T.R.
ONDOKUZ MAYIS UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
DEPARTMENT OF SOIL SCIENCE AND PLANT NUTRITION

# RELATIONSHIP BETWEEN SOME SOIL PHYSICAL QUALITY PROPERTIES AND SOIL ORGANIC CARBON

Master's Thesis

**Deividas MIKŠTAS**

Supervisor
**Prof. Dr. Orhan DENGIZ**

II. Supervisor

**Prof. Dr. Tatiana MINKINA**

SAMSUN
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SAMSUN
2022

# ACCEPTANCE AND APPROVAL OF THE THESIS

The study entitled **“RELATIONSHIP BETWEEN SOME SOIL PHYSICAL QUALITY PROPERTIES AND SOIL ORGANIC CARBON”** prepared by **Deividas MIKŠTAS**, and supervised by **Prof. Dr. Orhan DENGIZ** and **Prof. Dr. Tatiana MINKINA**, was found successful and majority of votes accepted by committee members as Master thesis, following the examination on the date 6.7.2022

| | **Title Name Surname**<br>**University**<br>**Department** | **Signature** | **Final Decision** |
|---|---|---|---|
| **Chairman** | Prof. Dr. Orhan DENGIZ<br>Ondokuz Mayıs University<br>Department of Soil Science and Plant Nutrition | | ☐Accept<br>☐ Reject |
| **Member** | Prof. Dr. Tatiana MINKINA<br>Southern Federal University<br>Academy of Biology and Biotechnology<br>Department of Soil Science and Land Resources Estimation | | ☐Accept<br>☐ Reject |
| **Member** | Prof. Dr. Coşkun GÜLSER<br>Ondokuz Mayıs University<br>Department of Soil Science and Plant Nutrition | | ☐Accept<br>☐ Reject |
| **Member** | Prof. Dr. Rıdvan KIZILKAYA<br>Ondokuz Mayıs University<br>Department of Soil Science and Plant Nutrition | | ☐Accept<br>☐ Reject |
| **Member** | Prof. Dr. Svetlana SUSHKOVA<br>Southern Federal University<br>Academy of Biology and Biotechnology<br>Department of Soil Science and Land Resources Estimation | | ☐Accept<br>☐ Reject |

This thesis has been approved by the committee members that already stated above and determined by the Institute Executive Board.

APPROVAL
… / … / 2022
Prof. Dr. Ali BOLAT
Head of Institute of Graduate Studies

# DECLERATION OF COMPLIANCE WITH SCIENTIFIC ETHIC

I hereby declare and undertake that I complied with scientific ethics and academic rules in all stages of my Master's Thesis , that I have referred to each quotation that I use directly or indirectly in the study and that the works I have used consist of those shown in the sources, that it was written in accordance with the institute writing guide and that the situations stated in the article 3, section 9 of the Regulation for TÜBİTAK Research and Publication Ethics Board were not violated.

Is Ethics Committee Necessary?
Yes (If it necessary, please add appendices.)
No ☒

06 / 07 / 2022
Deividas MIKŠTAS

# DECLERATION OF THESIS ORIGINALITY REPORT

**Thesis Title :** RELATIONSHIP BETWEEN SOME SOIL PHYSICAL QUALITY PROPERTIES AND SOIL ORGANIC CARBON

As a result of the originality report taken by me from the plagiarism detection program on 21 / 05 /2022 for the thesis titled above;

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# ÖZET

## BAZI TOPRAK FİZİKSEL KALİTE ÖZELLİKLERİ İLE TOPRAK ORGANİK KARBONU ARASINDAKİ İLİŞKİ

Deividas MIKŠTAS
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Toprak Bilimi ve Bitki Besleme Ana Bilim Dalı
Yüksek lisans, Temmuz /2022
Danışman I: Prof. Dr. Orhan DENGIZ
Danışman II: Prof. Dr. Tatiana MINKINA

Bu tez çalışmasının amacı, "Yeşil Küre" tarım arazilerinin topraklarını analiz etmek ve bazı toprak kalitesi özelliklerini bulmak ve tarım topraklarının toprak sıkışması, kabuk oluşumu ve aşınabilirlik - K ile yüzeydeki (0-20 cm) ve yüzey altındaki (20-40 cm) toprak organik karbon miktarı arasındaki ilişkiyi kontrol etmektir. Araştırma sonuçları toprak sıkışmasının, kabuk oluşumunun, aşınabilirlik-K'nın organik karbon, organik karbon stoğu, organik madde arasında yüksek oranda ($P < 0.001$) ilişkili olduğunu göstermiştir. Araştırma ayrıca tarım arazilerinin genel olarak killi bünyeye, nötr pH'a, düşük miktarda $CaCO_3$'a, yüzey toprağında (0-20 cm) yüksek miktarda, OC ve OM'ye ise alt toprakta (20-40 cm) orta miktarda olduğunu tespit edilmiştir. Üst ve alt topraklara ait özellikleri arasında anlamlı fark saptanmamıştır.

**Anahtar kelimeler:** tarım toprakları, toprak organik karbon, toprak sıkışması, kabuk oluşumu, aşınabilirlik K

# ABSTRACT

## RELATIONSHIP BETWEEN SOME SOIL PHYSICAL QUALITY PROPERTIES AND SOIL ORGANIC CARBON

Deividas MIKŠTAS
Ondokuz Mayis University
Graduate School of Education
Department of Soil Science and Plant Nutrition
Master, July /2022
Supervisior I: Prof. Dr. Orhan DENGIZ
Supervisor II: Prof. Dr. Tatiana MINKINA

The objective of this thesis study was to analyse the "Yeşil Küre" farmlands' soils and find out some soil quality properties and check relationship between soil compaction, crust formation and erodibility - K of the farm soils with the soil organic carbon amount in the surface (0-20 cm) and subsurface (20-40 cm) soils. The research outcomes showed that soil compaction, crust formation, erodibility K is highly significantly ($P < 0.001$) related to organic carbon, organic carbon stock, organic matter and between each other. The research also identifies that farmland generally, has clay texture, neutral pH, low amount of the $CaCO_3$, high amount of OC and OM in top layer (0-20 cm) and moderate amount in bottom layer (20-40 cm). It was not identified significant differences between the soil properties in top and bottom layers.

**Key Words:** agricultural soils, soil organic carbon, soil compaction, crust formation, erodibility K

# ACKNOWLEDGEMENT

I would like to express my gratitude to my grandparents Margarita, Ričardas and other family members who incorige me to continue my studies. Also I am deeply grateful to my thesis supervisor, Prof. Orhan Dengiz, who guided me throughout this project. I would also like to thank Nursaç Serda Kaya and other Ondokuz Mayıs University community members who helped me do this research.

6 July 2022, Samsun

Deividas MIKŠTAS

# TABLE OF CONTENT

# ABBREVIATIONS OF TERMS

| | |
|---|---|
| EC: | Electrical conductivity |
| pH: | Power of Hydrogen |
| Db: | Bulk density |
| $CaCO_3$: | Calcium carbonate |
| OM: | Organic mater |
| OC: | Organic carbon |
| SOC: | Soil organic carbon |
| SD: | Standard deviation |
| Min: | Minimum |
| Max: | Maximum |
| CV: | Coefficient of variation |

# FIGURES LEGENDS

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# 1 INTRODUCTION

In recent times the importance of soils organic carbon in the carbon cycle has been increasingly acknowledged as the $CO_2$ concentrations rising in the atmosphere and the increasing global warming (Rumpel et al., 2020). Soils organic carbon topic is researched in the scientific community not only for its imports for global warming but also for its effect on soil quality and sustainable food production. The soil organic carbon is one of the most important natural resources which is highly important to securing the soil quality. Soil is one of the vital natural resources which is a non-renewable and are necessary for all living creatures (Schoonover & Crim, 2015). One of the most major questions for scientist currently is finally to found efficient ways how increase soil organic carbon in soil and how to stop decrease $CO_2$ emission to the atmosphere.

The industrial agricultural system is rapidly reducing the soil quality, increasing climate change, and growing the hunger of the world (Adidja et al., 2019). The FAO study published in mid-2021 estimates that between 720 and 811 million people are still suffering from hunger in the world in 2020 (FAO et al., 2021). In this case, soil health is one of the vital elements of the European Union research and innovation program, by which they set a goal until 2030 to reach the 75% healthy soils in its territory (Lal et al., 2021). The soil organic carbon is one of the essential element of the healthy soil. Therefore, the relationship between soil quality and soil organic carbon are known but here are still need of studies on this topic to understand it more clearly.

The main goal of the thesis “Relationship between some soil physical quality properties and soil organic carbon” is to analyse the "Yesil kure" farmlands. These lands have been cultivated for a long time. The first name of the farmland was “Karaköy State Farm” established in 1946. After 2007, it was transferred to the private sector and its name was changed as “Yeşil Küre Organik” farm. These farmlands are used for organic agriculture purposes for a long period of time. The focus in this research is to find out some soil physical quality properties such as compaction, crust formation and erodibility - K of the farm soils and check its relationship with the soil organic carbon amount in the soil. Moreover, the research interest is on how organic carbon differences in different type used of land in organic farm and how it effects some soil physical properties. Also, the study will be very useful for science community for getting information about organic carbon amount and condition in the organic farmlands and at the same time help to search solutions for reducing the amount of carbon in the atmosphere for reducing global warming.

# 2 LITERATURE REVIEW

## 2.1 Organic carbon

### 2.1.1 Organic carbon cycle

The one of the most common elements in the earth is the carbon. It is in the soil, rock, ocean, air, and other materials. The carbon has a unique bonding ability which permits to combine with other elements in the world and create life, plants, animal etc. The carbon is not fix up for one material and it is continually moving. This carbon movement is called carbon cycle (Figure 2.1).

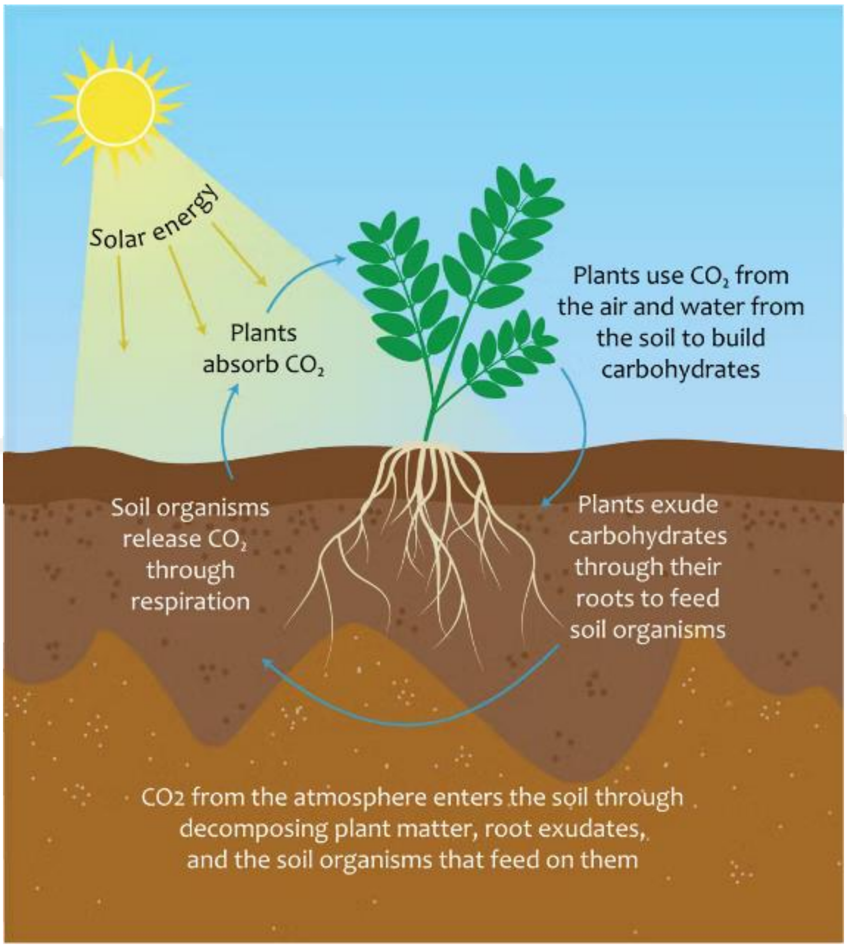

Figure 2.1. Soil Carbon Cycle diagram (Colorado State University https://sustainability.colostate.edu/humannature/jocelyn-lavallee/)

The biggest amount of active carbon is held in soil. The plants have an important part in carbon cycle too because they extract carbon from air and make plant tissue from it and part of carbon returns to soil as plant residue. The carbon cycle improves soil quality, increases food productivity, and reduce carbon amount in the atmosphere (Corning et al., 2016).

### 2.1.2 Soil organic carbon explanation

Soil organic carbon (SOC) is often mixed with soil organic matter. However, the SOC is quantifiable component of the SOM. The soil organic carbon is only the carbon component of organic compounds in the soil organic matter. It is generally agreed that SOM contain 58% SOC and it is mostly used to measure SOC from the organic matter analyses results (de Brogniez et al., 2015). Soil organic carbon has a very major role in global carbon cycle, soil health and quality for not only agricultural productivity but also land degradation and desertification process. The soil fertility, quality, and health increases when the soil has higher amount of the SOC (Lefevre et al., 2017).

### 2.1.3 Global stocks of SOC

The total amount of soil organic carbon in the global soils is unknown and the estimate numbers differ. Scharlemann by checking 27 different studies suggest that a global SOC estimate is about 1500 Pg C (petagrams of carbon), but the range between studies variats from as low as 504 Pg to as high as 3000 Pg C and the median across all estimates is 1460.5 Pg C (Scharlemann et al., 2014). The Batjes has different estimates on SOC by using data base of WISE (World Inventory of Soil Emission Potentials) project where information are about 4353 soil profiles around the world. He estimates SOC amount in top 30 cm around 684-724 Pg C, top 1 m 1462-1548 Pg C and in top 2 m 2376-2456 Pg C (Batjes, 1996). The Lal estimates of total global soil organic carbon are also different. His suggested numbers are 750 Pg C to top 30 cm, 1 425 Pg for the top 1 m and 2047 Pg to top 2 m (Lal, 2020).

In the 2018, Turkey’s General Directorate of Combating Desertification and Erosion published the results of a project ‘’Turkey Soil Organic Carbon Project’’. In this study estimates for Turkey SOC stock in top 30 cm is 3.5 billion tons. The amount of SOC stock per hectare is around 36 tons in agricultural areas, 50 tons in pasture areas and 56 tons in forests. (ÇEM, 2018) As a result of the project the detailed Turkey’s SOC stock map has been made (Figure 2.2).

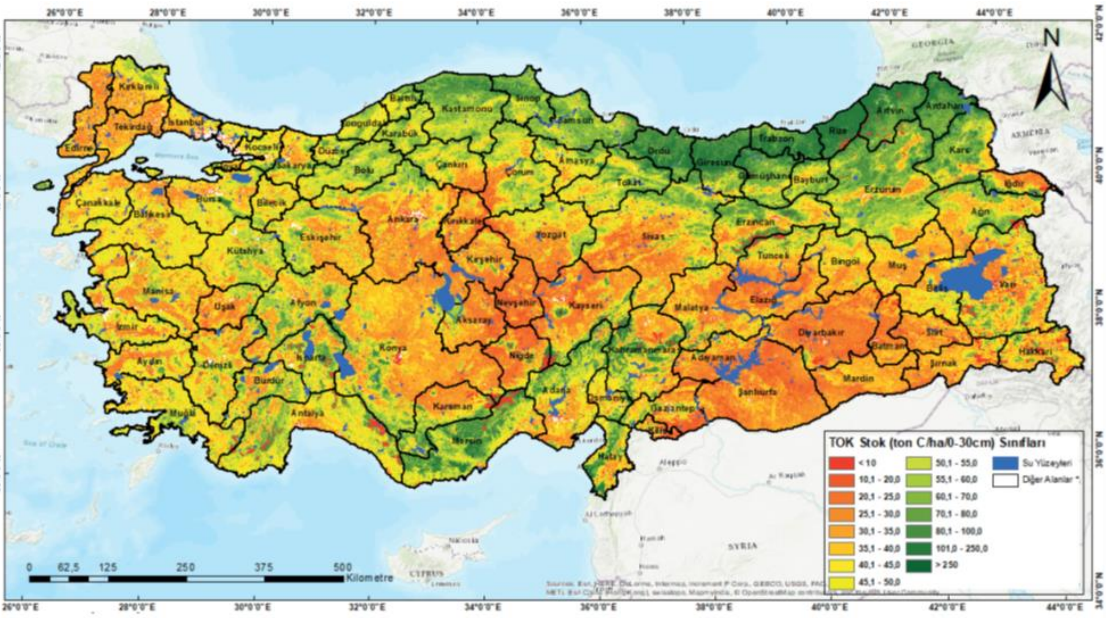

Figure 2.2. Soil Organic Carbon Stock Map of Turkey (ÇEM, 2018)

The soil organic carbon amount in the different lands is differentiating depending on many different aspects such as land use, climatic conditions, soil type and other. The differences in SOC amount in soil are highly connected to the balance of primary production input and its microbial decomposition. In the world, the widest amount of SOC stocks is in peatlands and wetlands (Köchy et al., 2015). 30 % of the Earth's SOC is hold in the peatlands and organic soils which covers only 3 % of the planet's land area. Another decent amount of SOC is in the grassland and forest lands. Grasslands contains around 20 % of the global SOC stocks (Lefevre et al., 2017). The amount of SOC in a soil is not stable and can increase and decrease depending on land use. The best know bad practices which decrease SOC in soil and set free $CO_2$ to the atmosphere are deforestation, cultivation of the grasslands, drainage of the land and burning forest. In the study done in the Argentina which calculated what is SOC change in forest land after cutting forest found out that 10 years after SOC loss was around 30 percentage (Villarino et al., 2017).

### 2.1.4 Measuring and monitoring of SOC

Now a days the most trusted soil organic stock measurement is based on physical soil sampling and calculations. First, the soil samples physically collected from the fields and analyses in laboratories are performed. To calculate SOC stock the results of organic carbon content, bulk density, layer depth, skeleton content is needed

(Pellegrini et al., 2018). SOC content must be found by multiplying soil organic matter analyses results by 0.58 coefficient. This coefficient is based on belief that here is 58 percentage SOC in soil organic matter (Zhi et al., 2014). For this measurement of SOC stock proper research design and sampling plan must be done (Minasny et al., 2017). The larger number of soil samples are needed for avoiding the error in soil organic carbon stock assessment (Garten & Wullschleger, 1999). Now a days are also other alternatives for SOC stocks measurements which are still on development stage such estimation SOC with remote sensing, flux measurements, non ‑ destructive field ‑ based spectroscopic methods (Smith et al., 2020).

### 2.1.5 SOC sequestration

When its organic matter decomposes, carbon-containing gases are released into the atmosphere, and this condition continues to contribute to global warming (IPCC, 2014). Maintaining or increasing soil organic carbon stocks and reducing greenhouse gas emissions not just by removing $CO_2$ from the atmosphere, but also by enhancing the soil by adding organic matter to the soil is critical for quality and productivity. As a result, re-tuning carbon to the organic structure is the most effective approach to recover carbon released into the atmosphere from the soil.

SOC decrease in soil because of wrong land use are big problem now a days. One of the wain goals for scientist worldwide is to increase SOC amount in the soil. The way to increase SOC in soil is called carbon sequestration. It can be defined as the uptake of C-holding materials such as $CO_2$ into another place of storage with a longer residence time (Lorenz & Lal, 2014). Currently numerous ways for carbon sequestration are known. For example, restoration or degraded lands, use of organic amendments, conservation agriculture applications are proposed by Lal (Lal, 2016b). The practices such as crop rotations, use of crops cover, other sustainable agricultural systems, agroforestry, use of compost and manure are recommended by the Olson (Olson, 2013). The main goal in carbon sequestration is to maximize the land covered by vegetation and minimize the sealed or built surfaces in these cases SOC increases (Lal, 2020).

## 2.2 Soil quality

Air, water, and soil are the three components of environmental quality. The soil quality is much more complex when description of water quality and air quality (Bünemann et al., 2018). The easiest definition to define soil quality is "the capacity (of soil) to function". Soil quality must contain 3 main parts — sustained biological productivity, plant and animal health and environmental quality. All these 3 parts must fully function and be balanced between each other (Karlen et al., 1997). Here are no one definition who would define soil quality, because here no common agreement on it by scientific community.

Soil quality can be break up into 2 parts: first is the inherent quality properties which are stable and second the dynamic quality which is changeable by soil management practises. The soil quality measurement is complex task where the vital part taking the selection of the soil quality indicators on which soil quality will be calculated. The soil quality indicators are commonly selected for specific soil functions which vary mostly on soil type use, however other aspects have role too. After the soil functions is clear the indicators can be selected from physical, chemical, and biological soil properties. The soil quality which is measured permits to establish the sustainable land management system (Carter et al., 1997).

Here are no one set of soil quality indicators recognised internationally by the scientists. However, here are common sense that the soil quality index must be made from the multiple physical, biological, and chemical attributes (Karlen et al., 2003). The most frequently used soil quality indicators are pH and soil organic carbon. Other commonly used indicators are available phosphorus, texture, bulk density, available potassium, various indicators of water storage and total nitrogen. The most used chemical indicators are total N, soil organic carbon content, available P and K, cation exchange capacity, pH, electrical conductivity. The commonly used physical indicators are mostly related to water storage. The commonly used biological indicators were earthworm density, soil respiration, N mineralization and microbial biomass. The chemical, biological and physical soil quality indicators were used in most of soil quality minimum datasets (at least one indicator of each group). However, in some soil quality minimum datasets biological indicators were missed (Bünemann et al., 2018).

## 2.3 Some soil physical properties

### 2.3.1 Compaction

Soil compaction is commonly described as decrease of soil porosity and increase of bulk density in the soil caused by applied loads, vibration, or pressure (Weiler & McDonnell, 2004). It is one of the problems which is growing in the agriculture rapidly because of human activities. The main causes are inappropriate soil management, intensive cropping, overuse of machinery, intensive grazing, short crop rotations and other. The soil compaction can occur in different climates and soils (Hamza & Anderson, 2005). The soil compaction has a vital role on the soil physical properties. It effects bulk density, porosity, decrease root penetration in the soil, limits water and air infiltration. Moreover, the increase in soil compaction reduces biodiversity in the soil (Nawaz et al., 2013).

### 2.3.2 Crust formation

The soil crusting has a lot of bad effects such as expends erosion, reduces infiltration, obstructs vegetation grow and other. Soil crusting forms by 2 steps. Firstly a heavy rain must breaks down the aggregates, and secondly in drying phase a uniform surface seal are formed. Here are amy soil properties which effect crust formation but the most key property is soil aggregate stability (Fox et al., 2004). The crurst formation depends on land management, soil type, climate. In the loamy temperate soils, an infilling crust slowly forms if the soil was wet, and a slaking crust quickly develops if the soil was dry before rainfall. However in silty soils, a coalescing crust appear whatever the primary condition (Bresson et al., 2006).

### 2.3.3 Erodibility

Soil erosion can be explained as the movement or transport of soil by different materials such as water, wind, and mass. The soil erosion is affected by climate factors such as wind, rainfall and its amount, frequency, duration, intensity. Other important factors are the land use, topography, soil type and other. Soil erosion is one of the main problems worlds is facing (Bullock, 2005). It increases land degradation by loss of soil, organic carbon, and nutrients (Bezak et al., 2021). Moreover, soil erosion is the main threat for world food production. Due to soil erosion about 10 million ha of cropland are lost yearly (Pimentel & Burgess, 2013).

The quantity of soil loss per unit of erosive force such as wind, rain is generally called erodibility. The most common term to call soil erodibility is the soil erodibility factor (K) (Wang et al., 2013). Soil erodibility is a key parameter in soil erosion prediction (Darboux & le Bissonnais, 2007). Now a days is a lot of different models for estimate erodibility K values, because it is one of main index for land degradation (Zhang et al., 2018). The erodibility is mostly connected to soil parameters such as texture, permeability, organic matter, and structure (Wischmeier et al., 1971).

## 2.4 Relationship between soil quality properties and soil organic carbon

The main soil quality indicator is the SOC stock because it is vital for physical, biological, and chemical soil functions (Jandl et al., 2014). Here are direct link for SOC stock in the soil and the soil quality properties (Figure 2.3).

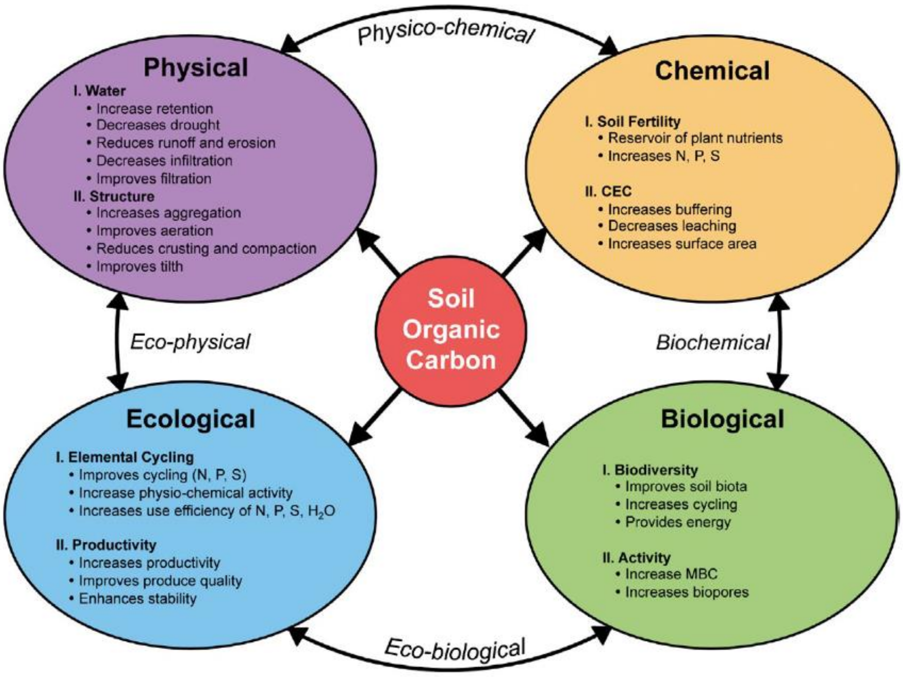

Figure 2.3. Effect of SOC pool on improvements of soil properties (Lal, 2016a)

The decrease of SOC stock in the soil consequence in reduce of soil quality indicators (X. G. Li et al., 2007). Blanco-Canqui and Benjamin study found out that the soil physical properties are highly affected by the agriculture practices where soil organic carbon amount is regulated in soil. If the SOC stock is reduced in soil, it enlarges soil compaction, decrease water repellency, lessen aggregate stability and strength, lowering macroporosity, hydraulic conductivity, and water retention (Blanco-Canqui & Benjamin, 2015). However here are many technological agriculture practices to improve the SOC pool in the soil (Figure 2.4). The most important technologies to restore soil health are such as conservative agriculture, use of organic amendments and complex farming systems. Generally saying, all soil physical, biological and chemical properties highly depend on the SOC stock amount in the soil. SOC have positive impact to the soil biodiversity, bioactivity, rises the CEC and plant nutrients level in the soil. (Lal, 2016b).

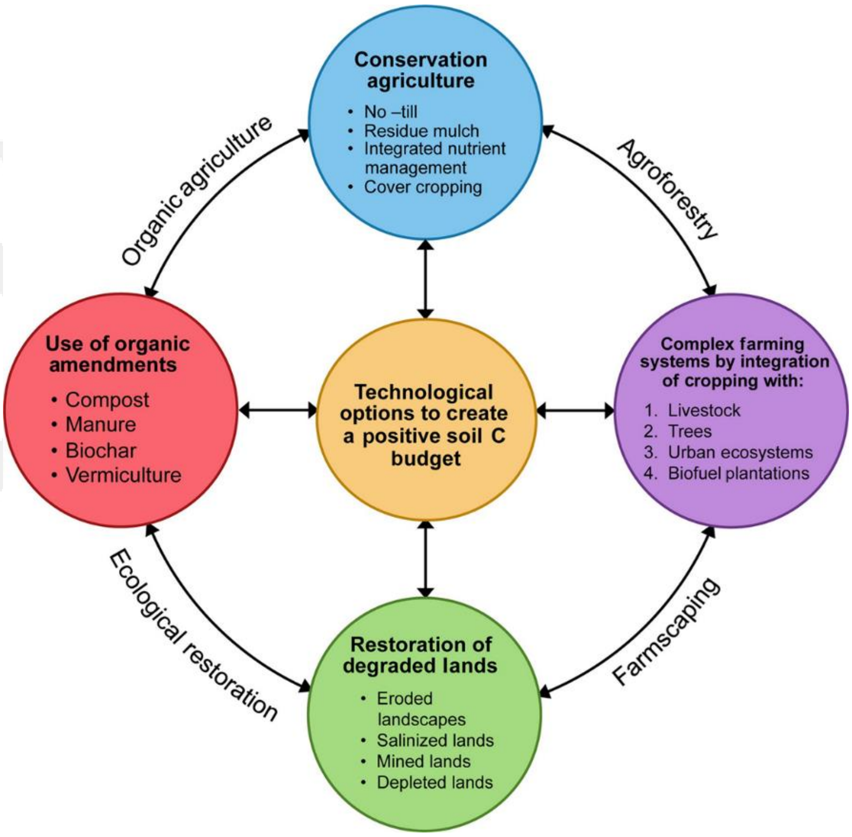

Figure 2.4. Technological alternatives for SOC sequestration (Lal, 2016b)

# 3 MATERIALS AND METHODS

## 3.1 Study area

The study area is Yeşil Küre organic farm territory (Figure 3.1) located between 41°31'15.8"N and 35°59'59.6"E in Karakoy village of Bafra district of Samsun province.

Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 3.1. Location map of the study area

Total land area is about 923.9 ha. The elevation of the farmlands is between 5 m to 74 m above sea level. The land in the north-western and south-eastern parts of the study region has medium steep and steep slopes, whereas the centre and north-western parts of the study area have a flat slope with a range of 0-4 percent (Figure 3.2).

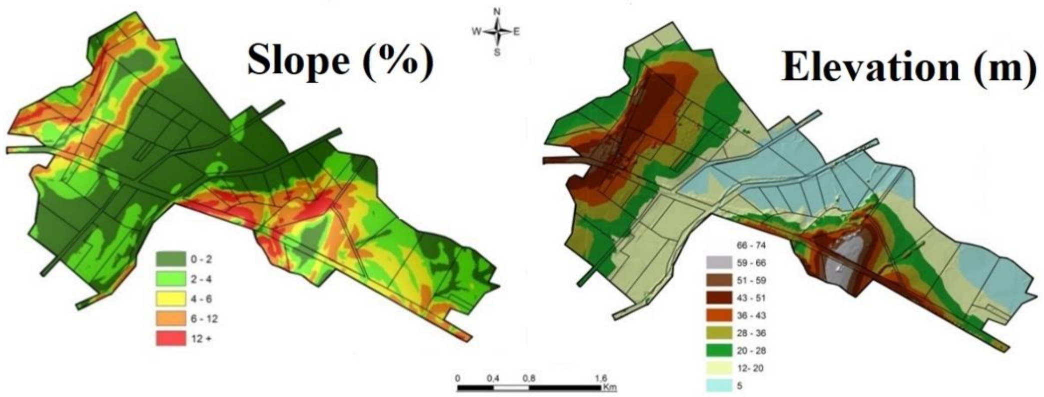

Figure 3.2. Schemes of slope and elevation of study area

The area receives about 710 mm of rainfall annually. The annual average temperature of area is 14.3˚C, with the highest average temperature being 18˚C and the lowest average temperature being 10.7˚C. The coldest months are January and February, and the hottest month is August. The climate of research area is rainy in all seasons, summers are cool, and winters are cooler but not very cold. The Yeşil Küre organic farmlands are in Bafra plain. It is a wide delta plain formed by the rich alluvial soils brought by the Kızılırmak river. The location of research is predominantly covered with Holocene alluvium soil (HGMM, 1974). Almost all the central part of the study area, called Hara, is used for grooving organic crops such as corn, wheat, garlic and etc. In other part of farm called Duden the rice farming is performed.

## 3.2 Land use data

The land use data is known for 2 years 2020 and 2021. The all farm was divided into 60 parcels from 0 to 59 (Table 1 and Figure 3.3).

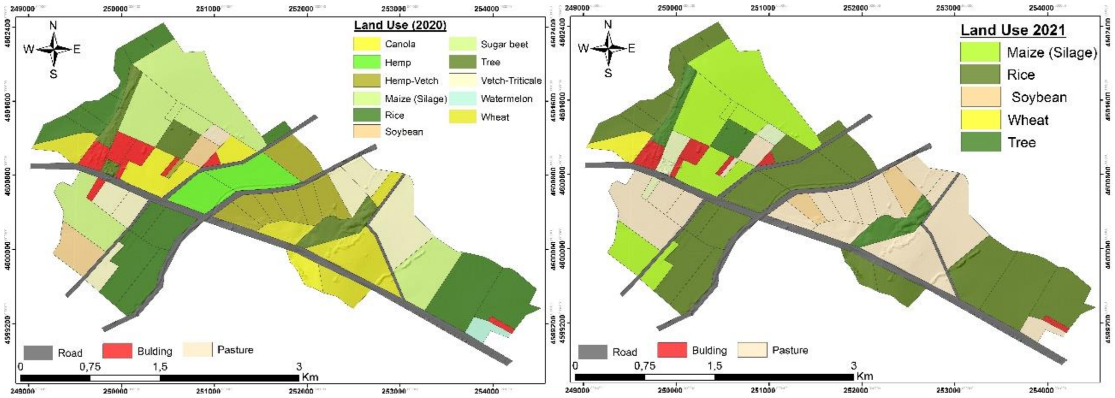

Figure 3.3. Land use maps 2020 (left) and 2021 (right)

Table 3.1**.** The parcels data of the farm for 2020 and 2021.

| Parcel no | Land use 2020 | Land use 2021 | Area | Parcel no | Land use 2020 | Land use 2021 | Area |
|---|---|---|---|---|---|---|---|
| 0 | Rice | Rice | 3.70 | 30 | Bulding | Bulding | 6.13 |
| 1 | Soybean | Maize (Silage) | 16.90 | 31 | Tree | Tree | 10.77 |
| 2 | Vetch-Triticale | Soybean | 8.11 | 32 | Wheat | Wheat | 11.83 |
| 3 | Rice | Rice | 14.31 | 33 | Bulding | Bulding | 6.50 |
| 4 | Hemp | Rice | 17.77 | 34 | Rice | Rice | 7.88 |
| 5 | Bulding | Bulding | 2.12 | 35 | Rice | Rice | 8.92 |
| 6 | Vetch-Triticale | Soybean | 7.94 | 36 | Sugar beet | Maize (Silage) | 28.30 |
| 7 | Hemp-Vetch | Rice | 16.74 | 37 | Sugar beet | Maize (Silage) | 6.65 |
| 8 | Hemp-Vetch | Soybean | 11.13 | 38 | Pasture | Pasture | 4.01 |
| 9 | Rice | Rice | 14.70 | 39 | Bulding | Bulding | 5.29 |
| 10 | Rice | Rice | 22.31 | 40 | Maize (Silage) | Rice | 31.55 |
| 11 | Rice | Rice | 6.49 | 41 | Wheat | Soybean | 30.92 |
| 12 | Tree | Tree | 2.37 | 42 | Road | Road | 79.15 |
| 13 | Hemp-Vetch | Soybean | 5.72 | 43 | Bulding | Bulding | 1.33 |
| 14 | Hemp-Vetch | Soybean | 6.72 | 44 | Tree | Tree | 17.67 |
| 15 | Hemp-Vetch | Soybean | 7.40 | 45 | Wheat | Soybean | 4.96 |
| 16 | Hemp-Vetch | Soybean | 8.09 | 46 | Bulding | Bulding | 1.25 |
| 17 | Vetch-Triticale | Soybean | 34.68 | 47 | Tree | Tree | 11.37 |
| 18 | Rice | Rice | 37.86 | 48 | Bulding | Bulding | 1.57 |
| 19 | Rice | Rice | 25.93 | 49 | Canola | Rice | 7.89 |
| 20 | Watermelon | Soybean | 6.54 | 50 | Soybean | Soybean | 7.14 |
| 21 | Canola | Rice | 8.41 | 51 | Hemp-Vetch | Soybean | 1.21 |
| 22 | Wheat | Rice | 12.72 | 52 | Bulding | Bulding | 1.69 |
| 23 | Vetch-Triticale | Maize (Silage) | 7.98 | 53 | Rice | Rice | 6.60 |
| 24 | Maize (Silage) | Soybean | 30.79 | 54 | Maize (Silage) | Maize (Silage) | 60.16 |
| 25 | Hemp | Rice | 23.41 | 55 | Vetch-Triticale | Soybean | 10.78 |
| 26 | Sugar beet | Maize (Silage) | 1.95 | 56 | Vetch-Triticale | Soybean | 11.13 |
| 27 | Rice | Rice | 6.74 | 57 | Canola | Maize (Silage) | 22.13 |
| 28 | Rice | Rice | 5.98 | 58 | Hemp-Vetch | Soybean | 7.93 |
| 29 | Rice | Rice | 5.18 | 59 | Wheat | Soybean | 9.48 |

## 3.3 Sampling and soil preparation

The grid-based soil sampling was conducted with 89 sampling points located 300 m from each other (Figure 3.4). From each sample point was taken 2 soil samples: one from depth 0 to 20 cm and another from 20 to 40 cm. In totally 178 soil samples were collected from the farm. The collection of samples was done in 2021. After collection all samples were air dry and passed on a 2 mm sieve.

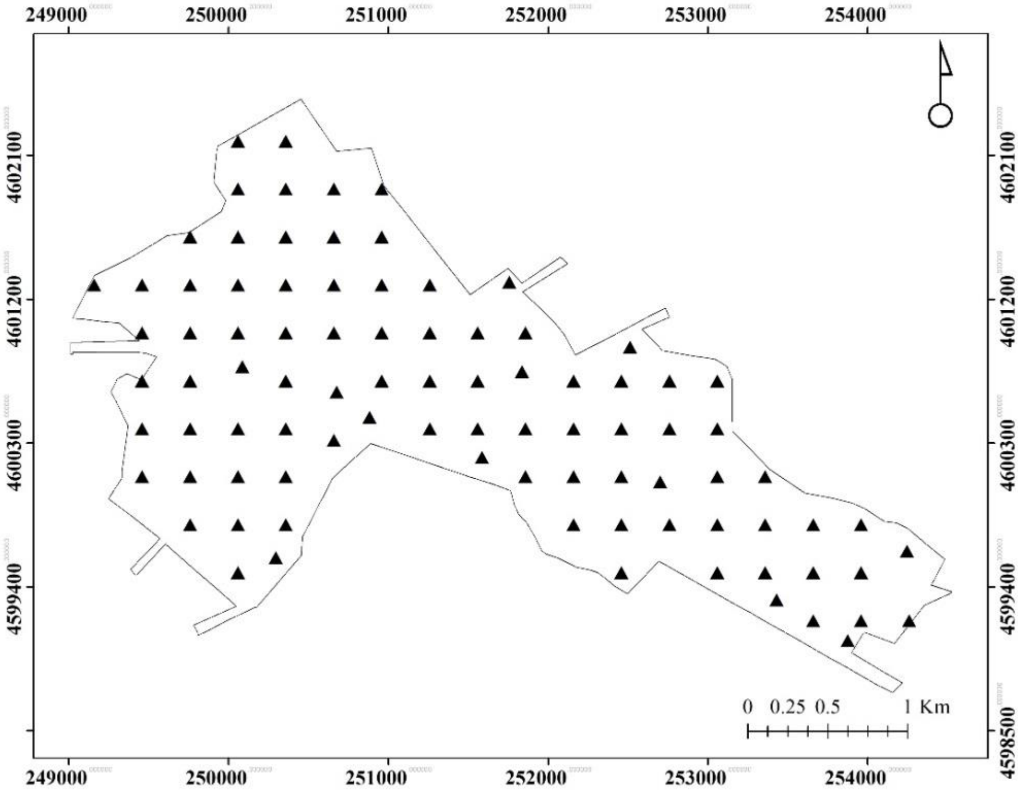

Figure 3.4. Soil sampling pattern

## 3.4 Soil analyses

For each soil sample sieved through 2 mm sieve selected soil analyses were conducted:

**Soil moisture.** It was measured by weighing the air-dry soil sample, drying it in an oven (105 ˚C) for 24 hours and then weighing the oven dry soil. The difference between air-dry and oven dry soil is soil moisture amount.

**pH.** It was measured by pH meter inside in mixture of 1:1 soil-water. (Hendershot et al., 2007)

**EC**. Electrical conductivity was measured by using an EC meter inside a mixture of 1:1 soil-water.(Soil Survey Staff, 2014)

**CaCO3.** Scheibler calcimeter method is used in determination of soil lime content. (Soil Survey Staff, 2014)

**Organic carbon and organic matter.** Walkley-Black method were used. (Nelson & Sommers, 2018)

**Soil particle size distribution.** This analysis was done by using Bouyoucos hydrometer method. (Bouyoucos, 1962)

**Bulk density.** It was not physically done due to high amount of water in part of research area. The bulk density was found of by using U.S. Department of Agriculture software SPAW. The program using Saxton et al. (2005) soil equation model where bulk density is determined by inserting the soil texture, organic matter, gravel, and compaction percentages.

## 3.5 Calculations of soil physical properties:

### 3.5.1 Soil organic carbon stock ($C_{stock}$)

The $C_{stock}$ of the surface layers (0–20 cm and 20-40 cm), expressed in kg $m^{-2}$, was calculated by the following equation (3.1): (Penman et al., 2003)

$$Cstock = SOC * BD * H * \frac{(100-SK)}{100} \tag{3.1}$$

SOC - soil organic carbon content (%)

BD - bulk density (g $cm^{-3}$)

SK - skeleton content (% by weight)

H - layer depth (2 dm)

### 3.5.2 Soil compaction susceptibility

For calculating the soil compaction susceptibility was used Vignozzi et al. index. This index is integrating the algorithm of Smith et al. with the equation for estimating the ρ100kPa (Pellegrini et al., 2018). Soil compaction susceptibility index (CI) calculated according to the following equation (3.2):

$\rho100kPa=1.04231+\exp(-0.486474-0.464448186*SOC)$ (3.2)

$CI= -0.09266+0.01576 * (Si+Cl)-0.00012 * (Si+Cl)^2+\rho100kPa$

SOC - soil organic carbon (%)

Si – silt (2–50 μm) (%)

Cl - clay (< 2 μm) (%)

### 3.5.3 Soil crusting susceptibility:

For calculating soil crusting susceptibility, the FAO (1979) crusting index (Ic, dimensionless) was used (Pellegrini et al., 2018). The soil crusting susceptibility calculated according to the following equation (3.3):

$$I_c=\frac{1.5*(Sif)+0.75*(Sic)}{Cl+5.8*SOC} \quad (3.3)$$

Sif - fine silt (2–20 μm) (%)

Sic - coarse silt (20–50 μm) (%)

SOC - soil organic carbon (%)

Cl - clay (< 2 μm) (%)

### 3.5.4 Soil erodibility:

The soil erodibility K-value based on the basic soil properties analyses results was expressed in calculation by Wischmeier et al. (USDA-NRCS, 2017). The soil erodibility was calculated with formula wish is below (3.4):

$$Kfactor =\{0.00021\times M^{1.14}\times(12-OM)+3.25\times(SSC-2)+2.5\times(PSHCC-3)\}/100 \quad (3.4)$$

OM - organic matter (%)

SSC - soil structure code (1, = very fine granular, 2, = fine granular, 3, = med or coarse granular, or 4 = blocky, platy, or massive)

PSHCC - profile saturated hydraulic conductivity code (1, 2, 3, 4, 5, or 6)

M - textural factor

M = (silt 0.002-0.05mm (%) + fine sand 0.05-0.1mm (%)) × (100 - clay <0.002mm (%))

## 3.6 Mapping

The maps were produced by using ArcGIS 10.5v program. Inverse Distance Weighing-(IDW) interpolation model was used to make maps. The IDW method approximate the values at the unsampled points using the inverse distance functions of the distances by using a linear combination of the values at the sampled points. IDW interpolation is often used in geographic information systems (GIS) to create raster layers from point data. When the data is in a regular grid system, the contour lines can be passed through interpolated values and the map can be created as a vector contour map or a raster shaded map (Burrough & Mcdonnell, 1998). Approximates are determined by the formula written below (3.5).

$$Z = [\sum_{i=1}^{n}(Zi/di^{m})\ \ /\sum_{i=1}^{n}(1/di^{m})] \qquad (3.5)$$

Z: estimated value, Zi: the value at the known point, di: the distance between point i and the point whose value will be estimated, dm: weight force (usually used between1-5). The weighting forces commonly used in the estimation of IDW in this study are (1, 2 and 3. force) has been used(Alaboz et al., 2021; Dengiz, 2020; Keshavarzi & Sarmadian, 2012).

## 3.7 Statistical analysis

Descriptive statistical analyses were done by using excel program. The corelation analysis was done by using SPSS program.

# 4 RESULTS AND DISCUSSION

## 4.1 Descriptive statistics of soil physical and chemical soil properties

The descriptive statistics of analysed soil physical and chemical properties for 0–20 cm and 20–40 cm depth in the study area is presented in the tables below (Table 4.1 and 4.2). The pH values of the soil samples ranged between 5.68 - 7.98 at top 20 cm and 6.05 – 8.11 in down 20 cm while the mean of both layers is around 7.0 which indicates neutral (Bickelhaupt, 2013). The electrical conductivity has big range from 124. 2 µS/m to 1873 µS/m at 0-20 cm and 139.8 – 1094 µS/m in the 20-40 cm layer while the average for both layers is around 400 µS/m. $CaCO_3$ mean is a little above 3 % in both layers. OC and OM are higher in top layer with mean 2.0 % and 3.45 % respectively and in down layer OC is 1.48 % and OM 2.55 %. The soil texture class is clay with clay content around 50 %, silt around 30 % and in sand around 20 % both layers. The estimate bulk density in the farm is estimated around 1.3 g/cm$^3$ in both layers. The organic carbon stock is higher in top layer where the mean is 5.10 kg m$^{-2}$ when down layer has mean of 3.81 kg m$^{-2}$. The compaction is mostly same in both layers with mean around 1.70 and the range around 1.5-2.0. The crust formation in both layers is generally same with a mean around 0.5. The erodibility K is also most same in both layers with a mean of 0.19 in top and 0.20 in bottom. According to Table 2 and Table 3, mostly all soil parameters were found in unsymmetrical position called as skewness. The coefficient of variation (CV) can be classified in 3 groups according to Wilding (1985): low (<15%), medium (15‑35%) and high (>35%). In the current study, the pH, bulk density and compaction of soils were classified as low, the silt, clay and erodibility K at top layer amounts were medium, and the values for the other properties were high.

Table 4.1. Descriptive statistics of soil properties in soils 0–20 cm depth

| Parameter | Mean | SD | CV (%) | Variance | Min. | Max. | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| pH | 7.21 | 0.52 | 7.27 | 0.27 | 5.68 | 7.96 | -0.83 | 0.20 |
| EC | 433.71 | 304.87 | 70.29 | 92946.80 | 124.20 | 1873.00 | 2.39 | 6.51 |
| CaCO3 (%) | 3.22 | 2.91 | 90.43 | 8.48 | 0.38 | 18.87 | 3.08 | 12.28 |
| Organic carbon (%) | 2.00 | 0.83 | 41.38 | 0.69 | 0.59 | 4.62 | 0.60 | 0.22 |
| Organic matter (%) | 3.45 | 1.43 | 41.38 | 2.04 | 1.02 | 7.96 | 0.60 | 0.22 |
| Sand (%) | 20.29 | 7.58 | 37.37 | 57.52 | 8.25 | 55.41 | 2.06 | 7.40 |
| Silt (%) | 31.78 | 4.84 | 15.23 | 23.42 | 16.70 | 44.61 | -0.23 | 1.39 |
| Clay (%) | 47.93 | 7.00 | 14.61 | 49.04 | 27.90 | 68.90 | -0.44 | 1.19 |
| Bulk density (g/cm$^3$) | 1.28 | 0.05 | 4.27 | 0.00 | 1.17 | 1.50 | 1.09 | 2.38 |
| Soil organic carbon stock (kgm$^{-2}$) | 5.10 | 1.99 | 39.12 | 3.98 | 1.60 | 10.81 | 0.43 | -0.12 |
| Compaction | 1.70 | 0.09 | 5.22 | 0.01 | 1.52 | 1.92 | 0.23 | -0.55 |
| Crusting | 0.49 | 0.17 | 34.56 | 0.03 | 0.04 | 1.11 | 0.93 | 3.07 |
| Erodibility K | 0.19 | 0.04 | 21.54 | 0.00 | 0.13 | 0.37 | 1.67 | 3.74 |

SD: standard deviation, Min: minimum, Max: maximum, CV: coefficient of variation.

Table 4.2. Descriptive statistics of soil properties in soils 20–40 cm depth

| Parameter | Mean | SD | CV (%) | Variance | Min | Max | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| pH | 7.28 | 0.50 | 6.81 | 0.25 | 6.05 | 8.11 | -0.54 | -0.45 |
| EC | 413.0 | 210.6 | 51.00 | 44377.9 | 139.8 | 1094.0 | 1.31 | 1.51 |
| CaCO3 (%) | 3.46 | 4.52 | 130.57 | 20.41 | 0.37 | 37.07 | 5.34 | 35.97 |
| OC (%) | 1.48 | 0.65 | 43.67 | 0.42 | 0.13 | 2.85 | -0.02 | -0.60 |
| OM (%) | 2.55 | 1.11 | 43.67 | 1.24 | 0.23 | 4.92 | -0.02 | -0.60 |
| Sand (%) | 20.31 | 9.76 | 48.08 | 95.32 | 7.36 | 74.56 | 3.23 | 13.69 |
| Silt (%) | 30.72 | 6.19 | 20.14 | 38.26 | 8.10 | 43.75 | -0.90 | 1.70 |
| Clay (%) | 48.98 | 7.62 | 15.55 | 58.00 | 17.34 | 62.01 | -1.40 | 3.19 |
| Bulk density (g/cm$^3$) | 1.30 | 0.07 | 5.43 | 0.005 | 1.19 | 1.58 | 1.74 | 3.66 |
| Soil organic carbon stock (kgm$^{-2}$) | 3.81 | 1.60 | 42.00 | 2.56 | 0.37 | 7.11 | -0.08 | -0.58 |
| Compaction | 1.76 | 0.10 | 5.57 | 0.01 | 1.59 | 2.02 | 0.54 | -0.11 |
| Crusting | 0.50 | 0.20 | 39.25 | 0.04 | 0.17 | 1.45 | 1.67 | 5.70 |
| Erodibility K | 0.20 | 0.06 | 31.04 | 0.004 | 0.13 | 0.59 | 3.54 | 18.22 |

SD: standard deviation, Min: minimum, Max: maximum, CV: coefficient of variation.

## 4.2 Spatial distribution of soil physical and chemical properties

The pH distribution between 2 researched soil layers is not significantly different. The lowest pH values which indicate acidification process are in the east of farm where the rice was growing for 2 years (parcels no 19, 18). It is known that intensive agricultural land-use for cultivated crops increases acidification in the soil profile (Q. Li et al., 2020). The main reason known for soil acidification is the long-term use of N fertilization, which significantly reduced soil pH in the surface soil layer, especially at the higher application levels. (Schroder et al., 2011). In Figure 4.1, the highest pH values which indicate alkaline soil is in the center of farm where hemp-vetch, pasture and soybean were growing in past (parcels no 13,15,14,16).

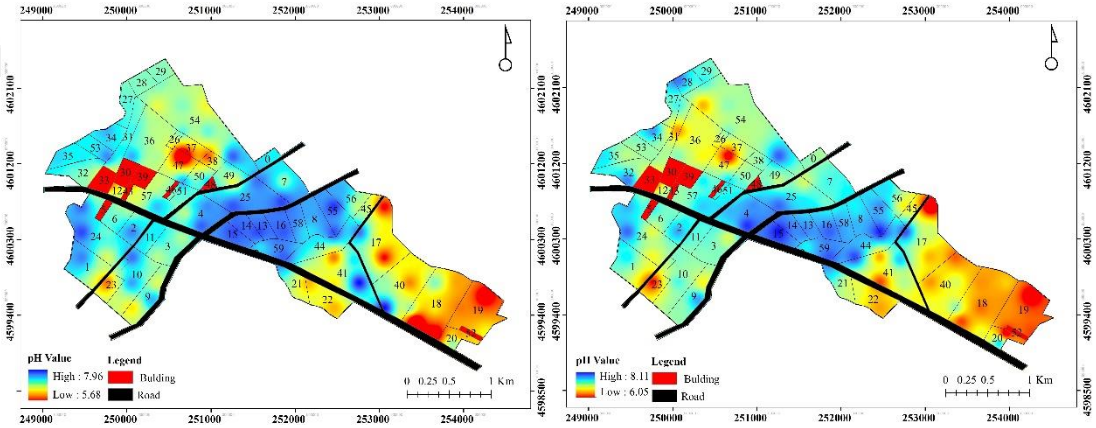

Figure 4.1 pH Map 0-20 cm (left) and 20-40 cm (right)

Electrical conductivity is higher in top layer. However, the location of low and high are distributed identical in the field. The highest amount of the EC is in the northwest (parcels no 27, 28, 29), northeast (parcels no 18, 19) and south (parcels 3, 9, 10, 11) where rice was growing for 2 years (Figure 4.2). All other area has lower amount. It is well known that EC decreases in cultivated lands. (Tiruneh et al., 2021)

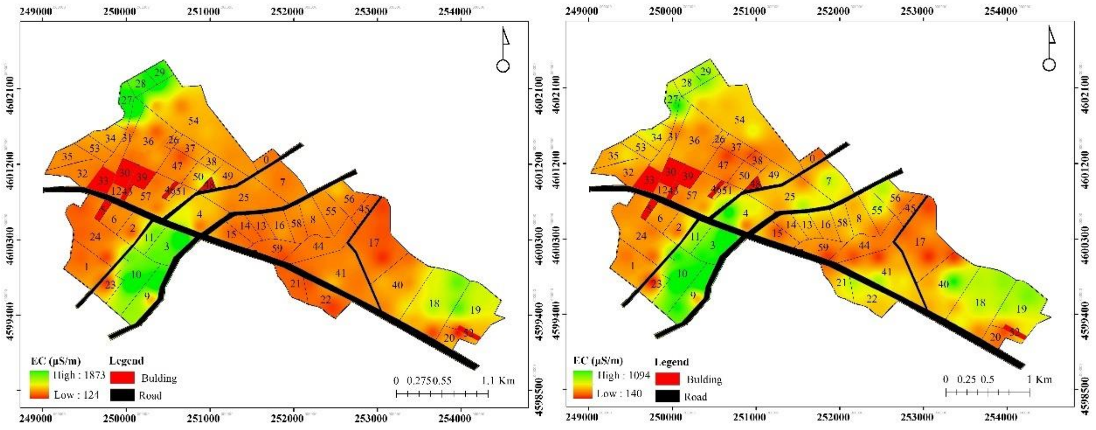

Figure 4.2. Electrical conductivity (µS/m) Map 0-20 cm (left) and 20-40 cm (right)

Generally, all the farm is in low $CaCO_3$ classification. However, some specific places have higher amount such as in 0-20 depth the parcels no 10, 53, 31, 34 and in 20-40 cm depth parcels 10, 44, 21, 59. Land use for the parcels differentiate such as rice, soybean, wheat, forest (Figure 4.3).

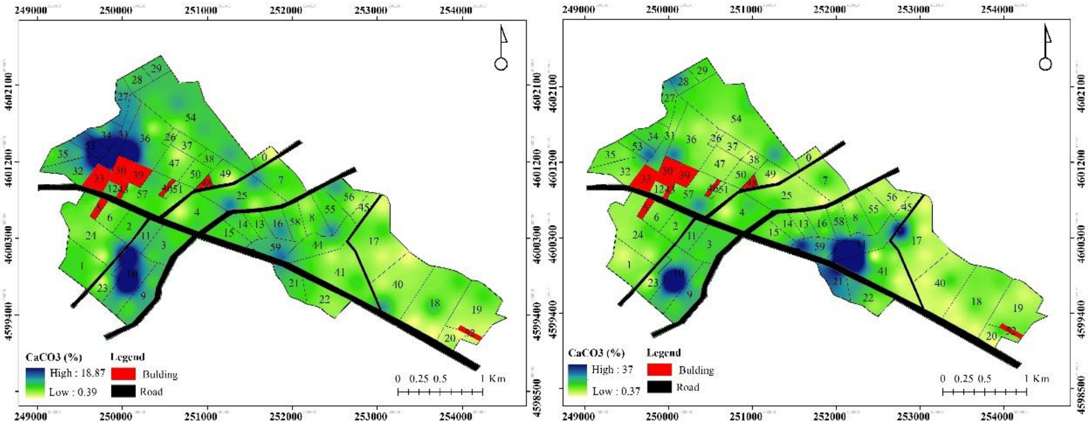

Figure 4.3 $CaCO_3$ (%) Map 0-20 cm (left) and 20-40 cm (right)

The bulk density distribution in filed are not different between top and bottom layers. The highest bulk density is in the center of the research area (parcels no 13, 14, 15, 16, 44, 58) where was pasture, forest land use and highest amount of sand in soil texture (Figure 4.4). All other area has lower density and higher clay amount in the soil. The bulk density is related directly with soil texture, the soil with more sand has higher bulk density and soil with more clay - lower. (Ahad et al., 2015)

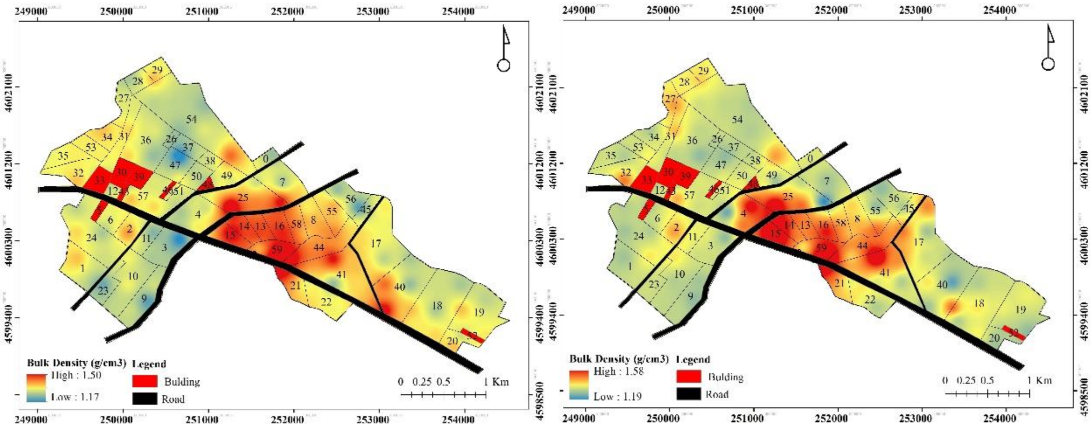

Figure 4.4 Bulk Density (g/cm3) Map 0-20 cm (left) and 20-40 cm (right)

The organic carbon and organic matter distribution between 2 layers in the area visually looks same. However, the higher amount of OC and OM is in the top layer. The highest amount of OC and OM has the lands located in the northwest part of the farm where sugar beet, corn was growing (parcels no 26, 36, 47, 37, 50, 54) and the lowest in the southeast were corn, sugar beet, soybean, rice was growing in past (parcels no 17, 40, 44) (Figure 4.5 and Figure 4.6).

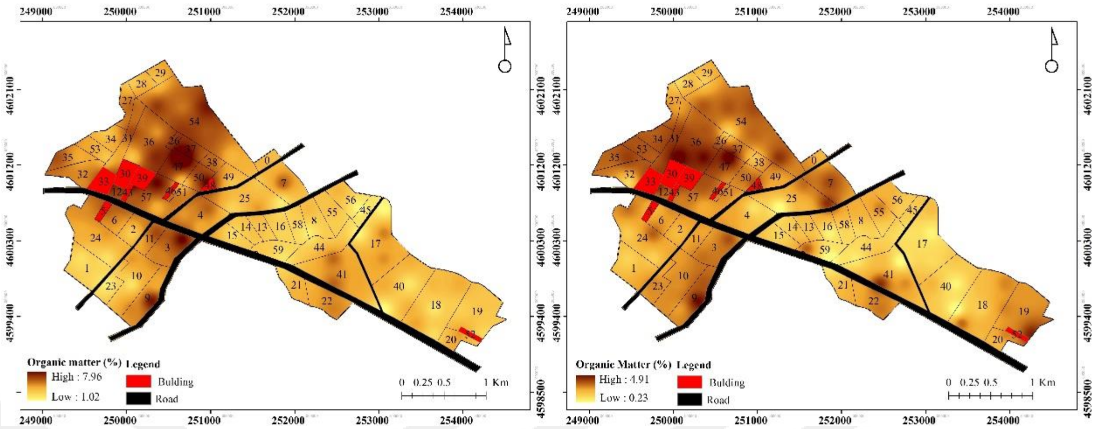

Figure 1.5 Organic Matter (%) Map 0-20 cm (left) and 20-40 cm (right)

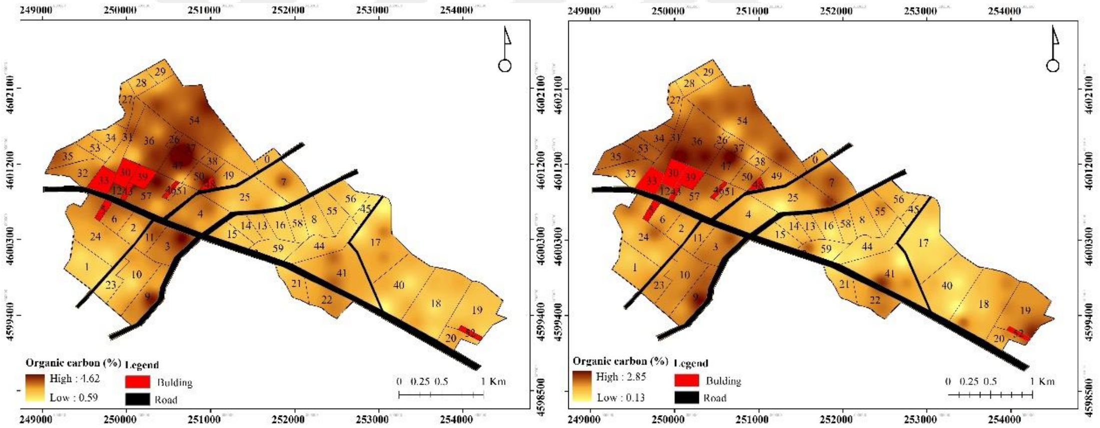

Figure 4.6 Organic Carbon (%) Map 0-20 cm (left) and 20-40 cm (right)

The distribution of clay, sand and silt is differentiating the farm. The clay is distributed in high amount generally in all the farm except in the center (parcels no 4, 13-16, 25, 44, 59) where the higher amount has clay and silt (Figure 4.7, Figure 4.8 and Figure 4.9). It is known from previous studies that soils in Bafra plain commonly have heavy clayey texture. (Dengiz et al., 2012) The land use for soil with high amount of sand and silt is pasture.

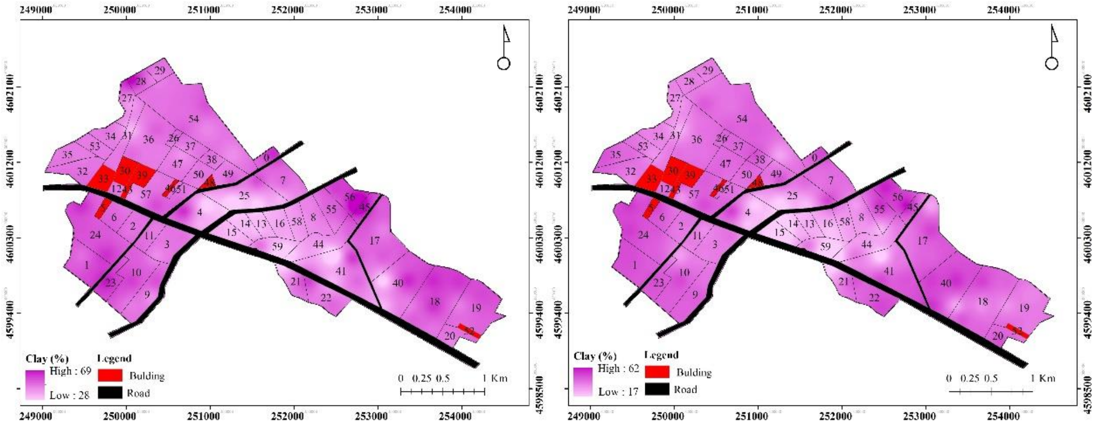

Figure 4.7. Clay (%) Map 0-20 cm (left) and 20-40 cm (right)

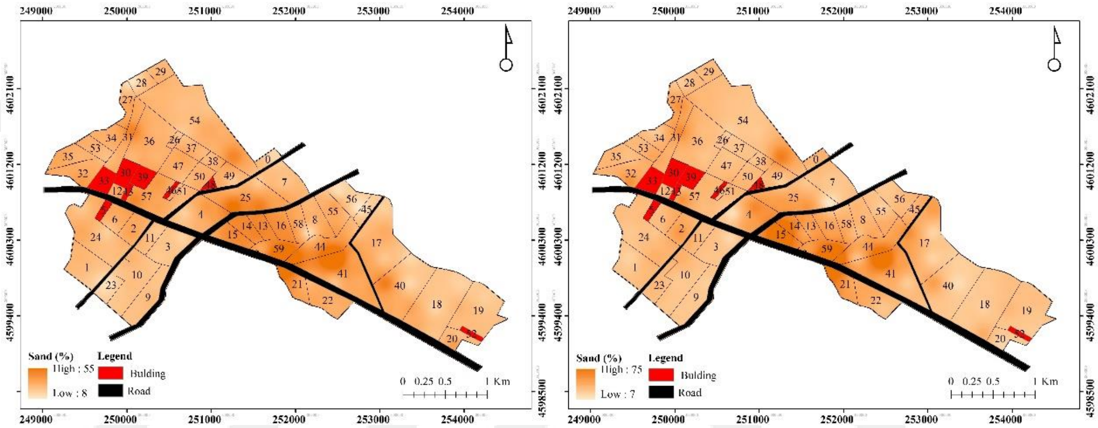

Figure 4.8. Sand (%) Map 0-20 cm (left) and 20-40 cm (right)

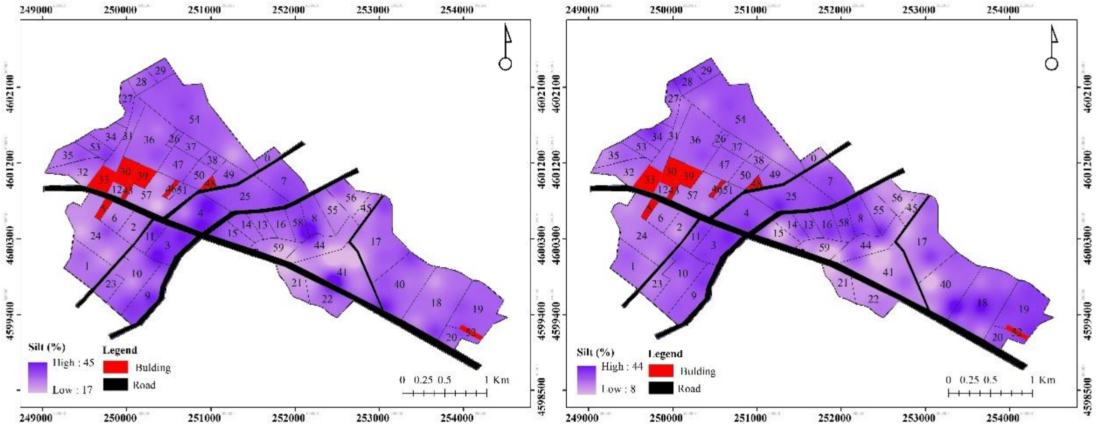

Figure 4.9. Silt (%) Map 0-20 cm (left) and 20-40 cm (right)

## 4.3 Organic carbon stock, soil compaction, crust formation and erodibility K distribution maps in the farm.

The top layer has more organic carbon stock when bottom layer. Previous study done in Ethiopia also states that SOC stock was significantly higher in the top layer (0 to 15 cm) compared with bottom layer (15 to 30 cm) (Mohammed et al., 2017). The distribution in the field is identical in both layers. The farm can be separated in 2 parts northwest and southeast (Figure 4.10). The highest concentration of organic carbon is in the northwest part and the lowest in the southeast part.

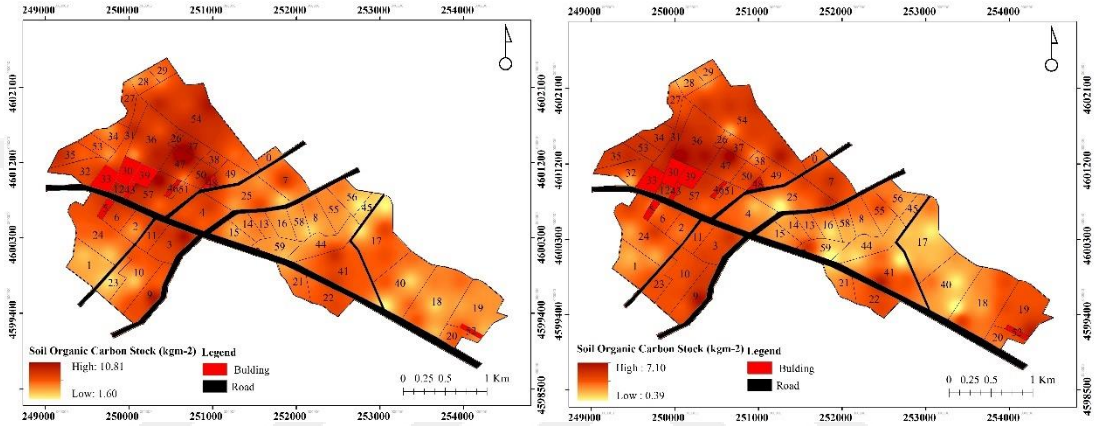

Figure 4.10 Soil Organic Carbon Stock (kgm-2) Map 0-20 cm (left) and 20-40 cm (right)

The soil compaction is higher in the bottom layer. However, the effected locations are mostly identical between 2 layers. The most compacted area is the centre place of the farm where is pasture, forest, and some rice fields (parcels (13-17, 44, 45, 55, 56, 58, 59). Also, the most compacted place has lower amount of organic carbon, higher bulk density and highest amount of sand and clay particles in the soil (Figure 4.11). The other cultivated areas are compacted less.

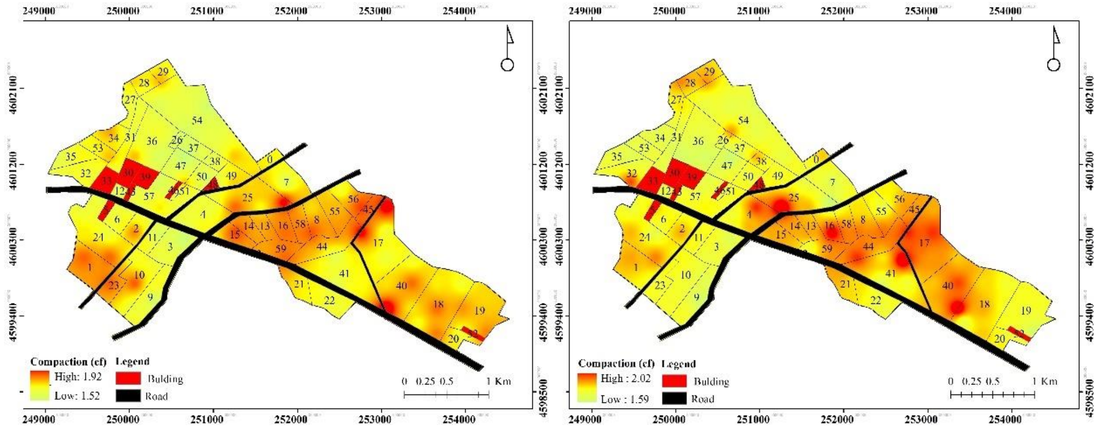

Figure 4.11 Soil Compaction (cf) Map 0-20 cm (left) and 20-40 cm (right)

The crust formation is much more visual in the top layer. In the top layer most, vulnerable location is in the centre location where is high amount of silt and sand, lowest amount of organic carbon (parcels no 4, 25, 14, 15) and bottom layer crusting is disperse in some regional parts in the parcels 8, 40, 41, 58.

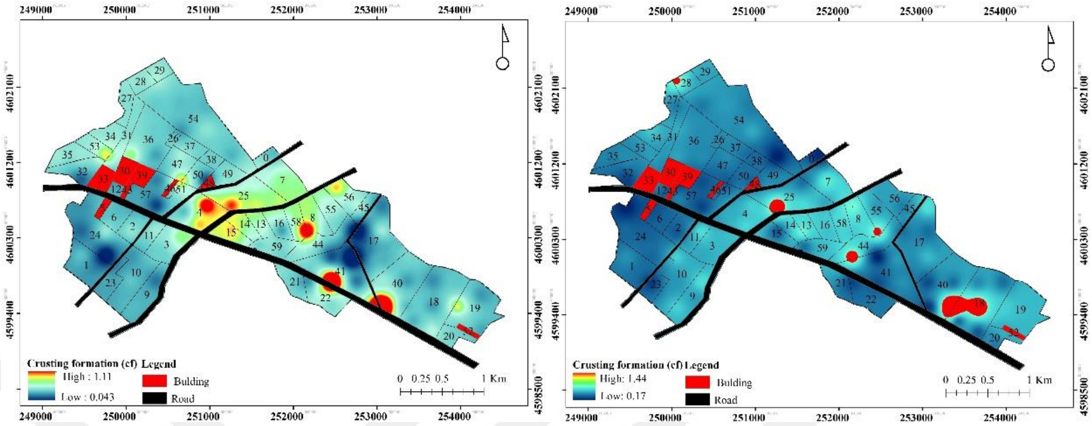

Figure 4.12. Soil Crusting Formation (cf) Map 0-20 cm (left) and 20-40 cm (right)

The soil erodibility maps of the top and bottom layers are mostly identical. The most areas at risk for soil erosion is the centre location of the farm with lowest organic carbon amount, the highest amount sand and silt particles in the soil (parcels no 4, 13-16, 25, 44, 58, 59), the other territory where high amount of clay particles is in soil is less vulnerable for erosion (Figure 4.13). The land use for most vulnerable location is pasture which was choose as a prevention against erosion. Cover crops prevents soil erosion and improves soil condition (Ruiz-Colmenero et al., 2013). Moreover, vegetation coverage has a big effect on erosion prevention and reducing loss ratio of nutrients and fine particles fine particles (Yan et al., 2013).

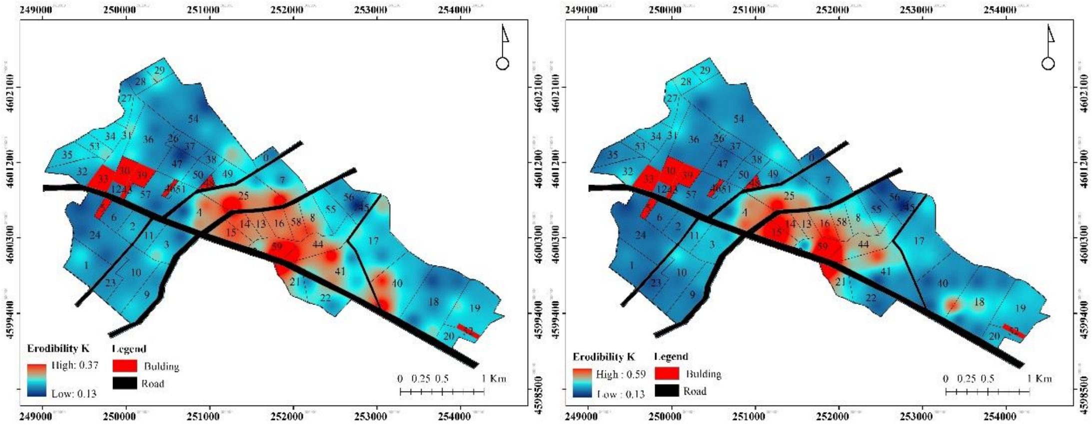

Figure 4.13 Soil Erodibility Factor (K) Map 0-20 cm (left) and 20-40 cm (right)

## 4.4 Relationship between soil properties and physical quality parameters

Correlation of soil properties are given in Table 4.3. The soil properties were examined for checking statistically significant relationships between soil organic carbon and soil physical properties such as soil compaction, crust formation, erodibility K.

The correlation analysis showed that erodibility K is highly significantly ($P < 0.001$) related to organic carbon, organic carbon stock, organic matter and between each other. Moreover, the Erodibility K has relationship ($P < 0.001$) with pH, sand, clay, bulk density. Many previous studies of soil erosion confirmed that erodibility is strongly related to soil organic matter, soil texture and structure. (Wang et al., 2013) Dikinya's study results have shown that erodibility factor K significantly correlates with organic matter amount, clay fractions percentage, slope length, bulk density, structural properties, and soil porosity. (Dikinya, 2013). The Radziuk study says that decrease in soil organic carbon increases the erodibility.(Radziuk & Switoniak, 2021)

The compaction has a relationship ($P < 0.001$) with to organic carbon, organic carbon stock, organic matter, clay, bulk density, and lesser relationship ($P < 0.005$) with sand. The previous studies confirm the findings. The Kumar study find that compaction of soil highly related with its texture (Kumar et al., 2009). Many other scientists studies confirmed the significant relationship between organic matter and soil compaction and stated that an increase in soil organic matter reduces the compactability (Kumar et al., 2009; Shahgholi & Jnatkhah, 2018; Soane, 1990)

The Crust formation has a relationship ($P < 0.001$) with organic carbon, organic carbon stock, organic matter, silt, and clay. It is well known in previous studies that the soil crusting not only depends on the external factors but also on soil factors such as organic matter content, soil texture, clay mineralogy, exchangeable cations, sesquioxide content, soil water content (Pagliai, 2007). Maïga-Yaleu study pointed out a significant relationship between soils crusting and SOC (Maïga-Yaleu et al., 2013). Négyes study states that the surface crusts differentiant depending on the soil textute and silty loamy soils resulted in harder and more solid crusts in comparison with other textures (Négyesi et al., 2021).

Also soil compaction, crust formation and erodibility K have strong relationship ($P < 0.001$) between each other.

Table 4.3. Pearson correlation between soil properties

| Soil property | SOC stock | Soil compaction | Crust formation | Erodibility K |
|---|---|---|---|---|
| pH | -.348$^{**}$ | .355$^{**}$ | 0.101 | .338$^{**}$ |
| EC | 0.109 | -0.180 | 0.187 | -0.132 |
| CaCO3 | -0.067 | 0.099 | 0.195 | 0.064 |
| OC | .996$^{**}$ | -.961$^{**}$ | -.290$^{**}$ | -.496$^{**}$ |
| OM | .996$^{**}$ | -.961$^{**}$ | -.290$^{**}$ | -.495$^{**}$ |
| Sand | -.212$^{*}$ | .262$^{*}$ | -0.136 | .767$^{**}$ |
| Silt | 0.060 | -0.034 | .682$^{**}$ | -0.110 |
| Clay | .223$^{*}$ | -.309$^{**}$ | -.379$^{**}$ | -.893$^{**}$ |
| Bulk density | -.469$^{**}$ | .569$^{**}$ | 0.201 | .852$^{**}$ |
| SOC stock | - | -.951$^{**}$ | -.300$^{**}$ | -.465$^{**}$ |
| Soil compaction |  | - | .324$^{**}$ | .455$^{**}$ |
| Crust formation |  |  | - | .369$^{**}$ |

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

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

# 5 CONCLUSION

The research conducted in the "Yeşil Küre" farmlands found out that the farmlands has generally neutral pH about 7.0, electrical conductivity about 400 µS/m, about 3 % of $CaCO_3$ in both layers, higher amount of OC and OM in top layer (0-20 cm) and lower amount in bottom layer (20-40 cm). The soil general texture class is clay. The most vulnerable farmlands for soil compaction, erodibility and crust formation are the centre part of the farm where were the lowest amount of organic carbon and clay, highest bulk density, silt and sand concentration. Comparing the farmland use maps for 2020-2021 with the soil properties maps, we can see that for the most vulnerable location for soil erodibility K, crust formation and compaction (the central part) the prevention agriculture techniques such as land cover by grass are already used. The land cover should be continued use in the risky territory for preventing erosion. The correlation analysis showed that soil compaction, crust formation, erodibility K is highly significantly ($P < 0.001$) related to organic carbon, organic carbon stock, organic matter and between each other. Here was not identified significant differences between the soil properties in top and bottom layers. The study showed importance of soil quality assessment for tracking the soil degradation and making policies for improving soil quality.

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# CURRICULUM VITEA

Deividas MIKŠTAS in 2014 graduated from Joniškis Aušra gymnasium. In 2018 was awarded by a bachelor degree in Agronomy, Faculty of Agronomy, Lithuania Aleksandras Stulginskis University (from 2019 Vytautas Magnus University Agriculture Academy). With the Erasmus exchange program studied in Latvia University of Life Sciences and Technologies (2016) and Turkey Ege University (2018). From 2020 was enrolled in a joint master degree program ‘’The Erasmus Mundus Master in Soil Science (emiSS)’’ and studied in 3 universities: Turkey Ondokuz Mayıs University, Poland University of Agriculture in Krakow and Russia Southern Federal University. 2021 done practical internship in the Denmark Aarhus University Department of Agroecology.

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**Won Awards, Incentives and Scholarships**

1. Erasmus mundus scholaship (2020-2022)