matrix;

$$a_{ji} = 1/a_{ij}.$$

$$a_{ij} > 0 (i, j = 1, 2, \dots, n)$$

In order for binary comparison to be fully consistent.

$$a_{ik} = a_{ji} a_{jk} (i, j, k = 1, 2, \dots, n).$$

If consistent $a_{ij} = W_i/W_j$.

W_i = priority value for element i, W_j : priority value for element J.

According to Saaty (1977), the values of the parameters on the diagonal of the comparison matrix must equal 1 because each parameter is equally important when compared to the others. The normalization of the matrix is done following the creation of the comparison matrix table. The data in each cell was divided by the total number of columns in that cell in order to accomplish normalization. In the normalization table generated by binary comparisons, the arithmetic mean of the total data in each row is used to create the W column vector, also known as the priority vector. The fraction of the criteria's important weights is expressed by this vector (Şenol et al., 2020) (Eq. 4).

$$W_i = \frac{\sum_{j=1}^n a_{ij}}{n} \quad \text{Equation 4}$$

a_i = element i in the normalization table, a_j = element j in the normalization table, n = number of criteria and W_i = priority vector or weighing of criterion i.

The binary comparison matrix (A) is multiplied by the priority vector (w) to obtain the vector D (Eq. 5).

$$D = A * W = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{1n} \\ a_{21} & a_{22} & a_{23} & a_{2n} \\ a_{31} & a_{32} & a_{33} & a_{3n} \\ a_{n1} & a_{n2} & a_{n3} & a_{nn} \end{bmatrix} * \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ w_n \end{bmatrix} = \begin{bmatrix} D_1 \\ D_2 \\ D_3 \\ D_n \end{bmatrix} \quad \text{Equation 5}$$

The elements of the D column vector ($D_1 = a_{11} \times w_1 + a_{12} \times w_2 + \dots + a_{1n} \times w_n$) are divided by the elements of the priority vector (W) to obtain the E values in Eq. 6.

$$E_i = \frac{D_i}{w_i}, \quad I = 1, 2..n \quad \text{Equation 6}$$

The arithmetical mean of the E_i values is determined by dividing their total by the number of criteria. This operation finds λ , the biggest eigenvalue of the matrix known as max (Eq. 7).

$$\lambda_{max} = \frac{\sum_{i=1}^n E_i}{n} \quad \text{Equation 7}$$

where λ_{max} is the maximum eigenvalue and n is the number of criteria.

The produced comparison matrix's consistency is determined by dividing the consistency ratio by a random index. The value of the random index is displayed in Table 3.3. To ensure consistency in the matrix, a value of CR must be < 0.1 .

$$CR = CI/RI$$

$$\text{Equation 8}$$

$CI = (\lambda_{\max} - n)/(n - 1)$ where: CI is the consistency index, $\lambda_{\max}$ is the largest or principal value of the matrix and n is the order of the matrix.

Table 3.2. Analytical Hierarchy scale Assessment Scale (Satty, 1980)

Intensity of importance	Definition	Explanation
1	Equal importance	Two variables are required equally to the intended objective
3	Weak importance of one over another	One variable is slightly more important than the other variable being compared
5	Essential or strong importance	One variable is strongly important over the other variable being compared
7	Demonstrated importance	Intermediate scale between the two adjacent comparisons
9	Absolute importance	One variable is very strongly important over the other variable being compared
2, 4, 6, 8	The reciprocal of the above non-zero values	When a compromise is necessary

Table 3.3. Values of Random Index (RI)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
R	0.0	0.0	0.5	0.9	1.1	1.2	1.3	1.4	1.4	1.4	1.5	1.4	1.5	1.5	1.5
I	0	0	8	0	2	4	2	1	5	9	1	8	6	7	9

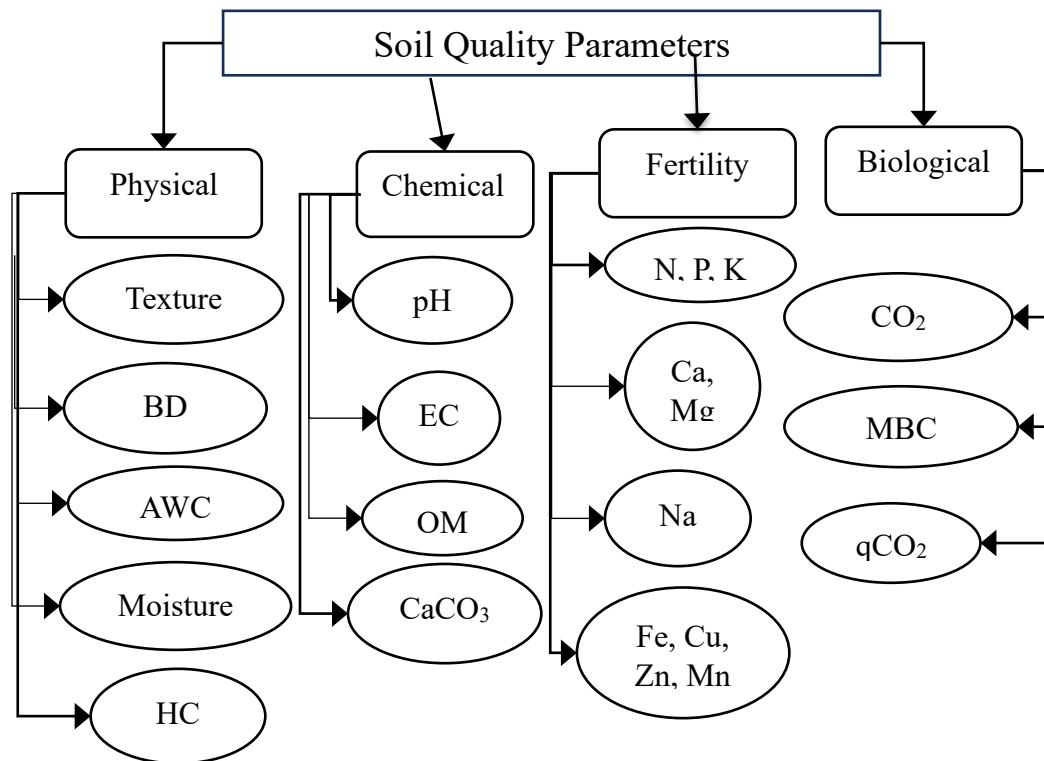


Figure 3.2. Main group of soil quality parameters

3.4. Soil Quality Index

The soil quality index is calculated after determining the standard scoring function and weights for each parameter (Doran and Parkin, 1994).

$$SQI = \sum_1^n (SSF \times Wi) \quad \text{Equation 9}$$

Where SQI; Soil quality index

SSF; Standard scoring function of the parameter

Wi; Weight of the parameters

After the determination of soil quality index using AHP techniques, the area's suitability is divided into five groups, ranging from very low to highly suitable, using Jenks' methods for optimization in ArcGIS.

Artificial neural networks (ANN) have gained significant popularity due to its ability to solve complicated nonlinear issues. It is more convenient than statistical methods, particularly when working with nonlinear systems (Odabas et al. 2014a, b, 2016). In this study, the ANN was implemented in the 64-bit (win64) MATLAB software Matlab® R2012a (7.14.0.739). The Levenberg-Marquardt (LM) method was used to train a neural network. Soil quality parameters such as physical, chemical and biological properties of soil as well as macro and micro nutrients selected as soil quality parameters are used as input and soil quality index (SQI) determined using AHP technique was used as output. The model was trained by using these input parameters and SQI_{AHP} as output. When all weighting indications were modified and the ANN fully approximated the output data as a function of input values, the training procedure was considered complete. The performance of ANN was evaluated by considering the coefficient of determination (R^2) and mean square error of prediction (MSE) (Pacci et al., 2022)

4. RESULTS AND DISCUSSION

4.1. Land Use Land Cover

Landsat image was obtained from USGS website. Image preprocessing techniques was applied before starting the analysis. ENVI 5.3 software was used to analyze the obtained image. The result reveals that agricultural land is the dominant land cover class 38.03% next to forest land 50.02% of the total area (243.13ha). grass land is the third largest land cover which account for 8.98 % of the total area followed by barren land, lake and settlements accounting for 1.23, 1.03 and 0.71% of the total area respectively (Figure 4.1).

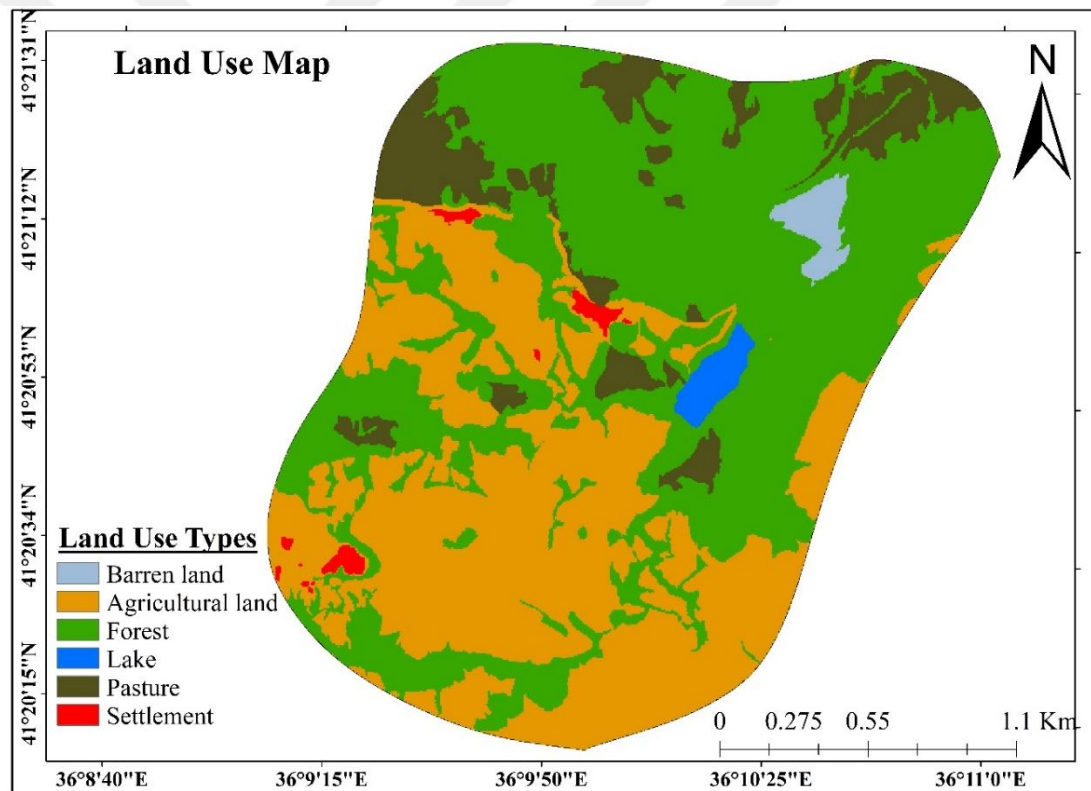


Figure 4.1. Land use map

4.2. Descriptive Statistics of soil quality parameters

4.2.1. Descriptive analytical Statistics of Forest Soil

25 soil samples were taken from forest in the study area. The soil physio-chemical and biological characteristics of these selected soil samples were analyzed and presented in (Table 4.1). The maximum and minimum pH values of these samples vary from 8.03 to 5.27. The organic matter content in this forest land use is high and it varies spatially ranging from 0.90 to 4.41%, low amount of organic matter is found in lower area which might be due to the effect of soil erosion in the lower stream. According to Wilding et al (1994) and Mulla and MCBratney (2000), The variability of these soil quality parameters are classified based on the coefficient of variation as low, medium and high. The coefficient of variation (CV) is a crucial component in describing the shifting nature of the soil qualities (Dengiz et al., 2020). Hydraulic conductivity, Available phosphorus and lime content shows high variation, 174.10, 236.47 and 123.55 respectively. The clay and sand content vary from 53.76 to 6.18 and 85.62 to 22.78 respectively (Figure 4.1). The descriptive statistics of soil biological properties as well as soil fertility parameters is described in the table below. The amount of micro nutrients is relatively high in this land use. The minimum and maximum value of soil quality index in forest was found to be 0.31 and 0.73 respectively.

Table 4.1. Descriptive analytical statistics of forest soil

S.No	Max	Min	Mean	St.D	CoV	Skewness	Kurtosis
EC	2910.00	265.20	1446.21	604.69	41.81	0.20	0.58
pH	8.05	5.27	6.66	0.71	10.60	0.25	-0.73
OM	4.41	0.90	2.63	1.10	41.91	-0.06	-1.26
Clay	53.76	6.18	31.46	11.03	35.05	-0.54	0.92
Silt	29.92	2.44	18.69	6.98	37.32	-0.34	-0.26
Sand	85.62	22.78	49.85	15.79	31.67	0.63	0.22
BD	1.58	1.31	1.45	0.07	5.13	0.12	-0.93
HC	88.51	0.41	12.83	22.33	174.10	2.93	7.95
AWC	13.30	4.80	11.09	2.26	20.33	-1.63	2.11
Agg.St	80.66	15.55	59.03	16.21	27.46	-1.58	2.32
DR	48.89	10.75	23.08	10.58	45.82	1.35	0.88
Fe	86.80	4.64	29.68	24.41	82.26	1.02	0.18
Cu	5.60	0.79	2.74	1.06	38.61	0.67	0.83
Zn	5.92	0.25	2.35	1.72	72.88	0.29	-1.16
Mn	93.16	3.31	23.07	20.51	88.93	1.76	4.45
P2O5	616.54	2.21	51.18	121.04	236.47	4.59	22.08
CaCO3	24.03	1.40	5.50	6.80	123.55	1.95	2.54
Tn	3.68	0.54	2.01	0.81	40.18	0.38	-0.34
Na	1.39	0.11	0.61	0.29	48.01	1.00	1.81
K	2.18	0.18	0.71	0.43	59.87	1.84	4.80
Ca	62.65	31.13	46.54	8.52	18.31	-0.11	-0.70
Mg	74.88	13.89	45.71	16.29	35.63	-0.07	-0.71
mgCO2	0.76	0.17	0.59	0.17	28.08	-0.96	0.03
mgMBC	104.79	15.55	60.52	21.52	35.56	-0.07	0.42
qCO2	0.02	0.01	0.01	0.00	24.65	0.93	1.51
SQI	0.73	0.31	0.58	0.11	18.95	-0.73	-0.03

N.B. Fe, Cu, Zn, Mn, P2O5 are measured in (ppm) and Na, K, Ca, Mg in meq/100g. CO2 and MBC in gsoil/24h.

4.2.2. Descriptive Statistics of Soil in cultivated land

Sixteen soil samples were collected from the cultivated land in the research region. Table 4.2 shows the physiochemical and biological parameters of the selected soil samples. The maximum and minimum values of pH for these samples range from 7.72 to 6.31. The organic matter content in these cultivated land uses is high and varies geographically, ranging from 0.53 to 3.28%. According to Wilding et al. (1994) and Mulla and McBratney (2000), the variability of these soil quality measures is characterized as

low, medium, or high depending on their coefficient of variation. Phosphorus and available zinc vary significantly in this land use, 121.34 and 139.77 respectively. The maximum and minimum values of aggregate stability ranging from 84.74 to 32.78 and also the amount of nitrogen is low in the area, ranging from 0.81 to 2.03. The soil quality index in this land use ranges from 0.32 to 0.71.

Table 4.2. Descriptive analytical statistics of cultivated land

S.No	Max	Min	Mean	St.d	CoV	Skewness	Kurtosis
EC	2699.0	466.80	1750.30	658.19	37.60	-0.35	-0.85
pH	7.72	6.31	7.39	0.41	5.57	-1.92	2.99
OM	3.28	0.53	1.85	0.76	41.21	0.02	-0.46
Clay	70.08	28.82	50.17	13.89	27.69	-0.39	-1.29
Silt	28.73	15.55	21.16	4.92	23.27	0.28	-1.61
Sand	55.62	7.39	28.67	16.63	57.99	0.55	-1.26
BD	1.57	1.25	1.37	0.10	7.21	0.54	-0.71
HC	7.60	0.31	2.59	2.16	83.40	0.89	0.11
AWC	18.50	10.20	12.43	2.15	17.27	1.96	3.82
Agg.St	84.74	32.78	55.85	13.54	24.24	0.17	0.23
DR	33.40	12.43	22.66	6.28	27.70	0.35	-0.89
Fe	26.46	1.71	8.65	5.82	67.36	2.06	5.42
Cu	4.66	0.96	2.64	1.16	43.88	0.34	-0.84
Zn	4.47	0.00	1.09	1.52	139.77	1.42	0.73
Mn	19.25	0.75	6.13	5.21	85.08	1.93	3.22
P2O5	405.45	7.50	100.03	121.38	121.34	2.01	3.25
CaCO3	31.64	1.60	13.23	11.36	85.89	0.46	-1.57
Tn	2.03	0.81	1.29	0.33	25.87	0.43	0.08
Na	0.86	0.12	0.51	0.19	37.29	0.25	0.22
K	2.52	0.18	0.82	0.59	72.32	1.73	3.67
Ca	69.23	39.17	51.70	10.14	19.61	0.39	-1.29
Mg	90.51	37.40	59.51	14.23	23.91	0.43	0.22
mgCO ₂	0.72	0.19	0.36	0.14	39.48	1.10	1.50
mgMBC	67.94	15.52	41.01	14.03	34.23	0.14	-0.21
qCO ₂	0.02	0.00	0.01	0.00	29.48	1.28	3.28
SQI	0.71	0.32	0.55	0.11	20.51	-0.49	-0.58

4.2.3. Descriptive Statistics of Soil in pasture land

In the research area, sixteen soil samples were taken from pasture land. The physiochemical and biological characteristics of the chosen soil samples are displayed in (Table 4.3). These samples aggregate stability ranging from 36.08 to 78.31 which is

considered as good physical quality of soil and the pH values ranging from 7.83 to 5.79 at both the maximum and minimum. This land use exhibits significant variation in phosphorus (184.75) and lime content (135.75). Compared to cultivated land, the amount of micronutrients is comparatively higher, with average values for Fe, Cu, Zn, and Mn being 19.27, 2.55, 1.49, and 17.41, respectively.

Table 4.3. Descriptive Statistics of Soil in pasture land

S.No	Max	Min	Mean	Std	CoV	Skewness	Kurtosis
EC	2673.00	543.60	1689.85	708.45	41.92	-0.21	-1.07
pH	7.83	5.79	6.70	0.59	8.87	0.66	-0.16
OM	3.19	0.23	2.30	0.87	38.01	-1.40	1.60
Clay	55.89	26.09	39.16	9.88	25.23	0.60	-0.59
Silt	36.19	4.64	19.27	7.97	41.34	0.06	1.10
Sand	65.49	11.85	41.57	15.22	36.61	-0.48	-0.15
BD	1.56	1.28	1.43	0.09	6.29	-0.29	-0.71
HC	8.53	0.48	3.33	2.53	76.14	1.02	0.10
AWC	13.10	8.80	11.58	1.15	9.92	-1.09	1.67
Agg.St	78.31	36.08	59.29	12.59	21.23	-0.39	-0.37
DR	39.38	10.04	22.61	7.41	32.77	0.57	1.27
Fe	42.13	1.44	19.27	14.19	73.63	0.46	-1.48
Cu	4.28	1.03	2.55	1.08	42.34	0.12	-0.93
Zn	3.31	0.00	1.49	1.03	69.61	0.51	-0.86
Mn	49.64	1.83	17.41	12.13	69.66	1.64	3.63
P2O5	407.17	1.66	58.01	107.17	184.75	3.34	11.65
CaCO3	22.62	1.20	5.02	6.82	135.75	2.13	3.60
Tn	3.19	0.37	1.74	0.81	46.85	0.11	-0.63
Na	1.23	0.12	0.52	0.25	48.30	1.71	5.54
K	2.19	0.19	0.74	0.56	76.03	1.52	2.51
Ca	58.81	34.24	47.04	7.38	15.68	0.09	-0.64
Mg	69.02	14.63	41.03	16.66	40.60	0.09	-0.85
mgCO2	0.77	0.18	0.55	0.18	32.30	-0.49	-0.20
mgMBC	81.81	7.73	54.62	19.93	36.49	-1.22	1.43
qCO2	0.02	0.01	0.01	0.00	39.27	1.42	2.43
SQITotal	0.79	0.35	0.57	0.12	21.60	0.07	-0.22

4.3. Spatial Distribution of Soil Quality Parameters

4.3.1. Spatial Distribution of Physical parameters

The analysis result of the collected soil samples was in point features, so interpolation techniques in ArcGIS 10.8.2 was applied in order to determine the spatial distribution of the soil physical properties. Inverse distance weighting (IDW) with a power of 1, 2, and 3 as well as ordinary kriging techniques such as spherical kriging (SK), exponential, and gaussian kriging approaches were used as geo-statistical and interpolation methods. The values of root mean square error was used to determine the accuracy of the interpolation techniques. The interpolation techniques with minimum root mean square error is considered as the best interpolation technique (Robinson and Metternicht, 2006). The RMSE value of the interpolation techniques is described in (Table 4.4).

The result of the interpolation shows that most of the area has higher level of aggregate stability with a maximum value of 84.7% and a minimum value of 6.2% which covers relatively low area (Figure 4.2). Since soil texture (Sand, silt and clay) is the inherent soil property (Brejda et al. (2000b) it doesn't show significant differences among different land uses. Soil bulk density is a little bit higher in forest soil than in cultivated and pasture land which might be due to the presence of higher organic matter in forest soil results in high soil water content which results good soil structure. The same report is raised by (Zhang et al. 2008). Bulk density fluctuates relative to the various land uses. Except for the grassland, where overgrazing had a stronger influence on BD than SOC, BD declined greatly in places with higher SOC.

Table 4.4. RMSE value of Physical Properties

Parameters	IDW			Ordinary Kriging		
	1	2	3	Spherical	Exponential	Gaussian
Clay	12.4786	11.6357	11.4727	11.7852	11.5398	11.8832
Silt	6.7046	6.7104	6.9221	6.9607	6.9287	6.9565
Sand	16.2820	15.2621	15.1639	15.9192	15.2628	15.7152
BD	0.0865	0.0828	0.0844	0.0876	0.0836	0.0862
HC	16.5870	17.1381	17.9881	16.6220	16.7442	16.8599
AWC	2.1445	2.1721	2.2468	2.2106	2.1946	2.1956
DR	8.9058	9.0007	9.4202	8.8501	8.8374	8.8699
SSI	15.0285	13.8761	13.6133	15.1029	14.1486	15.3722
AS	13.7700	13.4719	14.1594	13.5639	13.6067	13.5035

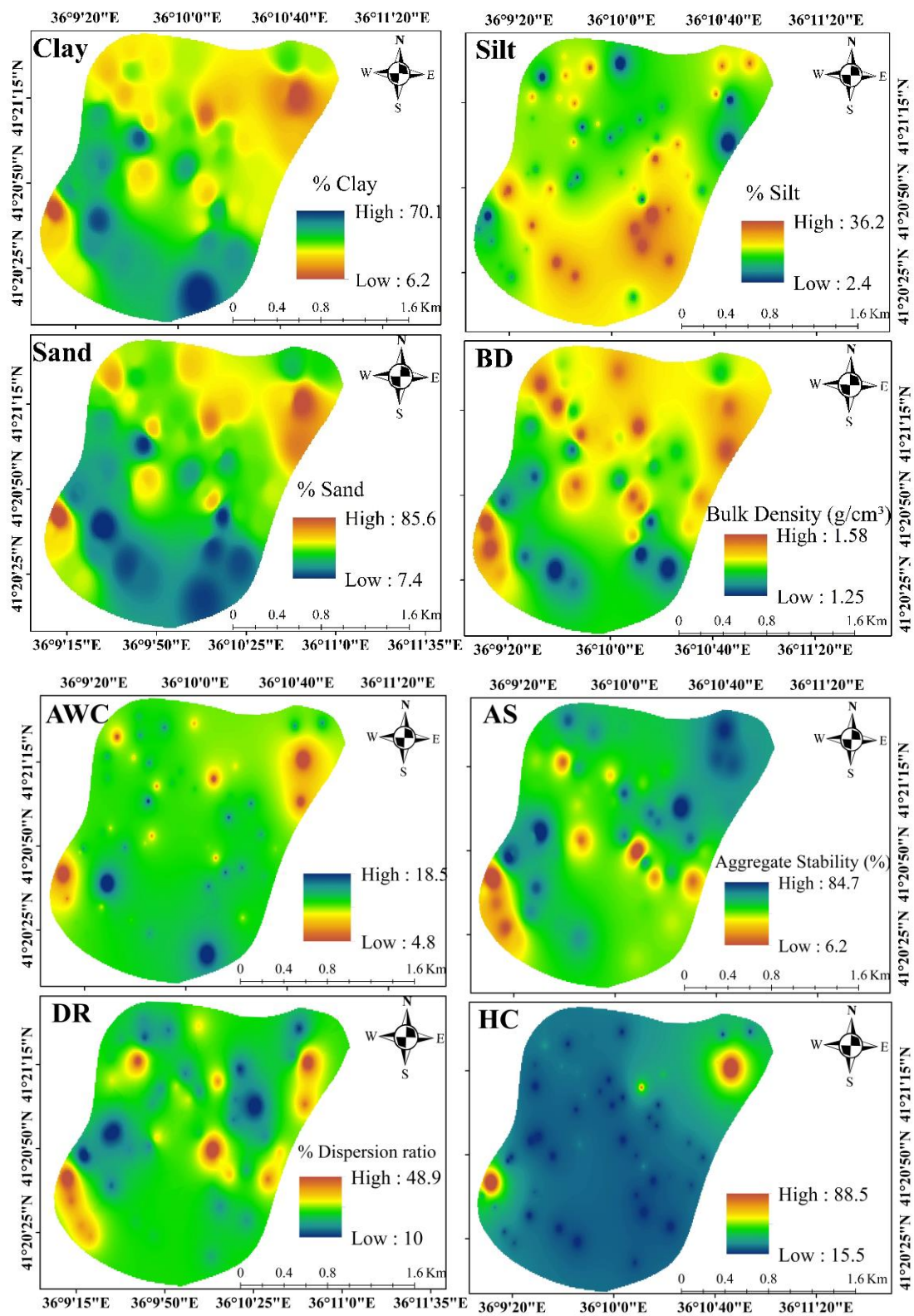


Figure 4.2. Spatial Distribution of Physical properties

4.3.2. Spatial Distribution of Chemical properties

The same to physical properties of soil chemical properties of soil were also in point format. Interpolation techniques using ArcGIS 10.8 was used to determine the spatial distribution of this parameters. The effectiveness of the interpolation techniques was determined by the Value of Root mean square error and coefficient of determination. the techniques of interpolation with minimum root mean square values and higher coefficient of determination (i.e. value closer to 1) is supposed to be better interpolation technique (Robinson and Metternicht, 2006).

The RMSE value of the interpolation techniques is described in (Table 4.5). Based on RMSE value, Soil Ph and electrical conductivity is interpolated by gaussian ordinary kriging technique, organic matter content is interpolated by using spherical ordinary kriging technique and an exponential ordinary kriging approach is used to interpolate the lime content. The highest amount of organic matter (4.41) is found in forest land which might be from tree litter and root exudates and the minimum value is 0.23 which is found in pasture land (Figure 4.3). Organic matter content was highly variable in all selected three land uses. The variability of organic matter in pasture land might be due to unequal distribution of manure by grazing animal, results in higher organic matter in area where the animals frequently graze and excrete and vice versa (Hiernaux & Turner, 2002). In cultivated land, the variability might be because of repetitive tillage practices and uneven distribution during the application of organic or inorganic fertilizers by a farmer and it might be affected by soil erosion (Drinkwater et al., 1998; Lal, 2004).

According to Six et al., 2002, the variability of organic matter content in the forest soil might be due to difference in soil textural class, soil having high clay content might have high organic matter content. The spatial variability of pH is very low in all land use land cover. The variability of calcium carbonate and electrical conductivity was relatively higher in all land uses. In pasture land the variability of CaCO_3 and EC might be due to the effect of livestock. Animal waste increase organic matter and increase decomposition then produce different ion that affects EC. The same suggestion is given by (Schnyder et al., 2010). Different plant species and forest soil parent materials affect the amount of calcium carbonate and electrical conductivity in the soil (Jobbágy & Jackson, 2001). Liming, application of calcium salt containing fertilizers as well as irrigation of saline

water affect the spatial variability of calcium carbonate and electrical conductivity in cultivated land (Rengel, 2011).

Table 4.5. Spatial Distribution of Chemical properties

Parameters	IDW			Ordinary Kriging		
	1	2	3	Spherical	Exponential	Gaussian
pH	0.5581	0.5964	0.6418	0.5374	0.5491	0.5224
EC	591.0918	619.3347	663.9880	568.0128	576.0625	561.5002
OM	0.9935	1.0269	1.0978	0.9537	1.0002	1.0077
CaCO ₃	8.1403	8.0240	8.1643	7.8956	7.7742	7.8094

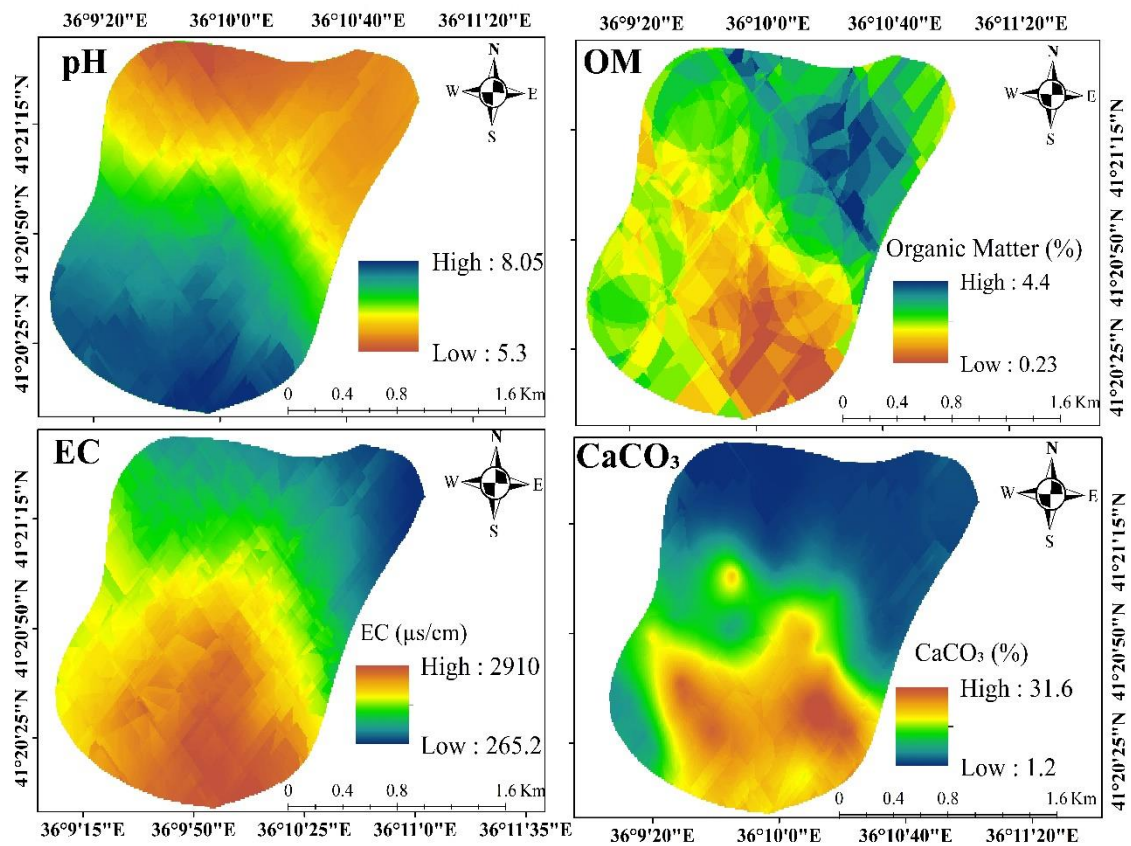


Figure 4.3. Spatial Distribution of Chemical Parameters

4.3.3. Spatial Distribution of Fertility Parameters

The spatial distribution of nutrient in the study area was also determined by applying interpolation techniques in ArcGIS software using the selected point samples as an input. The best interpolation method was selected by taking into account the root mean square error. Techniques with low root mean square error considered as best model for

interpolating the result (Robinson and Metternicht, 2006). The RMSE value of the interpolation techniques is described in (Table 4.6).

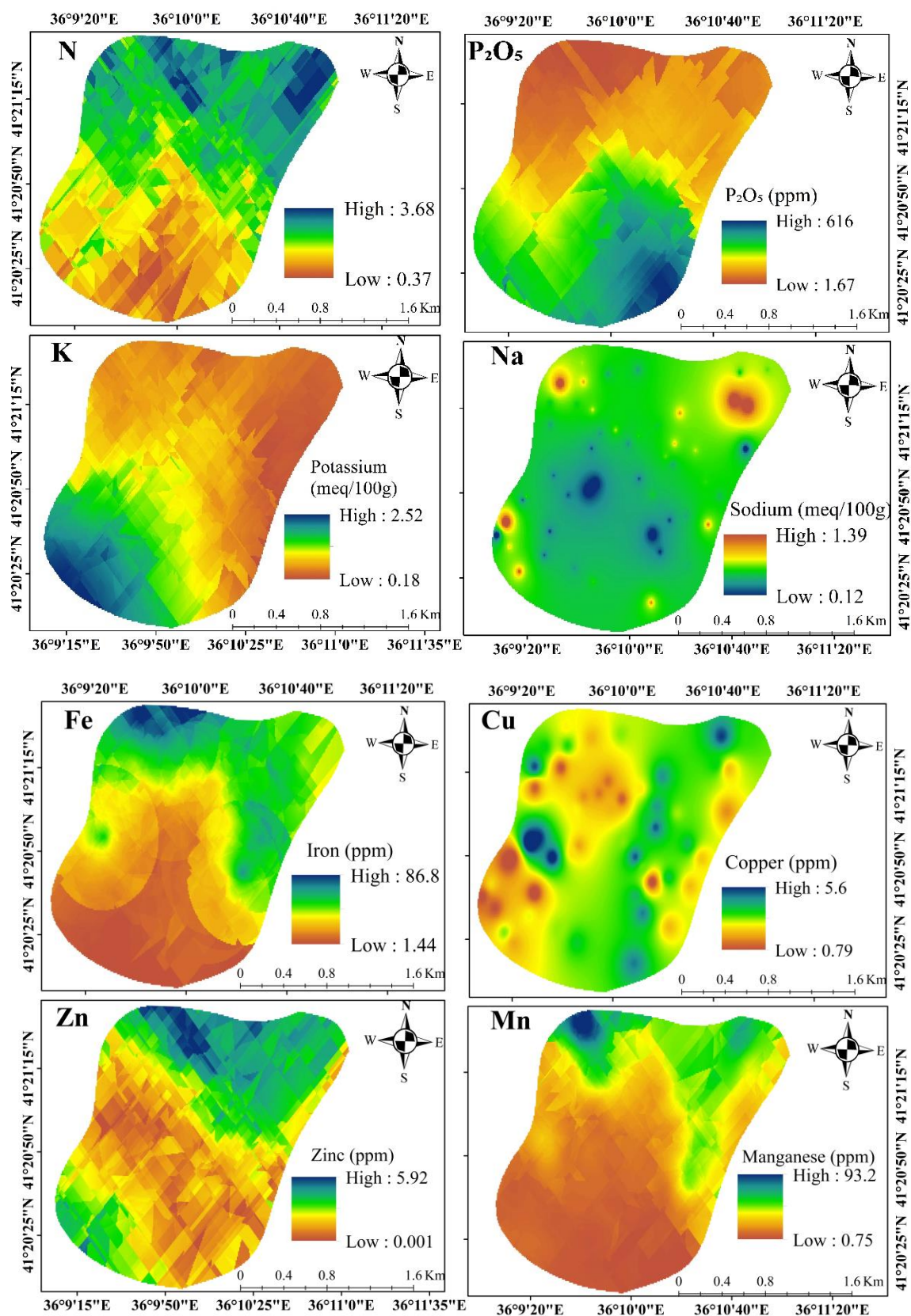
According to Figure 4.4, The result of interpolation reveals that, the spatial variability of soil fertility element or nutrient content was higher in all land use land cover except total nitrogen in the cultivated land having the coefficient of variation 25.87 which falls in the medium level of variation as per the classification reported by DENGIZ, 2020.

The losses of nitrogen by means of leaching (especially in nitrate form) and volatilization (particularly as ammonia) can occur, but they are frequently offset by continuous input from nitrogen fixation, fertilization, and organic matter decomposition, resulting in less variability when compared to other nutrients. Forest ecosystems experience unequal nutrient distribution due to interactions between plant species, microbes, and soil fauna, that influence litter fall and decomposition.

On the other hand, crops that may deplete particular nutrients are frequently planted on cultivated fields, which can result in variations due to crop rotation, fertilization techniques, and harvest. Grazing pastures can vary in terms of the kinds of grasses and the amount of grazing intensity, which impacts plant growth and the cycling of nutrients through the accumulation of animal waste (Lal, 2006). Animal activity and root exudation make natural or poorly managed woodlands very variable (Brady & Weil, 2017).

Table 4.6. Spatial Distribution of Fertility Parameters

Parameters	IDW			Ordinary Kriging		
	1	2	3	Spherical	Exponential	Gaussian
N	0.8258	0.8989	0.9829	0.7956	0.7959	0.7957
P	123.0912	130.3259	141.2740	118.6522	118.5861	118.3409
K	0.4855	0.5138	0.5560	0.4789	0.4823	0.4779
Ca	8.6494	8.7046	8.9159	8.9952	8.9111	8.9682
Mg	13.2812	12.7033	13.0649	11.8776	12.3403	11.9401
Na	0.2579	0.2658	0.2792	0.2633	0.2641	0.2634
Fe	19.5841	20.2800	21.4807	18.9897	18.8532	18.9631
Cu	0.9876	0.9028	0.9079	0.9573	0.9164	0.9139
Zn	1.7038	1.8029	1.9070	1.6655	1.6489	1.6688
Mn	15.2366	15.3726	15.8394	15.2642	15.2186	15.1949



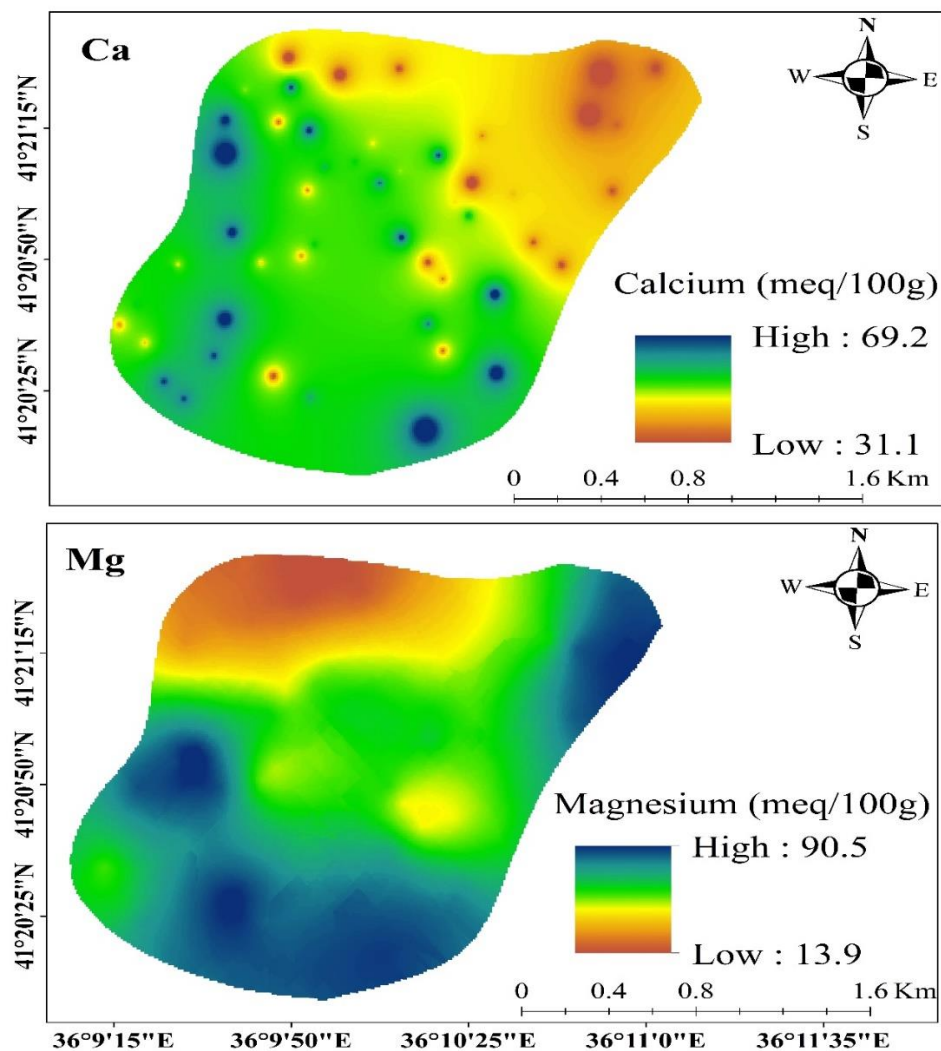


Figure 4.4. Spatial Distribution of Fertility Parameters

4.3.4. Spatial Distribution of Biological properties

The obtained results for the selected soil samples were used as input for determining the distribution of biological parameters (Carbon di oxide, Microbial biomass and metabolic quotient for CO₂). Interpolation techniques in ArcGIS was used to determine the spatial coverage of the biological indicators. The best method was selected by comparing the root mean square error of interpolation techniques. Inverse distance weight with a power of 1, 2 and 3, ordinary kriging (spherical, exponential and gaussian ordinary kriging method was compared to each other and as per the suggestion of Robinson and Metternicht, 2006, interpolation with a minimum value of root mean square error is taken as a best method to do the analysis.

The root mean square error value of the selected interpolation techniques is described in (Table 4.7). Based on this principle exponential ordinary kriging was used to interpolate both Carbon di oxide and Microbial biomass and Spherical ordinary kriging was used to determine the spatial distribution of metabolic quotient for CO₂. The result reveals the maximum and minimum values of the three biological factors such as, CO₂, MBC and qCO₂ are 0.77,0.17; 7.7,104.8; 0.005,0.02 respectively (Figure 4.5). The variability of biological parameters was higher in all land use except the amount of carbon di oxide and Metabolic quotient for CO₂ in forest soil which is found to be medium coefficient of variation. The stability of microbial populations and the relative uniformity of the environment are responsible for the low local variation of carbon di oxide and microbial quotient for carbon di oxide (Six et al., 2006; Wang et al., 2021; Mayer et al., 2022).

Table 4.7. Spatial Distribution of Biological properties

Parameters	IDW			Ordinary Kriging		
	1	2	3	Spherical	Exponential	Gaussian
CO ₂	0.1839	0.1962	0.2123	0.1797	0.1787	0.1793
MBC	21.5665	23.6869	26.3665	20.4576	20.4460	20.4499
qCO ₂	0.0034	0.0037	0.0040	0.0032	0.0033	0.0033

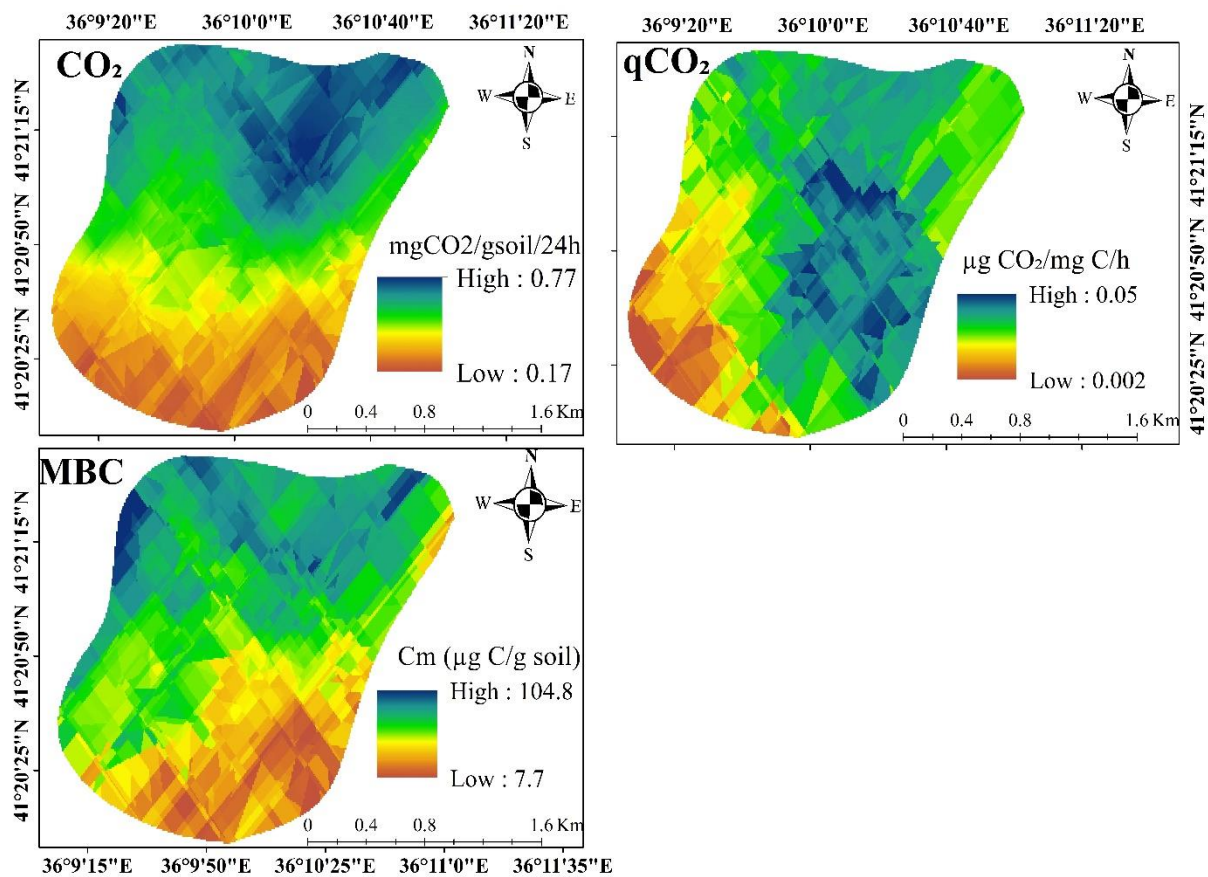


Figure 4.5. Spatial Distribution of Biological properties

4.4. Weight of Soil Quality Parameters

The selected 26 soil quality parameters were grouped into four main groups and weight was given for each main group by considering their contribution to soil quality. The evaluation scores with a consistency ratio smaller than 10% were produced using the AHP technique. A specific weight was given for each parameter in Table 6.

According to Ahmed et al., 2016; Ozkan et al., 2019 and Dengiz et al., 2020, physical properties of soil are crucial to the quality of soil and are mostly intrinsic, making them difficult to improve by the use of technology and the addition of materials, Physical qualities have the highest value at approximately 46 percent (0.4576), followed by soil chemical properties at 26% (0.2597). According to Bone et al. (2013) and Moncada et al. (2013), the primary indicators used to evaluate soil quality are chemical and physical indicators. Soil biological properties and soil fertility parameters encompass the lower value, 18% (0.1789) and 10% (0.1038) respectively.

Following the weighting of the main groups, the weight of the sub parameters was also identified as per their role in soil quality determination. The result shows that, the highest contribution of the indicators in the sub soil quality parameters is found in microbial biomass carbon (0.5278), organic matter (0.4827), Carbon dioxide (0.3325), pH (0.2574) Available available water content (0.2277) (Table 4.8). After weighing both main and sub criteria's the combined weight of each sub-criteria was determined by multiplying their individual weight with the respective main group.

Table 4.8. Weight of soil quality parameters

		Physical	Chemical	Fertility	Biological	Combined weight
		0.4576	0.2597	0.1038	0.1789	
Physical	Clay	0.061				0.0279
	Silt	0.0321				0.0147
	Sand	0.0418				0.0191
	BD	0.0945				0.0432
	AWC	0.2277				0.1042
	HC	0.07				0.0320
	AS	0.1549				0.0709
	SSI	0.1989				0.0910
	DR	0.1192				0.0545
Chemical	pH		0.2574			0.0668
	EC		0.1129			0.0293
	OM		0.4827			0.1254
	CaCO ₃		0.1470			0.0382
Fertility	N			0.2153		0.0223
	P			0.1889		0.0196
	K			0.1482		0.0154
	Ca			0.1189		0.0123
	Mg			0.096		0.0100
	Na			0.0218		0.0023
	Fe			0.0719		0.0075
	Cu			0.0369		0.0038
	Zn			0.0567		0.0059
	Mn			0.0453		0.0047
Biological	CO ₂				0.3325	0.0595
	MBC				0.5278	0.0944
	qCO ₂				0.1396	0.0250

4.5. Soil Quality Index

Following the determination of standard scoring function (SFF) and the combined weight of each soil quality parameters by Analytical Hierarchical Process (AHP) techniques, the soil quality index was determined by multiplying these two factors.

$$SQI_{AHP} = \sum_1^n (SSF \times Wi)$$

Where SQI_H ; Soil quality index

SSF; Standard scoring function of the parameters

Wi; Weight of the parameters

Jenks' optimization techniques have contributed to the classification of the area's suitability into five classifications, ranging from very low to highly suitable.

After determining the soil quality index via AHP techniques, Soil quality index was determined by using ANN techniques in MATLAB software. Soil quality parameters and soil quality index determined by AHP techniques was used as targets and output during the process. The histogram displays the error for 20 bins of normalized data used for validation, testing, and training. The fifth iteration yielded the best fit for the hidden layer. The majority of the predicted value was close to the actual data due to the error value being close to zero. The error histogram confirmed the validation, testing, and training performance (Figure 4.6).

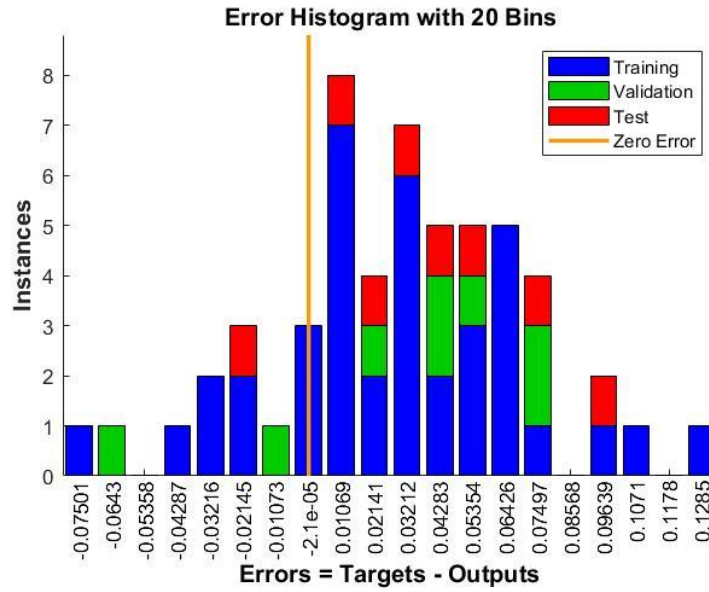


Figure 4.6. Histogram for the training of the data using ANN.

Figure 4.7 shows the actual performance structure for predicting structure MSE and regression. The training states were progressed using the Levenberg-Marquardt (LM) back-propagation method. The output and target of the analysis were then cross-checked using the ANN. The mean square error shows the deviation of the estimated value from the actual data.

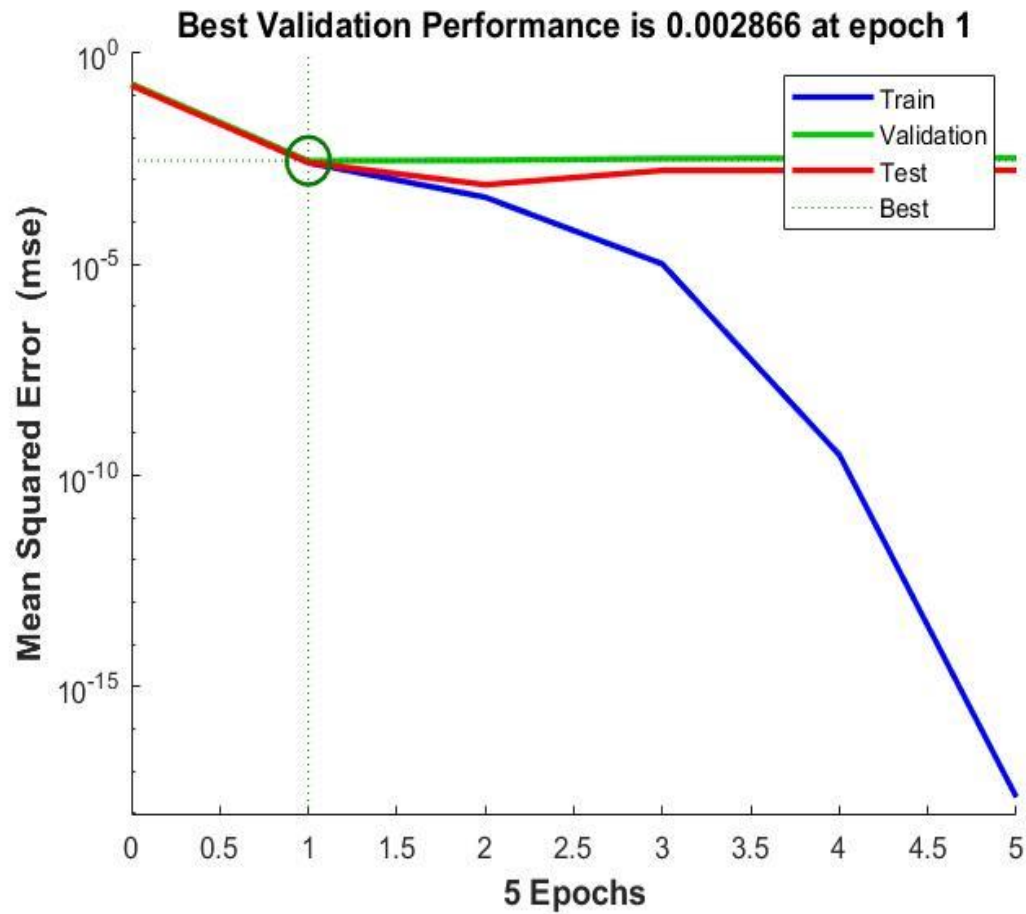


Figure 4.7. Validation of iteration 1 with the best fit occurring at iteration 5

The mean square error of the validation performance (0.92207) is lower than both the performance of the testing and the training points, 0.94225 and 0.93914 respectively. The findings were calibrated using Levenberg–Marquardt in the layer that was hidden, which incorporated backward error propagation (Figure 4.8).

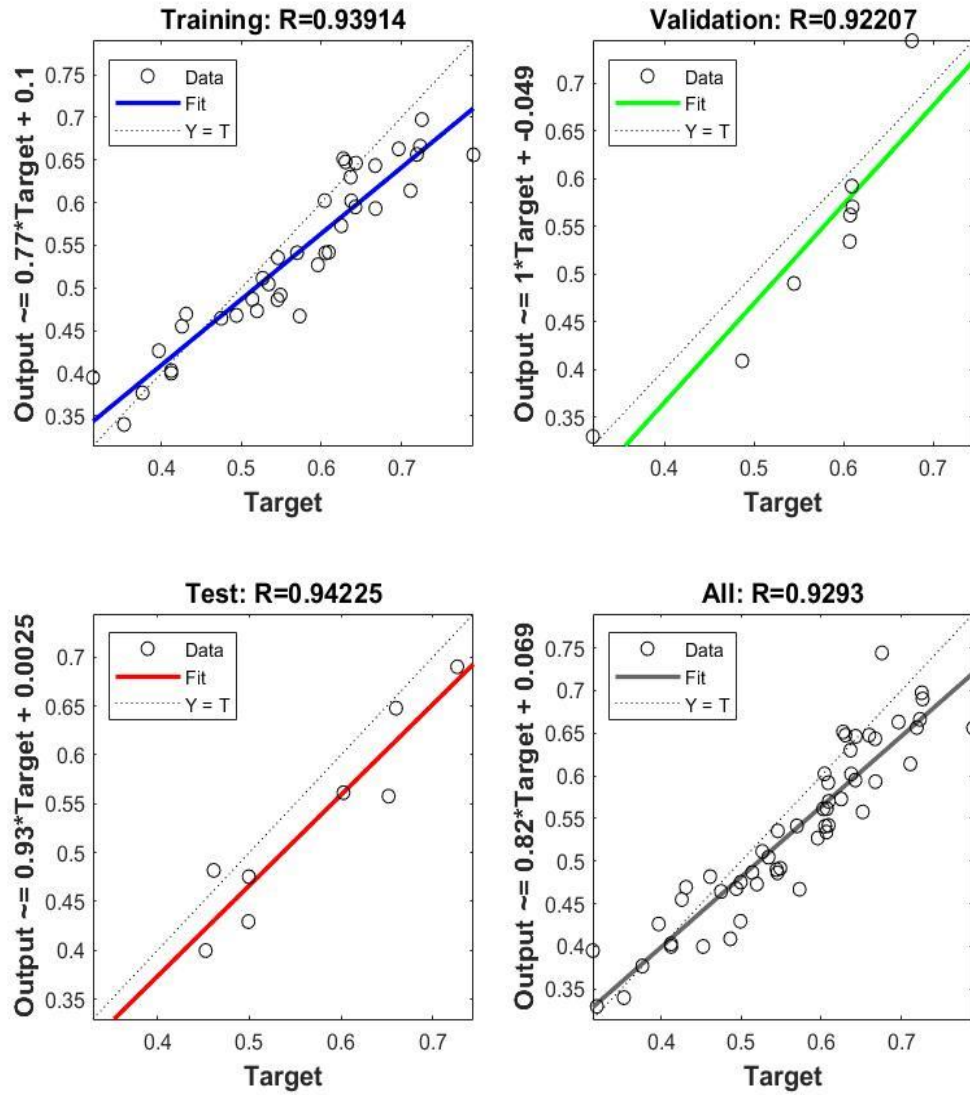


Figure 4.8. The regression between the output data and the targets for the LM approach

Coefficient of determination is used to determine the performance of the artificial neural network. After some trial the fifth iteration produce the best result. Figure 4.9 Illustrate the values of gradient, mu, and validation check in the training state as 6.1612×10^{-10} , 1×10^{-8} and 4 respectively.

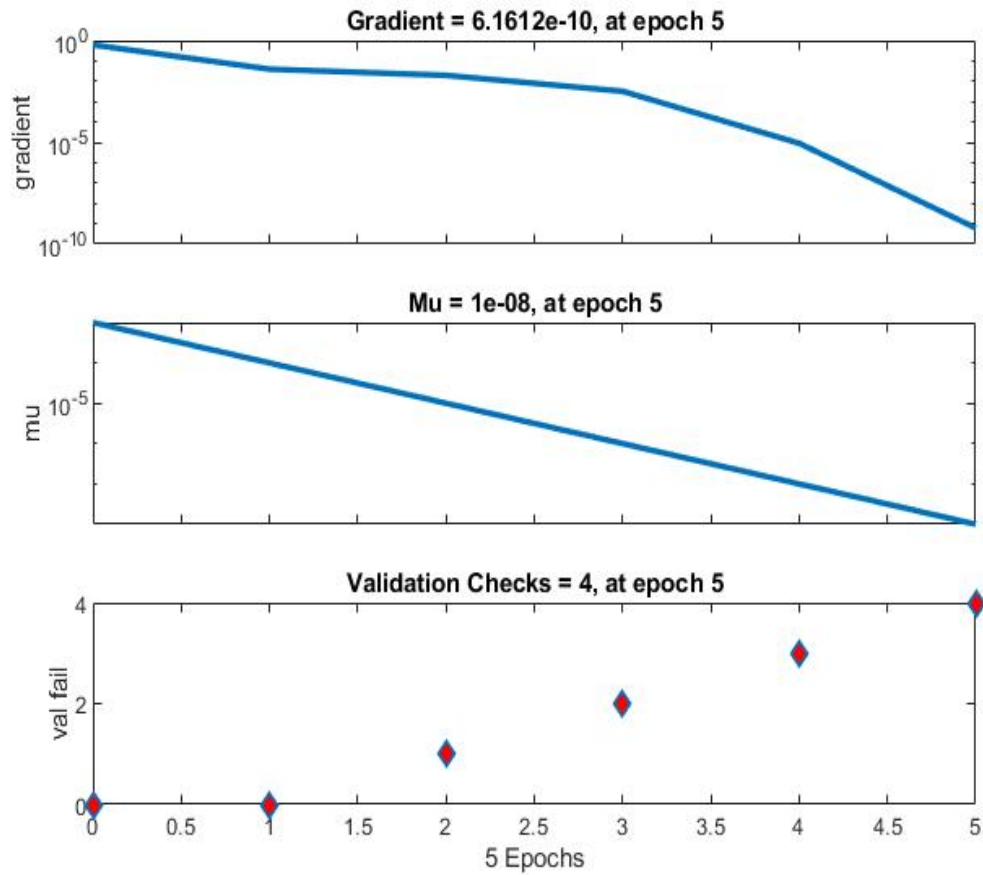


Figure 4.9. plot for the training in the fifth iteration

After determination of soil quality index using both AHP techniques and ANN approach for each soil samples, Interpolation techniques was applied to determine the spatial distribution of soil quality in the study area. Interpolation techniques was selected based on the minimum root mean square error (RMSE) value (Table 4.9). Inverse distance weight with a power of 2 was selected as accurate interpolation technique for both soil quality index in AHP techniques and ANN Approach. the maximum and minimum values of soil quality index AHP was found to be 0.79 and 0.31 respectively.

The maximum and minimum values of soil quality index ANN was 0.74 and 0.33. the highest value of soil quality index (0.79) is found in the pasture land. This might be due to the fact that Pastures typically consist of a continuous cover of grasses and legumes, which protect the soil from erosion and add organic matter through root turnover and litter (Franzluebbers, 2002). There are times when crop fields without vegetation cover,

exposing the soil to erosion. Crop residues are occasionally collected or burned to reduce organic matter the inflow (Lal, 2004). Due to the presence of leaf litter and dead wood, forest soils are rich in organic matter; however, owing to slower nutrient cycling as well as possible soil compaction from tree roots, they may have worse soil quality index values than pastures fields (Nave et al., 2010). One thing I realized during data collection was forest land was situated in the steep slope area which exposes nutrient losses by soil erosion.

The values of soil quality index were reclassified into five classes namely, very low, low, moderate, high and very high classes based on Jenks' optimization techniques in ArcGIS. The result reveals that 48.39% of the area covering 235.17ha of the total area is classified as moderate soil quality index. 24.06% (116.93ha) and 6.89% (33.51ha) of the area is considered as high and very high soil quality index. 5.35% (26.02ha) and 15.30% (74.38ha) the area falls in very low and low level of soil quality index (Table 4.10). Figure 4.10 a and b shows soil quality index by AHP and ANN.

Table 4.9. Root mean square error of soil quality index

Parameter	IDW			Ordinary Kriging		
	1	2	3	Spherical	Exponential	Gaussian
SQI _{AHP}	0.1136	0.1085	0.1106	0.1147	0.1102	0.1156
SQI _{ANN}	0.1001	0.0968	0.0997	0.1012	0.0976	0.1001

Table 4.10. Soil quality index classes

Class	Name	Value	SQI AHP		SQI ANN	
			Area_ha	Percentage	Area_ha	Percentage
I	Very low	1	26.02	5.35	33.62	6.92
II	Low	2	74.38	15.30	127.82	26.30
III	Moderate	3	235.17	48.39	207.7	42.74
IV	High	4	116.93	24.06	82.94	17.07
V	Very high	5	33.51	6.89	33.92	6.98
		Total	486.00	100	486.00	100

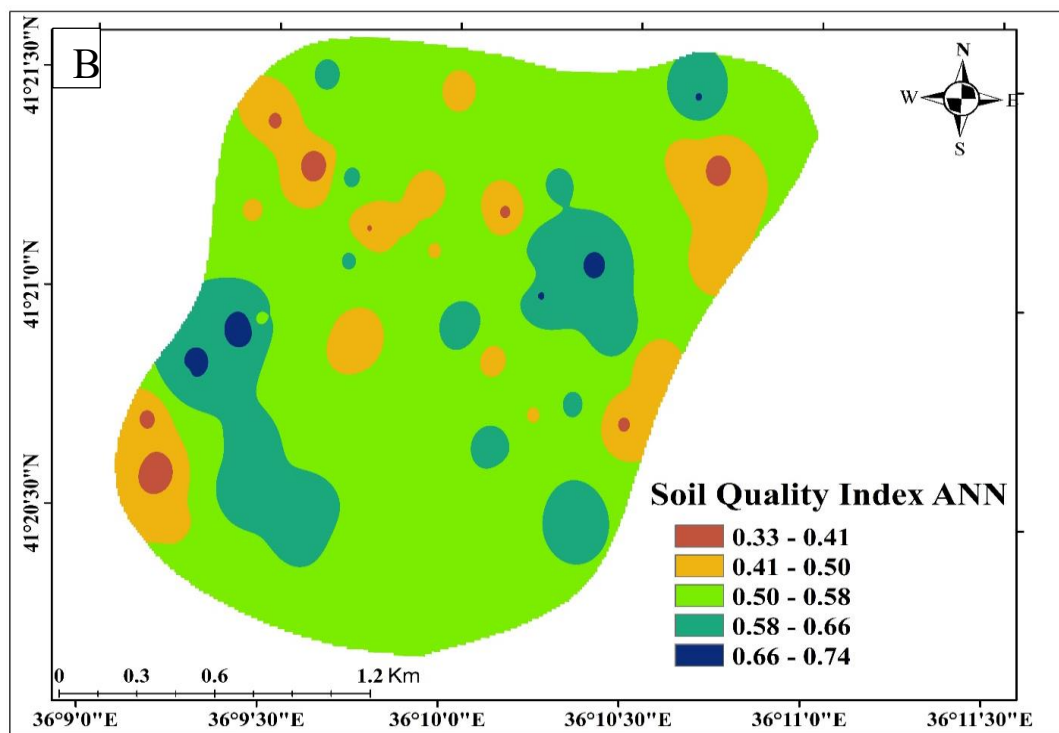
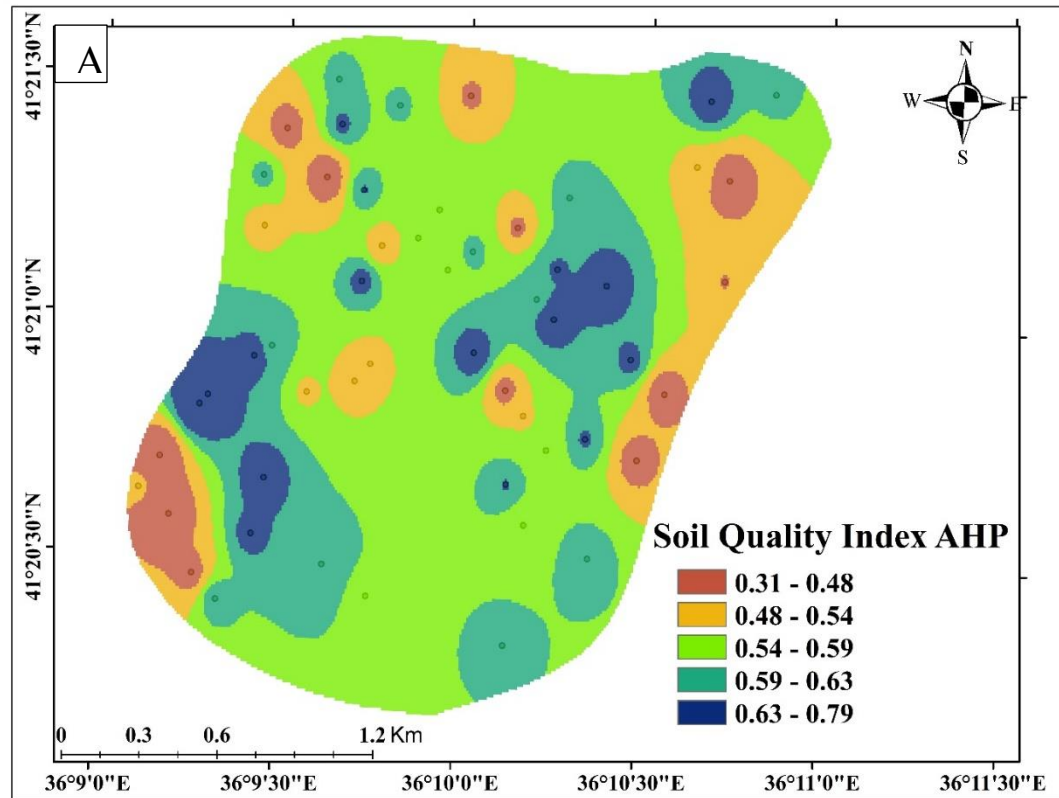


Figure 4.10. Soil quality index in AHP and ANN

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Soil quality is influenced by different factors such as physical indicators, chemical indicators, biological indicators and fertility indicators. In this study Soil quality index was determined by using multi criteria decision support system Analytical Hierarchical process (MCDA-AHP) and Artificial Neural Network (ANN). Soil physical properties is found to be the primary factor affecting soil quality and it accounts 46% followed by chemical property of soil which accounts 26%. the calculated soil quality index was divided into five classes namely, very low, low, medium, high and very high. The findings indicate that 48.39% of the entire area (235.17ha) has a moderate soil quality index. 24.06% (116.93ha) and 6.89% (33.51ha) of the area are classified as having high and extremely high soil quality indexes. 5.35% (26.02ha) and 15.30% (74.38ha) of the land is in the extremely low and low levels of soil quality index, respectively.

5.2 Recommendation

Despite the fact that the majority of the area is under moderate to high and very high level of soil quality index 20.65% of the total area or 100.4 ha of land is under low and very low level of soil quality index. based on this finding the following recommendation is given.

- The management of organic matter should be taken. Well-decomposed compost should be applied in the cultivated land to boost organic matter, build soil structure, and improve nutrient availability.
- In order to fix nutritional deficiencies without over-applying fertilizer, which can degrade soil quality, apply fertilizers based on the findings of soil tests and applying slow-release fertilizer to reduce the effect of leaching.
- Minimize runoff and soil erosion on slopes through the use of terraces or contour farming.

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Education

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Final grade: 4 out of 4
Thesis: Assessment of Soil Quality under Different Land Use and Land Cover Types in Samsun, Türkiye
2. Masters of Sciences Degree in Geographic Information Sciences and Remote Sensing, Hawassa University, Ethiopia
3. Bachelor of Sciences in Soil Resources and Watershed Management Hawassa University, Ethiopia
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Research Interest

Soil Mapping, Soil health and soil quality, Soil Erosion, GIS, Remote Sensing, Soil Sciences, Climate change and water resources, Soil fertility, carbon sequestration, soil conservation, watershed management and soil moisture dynamics

Publications

1. Rehman, M. U., Ahmad, N., Ullah, A., Pangilinan, P. J. M., & Alebachew, **Endalamaw. D.** (2023). Hazardous effects of heavy metal toxicity on soil and plants and their bioremediation: a review. *Agricultural University–Plovdiv, Agricultural Sciences*, 35, 12-32.
2. **Alebachew, E.**, Dengiz, O., & Pacci, S. (2023, December). Determination of Soil Quality Index for Production of Hazelnuts in Ordu Provinces, Turkey [Paper presentation]. International Soil Symposium on SOIL SCIENCE & PLANT NUTRITION (9th International Scientific Meeting) 2023, Samsun, Turkey. Federation of Eurasian Soil Science Societies, <http://www.fesss.org/pages.php?id=1>
3. **Alebachew, E. D.**, Dengiz, O., Abebaw, W. A., & Joshi, P. (2023, December). Geospatial Technology-Based Soil Erosion and Sediment Yield Models [Paper presentation]. International Soil Symposium on SOIL SCIENCE & PLANT NUTRITION (9th International Scientific Meeting) 2023, Samsun, Turkey. Federation of Eurasian Soil Science Societies, <http://www.fesss.org/pages.php?id=1>
4. Joshi, P., Dengiz, O., & **Alebachew, E. D.** (2023, December). Synergistic Effects of Biochar and Other Eco-Friendly Fertilizers on Soil Health and Plant Productivity [Paper presentation]. International Soil Symposium on SOIL SCIENCE & PLANT NUTRITION (9th International Scientific Meeting) 2023, Samsun, Turkey. Federation of Eurasian Soil Science Societies,

<http://www.fesss.org/pages.php> id=1

5. Abebaw, W. A., Lebay, M., **Alebachew**, E. D., & Dengiz, O. (2023, December). Global Impacts of Conservation Agriculture on Crop Yields Improvement and Soil Erosion Controls [Paper presentation]. International Soil Symposium on SOIL SCIENCE & PLANT NUTRITION (9th International Scientific Meeting) 2023, Samsun, Turkey. Federation of Eurasian Soil Science Societies, <http://www.fesss.org/pages.php> id=1

Won Awards, Incentives and Scholarships

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