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AGRICULTURAL & ENVIRONMENTAL REPORTS FOR SUSTAINABLE FUTURE

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İÇİNDEKİLER

PREFACE

Distinguished scientists, we are pleased and happy to be together with many scientists who contributed to the scientific field and literature in this book called "Agricultural and Environmental Reports for Sustainable Future". We would like to thank our valuable authors who contributed to science with their valuable studies in this book.

Over the past century, important progress has been achieved worldwide in improving human welfare. Societies have changed radically thanks to quantum leaps in technology, rapid urbanization and innovations in production systems. However, in recent years, there have been important developments that hinder sustainable life and agriculture. For example, the Covid-19 pandemic crisis. If these disasters continue, we may face problems in food supply. In this regard, scientists and authors who conduct research on this subject have great responsibilities. Humanity must do its best to protect the ecosystem from greater dangers.

Agriculture and food systems have already changed significantly, but will need to adjust further in this evolving global environment. We must consider the relationship between climate change and sustainable agriculture. If we need to take precautions in this regard, we should care about it. Even small changes in the climate, for example slight shifts in annual rainfall or seasonal precipitation patterns, can severely affect productivity.

One of purpose this book is not to present a menu of solutions, but rather to increase understanding of the nature of the challenges that agriculture, rural development and food systems are facing now and will be facing into the 21st century. Although agriculture at the global level has become more efficient, in recent years, competition for natural resources has intensified owing to consumption patterns driven mainly by population growth, changing dietary patterns, industrial development, urbanization, Covid-19 pandemic crisis and climate change. Finally, pressure on natural resources will be driven not only by changes in demand, but by changes in climate. Land degradation (example of reduction of organic matter, especially in agricultural soils), decrease in agricultural land, growing population, deforestation and water scarcities are among the most visible manifestations of this unsustainable competition. Despite all these disadvantages, the productivity of agriculture has been increasing, owing to the intensification of production methods. These and similar problems should be solved urgently, and the number of academic studies on these issues should be increased. The key to sustainable agricultural growth is more efficient use of land, labour and other inputs through technological progress, social innovation and new business models.

In this book, there are 14 chapters prepared by our very valuable authors. As editors, we would like to express our gratitude to all our authors who have made significant contributions with their knowledge, experience and suggestions and to our valuable readers. The book will generate awareness towards sustainable agriculture and its impact on environment, human health and other ecosystems along with some of the better management strategies.

Sincerely Yours,

October, 2022

Assoc. Prof. Dr. Korkmaz BELLİTÜRK

Assoc. Prof. Dr. Mehmet Fırat BARAN

Assoc. Prof. Dr. Ahmet ÇELİK

Assoc. Prof. Dr. Korkmaz BELLİTÜRK is Associate Professor of Soil Science and Plant Nutrition Department of Agriculture Faculty at the Tekirdag Namık Kemal University, in Tekirdag, Turkey. He did his undergraduate degree at the Trakya University in Turkey in 1996 as head of the department, followed by a Ph. D project on hydrolysis of urea. He started at the Trakya University in 1996, focusing on plant mineral nutrition, and was a Research Assistant at the Faculty of Agriculture from 1996 till 2007. In 2007, he became Assistant Professor of Soil Science and Plant Nutrition Department, Tekirdag Namık Kemal University, Turkey. He was assigned to lecture for one week each within the context of Erasmus teaching staff mobility at Trakia Democritus University in Greece in 2011 and at University of Technology and Life Sciences in Poland in 2013. He was assigned for 3 months between 11 July and 11 October at the University of Vermont in Burlington/Vermont, USA to take a part in a project called “use of soil earthworms in agriculture” in 2011. From 2014 to 2015, he worked as a postdoc researcher at the University of Vermont in USA, working on soil ecology, earthworms and vermicompost. After the postdoc he became Associate Professor of Soil Science and Plant Nutrition Department of Agriculture Faculty at the Tekirdag Namık Kemal University, in Tekirdag, in 2018, where he focused of phytoremediation, plant nutrition, soil and water pollution, soil ecology, organic farming, composting and vermicomposting. He conducts one of the bilateral cooperation projects signed between the Council of Higher Education-Turkey and Higher Education Commission-Pakistan. The universities involved in the project are Tekirdag Namık Kemal University-Turkey and University of

Agriculture Faisalabad-Pakistan in 2019. He served as project head and researcher in 29 projects supported by TUBITAK, Trakya University, Tekirdag Namık Kemal University, Nevsehir Hacı Bektas Veli University, Bilecik Seyh Edebali University, TAGEM, University of Agriculture-Faisalabad and Yozgat Bozok University Scientific Research Projects Units. He has 145 articles (*Totally, 21 of them are the articles published in international periodicals cited by international science indexes [SCI-SCI-Exp.]*), 9 book chapters and 3 books on soil science, ecological management for soil quality, plant nutrition, soil-water pollution, ecologic agriculture, vermicomposting and fertilization topics as research articles and papers presented in domestic and abroad scientific meetings. He has been awarded many projects and scientific publication awards in his field of study. He has been editor-in-chief of the journal Rice Research since 2015. He has one national patent. He features on ISI's list of highly cited authors in the field of soil fauna, soil fertility and plant sciences since 2010.

Research Interests: Soil Fertility, Soil Fauna, Soil Chemistry, Plant Nutrition, Soil Biology, Ecological Management for Soil Quality, Soil Pollution, Composting and Vermicomposting, Sustainable and Organic Agriculture, Fertilizers (Chemical, Organic and Organo-mineral fertilizers).

Assoc.Prof. Dr. Mehmet Fırat BARAN

He graduated from Trakya University, Faculty of Agriculture, and Department of Agricultural Machinery in 1997 as head of the department. At the same year, he both started to MSc. in institute of natural and applied sciences in Trakya University and started to work as research assistant in Trakya University, Faculty of Agriculture, Department of Agricultural Machinery. He assumed title "MSc Engineer" in 2000 and "PhD" in 2010. He is still working as Associate Professor in Siirt University, Faculty of Agriculture, Department of Biosystems Engineering. He attended many conferences, meetings, courses, seminary, panels, workshops, congress and festivals at home and abroad. He served as project head and researcher in 7 projects supported by Trakya University, Adiyaman University, Siirt University, TAGEM, University of Agriculture- Scientific Research Projects Units. He has 155 articles and 12Chapters on agricultural energy systems, energy use in agriculture, renewable energy technologies, recycling of agricultural waste, agricultural mechanization. topics as research articles and papers presented in domestic and abroad scientific meetings. Also, 39 of them are the articles published in international periodicals cited by international science indexes (SCI-SCI-Exp.). He studies the subjects about recycling of agricultural waste, biogas, energy use in agriculture and agricultural mechanization which are popular subjects all around the world recently. He still continuing his academic studies, trainings and projects in Siirt University. **Research Interests:** Energy Systems, Energy Use In Agriculture, Renewable Energy Technologies, Recycling of Agricultural Waste, Agricultural Mechanization.

Assoc. Prof. Dr. Ahmet ÇELİK

He completed his undergraduate (Harran University) education in 1995, his master's degree (Harran University) in 1997 and his doctorate (Çukurova University) in 2012. He worked in the private sector for 1 year in 1992. He started to work at the Ministry of National Education in 1997. Between 2000-2007, he worked as an Voluntary Instructor in the Directorate of Kahta Vocational School of Harran University. In 2007, he held various administrative positions at Adıyaman University. In 2013, he was appointed as Assistant Professor Doctor at Adıyaman University Kahta Vocational School, Department of Plant and Animal Production. He is still working as an Associate Professor at Adıyaman University, Faculty of Agriculture. He worked as an executive and assistant researcher in approximately 15 projects supported by the European Union, World Bank, GAP Administration, Çukurova, Adıyaman Universities and Non-Governmental Organizations. Assoc. Dr. Ahmet Çelik took part in 2 second thesis advisory and 22 graduate thesis juries. He is the Adıyaman Provincial Representative of TEMA Foundation and a member of the Turkish Soil Science Association. Assoc. Dr. Ahmet Çelik has been an assistant editor and member of the editorial board, columnist and section writer in various newspapers and scientific journals since 1994, as well as in DÜNYA Newspaper; He prepared research and informational supplements and supplements published alongside the newspaper. He has many national and international articles and papers published on soil quality, soil organic carbon, agriculture and waste management in environmentally friendly practices. He is married and has three children.

CHAPTER 1

DETERMINATION OF NUTRITIONAL STATUS OF SUNFLOWER (*Helianthus annuus* L.) PLANT IN ÇORLU DISTRICT OF TEKİRDAĞ PROVINCE, BY PLANT AND SOIL ANALYSIS

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INTRODUCTION

As a result of using our agricultural land outside of its purpose, our production areas have decreased in recent years. Subsequently, it occurs that production should be sustainable in order to get the maximum product from the unit area of our agricultural areas that cannot be expanded. The amount of product to be obtained from the soil depends on many factors such as soil, plant, climate, use of certified seeds, fertilization-plant nutrition, cultivation technique (Sağlam, 2012).

The seeds of many plants that are cultivated wild or cultured in the world contain oil. Some of these plants are perennial, mostly annuals. Sunflowers cultivated in agricultural activities are usually annual plants and they store oil in their seeds. The oil in the seeds of plants is extracted by applying various methods and used for many purposes.

With the rapidly increasing world population, it is seen that the level of life rises and oil consumption increases accordingly. Demand for vegetable oils is increasing rapidly due to the fact that our animal oil production is low compared to our consumption rate, and as a result of the fact that animal fats are expensive. Sunflower (*Helianthus annuus* L.) is one of the most important oil plants in the world and in our country.

It was observed that the production of sunflower plants in the world in 2020-2021 was carried out on an area of 26.3 million hectares and a yield of 1.8 tons / ha was obtained. Compared to 2019-2020, there was a 2% increase in sunflower production areas, but it was revealed that there was an 11% decrease in yield. In 2020-2021, production increased by 8% compared to 2019-2020 and it was realized as 54.7 million tons in total in the world. It was assumed that the production will be 49.7 million tons by 9% of decrease in 2021-2022 compared to the previous year, and the production areas wouldreach 26.9 million hectares by 2% of increase. The export of sunflower seeds in the world is quite low compared to sunflower oil. Most of the exports are made as crude oil after crushing. In 2020-2021, only 6.6% of sunflower seeds were exported (Anonymous, 2021).

Sunflower plant, which has an important place in today's agriculture, has the largest share in vegetable oil production in Turkey, with a ratio of 50%. Among the oil plants that meet the nutritional needs of human beings and in terms of food quality, sunflower is among the most used oils today. In our country, sunflower production is carried out between approximately 550.000-600.000 hectares of land, varying from year to year. When the sunflower plant production areas are examined, it is seen that 73% of the production areas are in the Thrace-Marmara region, 13% in the Central Anatolia region, 19% in the Black Sea region, 3% in the Aegean region and 1% in the Eastern and Southeastern Anatolia regions (Süzer, 2010).

Chemical fertilizers and chemical pesticides, which are unconsciously used in agricultural practices to meet our increasing nutritional needs, negatively affect the sustainable productivity of our agricultural lands. In addition, it is seen that the natural balance has begun to deteriorate. It has been observed that the use of chemical fertilizers and pesticides over a long period of time negatively adversely affects food quality and human health, as well as the deterioration of soil quality. Against these problems, agricultural production systems that aim to use organic products that do not threaten human health and that are friendly to the environment should be implemented, instead of making production using only the soil and using all kinds of chemical fertilizers and pesticides, without harming the nature, preserving the sustainable fertility of the soil and natural balance (Kıral, 2020).

The main issue in the productivity of our agricultural lands is the precise and accurate determination of the useful and favorable levels of plant nutrients in the soil for plants. In an examined fertile soil, plant nutrients should be present in sufficient amounts and in a balanced ratio in the plant root zone, but heavy metals should not have a toxic effect in terms of plant growth and diseases that occur as a result of adverse conditions (Karaman et al., 2012).

Conscious fertilization is of great importance in terms of agricultural production. Agricultural production should be done by making plant and soil analyzes. By making plant and soil analyzes, nutrient needs in plant production should be determined and fertilization should be done in line with these requirements (Parlak, 2016).

The sunflower plant, which is one of the annual oil plants that adapts to many climatic regions and is widely produced, is generally cultivated in hot, dry and low relative humidity regions during seed maturation. The sunflower plant is used in various ways such as seed, oil in the seed, pulp after oil extraction, dry stem and green silage feed. Sunflower plant is mainly cultivated for the oil in the seed.

The sunflower plant has an important position in agricultural production in our country and it ranks first among oil plants in production and consumption. When the sunflower plant is considered in terms of agricultural land, production amount and yield quality, it is seen that Turkey is among the first 20 countries in the world. However, it is of great importance that sunflower production should be increased in order to meet the oil requirement due to excess consumption in our country (Semerci and Özer, 2011).

Sunflower plant is used as animal feed in animal production as well as in human nutrition because its seed contains significant amounts of carbohydrates, proteins and fats. When evaluated in terms of healthy nutrition, the sunflower plant is also an important culture plant (Büyükfiliz, 2016).

In Turkey, the area of agricultural land used for sunflower production in 2020-2021 decreased by 3.2% compared to 2019-2020 and was found to be 728 thousand hectares. In 2020, it was observed that the oil sunflower production area in Turkey was 650,000 ha. 142.000 ha in Tekirdağ province, 90.000 ha in Edirne province, 60.000 ha in Adana province, 77.000 ha in Kırklareli province and 66.000 ha in Konya province constituted 67% of the oil sunflower production area (Anonymous, 2021).

The amount of sunflower production in Turkey in 2020-2021 decreased by 1.6% compared to 2019-2020 and became 2 million tons, and 1.9 million tons of it was produced as oil sunflower. With 278.000 tons of production in Konya, 195.000 tons in Adana, 240.000 tons in Edirne and 226,000 tons in Kırklareli, these provinces were placed near the top. When TUIK data was examined, it was predicted that sunflower production in 2021 would increase by 14.7% compared to 2020 and reach 2.4 million tons (Anonymous, 2021).

Although the Thrace region is the region where the highest yield is obtained from the unit area in sunflower cultivation, the biggest problem when the soils are examined in terms of plant nutrients is that the alternation is done in the form of sunflower-wheat continuously and the organic matter level decreases due to the fact that the plant residues left at the end of the harvest are not mixed with the soil and burned instead (Bellitürk, 2011).

In order to observe the effects of planting time on yield components of sunflower plant, a research was conducted in Khartoum region of Sudan, which has a semi-arid climate. In this study, it was observed that there was a significant increase in the height, leaf area index, table diameter, dry weight, number of seeds per table and 100 seed weights of sunflower in planting in March, May and July (Hilwa et al., 2019).

Mehmood et al. (2018) investigated the combined effects of nitrogen and boron in sunflower on growth, yield and oil quality with two sunflower hybrids (Hysun-33 and DK-4040), two nitrogen doses (0 and

150 kg ha^{-1} N) and three boron doses (0, 2 and 3 kg ha^{-1} B). They stated that plant height, plant stem thickness, table diameter, grain and biological yield were affected by different nitrogen and boron doses and determined that at 150 kg ha-nitrogen dose, the longest plant height was 155 cm, the widest table diameter was 20.17 cm, the highest number of grains per table was 719.2, maximum 1000 24 seeds weight was 51.70 g, the widest plant stem thickness was 2.17 cm, the maximum grain yield was 3748 kg ha, the highest harvest index was 24.16%. They reported that the highest oil rate was obtained from 0 kg ha-nitrogen dose with 37.25%.

In a study, the effects on yield and quality of sunflower were investigated by using four different nitrogen doses and four different sulfur doses. It was observed that there was a 12% increase in plant height in sunflower with nitrogen application. The widest table diameter was determined as 25 cm at a nitrogen dose of 10 kg da^{-1}. Maximum 1000 grain weight was obtained from a nitrogen dose of 10 kg da^{-1}. According to the nitrogen averages, the grain yield, which was 231.9 kg da^{-1} at 0 kg da^{-1} nitrogen dose, increased by 31.3% until 10 kg da^{-1} nitrogen dose and 304kg da^{-1} yield was obtained. The oil yield, which was 98.7 kg da^{-1} in the control parcels, increased by 31.5% up to the nitrogen dose of 10 kg da^{-1} and was obtained as 129.8 kg da^{-1}, and there was a decrease at 15 kg da^{-1} nitrogen dose, but it was determined that there was no statistical difference between this decrease and 10 kg da^{-1} nitrogen dose. It was suggested that 10 kg da^{-1} nitrogen and 5 kg da^{-1} sulfur should be used for higher grain yield and quality in sunflower (Erbaş and Şenateş 2020).

In a study, Aydoğdu (2019) observed the effects of nitrogen doses on the varieties by using three sunflower varieties (Bosfora, P64LE119 and LG5582) and five different nitrogen doses (0, 5, 10, 15 and 20 kg da^{-1} N) as the second crop in 2017. The earliest emergence, flowering and physiological maturity timeswere 5.78, 47.22 and 106.11 days at a dose of 20 kg da^{-1} nitrogen, respectively. The longest plant height was176.78 cm at 15 kg da- nitrogen dose, the widest table diameter, the most grain yield in the plant and the maximum 1000 grain weight were 20,95 cm, 73.05 and 71.38 g respectively at a nitrogen dose of 20 kg da^{-1}, the maximum shell rate, the most grain yield and the highest oil content were 25.21%, 407.32 and 50.76% at 15 kg da^{-1} nitrogen dose, respectively.

In a two-year study conducted in Ankara, yield and yield characteristics of 03M142 hybrid appetizer sunflower plant were investigated by applying nitrogen doses of 0, 4, 8 and 12 kg da^{-1} at 20 cm, 30 cm and 40 cm row spacin. It was observed that the longest plant height was 157.2 cm at a dose of 12 kg N da^{-1}. The highest level of grain yield per decare as 410.3 kg da^{-1} was observed to be over 20 cm in-row distance at 12 kg N da^{-1} application. It was revealed that there was an increase in yield in applications where the nitrogen doses were increased and the row spacing was narrowed (Day and Kolsarıcı, 2014).

A study was conducted with the sunflower plant in 2011-2012 and 2013-2014 to observe the effects of sulfur and nitrogen. Four different nitrogen doses (50, 75, 100 and 125 kg ha^{-1} N) and five different sulfur doses (0, 20, 30, 40 and 50 kg ha^{-1} S) were applied. The longest plant height was found as 113.5 cm from 125 kg ha^{-1} nitrogen application, the widest table diameter was found as 17.53 cm from 100 kg ha^{-1} nitrogen application, the highest grain yield was found as 1816 kg $ha^{-1}$from 100 kg ha^{-1} nitrogen application. The highest oil content was obtained as 36.4% from the parcels without nitrogen application (Biswas and Poddar, 2015).

The effects of increasing doses of phosphorus and potassium fertilization applications on the seedling growth, fruit characteristics and nutritional status of kumquat (*Fortunella margarita* L.) plant were investigated in the pot experiment. Phosphorus doses applied in the form of $NH_4H_2PO_4$ as 10, 40 and 80 mg kg^{-1} and potassium applied in the form of K_2SO_4 as 150, 300 and 450 mg kg^{-1} were combined with each other and added to the Hoagland solution and applied from the soil. Considering the application results, it was observed that root length, fruit weight, fruit number and yield were at the highest level in plants with 40 mg kg^{-1} of phosphorus fertilizer and 300 mg kg^{-1} of potassium fertilizer. It was found that there was an increase in the N, P, Fe and Mn levels in plant leaves with the applied phosphorus nutrient element and that there was an increase only in the amount of K in the plant leaves when the potassium nutrient was applied (Güneri et al., 2016).

In a study, the effects of copper applications at different doses on the pH of the soil and the removal of plant nutrients from the soil were determined. By increasing the doses of copper elements, it was observed that the soil pH level, variable magnesium and the amount of plant availableiron decreased. It was determined that increasing doses of applications had an effect on the total amount of nitrogen, the amount of obtainable potassium, the amount of exchangeable potassium, and the increase in the amount plant available zinc and copper (Sönmez et al., 2006).

It is known that the soils of our country are generally at a sufficient level in terms of available manganese element. Except for special cases, manganese fertilization is not needed. Although the removal of manganese from the soil by plants is at a quite low level, it is stated that the development period of plants is around 50-100 g Mn da^{-1} (Bellitürk, 2011).

In a study, the contents of Mn, Fe, Cu, Zn micronutrients were examined in soil samples taken from the Thrace region. When the results of the research were examined, it was determined that the iron content of the soils was between 0.10-58.17 mg kg^{-1}, the manganese content was between 1.34-113.20 mg kg^{-1}, and the copper content was between 0.01-4.98 mg kg^{-1} (Sağlam et al. 1997).

In one of the studies, when the Fe, Cu and Zn contents of the soils in large soil groups of Tekirdağ province were examined, it was determined that the iron content of the soils was between 0.40 mg kg^{-1}

and 3.79 mg kg^{-1}, the copper content were between 0.34 mg kg^{-1} and 1.74 mg kg^{-1} and the zinc content was between 0.10 mg kg^{-1} and 3.34 mg kg^{-1} (Ekinci and Adiloğlu, 1997).

The aim of this study was to reveal the nutritional problems of the sunflower (*Helianthus annuus* L.) plant cultivated in Çorlu district of Tekirdağ province by making some macro and micro nutrient analyzes of the plant and soil samples to be taken.

MATERIALS AND METHODS

In this research, 18 agricultural lands with different physical and chemical characteristics were determined in the district of Corlu, Tekirdağ province, where sunflower cultivation was carried out. Of these agricultural lands, leaf samples were taken from sunflower plant as reported by Jones et al. (1991) and soil samples were taken from the same fields as reported by Jackson (1967). The plant and soil samples taken were brought to the laboratory and prepared for the necessary analyzes. In the plant samples prepared for analysis, N, P, K, Ca, Mg, Cu, Fe, Mn and Zn plant nutrients were analyzed (Kacar and Inal, 2010). In soil samples, pH, salt, lime, organic matter, available phosphorus, exchangable K, Ca, Mg and available Fe, Cu, Zn and Mn (Sağlam, 2012a) and texture analyses were performed (Tuncay, 1984). The results of the research were compared with the critical adequacy values determined for the plant and soil and the nutritional status of the sunflower plant at the research site was revealed. Some figures are given from the sunflower fields (Fig. 1 and Fig. 2).

Figure 1. A view from researched sunflower fields

Figure 1. A view from researched sunflower fields

RESULTS AND DISCUSSION

Some Macro and Micro Plant Nutrient Elements Amounts of Sunflower Plant

The results of the analysis of nitrogen, phosphorus, potassium, magnesium and calcium macro plant nutrients of sunflower (*Helianthus annuus* L.) plant are given in Table 1.

Table 1. Amounts of some macro nutrients in sunflower plant, %

Sample No	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnessium (Mg)
1	1.85	0.11	3.83	3.58	0.59
2	1.76	0.07	1.87	5.25	0.81
3	1.62	0.07	3.07	4.57	0.96
4	2.29	0.10	3.98	3.40	0.65
5	1.65	0.08	2.36	4.98	0.86
6	2.10	0.11	2.19	4.34	0.85
7	1.51	0.09	2.76	5.07	0.6
8	1.79	0.07	2.74	4.53	0.86
9	2.24	0.12	3.66	3.32	0.43
10	1.00	0.04	1.88	4.26	0.97
11	1.51	0.08	2.20	4.42	0.99
12	1.43	0.09	2.48	5.32	0.76
13	1.20	0.06	2.14	4.27	0.87
14	2.38	0.12	4.45	3.11	0.58
15	1.71	0.08	3.08	4.25	0.79
16	1.82	0.08	3.43	3.64	0.71
17	2.10	0.09	3.01	3.99	0.68
18	1.90	0.07	2.69	3.67	0.6
Mean	1.77	0.08	2.87	4.22	0.75
Min.	1.00	0.12	1.87	3.11	0.43
Max.	2.38	0.04	4.45	5.32	0.99

When Table 1 was examined, it was seen that the nitrogen element values in 18 sampling points varied between 1.00% and 2.38% as a result of the investigation of the nutritional status of the sunflower plant by leaf analysis. The minimum and maximum values of phosphorus, potassium, calcium and magnesium nutrients were found to be 0.12-0.04%, 1.87-4.45%, 3.11-5.32%, 0.43-0.99%, respectively.

Reference values of the macro nutrient elements are given in Table 2 (Jones et al., 1996). The obtained values were compared with the results of this analysis.

Table 2. Reference values of some macro nutrient elements (Jones et al., 1996)

Macro nutrient elements (%)				
N	P	K	Ca	Mg
2.00-5.00	0.25-0.60	2.00-5.00	1.50-3.00	0.25-1.00

The analysis results of iron, copper, zinc and manganese micro nutrients of the sunflower (*Helianthus annuus* L.) plant are given in Table 3.

Table 3. The amounts of some micro nutrients in the sunflower plant, mg kg^{-1}

Sample No	Iron (Fe)	Copper (Cu)	Zinc (Zn)	Manganese (Mn)
1	343	19.85	14.05	70.35
2	491	14.29	22.98	71.15
3	545	14.88	23.54	79.65
4	759	21.89	29.18	29.29
5	630	24.12	16.29	73.49
6	350	16.97	26.80	65.09
7	419	22.57	8.55	66.11
8	500	16.67	13.23	68.66
9	255	27.49	17.21	63.74

10	915	20.77	19.53	64.37
11	756	20.40	25.20	75.83
12	434	25.36	16.36	71.16
13	1026	19.04	22.20	67.59
14	911	23.31	25.62	30.20
15	441	18.72	16.35	54.65
16	559	14.11	13.21	65.30
17	540	19.36	19.90	108
18	526	18.04	16.98	100
Mean.	577.77	19.88	19.28	68.03
Min.	255	14.11	8.55	29.29
Max.	1026	27.49	29.18	108

When the micro nutrient contents of the sunflower plant obtained as a result of the leaf analysis were examined, the minimum and maximum contents of iron, copper, zinc and manganese elements were determined to vary between 255-1026 mg kg^{-1}; 14.11–27.49 mg kg^{-1}; 8.55-29.18 mg kg-1; 29.29-108 mg kg^{-1}, respectively (Table 3).

Reference values of the micro nutrient elements are given in Table 4 (Jones et al., 1996). The obtained values were compared with the results of this analysis.

Table 4. Reference values of some micro nutrient elements (Jones et al., 1996)

Micro nutrient elements ($mgkg^{-1}$)			
Fe	Mn	Cu	Zn
50-750	50-1000	4-25	25-100

In a study conducted in Yağcı district of Tekirdag province, the effects of increasing doses of vermicompost on some biological properties such as oil content, table diameter, plant height yield and some macro and micro nutrient elements in sunflower plant were investigated. When the results were examined, it was stated that there was an increase in the biological, morphological, yield and plant nutrient amounts (Büyükfiliz, 2016).

Even if the total amount of Fe, Cu and Zn, which are the basic plant nutrient elements, are found excess in the soil, the deficiencies of these elements in plant nutrition are frequently encountered due to the low amount of their available forms. In a study conducted in the Thrace Region, the plant available Fe, Cu and Zn contents of soils were examined by the DTPA (Diethylentriaminpenta Acetic Acid) method. The researchers determined that the available Fe, Cu and Zn contents of the soils were 0.104-58.175 $mgkg^{-1}$, 0.004-4.986 $mgkg^{-1}$ and 0.194-13.715 $mgkg^{-1}$, respectively (Sağlam et al., 1997).

The results of some physical and chemical analyzes of the plant leaf samples taken from the agricultural lands where sunflowers werecultivated and the soil samples taken from the same agricultural lands are given in Table 5. When the soil characteristics at the sampling points were examined, it was seen that it had a wide range of pH values. This gives us the opportunity to evaluate in terms of pH, which plays an important role in productivity and the availability of plant nutrients.

Some Physical and Chemical Properties of Soil Samples

Some physical and chemical properties of soil samples are given below in Table 5.

Table 5. Some physical and chemical soil analysis results of the soil samples

Sample No	pH	Salt (%)	Organic Matter (%)	Texture Class	Lime (%)
1	7.21	0.02	1.22	Clay loam	0.57
2	7.47	0.02	1.54	Clay loam	2.84
3	7.01	0.02	1.22	Clay loam	0.16
4	5.77	0.01	1.31	Loamy	0.00
5	5.88	0.01	1.28	Loamy	0.00
6	5.82	0.01	1.39	Clay loam	0.00
7	6.62	0.02	1.42	Clay loam	0.00
8	4.14	0.01	1.31	Loamy	0.00
9	4.34	0.01	1.22	Loamy	0.00
10	7.70	0.03	1.51	Clay	2.68
11	7.45	0.03	1.19	Clay	2.36
12	7.74	0.02	0.98	Clay loam	5.45
13	7.66	0.03	1.45	Clay loam	1.34
14	7.60	0.03	1.66	Clay loam	2.93
15	6.62	0.03	1.19	Clay loam	0.00
16	6.81	0.02	1.39	Clay loam	0.00
17	5.56	0.01	1.22	Loamy	0.00
18	7.06	0.03	1.34	Clay loam	0.24

When Table 5 was examined, it was seen that the organic matter content of the soils was between 0.98% and 1.66%. Considering the results obtained, it can be said that this region is poor in terms of organic matter. When the salinity values were examined, it was observed that the soils were unsalted, but it was observed that there was a tendency for salinization in some areas. It can be said that the reason for this is the unconscious application of fertilization without analysis. When the texture and lime contents were observed, it was seen that the soils belonging to the sampling points mainly had clay-loam, loamy and clay soil texture, mostly belonging to the less calcareous class.

When agricultural lands are examined in terms of organic matter, it is observed that the soils in the Thrace region are insufficient in this respect. In this study conducted in Çorlu district, this situation showed parallelism. The relationship between the increase in the amount of organic matter in the soil and productivity was directly proportional. In a study, it was revealed that there were increases when the development, yield and some biological characteristics of the corn plant were observed by giving organic matter material to the soil in increasing doses (Taşova and Akın, 2013).

In the study, total N, available P, and exchangeable K contents, Mg and Ca macro nutrient contents in soil samples taken from sunflower agricultural areas are given in Table 6.

Table 6. Some macro nutrient element values of the soil samples

Sample No	Total Nitrogen (%)	Available P ($mgkg^{-1}$)	Exchangeable K ($mgkg^{-1}$)	Exchangeable Ca ($mgkg^{-1}$)	Exchangeable Mg ($mgkg^{-1}$)
1	0.06	5.69	244.60	3953.93	668.62
2	0.08	19.57	422.58	4908.08	360.82
3	0.06	1.79	213.64	3568.58	345.51
4	0.07	21.22	249.25	2058.89	387.07
5	0.06	12.92	152.37	1801.26	400.61
6	0.07	18.16	226.20	2728.60	862.23
7	0.07	9.45	249.93	3491.71	1089.44
8	0.07	43.77	91.12	374.95	54.21
9	0.06	37.44	207.71	912.47	296.45
10	0.08	5.63	252.81	5302.89	772.43
11	0.06	11.95	368.43	5446.21	564.00
12	0.05	4.72	230.51	5259.74	302.69
13	0.07	9.85	326.80	4808.33	266.87
14	0.08	6.05	348.16	5899.88	610.81
15	0.06	20.27	173.03	3995.42	514.55

16	0.07	14.57	255.61	3081.18	578.64
17	0.06	11.60	138.67	2389.22	634.09
18	0.07	12.07	302.62	5030.60	593.09
Mean	0.06	14.81	247.44	3611.77	516.78
Min.	0.05	1.79	91.12	374.95	54.21
Max.	0.08	43.77	422.58	5899.88	1089.44

When Table 6 was examined, it was seen that the nitrogen value of the leaves was insufficient. It can be said that this situation was caused by the lack of organic matter. When the phosphorus and potassium nutrients were examined, it was seen that the available phosphorus values were at a moderate level in most areaswhile it was seen that they were insufficient in some areas. It turned out that the available potassium level was sufficient. It was seen that the exchangeable Ca and Mg nutrients were sufficient and even in some samples, these values seemed to be excessive.

Many physical and chemical properties are known to affect the amount of potassium in soils. It is known that soil values such as wetting, drying, texture, lime and pH are effective in potassium intake. While K is more fixed in alkaline soils, its fixation decreases in acid soils because it can not competetion with K, Fe, Al and H (Öktüren et al., 2005).

The micro nutrient contents of iron, copper, zinc and manganese in soil samples taken from agricultural areas where sunflower was cultivated in Çorlu district of Tekirdağ province are given in Table 7.

Table 7. Some micro nutrient element values of the soil samples, $mgkg^{-1}$

Sample No	Fe	Cu	Zn	Mn
1	18.93	1.61	0.21	14.60
2	15.84	1.41	0.78	14.79
3	12.13	1.16	0.33	11.23
4	39.84	1.26	0.52	15.34
5	41.76	2.03	0.34	31.14
6	51.31	2.23	0.55	30.12
7	29.89	2.08	0.46	29.52
8	86.65	0.82	0.86	54.91
9	87.87	1.46	0.71	49.89
10	11.91	1.52	0.31	5.67
11	14.53	2.05	0.30	6.24
12	10.47	1.38	0.33	7.25
13	11.84	1.22	0.30	8.36
14	10.44	1.25	0.33	6.24
15	25.98	1.24	0.50	14.07
16	27.77	2.28	0.42	13.96
17	58.15	1.76	0.35	32.02
18	10.90	1.71	0.27	6.06
Mean	31.45	1.58	0.43	19.52
Min.	10.44	0.82	0.21	5.67
Max.	87.87	2.28	0.86	54.91

CONCLUSION AND SUGGESTIONS

In this research, in order to determine the contents of some absolutely necessary plant nutrients in the sunflower agricultural areas in the villages of Seymen, Şahpaz, Yakuplu, Türkmenli, Sarılar, Maksutlu, Deregündüz, Yenice, Balabanlı, Türkücü, Çeşmeli and in the center of Çorlu, the leaf and soil samples that were taken from the plants in different 18 sunflower fields were analyzed and the results were evaluated.

The levels of some macro and micro nutrient elements in sunflower plant cultivated in Çorlu district of Tekirdağ province and cultivated by most of the population of the district were examined by plant and soil analysis. The results of this study are summarized below.

It was determined that the nitrogen contents of plant leaf samples were between 1.00% and 2.38%. According to these results, when the analyzed sunflower plants were compared with reference values, it was observed that there was 72% nitrogen deficiency and 28% of nitrogen element was sufficient. In general, the nitrogen content of the plants was found to be insufficient. For this reason, it wasconcluded that a special nitrogen-containing fertilization program wasrequired and the current nitrogen fertilization applications were not sufficient.

It was determined that the phosphorus contents of the plants were between 0.048% and 0.12%. When the phosphorus analysis results were compared with reference values, the deficiency of the phosphorus element was determined. This deficiency of sunflower plant determined in terms of phosphorus should be eliminated with phosphorus fertilizer applications, considering the results of soil analysis.

Potassium values in plants were found between 1.87% and 4.45% in the research. The desired limit values for the sunflower plant are between 2.00% and 5.00%. According to these results, it was observed that potassium deficiency was 11% in the analyzed sunflower plants, and no potassium deficiency was observed in other samples. In general, the potassium content of the plants was found to be sufficient. For this reason, it was seen that there was no need for potassium-containing fertilizers in the fertilization program to be done for now, or that existing fertilizer applications were sufficient.

The calcium contents of the plants were determined between 3.11% and 5.32%. The calcium sufficiency range of the sunflower plant is between 1.50% and 3.00%. Accordingly, an excess of calcium element was observed in sunflower plants. For this reason, it was observed that there was no need for calcium-containing fertilizers in the fertilization program to be donefor now.

It was determined that the magnesium contents of the plants varied between 0.43% and 0.99%. It is known that the magnesium adequacy values of the sunflower plant are between 0.25% and 0.1%. When the analysis results were compared with these limit values, it was observed that the magnesium element was at a sufficient level in plants. For this reason, it can be said that there was no need for magnesium-containing fertilizers in the fertilization program.

It was determined that the iron contents of the plants were between 255 mg/kg and 1026 mg/kg. Iron sufficiency limit values of sunflower plant are between 50 mg/kg and 750 mg/kg. When the iron analysis results were compared with the critical iron values, it was determined that 83% of the iron element was sufficient in plants and only 17% of the excess of iron element was found. It was observed that there was no need for an iron-containing fertilization program in sunflower agriculture in Çorlu district for now.

The copper contents of the plants were determined between 14.11 mg/kg and 27.49 mg/kg, and when compared with the reference values, the copper values of the sunflower plants in the study area were found to be 95% sufficient and only 5% excess of the copper element was found. For this reason, it was observed that there was no need for copper-containing fertilizers in the fertilization program to be donefor now.

It was determined that the zinc content in plants varied between 8.55 mg/kg and 29.18 mg/kg. Zinc sufficiency limit values in sunflower plant are between 25 mg/kg and 100 mg/kg. According to these results, it was observed that the zinc element was not at a sufficient level at the rate of 78% in the analyzed sunflower plants, and was at a sufficient level at the rate of 22%. In general, the zinc content of the plants was found to be insufficient. This deficiency of the sunflower plant in terms of zinc should be eliminated by considering the results of soil analysis, with fertilizer applications containing zinc element.

The manganese contents of the plants were determined to be between 29.29 mg/kg and 108 mg/kg. It is known that the desired limit range of manganese element for the sunflower plant is between 50 mg/kg and 1000 mg/kg. When the analysis results were compared with these limit values, it was observed that the manganese element was at a sufficient level at the rate of 89% and the deficiency of manganese element was at the rate of 11%. In general, the manganese content of the plants was found to be sufficient. For this reason, it was observed that there was no need for manganese-containing fertilizers in the fertilization program to be done for now.

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REFERENCES

Anonymous, (2021). Ayçiçeği, Haziran-2021, Tarım Ürünleri Piyasa Raporu, TEPGE.pdf (Erişim Tarihi: 15.05.2022)

Aydoğdu, A. (2019). İkinci ürün koşullarında bazı ayçiçeği (*Helianthus annuus* L.) çeşitlerinde farklı azot dozlarının verim ve verim unsurları üzerine etkisi. Yüksek Lisans Tezi, Harran Üniversitesi Fen Bilimleri Enstitüsü, Şanlıurfa.

Büyükfiliz, F. (2016). Vermikompost gübrelemesinin ayçiçeği bitkisinin verim ve bazı kalite parametreleri üzerine etkisi (Yüksek Lisans Tezi), Namık Kemal Üniversitesi Fen Bilimleri Enstitüsü, Tekirdağ.

Bellitürk, K. (2011). Edirne İli Uzunköprü İlçesi Tarım Topraklarının Beslenme Durumlarının Belirlenmesi. Tekirdağ Ziraat Fakültesi Dergisi, 8 (3): 8-15, Tekirdağ.

Biswas, B., Poddar, R. (2015). Yield and nutrients uptake of sunflower (*Helianthus annuus* L.) as influenced by different level of nitrogen and sulphur. The Bioscan an International Quarterly Journal of Life Sciences, 10 (1): 439-444.

Day, S., Kolsarıcı, Ö. (2014). Ankara koşullarında hibrit çerezlik ayçiçeği (*Helianthus annuus* L.) genotipinde farklı sıra üzeri aralıkları ve azot dozlarının verim ve verim öğelerine etkisi. Toprak Su Dergisi, 3 (2),: 81-89.

Ekinci, H., Adiloğlu, A. (1997). Tekirdağ ili büyük toprak gruplarının (Toprak taksonomisi) yarayışlı demir, bakır ve çinko içerikleri bakımından incelenmesi. I. Trakya Toprak ve Gübre Sempozyumu Bildiriler Kitabı s: 257-261, 20- 22 Ekim, Tekirdağ.

Güneri, M., Akat, H., Yağmur, B., Yokaş., İ. (2016). Effect of Phosphorus and Potassium Aplications on Growth of Kumquat (*Fortunella margarita* L.) Swing Plant. Journal of Agricultural Faculty of Gaziosmanpaşa University, 33 (1): 64-74.

Hilwa, D., Marajan, W.A., Idris, B.E.M. (2019). Influence of sowing date on growth and yield components of sunflower (*Helianthus annuus* L.) in Semi-arid Zone. Journal of Agronomy Research, 2 (2): 36-42.

Jackson, M.L. (1967). Soil Chemical Analysis Handbook. Micro-Macro Publishing, Inc, USA.

Jones, J.B. Jr., Wolf, B., Mills, H.A. (1991). Plant Analysis Handbook. Micro- Macro Publishing Inc. p. 1-213, USA.

Jones, J.B. Jr., Mills, H.A. (1996). Plant Analysis Handbook II. A Practical Sampling, Preparation, Analysis and interpratation Guide p.1-422. Micro- Macro Publishing Inc. USA.

Karaman, M.R, Adiloğlu, A., Brohi, R., Güneş, A., İnal, A., Kaplan, M., Katkat, V., Korkmaz, A., Okur, N., Ortaş, İ., Saltalı, K., Taban, S., Turan, M., Tüfenkçi, Ş., Eraslan, F., Zengin, M. (2012). Bitki Besleme. Gübretaş Rehber Kitaplar Dizisi. No: 2, Dumat Ofset, Matbacılık San. Tic. Ltd. Şti. Ankara.

Kıral, M. (2020). Katı ve sıvı solucan gübresinde raf ömrü ve kalite parametreleri arasındaki ilişki (Yüksek Lisans Tezi), Çanakkale Onsekiz Mart Üniversitesi Fen Bilimleri Enstitüsü, Çanakkale.

Mehmood, A., Saleem, M.F., Tahir, M., Zohaib, A., Sarwar, M.A., Abbas, T., Abbas, H.T., (2018). Sunflower (*Helianthus* annuus L.) growth, yield and oil quality response to combined application of nitrogen and boron. Pakistan Journal of Agricultural Research, 31 (1): 86-97.

Öktüren, F., Sönmez, S., Kocabaş, I. (2005). Potasyumun Bitki Sağlığı Üzerine Etkileri. Tarımda Potasyumun Yeri ve Önemi Çalıştayı, 3-4 Ekim, s. 94-100, Eskişehir.

Parlak, B. (2016). Antalya- Kumluca bölgesi örtü altı sebze yetiştiriciliğinde toprak analizinin önemi (Yüksek Lisans Tezi), Namık Kemal Üniversitesi Fen Bilimleri Enstitüsü, Tekirdağ.

Sağlam, M.T. (2012). Gübreler ve Gübreleme. Namık Kemal Üniversitesi Yayınları, Yayın No: 14, Ders Kitabı No: 6, Tekirdağ.

Sağlam, M.T. (2012a). Toprak ve Suyun Kimyasal Analiz Yöntemleri. Namık Kemal Üniversitesi Yayınları No: 2, Ders Kitabı No: 2, Tekirdağ.

Sağlam, M.T., Tok, H.H., Adiloğlu, A., Demirkıran, A.R., Bellitürk, K. (1997). Trakya yöresinden alınan bazı toprak örneklerinin elverişli Fe, Cu, Zn ve Mn kapsamları üzerinde bir araştırma. I. Trakya Toprak ve Gübre Sempozyumu Bildiriler Kitabı s: 248- 251, 20- 22 Ekim, Tekirdağ.

Sönmez, S., Kaplan, M., Sönmez, N.K., Kaya, H. (2006). Topraktan Yapılan Bakır Uygulamalarının Toprak pH'sı ve Bitki Besin Maddesi İçerikleri Üzerine Etkisi. Akdeniz Üniversitesi Ziraat Fakültesi Dergisi, 19 (1): 151-158.

Süzer, S. (2010). Effects of potassium fertilization on sunflower (*Helianthus annuus* L.) and canola (*Brassica napus* ssp. oleifera L.) growth. Proceedings of the Regional Workshop of the International Potash Institute held at Antalya, Turkey, 22-25 Nov.

Taşova, H., Akın, A. (2013). Marmara Bölgesi Topraklarının Bitki Besin Maddesi Kapsamlarının Belirlenmesi, Veri Tabanının Oluşturulması ve Haritalanması. Toprak Su Dergisi, 2 (2): 83- 95.

Tuncay, H. (1994). Toprak Fiziği Uygulama Kılavuzu. E.Ü. Ziraat Fak. Teksir No: 29, İzmir.

CHAPTER 2

COLOR OF HOPE IN RURAL DEVELOPMENT IN SİLİFKE; LAVENDER (*Lavandula* spp.)

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INTRODUCTION

General information about lavender cultivation

Lavender is one of the plants which essential oil is economically valuable and the most traded. The essential oil quality is determined by the ratio of linalyl acetate and it is reported that the two most common compounds in the essential oil are linalool and linalyl acetate. The areas with the highest usage area are the cosmetics and perfume industry, but it is also used intensively in the pharmaceutical industry. In addition, lavender flowers are used for decorative purposes and as tea. It has become a focus of intense interest especially in aromatherapy, which importance has increased rapidly in recent years (Aslancan and Sarıbaş, 2011; Kurt and Tatlı Çetinkaya, 2021; Tisserand and Young, 2014). Lavender essential oil is antibacterial and is effective against many types of bacteria due to this feature (Ueno-Iio T, et al., 2014). It has been reported that it is good for migraine and sleep disorders (Tisserand and Young, 2014; Velasco-Rodríguez R., 2019); the knee pain is reduced by massage in patients (related to osteoarthritis) (Nasiri et al., 2016).

Lavender plant is a perennial plant that is not very picky in terms of soil, usually up to 1 meter in the form of a bush. It is not affected much by cold and hot conditions and is highly resistant to drought. It can be grown without problems in soils with a pH in the range of 5.8-8.3 (Aslancan ve Sarıbaş, 2011) with high lime content. While alkaline and calcareous soils increase the scent of lavender, the life of lavender decreases in soils below pH 6.5 (Anonymous, 2022c). Lavender seedlings can be produced productively and vegetatively. Taking the cuttings during the resting period of the plant and planting them after being treated with hormones(plant growth regulators) increases rooting (Aslancan and Sarıbaş, 2011).

Figure 1. Appearance of lavender plant (G.Y ; Isparta/kuyucak-2021)

Seedling Planting

In cultivation with quality seedlings produced in suitable conditions, first of all, the soil should be processed with a deep plough, and the necessary fertilizers should be given depending on the soil analysis results. Planting distances and planting time vary according to the climatic characteristics of the region and the type of lavender to be grown. From the beginning of March until the end of May, it should be planted in row spacings of 100x40 cm or 120x50 cm and water should be given immediately after planting. After planting, water should be given at certain intervals to ensure that the plant is in good contact with the soil and that the roots are connected to the soil. The use of drip irrigation system and wotering increase flower yield (Aslancan and Sarıbaş, 2011).

Fertilization and irrigation

It is sufficient to give 8-10 kg of N and 3-5 kg of P_2O_5, depending on the soil analysis results during the cultivation period (Aslancan and Sarıbaş, 2011). Lavender needs nitrogen more than phosphorus and potassium, but excess nitrogen can degrade essential oil quality. It can also cause problems by encouraging weed emergence. Another researcher reported that approximately 6 kg of N, 3 kg of P and 3 kg of K can be applied per decare (Anonymous, 2022f). Although lavender is resistant to drought, irrigation will positively affect plant growth. The first three months should be very careful. Generally, after the spring and summer plantings, irrigation is done every 3-5 days to facilitate the survival of the lavender plant. Then, the irrigation intervals should be adjusted according to the climatic conditions, soil structure and the period of the plant (Anonymous, 2022g). It will be useful to use the drip irrigation method in lavender cultivation. Thus, both fertilization and giving pesticides can be done easily. It will also be a suitable irrigation for weed control. When the drip irrigation system is used, it will be easier to control especially fungal diseases.

Harvesting and Drying

Several harvesting techniques can be used, depending on which part of the plant is needed. If we want to use dried flowers, it is important to harvest flowers with long stems. If we want to benefit from its essential oil (it can be obtained from the flower or leaves), the harvest should be done for this purpose. It is usually harvested with the help of scissors or a knife under the first set of leaves. However, machine harvesting is widely used in countries such as the USA, France and Spain (Anonymous, 2022d).

Lavender flowers should be harvested and dried in a well-ventilated place without being exposed to direct sun. Harvest is usually done in July-August. Harvesting is generally not recommended during the hot hours of the day. It is recommended to dry in bunches and hang down from the flower stalks. Dry lavender flowers retain their fragrance for a long time. For this reason, it is used a lot as a decorative. In addition, dried flowers are used as a spice in salads and some special dishes. It is known that it is also evaluated as tea (Anonymous, 2022c; Anonymous, 2022e).

"Drying" is one of the oldest methods of food preservation. Evaporating this water with different methods in order to minimize the water in the product; It provides convenience in storage, transportation and long-term storage. drying in the sun; It comes to the fore in drying lavender as it is in many agricultural products that are cheap, ubiquitous, not needing technological materials and need large areas. In some studies on this subject, drying in the shade and in the sun significantly affects the essential oil content (Pinto et al., 2007), and the most appropriate method in terms of drug effect and essential oil content in lavender (Lavandula officinalis) in Çukurova Region is drying in the shade (Özgüven et al. , 2007) and also reported that lavender dried in the shade has a higher essential oil content (Kara and Baydar, 2014).

Figure 2. Lavender flowers Silifke and Isparta (G.Y , Silifke-2020; Isparta-2021)

CONCLUSION

According to the data of 2021, 6,108 tons of lavender was produced from an area of 35,810 decares in Turkey. Mersin's lavender production is 128 tons. Silifke is the most lavender producing district of Mersin with 63 tons of lavender production on an area of 210 decares. Silifke is followed by the town of Toroslar with a production of 30 tons and Tarsus with a production of 12 tons. With its 300 kg/decare yield, Silifke is above the average of both Turkey and other districts in Mersin (TUIK, 2021). Considering this yield value, it can be said that lavender production will be advantageous in Silifke. In addition, it should be known that the suitability of climate and soil conditions are also important in yield.

Products that will come to the fore in rural development should be well planned and supported. Especially in rural development, agriculture is generally the first branch of production that comes to mind. In some studies on this subject, it has been reported that it is necessary to carry out alternative activities that will reduce migration from village to city and reduce poverty by creating employment especially in rural areas, but agriculture alone cannot be sufficient for the employment problem in rural areas (Kuter and Ünal, 2013; Schaller, 1993; Roy and Chan, 2012).

Sustainability and support of the activities and projects carried out in the rural development process will increase the chances of success. In this context, the projects produced must help the establishment of enterprises that will increase the economic level of the people of the region in a short time and provide permanent employment in the long run. In recent years, the idea of applicability of agrotourism in rural development has come to the fore. According to some researchers, agrotourism is considered as a sub-type of rural tourism and ecotourism applied in areas that are not preferred in agriculture (Demirbaş Topçu, 2007; Sungur, 2012; Çetin et al., 2017).

Lavender cultivation can be considered as an important product for Silifke, especially when considered as agrotourism. In our country, especially Isparta is a province that can set an example in this sense. In July and August, when the flowering is intense, many local and foreign tourists flock to it and provide income to the local people. If lavender cultivation is encouraged in Silifke with a planned study and supportable projects, an agricultural activity can be provided, as in the example of Isparta. Visitors from home and abroad can be a source of income for local people. Another advantage of Silike is that sea tourism is widespread. Lavender flowers time (July-August) coincides with the sea season. It will not be difficult to attract tourists who have already come for a holiday to these areas. With excursions, lavender gardens can be full of tourists. The sale of products obtained from lavender will increase its recognition and will be important as an additional source of income. It would be an advantage to have some leading producers, individuals and organizations in the region and to work actively in this regard. In Silifke, Çaltıbozkır Association has made important contributions in the context of lavender seedling supply and garden establishment (Anonymous, 2022a). In addition, Mersin Metropolitan Municipality has started studies to encourage lavender cultivation in Mersin and successful results have been obtained (Anonymous, 2022b).

Figure 3. Products offered for sale next to lavender gardens (G.Y , Isparta/kuyucak, 2021)

Tarhan et al., (2019) in a study they conducted in Isparta, reported that lavender cultivation in Kuyucak Village is an important example in terms of rural development and that its recognition with the name "Lavender Scented Village" has increased more. In addition, in this study, it was emphasized that the sustainability of lavender cultivation is important for the region. Advertising campaigns for Silifke, explaining the importance of lavender in rural development through the works to be done in the written and visual media, creating a striking and original name with the characteristics of Silifke will contribute to its recognition. In addition, in this region where beekeeping is important, lavender flowers can be important in honey production with their smell and aroma. Perhaps in the near future, it may be possible to produce lavender-scented honey in Silifke. Silifke, where yoghurt and strawberry became a brand with the great efforts of Silifke Chamber of Commerce and Industry, may also have an important production line with its lavender-scented honey. The possibility of meeting the smell of lavender and Silifke yoghurt can be investigated with studies to be carried out, and perhaps it can be presented to the markets as a new product.

Author Contribution Statement

Fuat LÜLE (F.L) contributed in the harvesting and drying section, while Garip YARŞI (G.Y) contributed to the research and writing of other sections of the article, and the taking of photographs.

REFERENCES

Anonymous,(2022a).https://www.silifkehavadis.com/haberler/caltibozkir-dernegin den-buyuk-girisim-haberi, *(Accessed date; 28.03.2022)*

Anonymous,(2022b).https://www.hurriyet.com.tr/yerel-haberler/mersin/mut/buyuk sehir-250-bin-lavanta-fidesini-uretici-il-41838716,, *(Accessed date; 28.03.2022)*

Anonymous, (2022c). How to grow and care for lavender. https://www.thespruce.com /growing-lavender-1402779, (*Accessed date*; 28.03.2022)

Anonymous, (2022d). Harvesting lavender-when and how to harvest lavender. https://wikifarmer.com/lavender-harvest/, *(Accessed date; 28.03.2022)*.

Anonymous, (2022e). Lavanta hasadı nasıl yapılır?. https://tarimgazete.com/lavanta-hasadi-nasil-yapilir/, *(Accessed date; 28.03.2022)*.

Anonymous, (2022f). How to fertilize lavender plants. https://wikifarmer.com/ lavender-fertilizer-requirements, *Accessed date; 28.03.2022)*.

Anonymous, (2022g). How often should you water lavender plants. https://www.gardenerreport.com/how-often-to-water-lavender/, *(Accessed date; 28.03.2022)*.

Aslancan, H. ve Sarıbaş. R. (2011). Lavanta Yetiştiriciliği. Meyvecilik Araştırma Merkezi Müdürlüğü (MAREM),Yayın No:41. (https://arastirma.tarimorman. gov.tr/marem, *(Accessed date: 20.03.2022)*

Çetin İ., Polat Üzümcü T., İçöz O. (2017). Kırsal Alanlarda Sürdürülebilir Kırsal Turizm ve Kocaeli- Kandıra Kırsal Turizm Gelişimi Modeli, *Erzincan Üniversitesi Sosyal Bilimler Enstitüsü Dergisi* (ERZSOSDE), ÖS-IV: 137-156

Demirbaş Topçu E. (2007). *Agri-Tourism: As a New Element of Rural Development*. MS., City and Regional Planning Department, Urban Design. A Thesis Submitted to the Graduate School of Natural and Applied Sciences of Middle East Technical University, Ankara, 187 p.

Kara, N., Baydar, H. (2014). Kurutma yöntemleri, Depolama Koşulları ve Sürelerinin Lavanta (*Lavandula spp*.)'nın Uçucu Yağ Oranı ve Bileşenlerine Etkisi. YYÜ Tarım Bilimleri Dergisi, 24 (2), 185-192

Kurt, N., Tatlı Çetinkaya, İ.İ. (2021). *Aromaterapi Uygulamaları ve Uçucu Yağlar Lokman Hekim Dergisi, 2021; 11 (2): 230-241*

Kuter, N., Ünal, H.E. (2013). Kırsal Kalkınmada Kırsal Turizmin Önemi. Kastamonu Üni., Orman Fakültesi Dergisi, 2013, 13 (2): 192-201

Nasiri, A., Mahmodi, M.A., Nobakht Z. (2016). Effect of aromatherapy massage with lavender essential oil on pain in patients with osteoarthritis of the knee: A randomized controlled clinical trial. Complement Ther Clin Pract, 25: 75-80.

Özgüven, M., Bux, M., Koller, W.D., Şekeroğlu, N., Kırpık, M., Muller, J., (2007). Influence of Fluctuating Drying Conditions DuringShade-, Sun-and Solar-Drying on the Quality of *Lavandula officinalis* L., *Origanum syriacum* L. und *Thymbra spicata* L., Zeitschrift für Arznei und Gewurzpflanzen, 12 (2), 80-87

Pinto, J.E., Cardosa, C.W., De Castro, E.M., Bertolucci, S.K.V., De Melo, L.A., Dousseau, S. (2007). Morphophysiological Aspect and Essential Oil Content in Brezilian-lavender as Affected by Shadowing. Horticultura Brasileira, 25 (2), 210-214

Roy R., Chan N. W. (2012). An Assessment of Agricultural Sustainability Indicators in Bangladesh: Review and Synthesis. The Environmentalist, 32(1): 99-110.

Schaller N. (1993). The Concept of Agricultural Sustainability Agriculture. Ecosystems and Environment, 46(1-4): 89-97.

Sungur Z. (2012). Sürdürülebilir Turizmin Toplumsal Etkileri: Türkiye'den Örnekler. *International Conference on Eurasian Economies,* ss.338-344.

Tarhan, Y., Açıksöz, S., Çelik, D. (2019). Lavanta tarımı ve sürdürülebilir kalkınma: Isparta/Keçiborlu-Kuyucak Köyü örneği. Bartın University International Journal of Natural and Applied Sciences, JONAS, 2 (2): 216-227.

Tisserand R, Young R. (2014). Essential Oils Safety. 2nd ed. London: Churchill Livingstone Elsevier.

TUİK, 2021. https://data.tuik.gov.tr/Kategori/GetKategori?p=tarim-111&dil=1, *(Erişim Tarihi; 20.03.2022)*

Ueno-Iio, T., Shibakura, M., Yokato, K., Aoe, M., Hyado, T., Shinohata, R., Kanehiro, A., Tanimoto, M., Kataoka, M. (2014). Lavender essential oil inhalation suppresses allergic airway inflammation and mucous cell hyperplasia in a murine model of asthma. Life Sci 2014; 108(2): 109-115.

Velasco-Rodríguez, R., Perez- Hernanez, M.G., Maturano-J.A., Hilerio-Lopes, A.G., Monroy-Rojas, A., Arana-Gomez, B., Vasquez, C. (2019). The effect of aromatherapy with lavender (Lavandula angustifolia) on serum melatonin levels. Complement Ther. in Med., 47: 102208-102215.

CHAPTER 3

THE IMPORTANCE OF MACRO AND MICRO NUTRIENTS IN COTTON (*Gossypium hirsutum* L.) PLANT IN TERMS OF SUSTAINABLE AGRICULTURE

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INTRODUCTION

Worldwide climate changes reduce the yield of plants, and therefore food safety problems are encountered (Soysal et al., 2021). The world population is constantly increasing. In parallel with the increase in the quality of life in industrialized and developing societies, especially the fiber requirement tends to increase day by day (Ekinci, et al., 2018). In countries whose economic structure is integrated into agriculture, the amount of product obtained from a unit area in plants is very important to meet the food demands (Soysal and Yılmaz, 2021). If sustainable agriculture is to be achieved economically, modern agricultural practices must be implemented, and agricultural management and production paradigms must change (Yılmaz et al., 2021). Despite the constantly renewed new methods in agricultural production, the desired level of production still has not been reached. One of the biggest reasons for this is undoubtedly the unconscious agricultural system. Inputs such as irrigation, spraying and fertilization, which are made unconsciously with the thought of gaining high income, especially ecological, economic and technological factors, adversely affect the physical, chemical and biological structure of the soil. This situation disrupts the balance of basic nutrients in the soil, which are vital for the growth and development of plants, and significantly affects soil productivity and plant yield, and brings along some problems (Çağlar and Demir, 2021).

Soil health is the common combination of chemical, physical and biological properties that enable soils to perform a wide variety of functions. The mineralization of various organic and inorganic nutrients and the consequent availability of nutrients in the soil depend on the enzymatic action of hydrolases and oxidoreductases (Xu et al., 2019).

Organic fertilizers have gained great importance in recent years, as the negative effects on the soil as a result of the increase in the use of chemical-based fertilizers and pesticides cause serious problems in terms of agriculture. Organic fertilizers are rich in organic carbon, which not only improves soil structure and available nutrients, but also increases soil microbial biomass and enzyme activity (Nyiraneza et al., 2018). The application of animal manure contributes to soil fertility and helps to increase yield. In addition, these practices promote soil structure improvement, increase in soil nutrient content, increase in the number of soil microorganisms, bacterial and fungal diversity (which increases extracellular enzyme activity), and crop growth (Wu et al., 2020).

Another reason is that plants constantly exchange nutrients from the soil in order to maintain their vital activities. This situation causes the soil to become poor in terms of nutrients over time (Anonymous, 2021). In order for the plant to grow and develop, it needs at least 17 plant nutrients or elements. Since it provides three of these nutrients (H, C, O) from air and water, it is considered as a non-mineral nutrient element (White, 2006; Gardiner and Miller, 2008; Fageria, 2009). The remaining 14 are provided by the nutrients we have grouped as macro (N, P, S, K, Mg, Ca) and micro (Fe, Mn, Cu, Zn, Mo, B, Cl, Ni) (Fageria et al., 2002; Rice, 2007). Here, although the precursor group for plants is macronutrients, micronutrients are as important for plants as macronutrients (Anonymous, 2021).

As in agricultural products, nutrients are also of vital importance for the cotton plant. The fact that it has wide usage areas especially in the industrial field increases the economic importance of this plant and highlights it as a strategic product (Eminur and Hançer, 2016). As in all agricultural products, the main purpose in cotton farming is to increase the cotton fiber quality and to obtain more and better quality products from the unit area (Yaşar et al., 2017). For this reason, in the face of the changes in the soil reaction of the nutrients that are of great importance for plant production, the effect on the yield of the cotton plant has been a matter of curiosity.

BASIC ACTIVITIES OF ORGANIC MATERIALS IN TERMS OF SUSTAINABLE AGRICULTURE

There are many practices related to sustainable agriculture. These; it is necessary to provide product diversity and thus to protect the soil, to reduce crop diseases, pests and weed problems, to use animals in weed control, to reduce the use of chemical substances, and to provide the producers with the necessary technical knowledge and skills in the use of chemical fertilizers and pesticides (Turhan, 2005). In this way, the use of more environmentally friendly products and production technologies in agricultural production gains importance in terms of protecting the natural resource stock and developing organic agriculture.

Table 1. Key Indicators of Sustainable Agriculture

İndicators	**Determinants**
Producer's long-term income	* The net income of the producers should be long-term * Increasing the marketing power of producers and developing foreign trade * Ensuring production efficiency that makes resources efficient
Natural resources	* Food quality and safety * Condition of the soil * Product variety * Water resources
Environment	*Chemical waste * Salinity in water *The effect of agriculture on natural resources
Administrative features	* Dissemination of training activities for the fulfillment of sustainable agricultural practices
Socio-economic effects	* Ensuring a human-oriented development in agriculture and developing studies for workforce training

Source: Sustainable Agriculture: Assessing Australia's Recent Performance (1998).

Soil organic matter consists of complex, high polymer substances that are resistant to environmental conditions, as well as compounds with relatively unstable reaction ability. Organic matter has a versatile effect on the soil and has positive contributions to the physical, chemical and biological properties of soils (Taban, 2009).

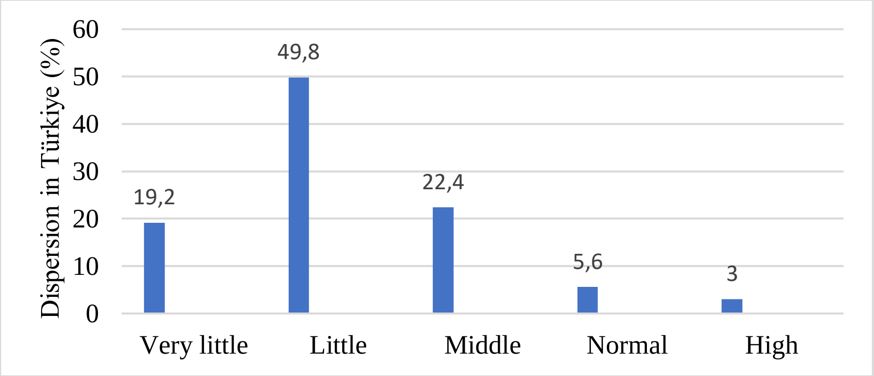

Figure 1. Organic Matter Scope of Agricultural Soils in Turkey

COTTON PLANT IN TERMS OF SUSTAINABILITY

Cotton in The World

Cotton is an industrial plant that has an important place in terms of humanity with its widespread and compulsory use. In terms of cotton processing, it is the raw material of the gin industry, the textile industry with its fiber, and the oil and feed industry with its seed. As an alternative to petroleum, the oil obtained from the cotton seed is used as a raw material in the production of biodiesel in increasing amounts. Cotton is also a product of great economic importance for producing countries with the added value and employment opportunities it creates (Mert, 2017). The wide usage areas of the cotton plant allow the competition between cotton producing countries to increase.

Cotton is grown in various geographical regions around the world. At the beginning of these regions is the Asian continent, which constitutes approximately 63% of the world's cotton cultivation areas, followed by America with 20% and Africa with 14% (ICAC, 2019). The countries with the highest production are India, China, USA, Brazil, Pakistan, Uzbekistan and Turkey, respectively. These countries also constitute about 77% of the world's cotton cultivation areas and 83% of its production (ICAC, 2021).

Table 2. World Cotton Area (thousand ha)

	Country	**2016/2017**	**2017/2018**	**2018/2019**	**2019/2020**	**2020/2021**
1	India	10.845	12.235	12.600	13.300	13.400
2	China	3.848	4.492	4.130	4.700	3.640
3	Usa	3.100	3.350	3.367	3.450	3.250
4	Brazil	2.496	2.665	2.325	2.450	2.200
5	Pakistan	939	1.175	1.618	1.670	1.550
6	Uzbekistan	1.250	1.208	1.100	1.010	980

(Source: Cotton Report, 2020, USDA)

Considering the world cotton cultivation areas in the 2020-2021 period, it is seen that it has decreased compared to the previous season. Although there is no change in the world cotton cultivation area ranking, it has been observed that there is a decrease in cotton cultivation areas compared to the previous period in all countries except India. As seen in Table 2, the values (in thousand hectares) were determined as 13,400 in India, 3,640 in the USA, 3,250 in China, 2,200 in Pakistan and 1,550 in Brazil. (USDA, 2020).

Table 3. World Fiber Cotton Production (tons)

	Country	**2016/2017**	**2017/2018**	**2018/2019**	**2019/2020**	**2020/2021**
1	India	5.865	6.350	5.350	6.423	6.423
2	China	4.900	5.890	6.040	5.933	5.987
3	Usa	3.738	4.560	4.000	4.336	3.473
4	Brazil	1.530	2.010	2.730	2.928	2.613
5	Pakistan	1.663	1.800	1.670	1.350	980
6	Uzbekistan	789	800	640	762	762

Source: Cotton Report, 2020, USDA

While China has led the world's largest production countries over the years, India has managed to rise to the first place in production in recent years. India has been the country with the highest production in the 2020/2021 production season with 6,423 thousand tons. Following India, China took the second place with 5,987 thousand tons and the USA took the third place with 3,473 thousand tons. After these countries, important producing countries such as Brazil, Pakistan, Uzbekistan and Türkiye follow (USDA, 2020). According to the estimations of the International Cotton Advisory Committee (ICAC) for the 2021/2022 production season, the world cotton cultivation area is 33,2 million ha and the production is 25,7 million tons. Its consumption is predicted to be 25,6 million tons (ICAC, 2021).

Cotton in Türkiye

Türkiye is an advantageous country with its ecological farming conditions and cotton production practice that has been going on for centuries. With its direct and indirect employment effects, cotton is accepted as a source of income for millions of people in Türkiye. In addition, cotton is an important raw material source for the textile, apparel and oil industry in Türkiye as well as in the world (Gazanfer, 2003). In this respect, cotton is grown as an important agricultural plant in our country.

Türkiye, which is among the leading countries of the world in cotton agriculture, ranks eleventh in cultivation area and seventh in production according to the latest data (ICAC, 2021). Although there has been an increase in both cotton cultivation areas and production in our country for years, a decrease has occurred since the 2019/2020 season. The main reason for this decline is thought to be the Covid-19 epidemic, which is seen in our country as well as all over the world, and as a result, it is seen that farmers are turning to different crops around the world. In 2021/2022, a recovery was observed in both cultivation area and production, and an increase was experienced again (Organic Cotton Market Report, 2020).

Table 4. Cotton Cultivation Area and Production in Türkiye in Recent Years

	2015	2016	2017	2018	2019	2020	2021
Area (da)	4.340.13	4.160.10	5.018.53	5.186.34	4.778.68	3.592.20	4.322.79
Production (tons)	2.050.0	2.100.0	2.450.0	2.570.0	2.200.0	1.773.6	2.250.0

Source: Cotton Newsletter, 2022, TUİK

According to TUİK data, Southeastern Anatolia Region takes the first place in terms of the width of cultivation areas. While the share of the Southeastern Anatolia Region in all cultivation areas was 60% in 2018, the share of the Aegean Region was 19,5%, the Çukurova Region 19%, and the Antalya region 1% (TUİK, 2019).

In Türkiye, in 2021, 832,500 tons of fiber cotton was produced in an area of 4.3 million decares in return for the production of 2.25 million tons of unseed cotton. The 6 provinces that meet 87% of the cotton produced in Turkey in 2021 are Şanlıurfa, Diyarbakır, Aydın, Hatay, İzmir and Adana, respectively. Fiber cotton production amount was 333 thousand tons in Southeastern Anatolia Region, 195 thousand tons in Aegean Region and 123 thousand tons in Çukurova Region (TUİK, 2022).

The province of Şanlıurfa has a large share in the Southeast Anatolian Region, as it ranks first in cotton production compared to other regions. According to TUİK 's cotton production data for 2020, 32 percent of the cotton in Türkiye was grown in Şanlıurfa. However, 42% of the cotton produced in Türkiye in the previous season was met by Şanlıurfa. The main reason for this decline was the "crop rotation" applied to keep the soil productive for many years, and about 600 thousand tons of unseed cotton were harvested from the cotton planting on an area of 1 million 287 thousand decares. The city has the highest production amount in Türkiye in general and an increase in production has been observed over the years (TUİK, 2020). The main reason for the increase in production is the introduction of the GAP (Southeast Anatolia Project). With the opening of new cultivation areas to irrigation within the framework of the GAP Project, this rate is increasing every year. The cotton yield of the region has also shown a great tendency to increase over the years with the adaptation of high-yielding varieties (Özüdogru, 2013).

MACRO NUTRITIONAL ELEMENTS IN COTTON

Nitrogen (N)

Nitrogen (N) is very important nutrient that play imperative parts in enhancing yield of lint and photosynthesis in cotton (Khan et al. 2017). The inability of the plant to get enough nitrogen from the soil causes slow growth, lack of leaves, shedding of its cocoons and late opening, thus reducing its productivity (Anonymous, 2019). In the case of excessive nitrogen intake, it was observed that fiber yield decreased from flowering period to ripening in hot weather, and excessive plant growth, slow fruiting and earliness index decreased. The earliness index in response to nitrogen may affect the possible balance between fiber yield and fiber quality (Madani and Oveysi, 2015).

With the application of 30% nitrogen organic fertilizer and 4 different nitrogen doses (0, 6, 12, 18, 24 kg/da) in cotton, the first fruit branch node number, plant height, number of wood branches, fruit branch, number of bolls, number of pods, weight, Earliness rate, seed cotton yield, 100 grain weight, fiber yield values increased statistically. In terms of yield and yield elements, the highest values were obtained at 18 kg/da nitrogen doses in both cultivars (Mert 2017). As a result of applying various nitrogen doses (0, 50, 100 and 150 kg N ha^{-1}) to 6 different medium fiber cotton genotypes; they found that nitrogen application significantly increased plant weight, side branching per plant, boll per plant, boll weight and seed cotton yield. However, they observed that there was a difference in percentage increases between varieties and the maximum value of the parameters given for the determined variety was higher than 150 kg N ha^{-1} (Bibi et al., 2011).

Phosphorus (P)

Phosphorus is important in early root development, photosynthesis, cell division, energy transfer, early cocoon formation and acceleration of maturity. The plant receives approximately 11,34 kg and 13,61 kg of P2O5 for every 220-250 kg (1 bale) of cotton produced. Its deficiency results in stunted plants, late fruit formation, and reduced maturity and yield (Anonymous, 2015).

Phosphorus has been found to be an important nutrient element in some previous studies for cotton plants. Sawan et al. (2001), phosphorus application; seed cotton yield, oil content and unsaturated fatty acids (oleic and linoleic) increase, (Berberoğlu and Karaaltın 2001) stated that the most appropriate phosphorus dose for cotton yield is 8 kg/da.

Potassium (K)

Potassium (K) is a vital macronutrient with important effects on soil availability, plant growth and development as well as crop productivity (Sardans and Pe˜nuelas, 2021). The plant receives about 27,22 kg of potassium for one bale (220-250 kg) of cotton. During the carding period, the need for potassium increases significantly and takes about 70% of the potassium after the first flowering (Anonymous, 2015). The lack of enough potassium in the soil makes it difficult for the plant to take nitrogen. On the other hand, excess potassium causes prolongation of the flowering period, decreased ginning efficiency, decreased fiber breaking strength and delayed maturation (Mert, 2007).

Calcium (Ca)

Calcium plays a regulatory role in seed germination, growth and development, water relations, photosynthesis and many more. In addition, Ca can regulate the yield improvement of various crops under abiotic stresses such as salinity, drought, flood, heat, cooling and heavy metal stress (Parvin et al., 2015).

In some studies, it has been stated that calcium content has a negative effect on the elasticity of cotton fibers, and there is a positive relationship between soil saturation with water and maturity index. In addition, it was determined that soil saturation with water, salt, calcium and magnesium contents had a positive effect on fiber spinnability and ginning yield. Moreover, the calcium content positively affects the seed cotton yield. However, they determined that the seed cotton yield was negatively affected depending on the planting date and the increase in the amount of sand in the soil (Aydın et al., 2014). In another study, it was observed that foliar calcium (20, 40 and 60 ppm) increased cotton yield, seed index, seed oil content, oil and protein yield, and total unsaturated fatty acids (oleic and linoleic) (Sawan et al., 2001).

Magnesium (Mg)

After the application of magnesium fertilization, the plants gradually disappear from the deficiency symptoms. Magnesium deficiency in the soil is eliminated by the application of limestone or by giving magnesium foliar fertilizer from the leaves (Mert, 2007).

Kızılgöz et al. (2011), when all plant parts and the amount of nutrients taken from the soil during the development period of cotton are examined, very little Mg is removed from the soil (İrget et al. 2010), they stated that plant height, number of bolls, number of fruit branches, 100 seed weight and seed cotton yield were statistically significant as a result of using different doses of Mg in cotton (Durmaz, 2002).

Sulfur (S)

In the absence of sulfur in plants, a homogeneous yellowing occurs on the leaves. This situation is very similar to nitrogen deficiency. However, the yellowing seen in the leaves in nitrogen deficiency first appears on the old leaves, while the yellowing seen in the leaves in the sulfur deficiency appears on the young leaves. When the plant is deficient in sulfur, protein synthesis is inhibited, plant growth slows down, leaf surfaces narrow; it gives a woody feel when touched (Güzel et al., 2004). In addition, foliar application of plant nutrients in reducing the effects of water stress is one of the subjects that have been researched in recent years. One of these nutrients is sulfur. It is stated that sulfur has preventive effects on the reduction of chlorophyll content, which plays an important role in the realization of photosynthesis, and increases in crop yield can be achieved by increasing the amount of chlorophyll under stress conditions (Li-Na et al., 2005).


Nitrogen deficiency Phosphorus deficiency


Potassium deficiency Calcium deficiency

Magnesium deficiency

Sulfur deficiency

MICRO-NUTRITIONAL ELEMENTS IN COTTON

Boron (B)

They stated that the application of increasing doses of boron to the soil increased the plant leaf boron content linearly and quadratic in some species (Fontes et al., 2008). It was observed that foliar boron application positively affected the number of bolls per plant, the number of bolls per square meter, the average boll weight, the yield of seed cotton, and the average 17% improvement in seed germination. It was determined that it increased seed viability, defined as accelerated growth, by an average of 25%. They also stated that foliar boron application can increase fiber, seed cotton yield and seed quality of cotton grown in calcareous soils (Dordas et al., 2006). Moreover, the effect of boron application on the increase in the number of bolls was found to be significant, but insignificant increases occurred in the cocoon seed weight and ginning yield, while significant increases occurred in the seed cotton and fiber yield (Yıldırım, 2003).

Iron (Fe)

Iron element plays a very important role in plant respiration and photosynthesis reactions. It enables the catalysis of many biochemical reactions by activating enzymes such as catalase, peroxidase and cytochrome oxidase in plants. Although it is not in the structure of chlorophyll, chlorophyll production decreases in iron deficiency, it is effective on the protein mechanism as well as slow plant growth (Kacar and Katkat, 2010).

Manganese (Mn)

Chloroplasts, where photosynthesis occur in plant organs, are the most sensitive cell organelles against manganese deficiency. In its deficiency, chloroplast formation is disrupted, plant cells shrink, and the cell wall becomes dominant. It is mostly seen on calcareous soils with high pH. The most prominent symptom in plants is interveinal chlorosis, which occurs in young leaves, as in iron (Kacar and Katkat, 2010). They stated that the application of manganese to the cotton plant produced darker green leaves, but had no effect on yield (Ahmad and Hasanuzzaman, 2020).

Zinc (Zn)

In zinc deficiency, the chlorophyll content of the plants decreases, chlorosis occurs between the leaf veins, the veins on the leaves remain green, the color of the parts between the veins may be light green, yellow or white. In addition, leaf formation in plants is adversely affected and leaves become sparse, shoots die and leaves fall prematurely, the number of buds decreases and the rate of bud opening decreases (Kacar and Katkat, 2010).

In cotton, the seedling period is the most sensitive period, the carding and cocoon formation period is the period when the zinc is absorbed the most, and the strongest development period is observed during the flowering period. They stated that zinc absorption and zinc consumption increased in this process, and the zinc level reached low levels during the opening period of the cocoon (Zhi JinHu et al., 2011). (Irshad et al. 2004), Zn deficiency affects differential growth in cotton varieties, according to (Kaya et al., 2005), the application of zinc and foliar fertilizer alone or together increases the grain yield per unit area in cotton compared to the control, (Efe et al. 2008), on the other hand, the zinc application methods greatly affected the yield in cotton except plant height.

Copper (Cu)

Copper is a plant nutrient that the plant needs for chlorophyll production, respiration and protein synthesis. Activation and transfer of a large number of electrons in various oxidase enzymes are carried out by copper. It is effective in protein and carbohydrate metabolism. It also has a role in symbiotic nitrogen fixation (McCauley et al., 2009).

Chlorine (Cl)

Chlorine is a plant nutrient needed by plants for photosynthesis and the turgor pressure of the leaves. Plants absorb chlorine in the form of gas from the atmosphere through their roots and Cl^- ions through their leaves. Chlorine is present in plants as a free anion or weakly attached to exchange surfaces. Plants can get chlorine from many sources such as soil, irrigation water, rain, fertilizers (Güneş et al., 2000).

Some symptoms that occur in the case of chlorine deficiency in plants are as follows; transpiration is affected, chlorosis occurs, leaf margins fade, cell proliferation regresses in some plants, and leaf growth slows significantly. In addition, chlorine toxicity is seen in plants grown in salty soils with high chlorine content. In this case, burning, tanning and premature shedding of leaves occur at the leaf tips and edges of the plant (Boşgelmez et al., 2001; Özbek et al., 2001).

Molybdenum (Mo)

It is one of the least consumed microelements by plants. Molybdenum is an essential element in enzyme activity for plants and nitrogen fixation in legumes. Although the molybdenum content of the soils is generally sufficient for the plants, molybdenum deficiency can be seen in the plants due to the precipitation of molybdenum in the soils with excessive acid reaction. It is in the structure of nitrogenase and nitrate reductase enzymes. It is necessary for biological nitrogen fixation and reduction of nitrate in plants to form amines. In molybdenum deficiency, nitrate assimilation is prevented, old leaves turn yellow, rapid necrosis occurs on the leaf margins due to nitrate accumulation, symbiotic and asymbiotic nitrogen fixation decreases (Kacar and Katkat, 2010).

Nickel (Ni)

As a result of many researches, it has been revealed that the nickel element is a nutrient needed for the growth and development of the plant (Fageria, 2009). Nickel-deficient plants accumulate toxic levels of urea in the leaf tips due to decreased urease activity.

Boron deficiency Iron deficiency

Manganese deficiency Zinc deficiency

Copper deficiency Molibdene deficiency

In nickel deficiency, the development of the aboveground and underground organs of the plants decreases, the green color of the plant gradually disappears, chlorosis and necrosis occur between the leaf veins. However, nickel deficiency is not usually seen in plants. On the other hand, it causes nickel toxicity to occur more frequently in areas where sewage residues are used. It causes poisoning in plants grown in soils containing high amounts of nickel. Therefore, fertilizing the soils with potassium and calcium prevents the toxic effect of nickel (Kacar and Katkat, 2010).

CONCLUSION

Today, the resources required for agricultural production in the world are not unlimited and a continuous development cannot be achieved to the desired extent by disrupting the natural balance. Sustainable agriculture is of utmost importance in terms of creating a society that meets its needs without endangering future generations. It is necessary to increase the productivity of our agricultural lands by protecting soil and water resources, protecting natural resources, combating erosion and forest fires, ensuring biodiversity, integrated pesticide management, and using appropriate cultivation techniques in agriculture. Organic agriculture, which has become more and more important in recent years, will always be an important requirement for sustainable living and sustainable agriculture.

For a sustainable agriculture, macro and micro nutrients have an important role for both the soil and the plant, in case of excessive or underuse, some adverse events occur in the soil and the plant, and accordingly, it causes great losses in terms of yield. Again, in terms of the sustainability of the cotton plant, macro and micro nutrients have important effects, and in case of deficiency and excess, it can cause significant problems in the plant.

REFERENCES

Ahmad, S., Hasanuzzaman, M. (2020). Cotton production and uses. Springer Nature Singapore Pte Ltd. (https://link. springer.com/book/10.1007/978-981-15-1472-2).

Anonymous, (2015). Cotton Nutrition and Fertilization. International Plant Nutrition Institute (IPNI), No: 7

Anonymous, (2019). https://www.gubrekapimda.com (Erişim Tarihi: 01.04.2019).

Anonymous, (2021). *www.tarlasera.com* (Erişim tarihi: 25.05.2021).

Aydın, M., Albayrak, H., Kaptan, M. A. (2014). Aydın merkez ilçesi pamuk üretiminde toprak organik maddesi ve diğer toprak özelliklerinin verim, lif ve tohum özellikleri üzerine etkisi. *Çalıştayı bildiriler*, 109.

Berberoğlu, F. ve Karaltın, S. (2001). Farklı Azot ve Fosfor Dozlarının Maraş 92 Pamuk Çeşidinde (Gossypium hirsutum L.) Verim ve Fizyolojik Özelliklere Etkisi. Türkiye 4. Tarla Bitkileri Kongresi, Cilt: II, 345-349, 17-21 Eylül,

Bibi, Z., Khan, N., Mussarat, M., Khan, M. J., Ahmad, R., Khan, I. U., Shahen, S. (2011). Response of Gossypium hirsutum genotypes to various nitrogen levels. Pak. J. Bot., 43(5): 2403-2409.

Boşgelmez, A., Boşgelmez, İ. İ., Savaşçı, S ve Paslı, N. (2001). Ekoloji – II (Toprak), Başkent Klişe Matbaacılık, Kızılay-Ankara.

Çağlar, F. D., Demir, Y. (2021). Toprak Düzenleyicisi Bazı Polimerlerin (Poliakrilamid ve Polivinil Alkol) Kanola (*Barassica napus* L.) ve Jüt (*Corchorus olitorius* L.) Bitkilerinin Besin Elementi Alımına Etkisi. *Türk Tarım ve Doğa Bilimleri Dergisi*, *8*(1), 8-16.

Dordas, C. (2006). Foliar boron application affects lint and seed yield and improves seed quality of cotton grown on calcareous soils. Nutrient Cycling in Agroecosystems,76: 19-28

Durmaz, M. (2002). Farklı Dozlardaki Mg Uygulamalarının Pamuk Bitkisinde Verim ve Kaliteye Etkisi. Çukurova Üniversitesi Fen Bilimleri Enstitüsü Tarla Bitkileri Anabilim Dalı Yüksek Lisans Tezi.

Ekinci, R., Basbağ, S., Demiray, YG., Yaşar, M. And Kayir, F. (2018). The Use of Heterotic Effects for the Improvement of Some Fiber Technological Properties of New Cotton Varieties in Diyarbakir Conditions. International Journal of Scientific and Technological Research. ISSN 2422-8702 (Online) Vol 4, No.10.

Efe, L., Yarpuz, E. (2008). The Effect Of Zınc Applıcatıon Methods On Seed Cotton Yıeld, Lınt And Seed Qualıty Of Cotton (*Gossypium hirsutum* L.) In East Medıterranean Regıon Of Turkey, Kahramanmaras Sutcu Imam University, Faculty of Agriculture, Field Crops Dept. Kahramanmaras-Turkey

Eminur, E. L. Ç. İ., Hançer, T. (2016). Pamuk (*Gossypium hirsutum* L.) Genotiplerinin Kısıntılı Sulama Koşullarında Çimlenme Analizleri ve Moleküler Karakterizasyonu. *Türkiye Tarımsal Araştırmalar Dergisi*, *3*(2), 122-129.

Fageria, N. K. (2009). The Use of Nutrients in Crop Plants. CRC Pres, Boca Raton, Florida, New York.

Fageria, N. K., Baligar, V. C ve Clark, R. B. (2002). Micronutrient in crop production. Adv. Agron. 77, 185– 268.

Fontes, R. L. F., Medeiros, J. F., Neves, J. C. L., Carvalho, O. S., Medeiros, J. C. (2008). Growth of Brazilian cotton cultivars in response to soil applied boron. Journal of Plant Nutrition, 31: 902-918.

Gardiner, D. T ve Miller, R. W. (2008). Soils in Our Environment. 11th Edition, Pearson/Prentice Hall, Upper Saddle Hill, Ne Jersey, USA.

Gazanfer, S. (2003). An overview of the Turkish cotton in dustry with special emphasis on the available tools and techniques of price risk management. Aegean Textiles and Raw Materials Exports Union Report.

Güneş, A., Alpaslan, M ve İnal, A. (2000). Bitki besleme ve gübreleme. Ankara Üniversitesi Ziraat Fakültesi Yayın No: 1514. Ders Kitabı: 467-576 s.

Güzel, N, Gülüt, K. Y ve Büyük, G. (2004). Toprak Verimliliği ve Gübreler. Ç.Ü. Ziraat Fakültesi Genel Yayın No: 246, Ders Kitapları Yayın No: A-80, Adana.

ICAC, (2019). International Cotton Advisory Committee. Cotton Data Book 2020, December 2019, Washington DC – USA.

ICAC, (2021). International Cotton Advisory Committee, Cotton This Month, 1 April 2021, Washington DC – USA.

Irshad, M., Gıll, M. A., Rahmatullah, T. A., Iftıkhar, A. (2004), Growth Response Of Cotton Cultıvars To ZıncDeficıency Stress In Chelator-Buffered Nutrıent Solutıon, Department of Soil Science,University of Agriculture, Faisalabad, Pakistan.

İrget, M, E., Tepecik, M., Çakıcı, H., Anaç, D., Atalay, İ. Z., Çolakoğlu, H. (2010). Farklı Taban Gübrelerinin Pamukta Verim ve Besin Maddesi Alınımına Etkisi. Ege Üniversitesi Ziraat

Kacar, B ve Katkat, V. (2010). Bitki Besleme. 5. Baskı, Nobel Yayın Dağıtım Tic. Ltd. Şti, Kızılay-Ankara.

Kaya, M., Atak, M., Çift, C. Y. Ünver, S. (2005), Çinko ve Humik Asit Uygulamalarının Ekmeklik Buğday (Triticum aestivum L.)' da Verim ve Bazı Verim Öğeleri Üzerine Etkileri. Süleyman Demirel Üniversitesi, Fen Bilimleri Enstitüsü Dergisi, 9(3):1-8

Khan A, Tan, D. K, Y., Afridi, M. Z., Luo, H., Tung, S. A., Ajab, M., Fahad, S. (2017). Nitrogen fertility and abiotic stresses management in cotton crop: a review. Environ Sci Pollut Res 24:1–16

Kızılgöz, İ., Sakin, E., Öztürkmen, A. R., Almaca, A. (2011). Tuzlu ve tuzsuz topraklarda yetiştirilen pamuk (gossypium hirsutum L.) bitkisinin makro ve mikro element kapsamlarının karşılaştırılması. *Uludağ Üniversitesi Ziraat Fakültesi Dergisi*, *25*(2), 19-30.

Li-Na, Z., Dong, Q., Li-Li, S., Wei-Jie, Y. (2005). Effects of sulfur fertilization on the contents of photosynthetic pigments and MDA under drought stress. Acta Botanica Boreali-Occidentalia Sinica, 2005-08.

Madani, A., Oveysi, M. (2015). Fiber quality and yield response of cotton to nitrogen supply. International Conference on Chemical, Food and Environment Engineering (ICCFEE'15), p. 12-14, (Jan.11-12, 2015) Dubai (UAE).

McCauley, A., Jones, C ve Jacobsen, J. (2009). Nutrient Management. Nutrient management module 9 Montana State University Extension Service. Publication, 4449-9, p.1–16.

Mert, M. (2007). Pamuk Tarımının Temelleri. TMMOB Ziraat Mühendisleri Odası Teknik Yayınlar Dizisi No:7, Hatay

Mert, (2017). Organik Olarak Yetiştirilen Pamuk Çeşitlerinin Azot Gereksiniminin Belirlenmesi. Mustafa Kemal Üniversitesi Ziraat Fakültesi Dergisi, 22(2), 19-34.

Nyiraneza, J., Vernon, R., Yvonne, U., Fraser, T. D., Erin, S., Fillmore, S., Mills, A. (2018). Long-Term Manure Application Effects on Nutrients and Selected Enzymes Involved in Their Cycling. Soil Science Society of America Journal, 82:(6), 1404-1414.

Organic Cotton Market Report, (2020). Covering production trends and initiative updates from the 2018/19 harvest year,

Özbek, H., Kaya, Z., Gök, M ve Kaptan, H. (2001). Toprak Bilimi. 5. Baskı, ÇÜ Ziraat Fakültesi Genel Yayın No 73, Ders Kitapları Yayın No A–16, Adana.

Özüdoğru, T. (2013). Pamuk Durum ve Tahmin Raporu, 2012/13 Gıda Tarım ve Hayvancılık Bakanlığı, Tarımsal Ekonomi ve Politika Geliştirme Enstitüsü. *TEPGE Yayın*, (217).

Parvin, K., Ahamed, K. U., Islam, M. M., Haque, M. N., Hore, P. K., Siddik, M. A., Roy, I. (2015). Reproductive behavior of tomato plant under saline condition with exogenous application of calcium. Middle-East J SciRes, 23(12):2920–2926.

Rice, R. W. (2007). The physiological role of minerals in the plant. In: Datnoff LE, Elmer WH, Huber DM (eds.) Mineral nutrition and plant disease, St. Paul, Minnesota: The American Phytopathological Society, pp 9–29.

Sardans, J., Pe˜nuelas, J. (2021). Potassium control of plant functions: ecological and agricultural implications. Plants 10 (2), 419.

Sawan, Z. M., Hafez, S. A., Basyony, A. E. (2001). Effect of phosphorus fertilization and foliar application of chelated zinc and calcium on seed, protein and oil yields and oil properties of cotton. The Journal Cotton Science, 136 (2):191-198.

Soysal, S., Yılmaz, A. (2021) Mikorizal Fungusların (MF) Tarla Bitkilerinde Kullanımı. G. Bengisu (Ed) Akademik Perspektiften Tarım'a Bakış (173-192. ss.). Adıyaman; Turkey: İKSAD.

Soysal, S., Erman M., Çığ, F. (2022) Biyoremediasyon Çalışmalarında Bitki Gelişimini Teşvik Eden Kök Bakterilerinin Rolü. A. Yılmaz, S. Soysal (Ed) Modern Tarım Uygulamaları (151-167. ss.). Adıyaman; Turkey: İKSAD.

Taban, S., Çaycı, G., Kütük, C. (2009). Tavuk dışkılarının organik gübreye dönüştürülmesi. *Kompostlaştırma Sistemleri ve Kompostun Kullanım Alanları Çalıştayı*, 18-19.

Turhan, Ş. (2005). Tarimda sürdürülebilirlik ve organik tarim. Tarım Ekonomisi Dergisi, 11(1 ve 2), 13-24.

TÜİK, (2018). Türkiye İstatistik Kurumu. Bitkisel Ürün İstatistikleri. https://data.tuik.gov.tr/. (Erişim Tarihi: 20.05.2018).

TÜİK, (2019). Türkiye İstatistik Kurumu. Erişim Adresi: http://www.upk.org.tr. (Erişim Tarihi: 19.04.2020).

TÜİK, (2020). Türkiye İstatistik Kurumu. Erişim Adresi: www.tuik.gov.tr. (Erişim Tarihi: Ocak 2020).

TÜİK, (2022). Türkiye İstatistik Kurumu. Bitkisel Ürün İstatistikleri. https://data.tuik.gov.tr/. (Erişim Tarihi: 20.05.2022).

USDA, (2020). United States Department of Agriculture Foreign Agricultural Service, December 2020 Report, Cotton: World Markets and Trade, 1-28.

White, R. E. (2006). Principles and Practice of Soil Science: The Soil as a Natural Resource. 4th Edition, Wiley-Blackwell Scientific Publication, London, United Kingdom.

Wu, L., Ma, H., Zhao, Q., Zhang, S., Wei, W., Ding, X. (2020). Changes in soil bacterial community and enzyme activity under five years straw returning in paddy soil. European Journal of Soil Biology 100, 103215.

Xu, C., Pu, L., Li, J., Zhu, M. (2019). Effect of reclamation on C, N, and P stoichiometry in soil and soil aggregates of a coastal wetland in eastern China. Journal of Soils and Sediments 19:(3), 1215-1225.

Yaşar, M., Basbağ, S. and Ekinci, R. (2017). Pamukta Farklı Zamanlarda Kesilerek Uzaklaştırılan Tepe Sürgünü Uygulamasının Lif Verimi ve Kalitesi Üzerine Etkisi. Iğdır Üni. Fen Bilimleri Enst. Der. / Iğdır Univ. J. Inst. Sci. & Tech. 7(2): 327-333.

Yıldırım, A. (2003). Pamukta (Gossypium hirsutum L.) Yaprağa Bor Uygulamalarının Verim ve Lif Kalitesine Etkisi. Çukurova Üniversitesi Fen Bilimleri Enstitüsü Tarla Bitkileri Anabilim Dalı Yüksek Lisans Tezi

Yılmaz, A., Soysal, S., Emiralioğlu, O., Yılmaz, H., Soydemir, H. E., Çiftçi, V. (2021) Sürdürülebilir Tarımda Anıza Ekimin Önemi. M.F. Baran, K. Bellitürk ve A. Çelik (Ed) Türkiye'de Sürdürülebilir Tarım Uygulamaları: Zorluklar ve Potansiyeller (221-230. ss.). Adıyaman; Turkey: İKSAD.

Zhi JinHu, Feng, H., Wang, L., Longlie, O. (2011). The effects of zinc spraying on zinc distrubition at different cotton growth stages. Xinjiang Agricultural Sciences, 48(12): 2315-2320.

CHAPTER 4

AGRICULTURAL EVALUATION OF ORGANIC MATERIAL: LEONARDITE

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INTRODUCTION

In recent years, there are various studies reporting that leonardite promotes root and stem development, increases the availability and uptake of plant nutrients from the soil (Akinremi et al., 2000; Dursun et al., 2002; Serenella et al., 2002; Cimrin and Yilmaz 2005; Unlu et al., 2010). In addition, it has been stated that such organic materials increase soil organic matter and increase plant growth and thus yield (Demirkıran, 2021) and various studies have been carried out (Erik et al., 2000; Hartwigsen and Evans, 2000; Hafez, 2003; El-Desuki, 2004; Asmaa and Hafez, 2010; Selim et al., 2012; Hopkins and Stark, 2003; Verlinden et al., 2009; El Sayed Hameda et al., 2011).

Leonardite is an organic material containing high amounts of humic acid and fulvic acid. When various studies are examined, it is understood that this rate is between 25% and 87% (Schnitzer and Khan, 1972; Akinremi et al., 2000; Erkoç, 2009; Suiger et al., 2013; Ratanaprommanee and Shutsrirung, 2014; Dong et al., 2009; Fong et al., 2006; Olivella et al., 2011; Canieren et al., 2016; Turgay et al., 2010).

Liquid or solid forms of leonardite and other products are commercially marketed and used in the agricultural sector. These consist of powdered leonardite, K-humates, Na-humates, liquid concentrates. Leonardite or lignite is sometimes combined with additional nutrients (such as P, K, S, and N) (Boughton, 1972; Iakimenko, 2005; Eady, 2012).

EFFECTS OF LEONARDITE ON HORTICULTURAL PLANTS

It has been reported that the application of humic material produced from leonardite tot cherry causes an increase in yield and in the P, K, Na, Ca, Mg, Fe, Mn and Zn elements in the leaf (Dias et al., 2020). It was observed that ungrafted seedlings treated with leonardite in olive seedlings produced more shoot growth than untreated grafted plants (Escobar et al., 1999). It was observed that the liquid leonardite solution applied to the leaves of olive had a positive effect on stem growth and leaf Fe content (Fernandez et al., 1996). Strydom (2014) applied leonardite to grape did not find a significant difference in macro elements in leaf analysis, and observed significant increases in Mn content.

The effects of leonardite in tomatoes and cabbage plants were investigated (Loffredo et al., 2005). In a study where tomato seedlings were grown with leonardite and 40% of the plant length, 134% of the age body weight, 82% of the age root weight, 133% of dry body weight and 400% of the dry root weight increased (Pertuite et al., 2001; David et al., 2014).

The effect of leonardite on plant nutrients were investigated and; P and K content in onion plant, N:P and N:K rates (Sarıyıldız, 2020), cherry trees N, P, K, Ca, Mg, Fe, Cu, Zn and Mn contents (Demirer, 2019), K content in spinach plant (Demirer, 2019) Yılmaz et al., 2012), tomatoes N, P, Ca, K, Mg, Zn, Cu and Fe contents (Adani et al., 1998), and pistachio seedlings (Demirkıran and Cengiz, 2010) has been reported to have a positive effect and increased. It is stated that its roots increase in carrot plant (Sanders et al., 1990). The nutrient content of the leonardite vineyard has not changed, but there have been increased organic matter and Fe contents in the soil (Olego et al., 2015). Leonardite has been reported to have positive effects on grape (Reynolds et al., 1995), cucumber (Rauthan and Schnitzer, 1981), and tomatoes (Bryan, 1976). Oguz et al. (2012) applied 100 kg/da leonardite to the pepper plant and suggested that applications did not have a significant effect on pepper yield and that these doses could be increased. Leonardite has a positive effect on the development of seedlings in tomatoes (Demirkıran et al., 2012) increases N and P contents (Adani et al., 1998). It has been reported that humic and fulvik acids increase plant development, for example, this development is observed in tomatoes, and it has positively affected the root development of tomatoes and the intake of nutrients of the roots (Adani et al., 1998; Pertuite et al., 2001; Dilk, 2002). The positive effects of leonardite were reported in the lettuce (Dudley et al., 2004). Topcuoglu and Onal (2006) reported that leonardite application to tomatoes had a positive effect on fruit yield and the content of Fe, Zn and Mn in the leaves increased.

As a result of Leonardite applications to Chinese cabbage, it was found that the element contents of the plant macro (N, P, K, Ca, and Mg) and micro (Fe, Cu, Zn, and Mn) increased (Adiloğlu et al., 2018b). Leonardite has also reported that it causes plant development in different plants and increases most nutrients (especially N, P, and K) in the soil (Duval et al., 1998).

Leonardite application to jasmine plant, plant length, number of branches, plant fruit, number of leaves, leaf area, fresh-dry leaf weight of the plant, age-root weight, total plant weigh, root length, chlorophyll content and stoma permeability increased (Moroccan et al., 2021).

Sesveren and Tas (2018), who investigate the effects of leonarditis on curly lettuce reported that leonardite was statistically important on yield and some developmental parameters and increased the amount of nitrogen.

Leonardite on the effects of spinach plant was investigated by Yildiz et al. (2019) emphasized that some efficiency criteria such as leaf width and weight, root weight and water-soluble dry matter content were also affected positively.

Leonardite application to *Rhodiola rosea* L. plant was increased the weight and biomass of the parts of the plant and was emphasized the positive effect on yield and quality values as well as in enzyme activities and soil organic substances (Kołodziej et al., 2013).

Leonardite applications to tomato were reported that yield in tomatoes increased (Wallaca and Wallaca, 1986). Majeed (2021). Leonardite on the cucumber plant found that the number of fruits increased nutrient contents (N, P, K, Ca, Mg, Cu, Zn, and Mn) in leaves, plant dry weight, plant length, and plant fruits. The effect of leonardite, which was used as relieving salinity in tomato cultivation, were examined and reported that leonardite had the negative effect of salt (Casierra-Posada et al., 2009), and the negative effect of salt on *Lepidium sativum* plant can be reduced with humic materials (Masciandaro et al., 2002).

It has been observed that leonardite applied to lettuce plant was positive effect on the root development (field, diameter, length and diversity), effecting such as indolacetic acid and giberellik acid, and increased the activities of glutamine synthetase and glutamate syntase enzymes in the root and stem (Consellval Ertani et al., 2019).

Leonardite extracts applied to the roots of wild birch and alder roots were examined from the formation of stem and leaf and increased the development, root development and root length of plants (Tahiri et al., 2015).

It was investigated that the effect of Leonarditis on the ornamental plant, reported that leonarditis yield, a thousand grain weight, plant and cluster length increased by Kenen and Tanrıverdi (2020).

EFFECTS OF LEONARDITE ON THE FIELD CROPS

Leonardite applying increased the amounts of dry matter and nutrients (N, P, K, Ca, Mg, Fe, Cu, Zn, and Mn) in the rye plants (Adiloğlu et al., 2018a), in the wheat plants (Easy et al., 2016). Leonardite was shown the positive effect on sunflower (Tamer et al., 2016) and potato yield, the number of tubers in the plant and the plant length of the plant was found the positive effects (Sanli et al., 2013). In wheat, leonardite was reported by Ayhan et al. (2021) that the plant length, spike grain weight, number of grains and normalized plant vegetation index (NDVI) increased. Wallaca and Wallaca (1986) reported that leonardite applications did not increase wheat yield. It was found that the powder form of leonardite increased wheat yield significantly. It has been reported that humic and fulvic acids increase plant growth, such as corn and canola plants, this development is observed that affects the root development of corn and the intake of nutrients of the roots positively (Adani et al., 1998; Pertuite et al., 2001; Dilk, 2002). The positive effects of leonardite were also reported in beans by Dudley et al. (2004).

Leonardite materials were reported to increase fat percentage, fat yield and fatty acids in the seeds of the rapeseed plant by Gursoy and Kolsarici (2017). Ergönül and Basalma (2013) also emphasized that leonardite application to sunflower increased the percentage of fat in the seed.

Leonardite-humate applications to legumes were rised stem and root development of plant as 15-25% (Cieschi et al., 2019), Application of leonardite to the bean plant was found that the root-body length, root-body weight, plant K and Na contents of plant were increased by Kiyas (2020). Leonardite-potassium humat and leonardite-iron humat were applied to soybeans and leonardite-iron humat caused more soil aggregate formation in the root area and can be used in Fe deficiency (Cieschi et al., 2018). It is emphasized that leonarditis increased plant length, number of plant branches, plant fruits, fruit weight and yield of potatoes (Akimbekov et al., 2020).

Leonardite was reported that the positive effects on corn (Tan and Nopamornbodi, 1979). Leonardite were applied to sorghum and significantly increased green grass yield and raw protein (Nazli et al., 2014a) and to bean (Ece et al., 2007), to potatoes (İron et al., 2012) and to silage corn (Nazli et al., 2014b) similar results were reported.

The effect of leonardites on plant nutrients were investigated by the different researchers. Leonardite effects to the P, N and K contents in corn plant (Duplessis and Mackenzie, 1983; Sağlam et al., 2012), to the N and K contents in wheat plant (Azizadeh et al., 2016), to the K, Mg, Ca, Mn and Fe contents in rye plant (Passenger et al., 2011), to the P content in corn (Kaya et al., 2020), to the Fe content in soybeans (Cieschi et al., 2019) and to the Fe content in mustard plant (Decock et al., 1960) were reported as positively and increasingly. It was found that leonardite applied to beans, wheat and canola plants had a positive effect on NPK intake and contents in the plant and increased the amount of dry matter (Akinremi et al., 2000).

Aygün and Mert (2020) reported that leonardite was not effected to cotton plant plant length, number of branches, number of boll, boll weight, fiber thinness, fiber strength and 100 seed weight criteria, but seed cotton yield was observed that fiber length significantly increased with the leonardite applications.

Ertekin et al. (2020) stated that leonardite applying to the vetch species increased fresh grass yield of widespread vetch, and dry grass yield of widespread vetch, Hungarian vetch and hairy vetch species.

It was reported that leonardite application to the rice plant was positive effects on the yield and yield criteria (grain/body ratio, harvest index) and increased the plant P, Mg, Fe, Mn, Zn, Cu, B contents (Litero et al., 2022). Natural leonardite and enriched leonardite were applied to rice and found that grain weight increased by 17-20% and biomass increased by 97-117% (Ratanaprommanee et al., 2017). Leonardite was used to prevent Cd and Zn over-accumulation in rice varieties, and applications have been reported to reduce excessive Cd and Zn accumulation and leonardite increased grain yield (Saengwilai and Meeinkuirt, 2021).

Leonardite application to the sugar beet was found to be due to the increase in the sugar content of the beet (Hajizadeh et al., 2019).

Leonardite was applied to mountain tobacco (*Arnica montana*) and increased the efficiency with the number of branches and flowers (Sugier et al., 2013). Leonardites were positive effect on root development, root surface area, root length, root area and the number of roots of beans and increases the K content in the root and stem of plant (Qian et al., 2015).

Leonardites were found that the root growth, protein content, and uptake of N, P and K elements in corn plants effected positively (David et al., 2014). In corn seedlings, leonardite was reported to increase root development (root length and total root area). Leonardite was also found to increase plant length with seedlings, leaf, root weights (Sun et al., 2016). In corn plants, leonardite was stated to increase the amounts of protein, sucrose, glucose and fructose in the roots and leaves (Consellvan et al., 2017; Ertani et al., 2019).

In a study where leonardite's effects on Cd and Zn intake in different types of rices were investigated and it was shown that the applications improve the physical-chemical properties of the soil, increased soil organic matter content and some nutrients (N, P, P, K, Ca and Mg), and their applications reduced soil Cd concentration (Saengwilai et al., 2017).

Uçar et al. (2020) investigated the effects of leonardite on the efficiency and some properties of chickpeas (*Cicer arietinum* L.) in Siirt, and found that leonardite effected to the plant height, first bean height, number of beans, number of grains in the plant, 100 grain weight and grain yield. In the study, it was emphasized that 100 kg/da leonarditis gives the highest values and doses should be increased slightly.

CONCLUSION

Organic materials are substances that take care of the ecological balance, make the efficiency of the soil sustainable, make more natural nutrition of plants, and increase the yield with the correct use of resources in nature. It is the leonardite material around the coal mines that fill an important place. These materials has many benefits to plants and soil, and they were investigated by most researchers and such research continues. It is a very important issue to continue the contributions of leonarditis materials to agriculture, which is determined to have significant contributions to the development of the different plants used in the trial, both in terms of increasing the organic materials. The widespread use of leonardite needs to be tested in different plants and trees, and it should be considered that the potential to reduce the amount of chemical fertilizer, which is an important input in agricultural production.

REFERENCES

Adani, F., Genevini, P., Zaccheo, P., Zocchi, G. (1998). The effect of commercial humic acid on tomato plant growth and mineral nutrition. Journal of Plant Nutrition 21: 561-575.

Adiloğlu, A., Bellitürk, K., Adiloğlu, S., Solmaz, Y. (2018a). The effect of increasing leonardit applications on dry matter yield and some nutrient elements contents of rye (*Secalecerale* L.) plant. Eurasian Journal of Forest Science 6(1): 44-51.

Adiloglu, A., Eryılmaz Acıkgoz, F., Solmaz, Y., Adiloglu, S., Karaman, M.R. (2018b). The effect of increased doses of leonardite applications on the content of some macro and micro nutrient elements of pak choi plant. Eurasian Journal of Forest Science 6(3): 8-14.

Akinbekov, N., Qiao, X., Digel, I., Abdieva, G., Ualieva, P., Zhubanova, A. (2020). The effect of leonardite-derived amandments on soil microbiome structure and potato yield. Agriculture 10(147): 1-17.

Akinremi, O.O., Janzen, H.H., Lemke, R.L., Larney, F.J. (2000). Response of canola, wheat and green beans to leonardite additions. Can. J. Soil Sci. 80: 437–443.

Asmaa, R.M., Hafez, M.M. (2010). Increasing productivity of potato plants (*Solanum tubersoum* L.) by using potassium fertilizer and humic acid application. International Journal of Academic Research 2(2): 83-88.

Aygün, Y.Z., Mert, M. (2020). Toprak düzenleyicileri ve azot uygulamalarının pamukta (*Gossypium hirsutum* L.) verim ve lif teknolojik özelliklere etkisi. Biyolojik Çeşitlilik ve Koruma 13(3): 290-297 (in Turkish).

Ayhan, M., Kızılgeçi, F., Iqbal, M.A. (2021). Fertilisation source and dose optımisation boost yield of durum wheat in mediterranean climatic conditions. Journal of Applied Life Sciences and Environment Vol. LIV (2-186): 225-240.

Azizzadeh, E., Naeini, S., Zeinali, E., Roshani, G.A. (2016). Nitrogen, phosphor an potassium changes in soil and wheat under foliar application of leonardite, N and K. International Journal of Advanced Biological and Biomedical Research 4(2): 202-210.

Boughton, P.L. (1972). Humic acid complexes from naturally oxidized lignite: Their genesis, chemistry and utilization. Proceedings, Eighth Forum on Geology of Industrial Minerals, Iowa, p. 153.

Bryan, H.H. (1976). Response of tomatoes to seed and seedling applications of humates and alpha-keto acids. Proceedings of the Florida State Horticultural Society 89: 87–90.

Canıeren, Ö., Karagüzel, C., Aydın, A., Karaca, S. (2016). Recovery of humic substance from leonardite by pneumatic vertical column. 15th International mineral Processing Symposium, October 19-21, İstanbul, Turkiye, p. 372-378.

Casierra-Posada, F., Rodriguez, C.A., Fischer, G. (2009). Reducing negative effects of salinity in tomato (*Solanum lycopersicum* L.) plants by adding leonardite to soil. Proc. IS on Tomato in the Tropics Eds.: G. Fischer et al. Acta Hort. 821, ISHS 2009, p. 133-140.

Cieschi, M.T., Lucena, J.J. (2018). Iron and humic acid accumulation on soybean roots fertilized with leonardite iron humates under calcareous conditions. Journal of Agricultural and Food Chemistry 66(51): 13386-13396.

Cieschi, M.T., Polyakov, A.Y., Lebedev, V.A., Volkov, D.S., Pankratov, D.A., Veligzhanin, A.A. (2019). Eco-friendly iron-humic nanofertilizers synthesis for the prevention of iron chlorosis in soybean (*Glycine* max) grown in calcareous soil. Frontiers in Plant Science 10: 413.

Cimrin, K.M., Yılmaz, I. (2005). Humic acid applications to lettuce do not improve yield but do improve phosphorus availability. Acta Agriculturae Scandinavica, Section B-Soil and Plant Science 55(1): 58-63.

Conselvan, G.B., Pizzeghello, D., Francioso, O., Di Foggia, M., Nardi, S., Carletti, P. (2017). Biostimulant activity of humic substances extracted from leonardites. Plant and Soil 420(1): 119-134.

David, J., Šmejkalová, D., Hudecová, S., Zmeškal, O., von Wandruszka, R., Gregor, T., Kučerik, J. (2014). The physicochemical properties and biostimulative activities of humic substances regenerated from lignite. SpringerPlus 3(1): 156-172.

DeKock, P.C., Hall, A., Mcdonald, M. (1960). A relation between the ratios of phosphorus to iron and potassium to calcium in mustard leaves. Plant and Soil 12(2): 128-142.

Demir, M., Noyan, F.O., Oğuz, İ. (2012). Leonardit kullanımı ile birlikte azaltılmış azotlu gübre uygulamalarının bitki verim ve toprak özellikleri üzerine etkileri. SAÜ Fen Edebiyat Dergisi 2012(1): 445-455 (in Turkish).

Demirer, T. (2019). Effect of leonardite application on leaf nutrient content and fruit chemical parameters of cherry (*Prunus avium* L.), J. Plant Nutrition 42(19): 2532-2538.

Demirkıran, A.R., Özbay, N., Demir, Y. (2012). Leonardit ve inorganik gübrelemenin domates bitkisinin gelişimi üzerine etkileri. Türk Doğa ve Fen Dergisi 1(2): 110-114 (in Turkish).

Demirkiran, A.R., Cengiz, M.C. (2010). Effects of different organic materials and chemical fertilizers on nutrition of pistachio (*Pistacia vera* L.) in organic arboriculture. African Journal of Biotechnology 9(38): 6320-6328.

Demirkıran, A.R. (2021). The using of leonardite on plant nutrition and fertilizing, Chapter 3, in Book (Eds: Belliturk K and Aslam Z): Fertilizer and their effcient use in sustainable agriculture p. 91-128.

Dilk, S. (2002). Agronomic evaluation of leonardite on yield and chemical composition of canola and wheat. Masters thesis. Winnipeg: University of Manitoba, p. 57.

Dong, L., Córdova-Kreylos, A.L., Yang, J., Yuan, H., Scow, K.M. (2009). Humic acids buffer the effects of urea on soil ammonia oxidizers and potential nitrification. Soil Biology and Biochemistry 41(8): 1612–1621.

Dudley, J., Pertuit, Jr A., Toler, J.E. (2004). Leonardite influences Zinnia and Marigold growth. Hort Science 39(2): 251-255.

Duplessis, G.L., Mackenzie, A.F. (1983). Effects of leonardite applications on phosphorus availability and corn growth. Canadian Journal of Soil Science 63(4): 749–751.

Dursun, A., Guvenc, I., Turan, M. (2002). Effects of different levels of humic acid on seedling growth and macro and micronutrient contents of tomato and eggplant. Acta Agrobotanica 55(2): 81-88.

Duval, J.R., Dainello, F.J., Haby, V.A., Earhart, D.R. (1998). Evaluating leonardite as a crop growth enhancer for turnip and mustard greens. Hort Technology 8(4): 564-567.

Eady, N. (2012). The use of humic substances – Leonardite as a soil amandment. Mining and Petroleum Environment Reserch Group (MPERG) Report 2012-2, p. 10.

Ece, A., Saltali, K., Eryiğit, N., Uysal, F. (2007). The effect of leonardite applications on climbing bean (*Phaseolus vulgaris* L.) yield and some soil properties. Journal of Agronomy 6(3): 480-483.

El-Desuki, M. (2004). Response of onion plants to humic acid and mineral fertilizers application. Annals of Agricultural Science, Moshtohor 42(4): 1955-1964.

El Sayed Hameda, E.A., Saif El Dean A., Ezzat, S., El Morsy A.H.A. (2011). Responses of productivity and quality of sweet potato to phosphorus fertilizer rates and application methods of the humic acid. International Research Journal of Agricultural Science and Soil Science 1(9): 383-393.

Ergönül U., Basalma, D. (2013). Ayçiçeği (*Helianthus annuus* L.) çeşitlerine uygulanan humik asit ve leonardit'in verim ve verim öğeleri üzerine etkileri, 10. Tarla Bitkileri Kongresi 10-13 Eylül, Konya, Cilt II: 174-181 (in Turkish).

Erik, B., Feibert, G., Shock, C.C., Saundres, L.D. (2000). Evaluation of humic acid and other non conventional fertilizer additives for onion productivity. Malheur Experiment Station Annual Report 2000, Special Report 1029, Oregon State University, Ontario, p. 211.

Erkoc, I. (2009). Effects of sulphur and leonardite on phosphor efficiency in greenhouse grown tomato. Msc. thesis, Department of Horticulture Institute of Natural and Applied Sciences, University of Cukurova, p. 127.

Ertani, A., Nardi, S., Francioso, O., Pizzeghello, D., Tinti, A., Schiavon, M. (2019). Metabolite-targeted analysis and physiological traits of *Zea mays* L. in response to application of a leonardite-humate and lignosulfonate-based products for their evaluation as potential biostimulants. Agronomy 9(8): 445-463.

Ertekin, İ., Atış, İ., Yılmaz, Ş. (2020). Bazı fiğ türlerinin yem verim ve kalitesi üzerine farklı organik gübrelerin etkileri. Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi 25(2): 243-255 (in Turkish).

Escobar-Alarcón L., Haro-Poniatowski, E., Camacho-López, M.A., Fernández-Guasti, M., Jimenez-Jarquin, J., Sánchez-Pineda, A. (1999). Growth of rutile TiO_2 thin films by laser ablation. Surface Engineering 15(5): 411–414.

Fernandez, R.E., Benlock, M., Barranco, D., Duenas, A., Ganan, J.A.G. (1996). Response of olive trees to foliar application of humic substances extracted from leonardite. Scientia Horticulturae 66(3-4): 191-200.

Fascella, G., Montoneri, E., Rouphael, Y. (2021). Biowaste-derived humic-like substances improve growth and quality of orange jasmine (*Murraya paniculata* L. Jacq.) plants in soilless potted culture. Resources 10(8): 80-92.

Fong, S.S., Seng, L., Chong, W.N., Asing, J., Nor, M.F.B.M., Pauzan, A.S.B.M. (2006). Characterization of the coal derived humic acids from Mukah, Sarawak as soil conditioner. Journal of Brazilian Chemical Society 17(3): 582–587.

Gursoy, M., Kolsarici, O. (2017). Effects of different humic acid doses in leonardite environment on the oil percentage and fatty acids of summer rapeseed (*Brassica napus* ssp. Oleifera L.) under Central Anatolian conditions. Fresenius Environmental Bulletin 26(11): 6447-6456.

Hafez, M.M. (2003). Effect of some sources of nitrogen fertilizer and concentration of humic acid on the productivity of squash plant. Egyptian Journal of Applied Science 19(10): 293-309.

Hajizadeh, H.S., Heidari, B., Bertoldo, G., Della Lucia, M.C., Magro, F., Broccanello, C., Baglieri, A., Puglisi, I., Squartini, A., Campagna, G., Concheri, G., Nardi, S., Stevanato, P. (2019). Expression profiling of candidate genes in sugar beet leaves treated with leonardite-based biostimulant. High-throughput 8(4): 18-36.

Hartwigsen, J.A., Evans, M.R. (2000). Humic acid seed and substrate treatments promote seedling root development. HortScience 35(7): 1231-1233.

Hopkins, B., Stark, J. (2003). Humic acid effects on potato response to phosphorus. Idaho Potato Conference January 22-23, p. 87-92.

Iakimenko, O.S. (2005). Commercial humates from coal and their influence on soil properties and initial plant development. NATO Science Series: IV. Earth and Environmental Sciences, p. 365.

Kaya, C., Şenbayram, M., Akram, N.A., Ashraf, M., Alyemeni, M.N., Ahmad, P. (2020). Sulfur-enriched leonardite and humic acid soil amendments enhance tolerance to drought and phosphorus deficiency stress in maize (*Zea mays* L.). Scientific Reports 10(1): 6432.

Keten, M., Tanrıverdi, Ç. (2020). Effect of the leonardite dose applied at different rates on the water-yield relationship of amaranth (*Amaranthus cruentus* L.) plants. ISPEC Journal of Agricultural Sciences 4(4): 823-833.

Kiyas, Ü. (2020). Farklı leonardit ve tuz seviyelerinin fasulyenin (*Phaseolus vulgaris* L.) fide gelişimi üzerine etkisi. Yüksek Lisans Tezi, Bingöl Üniversitesi Fen Bilimleri Enstitüsü, Bingöl, p. 73.

Kolay, B., Gürsoy, S., Avşar, Ö., Bayram, N., Öztürkmen, A.R., Aydemir, S., Aktaş, H. (2016). Toprağa farklı miktarlarda uygulanan leonarditin buğday bitkisinin verim, verim öğeleri ve bazı kalite özellikleri üzerine etkisi. Dicle Üniversitesi Fen Bilimleri Enstitüsü Dergisi 5(3): 93-98 (in Turkish).

Kołodziej, B., Sugier, D., Bielińska, E. (2013). The effect of leonardite application and various plantation modalities on yielding and quality of roseroot (*Rhodiola rosea* L.) and soil enzymatic activity. Journal of Geochemical Exploration 129: 64-69.

Litardo, R.C.M., Bendezu, S.J., Zenteno, M.D.C., Perez-Almeida, I.B., Parismoreno, L.L., Garcia E.D.L. (2022). Effect of mineral and organic amendments on rice growth and yield in saline soils. Journal of the Saudi Society of Agricultural Sciences 21(1): 29-37.

Loffredo, E., Monaci, L., & Senesi, N. (2005). Humic substances can modulate the allelopathic potential of caffeic, ferulic, and salicylic acids for seedlings of lettuce (*Lactuca sativa* L.) and tomato (*Lycopersicon esculentum* Mill.). Journal of Agricultural and Food Chemistry, 53(24), 9424-9430.

Majeed A.J. (2021). Cucumber (*Cucumis sativus* L.) growth and nutrient content response to applications of leonardite and phosphorus fertilizer. Agricultural Science 5(1): 1-12.

Masciandaro G., Ceccanti B., Ronchi V., Benedicto S., Howard L. (2002). Humic substances to reduce salt effect on plant germination and growth. Communications in Soil Science and Plant Analysis 33(3-4): 365-378.

Nazli R.I., Kusvuran A., Tansi V. (2014a). Effects of different organic materials on forage production from sorghum x sudangrass hybrid (*Sorghum bicolor x sorghum bicolor var. sudanense*). Türk Tarım ve Doğa Bilimleri Dergisi 1(Özel sayı-2): 2075-2082.

Nazli R.I., Kusvuran A., Inal I., Demirbas A., Tansi V. (2014b). Effects of different organic materials on forage yield and quality of silage maize (*Zea mays* L.). Turkish Journal of Agriculture and Forestry 38(1): 23-31.

Oğuz İ., Noyan Ö.F., Karaman M.R., Koçyiğit R., Özen M. (2012). Jalapeno biber tarımında farklı organik ve inorganik materyallerin toprak özellikleri ve ürün verimi üzerine etkilerinin araştırılması. SAÜ Fen Edebiyat Dergisi 1: 393-403 (in Turkish).

Olego M.A., Cordero J., Quiroga M.J., Sánchez-García M., Álvarez J.C., Garzón-Jimeno E. (2015). Effect of leonardite application on soil organic matter and micronutrient levels in an inceptisol soil cultivated with vine (*Vitis vinifera* L.). International Tuba Euphonium Association Journal (ITEA) 111(3): 210-226.

Olivella M., Sole M., Gorchs R., Lao C., de las Heras F.X.C. (2011). Geochemical characterization of a spanish leonardite coal. Archives of Mining Sciences 56(4): 789–804.

Pertuit A.J., Dudley J.B., Toler J.E. (2001). Leonardite and fertilizer levels influence tomato seedling growth. HortScience 36(5): 913-915.

Ratanaprommanee C., Shutsrirung A. (2014). Chemical properties and potential use in agriculture of leonardite from different sources in Thailand. pp. 1236-1246. In: Proceedings of the 5th National and International Hatyai Conference. May 16, 2014. Hatyai University, Hat Yai, Songkhla, p. 1236-1246.

Reynolds A.G., Wardle D.A., Drought B., Cantwell R. (1995). Gro-Mate soil amendment improves growth of greenhouse-grown 'Chardonnay' grapevines. HortScience 30(3): 539–542.

Rauthan B.S., Schnitzer M. (1981). Effects of a soil fulvic acid on the growth and nutrient content of cucumber (*Cucumis sativus*) plants. Plant and Soil 63(3): 491–495.

Saengwilai P., Meeinkuirt W., Pichtel J., Koedrith P. (2017). Influence of amendments on Cd and Zn uptake and accumulation in rice (*Oryza sativa* L.) in contaminated soil. Environmental Science and Pollution Research 24(18): 15756-15767.

Saglam M.T., Ozel E.Z., Belliturk K. (2012). The effect of two type textured soil with the leonardite organic material on the nitrogen uptaking of corn plant. Sakarya University Journal of Arts and Science 14(1): 383–91.

Sanders D.C., Ricotta J.A., Hodges L. (1990). Improvement of carrot stands with plant biostimulators and fluid drilling. HortScience 25(2): 181-183.

Sanlı A., Karadoğan T., Tonguç M. (2013). Effects of leonardite applications on yield and some quality parameters of potatoes (*Solanum tuberosum* L.). Turkish Journal of Field Crops 18(1): 20-26.

Sarıyıldız T. (2020). Effects of leonardite and mineral fertilizer applications on plant growth and soil quality of garlic (*Allium sativum* L.). Turkish Journal of Agriculture-Food Science and Technology 8(8): 1763-1772.

Schnitzer M., Khan M.U. (1972). Humic substances in the environment. Marcel Dekker, New York, No: 631-417.

Selim E.M., Shedeed S.I., Asaad F.F., El-Neklawy A.S. (2012). Interactive effects of humic acid and water stress on chlorophyll and mineral nutrient contents of potato plants. Journal of Applied Sciences Research 8(1): 531-537.

Serenella N., Pizzeghello D., Muscolo A., Vianello A. (2002). Physiological effects of humic substances on higher plants. Soil Biology and Biochemistry 34(11): 1527-1536.

Sesveren S., Tas B. (2018). Farklı leonardit düzeylerinin kıvırcık yaprak salatada (*Lactuva sativa* var. crispa) su tüketimi ve bazı gelişim parametreleri üzerine etkisi. Türk Tarım - Gıda Bilim ve Teknoloji Dergisi 6(4): 421-426 (in Turkish).

Strydom J. (2014). The effect of foliar potassium and seaweed products in combination with a leonardite fertigation product on Flame Seedless grape quality. South African Journal of Enology and Viticulture 35(2): 283-291.

Sugier D., Kołodziej B., Bielińska E. (2013). The effect of leonardite application on *Arnica montana* L. yielding and chosen chemical properties and enzymatic activity of the soil. Journal of Geochemical Exploration 129: 76–81.

Sun Q., Ding W., Yang Y., Sun J., Ding Q. (2016). Humic acids derived from leonardite-affected growth and nutrient uptake of corn seedlings. Communications in Soil Science and Plant Analysis 47(10): 1275-1282.

Tahiri A., Destain J., Thonart P., Druart P. (2015). In vitromodel to study the biological properties of humic fractions from landfill leachate and leonardite during root elongation of *Alnus glutinosa* L. Gaertn and Betula Pendula Roth. Plant Cell, Tissue and Organ Culture (PCTOC) 122(3): 739–749.

Tamer N., Başalma D., Türkmen C., Namlı A. (2016). Organik toprak düzenleyicilerin toprak parametreleri ve ayçiçeği (*Helianthus annuus* L.) bitkisinin verim ve verim öğeleri üzerine etkileri. Toprak Bilimi ve Bitki Besleme Dergisi 4(1): 11-20 (in Turkish).

Tan K.H., Nopamornbodi V. (1979). Effect of different levels of humic acids on nutrient content and growth of corn (*Zea mays* L.). Plant and Soil 51(2): 283–287.

Topcuoglu B., Onal M.K. (2006). The effects of leonardite application on yield, quality and mineral contents of tomato plant in greenhouse conditions. III. Organic Farming Symposium, Yalova, s. 55.

Turgay O.C., Erdogan E.E., Karaca A. (2010). Effect of humic deposit (leonardite) on degradation of semi-volatile and heavy hydrocarbons and soil quality in crude-oil-contaminated soil. Environmental Monitoring and Assessment 170(1): 45-58.

Uçar Ö., Soysal S., Erman M. (2020). Farklı leonardit dozlarının nohut (*Cicer arietinum* L.)'un verim ve bazı verim özelliklerine etkileri. Avrupa Bilim ve Teknoloji Dergisi 20: 917-921 (in Turkish).

Unlu H., Ozdamar-Unlu H., Karakurt Y. (2010). Influence of humic acid on the antioxidant compounds in pepper fruit. Journal of Food, Agriculture and Environment 8(3/4): 434-438.

Wallaca A., Wallaca G.A. (1986). Additive and synergistic effects on plant growth frompolymers and organic matter applied to soil simultaneously. Soil Science 141(5): 334-342.

Yıldız K.Y., Demirer T., Gürbüz Kılıç Ö. (2019). Farklı dozda uygulanan leonardit ile vermikompostun ıspanakta verim ve bazı kalite kriterlerine etkisi. Turan-Sam Dergisi 11(43): 468-481 (in Turkish).

Yılmaz F., Harmankaya M., Gezgin S. (2012). The effects of different iron compounds and TKI-Humas treatments on iron uptake and growth of spinach. Sakarya Universitesi Fen Edebiyat Dergisi (Sakarya University Journal of Arts and Science) 14(1): 217–31.

CHAPTER 5

TILLAGE, NO-TILL AND COVER CROPS SYSTEMS

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INTRODUCTION

By 2050, the world population will be 9.5-10.0 billion is expected. In order to meet the food needs of this growing population, it becomes mandatory to increase plant production by 60 -70% come. As in the whole world, it will be opened to agriculture in our country. Contrary to the fact that the areas are almost non-existent, Agricultural production is the areas where it is made are decreasing day by day. That's why intensive agricultural activities to increase production in existing areas is done. Agricultural application systems in our country are monoculture. agriculture, excessive and unnecessary irrigation, tillage and stubble burning, based on fertilization and chemical use. intensive agricultural as a result of these activities, soil quality deteriorates, excess chemical inputs The soil and environment are polluted, biodiversity decreases. the use of energy inputs increases, the quality of food produced decreases; and since agricultural activities are not economical, remains far from sustainable. To reduce the negative effects of these intensive agricultural activities in our country and new agricultural management that maximizes ecosystem activities. Systems are inevitable. In recent years all which attracts attention in the world and has not yet been studied in this regard in our country? Reduced, which increases the functionality of ecosystems that have just begun different crop rotation in tillage or direct sowing management. Developed with the use of cover crops in the 21st century will be an important agro-ecosystem services. This system also known as 3C (Crop rotation, Cover crop and Conservation tillage). So-called crop rotation, cover crops and protective tillage is based on In addition, it is stated that the gases that are the source of 14% of the greenhouse gases and are released into the atmosphere due to improper agricultural soil management. is reported (Yücel et al., 2021) On the other hand, the increasing amount of CO2 in the atmosphere as well as technological and cultural measures in reducing the level of management of agricultural models should also be considered. In recent years agriculture and soil changes, the effects of which are clearly seen, Extensive research has been done on its effects. Promise With the application of the 3C systems in question, the excess in the soil and the plant Increasing soil quality by accumulating carbon (C) and nitrogen (N) (Yücel et al., 2021). In addition, it contributes to climate changes by reducing the intensity of greenhouse gases will also make a positive contribution.

Current status of Turkish agriculture

Current agricultural production systems in Turkey rely heavily on traditional irrigation, excessive use of tillage and reactive chemicals, and a very limited crop rotation, which are responsible for degrading agro ecosystem services in Turkey.

Agriculture is one of the important strip that plays a part in the Turkish economy. However, current agricultural practice systems are immoderate and unnecessary; monoculture agriculture, irrigation, tillage and stubble burning (Yücel et al., 2021).

Agricultural management practices that produce economic crop yields while improving soil quality are the keys of sustainable production systems. The goal of us to study the continuous no-till (NT) with and without multi-functional cover crops in agronomic crop rotation and determine management systems impact on agro ecosystem services. Specific objectives are to determine the effects of NT and cover crops on (1) soil biological properties and processes associated with cover crops residue decomposition and nutrient recycling, (2) distribution and partitioning of C and N in chemical and physical pools, (3) soil aggregate dynamics and compaction properties,(4) soil quality and its relationship with soil C sequestration. No long-term information regarding continuous NT and cover crop effects on soil quality and C sequestration is available in Turkey.

Monoculture agriculture: The current agricultural production in Turkey is basically monoculture agriculture (planting the same products in succession in the same area) system is based. Monoculture agriculture practiced for many years system, especially the existing nitrogen and phosphorus balance in the soil. Effects. In addition, the continuation of the monoculture farming system as a result, soils are contaminated by pathogens, disease agents, and cause an increase in the weed problem. As a result biological nitrogen (N) and phosphorus commonly seen with a significant loss of diversity With (P) deficiency, post-harvest plant residues remain undecomposed (Yücel et al., 2021).

Irrigation: 7000 m3 per unit area/ha of water use, our country's total water Irrigated agriculture, which accounts for 75% of the world's average is on it. In plant cultivation, usually keel (wild) irrigation is used. Unsustainable agricultural production in crop production agricultural activities with immoderate use of water together, the drying up of lakes and rivers.it causes severe droughts and yield losses. The ground water level in Turkey has decreased in recent years. Its second level soil exacerbated by wind erosion as a result of soil quality and agricultural ecosystems with salinity increases in relation to the decrease (Yücel et al., 2021).

Tillage and stubble burning: Tillage, especially in sloping areas, by plow parallel to the slope. greater evaporation at the soil surface with deep and excessive tillage and increased wind erosion, decreased biodiversity and leads to loss of soil organic matter (TOM) content. Similarly, burning plant residues only reduces CO2 emissions. Evaporation, salinity and soil erosion In addition to increasing the soil quality, TOM content and It also increases the loss of biodiversity.

Stubble burning: agricultural activities of farmers/producers in their fields These plant residues are mostly burned in order to keep them alive. End In recent years, especially, the use of plant residues as biomass energy, the burning of straw by legal means has been prohibited. There has been a significant decrease in combustion in recent years. Routine burning of plant residues eliminates soil diseases and pathogens. The spread and especially the important elements in the soil are N and P. Such causes severe nutrient deficiencies. Farmers are required to ensure the continuity of crop production. and in this case increases applications of chemicals and fertilizers. All of these as a result, soil surface and groundwater resources contain these nutrients and contaminated with chemicals.

Century agriculture and proposed 3C Agricultural Ecosystem Systems 3C, reduced tillage and An important agro-ecosystem services of the 21st century, developed by the combined use of cover crops in different rotation systems is happening (Figure-1). This system is also called 3C (Crop rotation, Cover crop and Conservation tillage). The system is also referred to as 3C It is also schematically stated below (Islam, 2009). many of the world's heavily practiced in his country; conservation tillage management, different crop rotation systems are applied. In this production system, agricultural production by cultivating different plant species together in idle periods when soil surface, 2-3 weeks before main crop planting.by stopping the vital activities of plants (by killing plants, by drying) as a system based on main crop cultivation is named. this system, reduced tillage, crop rotation agricultural systems and, the co-integration of cover crops. Functionality of ecosystems, soil and water management systems, and positive contributions to reducing the effects of climate change provides. The importance of cover crops, and their contribution to ecosystem services Excessive and useless irrigation in naturally arid conditions, dense soil processing, burning of crop residues, monoculture farming system dominance (density), excessive fertilization and use of reactive chemicals. As a result, the functionality of ecosystem services decreases. Conservative tillage, holistic integration of cover crops based on recommended agricultural practices; (1) To provide food, feed, and energy production, (2) Nutrient elements, water availability and quality of the soil increase. Improved ecosystem services, Turkey's arid and secondary saline its impact on agro-ecosystems in Plant-soil-water ecosystems degraded by the reduction of ET will renew. It is natural to develop these agro-ecosystem services. Will renew the infrastructure. Reduced tillage practices, high traditional tillage with inputs (energy, chemical, time) has many advantages compared to its Which reduces the deterioration of the soil structure; reduces the energy requirement, and it is based on practices that control erosion (Islam, 2009).

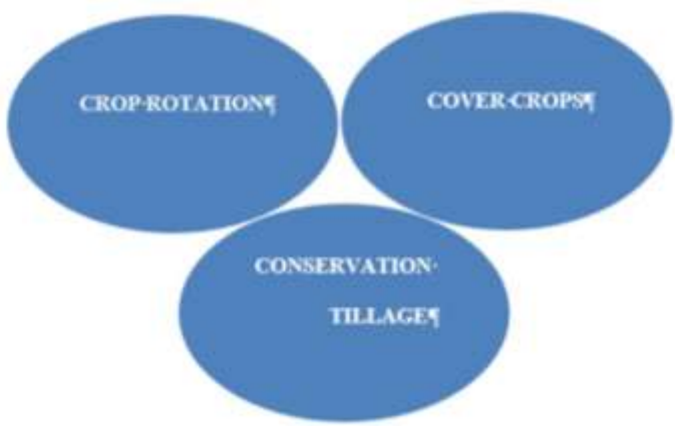


Figure-1. 3C Agricultural Ecosystem Systems

Goal and specific objective

The goal of my proposal is to study the long-term effects of continuous NT with multi-functional cover crops in wheat-corn-soybean rotation for enhanced agro ecosystem services including cover crops biomass nutrient contribution, soil bio-diversity, soil C sequestration, compaction alleviation, and soil health and farm productivity. Specific objectives of the proposal are to evaluate long-term no-till and cover crops effects on:

- Soil biological properties and processes associated with cover crops residue decomposition and nutrient recycling.
- Distribution of C and N in chemical and physical pools.
- Soil aggregate dynamics and compaction properties.
- Soil quality and its relationship with soil C sequestration, and

COVER CROPS

Cover crops have been used to improve soil and the yield of subsequent crops since antiquity. Chinese manuscripts indicate that the use of green manures is probably more than 3,000 years old. Green manures were also commonly used in ancient Greece and Rome. Today, there is a renewed interest in cover crops, and they are becoming important parts of many farmers ' cropping systems.

Three different terms are used to describe crops grown specifically to help maintain soil fertility and productivity instead of for harvesting: green manures, cover crops, and catch crops. The terms are sometimes used interchangeably and are best thought of from the grower's perspective. A green manure crop is usually grown to help maintain soil organic matter and increase nitrogen availability. A cover crop is grown mainly to prevent soil erosion by covering the ground with living vegetation and living roots that hold on to the soil. This of course, is related to managing soil organic matter because the topsoil lost during erosion contains the most organic matter of any soil layer. A catch crop is grown to retrieve available nutrients still in the soil f lowing an economic crop and prevents nutrient leach over the winter .Sometimes which term to use is confusing. We usually have more than one goal when we plant these crop during or after our main crop , and plants grown for one of these purposes may also accomplish the other two goals. The question of which term to use is not really important , so in our discussion below, the term cover crop will be used.

Cover crops are usually killed on the surface or incorporated into the soil before they mature (This is the origin of the term green manure). Since annual cover crop residues are usually low in lignin content and high in nitrogen, they decompose rapidly in the soil (Magdoff and Es, 2009).

A cover crop is any plant that has been seeded in addition to a cash crop in order to gain environmental and economic benefits.

One of the main goals of cover crops in Iowa is to protect the soil when corn and soybeans are not actively growing on the landscape.

We use cover crops in a typical corn–soybean rotation, there are only living roots in the ground four to five months out of the year.

Fall and spring rains often arrive in Iowa when there are no living roots on agricultural fields, leading to nitrate-nitrogen being washed away. Cover crops provide living roots during this time of year. These roots absorb nitrate-nitrogen and prevent it from being lost. (Anonymous, 2022).

Benefits of Cover Crops

- Decrease soil erosion
- Increase soil microbial activity (soil health)
- Decrease nutrient runoff and leaching
- Increase soil carbon
- Suppress weeds
- Improve soil structure (increased infiltration, decreased compaction, increased water holding capacity)
- Manage soil moisture
- Provide habitat for beneficial insects, pollinators, and wildlife
- Provide forage for farm animals
- Break disease cycles

Cover crops provide multiple potential benefits to soil health and the following crops, while also helping maintain cleaner surface and groundwater (Figure 2). They prevent erosion, improve soil physical and biological properties, supply nutrients to the following crop, sup press weeds, improve soil water availability, and break pest cycles. Some cover crops are able to break into compacted soil layers, making it easier for the following crop's roots to more fully develop. The actual benefits from a cover crop depend on the species and productivity of the crop you grow and how long it's left to grow before the soil is prepared for the next crop (Vinayak and Islam, 2017).

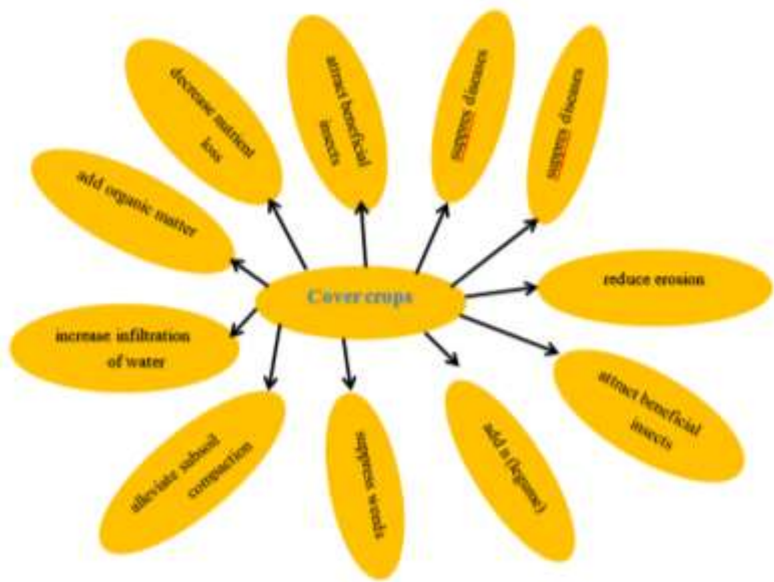


Figure-2. Cover crops have multiple benefits (Anonymous, 2009).

Organic Matter

Grass cover crops are more likely than legumes to increase soil organic matter. The more residue you return to the soil, the better the effect on soil organic matter. The amount of residue produced by the cover crop may be very small, as little as half a ton of dry matter per acre. This adds some active organic matter, but because most of it decomposes rapidly after the crop is killed, there is no measurable effect on the total amount of organic matter present. On the other hand, good production of hairy vetch or crimson clover cover crops may yield from 1 1/2 to more than 4 tons of dry weight per acre. If a crop like winter rye is grown to maturity, it can produce 3 to 5 tons of residue.

A five - year experiment with clover in California showed that cover crops increased organic matter in the top 2 inches from 1.3 % to 2.6 % and in the 2 - to 6 - inch layer from 1 % to 1.2 %. Some researchers have found that cover crops do not seem to increase soil organic matter, Low - growing cover crops that don't produce much organic matter may not be able to counter the depleting effects of some management practices, such as intensive tillage. Even if they don't significantly increase organic matter levels, cover crops help prevent erosion and add at least some residues that are readily used by soil organisms.

Cover crops help maintain high populations of mycorrhizal fungi spores during the fallow period between main crops. The fungus also associates with almost all cover crops, which helps maintain or improve inoculation of the next crop. (As discussed in chapter 4, mycorrhizal fungi help promote the health of many crop plants in a variety of ways and also improve soil aggregation.) Cover crop pollen and nectar can be important food sources for predatory mites and parasitic wasps, both important for biological control of insect pests. A cover crop also provides a good habitat for spiders, and these general insect feeders help decrease pest populations. Use of cover crops in the Southeast has reduced the incidence of thrips, bollworm, budworm, aphids, fall armyworm, beet armyworm, and white flies. Living cover crop plants and their residues also increase water infiltration into soil, thus compensating for the water that cover crops use.

Selection of Cover Crops

Before growing cover crops, you need to ask yourself some questions:

- What type of crop should I plant ?
- When and how should I plant the crop ?
- When should the crop be killed or incorporated into the soil ?

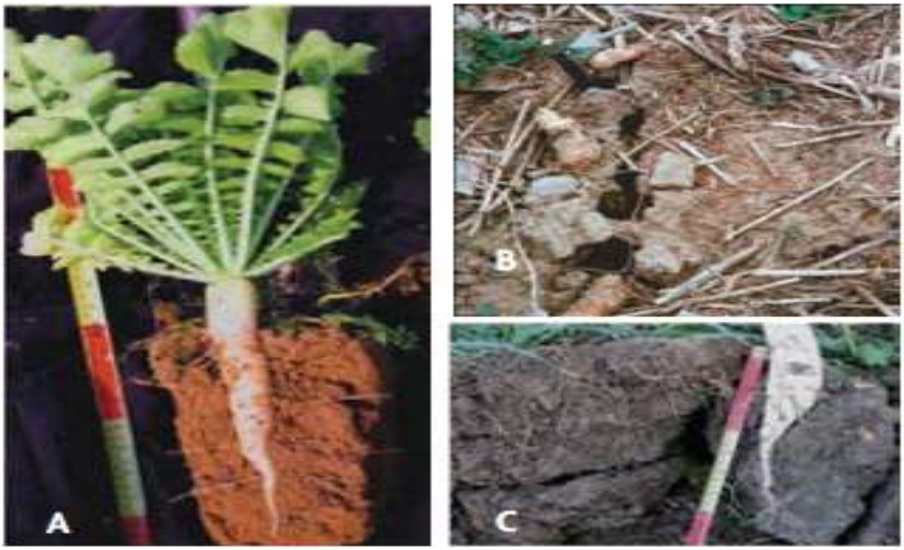
When you select a cover crop, you should consider the soil conditions, climate, and what you want to accomplish by answering these questions:

- Is the main purpose to add available nitrogen to the soil, or to scavenge nutrients and prevent loss from the system? (Legumes add N; other cover crops take up available soil N.)
- Do you want your cover crop to provide large amounts of organic residue?
- Do you plan to use the cover crop as a surface mulch, or incorporate it into the soil?
- Is erosion control in the late fall and early spring your primary objective?
- Is the soil very acidic and infertile, with low avail ability of nutrients?
- Does the soil have a compaction problem? (Some species, such as Sudan grass, sweet clover, and forage radish, are especially good for alleviating compaction.)

- Is weed suppression your main goal? (Some species establish rapidly and vigorously, while some also chemically inhibit weed seed germination.)
- Which species are best for your climate? (Some species are more winter - hardy than others.)
- Will the climate and water - holding properties of your soil cause a cover crop to use so much water that it harms the following crop?
- Are root diseases or plant - parasitic nematodes problems that you need to address? (Winter [cereal] rye, for example, has been found to suppress a number of nematodes in various cropping systems.) In most cases, there are multiple objectives and multiple choices for cover crops.

Cover Crop Management

There are numerous management issues to consider when using cover crops. Once you decide what your major goals are for using cover crops, select one or more to try out. Consider using combinations of species. You also need to decide where cover crops best fit in your system - planted following the main crop, intercropped during part or all of the growing of the main crop, or grown for an entire growing season in order to build up the soil. The goal, while not always possible to attain, should be to have something growing in your fields (even if dormant during the winter) all the time. Other management issues include when and how to kill or sup-press the cover crop, and how to reduce the possibility of interference with your main crops either by using too much water in dry climates or by becoming a weed in subsequent crops (Magdoff and Es, 2009).



a) Root of forage radish .

b) Root holes (bio - drilling) and root remains in spring following fall forage radish . Black pen (see arrow) in hole for scale .

c) Horizontal cracks with rye (left) and vertical cracks with forage radish (right) .

Figure 3. Brassica cover crop roots. Photos by Ray Weil (Magdoff and Es, 2009).

Why Should I Use Cover Crops on My Farm Or Ranch?

Integrating cover crops can have significant ecological impacts on the farming system. Cover crops can improve soil physical, chemical, and biological properties; supply nitrogen; reduce leaching of nutrients and pesticides; reduce erosion; mitigate damage from plant pests and/or reduce their population densities; as well attract beneficial insects. Cover crops can also generate additional income when grown for seed or feed, or as an energy crop. While it is difficult to achieve all of the listed benefits with one crop, producers should select cover crops that offer multiple benefits at once. Producers should also consider potential drawbacks before deciding to include a cover crop. In some instances, the cover crop can require additional labor and expense, delay crop planting, or serve as an alternate host for crop insects or diseases. (Treadwell et al., 2008).

How are Cover Crops Used in Farming Systems?

Cover crops are integrated into organic farming systems in many ways. They are used in rotation in vegetable and dairy pasture systems, as living mulches, as green manures, and as a mulch on the soil surface. Cover crops provide many benefits, but there is no single cover crop that will fulfill all your requirements in every situation. Read the steps below for an overview on how to select a cover crop for your operation. Then, visit the specific cover crop profiles for recommended cultural practices for examples of how cover crops are used in farming systems. (Sarrantonio., 1994).

TILLAGE SYSTEMS

The purpose of tillage is to preserve soil fertility, reduce erosion, prevent soil compaction, and preserve the diversity of flora and fauna in the soil (Önal, 1995; Aykas and Önal, 1999). The specific characteristics of agricultural areas and their products have led to the emergence of different agricultural systems. These systems are gathered in two main groups

1. Conventional tillage
2. Conservation tillage

Compared to traditional tillage, protective tillage is a tillage technique that prevents soil loss by wind and water erosion and aims to preserve soil moisture. While plant residues can be used for erosion control in protective tillage, it is one of the methods used for soil conservation in coarse-grained tillage. For this reason, protective soil also includes reduced tillage and no-till agriculture. However, reduced tillage should not be confused with direct sowing (no-till farming). In no-till agriculture, it is undoubtedly for soil protection. Conservative tillage, as explained in the tillage triangle, includes both no-till farming and reduced tillage. If reduced tillage; If the plant residues are applied to the soil surface without being burned, the room can be considered within the scope of protective tillage. Figure-4 shows the use of tools in traditional tillage and reduced tillage and direct sowing methods (Zeren, 1990).

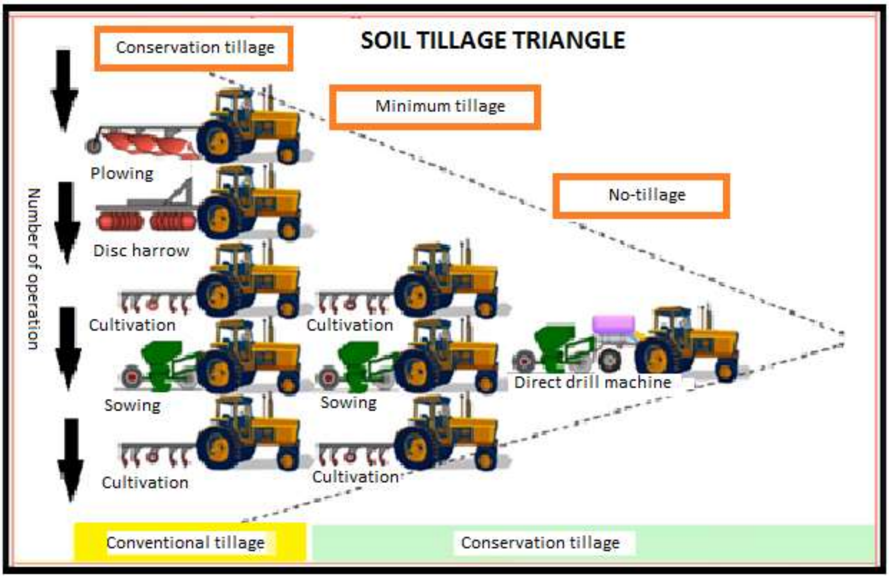


Figure 4. Soil tillage triangle systems (Zeren, 1990)

Conventional Tillage

Tillage operations traditionally performed in preparing a seedbed for a given crop and grown in a given geographical area (Anonymous, 2005).

In traditional tillage, the deep tillage of the soil and the upper surface of the soil are raised at the tillage depth. The traditional method is based on the principle of overturning the soil with a plow. Traditional tillage brings with it intensive and excessive tillage, especially in our country, and encourages soil compaction and erosion. Traditional tillage can be defined as the preparation of the field for planting by using first and second class tillage tools. A typical traditional tillage agriculture includes all of the following processes (Zeren, 1990):

- Machining with ear plow,

- Disc harrow pulling (1 or 2 times)
- Processing with a harrow or cultivator (1 or 2 times),
- Sowing and fertilizing,
- Hoeing with a cultivator or rotary hoe (1 or 2 times) and
- Includes herbicide applications.

Conservation Tillage

In the traditional method used in sunflower planting after wheat harvest in Thrace Region, plow, cultivator in spring, rake and pneumatic planting machine can be given as an example.

In the conservation tillage system, plows and similar tools that work the soil by overturning are not used. In places where soil compaction is a problem, chisel, etc., which processes the soil by tearing the soil at a certain depth. tools are used. In this system, pre-plants or crop residues are left on the surface of the field. The positive effects of direct agriculture on protective tillage and erosion control have been demonstrated. In general, the aim is to cover the field surface with at least 30% plant residue in a protective tillage system (Köller, 2003).

Conservation tillage; It is a system for weed control and seed bed preparation, which significantly reduces the number of passes in the field compared to conventional tillage. In principle, the system includes the application of tillage without overturning the soil. Seedbed preparation and planting operations in conservatory tillage can be carried out separately or in combination with conventional tillage in conservatory cultivation. The aim is to realize the two basic ideas of the protective tillage system.

- Placing the pre-plant or second crop residues on the field surface or in layers close to the surface,
- Reduction of tillage intensity (Önal, 1995; Aykas et al., 2013).

Conservation tillage provides significant savings in terms of labor, energy consumption and timeliness. This method has many advantages over conventional tillage. The total power requirements, fuel consumption, working hours and investment costs of the machinery and equipment used in the protective soil tillage system are significantly reduced.

- Aggregate stability and organic matter content are higher in soils where this system is applied. Therefore, the risk of erosion is less. In the researches, although the N2O (Nitrogen Oxide) emission rate did not show a significant difference between different tillage systems, nitrogen and herbicide leaching was found to be less in the protective tillage system. The soil structure is more homogeneous in the protective tillage system, especially in direct sowing. In the protective tillage system, the soil is processed in different ways. Some of the important soil cultivation methods are as follows;
    - Minimum tillage
    - Strip tillage
    - Plant-tillage

- Mulch tillage
- No-tillage or zero tillage

Minimum Tillage

This tillage method is also known as reduced tillage or minimum tillage or limited tillage. Reduced tillage is a method in which some processes are not applied compared to conventional tillage methods. If the cultivation is done so that the stubble remains on the soil surface, it can also be assumed as one of the forms of soil conservation tillage.

Reduced tillage is available in the subcategory of conservation tillage. In this system, chisel or disc tools are used in primary tillage, disc tools or cultivators are used in secondary tillage and seed bed preparation. Compared with traditional tillage, it can save a lot of energy. Normally, ploughing is included in the concept of reduced and plowless tillage. It includes reducing the use of tools in the preparation of the seed bed by using other tillage tools other than the plow. Some of the following reduced tillage programs may be appropriate in first crop barley, wheat or second crop farming:

- Disc harrow or field cultivator + sowing
- Rota tiller + sowing
- rotary hoe + sowing
- Heavy plot or field cultivator + sowing
- Disc harrow + sowing

Except for the rotary tiller + sowing and rotary hoe + sowing programs from the programs listed above, the other three programs still have the opportunity to be implemented in the second crop soybean and corn production in Çukurova. After the plow, the plow is not used in the planting of winter wheat and barley, and a reduced tillage production program consisting of cultivator and disc harrow + sowing is applied. In these production programs, the plow is almost completely out of operation.

After the sunflower harvest in the Thrace region, it is a suitable method as a reduced tillage method in sowing after the use of a cultivator and harrow after the stalks are shredded with a trailed stalk shredder or a disc harrow. The appearance of the tools in the reduced tillage system applied after the sunflower harvest in the Thrace Region is given below.

Strip Tillage

1/3 of the field surface can be processed before planting and preparing for planting. It is a protective soil farming practice. In this application, tillage is usually done with planting. In addition to the area where the row will be planted, a 5 to 30 cm wide tillage area is used, the rest is left covered with stubble (Godwin, 1990). In addition to this application, soil disc agricultural implements and equipment are also used for ridge processing on strips that only make ridges.

Plant-Tillage

These machines, which are called soil mills, rototillers or PTO driven harrows, are soil cultivation machines that work by taking their movement from the PTO with PTO harrows and vibrating bottom boilers. With this application, the soil is broken up, crumbled, overturned and cultivated. Soil cultivation can be carried out in the whole field or similar to strip cultivation.

Mulch Tillage

The main principle of mulch tillage is to keep the soil surface covered with plant residues or plants, to prevent the formation of a cream layer, to minimize sprout problems and erosion. In this way, tools such as chisel, cultivator, disc harrow are used. In addition to the success of the seed sowing in the mulched seed bed, the performance of the seed drill, as well as the physical and chemical effects that occur around the seed bed after sowing, vary. After sowing and direct sowing, the area where the seed will be planted must be separated from the chaff. It is therefore essential to use a suitable seeder equipped with special scratch openers for wavy surfaces.

No Tillage (Zero tillage and Direct Drill)

If the narrow end bars of the sowing machine are used in direct sowing machines, these machines are called No-till. If the scratch opener of the direct seed drill is disc opener, it is defined as zero till (Ashworth et al., 2010).

In direct sowing, after the main crop harvest, no tillage tools are used before sowing. In direct sowing machines, seeds are left on the scratches opened by the spring-loaded burying feet that can work on the stubble, they are covered with plant remains and soil and pressed with special pressing equipment.

The success of the direct sowing method depends on the climatic and soil conditions, the working capacity of the seeder and weed control. Weed control is generally done by applying chemical method. If there is a large amount of weed problems in the direct sown fields, the soil cultivation before planting can be reduced every 4-5 years. However, when researchers used direct farming methods for many years, it was determined that the weed population decreased (Aykas, 2010).

It has been determined that secondary tillage tools can be used by applying the second fertilizer during the development period of the hoe plants planted by applying the direct sowing method, activating the furrows for irrigation and filling the throat. Thus, we can say that weed control is prevented to some extent.

Direct tillage can improve soil structure and maintain soil moisture, for example in tillage or zero tillage. In direct sown areas, autumn soil cultivation may be permitted to a certain extent. After decomposition of the stubble residue in the field, the soil can be cultivated in autumn with tools that do not crush the soil. In this case, at least 50% of the stubble should remain on the soil surface. In terms of soil protection, plant residues on the surface of the soil are very important. The relationship between plant residues and soil loss left on the field surface is given in Table 1 (Korucu et al., 1998).

Table-1. The relationship between plant residue and soil loss on the field surface.

Plant Residue (Ton/ha)	**Runoff (%)**	**Infiltration (%)**	**Soil Loss (Ton/ha)**
0.00	45.00	54	13.00
0,63	40,00	60	7,50
1,25	25,00	74	2,50
2,50	0,50	99	0,75
5,00	0,10	99	0,00
10,00	0,00	100	0,00

As a result of the researches and trials, it has been observed that even the presence of a very small amount of plant residues on the surface prevents erosion to a large extent. It was determined that approximately 500 kg/ha of vegetation on the surface decreased the surface flow to 0.1% and increased the water intake capacity to 99%. The kinetic energy calculated for this area is 275,600 kpm with a rainfall of 25.4 mm in an area of approximately 4 decrees (1 Acre). In the fields where there is no plant residue on the surface, this energy causes the soil particles to break and fragment, thus becoming vulnerable to water and wind erosion, that is, to become free. Plant residues on the surface trap this energy and ensure that the soil is not damaged (Önal, 1995).

It was observed that the amount of organic matter increased in the upper parts of the soil in protective tillage and direct sowing. It has been determined that the increase in the amount of organic matter increases the stability and strength of the soil aggregate and reduces the risk of erosion. It has been observed that the amount of soluble phosphorus in the soil along with the organic matter also increased thanks to direct cultivation. With the direct sowing method, it is desirable that the seed placement devices are not more than 25-35% of the total planted area. It is tried to reduce this rate below 25% (Aykas et al., 2013).

Thus;

- Moisture loss in the soil is minimized,
- Less germination of weed seeds in this region is ensured,
- Less fuel consumption occurs,
- Water and wind erosion is minimized.

It is to create and maintain the optimum microenvironment for the germination of the seed and the development of the germinating sprout. These two basic issues are not neglected in no-till agriculture, but a different solution is applied. In this system;

- Herbicide use replaces tools in mechanical weed control,
- The germination of the seed and the development of the sprout are provided by organic residues that continuously mix with the soil, enrich it with humus, improve its structure, increase its water and nutrient holding capacity, act as mulch, and prevent wind and water erosion. In addition, since the vehicle traffic on the field is minimized in no-till agriculture, soil compaction is reduced.

REFERENCES

Anonymous 2022. Conservation media library website slide player.com/slide/153827061.

Anonymous, 2005. ASABE Standards. Terminology and Definitions for Soil Tillage and Soil-Tool Relationships. ASAE EP291.3 FEB2005 (R2018).

Anonymous, 2009. Building soil for better crops. Sustainable soil management, 3rd Ed. (Fred Magdoff and Harold Van Es), Handbook Series Book 10. Published in 2009 by the Sustainable Agriculture Research and Education (SARE) program wıth funding form the National Institute of Food and Agriculture, U.S. Department of Agriculture.

Ashworth, M., Desbiolles, J. ve Tola, E. (2010). Disc seeding in zero-till farming systems, a review of technology and paddock issues (1.Baskı) içinde (1-2). Western : Western Australian No-tillage Farmers' Association (WANTFA), Western, Australia.

Aykas, E. Çakır, E. Yalçın, H. Okur, B. Nemli, Y. ve Çelik, A. (2010). Koruyucu toprak işleme doğrudan ekim ve Türkiye'deki uygulamaları. Ziraat Mühendisliği VII Teknik Kongresi, Bildiriler Kitabı-I, ISBN: 978-9944-89-869-0, S:269-292, (Turkish).

Aykas, E. Yalçın, H. ve Yazgı, A. (2013). Balta tipi gömücü ayağa sahip tek dane ekim makinalarının farklı bölgelerde mısır ekiminde ekim performanslarının karşılaştırılması. Tarım Makinaları Bilimi Dergisi, 9 (1), 67-72, (Turkish).

Aykas, E., İ. Önal. 1999. *Effects of different tillage seeding and weed control methods on plant growth and wheat yield.* 7. International

Congress on Mechanization and Energy in Agriculture, Proceedings, pages: 119-124, Adana- TURKEY, (Turkish)

C., Yücel, G., Kamçi, D., Yücel, Y. Bayhan, 2021. Cover Plants in Direct Sowing System Using(Turkish). Doğal Kaynaklarimizin Geleceği:Sürdürülebilirlik Ve İnovasyon. Editör: EM.Oant. Iksadyayinevi, Ankara-Turkey, SBN: 978-625-7636-68-1, Page:36-50 (Turkish).

Godwin, R. J. (1990). Agricultural engineering in development: tillage for crop production in areas of low rainfall. FAO, Rome. P. 124, (Turkish).

Islam, K.R. 2009. Plant roots: The biological plow. Professional presentation at annual meetings of the Conservation Tillage and technology Conference (CTTC), Ada, Ohio. Kaspar, T.C., and Singer, J.W., 2011. The use of cover crops to manage soil. In:

Köller, K. 2003. Conservation tillage-technical, ecological and economic aspects. Koruyucu Toprak İşleme ve Doğrudan Ekim Çalıştayı Bildiriler Kitabı, ISBN 975-483-601-9. İzmir, (Turkish).

Korucu, T., V.Kirişçi, S. Görücü. 1998. Korumalı toprak işleme ve Türkiye'deki uygulamaları. Tarımsal Mekanizasyon 18. Ulusal Kongresi Bildiriler CD'si, s.321-333, Tekirdağ, (Turkish).

Magdoff, F. and Es, H,V. 2009. Building soil for better crops sustainable soil management, P:101-112.

Önal, İ. 1995. Ekim Bakım ve Gübreleme Makinaları. Ege Üniversitesi Ziraat Fakültesi Yayınları, No: 490, s.52-65, İzmir, (Turkish).

Sarrantonio, M., 1994. Northeast Cover Crop Handbook. ISBN 10: 0913107174 / ISBN 13: 9780913107171, Published by Rodale Institute, US.

Treadwell, D., W. Klassen, and M. Alligood. 2008. Annual cover crops in Florida vegetable systems Part I. Objectives: Why grow cover crops? HS387. Institute of Food and Agricultural Sciences, University of Florida, Gainesville.M. AbolanleBusari,

Vinayak, S., Islam, R., 2017. Healthy soil, healthy environment building Ohio`s soil health. Ohio Farm Science Review, September 19-21, 2017. The Ohio State University. College of Food, Agricultural, and Environmental Sciences.

Zeren, Y. (1990). İkinci ürün mekanizasyonu yüksek lisans ders notları. Çukurova Üniversitesi, Fen Bilimleri Enstitüsü, Tarım Makinaları Anabilim Dalı, (Basılmamış Ders Notları), Adana (Turkish).

CHAPTER 6

FARM LEVEL RECOMMENDATIONS FOR TURKEY ON HARMONIZING CROSS COMPLIANCE RULES

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INTRODUCTION

Compared to other sectors, the agricultural sector is used more in meeting the increasing food, feed and energy needs of the growing global human population, which adversely affects natural resources. In the field of the CAP, in order to benefit from agricultural subsidies, Cross-Compliance is a system includes the rules that the member states of the EU have to comply, while the candidate countries should adapt. The system established to manage the agricultural supports is called the Integrated Administration and Control System (IACS). In this process, in EU member states of farmers who apply directly to supports and want to benefit from supports are required to comply with the basic rules regarding the environment, food safety, plant and animal health, animal welfare, and maintaining good production conditions on the land. This is expressed as cross compliance. In case of non-compliance with the rules, payments may be suspended and reductions may be applied.

The CAP was created in order to ensure the EU's food security, sustainable use of natural resources and the balanced development of rural areas in Europe. The first step for the CAP was laid with the establishment the European Economic Community by six European countries in the 1957 Treaty of Rome. CAP as a policy had been aimed to provide EU citizens with food at a reasonable price and to bring fair living conditions to farmers, and later included a series of reforms and changes. With the CAP 2003 reform, the Cross Compliance in the EU has become a necessity for farmers. The regulation no 1782/2003/EC was replaced by the regulation 73/2009/EC and the cross-compliance rules were put into practice with this regulation. EU Council regulation 1306/2013 of the European Parliament constitutes the legal basis for cross-compliance.

Direct payments to farmers and support for sustainable farming practices (column 1) are provided they meet the criteria for food safety, environmental protection, animal health and welfare. In the EU, these payments constitute 70% of the CAP budget. Direct support payment is the most important part of CAP payments. Rural Development measures (Column 2) are the measures taken to protect the environment, diversify agricultural and non-agricultural activities, ensure the continuity of rural life, and make farms more competitive by modernizing them. These measures constitute 20% of the CAP budget. Market Measures, on the other hand, are the 3rd budget usage class of the CAP and are the measures that come into play in case of market instability. It accounts for less than 10% of the CAP budget.

Many stakeholders are involved in the operation of the cross-compliance system and their coordination is of great importance. Stakeholders consist of a combination of organizational structures that include public institutions, relevant non-governmental organizations (NGOs), organizations and the public (farmer) (Rooij et all., 2014). Within the scope of preparing the governance framework in the cross-compliance system, who the stakeholders are, who will be served, and the control system should be developed. Although the definition of the governance framework is very complex, the process by which societies and organizations make important decisions, determine who will be involved and accountability is defined as governance (Graham et all., 2003). In the decision-making process for good governance, private sector and non-governmental organizations should be involved, as well as public institutions. There must be a well-coordinated communication between the relevant institutions and organizations and the society (Tortajada, 2010).

Compliance with the Cross Compliance Rules is of great importance to society. With these rules, the control of the maximum allowed limits in fertilization is ensured in order to prevent pollution and measures to prevent erosion, ensuring food safety standards, complying with animal welfare rules, ensuring traceability of animal feeds, protecting biodiversity and combating climate change. Cross-Compliance helps make agriculture in Europe more sustainable by raising awareness of CAP beneficiaries and contributes to making CAP more beneficial for the EU society at large. The Cross Compliance Rules are included in the commitments made within the scope of harmonization with Chapter 11: Agriculture and Rural Development, Chapter 12: Food Safety, Veterinary and Phytosanitary Policy and Chapter 27: Environment of the accession negotiations to the EU.

In our country, some projects related to the development of cross-compliance and good agricultural practices have been carried out and legislative arrangements have been made. Some of the projects carried out by the Ministry of Agriculture and Forestry (MoAF) are as follows; In 2008, the “Improving Cross Compliance in Turkish Agricultural Production Project” supported by the MATRA program was carried out. It is important to determine the Turkish Cross Compliance Criteria in order to ensure that agricultural production activities are carried out in a system that is sensitive to the environment, does not harm human and animal health, and aims to protect natural resources (Dişbudak, K, 2008). Another project is “Improving Cross Compliance in Agricultural Production in Türkiye” carried out between 2008-2010. With this project, it is aimed to determine the Legal Administrative and Good Agricultural and environmental conditions for Türkiye, to increase the knowledge, skills and application capacities of those who will be involved in the creation and implementation maintenance of Cross Compliance Standards. Cross Compliance implementation plans have also been prepared. Then, the “Harmonization of Cross Compliance Rules” was carried out between 2016-2018. It is aimed to contribute to the future implementation of the EU and CAP by developing the Cross Compliance System draft for Türkiye. GAEC and SMR rules in current EU legislation have been examined, draft legislation has been prepared for Türkiye, and capacity building activities have been carried out on Cross Compliance. In order for the cross-compliance rules to be implemented in our country, full institutional and administrative capacity should be established in the regulatory framework and implementation (Yüksel et al., 2011).

For sustainable agriculture, it is necessary to protect the environment, make natural resource management planning, and establish a consistent relationship between agriculture and the environment. This is a necessity in order to transfer natural resources and the environment to future generations in a healthy way. In order for the Cross Compliance rules to function fully in our country during the EU accession process, the existing cross compliance studies and related good agricultural practices have been examined. In the membership process, it is necessary to develop the applications of cross compliance rules, to harmonize the legislation with the EU and to accelerate the implementation process, and suggestions are presented on the subject.

CROSS COMPLIANCE RULES

Components of Cross Compliance

The Statutory Management Requirements (SMRs): They are the criteria that determine the rules regarding food safety, plant health, animal welfare and the environment. The public details requirements such as animal and phytosanitary, food and feed safety, animal welfare, biodiversity conservation, nitrate pollution, fertilizer use and environmental protection. There are 13 different SMRs included in the EU directive and regulations.

Good Agricultural and Environmental conditions (GAECs): It is the criteria to be followed for the management and protection of soil, water and environmental quality. It includes criteria to be followed such as protecting the soil, ensuring the continuity of soil structure and organic matter content, effective management of water resources and preventing habitat degradation in order to keep the agricultural land and its environment in good conditions. GAECs should be shaped and elaborated on the basis of member states' own national legislation.

There are 7 different GAECs included in the EU directive and regulations. Cross-compliance rules are given in table 1 in general terms.

Table 1. Cross-Compliance Rules

Area	Main Issues	Rules and Criteria	Responsible
Environment, climate change, good agricultural condition of land	*Water*	SMR 1 - Protection of water against nitrate pollution in NVZs	Farmers who have farmland in Nitrates Vulnerable Zones NVZs
		GAEC 1 - Buffer strips	Farmers who have farmland adjacent waterways and using chemical/organic fertilizer
		GAEC 2 - Water abstraction licence	All farmers who have withdrawing water from surface water and groundwater
		GAEC3- Protection of groundwater	All farmers storing groundwater pollutants

	Soil	GAEC 4 - Minimum soil cover	All farmers having agricultural area
		GAEC 5 - Prevention of Erosion	All farmers having agricultural area
		GAEC 6 - Maintenance of Soil Organic Matter	All farmers having agricultural area
	Biodiversity	SMR 2 - Protection of Wild Birds	Farmers whose agricultural lands are located in the designated area of special protection
		SMR 3 - Protection of Natural Habitats	Farmers in the area defined as a special protected area under the agricultural land Habitats Directive
	Landscape	GAEC 7 - Maintenance of Landscape Features	All farmers with a landscape element in the agricultural land

Public, animal and plant health	*Food Safety*	SMR4- Gıda ve Yem Güvenilirliği	All farmers producing food or feed from plants and rearing animals for food or producing products of animal origin
		SMR 5 - Use of hormones	All farmers keeping animals
	Animal I&R	SMR 6 - Identification and registration of pigs	All farmers having pigs
		SMR 7 - Identification and registration of bovines	All farmers keeping bovines
		SMR 8 - Identification and registration of ovine	All farmers keeping sheep and goats
	Animal Diseases	SMR 9 - Prevention of TSE	All farmers who keep animals for farming purposes

	Plant Protection Products	SMR 10 - Plant protection products	All farmers using pesticides
Animal welfare	*Animal welfare*	SMR 11 - Welfare of Calves	All farmers keeping calves
		SMR 12 - Welfare of Pigs	All farmers keeping pigs
		SMR 13 - Welfare of Farm Animals	All farmers keeping any species of animals for farming purposes

The Place of Cross-Compliance in Agricultural Support System and Controls

Agricultural support system generally consists of Application, Controls and Payments sections. Farmers who want to receive agricultural support must first apply for support. Applications in EU countries are made using the Geo-Spatial Aid Application system on IACS. The accuracy of the agricultural assets declared in the support application, good agriculture, organic agriculture, greening, rural development measures and cross compliance controls should be checked with a series of works and transactions that must be done between the application and the payment. Cross Compliance Controls are handled in two parts as Administrative Controls and On-The-Spot Controls. Administrative controls are controls without visiting farm and require computerized systems with high data processing capacity and accurate numerical records. On-spot controls are checks made by visiting the farm. For this, trained inspectors to control, manual and digital tools are needed. Administrative controls can also be carried out by using remote sensing methods increasingly nowadays. Administrative checks are done on 100% of all support applications, while Cross Compliance Control are on 1% of all applications. Control samples can be taken randomly as well as risk-based selection. Risk analysis is divided into two groups as historical risks (past risks) and sectoral risks. The random sample should constitute 20-25% of the sample, which is 1% in total. The sample based on the risk analysis should make up the remainder of the total sample (75-80%). The enterprises from which the sample has been taken should be notified in advance that on-site control will be carried out. Reports are prepared indicating whether the On-The Spot Control, Administrative Control and Cross Compliance Rules are complied with.

Main Resources of the Cross Compliance System

The following resources are required for the implementation of the Cross Compliance System;

Staff; Recruiting a sufficient number of personnel, making job descriptions, meeting the necessary tools and equipment, updating personnel training,

Guidelines, Procedures and Rules; Preparing the necessary guides, determining the control procedures and rules and making regular updates,

Testing-measuring equipment; Regular maintenance, repair and calibration of the devices to be used

Computerised systems hardware and software; Computer software and hardware maintenance

Digitised data; Correction, addition and removal of data uploaded to the system

CROSS COMPLIANCE CRITERIA AND LEGAL BASIS IN TÜRKİYE

Political Developments in Türkiye

Political developments supporting compliance with the Cross Compliance Rules in Türkiye can be listed as;

- The Tenth Development Plan (2014-2018)
- The Eleventh development plan (2019-2023)
- The Medium Term Programme (2018-2020)
- The National Strategy for Regional Development (2014-

2023)

- The Pre-accession Economic Reform Programme 2017
- The 2018-2022 Strategic Plan of the MoAF 2018-2022

EU Legal Framework

The cross-compliance system is an integral part of the CAP and the legislation is listed at 3 different levels in the EU legal framework;

- Basic Laws
- By-laws/Regulation Based on Delegation
- Implementing By-laws/Regulations

Basic Laws are prepared at the level of the European Parliament and the Council of Europe and contain all the requirements, while the Implementing By-law and Regulations contain more detailed information, technical specifications and procedures for the enforcement of the law. The European Commission is working on a new CAP that will cover the 2021-2027 period, and the mentioned cross-compliance rules are emphasized. Currently, it is on the agenda to change the name of the Cross Compliance System to the Conditions System. In addition to improving environmental indicators, it is important in terms of rural development, improvement of social status, dissemination of information exchange and thus contributing to decision makers and policy makers.

Cross Compliance Sanction System

In the EU, support reductions resulting from cross-compliance are proportional to the extent of the non-compliance, its permanence, severity, repetition, and whether it is deliberate or not. First of all, it should be determined whether the non-compliance is repeated and whether it is negligent or intentional. In cases of non-compliance caused by negligence, a reduction of 1% to 5% from the total support may be applied. In cases of intentional non-compliance, the reduction rate is between 15% and 100%.

Problems Encountered in the Application of Cross Compliance

Some problems arising from stakeholders may be encountered in the implementation of cross compliance. Farmers can prevent the implementation of cross-compliance by not applying for support and opposing cuts as a result of controls. They can also prevent the ministry from enforcing the law by creating a strong lobbying activity. Cross-compliance work team and field auditors may also have objections to meeting their cross-compliance responsibilities and resistance to pursuing CAP reforms. There may also be requests from senior bureaucrats and politicians to cancel the cross-compliance mechanism or to change some criteria.

SMR/GAEC Rules, Official Basis, Farm Level Recommendations

In this section, SMR and GAEC criteria for cross-compliance are detailed and the rules that farmers must comply with at the farm level were examined. The stated legal bases are the legal regulations that directly or indirectly affect cross-compliance.

SMR1 (Protection of Water Against Nitrate Pollution): SMR1 contains rules for managing the use of animal manure, chemical fertilizers and other nitrogen-containing substances on land. Underground and surface waters are polluted as a result of irregularly managed use of animal and chemical fertilizers and accumulation of nutrients such as nitrogen and phosphorus. In order to prevent this situation, a Nitrate Action Program has been developed in Türkiye. In NVZs which are so-called easily polluted areas standards have been established regarding the careful collection, storage and use of chemical and animal fertilizers. These established standards coincide with SMR1. NVZs are determined by MoAF. The Nitrate Action Program includes rules aimed at making the use of organic and chemical fertilizers effective, preventing erosion, and improving water quality by preventing water pollution. Farmers should pay attention to soil cover, soil type/texture and drainage conditions, slope of the land, distance to water sources, weather conditions, equipment and methods to be used in fertilizer applications while using animal and chemical fertilizers. Especially if agriculture is carried out within the NVZ, it is necessary to comply with the Code of Good Agricultural Practices (Legal Basis; code of GAP Communiqué OJ 11.02.2017 No: 29976). It is necessary to create a fertilizer management plan, which includes information such as the size of the land, its location and characteristics, fertilizer and soil analysis, fertilizer storage, transportation and application conditions, the content of the fertilizer and how to apply it, and the crop rotation. Farmers should store chemical fertilizers indoors, dry and away from foodstuffs, and keep the sales contract. Animal manures should be stored in impermeable warehouses that can be covered in rainy times. The front of the pile can be dammed to drain the leak. It should not be stored in the same place for 12 months. Storage areas should be planned at a distance of 15 m from wells and 50 m from water sources with appropriate capacity.

SMR 2 (Conservation of Wild Birds) : With this SMR aims to protect wild birds, their eggs and nests by preserving and maintaining land classified as a Special Protection Area (SPA). Irregular urbanization and transportation networks, intensive agricultural activities, deforestation, fishing, pesticide use limit the birds' food availability, and irregular hunting activities endanger these bird species. Hunting should not be done during periods when birds are most vulnerable, such as breeding, rearing their young, and migrating. In NATURA 2002, the necessary rules and criteria have been determined in the network formed by the member states for the protection of threatened bird species and habitat. In our country, the competent authority is the Ministry of Environment and Urbanization and MoAF. Farmers should avoid activities that will disturb bird species, should not damage, restrict or destroy these areas, and should avoid works and transactions without the consent of the competent authority.

SMR 3 (Conservation of Natural Habitats and of Wild Flora and Fauna): The purpose of this SMR is to ensure the protection of lands designated as SPA. If the farmer's land falls under a Special Protection Area, he must comply with this SMR. It should not damage, destroy or disrupt the flora in the aforementioned areas. If any work or transaction is to be carried out compulsorily, permission must be obtained from the relevant authority.

SMR 4 (Food and Feed Law): The aim of SMR is to ensure the safe production of food and feed given to animals. All producers raising products to produce animal feed and all beneficiaries raising animals must comply with this SMR. Food and feed law includes laws, regulations and administrative regulations concerning food safety. It covers all stages of the production, processing and distribution of food and feed given to animals with nutritional value. Animals with food value, products intended for human consumption such as meat, fish, milk, eggs, and products consumed as feed by animals fed for this purpose must be safe for human health. The name and address of the supplier, the product supplied and its quantity and date, the name and address of the customer, the type and quantity of the product and the date of departure should be recorded for all kinds of inputs taken to their farms for production purposes. It is necessary to carry out quality control of the product they produce at regular intervals. Unreliable products should not be put on the market, if they are, the relevant authorities should be notified and they should be withdrawn from the market. All farmers producing animals or animal primary products should use the feed from licensed and approved businesses, the amount of feed type quality, veterinary services, all medical and administrative controls performed on the animals should be reported. All farmers engaged in herbal production should keep records of the plant protection products they use, all kinds of pesticides, sampling and inspection processes. The storage of the feeds should be done in accordance with the hygiene conditions, and the cleaning of the feeding equipment and feed transfer vehicles should be done regularly. Dairy producers should make sure that the animals are healthy, and pay attention to the production of raw milk in enterprises free from tuberculosis and brucella diseases. If there is a suspicion of the contrary, he should not put the product he produces on the market, he should immediately isolate the animals showing the symptoms of these diseases in his business and inform the competent authority. Milking, cooling and storage equipment should be kept clean. Milked milk should be cooled without waiting to be more than 60^0C -80^0C. Egg producers should store eggs in clean, dry places away from strong odors and direct sunlight. There should be no pesticide or drug residues higher than the maximum permitted residue limit (MRL) in the produced product, and only licensed pesticides should be used. (Legal Basis; Veterinary Services, Plant Health, Food and Feed Law No.5996 (OJ 13.06.2010, No. 27610); Regulation on Food Hygiene (OJ 17.12.2011, No. 28145); Regulation on Special Hygiene Requirements for Products of Animal Origin (OJ 27.12.2011 No. 28155), Regulation on General Provisions for Combat with Contagious Animal Diseases (OJ 20.01.2012 No. 28179); Regulation on Authorisation of Plant Protection Products (OJ 25.03.2011, No. 27885))

SMR 5 (Use of Hormones): The purpose of this SMR is to prevent the use of 'restricted substances' such as thyrostatic agents, stilbenes and stilbene derivatives, salts and esters, estradiol 17 beta and ester-like derivatives, and substances with estrogenic, androgenic or gestagenic effects, and beta-agonists. Hormones used illegally to increase growth in farm animals are prohibited due to their possible risks to human and animal health. Farmers should not give restricted substances to their animals, if they do, they should not put them on the market, if they are put on the market, they should be withdrawn from the market by notifying the competent authorities. They must keep the records of veterinary and medicinal products for at least 5 years. (Legal Basis; Communique on Hormones and Similar Substances Forbidden and Subject to Specific Conditions to be Administered to Food Producing Animals (OJ 19.06.2003 No.25143)).

SMR 6 (Identification and Registration of Swine): This SMR aims to reduce the risk of spread of swine diseases and to ensure swine movement control and traceability. It is not a priority for Türkiye.

SMR 7 (Identification and Registration of Bovines): With this SMR, it is aimed to facilitate and record the traceability of bovine animals, especially at the time of the epidemic. Cattle breeding enterprises are obliged to record the animals entering and leaving their enterprises with the "Operation Registry/Form for cattle breed animals" determined by MoAF and keep these records for at least 3 years from the last data entry. Farmers must inform the registration unit within 30 days at the latest in cases such as birth, death, slaughter of each cattle, and within 7 days at the latest for all cattle movements in and out of the farm. If the movement of animals is going to be between provinces, the farmers should put the veterinary health report in addition to the passport. Each bovine animal should be recorded in the relevant registry by wearing ear tags within 3 months after birth. Lost or illegible ear tags should be replaced within 30 days (90 days for pasture livestock) by notifying the relevant unit. Farmers should not remove or replace ear tags without MoAF permission. In cases where both ear tags are missing and new ones need to be fitted, the identity of the animal must be proven through a passport. (Legal Basis; Regulation on Identification, Registration and Monitoring of Bovines (OJ 02.12.2011 No. 28130)).

SMR 8 (Identification and rRegistration of Ovines): With this SMR, it is aimed to facilitate and record the traceability of sheep and goats, especially at the time of the epidemic. Sheep and goat breeding enterprises are obligated to records of birth, death and animal movement of their herds in the "Operation Registry/Form for Sheep and Goat Animals" determined by MoAF. Relevant records must be retained for 3 years from the last data entry. For all sheep and goats born in the farmer's enterprise, they should be tagged with earrings given by MoAF within 6 months after birth (up to 9 months for pasture livestock). When the missing ear tag is noticed or before the animal leaves the farm the relevant persons should be informed within 30 days (90 days for pasture livestock). Ear tags should not be damaged and should not be removed without the permission of MoAF. Farmers must obtain a valid transport document for each group of animals before they leave the farm. If the transfer will be between provinces, the veterinary health report must also be attached. (Legal Basis; Regulation on Identification, Registration and Monitoring of Ovines (OJ 02.12.2011 No. 28130)).

SMR 9 (Prevention of TSE): The purpose of this SMR is to minimize the risks to human and animal health of certain transmissible spongiform brain diseases. Farmers should immediately report their infected animal to the MoAF provincial/district directorate and initiate the necessary procedures for the destruction of the animal. Farm animals should not be fed processed proteins obtained from the bodies or parts of animals of the same species. Animal protein or foodstuffs containing animal protein should not be given to ruminant animals. It can be fed with milk, dairy products and colostrum, egg and egg products, and gelatin obtained from non-ruminant animals. Produced sperm, ovum and embryos are kept in the storage room for three months from the date of production and shipped if there is no disease in the breeders where the semen is produced. (Legal Basis; Regulation on Animal By-products Not Used For Human Consumption (OJ 24.12.2011 No. 28152); Regulation on Placing Feed on Market (OJ 27.12.2011 No. 28155))

SMR 10 (Plant Protection Products): The purpose of this SMR is to ensure that plant protection products are used correctly and to minimize risks to humans, animals and the environment. Farmers should use plant protection products in accordance with the criteria in good agricultural practices and the Plant Protection Products Regulation. He should apply the plant protection product he uses according to the conditions and rules written in the usage document and keep a record. The plant protection product must be suitable plant protection product to prevent contamination of surface and groundwater, and appropriate machinery and techniques must be used. The application should be made as it is offered for use and according to the recommendations on the label. (Legal Basis; Regulation on Recommending, Application and Registration of Plant Protection Products (OJ 03.12.2014, No. 29194); Veterinary Services, Plant Health, Food and Feed Law No.5996 (OJ 13.06.2010, No. 27610)).

SMR 11 (Welfare of Calves): The purpose of this SMR is to ensure the welfare of calves by setting minimum standards for their care and rearing. Bovine animals not older than 6 months are called calves. If the calves are indoors, they should be checked at least twice a day, if they are outdoors, at least once a day. Those who are sick or injured should be treated immediately. Calves should be able to move freely, turn around and should not be tied up. If it is necessary to tie it, the time should not exceed 1 hour. The ropes should not hurt the calves and should not be in a position to hurt itself with the rope. Care should be taken to ensure that there are no sharp objects in their environment that could injure them. They should be allowed to groom themselves without difficulty. Calves must not be muzzles. The environment they live in must be of a type that will not harm them and be disinfectable. Electrical circuits and equipment should be checked; building insulation, ventilation, dust level, temperature, air relative humidity and gas concentration should be kept at a level that will not harm the calves. In case of any malfunction in these systems, immediate action should be taken; The problem should be resolved with spare equipment and alternative solutions should be produced. Feed and irrigation equipment should be designed in such a way that they are not easily contaminated. An 8-week-old calf should not be kept in an individual enclosure unless it is sick or isolated, except on the advice of a veterinarian. If they are to be kept together, they must be separated by a perforated wall that will prevent them from seeing each other and making physical contact. Planning should be done in such a way that 1.5 m^2 for each calf with a live weight of less than 150 kg, 1.7 m^2 for calves with a weight of 150-220 kg, and 1.8 m^2 for calves over 220 kg. The area where they are held should not be made of slippery and flexible material. If artificial lighting is used in the environment where the calves are housed, approximately 8 hours of lighting should be provided, which corresponds to one day. Keepers should carry out daily control of under-calves stools, cleaning of inedible foods, and control of flies and other insects in their daily check-ups. Weaning calves should be fed at least twice a day, if group feeding is done, each calf should have equal access to food, and animals that are sick and in extreme heat should be provided with fresh water at all times. Keepers must give all calves food which contains enough iron to make sure they have a blood haemoglobin level of at least 4.5mmol/litre. Keepers must provide fibrous food daily to calves over 2 weeks of age; at least 50 grams must be provided at 8 weeks of age, rising in line with growth to at least 250 grams at 20 weeks old. Keepers must make sure that each calf receives bovine colostrum as soon as possible after it is born. (Legal Basis: Regulation on Minimum Standards for Protection of Calves (OJ 22.11.2014, No. 29183)).

SMR 12 (Welfare of Pigs): It is not a priority for Türkiye.

SMR 13 (Welfare of Farm Animals): The purpose of this SMR is to protect the welfare of farm animals by setting minimum standards for their care and rearing. The shelter physical criteria of the SMR13 are the same as the SMR11. All employees who take care of animals on farms must have sufficient knowledge and skills. Shelters should be checked frequently to ensure animal welfare. All medical treatments applied and dead animals detected during control should be recorded and these records should be kept for at least 3 years. If animals are to be kept outside, they must be protected from predators and other hazards. Automatic and mechanical systems in the shelter should be checked regularly. In case of failure of the ventilation system, a backup ventilation system should be available and an alarm system should be installed for possible problems. Such automatic systems should be checked regularly every 7 days, and if a malfunction is noticed, urgent action should be taken. Animals should be fed appropriately for their age and breed (at least once a day), with access to feed at appropriate intervals unless the veterinarian recommends otherwise. They should be provided with adequate and fresh drinking water and adequate fluids every day. No medication should be given for therapeutic purposes other than the veterinarian's recommendation. Any natural or artificial breeding that causes suffering or injury to animals should be avoided. The normal progeny characteristics (genetic and physical) of animals must be preserved. (Legal Basis: Regulation on General Provisions for Welfare of Farm Animals (OJ 22.11.2014, No. 29183),

GAEC 1 (Buffer Strips): The purpose of this GAEC is to protect water resources against pollution caused by chemical and animal fertilizers. The criteria that restrict the use and storage of fertilizers close to wells, coastal waters, estuaries, lakes, ponds, rivers, streams, canals, irrigation ditches and similar water sources are included in the Nitrate Action Plan. Some materials used in agricultural activities can reach water resources by infiltrating surface flow and underground and cause pollution. Creating a physical barrier in stripes with grass and other vegetation around agricultural areas prevents surface runoff, allowing pollutants to be absorbed without blocking their access to waterways. Buffer lane width in NVZs should be at least 10 m, and lanes outside NVZ should be at least 5 m. Buffer strips should not be plowed and other tillage techniques should not be applied. Organic and inorganic fertilization should not be done and plant protection products should not be used. These areas should not be used for the storage of agricultural tools and equipment, and the accumulation of harvested and by-products and waste materials should be prevented. Although these areas are allowed to be used as pasture, soil compaction by overgrazing should not be allowed. Vegetation in the buffer strips should be preserved and the ground should not be left bare. There is no legal obligation regarding this GAEC rule in Türkiye yet.

GAEC 2 (Water Abstraction Licence): It is aimed to control the use of water by subjecting the withdrawal of water resources used for irrigation purposes to a certain permit. Ground and surface waters are the most important elements of the landscape that support plant and animal habitats. While drawing water, it is necessary to determine the water need to be used in industry and agriculture, to determine the amount to be drawn, to pay attention to ecosystem sensitivity, seasonality, amount of returned water, distances between water withdrawal and discharge points. While irrigation, the current water consumption guide published by TAGEM should be used (Anonymous 2017). Excessive withdrawal of water can lead to a decrease in water resources, damage to the natural habitat in these areas, pollution of water resources due to reduced water dilution and damage to the landscape. It is necessary to obtain permission from the relevant authority (GDSW) for drilling all kinds of wells, pits and boreholes. With the wells drilled by hand, enough water can be drawn to meet the urgent need. If a total area of 100 ha or more will be irrigated using a single irrigation source, the use of modern irrigation techniques that save water should be encouraged. Users who have a water withdrawal permit must obtain a water usage certificate and have a meter installed on the well. (Legal Basis: Regulation on Control of Water Use in Irrigation Systems and Reduction of Water Losses (OJ 16.02.2017, No. 29981); Law on Groundwaters (OJ 23.12.1960 No.10688, Law no.167)).

GAEC 3 (Protection of Groundwater): The purpose of this GAEC rule is to protect groundwater from pollution by controlling the discharge of harmful substances or pollutants. These rules apply to farmers who use, store or discharge substances such as pesticides, ammonia and biocides. The list of harmful and less harmful substances is listed in the Regulation on the Control of Pollution Caused by Dangerous Substances in Water and its Environment. Discharge of harmful substances is subject to MoAF and DGSW permission. Discharge permit conditions; defining the land to be discharged, determining the distance to the waterways, taking the necessary precautions to protect the groundwater pollution and monitoring the groundwater depend on the determination of the type of chemical used and the discharge time. The distance between the area where fertilizer application will be made and the boreholes should be 5 m in areas with a slope of less than 12% and 10 m in areas with a slope of more than 12%. Fertilizer storage units should be built at least 15 m away from the open or closed water well. (Legal Basis: Regulation on Control of Pollution Caused by Hazardous Substances in and around Water (OJ 26.11.2005, No. 26005); Communiqué on GAP for Protection of Waters Against Pollution Caused by Nitrates from Agricultural Sources (OJ 11.02.2017 No. 29976), Code of GAP 2.10)

GAEC 4 (Minimum Soil Cover): The aim of this GAEC rule is to protect the soil resource by creating a minimum level of soil cover against soil erosion. Farmers should avoid bare soil by planting cover crops. The preservation of the vegetation on the soil increases the soil fertility and quality by increasing the amount of organic matter in the soil. The longer the vegetation period, the higher the soil organic content. Vegetation density prevents water and wind erosion, but also reduces plant nutrient loss as it prevents surface runoff. At the same time as the cover crop, weeds will be combated, the amount of soil nitrogen will be increased and the soil will be improved. Soils cultivated for crop production are more susceptible to soil erosion. In such areas, turf buffer areas with high density can be created to prevent sediment flow. The buffer strip rules mentioned in GAEC1 can be applied, thus preventing the pollution of waterways from chemical and organic fertilizers. Farmers should not leave their agricultural lands empty, harvested plant residues should be left on the ground, cover crops such as grass clover and legumes should be planted, allowing self-growing plants to allow the formation of green fallow. (Legal Basis: Communiqué on GAP for Protection of Waters Against Pollution Caused by Nitrates from Agricultural Sources (OJ 11.02.2017 No. 29976))

GAEC 5 (Prevention of Erosion): This GAEC rule applies to farmers who own land that is prone to water and wind erosion due to slope and climatic conditions. Soil erosion clogs waterways and fills dams, causing deterioration of water quality and harming aquatic life. The topsoil affects the amount of organic matter and the physical, chemical and biological properties of the soil. This is important in terms of ease of tillage, availability of nutrients, and water holding capacity. They should apply tillage techniques that prevent erosion. When the soil is very wet, it should not be processed with heavy machinery and controlled grazing should be done. Especially on sloping and wide lands it is necessary to apply terracing and contouring techniques and to form plant strips such as grass bushes. Physical structures such as terraces, wind barriers, fences that prevent soil loss should not be damaged. There is an important link between GAEC 4 and GAEC6, which is related to sustainable soil management. On lands with a slope of 2% to 12% contouring and planting perpendicular to the slope should be done. On lands with a slope of 12-20% root and tuber plants should not be grown. Tillage should be minimized and plowing and contouring should be done perpendicular to the slope. Vineyards such as grapes and kiwi can be grown on the terraces, and other greenhouse plants can be planted in the spaces in between. For lands with a slope of more than 20%, field agriculture should not be done, cover crops should be planted and plow ploughing should not be allowed. (Legal Basis: Soil Conservation and Land Use Law (OJ 19/7/2005, No. 25880, Law No. 5403); Regulation on Pastures; Communiqué on GAP for Protection of Waters Against Pollution Caused by Nitrates from Agricultural Sources)

GAEC 6 (Maintenance of Soil Organic Matter): With this GAEC rule, it is aimed to protect and increase the amount of soil organic matter with appropriate sowing and planting methods. Farmers should keep the organic matter content of the soil they cultivate at an optimum level. The fact that plant residues are left in the field after harvest not only prevents soil and water erosion, but also decays over time and increases soil organic matter. The excess of soil organic matter also increases the plant nutrient content and causes an increase in soil fertility. It also facilitates tillage and increases the soil water holding capacity. One of the obligations under GAEC6 is to prevent stubble burning. Stubble burning deteriorates the biological, physical and chemical structure of the topsoil, negatively affects soil fertility by reducing the amount of organic matter. The only exception is to get permission from the Governor's Office in order to carry out this process in order to destroy plant diseases and plant pests. (Legal Basis: Environment Law (OJ 1/8/1983, No. 18132, Law No. 2872); Forestry Law (OJ 8/9/1956, No. 9402, Law No. 6831); Regulation On Good Agricultural Practices; Circular On Good Agricultural Practices Criterias For Plant Production; Circular On Stubble And Burning Of Stubble On Roadsides And Forages; Communique On Prevention Of Stubble Burning)

GAEC 7 (Maintenance of Landscape Features): This GAEC rule aims to protect landscape elements and natural environmental diversity. Sustainability in agricultural production depends on the protection of natural resources and the environment. Stone walls, hedges, in-line or groups of trees, ditches and waterways can be considered as landscape elements. The listed landscape elements are important in that they support the natural habitat, protect the plants from the possible effects of wind, prevent wind and water erosion, provide shelter for farmers and livestock under normal conditions, provide firewood and allow the cultivation of wild fruits. Dense natural forest areas covering 0.3 ha or less are called tree groups. The trees in-line are defined as a group of trees in a line formed by at least 5 natural trees with a distance of 5 m between them and a length of 25 m. Woodland boundaries are traditionally defined as natural boundaries that include more than 75% tree and shrub vegetation among agricultural parcels that are very common. Landscape elements are located within the agricultural land and the land border should be 2-10 m wide and 25 m long. Farmers should not damage and reduce the size of the landscape elements in agricultural lands, should not allow invasive species to form. Farmers should not cut hedges and trees during bird breeding season and should not prune. If the landscape element is to be modified, permission must be obtained from the legal authority. (Legal Basis: Regulation On Formation Of Spatial Plans; Law On Approval Of Endorsement Of European Landscape Convention; Regulation On Rehabilitation Of Olive Cultivation Through Budding Of Wild Species; Regulation On Utilisation Of Trees And Shrubs That Are Not Located In Forests)

CONCLUSION and RECOMMENDATIONS

It is necessary to take some measures to increase the variety of products in agriculture, to produce better quality and safe food, to protect natural resources and to ensure sustainability in agriculture. This study emphasizes not only the steps prepared for the rules that our country, which is in the EU accession process, must follow, but also the existence of a system necessary for the agricultural support mechanism in Türkiye to be more sustainable. Although some legislations related to good agricultural practices, organic agriculture, environment and soil protection in Türkiye indirectly support the Cross Compliance Rules, there is no legal basis that obliges the Cross Compliance Rules to be followed directly. In order for the Cross Compliance Rules to be compatible with the CAP and the EU support mechanism, a structure compatible to IACS must be established. In practice, first of all, it must be clarified which supporting items will be subject to cross-compliance. Records used by farmers, statistics and Farm Accounting Data Network (FADN) data run by MoAF can be used to decide which rules and criteria are applicable. After that, the target audience should be determined. Here, the farm size can be taken as a basis in determining the farmers who have to comply with cross compliance. For this, first of all, a pilot study on the applicability of cross-compliance rules should be planned and analyzed which SMR and GAEC rules will be applied first. Since the implementation of cross-compliance requires an extra budget, the issue should also be included in the national budget.

Transactions involved in the operation of the cross-compliance mechanism can be at the national, regional and local level. It can be planned that there is only one IACS that provides management and coordination, and that administrative tasks and field controls are carried out by units outside the center. Coordination needs to be ensured between the ministries that take on SMR and GAEC responsibilities. Capacity increase can be achieved with the Farm Edvisory System (FAS), which is the consultancy made to the farmers by creating a good communication strategy. An internal motivation should be created for farmers to comply with the cross-compliance rules. The records kept by the consultants in addition to the consultancy services they provide to the farmers can be used in cross compliance checks. In order to inform the farmers, training seminars should be organized at regular intervals, brochures, posters, information notes should be shared and web sites should be developed.

Cross compliance is a complex combination that includes the regulations of different institutions and organizations, referring to different legislation, such as environment, food safety, animal welfare etc. For this reason, when being included in the Turkish Agricultural Policy, there should be good communication and coordination between the institution that is responsible for the legal basis and legislation, and the institution that is responsible for the operation of cross-compliance.

All components of cross-compliance need to be defined in national legislation. Because of their link with IACS and FAS, they should be considered together and combined into a single document. The legal framework should be based on the relevant regulation within the Agriculture Law No. 5488. The legal basis for the establishment of IACS in Türkiye is contained in subparagraph (d) of Article 20 of the Agriculture Law No. 5488, but it has not yet been fully operational. In order to fully comply with SMR and GAEC rules, IACS needs to be operational.

In this study, the rules and criteria affecting the production of safe food, animal welfare, environment, public and animal health were investigated in the farm dimension. The rules have been reviewed with their benefits and legal basis and are presented in a language that farmers can use as amanual. The implementation of the aforementioned systems in national legislation will be an important step in fulfilling the obligations that must be made in the EU membership process, as well as contributing to a more livable environment and sustainability in agriculture in the future.

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REFERENCES

Anonim (2017). Türkiye'de Sulanan Bitkilerin Su Tüketimleri. TAGEM&DSİ, Ankara. https://www.tarimorman.gov.tr/TAGEM/Belgeler/yayin/Tu%CC%88rkiyede%20Sulanan%20Bitkilerin%20Bitki%20Su%20Tu%CC%88ketimleri.pdf

Dişbudak, K., (2008). Avrupa Birliği'nde Tarım-Çevre İlişkisi ve Türkiye'nin Durumu. T.C.Tarım ve Köyişleri Bakanlığı Dış İlişkiler ve Avrupa Birliği Koordinasyon Dairesi Başkanlığı, Uzmanlık Tezi, Ankara.

Yüksel B., Olhan, E., İçel, C. D, (2011). Avrupa Birliği'nde Çapraz Uyum ve Türkiye için Öneriler. Ankara Avrupa Çalışmaları Dergisi, Cilt:10, No:1 s.33-65

Graham, J., Plumptre, T. W., & Amos, B. (2003). Principles for good governance in the 21st century (21. yüzyılda iyi bir yönetişim için gereken ilkeler). Ottawa: Institute on governance (Yönetişim Enstitüsü).

Tortajada, Cecilia (2010). Water Governance Some Critical Issues, International Journal of Water Resources Development (Su Yönetişiminde Bazı Kritik Konular, Uluslararası Su Kaynaklarının Geliştirilmesi Dergisi) , 26:2, sf. 297-307.

Rooij, L.L. de; Sticker, T; Schrandt, C. (2014). Guidance document on the participation of the public and stakeholders in flood risk management, EU IPA 2010 Twinning project "Development of Flood Hazard Maps and Flood Risk Maps" HR/2010/IB/EN/01.

https://www.resmigazete.gov.tr/

https://agriculture.ec.europa.eu/common-agricultural-policy/financing-cap/assurance-and-audit/managing-payments_en

https://agriculture.ec.europa.eu/common-agricultural-policy_en

www.capreform.eu

http://ec.europa.eu/agriculture/simplification/crosscom/index_en

https://www.tarimorman.gov.tr/Konular/Bitkisel-Uretim/Iyi-Tarim-Uygulamalari/Projeler).

https://www.tarimorman.gov.tr/TRGM/Link/48/Projeler https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=38185

https://www.eca.europa.eu/en/Pages/search.aspx?k=cross%20compliance%20rules

CHAPTER 7

THE EFFECTS OF IMAGE PROCESSING APPLICATIONS ON THE HARVEST LOSS IN TOMATOES (LYCOPERSICON ESCULENTUM) IN TERMS OF SUSTAINABILITY IN AGRICULTURE

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INTRODUCTION

Today, in parallel with the increase in the world population, agricultural production gains great importance. Agricultural production is decreasing due to the factors such as decrescent agricultural areas and global warming. It is getting harder and harder to meet the food needs of the human population.Various studies are being carried out to get more efficiency from small areas. Automation is replacing traditional agriculture (Yilmaz and Soysal, 2021). With the introduction of computer and robotic systems into our daily lives, their use in agriculture is becoming widespread.In particular, studies are carried out all over the world for the use of robotic studies in agricultural production. Robotic systems are used in the period from seed selection to harvest. Systems such as harvesting systems, autonomous irrigation and spraying can be given as examples.One of the products with the highest export potential in our country, tomato production and harvest quality is of great importance.The product quality of tomato is determined by the processes from the seedling planting to the processes applied during the harvest.While table tomatoes are mostly harvested by hand, paste tomato harvesting is done by mechanization.Sensitivity during harvest is the factor that increases the quality and value of the product to be exported. Studies on this subject have been made both in our country and in the world. It has been seen that the studies for sensitive harvesting applications are mostly in the prototype stage in the scanned literature.Some of these studies are as follows.Zhao Y. et al. (2016) made a modular double-arm robot concept with 3 DOF in their study. The system and its structure are shown in Figure 1.

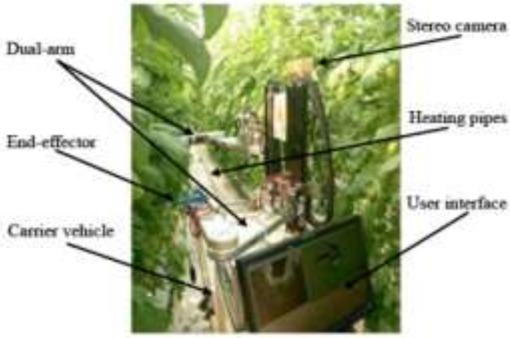

Figure 1. Installed system and its structure

Lili W. et al. (2017) developed a tomato harvesting robot consisting of a four-wheel independent steering system, 5-DOF harvesting system, navigation system and binocular stereo vision system.With the image processing system they applied, 86% of ripe tomatoes were separated on the seedling. The system installed is shown in Figure 2.

Figure 2. Robotic harvesting system

Oktarina Y. et al. (2019) designed a robotic harvester according to the size and maturity level of the tomato in their research in 2019.They distinguished between green and red tomatoes on the branch.The required time measurement for the robot was determined as 9,676 s for detecting the red tomato and returning to the standby position, and 10,586 s for the green.Image selection results are shown in Figure 3.

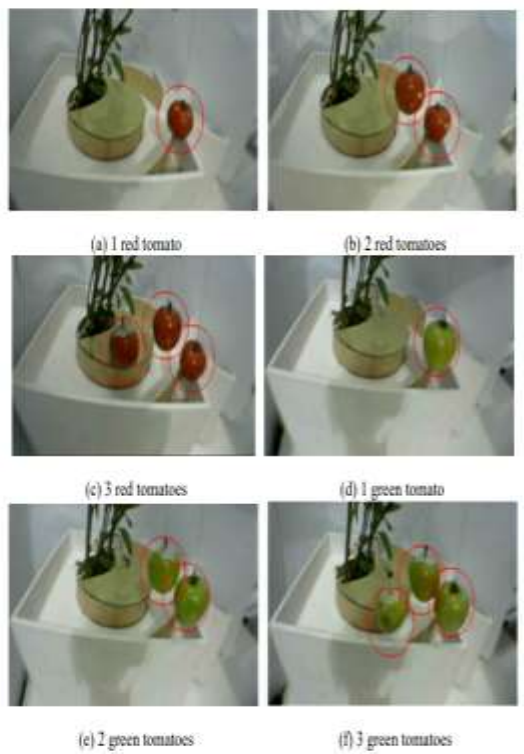

Figure 3. Image selection screen

The common feature in the systems made is the processing of real-time images transferred to digital media.The most important input for robotic systems is the information that comes with image processing.This information contains the requested feature information. These are color, size and location.Thanks to this information that comes with image processing, robotic systems perform the requested processes according to the position of the product.

The aim of our study is to determine the location on the seedling according to the maturity color condition of the tomato.It is aimed to harvest according to these coordinate values determined by the robotic system that is planned to be designed later.

MATERIALS AND METHODS

Tomato

Although it is known that tomato, whose homeland is South America and which has an important place in Turkish agriculture and food industry, was brought to Turkey through Adana during the Ottoman Empire, it is also reported that it was brought during the First World War, according to some sources, since there is no written document (Şalk et al. . 2008., Demiray and Tülek 2008).Due to the favorable climatic conditions, Turkey is one of the important countries in tomato cultivation. Tomatoes can be grown everywhere in our country, except the areas with heavy rainfall in the Black Sea Region. Especially Marmara, Aegean and Mediterranean are our important tomato growing regions (Vural et al., 2000).

Tomato is one of the most important vegetables due to its production and consumption amount in the world, being the first among the agricultural products subject to trade, its importance in human nutrition and its wide range of uses such as frozen, canned, tomato paste, ketchup, pickles, tomato juice in the food industry.

According to the data of TUIK for 2021, a total of 13,095,258 tons of tomatoes are produced in the open and under greenhouse. In terms of greenhouse vegetable cultivation, the total vegetable production is 7,771,766 tons according to 2020 data, and tomatoes account for more than half of the total production, with an amount of 4,099,129 tons. Varieties, seasonal weather conditions and market conditions are some of the determining criteria in the selection of the type of harvest in vegetables. In general, selective harvesting is appropriate for a specimen maturity that is cool during the flowering period and growing season. Since flowering is repeated in certain periods in tomato, harvesting should be done accordingly.(Karaçalı 2004)

In tomato production, harvesting can be done at any stage, starting from the white stage to the red ripening stage, depending on the purpose of cultivation, the buyer's wishes, the distance and proximity of the market, the fruit characteristics of the variety (Vural et al. 2000). However, it is a known fact that the red color positively affects the market value of tomatoes. Because during this period, the fruit's sugar is 29.8% and its starch is 1.3%, so its taste is also the best (Sevgican 2002).

Tomatoes are harvested by hand or machine. At hand harvest, the ripe fruit is taken into the palm of one hand and separated from the stem with a twisting and wiggling motion (Şalk et al.2008). In tomato harvest, plucking the fruits from the branch should be done carefully. During the harvest of the fruits, mostly the fruit stalk and some fleshy part remain on the branch.Thus, a dimple may form around the stem pit, reducing the sales value. The easy and difficult separation of tomatoes from their stems is a cultivar feature. Especially in cluster tomato varieties, even though the fruits are ripe, the fruit stalk is difficult to break from the cluster stem, so it is marketed in bunches and all fruits are requested to be red on sale.

In the production of table tomatoes made in small family businesses, the harvest is done by hand, increasing the number of harvests and increasing the yield as well as meeting the quality demands of the market. In industrial tomato production, it is aimed to harvest as little as possible. Thus, the harvesting cost is reduced and if machine harvesting is to be done, the harvest should be done at once. In this context, another feature sought in varieties suitable for machine harvesting is that 90% of the fruits on the plant must have reached harvest maturity.

HD Digital Camera and Features

For the robotic system, the processing of transferring the image to the digital environment has been used. It is the most important input unit in the process of determining the position of the image transferred to the digital media by processing. The camera is shown in Figure 4.

Figure 4. Dijital Camera

Feature:

1. High speed 720P 4MP 5MP HD USB camera

2.2.8-12mm/5-50mm/6mm Lens optional

3. Deliver high frame rate MJPG-1920X1080 resolution 30fps, 2560x1440 resolution 30fps.

4. Camera with UVC, driverless.

Specification:

Sensor: 4MP 1/2.9" CMOS GC4053; 5MP SONY 335, 720p CMOS

Pixels: 4MP, 4 megapixels, 2560(H)x1440 (V) pixels

Maximum resolution: 2560x1440

Output image format: MJPEG

USB protocol: USB2.0

Frame rate:

2560(H)x1440 (V) piksel MJPEG 30fps

1920(H)x1080 (V) piksel MJPEG 30fps

1280(H)x 720 (V) piksel MJPEG 30fps YUV2 30fps

640(H)x480 (V) piksel MJPEG 30fps YUV2 30fps

Night Vison: no

Minimum illumination: 0.1(F1.2,AGC ON)

Angle of view: wide angle

Operating voltage: DC 5V

Working current: 150mA

Supported systems:

WinXP/Vista/Win7/Win8

Locating the Tomato

An HD digital camera was used to transfer the instant digital image required to determine the location of the tomato on the branch.

Connecting the camera to the computer is done via the USB port. The program written in C# language was used for image acquisition and processing. The installed system is shown in Figure 5.

Figure 5. Installed System Structure

The real-time images transferred to the C# program were processed with the written program and the ripe tomatoes were determined by color analysis. The flow chart of the written program is shown below.

The algorithm of the program written in Figure 6 and the program interface in Figure 7 are given.

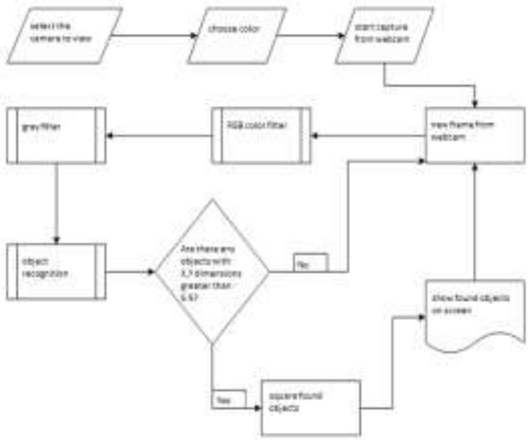

Figure 6. Program algorithm

Figure 7. Program screenshot

The images obtained as a result of image processing are shown in Figure 8.

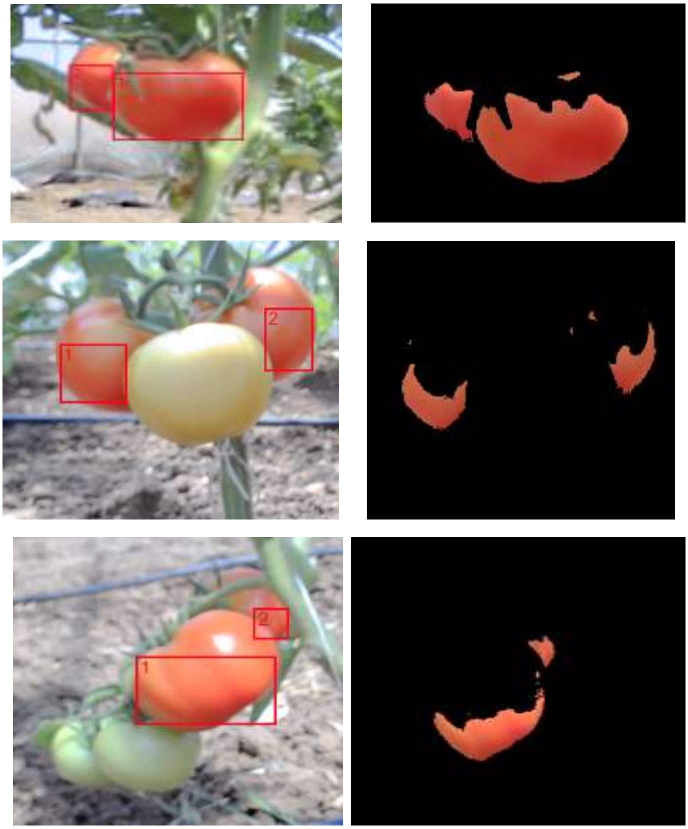

Figure 8. Result screenshot

As a result of the analysis made according to the red color, ripe and unripe tomatoes were differentiated with a success rate of 90.7%. Figure 9 shows the success graph of the results obtained as a result of the experiment.

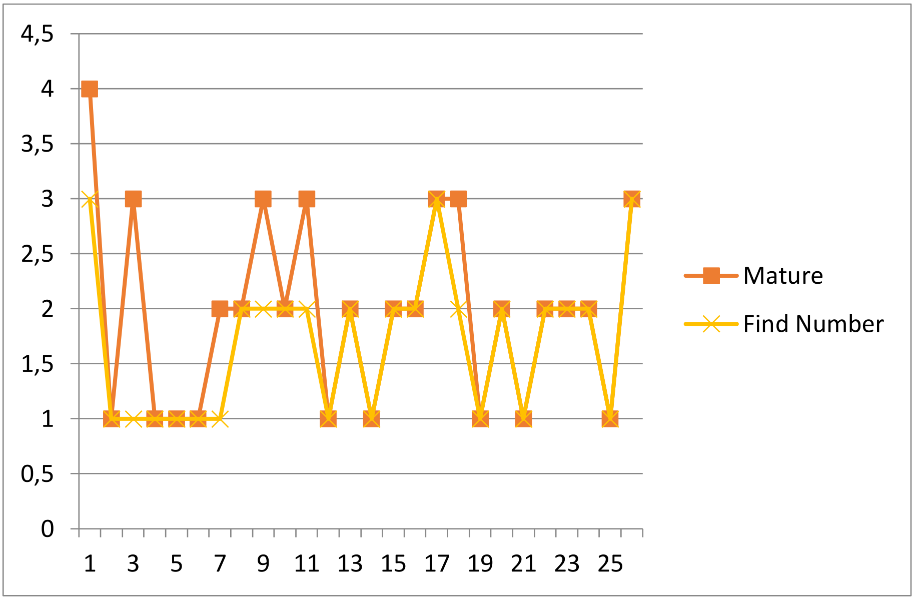

Figure 9. Trial result graph

CONCLUSION AND DISCUSSION

Harvesting of table tomato varieties is usually done by hand, while in industrial cultivation, it is done by machine.The program is designed with the goal of selective harvesting.It is thought that this will enable selective harvesting applications, especially for tomato plants that are not brought to the market at once, maturing and harvested in different periods depending on price and climatic conditions.

REFERENCES

Şalk A., Arın L., Deveci M., Polat S., 2008. Özel Sebzecilik, Namık Kemal Üniversitesi Ziraat Fakültesi, ISBN 978-9944-0786-0-3, s: 488. Onur Grafik Matbaa ve Reklam Hizmetleri, İstanbul.

Demiray E ve Tülek Y (2008). "Domates kurutma teknolojisi ve kurutma işleminin domatesteki bazı antioksidan bileşiklere etkisi", Gıda Teknolojileri Elektronik Dergisi, 3: 9-20.

Vural H., Eşiyok D., Duman İ., 2000. Kültür Sebzeleri (Sebze Yetiştirme) E.Ü. Ziraat Fakültesi Bahçe Bitkileri Bölümü, E.Ü Basımevi, s: 440, Bornova.

Karaçalı, İ., 2006. "Bahçe Ürünlerinin Muhafazası ve Pazarlanması", Ege Üniversitesi Ziraat Fakültesi Yayın No: 454.SEVGİCAN A., 2002. Örtüaltı Sebzeciliği Cilt I, E.Ü. Basımevi İzmir

Zhao Y., Gong L.,Liu C.,Huang Y.(2016)," Dual-arm Robot Design and Testing for Harvesting Tomato in Greenhouse", IFAC-PapersOnLine 49-16 (2016) 161–165

Lili W., Bo Z., Jinwei F., Xiaoan H.,, Shu W., Yashuo L., Qiangbing Z.,Wei Chongfeng W. (2017)," Development Of A Tomato Harvesting Robot Used In Greenhouse ",Int J Agric & Biol Eng, 2017; 10(4): 140–149., DOI: 10.25165/j.ijabe.20171004.3204

Oktarina Y.,Dewi T., Risma P., Nawawi M.(2019)," Tomato Harvesting Arm Robot Manipulator; a Pilot Project", Journal of Physics: Conference Series, doi:10.1088/1742-6596/1500/1/012003

Anonymous 2022, http://www.robotdevreleri.com/nesne-takibi-joistik-ile-lazer-konum-kayit/, Son erişim tarihi:04/10/2022

Yılmaz A., Soysal S. (2021). The Necessity of Autonomous Systems in Agriculture. In Çelik A, Bellitürk K, Baran MF, editors. Agricultural Researches Resourcebook. İKSAD, Adıyaman, 301-322.

CHAPTER 8

SOME IMPORTANT CONSIDERATIONS WHEN APPLYING INSECTICIDES WITH UAVs

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INTRODUCTION

One of the reasons for the price increases in today's food prices is the rapid increase in the world population and therefore the need for food. According to the FAO estimation, this need is expected to increase by around 70% in 2050. This demand and the sustainable use of resources increase the importance of plant protection application strategies. The use of pesticides not only increases yield and quality, but also creates negative effects due to drift (Melo et al., 2015).

Unmanned Aerial Vehicles (UAV) cameras, sensors, etc. techniques and technologies are used in applications. In addition to these, pesticide-spraying UAVs with small tanks in agricultural areas have also started to be seen frequently. With the short but intense development of UAV technology and its adoption by farmers, it has taken its place as a plant protection technique. In particular, the problems that arise as a result of mistakes made in plant protection technologies can be greater in larger areas when UAVs are used. (Barbedo, 2019; Li et al., 2020; Radoglou-Grammatikis et al., 2020).

Practitioners are in the confusion of not being able to choose for these vehicles, which do not have a standard and carry the spray system with different configurations. Users need guidance in choosing the right one for them and for an effective application. In particular, they fall into distrust in the face of uncertainties about which application, at what height, and at what rate of pesticide.

UAV users have little knowledge and experience about spraying quality and effectiveness, as well as the correct application. To support this,

this section has attempted to describe Best Management Practices (BMPs) in pesticide application with the right UAV. While many researchers try to minimize drift due to factors such as changing environmental conditions, product development and pest biology, they focus on how to maximize spray success and dispersion (Woldt et al., 2018; Zhang et al., 2021; Qin et al., 2021). : Liu et al., 2021). BMPs reduce many variables that affect a quality spray with the use of UAVs. However, it is imperative to increase the knowledge and experience about how to use UAVs in plant protection applications, especially for BMP applications.

Effective pest control depends on the technical suitability of the applications. The effect of contact pesticides depends entirely on the correct rate and adequate coverage. This is the case for all aerial or ground applications. The biggest challenge here is to keep environmental and biological variables under control while minimizing pesticide drift. In other words, the product, pest and environmental variables should be well known. It is possible to apply BMPs with Unmanned Aerial Vehicles technology. This is the same for all pesticides (herbicides, insecticides, fungicides, etc.).

A quality spray application will reveal all the benefits a pesticide formulation can provide. While using plant protection products, the expected effect from pesticides will decrease as the application standards move away.

FACTORS AFFECTING THE UAV APPLICATION

In terms of plant protection science, the factors affecting success in applications with Unmanned Aerial vehicles; pest population density, protective applications, pest resistance, pesticides and additives, sprayers. Considering these factors in the spraying application to be made will bring success.

High Pest Population Density

In plant protection practices, the main objective is to increase the effectiveness of controlling pest populations below the economic damage level and to keep the damage to the product at the lowest level. For this, first of all, areas should be checked frequently to determine the pest population and the application rate to be discarded before they are damaged. The development of the population should be detected early and spraying should be started, especially during the spawning period and adult flight period (Tiryaki, 2016).

In pesticide applications, plant species and environmental conditions, spraying time, application volume, spray structure, pesticide formulation and covarage affect the success of agricultural control (Çelen et al., 2007). Especially, in some applications, the droplets reaching under the leaves bring success. In addition, droplets reaching all over the leaf (top-bottom) should also provide a good protective coverage on the surface. (Sumner et al., 2000; Karabey et al., 2020))

Larvae should not be expected to grow as they become more difficult to kill and will migrate into the interior of the plant's canopy where droplets are more difficult to reach. Once the larvae have settled on the stem, they cannot be controlled by spraying the leaves. Matthews (1997) stated that the minimum drop size is approximately 50μm to ensure accumulation and penetration in plant leaves. Droplets smaller than 50μm should be directed onto the plant or directly to the pest (Tücer and Yılmaz, 1998).

Some insect species can transition to a larger stage in a very short time when the temperature rises. Apple internal worms are an example of this. Rapid life cycles, overlapping generations resulting in continuous spawning, will require multiple applications to manage populations. Under these conditions, it is also recommended to use the highest application rate specified on the label of the pesticide to be mixed into the water.

Spraying in the early morning or early evening, when insects are active and environmental conditions are suitable, will be effective. Avoid spraying during temperature inversions.

Protective Applications

It is very important to protect the crop from more than one pest generation while growing. Therefore, it is necessary to take some precautions. Most foliar-applied insecticides cannot protect growing plants after spraying. For example, if the moths continue to lay eggs and the larvae feed on new plant shoots, etc., additional treatments are needed. Therefore, the number of applications should be increased or additional techniques should be applied.

Pest Resistance

The pests' high fecundity, short life cycle and control measures enable them to withstand a very short period of time. For this reason, the control techniques applied while continuously plant protection applications with pests enabled the pests to develop hereditary characteristics. Insects show a resistance to chemical control methods due to changes in behavior, maturation or biochemical processes that occur with the development of these characteristics. Studies on this subject have reported that insects have developed a behavioral or metabolic resistance to pesticides. (Nasreen, 2016).

In order to reduce pest populations with high resistance, the statements by pesticide manufacturers and publications describing application details should be carefully studied. The information on the label should be read carefully and the recommended pesticide ratio should be used. Overdose should not be done. At all life stages of pests (eggs, larvae, adults) the highest mortality level should be sought.

It should be avoided to use the same formulation continuously throughout the season. It will be beneficial to use different formulations by alternating. The rotation of different insecticide chemistries delays insect resistance and extends the life of effective crops.

Pesticide and Adjuvant

The contact angle refers to the wettability of a metric solid surface. This value is used when evaluating the wettability of the leaf surface or the spreading performance of adjuvants (He et al., 2019). As the contact angle of the water on the surface of a hydrophobic leaf gets larger, it prevents it from spreading on the leaf and causes the droplets to flow. Considering that many pesticides are diluted with water in applications, it is necessary to reduce the contact angle of spray liquids to facilitate spreading to the leaf surface. This will reduce the drift (Melo et al., 2015). Mixing the additives into the spray liquid contributes to the reduction of contact angles of the spray droplets, which are expected to achieve a better dispersion (Celen, 2010; Santos et al., 2019; Mehdizadeh et al., 2020; Sobiech et al., 2020) . Thus, environmental pollution can also be reduced by using less pesticides and increasing efficiency (Jibrin et al., 2021; Meng et al., 2018; Preftaks et al., 2019; Wang et al., 2018).

Adjuvants are used to improve and control the chemical and physical properties of the pulverization. Some are effective in stability, solubility, pH balance, buffering, compatibility and foaming between pesticide and carrier liquid, while others reduce droplet drift or evaporation drift, and some facilitate penetration of pesticides. Some of them provide better adhesion of pesticides to the applied surface and show a coverage (Green and Beestman, 2007; Çelen, 2010). Pesticide performance has recently been further enhanced by the use of adjuvants. Although successful products are easy to use and cost effective, the technology of additives is developing rapidly.

It is an important issue to choose the appropriate adjuvant that will maximize the effectiveness in pest control with Unmanned Aerial

Vehicles. Many chemical manufacturers are working on suitable adjuvants that can be used in drone spraying.

Although there are many studies on the distribution of droplet sizes in the mixture and especially the adjuvants in the tank in spraying with Unmanned Aerial Vehicles, there are not many studies on the spraying technique, especially on trees (Chen et al., 2021; Kim et al., 2019).

Approved quality adjuvants should be used to ensure the compatibility of the mixture in the tank and to increase the effectiveness of the pesticide. Adjuvants that penetrate the leaf surface and also reduce the surface tension of the spray liquid droplets should be preferred. The combination of all components in the spray liquid mixture, especially the presence of adjuvant, will affect droplet size. Therefore, this will also affect the risk of drift. Droplet size must be checked again when oils or other additives are added.

Ensuring the compatibility of the tank mixture, thus preventing the spray nozzles from clogging, will bring application success. Spraying equipment should be clean and free of residues of previously used pesticides. The sprayer tank should be filled ¼ to ½ with water and add the ingredients directly to the tank, mixing thoroughly after each addition. As indicated in the ordering on the label or respectively water-soluble packs, water-dispersible granules, water-soluble granules, wettable powders, water-based suspension concentrates (aqueous fluids), water-soluble concentrates, oil-based suspension concentrates (OD, SE) - Omnera (Provalia/Avaletta), emulsion concentrates, oils, additives, surfactants, soluble fertilizers, drift retardants should be added. Care should be taken when adding products with different formulation types to the tank. Compatibility testing of any new product combination is strongly recommended, especially when using concentrated premixes.

After adding each product to the tank, a period of time should be waited for complete mixing and dispersion. Pesticides should not be kept waiting after preparation and should be applied as soon as possible. In particular, it should not store the spray liquid in the tank overnight. In deferred applications, it is recommended to shake the tank.

Sprayer Variables

Some previous studies have tried to determine the parameters of UAV applications that apply pesticides in order to achieve an ideal control efficiency in orchards. Hou et al. (2019) determined that flight speed contributes to 74% of the effect on droplet accumulation in citrus trees. Tang et al. (2018) determined that in applications with UAVs, flight altitude and tree shape have significant effects on droplet distribution in the citrus trees (Zhang et al., 2017).

Spray System Calibration in Spraying UAVs for Agriculture

In order to ensure the amount of pesticide to be thrown per unit area, necessary inspection, test and calibration processes should be performed before and after the UAV application specified in ISO 9357. Improperly calibrated spray systems can accelerate failed pest control, low yields and pest resistance.

Spray system calibration is extremely effective for drone application at low tank capacities. Some spray system parameters (rotor configuration, spray nozzle spacing, distance from spray nozzle to rotor) are specified by the manufacturer and do not need to be changed. Other spray system parameters need to be calibrated. Specifically, flight speed,nozzle type, spray pressure, flow rate, orifice size, spray width, spray height, etc. all parameters affect application speed and quality. For example, flight speed, flow rate, nozzle width, , etc. as a result, the product usage rate changes. Similarly, droplet size is affected as a result of nozzle type, orifice size, spray pressure, etc. In fact, variables such as nozzle selection, distance between nozzles, boom configuration, spray height and application speed also affect the spray pattern.

Besides, it is recommended to use precision flight controller equipped with RTK - GPS for accurate route planning and real-time tracking.

Choosing the Right UAV

In order to ensure a quality application that increases residue accumulation and homogeneity and yields the right amount of product, factors such as flight speed, spray height and width, and homogeneity of distribution should not change during the application, taking into account the geographical and meteorological conditions. Flying too high (approximately >3 m) or too low (approximately <1.5 m) may disrupt the spray pattern. Thus, it can cause insufficient surface coverage and increase the drift potential. Flying too close to the ground can change the droplet trajectory and spray distribution due to the interaction of the rotor airflow with the ground surface.

During the application, a constant flight speed (3 - 6 m/s) must be ensured depending on the UAV model. There should never be spraying when entering or leaving a field. Spraying that starts too late or is done too early can result in poor coverage, resulting in crop damage. Spraying should start after entering each new row and should be turned off before exiting at the end of each row. Then, after completing all parallel rows, it must be flown along the edges of the field to finish the application.It should not be sprayed even while hovering or circling.

Downward motion of small multi-rotor UAVs is weaker than single-rotor UAVs and therefore more affected by wind. Under these conditions, maintaining a constant flight speed, altitude, and wetting width is necessary to achieve homogeneous spray distribution.

In bumpy fields, where hills or mountains limit the application area, all crossings should be made in one direction, downhill. Uphill spraying can be dangerous and should be avoided.

Airwave and spray system configuration of the UAV affects dispersion uniformity. The boom and nozzles should be positioned so that fine droplets are not caught and pushed upwards by the rotor vortex and there is minimal contamination on the drone. For a single rotor UAV, the boom length should be 85% of the rotor width or less.

Figure 1. Equipment-Related Factors Affecting Application Success in Pesticide Applications with Unmanned Aerial Vehicles

The selection of the appropriate nozzle type, spray volume and droplet size is of strategic importance to improve the quality of the UAV application. In pesticide applications with UAV, spray nozzle types that create low spray volumes and small droplets can be used. However, while operating efficiency is maximized, the coverage may deteriorate.

Most drones produce droplet sizes with Volumetric Median Diameter in the "very fine (VF)" (61-105 µm) to "fine (F)" (106-235 µm) categories (ASABE standard S572.1). Droplets smaller than 150 µm can endanger neighboring non-target crops and also create unsuitable spray rates for the target crop, even causing high drift potential.

Drift

In addition to the application rate difference between the applications made from the ground and the UAV-based applications, the drift effect also differs. Drift potential is high in applications with UAVs (Wang et al., 2020). For this reason, it is expected that the droplet distribution in the target area will be improved when UAVs are used as sprayers. In spraying, the spray quality of the sprayers depends on the properties of the sprayed liquids and the spraying technologies, and are the main issues to be considered most (Ahmad et al., 2021). In UAV applications, droplet distribution can be achieved by adjusting the drop size and the amount of pesticide to be applied per unit area in order to obtain homogeneity and good penetration. In addition to these, we can also say that pesticide formulations should be changed.

In order to ensure a targeted application and reduce the risk of drift, it should be noted that the authorized person or persons wearing protective equipment as the operator should deal with pesticide products during the application.

The operator must consider all factors necessary to make a correct and safe application. Compliance with general safety principles and procedures is critical for civil aviation. Pesticide drift is not an accident. In drone application, downwind drift and drift losses can be controlled when weather is effectively managed in terms of equipment and product related factors.

Drift potential is affected by drone type, nozzle type and configuration, flight speed and altitude, target product, wind speed and direction, and even environmental conditions. Plant hosts created for aquatic habitats, livestock, beekeeping, and silkworm breeding can be damaged, especially in low-volume applications.

A checklist should be available for the operator, grower and operator to reduce pesticide drift. In addition, UAV applications require sufficient aerial vision for both the operator and the observer.

Environmental variables

Environmental variables should be constantly controlled in order to increase the effectiveness and success of the targeted control and to minimize pesticide drift. Especially after spraying, there should be no rain or irrigation for at least two hours to ensure product absorption and develop pesticide effect.

Spraying should be done when the wind speed is between 1.5 m/s and 3 m/s (Beaufort scale 1-3). Spraying should be avoided in windy conditions or when the wind exceeds 5 m/s (Beaufort scale >3). Spraying when wind speed is less than 1.5 m/s (Beaufort scale 1) can reduce penetration into the canopy and increase the risk of drift. At low wind speeds, larger droplet size and higher water volume should be preferred (Kountouriotis et al., 2014).

Avoid spraying during temperature inversions. It should increase droplet size when conditions are marginal, i.e. low relative humidity and high temperature conditions. Higher application volumes should be used to improve surface coverage and reduce the risk of drift due to increased evaporation.

Figure 2 shows the relative humidity and air temperature according to the Delta T values calculated by taking the difference of the dry-bulb temperature and wet-bulb temperature values. Delta T is one of the main indicators of suitable spraying conditions, especially in summer, when we experience the combination of high daily temperatures and very low relative humidity that limit the spraying time. The higher the Delta T value, the drier the atmosphere and the greater the potential for evaporation of spray droplets. Delta T assists operators in determining when and how to apply pesticides to increase efficacy and reduce drift. Spraying can be done when Delta T values are between 2 and 8. Delta T color bands, which are preferred with the desired air temperature and humidity combinations, should be examined (Annonymous, 2022).

In summer, when the Delta T is high (>10), spray droplets can dry out before they have a chance to enter the canopy. This leads to a decrease in the effectiveness of the insecticide. If the Delta T value is too low, the spray conditions will not be suitable either. Often cold and humid mornings (high humidity and low temperatures) and temperature changes can cause an increased risk of drift.

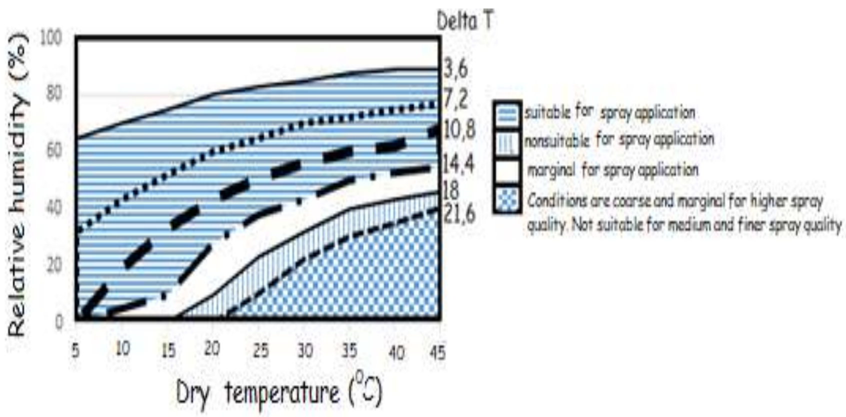

Figure 2. Delta T Values Depending on Humidity and Temperature Suitable For Spraying (Annonymous, 2022)

CONCLUSION

As the technologies of unmanned aerial vehicles develop, they have started to be seen in many areas around the world. It is the focus of solution in many issues in agriculture. In fact, it is shaped according to the land, plant and application in agriculture. It is preferred in applications where the tractor is not suitable. It has a wider spray range compared to spraying with tractors. Damage to the tractor is eliminated. In addition, studies have shown that while the effect of pesticides on plants is 40%, this rate increases up to 90% in applications with UAVs. Approximately 40% savings can be achieved from pesticides. It is even possible to spray in a shorter time compared to back sprayers. Other functions of UAVs (image analysis, etc.) allow monitoring of plant status, health, life-long, early detection and rapid application in case of problems.

In addition to these advantages, there are also facts that many studies should be conducted on pesticide applications with UAVs. Studies on the use of Unmanned Aerial Vehicles, carried out in the world and in Turkey, on the standardization, regulation, application technique and on which plants it will be applied are continuing. There are many different vehicle capacities and functions. It may not be correct to use them in all areas. It is very important to know the condition of the area to be sprayed, plant characteristics, plant protection product feature, sprayer type, meteorological conditions and surrounding habitats (sensitive areas, etc.).

Applications made with UAVs, which can be as harmful as beneficial if not applied correctly, can endanger both people's health and living spaces. The effectiveness of pesticide application due to many factors such as the amount of pesticide to be applied per unit area, application method and time, use of protective work equipment, meteorological conditions is important for the health of the applicator who is constantly exposed to pesticides.

Many farmers own UAVs or receive support from firms. However, it is not known how the applications will be made and the issue of taking the necessary precautions is not given much importance. Practices are carried out entirely on gaining experience. In this regard, it is necessary for the Ministries of Agriculture to establish the emergency regulations in full.

REFERENCES

Ahmad, F., Khaliq, A., Qiu, B., Sultan, M. and Ma, J. (2021). Advancements of spraying technology in agriculture. In: Ahmad F, Sultan M, Editors. Technology in Agriculture. London: IntechOpen, p. 536.

Annonymous (2022). Delta T: A Tool for Pesticide Application Decision Making. Access date: June 2022. chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.ndsu.edu/agriculture/sites/default/files/2022-01/DeltaT-WeedGuide.pdf

Barbedo, J.G.A. (2019). A review on the use of unmanned aerial vehicles and imaging sensors for monitoring and assessing plant stresses. Drones, 3(2):40.

Celen, I.H., Arın, S., Durgut, M.R. and Okur, E. (2007). Bağlarda Kalıntı ve Damla Dağılımı Üzerinde Pülverizatör İlerleme Hızı Değişiminin Etkisi. Tarımsal Mekanizasyon 24. Ulusal Kongresi, 57 Eylül, Kahramanmaraş, Türkiye, s.407-414.

Celen, I. H. (2010). The Effect of Spray Mıx Adjuvants on Spray Drıft. Bulgarian Journal of Agricultural Science, 16 (1): 105-110

Chen, H., Lan, Y., Fritz, B.K., Hoffmann, W.C. and Liu, S. (2021). Review of agricultural spraying technologies for plant protection using unmanned aerial vehicle (UAV). International Journal of Agricultural and Biological Engineering, 14(1):38–49.

Green, J. M. and Beestman, G. B. (2007). Recently patented and commercialized formulation and adjuvant technology. Crop Protection, 26 : 320–327.

He, Y., Xiao, S., Wu, J. and Fang, H. (2019). Influence of multiple factors on the wettability and surface free energy of leaf surface. Applied Sciences, 9(3):593.

Hou, C., Tang, Y., Luo, S., Lin, J., He, Y., Zhuang, J., He, Y., Zhuang, J. and Huang, W. (2019). Optimization of control parameters of droplet density in citrus trees using UAVs and the Taguchi method. International Journal of Agricultural and Biological Engineering, 12(4):1–9.

ISO. 9357 (1990). Equipment for crop protection: Agricultural sprayers --Tank nominal volume and filling hole diameter: Geneva, Switzerland: ISO.

Jibrin, M.O., Liu, Q., Jones, J.B. and Zhang, S. (2021). Surfactants in plant disease management: a brief review and case studies. Plant Pathology, 70(3):495–510.

Karabey, A., Özkan, Y., Sayıncı, B. and Yeşildal, F., (2020). Pestisit Uygulamaları İçin Optimize Edilmiş Koşullarda Sprey Karakteristiklerinin Belirlenmesi/ Gümüşhane Üniversitesi Fen Bilimleri Enstitüsü Dergisi GUFBED 10(3):733-741

Kim, J., Kim, S., Ju, C. and Son, H.I., (2019). Unmanned aerial vehicles in agriculture: a review of perspective of platform, control, and applications. IEEE Access, 7:105100–105115.

Kountouriotis, A., Aleiferis, P.G., Charalambides, A.G., (2014). Numerical investigation of VOC levels in the area of petrol stations. Science of The Total Environment, Volumes 470–471, Pages 1205-1224

Li, X., Giles, D.K., Niederholzer, F.J., Andaloro, J.T., Lang, E.B. and Watson, L.J. (2020). Evaluation of an unmanned aerial vehicle as a new method of pesticide application for almond crop protection. Pest Management Science, 77(1):527–537.

Liu, Q., Chen, S., Wang, G. and Lan, Y. (2021). Drift Evaluation of a Quadrotor Unmanned Aerial Vehicle (UAV) Sprayer: Effect of Liquid Pressure and Wind Speed on Drift Potential Based on Wind Tunnel Test. Appl. Sci. 2021, 11, 7258.

Matthews, G.A. (1997). Pesticicle application: Current status and further development. Phytoparasitica25 (Suppl): 11s- 19 s.

Meng, Y., Lan, Y., Mei, G., Guo, Y., Song, J. and Wang, Z. (2018). Effect of aerial spray adjuvant applying on the efficiency of small unmanned aerial vehicle on wheat aphids control. International Journal of Agricultural and Biological Engineering, 11(5):46–53.

Mehdizadeh, M., Mehdizadeh, Z. and Baghaeifar, Z. (2020). Efficacy evaluation of tribenuron methyl herbicide by using different adjuvants for common lambsquarters (Chenopodium albüm L.) control. International Journal of Advanced Biological and Biomedical Research, 8(1):1–8.

Melo, A., Usano-Alemany, J., Guedes, J. and Hunsche, M. (2015). Impact of tank-mix adjuvants on deposit formation, cuticular penetration and rain-induced removal of chlorantraniliprole. Crop Protection, 78(3):253–262.

Nasreen, A. (2016). IPM Odaklı Çevre Yönetimi. Greenhouse Canada,Eylül, https://www.greenhousecanada.com/environmental-stewardship-with-an-ipm-focus-31245/,Erişim tarihi Haziran 2022

Preftakes, C.J., Schleier, J.J., Kruger, G.R., Weaver, D.K. and Peterson, R.K.D. (2019). Effect of insecticide formulation and adjuvant combination on agricultural spray drift. PeerJ, 7 (Suppl. 1):e7136.

Qin, Z., Wang, W., Dammer, K., Guo, L. and Cao, Z. (2021). A Real-time Low-cost Artificial Intelligence System for Autonomous Spraying in Palm Plantations. *ArXiv, abs/2103.04132*.

Radoglou-Grammatikis, P., Sarigiannidis, P., Lagkas, T. and Moscholios, I. (2020). A compilation of UAV applications for precision agriculture. Computer Networks, 172(3):107148.

Santos, R., Ferreira, M.C. and Viana, R.G. (2019). Does the use of adjuvants alter surface tension and contact angle of herbicide spray droplets on leaves of Sida spp.? Planta Daninha, 37(5):888.

Sobiech, U., Grzanka, M., Skrzypczak, G., Idziak, R. and Ochowiak, M. (2020). Effect of adjuvants and pH adjuster on the efficacy of sulcotrione herbicide. Agronomy,10(4):530.

Sumner, H.R. and Herzog, G.A. (2000). Assessing the Effectiveness of Air-assisted and Hydraulic Sprayers In Cotton Via Leaf Bioassay. The Journal of Cotton Science, 4, 79-83.

Tang, Y., Hou, C., Luo, S., Lin, J., Yang, Z. and Huang, W. (2018). Effects of operation height and tree shape on droplet deposition in citrus trees using an unmanned aerial vehicle. Computers and Electronics in Agriculture, 148:1–7.

Tiryaki, O. (2016). Bitki Sağlığı ve Gıda Güvenliği. ÇOMÜ Zir. Fak. Derg.: 4 (2): 65–73

Tücer, A. and Yılmaz, A. (1998). Seralarda Entegre Mucadeleye Uygun Pestisit Aplikasyon Teknıkleri. Tarımsal Mekanizasyon 18. Ulusal Kongresi, Tekirdağ /Türkiye.

Wang, X., He, X., Song, J., Wang, Z., Wang, C., Wang, S., Wu, R. and Meng, Y. (2018). Drift potential of UAV with adjuvants in aerial applications. International Journal of Agricultural and Biological Engineering, 11(5):54–58.

Wang, C., Zeng, A., He, X., Song, J., Herbst, A. and Gao, W. (2020). Spray drift characteristics test of unmanned aerial vehicle spray unit under wind tunnel conditions. International Journal of Agricultural and Biological Engineering, 13(3):13–21.

Woldt, W., Martin, D., Latheef, M., Kruger, G., Wright, R., McMechan, J., Proctor, C. and Jackson-Ziems, T. (2018). Field Evaluation of Commercially Available Small Unmanned Aircraft Crop Spray Systems. An ASABE Meeting Presentation DOI: https://doi.org/10.13031/aim.201801143 Paper Number: 1801143. Written for presentation at the 2018 ASABE Annual International Meeting Sponsored by ASABE Detroit, Michigan July 29-August 1

Zhang, P., Wang, K., Lv, Q., He, S., Yi, S., Xie, R., Zheng, Y., Ma, Y. and Deng, L. (2017). Droplet distribution and control against citrus Leafminer with UAV Spraying. International Journal of Robotics & Automation, 32(3):299–307.

Zhang, C., Valente, J., Kooistra, L., Guo, L. and Wang, W. (2021). Orchard management with small unmanned aerial vehicles: a survey of sensing and analysis approaches. Precision Agriculture, 22(6):2007–2052.

CHAPTER 9

THE ROLE OF SILICON IN FUNGAL PLANT PATHOGENS CONTROL

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INTRODUCTION

Among the most important factors that reduce the yield and quality of agricultural products, biotic factors including diseases, pests and weeds take the first place and cause losses of millions of lira every year (Alkan, 1968; Islamoğlu, 2021a, 2022).

In order to prevent these losses caused by pests, physical, mechanical, biotechnical and biological control methods, especially chemical, have achieved significant success (Vojtech et al., 2006; Islamoğlu, 2021b).

In addition to the use of chemicals in the control against diseases, interest in control methods has increased recently.

Oxygen is the most abundant element in the earth's crust, after oxygen, Silicon (Si) is the most abundant, and it constitutes approximately 70% of the soil mass (Epstein, 1994; Savant et al., 1997; Ma and Yamaji, 2006). It is found in the soil solution as monomeric or monosilicic acid (H_4SiO_4), and its uptake from plant roots is usually as silicic acid [$Si(OH)_4$] (Ma and Yamaji, 2006). Uptake from roots may differ according to plant species (Takahashi et al., 1990), and uptake by root absorption is also easy. Si is a highly beneficial element as it increases tolerance to drought, provides greater resistance to metal toxicity, and reduces the intensity of disease and pests. If soil fertility, pH, soil type and climate and other product needs are appropriate, it is recommended to be used in plant protection applications (Pozza et al., 2015).

According to recent studies, Si accumulated in the cell wall of plants, has beneficial effects in many plants. (Epstein, 1999; Fauteux et al., 2005; Liang et al., 2005b). By causing improvements in plant mechanisms and physiology, it is beneficial in combating many biotic and abiotic stress factors (Richmond and Sussman, 2003; Ma, 2004; Ma and Yamaji, 2006), increasing the resistance of plants in the control against fungi (Fauteux et al., 2005; Marschner, 2012) have inhibitory effects on various abiotic stresses such as shelter, drought, nutrient imbalance, metal toxicity, UV, salt stress, high temperature, freezing conditions, radiation damage in plants (Epstein, 1994, 1999; Ma and Yamaji, 2006; Liu et al., 2014; Coşkun et al., 2016).

Diseases caused by many fungal pathogens are one of the main problems of crop production. One of the most effective ways to combat these diseases is to use appropriate fungicide and the other is to use resistant varieties (Dubin and Rajaram, 1996; Shephard, 1997). Since the continuous use of fungicide has resulted in serious economic losses, the emergence of resistant pathogen populations and potential environmental problems (Ma and Michailides, 2005), it has been necessary to search for alternative and environmentally friendly methods for the control of fungal diseases.

It has been reported that soil fertilizers containing different nutrients are effective in preventing some disease formations (Datnoff et al., 2007). Si application has been proposed as an alternative to traditional control methods. Si has the potential to improve environmental stress tolerance and increase product quality and productivity (Ma and Yamaji, 2006; Datnoff et al., 2007) and provides a protective effect for many fungal diseases (Fauteux et al., 2005; Datnoff et al., 2007; Van Bockhaven et al., 2013).

Si;

1) by strengthening the plant structure (Epstein, 1999, 2001; Rodrigues et al., 2015b),

2) by enabling the production of antimicrobial compounds,

3) increasing vegetative resistance by activating multiple signaling pathways and triggering defensive gene expression (Fauteux et al., 2005; Chen et al., 2014; Vivancos et al., 2015),

4) by inducing systemic acquired resistance and inhibiting pathogen colonization (Fauteux et al., 2005; Datnoff et al., 2007; Van et al., 2013) they were successful in preventing plant diseases by preventing pathogen entry.

USAGE OF SILICON IN FUNGAL PLANT PATHOGENS

In many studies conducted so far, it has been determined that Si is effective in controlling and reducing the effect and severity of fungal diseases in some plants (Table 1).

Table 1. Effects of Si on plant diseases (Wang ve ark., 2017).

Hosts	Diseases	Pathogens	References
Arabidopsis	Powdery mildew	*Erysiphe cichoracearum, Agrobacterium tumefaciens*	Ghanmi et al., 2004 Fauteux et al., 2006 Vivancos et al., 2015
Banana	Black sigatoka Fusarium wilt Root rot *Xanthomonas* wilt	*Mycosphaerella fijiensis* *Fusarium oxysporum f. sp. cubense* *Cylindrocladium spathiphylli* *Xanthomonas campestris*	Kablan et al., 2012 Fortunato et al., 2012 Vermeire et al., 2011 Mburu et al., 2015
Barley	Powdery mildew	*Blumeria graminis*	Wiese et al., 2005
Wheat	Blast Leaf blast Leaf streak Powdery mildew	*Pyricularia grisea* *Pyricularia oryzae* *Xanthomonas translucens* *Blumeria graminis*	Filha et al., 2011 Silva et al., 2015 Silva I.T. et al., 2010 Chain et al., 2009; Guével et al., 2007 Moldes et al., 2016
Bean	Angular leaf spot	*Pseudocercospora griseola*	Rodrigues et al., 2010
Common bean	Anthracnose	*Colletotrichum lindemuthianum*	Polanco et al., 2014 Rodrigues et al., 2015
Cherry	Fruit decay	*Penicillium expansum, Monilinia fructicola*	Qin and Tian, 2005
Cotton	Fusarium wilt	*Fusarium oxysporum f. sp.vasinfectum*	Whan et al., 2016
Cucumber	Crown and root rot Fusarium wilt Powdery mildew	*Pythium ultimum* *Fusarium oxysporum f. sp. cucumerinum* *Sphaerotheca fuliginea, Podosphaera xanthii*	Chérif et al., 1994 Miyake and Takahashi, 1983 Menzies et al., 1991, 1992 Fawe et al., 1998 Liang et al., 2005a

Lettuce	Downy mildew	*Bremia lactucae*	Garibaldi et al., 2011
Melon	Bacterial fruit blotch Powdery mildew	*Acidovorax citrulli* *Podosphaera xanthii*	Conceição et al., 2014 Dallagnol et al., 2015
Potato	Dry rot	*Fusarium sulphureum*	Li et al., 2009
Rice	Blast	*Pyricularia oryzae,* *Magnaporthe grisea,* *Magnaporthe oryzae*	Seebold et al., 2000 Kim et al., 2002 Rodrigues et al., 2003 Cai et al., 2008 Hayasaka et al., 2008 Brunings et al., 2009 Domiciano et al., 2015
Strawberry	Powdery mildew	*Sphaerotheca aphanis*	Kanto et al., 2006
Soybean	*Phytophthora* stem and root rot Rust	*Phytophthora sojae* *Phakopsora pachyrhizi*	Guérin et al., 2014 Cruz et al., 2014
Pumpkin	Powdery mildew	*Erysiphe cichoracearum* *Podosphaera xanthii*	Menzies et al., 1992 Savvas et al., 2009

Silicon application as given in Table 1; against powdery mildew on barley (Wiese et al., 2005), wheat (Guével et al., 2007; Chain et al., 2009; Moldes et al., 2016), cucumber (Menzies et al., 1991, 1992; Fawe et al., 1998; Liang et al., 2005a), melon (Dallagnol et al., 2015) and strawberry (Kanto et al., 2006), pumpkin (Menzies et al., 1992; Savvas et al., 2009) (Figure 1); against dry rot on potato (Li et al., 2009); against Fusarium wilt and root rot on cucumber (Miyake and Takahashi, 1983) and banana (Fortunato et al., 2012) (Chérif et al., 1994), against anthracnose on beans (Polanco et al., 2014, Rodrigues et al., 2015), mildew on lettuce (Garibaldi) et al., 2011) has been found to be effective against many diseases.

Figure 1. Silicon applications against downy mildew in pumpkin plant

(Left: Control treatment; Right: Silicon treatment) (Photos by Joseph Heckman)

Datnoff and Rodrigues, in their study conducted in 2005 with Si and fungicide combinations on rice plants, determined that the highest decrease in disease was achieved by integrating Si fertilization with fungicides (Figure 2).

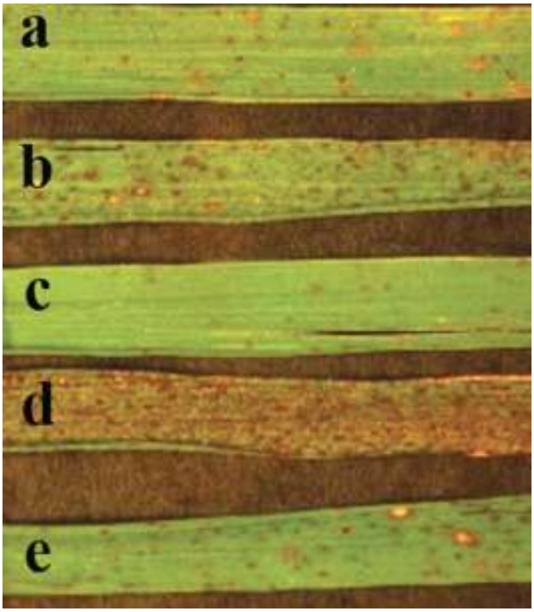

Figure 2. In the brown spot symptoms seen on the leaves, a and e) silicon application was made; (b) application of propiconazole fungicide; (c) silicon + propiconazole; (d) control (Datnoff, and Rodrigues, 2005).

Si fertilizers seem to be beneficial for plants because they are cost-effective, increase soil pH, have convenient storage properties, provide high amounts of Si in soluble form, and are not contaminated with heavy metals (Heckman, 2013; Datnoff and Heckman, 2014). For these reasons, it is stated that when Si is given to the plant as a fertilizer, an increase in resistance levels against some pathogenic fungi is observed (Datnoff et al., 2007). Potassium silicate (K_2SiO_3) or sodium silicate (Na_2SiO_3), which is used as a foliar spray, and calcium silicate ($CaSiO_3$) applied to the soil have been successfully used in plants (Sakr, 2016).

SILICON-MEDIATED DISEASE RESISTANCE

Si has an important effect on plant health when plants are under the influence of more than one stress (Epstein, 2009). Despite many studies on the effects of Si on fungal diseases, there are still uncertainties in the mode of action, properties and range of activity of Si. It is thought that they have an effect on disease resistance in the plant due to the host's defense mechanisms or the accumulation of Si in the epidermal tissue (Datnoff et al., 2007; Van Bockhaven et al., 2013) (Figure 3).

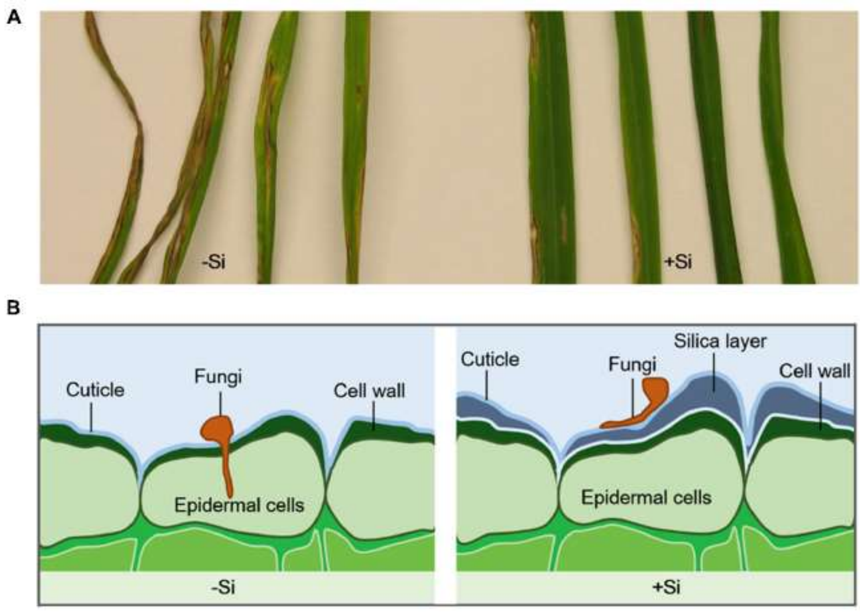

Figure 3. (A) Leaf symptoms after inoculation of Magnaporthe grisea on the leaves of rice plant (Sun et al., 2010). Rice leaves (B) treated with Si (+Si) continuously or without Si (–Si) produced a Si layer in the cell wall of Si-treated plants and increased plant resistance to fungal infection by physical barrier (Wang et al., 2017).

Si resistance mechanisms; physical defense and biochemical defense (with enzymes, antifungal compounds, molecular mechanisms) (Sakr, 2016).

Briefly, researchers have proposed two hypotheses for Silicon-enhanced resistance to fungal diseases; The biologically active role of Si in natural defense mechanisms and its protective role against many plant pathogens are explained, one of which is high Si accumulation in the leaf to provide a physical barrier to prevent the penetration of the pathogen (Fauteux et al., 2005; Datnoff et al., 2007). Si accumulates more in older leaves than in younger leaves (Ma and Takahashi, 2002).

RESULTS

Silicon application in plants is seen as one of the most promising approaches, which has a very important place in the effective control and sustainability of fungal diseases. In this struggle, many studies have been done and should continue to investigate the protective properties of si in the plant. As a result of the researches, it has been determined that it strengthens the plant, increases the antimicrobial compounds, prevents the development of pathogens and increases the physical and biochemical resistance of the plant. It is thought that a more detailed investigation of the use of Si in plants will allow it to be used effectively to increases crop yield and increases resistance against fungal diseases.

REFERENCES

Brunings, A.M., Datnoff, L.E., Ma, J.F., Mitani, N., Nagamura, Y., Rathinasabapathi, B., et al. (2009). Differential gene expression of rice in response to silicon and rice blast fungus Magnaporthe oryzae. *Ann. Appl. Biol.* 155, 161–170. doi: 10.1111/j.1744-7348.2009.00347.x

Cai, K., Gao, D., Luo, S., Zeng, R., Yang, J., and Zhu, X. (2008). Physiological and cytological mechanisms of silicon-induced resistance in rice against blast disease. *Physiol. Plant*, 134, 324–333. doi: 10.1111/j.1399-3054.2008. 01140.x.

Chain, F., Côté-Beaulieu, C., Belzile, F., Menzies, J., and Bélanger, R. (2009). A comprehensive transcriptomic analysis of the effect of silicon on wheat plants under control and pathogen stress conditions. *Mol. Plant Microbe Interact.*, 22, 1323–1330. doi: 10.1094/MPMI-22-11-1323.

Chen, Y., Liu, M., Wang, L., Lin, W., Fan, X., and Cai, K. (2014). Proteomic characterization of silicon-mediated resistance against *Ralstonia solanacearum* in tomato. *Plant Soil*, 387, 425–440. doi: 10.1007/s11104-014-2293-4.

Chérif, M., Asselin, A., and Bélanger, R. (1994). Defense responses induced by soluble silicon in cucumber roots infected by *Pythium* spp. *Phytopathology*, 84, 236–242. doi: 10.1094/Phyto-84-236.

Conceição, C. S., Felix, K. C. S.,Mariano, R. L. R., Medeiros, E. V., and Souza, E. B. (2014). Combined effect of yeast and silicon on the control of bacterial fruit blotch in melon. *Sci. Hortic.*, 174, 164–170. doi: 10.1016/j.scienta. 2014.05.027.

Coskun, D., Britto, D. T., Huynh, W. Q., and Kronzucker, H.J. (2016). The role of silicon in higher plants under salinity and drought stress. Front. *Plant Sci.*, 7:1072. doi: 10.3389/Fpls.2016.01072.

Cruz, M.F.A., Rodrigues, F., Diniz, A.P.C., Alves Moreira, M., and Barros, E.G. (2014). Soybean resistance to Phakopsora pachyrhizi as affected by acibenzolar- S-methyl, jasmonic acid and silicon. *J. Phytopathol.*, 162, 133–136. doi: 10.1111/ jph.12170.

Dallagnol, L., Rodrigues, F., Pascholati, S., Fortunato, A., and Camargo, L. (2015). Comparison of root and foliar applications of potassium silicate in potentiating post-infection defences of melon against powdery mildew. *Plant Pathol.*, 64, 1085–1093. doi: 10.1111/ppa.12346.

Datnoff , L., Elmer, W. and Huber, D. (2007). Mineral nutrition and plant disease. *The American Phytopathological Society*, St. Paul, USA. 278 p.

Datnoff, L.E. and Heckman, J.R. (2014). Silicon fertilizers for plant disease protection. In Proceedings of the 16th World Fertilizer Congress of CIECRio. De Janeiro-RJ, Brazil, 20-24 October, p. 37-38.

Dubin, H.J. and Rajaram, S. (1996). Breeding diseaseresistant wheats for tropical highlands and lowlands. *Annual Review of Phytopathology*, 34: 503- 526.

Epstein, E. (1994). The anomaly of silicon in plant biology. Proc. Natl. Acad. Sci. U.S.A. 91, 11–17. doi: 10.1073/Pnas.91.1.11

Epstein, E. (1999). Silicon. Ann. Rev. Plant Physiol. *Plant Mol. Biol.* 50, 641–664. doi: 10.1146/annurev.arplant.50.1.641.

Epstein, E. (2001). Silicon in Plants: Facts vs Concepts. Amsterdam: Elsevier Science.

Fauteux, F., Remus-Borel, W., Menzies, J.G., and Belanger, R.R. (2005). Silicon and plant disease resistance against pathogenic fungi. FEMSMicrobiol. Lett. 249, 1–6. doi: 10.1016/j.femsle.2005.06.034.

Fauteux, F., Chain, F., Belzile, F., Menzies, J.G., and Belanger, R.R. (2006). The protective role of silicon in the Arabidopsis-powdery mildew pathosystem. Proc. Natl. Acad. Sci. U.S.A. 103, 17554–17559. doi: 10.1073/pnas.0606330103.

Fawe, A., Abou-Zaid, M., Menzies, J., and Bélanger, R. (1998). Silicon-mediated accumulation of flavonoid phytoalexins in cucumber. *Phytopathology*, 88, 396–401. doi: 10.1094/PHYTO.1998.88.5.396

Filha, M.S.X., Rodrigues, F.A., Domiciano, G.P., Oliveira, H.V., Silveira, P.R., and Moreira, W.R. (2011). Wheat resistance to leaf blast mediated by silicon. Australas. *Plant Pathol.*, 40, 28–38. doi: 10.1007/s13313-010-0010-1.

Fortunato, A.A., Rodrigues, F., Baroni, J.C.P., Soares, G.C.B., Rodriguez, M.A.D., and Pereira, O.L. (2012). Silicon suppresses Fusarium wilt development in banana plants. *J. Phytopathol*., 160, 674–679. doi: 10.1111/jph. 12005.

Garibaldi, A., Gilardi, G., Cogliati, E. E., and Gullino, M. L. (2011). Silicon and increased electrical conductivity reduce downy mildew of soilless grown lettuce. *Eur. J. Plant Pathol*., 132, 123–132. doi: 10.1007/s10658-011-9855-6.

Ghanmi, D., Mcnally, D.J., Benhamou, N., Menzies, J.G., and Bélanger, R.R. (2004). Powdery mildew of Arabidopsis thaliana: a pathosystem for exploring the role of silicon in plant-microbe interactions. *Physiol. Mol. Plant Pathol.*, 64, 189–199. doi: 10.1016/j.pmpp.2004.07.005.

Guérin, V., Lebreton, A., Cogliati, E.E., Hartley, S.E., Belzile, F., Menzies, J.G., et al. (2014). A zoospore inoculation method with *Phytophthora sojae* to assess the prophylactic role of silicon on soybean cultivars. *Plant Dis.*, 98, 1632–1638. doi: 10.1094/pdis-01-14-0102-re

Guével, M.H., Menzies, J.G., and Bélanger, R.R. (2007). Effect of root and foliar applications of soluble silicon on powdery mildew control and growth of wheat plants. *Eur. J. Plant Pathol*., 119, 429–436. doi: 10.1007/s10658-007-9181-1.

Hayasaka, T., Fujii, H., and Ishiguro, K. (2008). The role of silicon in preventing appressorial penetration by the rice blast fungus. *Phytopathology*, 98, 1038–1044. doi: 10.1094/PHYTO-98-9-1038.

Heckman, J. (2013). Silicon: A Beneficial Substance. *Better Crops,* 97: 14-16.

Islamoğlu, M. (2021a). Sürdürülebilirlik için Gıda, Çevre, Tarımsal Ormancılık ve Tarımda Yeni Araştırmalar. Gelişen Dünyada Biyolojik Mücadelenin Yeri ve Önemi, Edited by: K. Bellitürk, M.F. Baran ve A. Çelik İKSAD Yayınevi. ISBN: 978-625-7562-28-7.

Islamoğlu, M. (2022). İklim Değişikliği ve Tarımda Dönüşüm. İklim Değişikliğinin Bitki Zararlılarına Potansiyel Etkileri, Edited by: M.F. Baran ve A. Çelik İKSAD Yayınevi. ISBN: 978-625-8377-92-7

Islamoğlu, M. (2021b). Agrıcultural Researches Resourcebook. The Place and Importance of Bıologıcal Control in Turkey and Some Application Examples. Edited by: A. Çelik, K. Bellitürk ve M.F. Baran. İKSAD Yayınevi. 978-625-8007-36-7.

Kablan, L., Lagauche, A., Delvaux, B., and Legrève, A. (2012). Silicon reduces black sigatoka development in banana. *Plant Dis*., 96, 273–278. doi: 10.1094/pdis-04-11-0274.

Kanto, T., Miyoshi, A., Ogawa, T., Maekawa, K., and Aino, M. (2006). Suppressive effect of liquid potassium silicate on powdery mildew of strawberry in soil. *J.Gen. Plant Pathol*., 72, 137–142. doi: 10.1007/s10327-005-0270-8.

Kim, S.G., Kim, K.W., Park, E.W., and Choi, D. (2002). Silicon-induced cell wall fortification of rice leaves: a possible cellular mechanism of enhanced host resistance to blast. Phytopathology 92, 1095–1103. doi: 10.1094/PHYTO.2002. 92.10.1095.

Li, Y.C., Bi, Y., Ge, Y.H., Sun, X.J., and Wang, Y. (2009). Antifungal activity of sodium silicate on Fusarium sulphureum and its effect on dry rot of potato tubers. *J. Food Sci*., 74, 213–218. doi: 10.1111/j.1750-3841.2009.01154.x.

Liang, Y. C. (1999). Effects of silicon on enzyme activity and sodium, potassium and calcium concentration in barley under salt stress. *Plant Soil*, 209, 217–224. doi: 10.1023/A:1004526604913.

Liang, Y. C., Sun, W., Si, J., and Römheld, V. (2005a). Effects of foliar-and rootapplied silicon on the enhancement of induced resistance to powdery mildew in *Cucumis sativus*. *Plant Pathol*., 54, 678–685. doi: 10.1111/j.1365-3059.2005. 01246.x.

Liang, Y.C., Wong, J.W.C., and Wei, L. (2005b). Silicon-mediated enhancement of cadmium tolerance in maize (*Zea mays* L.) grown in cadmium contaminated soil. Chemosphere 58, 475–483. doi: 10.1016/j.chemosphere.2004. 09.034.

Liu, P., Yin, L.N., Deng, X.P., Wang, S.W., Tanaka, K., and Zhang, S.Q. (2014). Aquaporin mediated increase in root hydraulic conductance is involved in silicon-induced improved root water uptake under osmotic stress in *Sorghum bicolor* L. *J. Exp. Bot*., 65, 4747–4756. doi: 10.1093/jxb/eru220.

Ma, J.F. (2004). Role of silicon in enhancing the resistance of plants to biotic and abiotic stresses. Soil Sci. Plant Nutr. 50, 11–18. doi: 10.1080/00380768.2004. 10408447

Ma, Z. and Michailides, T.J. (2005). Advances in understanding molecular mechanisms of fungicide resistance and molecular detection of resistant genotypes in phytopathogenic fungi. Crop Protection, 24: 853-863.

Ma, J.F. and Yamaji, N. (2006). Silicon uptake and accumulation in higher plants. *Trends in Plant Science*, 11: 392-397.

Marschner, P. (2012). Marschner’s Mineral Nutrition of Higher Plants. London: Academic Press. Pozza, E. A., Pozza, A. A. A., & Botelho, D. M. D. S. (2015). Silicon in plant disease control. *Revista Ceres*, 62, 323-331.

Mburu, K., Oduor, R., Mgutu, A., and Tripathi, L. (2015). Silicon application enhances resistance to xanthomonas wilt disease in banana. *Plant Pathol.*, 65, 807–818. doi: 10.1111/ppa.12468.

Menzies, J., Ehret, D., Glass, A., and Samuels, A. (1991). The influence of silicon on cytological interactions between Sphaerotheca fuliginea and *Cucumis sativus*. Physiol. *Mol. Plant Pathol.*, 39, 403–414. doi: 10.1016/0885-5765(91)90007-5.

Menzies, J., Bowen, P., Ehret, D., and Glass, A. D. (1992). Foliar applications of potassium silicate reduce severity of powdery mildew on cucumber, muskmelon, and zucchini squash. *J. Am. Soc. Hortic. Sci*., 117, 902–905.

Miyake, Y., and Takahashi, E. (1983). Effect of silicon on the growth of solutioncultured cucumber plant. *Soil Sci. Plant Nutr*., 29, 71–83. doi: 10.1080/00380768. 1983.10432407.

Moldes, C.A., De Lima Filho, O.F., Merini, L. J., Tsai, S. M., and Camiña, J. M. (2016). Occurrence of powdery mildew disease in wheat fertilized with increasing silicon doses: a chemometric analysis of antioxidant response. *Acta Physiol. Plant*., 38, 206. doi: 10.1007/s11738-016-2217-4.

Polanco, L.R., Rodrigues, F.A., Nascimento, K.J., Cruz, M.F., Curvelo, C.R., Damatta, F.M., et al. (2014). Photosynthetic gas exchange and antioxidative system in common bean plants infected by Colletotrichum lindemuthianum and supplied with silicon. *Trop. Plant Pathol.*, 39, 35–42. doi: 10.1590/S1982- 56762014000100005.

Qin, G.Z., and Tian, S.P. (2005). Enhancement of biocontrol activity of Cryptococcus laurentii by silicon and the possible mechanisms involved. *Phytopathology*, 95, 69–75. doi: 10.1094/PHYTO-95-0069.

Richmond, K.E., and Sussman, M. (2003). Got silicon? The non-essential beneficial plant nutrient. Curr. Opin. *Plant Biol.*, 6, 268–272. doi: 10.1016/S1369-5266(03) 00041-4.

Rodrigues, F., Benhamou, N., Datnoff, L.E., Jones, J.B., and Bélanger, R.R. (2003). Ultrastructural and cytochemical aspects of silicon-mediated rice blast resistance. *Phytopathology*, 93, 535–546. doi: 10.1094/PHYTO.2003.93. 5.535.

Rodrigues, F., Duarte, H.S.S., Rezende, D.C., Filho, J.A.W., Korndörfer, G.H., and Zambolim, L. (2010). Foliar spray of potassium silicate on the control of angular leaf spot on beans. *J. Plant Nutr.*, 33, 2082–2093.

Rodrigues, F.A., and Datnof, L.E. (2015). Silicon and Plant Diseases. Berlin: Springer. doi: 10.1007/978-3-319-22930-0.

Sakr, N. (2016). The role of silicon (Si) in increasing plant resistance against fungal diseases. *Hellenic Plant Protection Journal*, 9(1), 1-15.

Savant, N.K., Snyder, G.H., and Datnoff, L.E. (1997). Silicon management and sustainable rice production. Adv. Agron. 58, 151–199. doi: 10.1016/S0065-2113(08)60255-2.

Savvas, D., Giotis, D., Chatzieustratiou, E., Bakea, M., and Patakioutas, G. (2009). Silicon supply in soilless cultivations of zucchini alleviates stress induced by salinity and powdery mildew infections. *Environ. Exp. Bot.*, 65, 11–17. doi:10.1016/j.envexpbot.2008.07.004

Shephard, M.C. (1997). Screening for Fungicides. *Annual Review of Phytopathology*, 25: 189-206.

Seebold, K.W., Datnoff, L., Correa-Victoria, F.J., Kucharek, T.A., and Snyder, G.H. (2000). Effect of silicon rate and host resistance on blast, scald, and yield of upland rice. *Plant Dis.*, 84, 871–876. doi: 10.1094/PDIS.2000.84.8.871.

Silva, I.T., Rodrigues, F.A., Oliveira, J.R., Pereira, S.C., Andrade, C.C.L., Silveira, P.R., et al. (2010). Wheat resistance to bacterial leaf streak mediated by silicon. *J. Phytopathol.*, 158, 253–262. doi: 10.1111/j.1439-0434.2009. 01610.x

Silva, W.L.D., Cruz, M.F.A., Fortunato, A.A., and Rodrigues, F. (2015). Histochemical aspects of wheat resistance to leaf blast mediated by silicon. *Sci.Agric*., 72, 322–327. doi: 10.1590/0103-9016-2014-0221.

Sun, W., Zhang, J., Fan, Q., Xue, G., Li, Z., and Liang, Y. (2010). Silicon-enhanced resistance to rice blast is attributed to silicon-mediated defence resistance and its role as physical barrier. *Eur. J. Plant Pathol*., 128, 39–49. doi: 10.1007/s10658- 010-9625-x.

Takahashi, E., Ma, J.F., and Miyake, Y. (1990). The possibility of silicon as an essential element for higher plants. *Comment. Agric. Food Chem*., 2, 99–102. doi: 10.1016/j.bbagen.2013.11.021.

Van Bockhaven, J., Vleesschauwer, D.D. and Hofte, M. (2013). Towards establishing broad-spectrum disease resistance in plants: silicon leads the way. *Journal of Experimental Botany*, 64: 1281– 1293.

Vermeire, M.L., Kablan, L., Dorel, M., Delvaux, B., Risède, J. M., and Legrève, A. (2011). Protective role of silicon in the banana-Cylindrocladium spathiphylli pathosystem. *Eur. J. Plant Pathol*., 131, 621–630. doi: 10.1007/s10658-011-9835-x.

Vivancos, J., Labbe, C., Menzies, J.G., and Belanger, R.R. (2015). Silicon-mediated resistance of Arabidopsis against powdery mildew involves mechanisms other than the salicylic acid (SA)-dependent defence pathway. *Mol. Plant Pathol*., 16, 572–582. doi: 10.1111/mpp.12213.

Whan, J.A., Dann, E.K., and Aitken, E.A. (2016). Effects of silicon treatment and inoculation with *Fusarium oxysporum* f. sp. *vasinfectum* on cellular defences in root tissues of two cotton cultivars. *Ann. Bot*., 118, 219–226. doi: 10.1093/aob/ mcw095.

Wang, M., Gao, L., Dong, S., Sun, Y., Shen, Q., & Guo, S. (2017). Role of silicon on plant–pathogen interactions. *Frontiers in Plant Science*, 8, 701.

Wiese, J., Wiese, H., Schwartz, J., and Schubert, S. (2005). Osmotic stress and silicon act additively in enhancing pathogen resistance in barley against barley powdery mildew. *J. Plant Nutr. Soil Sci*., 168, 269–274. doi: 10.1002/jpln.2004 20490

CHAPTER 10

EFFECT OF FLUIDIZED BED HEIGHT ON PRESSURE DROP IN VERTICAL FLUID BED DRYER

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INTRODUCTION

Salt is a mineral rich mineral type and is generally used as a condiment and food preservative. It is thought that the origin of the word "salary", which means salary in the English language, comes from the word "salt" (salt) (Elias et al., 2020). Today, salt is a substance; it is used directly or indirectly in agriculture, animal husbandry, medicine, traffic, and industry branches, especially as food (Güngörmez, 2015).

Drying is the process of removing water from a substance with the help of a heat source. The water is given enough energy to reach the latent evaporation energy. Accordingly, water is converted into water vapor and separated from the environment (Kepceoğlu et al., 2020).

Drying is a complicated process that involves simultaneous heat and mass transfer. Water molecule transport has a close relationship with the drying process, including molecular diffusion, such as capillary motion, liquid diffusion, vapor diffusion, and hydrodynamics (Çelen et al., 2017).

Conditions such as the structure of the product to be dried, the energy source to be used, and the drying capacity determine the type of drying. There are different dryer models according to the drying type. The main founding models used in the industry are; rotary dryer, belt dryer, vacuum dryer, microwave dryer, fluid bed dryer, hybrid dryer, etc. (Souza et al., 2021; Köse Tınmaz et al., 2019; Ekici et al., 2021; Çelen and Karataşer, 2019).

Today, fluidized bed dryers have replaced traditional drying methods due to their high drying rates, thermal efficiency, small flow area, low cost, and easy controllability. In a fluidized bed drying process, the product is fluidized in the dryer chamber, ensuring an equal distribution of material particles, and thus heat and mass transfer are achieved (Parlak, 2014). Fluidized bed drying is used in chemical, coal, pharmaceutical, food, waste, and biomass management processes (Bizmark et al., 2010; Zanoelo; 2007; Chen et al., 2020; Sozzi et al., 2021; Yan et al., 2022).

In this study, the drying of salt products in static fluidized bed dryer equipment was investigated. The effects of air velocity, air temperature, and bed height parameters on the drying performance were investigated. The bed height was changed by keeping the speed and temperature constant in the parameters. Pressure drop values were calculated. Pressure value, drying time curve, and fluidization conditions were investigated in the experiments carried out in the laboratory environment. As a result of the study, it is aimed to determine how these parameters affect the drying of the salt product in a pilot fluid bed dryer and to form the basis for the main machine to be manufactured later.

MATERIALS AND METHOD

Salt

The salt used in this study was the lake salt from Izmir Tuz Lake and was obtained from a local company (Figure 1). The salt subjected to drying in the experiments is not raw salt but salt brought to drying conditions after certain processes (pre-treatment, evaporation, grinding, washing, centrifugation, etc.) in the specified establishment (Pektaş, 2022).

Figure 1. Salt sample

Moisture Analyzer

The basic design of the moisture analyzer consists of a precision balance and a heater. Working principle: It gives the moisture value as a percentage by calculating the difference between the initial weight of he sample to be measured and the new weight value formed at the end of the drying process.

In this study, a Radwag brand MA50.R model moisture analyzer, whose image is shown in Figure 2, was used.

Figure 2. Radwag MA50.R moisture analyzer

Sieve Device

The dimensional separation process based on the principle that a product can pass or fail to pass through known ranges is called sieving. Sieve analysis is performed to determine the particle size distribution of particles of different diameters. Determining the amount according to the particle diameters of the sieve analyzed product expresses the size distribution. Laboratory sieve shakers are used because they give fast and reproducible results in sieve analysis. In the sieve shaker, sieve selection is made by considering the particle diameters of the product to be measured. The selected sieves are arranged in such a way that, starting from the sieve with the largest hole opening, the opening gets smaller from top to bottom. When the sieving process is completed, the products collected on the sieves are weighed, and it is concluded how much product is in that particle size. Dimensional distribution is achieved by proportioning the total amount of sieved product on the basis of grain size. In this study, the Reetcsh brand As200 Basic model sieve device, whose image is available in Figure 3, was used.

Figure 3. Reetcsh As 200 Basic sieve device

Sieves with 4000, 3500, 3000, 2000, 1000, and 500 micron particle sizes were used in the sieve analysis. The test was carried out for 10 minutes at 90 rpm. In the sieve analysis, firstly, the product to be distributed 200 grams was prepared by weighing. Then, the weights of the sieves to be used were weighed. After the process was completed in the sieving device, the sieves were weighed again and the amount of salt remaining on the sieve was found.

Fluid Bed Dryer

In this study, a laboratory type static fluidized bed dryer located in the Asos Process Engineering company, whose image is shown in Figure 4, was used. The fan equipment with which the compressed drying air is supplied is indicated by the number 1. The resistance heater is indicated by the number 2. The piping through which the hot air is transferred into the machine is indicated by the number 3. On this line, there is a manometer to measure the under-sieve pressure. Part 4 shows the machine chassis, and Part 5 shows the product hopper. The glass column, in which the boiling movement is observed during drying, is shown in number 6. The filter cloth fitted to prevent the escaping of the powder product during drying is shown with the number 7.

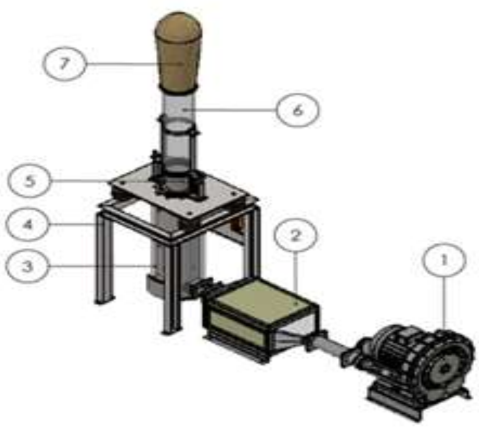

Figure 4. Laboratory type static fluidized bed dryer system

Moisture Amount

Moisture content (M_w) is defined as the ratio of the amount of water in a product to the total weight of the product. It is usually expressed in terms of "%". Equation 1 shows the calculation formulation of the moisture content.

$$\mathrm{Mw} = \frac{Total\ Water\ Weight\ (kg)}{\text{Total Sample Weight}\ (kg)} x100 \qquad (1)$$

Analysis Method

The flow program was used in the analysis made in this study.The drag model between particles and air, Syamlal-O'Brien, was used. The Syamlal-O'Brien drag model is used to determine the hydrodynamics of the bed in turbulent fluidization. In the analysis, the particle diameter was determined as 2.4 mm. Figure 5 shows the dryer model applied in program. The air inlet is defined as the bottom of the geometry, the air outlet is defined as the upper part, and the side walls are defined as non-slip surfaces. The geometry is 200 mm in the x direction and 1500 mm in the y direction. The analysis was carried out in two dimensions. Bed height, air velocity, and air temperature were taken as variables in the analysis.

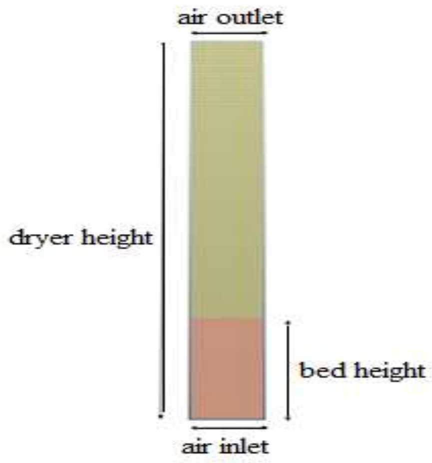

Figure 5. Dryer model

RESULTS AND DISCUSSION

Sieve Analysis Findings

In Table 1, the results of the sieve analysis of the salt in which the drying experiments will be carried out are given. In the theoretical calculations, the diameter of the salt particle was accepted as 2.4 mm.

Table 1. Salt sieve analysis results

Sample Quantity (g): 200						
Number of Revolutions (rpm): 90						
Test Time (min): 10						

Sieve No	Particle Size (micron,μ)	Hole Size (mesh)	Sieve Weight (g)	Full Sieve Weight (g)	Sample Weight (g)	Weight Value%
1	4000	5	398,2	431,6	33,4	16,7
2	3500	6	359	385,8	26,8	13,4
3	3000	8	365	389,4	24,4	12,2

Pressure Drop Values

In laboratory trials, the system was operated at an air speed of 1.36 m/s without the product in the dryer. In this way, the pressure value created by the sieve was reached at the desired air speed. In the test, sudden increases and fluctuations were experienced in the manometer at the moment of overcoming the pressure created by the bed and transitioning to fluidization. In this study, the manometer value is assumed to be constant when fluidization occurs. In the drying tests, the pressure drop value caused by the product was found by subtracting the pressure value under the sieve from the manometer value at the boiling point.

Table 2. Pressure Drop Values

No	U (m/s)	T (ºC)	H (mm)	US (Pa)	PB (Pa)	PP (Pa)
1	1.36	120	70	800	1100	300
2	1.36	120	80	800	1150	350
3	1.36	120	90	800	1200	400

U: Air speed, T: Drying Temperature, H: Bed Height, US: Under Sieve Pressure, PB: Pressure Value During Boiling, PP: Pressure Value Created by Product

In Figure 7, the test plan and the pressure drop values created by the product are shown with the graphic method. When the tests were compared among themselves, it was observed that the pressure drop increased as the bed height increased. The temperature parameter had no observable effect on the pressure drop.

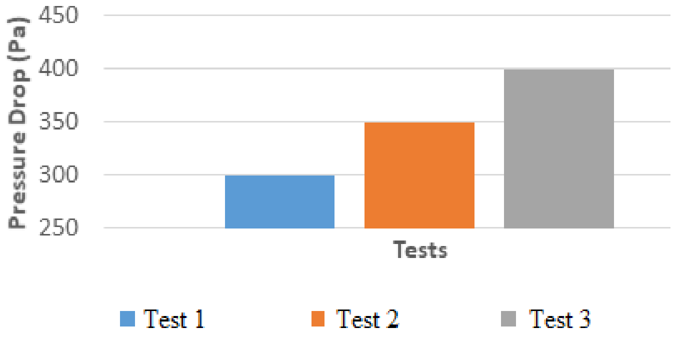

Figure 7. Graph of effect of fluidized salt product on pressure drop (Test 1: 70 mm, Test 2: 80 mm, Test 3: 90 mm)

Test Drying Results

The test time was determined as 5 minutes. Table 3 shows the moisture values of the samples taken. In this study, it has been observed that the product reaches the moisture value to be considered dry in 3 minutes on average. In order to discuss which parameter is more effective on the drying time, the moisture values of the samples taken at 2.5 minutes were examined. Samples were taken through a fluidized bed and may not accurately reflect the total moisture in the chamber.

Table 3. Moisture measurement results of drying test

No	U (m/s)	T (ºC)	H (mm)	IMV	FMV	SMV	TMV	OMV
1	1.36	120	70	3	1.988	1.008	0.057	0.051
2	1.36	120	80	3	2.095	1.055	0.082	0.072
3	1.36	120	90	3	2.173	1.16	0.088	0.072

IMV: Input Moisture Value, FMV: First Sample Moisture Value, SMV: Second Sample Moisture Value, TMV: Third Sample Moisture Value, OMV: Out Moisture Value

The moisture ratio results of the experiments are shown graphically in Figure 8. When the trials were examined, it was determined that the bed height had a negative effect. The fact that the temperature was the maximum value of 160°C in four of the five selected trials reveals the argument that the temperature is the most effective on the drying time.

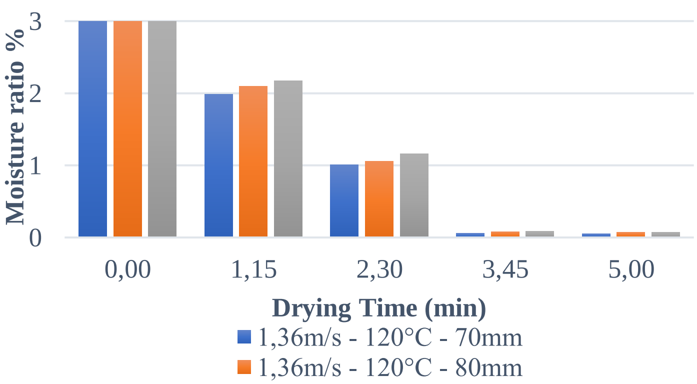

Figure 8. Moisture change graph over time

CONCLUSIONS

In this study, the effect ratios of the factors affecting the fluid bed dryer's performance were investigated. These factors are air velocity, temperature, and bed height parameters. The speed and temperature of the parameters were kept constant, and the bed height was changed. The selection of the selected numerical values, the salt product to be dried and the characteristics of the laboratory type static dryer system in which the drying process is carried out were taken into account.

The basic principle in fluidized bed dryers is that the solid product overcomes gravity and behaves like a liquid, that is, its fluidization. Therefore, the first criterion for determining the speed in this type of dryer is always to ensure the minimum fluidization rate. In this study, the speed parameter was chosen as 1.36m/s.

In the determination of the temperature parameter, the product to be dried should be at a level that will ensure that the structural and physical criteria are maintained in the process of becoming the final product. In this study, the air temperature chosen to dry the salt product with 3% moisture is 120°C.

The first criterion in the selection of the numerical value of the bed height parameter is the dryer design. Considering the product chamber of the laboratory type static dryer equipment we used in this study, the bed height was selected as 70 mm, 80 mm, and 90 mm. Excessive bed height will increase the air velocity required for fluidization and the temperature required for drying.

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REFERENCE

Bizmark, N., Mostoufi, N., Sotudeh-Gharebagh, R., Ehsani, H., (2010). Sequential Modeling of Fluidized Bed Paddy Dryer, Journal of Food Engineering, Vol. 101, pp 303–308.

Chen, Q., Hu, J., Yang, H., Wang, D., Liu, H., Wang, X. and Chen, H., (2020). Experiment and simulation of the pneumatic classification and drying of coking coal in a fluidized bed dryer, Vol. 214, pp 115364.

Çelen, S. and Karataşer, M. A., (2019). Investigation of the Performance of a Hybrid Dryer Designed for the Food Industry, Foods, Vol. 8, No. 2, pp 81.

Çelen, S., Haksever, A. and Moralar, A. (2017). The Effects of Microwave Energy to the Drying of Apple (Gala) Slices, Karaelmas Science & Engineering Journal, Vol. 7, No. 1, pp 228-236.

Ekici, T., E Köse Tınmaz E., Çelen, S., (2021). Effect Of Microwave And Conveyor Drying On The Drying Characteristics, Modeling, And Thermal Properties Of Municıpal Wastewater Sludge, Journal of Scientific Reports-A, Vol. 47, pp 117-138.

Elias, M., Laranjo, M., Agulheiro-Santos, A. C., & Potes, M. E. (2020). The role of salt on food and human health. Salt in the Earth (1st ed.) (19-45). London: Intechopen

Güngörmez, H. (2015). İktisadi açıdan bir faliyet: Tuzluca kaya tuzlası. Coğrafya Dergisi, Vol. 30, pp 26-37.

Kepceoğlu, S., Moralar, A. and Çelen, S. (2020). Determination of the ideal flow rate in drying of tabla salt. Theory and Research in Engineering II (1.Baskı) içinde (35-46). Ankara: Gece Kitaplığı.

Köse Tınmaz E., Çelen, S., Çelik S. Ö., Akın, G. and Akyıldız, A. (2019). Drying Of Drilling Sludge: Conventional And Microwave Drying, Hittite Journal Of Science & Engineering, Vol. 6, No. 2, pp 119-122.

Parlak, N., (2014). Investigation Of Drying Kinetics Of Ginger In A Fluidized Bed Dryer, Journal of the Faculty of Engineering and Architecture of Gazi University, Vol 29, No 2, pp 261-269.

Pektaş, S. (2022). Akışkan Yataklı Kurutucu Performansını Etkileyen Faktörlerin Optimizasyonu, Tekirdağ Namık Kemal Üniversitesi, Yüksek Lisans Tezi, Tekirdağ, Türkiye.

Souza, G.F.M.V., Avendano, P.S., Francisquetti, M.C.C., Ferreira, F.R.C., Duarte, C.R. and Barrozo, M.A.S. (2021). Modeling of heat and mass transfer in a non-conventional rotary dryer, Applied Thermal Engineering, Vol. 182, pp 116118.

Sozzi, A., Zambon, M., Mazza, G. and Salvatori, D. (2021). Fluidized bed drying of blackberry wastes: Drying kinetics, particle characterization and nutritional value of the obtained granular solids, Powder Technology, Vol. 385, pp 47-49.

Yan, Y., Qi, B., Zhang, W.,. Wang, X. and Mo, Q. (2022). Investigations into the drying kinetics of biomass in a fluidized bed dryer using electrostatic sensing and digital imaging techniques, Fuel, Vol. 308, pp 122000.

Zanoelo, E. F., (2007). A Theoretical and Experimental Study of Simultaneous Heat and Mass Transport Resistances in a Shallow Fluidized Bed Dryer of Mate Leaves, Chemical Engineering and Processing, Vol. 46, pp 1365–1375.

CHAPTER 11

CAN SOIL ORGANIC MATTER BE THE ROBUST INDICATOR OF SOIL HEALTH ABILITY AND SOIL QUALITY?

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INTRODUCTION

Soil is an important component in the earth ecosystem and plays a key role in human life and health (Brevik et al., 2020; Brevik, Steffan, Burgess, & Cerdà, 2017; Keesstra et al., 2016; Krzywoszynska, 2019; G. Li, Sun, Ren, Luo, & Zhu, 2018; Steffan, Brevik, Burgess, & Cerdà, 2018). Soil health and fertility are also important factors that affect air, water, and all organisms' life on this planet (Ashraf & Hanafiah, 2019). To evaluate anything in this world, whether it is alive or not, we pay attention to its quality. A comprehensive definition of soil quality (SQ) is very broad and diverse. Generally, according to many authors, SQ is the ability of soil to contribute to ecosystem services to increase the plants' growth, protect soil from all kinds of erosion by its strong structure stability and also prohibit air and water pollution by using organic and chemical components to promote its inherent buffering potential (Bouma et al., 2017; Bünemann et al., 2018; Doran & Parkin, 1994; Sims, Cunningham, & Sumner, 1997). Additionally, soil quality is a major area of interest not only in soil science and agriculture but also in all fields attributed to ecosystem services (Drobnik, Greiner, Keller, & Grêt-Regamey, 2018; Soto, Padilla, & de Vente, 2020). The issue of soil organic matter (SOM) effect on SQ has received considerable critical attention. SOM determination is a tool for understanding human effects on the ecosystem, moreover, finding one method to enhance soil health (Coleman & Elliot, 1988; Tiessen, Cuevas, & Chacon, 1994).

Although many studies have emphasized the importance of SOM and therefore labile carbon in soil organic carbon (SOC) management (Awale, Emeson, & Machado, 2017; Culman et al., 2012; Geraei, Hojati, Landi, & Cano, 2016; Ibrahim, Cao, Zhan, Li, & Iqbal, 2015; Mirsky, Lanyon, & Needelman, 2008) and its major effect on soil quality measurements (Bongiorno et al., 2019; Culman et al., 2012; Geraei et al., 2016; Gregorich, Carter, Angers, Monreal, & Ellert, 1994; Wander, 2004) but the studies which directly focus on how SOM effect on physical, chemical and biological properties which could be the comprehensive indicator of soil quality assessments is limited (Bünemann et al., 2018). However, some properties of the soil for SQ measurements are natural or inherent characteristics but some of them are obtained from environmental changes and management practices (Schwilch et al., 2016). This approach lighted us the way to find some properties of the soil, which are sensitive to management functions to show us how and whether determined SQ is positively changed or not. Although, several studies in the field of soil science have focused on the SOM impact on SQ we aim to give a clear and detailed review of the published results to prove our hypothesis about SOM and SOC as the comprehensive indicator of SQ with respect to its positive effect on all soil properties which lead to enhance crop yield.

SOIL ORGANIC MATTER (SOM)

SOM is a natural resource (Campbell & Paustian, 2015) produced by plants or animals which is returned to the soil through the decomposition process (A. Edward Johnston, Paul R. Poulton, & Kevin

Coleman, 2009). As indicated by Manson (2018) alive organisms which, are smaller than 2 mm are also considered part of SOM. Generally, due to Jones, Nguyen, and Finlay (2009) from 20- 40% of photosynthetic C which moved to below-ground, 2-18% converted to SOM.

The chemical and biochemical reactions which are worked in the decomposition process of SOM were described by Flaig, Beutelspacher, and Rietz (1975); Schnitzer (1978); Stevenson (1994); Ziechmann (1980). Stolt and Lindbo (2010) and Ismail-Meyer, Stolt, and Lindbo (2018) by micromorphological approaches reported that land use and climate change can have a great influence on the soil environment and thus, the quality, decomposition, and distribution of OM in the soil. In consequence, Cotrufo et al. (2015) in grassland in Kansas, USA, for three years used isotopically labeled litter and laboratory incubations to measure the decomposition rates of litter. They come to the conclusion that there are two ways to litter decomposition and SOM formation efficiently. One happens in the early step of decomposition when non-structural materials were lost from litter. The other way occurred when both non-structural and structural compounds were lost at the end of decomposition process at similar rates. Indeed, the SOM decomposition rate is under the effect of global environmental change which has a great impact on the global C cycle (Sierra, Trumbore, Davidson, Vicca, & Janssens, 2015). Soil Fauna have also influenced the microbial community and the decomposition rate of litter and SOM (Frouz, 2018). Conant et al.

(2011); Davidson, Janssens, and Luo (2006); Friedlingstein et al. (2006) also emphasized that high temperature can enhance the SOM decomposition rate. Aeration, especially after cultivation in the tropics and the semi-arid regions, cause to rapidly decomposition of SOM (Ashagrie, Zech, Guggenberger, & Mamo, 2007).

SOM plays an important role in agriculture through improved soil physical properties like structural stability and aggregation (Tisdall, 2020). In this respect, SOM and clay content can be useful tools for predicting soil particle density (Dp) (P Schjønning, McBride, Keller, & Obour, 2017). SOM helps to minimize tillage and protect the soil against erosion. Apart from erosion, from the SOM content, we can estimate the severity of different forms of soil degradation. Therefore, according to Obalum, Chibuike, Peth, and Ouyang (2017) SOM can be the sole indicator of soil degradation.

On the other hand, SOM acts as a powerhouse of plant nutrients and helps to increase the fertility of the soil (Senesi & Loffredo, 2018) by humus (Bot & Benites, 2005). SOM distribution is vital to controlling the mobility of pollutants (Ondrasek et al., 2019).

SOM models also are the methods to better comprehend nutrient cycling under the effect of SOM and understand how and which soil management practices are better to use in long term (Campbell & Paustian, 2015; Parton, Ojima, & Schimel, 2020). To indicate the importance of soil management in enhancing SOM contents Machmuller et al. (2015) reported that management practices in the soils with high degradation in the southeastern United States led to the accumulation of C at 8.0 Mg ha^{-1} yr^{-1}, enhancing cation exchange (by 95%) and water holding capacity (by 34%) and thus, reduced soil demands to fertilizer and irrigation. Furthermore, Mirzaee, Ghorbani-Dashtaki, Mohammadi, Asadi, and Asadzadeh (2016) introduced the ANNOK (artificial neural network ordinary kriging) model as a hybrid geostatistical method for the best estimation of SOM spatial distribution, to prepare SOM maps and soil management in Selin plain, northwest Iran.

According to Y. Chen, Nobili, and Aviad (2004) definition of humus is the natural organic matter with no identifiable plant and animal residues or living organisms. Humus, which is composed of humic substances (Angst, Mueller, Nierop, & Simpson, 2021), has a direct impact on the growth of plants by adsorbing nutrients like P in the available form for the plant in the soil (Gerke, 2018). In addition, Lehmann et al. (2008) indicated that “humic substances” contain countless definable structures. Apart from the labile portion of SOM, humic substances which represent 40%–60% of SOM (Paul, Collins, & Leavitt, 2001) are more stable and contain a great portion of SOC and total N (Milori, Martin-Neto, Bayer, Mielniczuk, & Bagnato, 2002). The polymerization of phenolic molecules, which are from the source of the degradation of lignin to phenylpropene (Flaig et al., 1975; Haider & Martin, 1967; Waksman, 1936) through the help of soil minerals, and microorganisms is the central reaction which improves the formation of soil humic substances (Gerke, 2018). Humic substances by enhancing the buffering capacity of the soil can also bind heavy metals and lead to reduce soil pollution (MacCarthy, 2001). Humic substances contained humin (H=non soluble), humic acid (HA=soluble under alkaline conditions), and fulvic acid (FA=soluble under both alkaline and acidic conditions) (Sutton & Sposito, 2005). Guimarães et al. (2013) investigated humic substance content under different land uses, in the northeast region of Brazil. They observed a great loss of SOM (47.5%) in the topsoil of the conventional coconut and citrus orchards and reported high SOM content in the in integrated coconut orchard soil due to using cover crops. According to their measurements due to the loss of fulvic acids (H/FA (>1.0)), labile fractions of SOM were high in the subsurface. They concluded that the distributions of FA, HA, and H were 12% –32.5%, 12% –34.5%, and 40%–69.5%, respectively.

Therefore, the mechanisms of SOM perseverance seem to be the best investigations on the molecular level, in the framework of the factors affecting SOM stability. The portion of SOM, which is resistant to decomposition is named as ‘recalcitrant SOM’(Kleber, 2010). As mentioned by Deb, Bhadoria, Mandal, Rakshit, and Singh (2015), SOM is made up of simple and complex compounds, that may have different stability. A plethora of studies has investigated on stabilized SOM. Angst et al. (2021) reported that SOM is stabilized by two mechanisms. One mechanism is the formation of mineral-associated organic matter and the other one is aggregate formation, which is composed mostly of microbial compounds. They also indicated that land use and soil type seem to strongly influence microbial and plant compounds in stabilizing SOM. Thus, in Grasslands or fertile Chernozems or Luvisols microbial compounds and in forest soils or Podzols/Alfisols plant compounds seem to contribute to SOM stabilization. Shahbaz, Kuzyakov, and Heitkamp (2017) reported low and high plant and root residual input to the soil can improve SOM mineralization by 50% and 90%, respectively which can reduce SOM stabilization. According to Cotrufo, Wallenstein, Boot, Denef, and Paul (2013); Miltner, Bombach, Schmidt-Brücken, and Kästner (2012); Schmidt et al. (2011) in addition to land use and soil type, not only the molecular structure but also the optimal environment for the useful microbes of OM activity could help to stabilize SOM.

According to Carter (2020) mean annual temperature and precipitation provide remote control over SOM storage, while soil type and vegetation cover have close control. He also highlighted that the soil topography and drainage can also shift the microclimate and as a result, it creates a wide range of different microclimates and greatly impacts SOM storage.

Hobley, Wilson, Wilkie, Gray, and Koen (2015) re-emphasize the significant role of climate and its relation with soil depth in controlling the stabilization of SOM and its storage. They stated that there is a decrease in SOM with increasing soil depth. This result conforms to Murphy (2015) who indicated that SOM has a strong impact on the physical properties of the topsoil (0-20 cm) where seeds grow.

In contrast to the above founding which claimed about persistent ‘large-molecular-size humic substances’ in soils, Lehmann and Kleber

(2015) pointed out that SOM is a gradually decomposing organic compound and used this nature of SOM for carbon-climate interactions and soil management. Kögel-Knabner (2017) also demonstrated that the persistence of organic matter in the soil is strongly dependent on its local environment and system properties.

In contrary to traditional theory C. Liang, Schimel, and Jastrow (2017); Miltner et al. (2012) stated that apart from undecomposed SOM which originated from plant materials the other compounds are metabolized by microorganisms and processed again in the microorganisms' food chain and left as necromass. Thus, some parts of these organic compounds may be composed of microbial debris and their biomolecular structure is dominated by fungal and bacterial cell coats. To support this, several authors have reported quantitative microbial models on the abiotic stabilization of SOM which originated from microbial residues (Manzoni, Schaeffer, Katul, Porporato, & Schimel, 2014; Tang & Riley, 2015). Moreover, although Kaiser, Zederer, Ellerbrock, Sommer, and Ludwig (2016); Kleber et al. (2015) pointed out that clay mineralogy gives obvious information about SOM dynamics, according to Kallenbach, Frey, and Grandy (2016) where higher soil microbial biomass (MB) production and fungal accumulation were observed, SOM accumulation is originated from microbial residues. They want to emphasize that the microbial community's residue, which enters SOM may have a more important effect than soil mineral structure impact on SOM stabilization.

Undoubtedly, SOM plays an important role in human health (Bevis, 2015; Hurst et al., 2013; Mitchell et al., 2007). Interestingly, Wood, Tirfessa, and Baudron (2018) reported that protein and Zinc (Zn) contents of wheat yields were related to N and carbon (C) content of organic matter (OM), respectively. They also suggested that increasing the N and C content of OM, by 1% led to an increase of protein and Zn equivalent to the needs of 0.1 and 0.2 additional people per hectare, respectively.

SOM by its significant impact on soil properties directly affects SQ (Wendling, Jucksch, Mendonca, & Alvarenga, 2010).

The largest component of SOM consists of plant residuals which contain about 90% moisture. The remaining part of this residue consists of oxygen (O), C, hydrogen (H), and essential macronutrients for crop growth. SOM has been increasingly great associated with C, which has altered the aims of papers since 1990 (Smith et al., 2018). SOM represents the main reservoir of carbon (C) and stores more C than the atmosphere and vegetation (Lehmann & Kleber, 2015) and is a vital factor in soil fertility, and climate change mitigation (Ciais et al., 2014; Trivedi, Singh, & Singh, 2018). According to Senesi and Loffredo (2018), the total SOC content is been measured at 22×10^{14} kg, while the other C stocker contains 21×10^{14} kg C.

SOIL QUALITY (SQ)

A large and growing body of literature has investigated the definition of soil quality. Besides water and air quality, soil quality is one of the most important components of ecosystem quality (Andrews, Karlen, & Mitchell, 2002; Bünemann et al., 2018). In general, soil quality is the ability of the soil from inherent characteristics (Doran & Parkin, 1994) to promote plant growth (Larson & Pierce, 1991; Mausel, 1971), and animal and plant health by buffering the potential to prevent water and air from pollution by industrial chemicals (Sims et al., 1997) and contributing to ecosystem services, including biomass production (Bouma et al., 2017). Hermans et al. (2020) indicated that soil ecosystems include the complexity of the relationship between biological and physicochemical variables, all of which contribute to overall soil quality. In the same vein, Oliver and Gregory (2015) indicated that soils with high quality are important for preserving the agricultural and livestock industries, on which food security and financial conditions depended on it. A considerable amount of literature has been published with mentions the main title of determining SQ and the factors affecting SQ. For instance, Tresch et al. (2018) reported an increased SOC/clay ratio due to garden management practices, which explains a higher structural soil quality. In addition, Edmondson, Davies, Gaston, and Leake (2014) suggested better soil quality in urban gardens compare to agricultural soils. Likewise, K Nabiollahi, Golmohamadi, Taghizadeh-Mehrjardi, Kerry, and Davari (2018) pointed out that soil quality indexes SQI values at cultivating land slopes were low. Therefore, they suggested soil management to improve soil quality by using sustainable functions and giving up overgrazing in these lands. Y. Zhang et al. (2019) have also determined SQ in 302 soil samples from 11 vegetation types in karst landscapes of southwest China. They found that vegetation species had a major impact on all soil properties and therefore on soil quality. They also reported that vegetation restoration practices can increase SQ and the highest and lowest SQI was observed under the cover of the forest and crop, respectively. High SQ was determined under deciduous broad-leaved forest and combined needle-broadleaf forest in Mount Tai, Central Eastern China (Shao, Ai, Sun, Hou, & Dong, 2020). Different land use types can affect the SQ (Marzaioli, D'Ascoli, De Pascale, & Rutigliano, 2010). The measured SQ under Oxisol natural vegetation cover was higher than that of human-centered uses in Brazil (Leite Chaves, Concha Lozada, & Gaspar, 2017).

Moreover, improving soil quality by biochar, which has high C content (60–80%) and high potential of C sequestration and brown coal waste as OM input was reported by Amoah-Antwi et al. (2020) (Fig. 1). Stockmann et al. (2013) also introduce biochar as the largest OC storage in the soil. However, high quality of the OM amendments is needed to enhance SQ (Cotrufo et al., 2013). Soil and crop type (Cheng, Ding, Li, Zhang, & Wang, 2016) and soil management practices (Alaoui et al., 2020) is also important factor in SQ measurement. The SQ under Inceptisols was better than Entisols and Alfisols in the rice-rice system in the Indo-Gangetic Plains (IGP) of South Asia (S. Biswas et al., 2017).

Core Indicator of SQ

SQ indicators play a significant role in ecosystem restoration due to the great diversity in soil, climate, and ecosystem types (Muñoz-Rojas, 2018). The main objective to assess soil quality is to find a precise and confident method for soil management, especially on agricultural land (Doran, Jones, Arshad, & Gilley, 2018). According to Nortcliff (2002) converse to air and water, due to the slow reaction of the soil to manage properties, it's very difficult to determine soil quality changes before the observation of the soil management outcomes. Therefore, as noted by Bünemann et al. (2018), the management functions often have only limited short-term influences on soil properties like texture and mineralogy, and biological properties. Therefore, the most important way in soil quality assessment is to find the list of the most sensitive soil properties and rapidly reflect the indicators of soil quality (Maurya et al., 2020). Furthermore, the relationship between soil management and soil quality has been widely investigated by Z. Bai et al. (2018); Spiegel et al. (2015). As a matter of fact, Islam and Weil (2000) highlighted that soil quality is determined by soil properties that are neither stable assessments that are insensitive to management practices, nor so easily vary and show long-term changes. Additionally, as others Bünemann et al. (2018); Reeves (1997) have highlighted, SOM is a core indicator of soil quality which influences all soil chemical properties such as nutrient cycling, pH and available P and K, physical properties like soil aggregate formation, and water holding capacity and biological properties such as providing a habitat for biodiversity. Moreover, improving soil quality by biochar which has high C content (60%–80%) and high potential of C sequestration and brown coal waste as OM input was reported by Amoah-Antwi et al. (2020) (Fig. 1). Stockmann et al. (2013) also introduce biochar as the largest OC storage in the soil. Besides the high potential of biochar in C sequestration, it has greatly impacted reducing GHGs emissions from the soil and GHGs concentrations such as N_2O and CO_2 in the atmosphere and helped to mitigate climate change (Case, Uno, Nakajima, Stoumann Jensen, & Akiyama, 2018; Oladele & Adetunji, 2021; Pujol Pereira, Suddick, & Six, 2016). However, high-quality OM amendments are needed for enhancing SQ (Cotrufo et al., 2013).

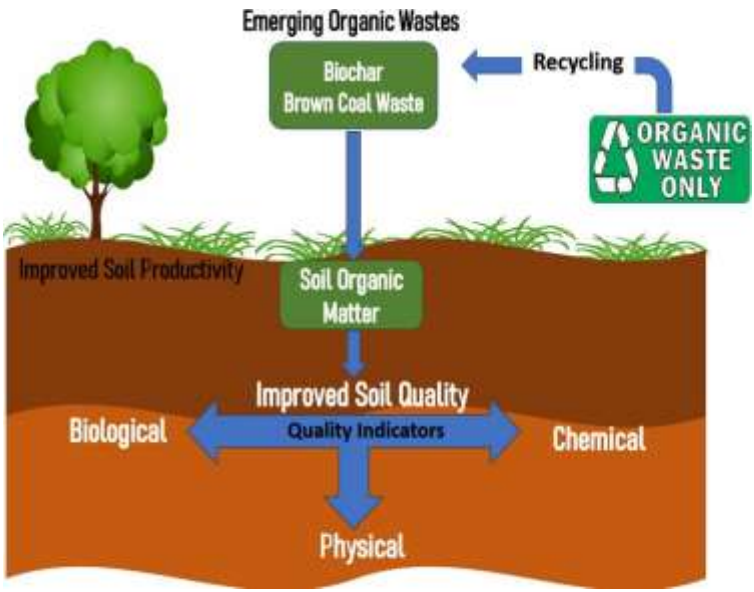

Figure 1. The effect of biochar and brown coal waste as organic matter input for improving SQ (Source= (Amoah-Antwi et al., 2020)).

HOW SOM AFFECTS INDUCTIVE SQ – BIOLOGICAL PROPERTIES?

Soil Biological Properties and SQ:

It has been demonstrated that less content of soil biota has a negative effect on soil properties and therefore on soil ecosystem health (Handa et al., 2014). Soil microorganism community content is just < 0.5% of the total soil (J. C. Biswas & Naher, 2019) but this low portion has a critical role in soil fertility and SQ. Soil macrofauna like earthworms burrow the soil and create soil macroporosity to enhance water infiltration and stable structure formation and helping the decomposition of plant residues and inputting OM into the soil can help improve the nutrient cycle in the soil (Spurgeon, Keith, Schmidt, Lammertsma, & Faber, 2013) and modify soil fertility and enhance SQ and increase fruit yield (Sofo, Mininni, & Ricciuti, 2020). Soil mesofauna differences were connected with the SQI, which can subsequently be utilized as accommodating bioindicators in soil management practices (Heydari et al., 2020).

There is a long discussion on the best selection of biological indicators that affect soil quality (Schloter, Nannipieri, Sørensen, & van Elsas, 2018; Thiele-Bruhn et al., 2020). This view is supported by Hermans et al. (2020) who determined the bacterial community composition of 3000 soil samples from 606 sites in New Zealand. They came to the conclusion that analyzing bacterial DNA data can be used to check SQ. Indeed, the soils contain high content of microbial life, which can protect the other organism from diseases and pathogens and help plant growth (Compant, Duffy, Nowak, Clément, & Ait Barka, 2005; R. Mendes, 2009; Wolters, 2001). Moreover, using enzyme activity as a soil quality indicator is a feasible method to evaluate the effect of pesticides on agricultural soils (Attademo, Sanchez-Hernandez, Lajmanovich, Repetti, & Peltzer, 2021). Soil microbial community also helps to reduce soil pollution by heavy metal contamination (Fazekašová & Fazekaš, 2020). In this case, Aponte et al. (2020) proposed the use of enzyme activities to increase soil biotic functions and therefore, soil quality in heavy metal-contaminated soils.

Moreover, soil microorganisms by their diversity and composition have a great impact on changing the chemical properties of the soil (Zhalnina et al., 2015; Q. Zhang et al., 2020), nutrient availability (Tian, Razavi, Zhang, Wang, & Blagodatskaya, 2020), soil physical properties (Ascari, de Araújo, Mendes, Prieto, & de Carvalho, 2020) and managing soil fertility (Mohamed et al., 2021). On the other hand, surveys such as that conducted by Hermans et al. (2017); Kaminsky, Trouche, and Morales (2017); Prober et al. (2015) have shown that soil type (Gömöryová et al., 2020), plant diversity (Gillespie et al., 2020; Wen et al., 2020; Zhong et al., 2020), soil water (Barreiro et al., 2020; Q. Chen, Niu, Hu, Luo, & Zhang, 2020), land use (de Carvalho et al., 2016; Plassart et al., 2019; Yang, Siddique, & Liu, 2020), vegetation and topography (Tajik, Ayoubi, & Lorenz, 2020) soil management (Cassman et al., 2016; De Corato, 2020; Figuerola, Guerrero, Türkowsky, Wall, & Erijman, 2015; B. Sun et al., 2020), soil chemical properties (Y.-C. Bai et al., 2020; Griffiths et al., 2016; X. Pan et al., 2020; Roh et al., 2010; Yuan et al., 2013) as well as, physical properties (Barreiro et al., 2020; Constancias, 2014; Gałązka, Niedźwiecki, Grządziel, & Gawryjołek, 2020; Hartmann et al., 2012) which have a significant effect on SOM content (Dignam et al., 2018) can change microbial communities and SQ. In this case, in their major study, Yuanji Wang et al. (2020) reported that mulching as a soil management practice increases the diversity and population of microorganisms and promotes the relationship between microorganisms, which is beneficial for SQ.

Soil Biological Properties and SOM (SOC)

Several studies thus far have linked soil biological activity with SOM or SOC (Herrick & Wander, 2018). Soil microorganisms play an important role in C cycling between soil and atmosphere from one side decrease SOC storage by mineralization, on the other hand, enhance SOC pool by MB formation and SOC stability by minerals (Babur & Dindaroglu, 2020; Kästner & Miltner, 2018; Sun, Wang, Hui, Jing, & Feng, 2020). Microorganisms also use SOC to adjust the balance of C stock in the soil and the atmosphere (Anthony, Crowther, Maynard, van den Hoogen, & Averill, 2020).

In addition, high SOC content provides more favorable environmental conditions for the microbial communities by improvement of soil aggregation, moisture, and proper soil temperature which can lead to an increase in microbial abundance (Helgason, Walley, & Germida, 2009; X. Zhang et al., 2018). But soil MB and its relationship with SOC decrease with increasing soil depth (T. Sun et al., 2020). Furthermore, the diversity and species of active rhizosphere microbial communities can also change during the C sequestration process (Song, Tong, Liu, & Li, 2020).

Different soil management practices can affect the microbial community (De Mastro et al., 2020) and enhance soil quality (Adetunji, Ncube, Mulidzi, & Lewu, 2020). In this way, Novara et al. (2020) demonstrated that the cover crop can increase the soil bacterial diversity, plant growth-promoting genera, and SOC stabilization, while the fungal diversity and drought-tolerant genera were higher under conventional tillage management practices. Cover crops also increase soil nitrogen content due to the symbiotic fixation of N_2 by increasing SOC content and soil microbial activity (Kocira et al., 2020).

In the poor soil with Ag and humus, the soil microbial community increased under heavy metals contamination compared to rich soil with humus which soil microbial species and their percentages are not influenced by the addition of heavy metals (Terekhova, Fedoseeva, Kiryushina, Caracciolo, & Verkhovtseva, 2021).

As indicated above SOC have a great impact to modify soil microorganisms to improve soil nutrient availability. In this vein, Brucker, Kernchen, and Spohn (2020) indicated that the microbial dissolution of P in apatite is limited by the availability of OC. Interestingly, in soils without P application, the bacteria change their communities, composition, and activity to extract limited and needed nutrients from SOC by increasing SOC mineralization (Wei et al., 2020).

Additionally, recent evidence suggests that although bacterial communities are important in soil health non-bacterial taxa like fungi and other microorganisms could be more useful for predicting soil quality (Hermans et al., 2020). The previous research has indicated that the abundance of earthworms under organic agriculture can increase soil aggregate stability and SOM content and therefore have a positive impact on soil quality (Z. Bai et al., 2018). There is also a positive correlation between SOM content and the spatial distribution of nematodes at the field scale (Quist et al., 2019). According to Tresch et al. (2018), higher content of SOC by garden management could lead to higher biological activity like earthworm densities for increasing soil quality compared to agricultural soils. In their study, Tresch et al. (2018) also, reported no correlation between heavy metals and earthworm communities in garden soils. A possible explanation for these results may be that high SOM content due to garden management can decrease the toxic impacts of heavy metals (Fliessbach, Martens, & Reber, 1994) and help to enhance SQ.

HOW SOM AFFECTS INDUCTIVE SQ – CHEMICAL PROPERTIES

Soil Chemical Properties and SQ

Besides other soil characteristics, there is a significantly positive correlation between soil chemical properties and SQ (Ranjendra & Gadekar, 2020; Teimouri, Mohamadi, Jalili, & Dick, 2018). This concurs well with Amorim et al. (2020) who reported the difference in the soil quality index (SQI) by the soil chemical properties such as pH, electrical conductivity (EC), and soil P and K content under pasture with long-term conservation management functions. The SQ can be measured by the chemical properties of the soil according to the soil type, different soil practices, and soil depth. Soil management and cropping system have a remarkable effect on soil chemical properties and thus, in SQ (Valani, Vezzani, & Cavalieri-Polizeli, 2020). This matches with a study by P. Li et al. (2019) who indicated that available N, SOM, and MB to TN ratios were the comprehensive indicators that limit wheat yield, which has a significant positive effect on SQI in the wheat-maize cropping system. Again, it was proven that using the catch crops (legumes + white mustard) in the cropping system usefully influenced the chemical SQ properties such as SOC and soil humus, P, Mg, and micronutrients and thereby, SQ and reduced soil phenolic compounds (Kwiatkowski, Harasim, & Staniak, 2020). P-fertilization of the soil as a soil management practice also led to enhancing soil properties, SOC, SQI, and crop yields (I. C. Mendes et al., 2021). In this case, Zarafshar et al. (2020) also indicated that under cultivated fields the soil C and N stocks and SQ were reduced compared to the soil under natural tree canopies. They also reported that plantation with Persian oak in Zagros forest can enhance soil productivity, as well as, SQ in the long-term. According to Chaganti et al. (2020), although the application of wastewater on sorghum can increase root zone soil salinity and sodicity and decline SQ, application of gypsum and sulfur as soil management practices can reduce soil SAR in arid regions. de Paul Obade (2019) also suggested SOC, available water content, and EC as the essential soil parameters that influence SQ. In addition, Xie et al. (2020) indicated that low content of TN and high level of EC are the main factors that limit the SQ of the bare soil in the initial stage of reclamation in the coastal saline soil of Eastern China. It has been suggested that soil Ca, P, pH, and OM were as imperative indicators for surveying the fertility status and SQ of the distinctive soils within the Tombel region in South-West Cameroon (Nguemezi, Tematio, Yemefack, Tsozue, & Silatsa, 2020). Contaminated water was applied to the soil beside the extensive use of chemical fertilizers and pesticides can change soil physical and chemical properties and therefore, decrease SQ (Singh & Dhumal, 2019). Tree density affects soil chemical properties like SOM, total P, available P, and N, and thereby, SQ (Ali et al., 2019). As a consequence, Mulyono, Suriadikusumah, Harriyanto, and Djuwansah (2019) used pH, exchangeable Ca, OC, and exchangeable Na as the indicators of SQ in Upper Citarum Watershed, Indonesia. Tree species and vegetation type is an important factor that affects soil chemical properties and SQ. This substantiates Heydari et al. (2020) finding who indicated that most of the soil chemical properties (TN, available K, and SOC) were significantly higher beneath trees than beneath shrubs which has a great impact on SQI in one of the semiarid oak forests in western Iran. Moreover, it was reported that deforestation can increase soil pH, EC, and bulk density (BD) and significantly reduce SOC content and SQI (by 44.5 %) in the sparse forest of Baneh in western Iran (Davari, Gholami, Nabiollahi, Homaee, & Jafari, 2020).

Soil Chemical Properties and SOM (SOC)

The SOC as one of the soil chemical properties plays a key role in SQ. The relationship between SOC and other soil chemical properties has been widely investigated. SOM content can positively influence plant essential nutrients (A Edward Johnston, Paul R Poulton, & Kevin Coleman, 2009; Per Schjønning et al., 2018b), particularly under nutrient-limiting situations (Rattan Lal, 2020). By increasing CEC, SOM can lead to increase nutrient availability in the soil (Ramos et al., 2018). There is a significant positive correlation between CEC and specific surface area with SOM in silty soils (J. Liu et al., 2020). Moreover, there is a positive correlation between soil enzyme activities and SOC (Teimouri et al., 2018). In order for the sorption of pesticides to release from the soil not only SOM content, but also SOM quality and HA are important factors, which strongly affect this process (Novotny, Turetta, Resende, & Rebello, 2020). A long-term high rate of N Fertilization (more than 90 kg ha^{-1}) can also significantly increase topsoil SOC content (Aula, Macnack, Omara, Mullock, & Raun, 2016). The chemical properties overwhelmingly controlled SOC content in Sydney, Australia (J. Li, Nie, & Pendall, 2020). The conversion of natural forest by agricultural land leads to a reduction in SOC, as well as, soil organic N and soil N usage efficiency (Han et al., 2020). Using cover crops with low C: N ratios is recommended as a key factor in the formation of new organo-mineral associations for enhancing SOM stabilization (Kopittke et al., 2020). Moreover, H. Zhang et al. (2020) used the Microbial-Mineral Carbon Stabilization model to predict SOC dynamics, formation, and stabilization at a large scale. The promotion of the formation of the Fe-bound OC by tillage can reduce SOC loss in the 0–40 cm depth in acidic red soils (Zong et al., 2021).

HOW SOM AFFECTS INDUCTIVE SQ – PHYSICAL PROPERTIES

Soil Physical Properties and SQ

The relationship between soil physical properties and SQ has been widely investigated (Aziz, Mahmood, & Islam, 2013; Rattan Lal, 2015; Kamal Nabiollahi, Taghizadeh-Mehrjardi, Kerry, & Moradian, 2017; Santos-Francés, Martínez-Graña, Ávila-Zarza, Criado, & Sánchez, 2019).

R Lal, Mokma, and Lowery (2018) claimed that erosion affected biophysical factors, which could influence SQ. Meanwhile, the combined use of physical and biological soil and water conservation functions would have fundamental significance in enhancing SQ (Dagnachew, Moges, Kebede, & Abebe, 2020). Cover crops by reduction of soil and water losses can enhance SQIs (dos Santos et al., 2021). According to Sione, Wilson, Lado, and González (2017) SQI can help us implement early land management practices to prevent soil degradation. Soil management practices are one of the useful methods for enhancing soil physical properties and SQ. Improving the physical properties of the soil such as no-tillage help to reduce bulk density and improve soil structure in the topsoil (Hamza & Anderson, 2005), changing the morphology of the soil aggregates (C. d. R. Ferreira et al., 2020), improving the capacity of the soil for moisture preservation and water infiltration, and aggregate stability, which can be enhancing SQ (Aziz et al., 2013; Palm, Blanco-Canqui, DeClerck, Gatere, & Grace, 2014; Pittelkow et al., 2015). The reduction of tillage and soil bulk density induced by soil management can lead to improved water stable aggregates and the physical quality of soil (Kochiieru et al., 2020). Conservation tillage and the use of catch crops can enhance soil structure, particle-size distribution, and water content (Harasim, Antonkiewicz, & Kwiatkowski, 2020). Abolla, Sartohadi, Utami, and Basuki (2020) also reported the enhancement of SQ by a minimum tillage system. Long-term (Thirty-four years) using combined cover crops and no-till can move forward SQ (Nouri, Lee, Yin, Tyler, & Saxton, 2019). In contrast, other than soil biological properties, there was no significant relationship between soil physical variables and tillage in SQ determination in an irrigated arid agroecosystem in the southwestern USA (Idowu, Sultana, Darapuneni, Beck, & Steiner, 2019). He et al. (2021) suggested no-tillage/subsoiling rotation as optimal tillage for enhancing SQ and yield of crops in the Loess Plateau. Land use is an important factor, which affects the soil physical properties and SQ. As proposed by Duran-Bautista, Chilatra, Galindo, Ortiz, and Bermúdez (2020) soil physical quality is at its highest and lowest values under natural regeneration and rubber plantations, respectively.

Zaher, Sabir, Benjelloun, and Paul-Igor (2020) observed a reduction in soil physical quality when cedar forest was converted into a cleared area. The decrease in SQIs was reported to be due to land use conversion (Zeraatpisheh, Bakhshandeh, Hosseini, & Alavi, 2020). Among other soil properties, soil aggregation was known as one of the SQ indicators in rangelands in Iran (Raiesi & Salek-Gilani, 2020).

Through the fine soil texture and stable aggregate structure, as well as, some other chemical properties, the better SQ was determined at higher altitudes compared to lower altitudes in the cut slopes of mountainous of southwest China (Zhu et al., 2020). Balanced fertilization also fundamentally affects soil physical properties and water relations, SQ, and plant productivity (Kiani et al., 2017). The obtained results from this study showed that the artificial soil quality of the cut slopes was better at a higher altitude compared to a lower altitude. The artificial soil texture was finer and the aggregate structure was more stable at high altitudes in the mountainous subalpine highway of southwest China. Improving some soil physical properties such as water-stable aggregates, aggregation, and water infiltration resulting in zeolite application, led to the enhancement of SQ and sugarcane yield on the north coast of Cuba (Cairo et al., 2017).

Soil Physical Properties and SOM (SOC)

Several studies thus far have linked soil physical properties with SOM or SOC as a major planetary resource (Dexter et al., 2008; O. Ernst & Siri-Prieto, 2009; Hati, Swarup, Dwivedi, Misra, & Bandyopadhyay, 2007; Mondal, Chakraborty, Bandyopadhyay, Aggarwal, & Rana, 2020; Rasool, Kukal, & Hira, 2008; Redmile-Gordon, Gregory, White, & Watts, 2020).

According to A. Edward Johnston et al. (2009) the SOM contents depend on soil texture and climate conditions. They reported that the SOC content of clay soil was larger than that in sandy soil. This view is supported by Deb et al. (2015); Loveland and Webb (2003); Tsiafouli et al. (2015) who claimed a close relationship between SOM content and structure or aggregate stability. Moreover, Panettieri, Berns, Knicker, Murillo, and Madejón (2015) reported that SOC management practices would be effective in enhancing carbon cycling and soil aggregation, and play a major role in SOC sequestration. In addition, the loss of SOC is lower under cover crops compared to tillage which indicates the importance of soil management to prevent soil fertility loss (Ruiz-Colmenero, Bienes, Eldridge, & Marques, 2013). Soil aggregate stability and SOC contents are the foremost compelling variables for OC sequestration (Mustafa et al., 2020). The SOC content increased under no-tillage and subsoiling compared with conventional tillage over 11 years in the Northern China Plain (Xu, Han, Ning, Li, & Lal, 2019). Similarly, C. d. R. Ferreira et al. (2020) indicated that long time no-till farming, which affected the soil aggregation dynamics, enhanced C stock in more steady OM fractions.

The reduction of SOC content and increase in bulk density induced by the land cover conversion and land degradation were observed in the Gumara watershed, northwestern Ethiopia (Wubie & Assen, 2020). In truth, among other universal factors, SOC storage is a core indicator of soil degradation (Lorenz, Lal, & Ehlers, 2019). When SOC content is more than 20 $g \cdot kg^{-1}$ the soil erodibility related to soil aggregate stability is low but it remarkably increases with SOM losses (M. Liu, Han, & Zhang, 2019). There is also a positive correlation between SOC content and the number of soil pores > 100 μm which can help C sequestration (A. Liang et al., 2019).

Soil parameters such as water holding capacity and SOM have the greatest potential as SQ indicators under different forest covers in Mount Tai, central Eastern China (Shao et al., 2020). Indeed, soil fractionation results in different soil physical changes, and labile and recalcitrant portions of SOM, which are protected in these fractions are the main factors that affect SOC stability and mineralization rate in the soil (Collins, Paul, Paustian, & Elliott, 2019). An increment in biochar rate (60 t ha^{-1}) was accompanied by an increase in the extent of soil aggregates of 2000–1000 μm and SOC content (Z. Sun et al., 2020).

HOW SOM RELATED TO DEDUCTIVE SQ – CROP YIELD

Crop Yield and SQ

The relationship between crop productivity and SQ had been widely investigated (Braimoh & Vlek, 2006; Luo et al., 2017; Manna et al., 2005; Martini, Buyer, Bryant, Hartz, & Denison, 2004; Sharma et al., 2005; Van Asten et al., 2003; Vasu et al., 2016). In this concept, J. Pan, Zhang, He, Chen, and Cui (2019) highlighted the optimum use of N fertilizer in farming systems resulting in soil N management practices that can lead to promoting high SQ and grain yield (J. Pan et al., 2019). Moreover, It was reported that long-term P fertilization can improve soil properties and SQ which can increase crop yield (Carvalho Mendes et al., 2021). Furthermore, long-term tillage systems and diversified crop rotation influenced the soil physical quality and crop yield (Vizioli, Cavalieri-Polizeli, Tormena, & Barth, 2021). SQ and corn yield increased under long-term no-till compared to plow-till (Nunes, van Es, Schindelbeck, Ristow, & Ryan, 2018). Enhancement of SQ through drip irrigation and conservation agriculture can increase crop yield by 37.4% (Assefa et al., 2020). In addition, a positive relationship between conservation agriculture, no-till, and crop rotation was found with SQ and crop production (Naab, Mahama, Yahaya, & Prasad, 2017). In contrast, Okur, Kayikcioglu, Ates, and Yagmur (2016) reported that although organic management can enhance vineyard SQ after 2 years, this event did not increase crop yield. Similarly, Sithole, Magwaza, and Mafongoya (2016) highlighted the positive impact of conservation agriculture on SQ, as well as, maize yield.

Moreover, using cover crops in a cropping system can enhance SQ and hazelnut yield (Demir & Işık, 2020). In this case, Maughan et al. (2009) highlighted that winter cover crops and cool-season pastures within the coordinates of crop livestock could enhance SQ and crop yield. Mulching treatment as other soil management practices in conservation agriculture led to significantly higher productivity of maize and rapeseed than control treatments in Eastern Himalaya (Das, Ghosh, Lal, Saha, & Ngachan, 2017). It was reported that soil invertebrates as one of the SQ indicators, have a great impact on soil health and thereby, crop productivity (Jernigan et al., 2020). As a consequence, a higher range of soil compaction had a negative effect on soil physical quality and soybean yield (C. J. B. Ferreira, Tormena, Severiano, Zotarelli, & Betioli Júnior, 2021). In continuous, no-tillage+ different species of annual cropping can negatively affect soil properties, as well as SQ and wheat yield (O. R. Ernst, Dogliotti, Cadenazzi, & Kemanian, 2018).

Crop Yield and SOM (SOC)

Several studies have investigated the effects of SOM productivity and the yield of plants (Aref & Wander, 1997; Johnston, 1986; Juma, Izaurralde, Robertson, & McGill, 2019; Manna, Swarup, Wanjari, Mishra, & Shahi, 2007; Sainju, Lenssen, Caesar-TonThat, & Evans, 2009; Per Schjønning et al., 2018a; Shen et al., 2021; Yaduvanshi & Sharma, 2008). Kane, Bradford, Fuller, Oldfield, and Wood (2021) focused on the positive relation of SOM and yields in water-deficient conditions in the USA.

The depletion of soil OM is associated with a loss of fertility and crop productivity (Bauer & Black, 1994). In addition, A. Edward Johnston et al. (2009) reported higher yields of long-term crops on soils with more OM compared to less OM content. Soil management also has a considerable impact on SOM improvement as well as SQ and crop yield. In this context, Brock et al. (2011) reported that SOM management is significantly relevant for crop yield in organic agriculture. Quiroga, Funaro, Noellemeyer, and Peinemann (2006) recommended SOM for clay + silt ratio as the important indicator for predicting grain yield.

A long-term (14 years) no-tillage system leads to a higher rate of SOM, and a higher yield of rice compared to conventional tillage in the soils of the Brazilian subtropical region (Denardin et al., 2019). The tillage and mulching could increase SOC and improve soil properties and sunflower crop yields (Selolo, 2021).

It is worthwhile to consider the soil texture and the climate conditions effect on the SOC and crop yield relations. In this context, Soinne et al. (2020) proposed the need for more SOC content to reduce N losses to the ecosystem and achieve desirable crop yield under clay soils and cool and humid climate conditions. It was demonstrated that only under proper climate conditions, no-tillage can increase SOC levels (1.4–2.0 t/ha) and crop yield (L. Liu & Basso, 2020). Alternating small and large ridges+ straw mulching in coarse soil texture can increase both SOC and yield under proper climate conditions (annual mean precipitation > 400 mm and mean temperature >10°C in China (Yunqi Wang et al., 2021). It was found that the increase of every 1 Mg ha^{-1} SOC by fertilization can increase rice, maize, and wheat yield by about 143 kg ha^{-1}, 255 kg ha^{-1}, and 202 kg ha^{-1}, respectively (Waqas, Li, Lal, et al., 2020). Waqas, Li, Smith, et al. (2020) recommended 33.43-45.51 Mg C ha^{-1} SOC content as the maximal yield responsive for the production of rice, wheat, and maize. The positive impact of SOC contents on maize yield was also indicated by Arif et al. (2021); Y. Li et al. (2020). While SOC content is in the medium range (7–10 g kg^{-1}), the crop rotation works better to increase the crop yield (by 20%) compared to continuous monoculture in china (Zhao et al., 2020). H. Li et al. (2017) highly recommended the application of NPK fertilizers+ manure combination to significantly enhancement of SOC storage and reach high maize yield in the Northeast China Plain. Compost application alone had a negative impact on C sequestration and crop yields (Cai & Qin, 2006). Indeed, there is a two-sided relationship between SOC content and crop yield (Rasmussen &

Parton, 1994). Besides the positive effect of SOC on crop yield, the higher yields also return a higher rate of crop residues to the soil which can improve SOC stock (Jarecki et al., 2020). Warren Raffa, Bogdanski, and Tittonell (2015) underlined that in tropical, and arid areas, crop residue removal leads to decrease SOC and crop yields. Qiu et al. (2009) have already noted that SOC content has great potential for improving crop yield in every area of China. Another previous study also highlighted that C sequestration could lead to improving crop productivity and yield in China's croplands (G. Pan, Smith, & Pan, 2009). Consequently, by enhancing the SOC content (by 1 Mg ha^{-1} y^{-1}), the grain yield increase (by 32 million Mg y^{-1}) (Rattan Lal, 2006).

CONCLUSIONS

A recent review is a collection of significant results of a large number of studies that tried to indicate the definition and importance of SQ on living organism life and the main factors which influence it. First of all, the definition of SOM (or SOC) and the components which are in relation to those was indicated through numerous studies. In the next steps, the soil biological, physical, and chemical properties effect on SQ and its relationships with SOM (or SOC) was explained by referring to multiple references which proved our hypothesis of this review research about SOM, SOC as the best indicators of SQ assessment. We further have drawn attention to the importance of SOM (or SOC) as well as SQ to achieve the main goal of agriculture to reach high crop yields.

It is now possible to state the net key impact of SOM on SQ. Overall, data from several sources have identified the enhancement of SQ associated with the increase of SOM in terms of improving soil properties. The study presented thus far provides evidence that SOM (or SOC) management practices that focus on enhancing soil biological, chemical, and physical properties can prepare high SQ for improving plant growth and productivity.

REFERENCES

Abolla, N. B., Sartohadi, J., Utami, S. N. H., & Basuki, T. (2020). Improvement of Soil Quality through Minimum Tillage for Sen Cropping Pattern in Indonesia. *Indian Journal of Agricultural Research, 54*(2), 205-210.

Adetunji, A. T., Ncube, B., Mulidzi, R., & Lewu, F. B. (2020). Management impact and benefit of cover crops on soil quality: A review. *Soil and tillage research, 204*, 104717.

Alaoui, A., Barão, L., Ferreira, C. S., Schwilch, G., Basch, G., Garcia-Orenes, F., . . . Glavan, M. (2020). Visual assessment of the impact of agricultural management practices on soil quality. *Agronomy journal*.

Ali, A., Dai, D., Akhtar, K., Teng, M., Yan, Z., Urbina-Cardona, N., . . . Zhou, Z. (2019). Response of understory vegetation, tree regeneration, and soil quality to manipulated stand density in a Pinus massoniana plantation. *Global Ecology and Conservation, 20*, e00775.

Amoah-Antwi, C., Kwiatkowska-Malina, J., Thornton, S. F., Fenton, O., Malina, G., & Szara, E. (2020). Restoration of soil quality using biochar and brown coal waste: A review. *Science of the Total Environment, 722*, 137852.

Amorim, H. C., Ashworth, A. J., Moore Jr, P. A., Wienhold, B. J., Savin, M. C., Owens, P. R., . . . Xu, S. (2020). Soil quality indices following long-term conservation pasture management practices. *Agriculture, Ecosystems & Environment, 301*, 107060.

Andrews, S. S., Karlen, D., & Mitchell, J. (2002). A comparison of soil quality indexing methods for vegetable production systems in Northern California. *Agriculture, Ecosystems & Environment, 90*(1), 25-45.

Angst, G., Mueller, K. E., Nierop, K. G. J., & Simpson, M. J. (2021). Plant- or microbial-derived? A review on the molecular composition of stabilized soil organic matter. *Soil Biology and Biochemistry, 156*, 108189. doi:https://doi.org/10.1016/j.soilbio.2021.108189

Anthony, M. A., Crowther, T. W., Maynard, D. S., van den Hoogen, J., & Averill, C. (2020). Distinct assembly processes and microbial communities constrain soil organic carbon formation. *One Earth, 2*(4), 349-360.

Aponte, H., Medina, J., Butler, B., Meier, S., Cornejo, P., & Kuzyakov, Y. (2020). Soil quality indices for metal (loid) contamination: An enzymatic perspective. *Land Degradation & Development, 31*(17), 2700-2719.

Aref, S., & Wander, M. M. (1997). Long-term trends of corn yield and soil organic matter in different crop sequences and soil fertility treatments on the Morrow Plots. *Advances in agronomy, 62*, 153-197.

Arif, M., Ali, S., Ilyas, M., Riaz, M., Akhtar, K., Ali, K., . . . Shah, S. (2021). Enhancing phosphorus availability, soil organic carbon, maize productivity and farm profitability through biochar and organic–inorganic fertilizers in an irrigated maize agroecosystem under semi-arid climate. *Soil use and management, 37*(1), 104-119.

Ascari, J., de Araújo, D., Mendes, I., Prieto, R., & de Carvalho, M. (2020). Influence of biological fertilizer and plant cover in the physical properties of soil. *Revista Agrarian, 13*(47), 42-55.

Ashagrie, Y., Zech, W., Guggenberger, G., & Mamo, T. (2007). Soil aggregation, and total and particulate organic matter following conversion of native forests to continuous cultivation in Ethiopia. *Soil and tillage research, 94*(1), 101-108.

Ashraf, M. A., & Hanafiah, M. M. (2019). Sustaining life on earth system through clean air, pure water, and fertile soil: Springer.

Assefa, T., Jha, M., Reyes, M., Worqlul, A. W., Doro, L., & Tilahun, S. (2020). Conservation agriculture with drip irrigation: Effects on soil quality and crop yield in sub-Saharan Africa. *Journal of soil and water conservation, 75*(2), 209-217.

Attademo, A. M., Sanchez-Hernandez, J. C., Lajmanovich, R. C., Repetti, M. R., & Peltzer, P. M. (2021). Enzyme Activities as Indicators of Soil Quality: Response to Intensive Soybean and Rice Crops. *Water, Air, & Soil Pollution, 232*(7), 1-12.

Aula, L., Macnack, N., Omara, P., Mullock, J., & Raun, W. (2016). Effect of fertilizer nitrogen (N) on soil organic carbon, total N, and soil pH in long-term continuous winter wheat (Triticum aestivum L.). *Communications in Soil Science and Plant Analysis, 47*(7), 863-874.

Awale, R., Emeson, M. A., & Machado, S. (2017). Soil organic carbon pools as early indicators for soil organic matter stock changes under different tillage practices in Inland Pacific Northwest. *Frontiers in ecology and evolution, 5*, 96.

Aziz, I., Mahmood, T., & Islam, K. R. (2013). Effect of long term no-till and conventional tillage practices on soil quality. *Soil and tillage research, 131*, 28-35.

Babur, E., & Dindaroglu, T. (2020). Seasonal changes of soil organic carbon and microbial biomass carbon in different forest ecosystems. *Environmental Factors Affecting Human Health*.

Bai, Y.-C., Chang, Y.-Y., Hussain, M., Lu, B., Zhang, J.-P., Song, X.-B., . . . Pei, D. (2020). Soil chemical and microbiological properties are changed by long-term chemical fertilizers that limit ecosystem functioning. *Microorganisms, 8*(5), 694.

Bai, Z., Caspari, T., Gonzalez, M. R., Batjes, N. H., Mäder, P., Bünemann, E. K., . . . Ferreira, C. S. S. (2018). Effects of agricultural management practices on soil quality: A review of long-term experiments for Europe and China. *Agriculture, Ecosystems & Environment, 265*, 1-7.

Barreiro, A., Lombao, A., Martín, A., Cancelo-González, J., Carballas, T., & Díaz-Raviña, M. (2020). Soil heating at high temperatures and different water content: effects on the soil microorganisms. *Geosciences, 10*(9), 355.

Bauer, A., & Black, A. (1994). Quantification of the effect of soil organic matter content on soil productivity. *Soil Science Society of America Journal, 58*(1), 185-193.

Bevis, L. E. (2015). Soil-to-human mineral transmission with an emphasis on zinc, selenium, and iodine. *Springer Science Reviews, 3*(1), 77-96.

Biswas, J. C., & Naher, U. (2019). Soil nutrient stress and rice production in Bangladesh *Advances in Rice Research for Abiotic Stress Tolerance* (pp. 431-445): Elsevier.

Biswas, S., Hazra, G. C., Purakayastha, T. J., Saha, N., Mitran, T., Singha Roy, S., . . . Mandal, B. (2017). Establishment of critical limits of indicators and indices of soil quality in rice-rice cropping systems under different soil orders. *Geoderma, 292*, 34-48. doi:https://doi.org/10.1016/j.geoderma.2017.01.003

Bongiorno, G., Bünemann, E. K., Oguejiofor, C. U., Meier, J., Gort, G., Comans, R., . . . de Goede, R. (2019). Sensitivity of labile carbon fractions to tillage and organic matter management and their potential as comprehensive soil quality indicators across pedoclimatic conditions in Europe. *Ecological Indicators, 99*, 38-50.

Bot, A., & Benites, J. (2005). *The importance of soil organic matter: Key to drought-resistant soil and sustained food production*: Food & Agriculture Org.

Bouma, J., Van Ittersum, M., Stoorvogel, J., Batjes, N. H., Droogers, P., & Pulleman, M. M. (2017). Soil capability: exploring the functional potentials of soils *Global soil security* (pp. 27-44): Springer.

Braimoh, A., & Vlek, P. (2006). Soil quality and other factors influencing maize yield in northern Ghana. *Soil use and management, 22*(2), 165-171.

Brevik, E. C., Slaughter, L., Singh, B. R., Steffan, J. J., Collier, D., Barnhart, P., & Pereira, P. (2020). Soil and human health: current status and future needs. *Air, Soil and Water Research, 13*, 1178622120934441.

Brevik, E. C., Steffan, J. J., Burgess, L. C., & Cerdà, A. (2017). Links between soil security and the influence of soil on human health *Global soil security* (pp. 261-274): Springer.

Brock, C., Fließbach, A., Oberholzer, H. R., Schulz, F., Wiesinger, K., Reinicke, F., . . . Zimmer, J. (2011). Relation between soil organic matter and yield levels of nonlegume crops in organic and conventional farming systems. *Journal of Plant Nutrition and Soil Science, 174*(4), 568-575.

Brucker, E., Kernchen, S., & Spohn, M. (2020). Release of phosphorus and silicon from minerals by soil microorganisms depends on the availability of organic carbon. *Soil Biology and Biochemistry, 143*, 107737.

Bünemann, E. K., Bongiorno, G., Bai, Z., Creamer, R. E., De Deyn, G., de Goede, R., . . . Mäder, P. (2018). Soil quality–A critical review. *Soil Biology and Biochemistry, 120*, 105-125.

Cai, Z. C., & Qin, S. W. (2006). Dynamics of crop yields and soil organic carbon in a long-term fertilization experiment in the Huang-Huai-Hai Plain of China. *Geoderma, 136*(3), 708-715. doi:https://doi.org/10.1016/j.geoderma.2006.05.008

Cairo, P. C., de Armas, J. M., Artiles, P. T., Martin, B. D., Carrazana, R. J., & Lopez, O. R. (2017). Effects of zeolite and organic fertilizers on soil quality and yield of sugarcane. *Australian Journal of Crop Science, 11*(6), 733-738.

Campbell, E. E., & Paustian, K. (2015). Current developments in soil organic matter modeling and the expansion of model applications: a review. *Environmental Research Letters*, *10*(12), 123004.

Carter, M. (2020). Analysis of soil organic matter storage in agroecosystems *Structure and organic matter storage in agricultural soils* (pp. 3-11): CRC press.

Carvalho Mendes, I., Martinhão Gomes Sousa, D., Dario Dantas, O., Alves Castro Lopes, A., Bueno Reis Junior, F., Ines Oliveira, M., & Montandon Chaer, G. (2021). Soil quality and grain yield: A win–win combination in clayey tropical oxisols. *Geoderma, 388*, 114880. doi:https://doi.org/10.1016/j.geoderma.2020.114880

Case, S. D., Uno, H., Nakajima, Y., Stoumann Jensen, L., & Akiyama, H. (2018). Bamboo biochar does not affect paddy soil N2O emissions or source following slurry or mineral fertilizer amendment—A 15N tracer study. *Journal of Plant Nutrition and Soil Science, 181*(1), 90-98.

Cassman, N. A., Leite, M. F., Pan, Y., de Hollander, M., van Veen, J. A., & Kuramae, E. E. (2016). Plant and soil fungal but not soil bacterial communities are linked in long-term fertilized grassland. *Scientific reports, 6*(1), 1-11.

Chaganti, V. N., Ganjegunte, G., Niu, G., Ulery, A., Flynn, R., Enciso, J. M., . . . Kiniry, J. R. (2020). Effects of treated urban wastewater irrigation on bioenergy sorghum and soil quality. *Agricultural Water Management, 228*, 105894.

Chen, Q., Niu, B., Hu, Y., Luo, T., & Zhang, G. (2020). Warming and increased precipitation indirectly affect the composition and turnover of labile-fraction soil organic matter by directly affecting vegetation and microorganisms. *Science of the Total Environment, 714*, 136787.

Chen, Y., Nobili, M. D., & Aviad, T. (2004). Stimulatory effects of humic substances on plant growth. *Soil organic matter in sustainable agriculture*, 103-129.

Cheng, J., Ding, C., Li, X., Zhang, T., & Wang, X. (2016). Soil quality evaluation for navel orange production systems in central subtropical China. *Soil and tillage research, 155*, 225-232.

Ciais, P., Sabine, C., Bala, G., Bopp, L., Brovkin, V., Canadell, J., . . . Heimann, M. (2014). Carbon and other biogeochemical cycles *Climate change 2013: the physical science basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 465-570): Cambridge University Press.

Coleman, D., & Elliot, E. (1988). Let the soil work for us. *Ecol Bull, 39*, 23-32.

Collins, H. P., Paul, E., Paustian, K., & Elliott, E. (2019). Characterization of soil organic carbon relative to its stability and turnover *Soil organic matter in temperate agroecosystems* (pp. 51-72): CRC Press.

Compant, S., Duffy, B., Nowak, J., Clément, C., & Ait Barka, E. (2005). Biocontrol of plant diseases using plant growth-promoting bacteria (PGPB): principles, mechanisms of action and future prospects. *Appl Environ Microbiol, 71*, 4951-4959.

Conant, R. T., Ryan, M. G., Ågren, G. I., Birge, H. E., Davidson, E. A., Eliasson, P. E., . . . Hopkins, F. M. (2011). Temperature and soil organic matter decomposition rates–synthesis of current knowledge and a way forward. *Global change biology, 17*(11), 3392-3404.

Constancias, F. (2014). Chemidlin Prévost-Bouré N., Terrat S., Aussems S., Nowak V., Guillemin J. *P., Bonnotte A., Biju-Duval L., Navel A., Martins JMF, Maron P.-A., Ranjard L., Microscale evidence for a high decrease of soil bacterial density and diversity by cropping. Agron. Sustain. Dev, 34*, 831-840.

Cotrufo, M. F., Soong, J. L., Horton, A. J., Campbell, E. E., Haddix, M. L., Wall, D. H., & Parton, W. J. (2015). Formation of soil organic matter via biochemical and physical pathways of litter mass loss. *Nature Geoscience, 8*(10), 776-779.

Cotrufo, M. F., Wallenstein, M. D., Boot, C. M., Denef, K., & Paul, E. (2013). The M icrobial E fficiency-M atrix S tabilization (MEMS) framework integrates plant litter decomposition with soil organic matter stabilization: do labile plant inputs form stable soil organic matter? *Global change biology, 19*(4), 988-995.

Culman, S. W., Snapp, S. S., Freeman, M. A., Schipanski, M. E., Beniston, J., Lal, R., . . . Grandy, A. S. (2012). Permanganate oxidizable carbon reflects a processed soil fraction that is sensitive to management. *Soil Science Society of America Journal, 76*(2), 494-504.

Dagnachew, M., Moges, A., Kebede, A., & Abebe, A. (2020). Effects of soil and water conservation measures on soil quality indicators: The case of Geshy subcatchment, Gojeb river catchment, Ethiopia. *Applied and Environmental Soil Science, 2020.*

Das, A., Ghosh, P. K., Lal, R., Saha, R., & Ngachan, S. (2017). Soil quality effect of conservation practices in maize–rapeseed cropping system in Eastern Himalaya. *Land Degradation & Development, 28*(6), 1862-1874.

Davari, M., Gholami, L., Nabiollahi, K., Homaee, M., & Jafari, H. J. (2020). Deforestation and cultivation of sparse forest impacts on soil quality (case study: West Iran, Baneh). *Soil and tillage research, 198*, 104504.

Davidson, E. A., Janssens, I. A., & Luo, Y. (2006). On the variability of respiration in terrestrial ecosystems: moving beyond Q10. *Global change biology, 12*(2), 154-164.

de Carvalho, T. S., Jesus, E. d. C., Barlow, J., Gardner, T. A., Soares, I. C., Tiedje, J. M., & Moreira, F. M. d. S. (2016). Land use intensification in the humid tropics increased both alpha and beta diversity of soil bacteria. *Ecology, 97*(10), 2760-2771.

De Corato, U. (2020). Towards New Soil Management Strategies for Improving Soil Quality and Ecosystem Services in Sustainable Agriculture: Editorial Overview: Multidisciplinary Digital Publishing Institute.

De Mastro, F., Traversa, A., Brunetti, G., Debiase, G., Cocozza, C., & Nigro, F. (2020). Soil culturable microorganisms as affected by different soil managements in a two year wheat-faba bean rotation. *Applied Soil Ecology, 149*, 103533.

de Paul Obade, V. (2019). Integrating management information with soil quality dynamics to monitor agricultural productivity. *Science of the Total Environment, 651*, 2036-2043. doi:https://doi.org/10.1016/j.scitotenv.2018.10.106

Deb, S., Bhadoria, P. B. S., Mandal, B., Rakshit, A., & Singh, H. B. (2015). Soil organic carbon: Towards better soil health, productivity and climate change mitigation. *Climate change and environmental sustainability, 3*(1), 26-34.

Demir, Z., & Işık, D. (2020). Using cover crops to improve soil quality and hazelnut yield. *Fresenius Environmental Bulletin, 29*(4), 1974-1987.

Denardin, L. G. d. O., Carmona, F. d. C., Veloso, M. G., Martins, A. P., Freitas, T. F. S. d., Carlos, F. S., . . . Anghinoni, I. (2019). No-tillage increases irrigated rice yield through soil quality improvement along time. *Soil and tillage research, 186*, 64-69. doi:https://doi.org/10.1016/j.still.2018.10.006

Dexter, A. R., Richard, G., Arrouays, D., Czyż, E. A., Jolivet, C., & Duval, O. (2008). Complexed organic matter controls soil physical properties. *Geoderma, 144*(3), 620-627. doi:https://doi.org/10.1016/j.geoderma.2008.01.022

Dignam, B. E., O'Callaghan, M., Condron, L. M., Kowalchuk, G. A., Van Nostrand, J. D., Zhou, J., & Wakelin, S. A. (2018). Effect of land use and soil organic matter quality on the structure and function of microbial communities in pastoral soils: implications for disease suppression. *PLoS one, 13*(5), e0196581.

Doran, J. W., Jones, A. J., Arshad, M., & Gilley, J. (2018). Determinants of soil quality and health *Soil quality and soil erosion* (pp. 17-36): CRC Press.

Doran, J. W., & Parkin, T. B. (1994). Defining and assessing soil quality. *Defining soil quality for a sustainable environment, 35*, 1-21.

dos Santos, W. P., Silva, M. L. N., Avanzi, J. C., Acuña-Guzman, S. F., Cândido, B. M., Cirillo, M. Â., & Curi, N. (2021). Soil quality assessment using erosion-sensitive indices and fuzzy membership under different cropping systems on a Ferralsol in Brazil. *Geoderma Regional, 25*, e00385.

Drobnik, T., Greiner, L., Keller, A., & Grêt-Regamey, A. (2018). Soil quality indicators–From soil functions to ecosystem services. *Ecological Indicators, 94*, 151-169.

Duran-Bautista, E. H., Chilatra, Y. M., Galindo, J. D., Ortiz, T. A., & Bermúdez, M. F. (2020). Soil physical quality and relationship to changes in termite community in northwestern Colombian Amazon. *Frontiers in ecology and evolution, 8*, 419.

Edmondson, J. L., Davies, Z. G., Gaston, K. J., & Leake, J. R. (2014). Urban cultivation in allotments maintains soil qualities adversely affected by conventional agriculture. *Journal of Applied Ecology, 51*(4), 880-889.

Ernst, O., & Siri-Prieto, G. (2009). Impact of perennial pasture and tillage systems on carbon input and soil quality indicators. *Soil and tillage research, 105*(2), 260-268.

Ernst, O. R., Dogliotti, S., Cadenazzi, M., & Kemanian, A. R. (2018). Shifting crop-pasture rotations to no-till annual cropping reduces soil quality and wheat yield. *Field crops research, 217*, 180-187. doi:https://doi.org/10.1016/j.fcr.2017.11.014

Fazekašová, D., & Fazekaš, J. (2020). Soil quality and heavy metal pollution assessment of Iron ore mines in Nizna Slana (Slovakia). *Sustainability, 12*(6), 2549.

Ferreira, C. d. R., Silva Neto, E. C. d., Pereira, M. G., Guedes, J. d. N., Rosset, J. S., & Anjos, L. H. C. d. (2020). Dynamics of soil aggregation and organic carbon fractions over 23 years of no-till management. *Soil and tillage research, 198*, 104533. doi:https://doi.org/10.1016/j.still.2019.104533

Ferreira, C. J. B., Tormena, C. A., Severiano, E. D. C., Zotarelli, L., & Betioli Júnior, E. (2021). Soil compaction influences soil physical quality and soybean yield under long-term no-tillage. *Archives of Agronomy and Soil Science, 67*(3), 383-396.

Figuerola, E. L., Guerrero, L. D., Türkowsky, D., Wall, L. G., & Erijman, L. (2015). Crop monoculture rather than agriculture reduces the spatial turnover of soil bacterial communities at a regional scale. *Environmental Microbiology, 17*(3), 678-688.

Flaig, W., Beutelspacher, H., & Rietz, E. (1975). Chemical composition and physical properties of humic substances *Soil components* (pp. 1-211): Springer.

Fliessbach, A., Martens, R., & Reber, H. (1994). Soil microbial biomass and microbial activity in soils treated with heavy metal contaminated sewage sludge. *Soil Biology and Biochemistry, 26*(9), 1201-1205.

Friedlingstein, P., Cox, P., Betts, R., Bopp, L., von Bloh, W., Brovkin, V., . . . Fung, I. (2006). Climate–carbon cycle feedback analysis: results from the C4MIP model intercomparison. *Journal of climate, 19*(14), 3337-3353.

Frouz, J. (2018). Effects of soil macro-and mesofauna on litter decomposition and soil organic matter stabilization. *Geoderma, 332*, 161-172.

Gałązka, A., Niedźwiecki, J., Grządziel, J., & Gawryjołek, K. (2020). Evaluation of Changes in Glomalin-Related Soil Proteins (GRSP) Content, Microbial Diversity and Physical Properties Depending on the Type of Soil as the Important Biotic Determinants of Soil Quality. *Agronomy, 10*(9), 1279.

Geraei, D. S., Hojati, S., Landi, A., & Cano, A. F. (2016). Total and labile forms of soil organic carbon as affected by land use change in southwestern Iran. *Geoderma Regional, 7*(1), 29-37.

Gerke, J. (2018). Concepts and Misconceptions of Humic Substances as the Stable Part of Soil Organic Matter: A Review. *Agronomy, 8*(5), 76.

Gillespie, L. M., Fromin, N., Milcu, A., Buatois, B., Pontoizeau, C., & Hättenschwiler, S. (2020). Higher tree diversity increases soil microbial resistance to drought. *Communications biology, 3*(1), 1-12.

Gömöryová, E., Barančíková, G., Tobiašová, E., Halás, J., Skalský, R., Koco, Š., & Gömöry, D. (2020). Responses of soil microorganisms to land use in different soil types along the soil profiles. *Soil and Water Research, 15*(2), 125-134.

Gregorich, E., Carter, M., Angers, D., Monreal, C., & Ellert, B. (1994). Towards a minimum data set to assess soil organic matter quality in agricultural soils. *Canadian journal of soil science, 74*(4), 367-385.

Griffiths, R. I., Thomson, B. C., Plassart, P., Gweon, H. S., Stone, D., Creamer, R. E., . . . Bailey, M. J. (2016). Mapping and validating predictions of soil bacterial biodiversity using European and national scale datasets. *Applied Soil Ecology, 97*, 61-68.

Guimarães, D. V., Gonzaga, M. I. S., da Silva, T. O., da Silva, T. L., da Silva Dias, N., & Matias, M. I. S. (2013). Soil organic matter pools and carbon fractions in soil under different land uses. *Soil and tillage research, 126*, 177-182.

Haider, K., & Martin, J. (1967). Synthesis and transformation of phenolic compounds by Epicoccum nigrum in relation to humic acid formation. *Soil Science Society of America Journal, 31*(6), 766-772.

Hamza, M., & Anderson, W. (2005). Soil compaction in cropping systems: A review of the nature, causes and possible solutions. *Soil and tillage research, 82*(2), 121-145.

Han, G., Tang, Y., Liu, M., Van Zwieten, L., Yang, X., Yu, C., . . . Song, Z. (2020). Carbon-nitrogen isotope coupling of soil organic matter in a karst region under land use change, Southwest China. *Agriculture, Ecosystems & Environment, 301*, 107027. doi:https://doi.org/10.1016/j.agee.2020.107027

Handa, I. T., Aerts, R., Berendse, F., Berg, M. P., Bruder, A., Butenschoen, O., . . . Makkonen, M. (2014). Consequences of biodiversity loss for litter decomposition across biomes. *Nature, 509*(7499), 218-221.

Harasim, E., Antonkiewicz, J., & Kwiatkowski, C. A. (2020). The effects of catch crops and tillage systems on selected physical properties and enzymatic activity of loess soil in a spring wheat monoculture. *Agronomy, 10*(3), 334.

Hartmann, M., Howes, C. G., VanInsberghe, D., Yu, H., Bachar, D., Christen, R., . . . Mohn, W. W. (2012). Significant and persistent impact of timber harvesting on soil microbial communities in Northern coniferous forests. *The ISME journal, 6*(12), 2199-2218.

Hati, K. M., Swarup, A., Dwivedi, A. K., Misra, A. K., & Bandyopadhyay, K. K. (2007). Changes in soil physical properties and organic carbon status at the topsoil horizon of a vertisol of central India after 28 years of continuous cropping, fertilization and manuring. *Agriculture, Ecosystems & Environment, 119*(1), 127-134. doi:https://doi.org/10.1016/j.agee.2006.06.017

He, L., Lu, S., Wang, C., Mu, J., Zhang, Y., & Wang, X. (2021). Changes in soil organic carbon fractions and enzyme activities in response to tillage practices in the Loess Plateau of China. *Soil and tillage research, 209*, 104940. doi:https://doi.org/10.1016/j.still.2021.104940

Helgason, B. L., Walley, F. L., & Germida, J. J. (2009). Fungal and bacterial abundance in long-term no-till and intensive-till soils of the Northern Great Plains. *Soil Science Society of America Journal*, *73*(1), 120-127.

Hermans, S. M., Buckley, H. L., Case, B. S., Curran-Cournane, F., Taylor, M., & Lear, G. (2017). Bacteria as emerging indicators of soil condition. *Applied and environmental microbiology, 83*(1), e02826-02816.

Hermans, S. M., Buckley, H. L., Case, B. S., Curran-Cournane, F., Taylor, M., & Lear, G. (2020). Using soil bacterial communities to predict physico-chemical variables and soil quality. *Microbiome, 8*, 1-13.

Herrick, J. E., & Wander, M. M. (2018). Relationships between soil organic carbon and soil quality in cropped and rangeland soils: the importance of distribution, composition, and soil biological activity *Soil processes and the carbon cycle* (pp. 405-425): CRC Press.

Heydari, M., Eslaminejad, P., Kakhki, F. V., Mirab-Balou, M., Omidipour, R., Prévosto, B., . . . Lucas-Borja, M. E. (2020). Soil quality and mesofauna diversity relationship are modulated by woody species and seasonality in semiarid oak forest. *Forest Ecology and Management, 473,* 118332.

Hobley, E., Wilson, B., Wilkie, A., Gray, J., & Koen, T. (2015). Drivers of soil organic carbon storage and vertical distribution in Eastern Australia. *Plant and Soil, 390*(1), 111-127.

Hurst, R., Siyame, E. W., Young, S. D., Chilimba, A. D., Joy, E. J., Black, C. R., . . . Gondwe, J. (2013). Soil-type influences human selenium status and underlies widespread selenium deficiency risks in Malawi. *Scientific reports, 3*(1), 1-6.

Ibrahim, M., Cao, C.-G., Zhan, M., Li, C.-F., & Iqbal, J. (2015). Changes of CO 2 emission and labile organic carbon as influenced by rice straw and different water regimes. *International Journal of Environmental Science and Technology, 12*(1), 263-274.

Idowu, O. J., Sultana, S., Darapuneni, M., Beck, L., & Steiner, R. (2019). Short-term conservation tillage effects on corn silage yield and soil quality in an irrigated, arid agroecosystem. *Agronomy, 9*(8), 455.

Islam, K. R., & Weil, R. (2000). Soil quality indicator properties in mid-Atlantic soils as influenced by conservation management. *Journal of soil and water conservation, 55*(1), 69-78.

Ismail-Meyer, K., Stolt, M. H., & Lindbo, D. L. (2018). Soil organic matter *Interpretation of micromorphological features of soils and regoliths* (pp. 471-512): Elsevier.

Jarecki, M., Grant, B., Smith, W., Deen, B., Drury, C., VanderZaag, A., . . . Wagner-Riddle, C. (2020). Long-term trends in corn yields and soil carbon under diversified crop rotations.

Jernigan, A. B., Wickings, K., Mohler, C. L., Caldwell, B. A., Pelzer, C. J., Wayman, S., & Ryan, M. R. (2020). Legacy effects of contrasting organic grain cropping systems on soil health indicators, soil invertebrates, weeds, and crop yield. *Agricultural Systems, 177*, 102719. doi:https://doi.org/10.1016/j.agsy.2019.102719

Johnston, A. (1986). Soil organic matter, effects on soils and crops. *Soil use and management, 2*(3), 97-105.

Johnston, A. E., Poulton, P. R., & Coleman, K. (2009). Chapter 1 Soil Organic Matter: Its Importance in Sustainable Agriculture and Carbon Dioxide Fluxes. In D. L. Sparks (Ed.), *Advances in agronomy* (Vol. 101, pp. 1-57): Academic Press.

Johnston, A. E., Poulton, P. R., & Coleman, K. (2009). Soil organic matter: its importance in sustainable agriculture and carbon dioxide fluxes. *Advances in agronomy, 101*, 1-57.

Jones, D. L., Nguyen, C., & Finlay, R. D. (2009). Carbon flow in the rhizosphere: carbon trading at the soil–root interface. *Plant and Soil, 321*(1), 5-33.

Juma, N., Izaurralde, R., Robertson, J., & McGill, W. (2019). Crop yield and soil organic matter trends over 60 years in a Typic Cryoboralf at Breton, Alberta *Soil organic matter in temperate agroecosystems* (pp. 273-282): CRC Press.

Kaiser, M., Zederer, D. P., Ellerbrock, R. H., Sommer, M., & Ludwig, B. (2016). Effects of mineral characteristics on content, composition, and stability of organic matter fractions separated from seven forest topsoils of different pedogenesis. *Geoderma, 263*, 1-7.

Kaminsky, R., Trouche, B., & Morales, S. E. (2017). Soil classification predicts differences in prokaryotic communities across a range of geographically distant soils once pH is accounted for. *Scientific reports, 7*(1), 1-9.

Kane, D. A., Bradford, M. A., Fuller, E., Oldfield, E. E., & Wood, S. A. (2021). Soil organic matter protects US maize yields and lowers crop insurance payouts under drought. *Environmental Research Letters, 16*(4), 044018.

Kästner, M., & Miltner, A. (2018). SOM and microbes—What is left from microbial life *The future of soil carbon* (pp. 125-163): Elsevier.

Keesstra, S. D., Bouma, J., Wallinga, J., Tittonell, P., Smith, P., Cerdà, A., . . . Van Der Putten, W. H. (2016). The significance of soils and soil science towards realization of the United Nations Sustainable Development Goals. *Soil, 2*(2), 111-128.

Kiani, M., Hernandez-Ramirez, G., Quideau, S., Smith, E., Janzen, H., Larney, F. J., & Puurveen, D. (2017). Quantifying sensitive soil quality indicators across contrasting long-term land management systems: Crop rotations and nutrient regimes. *Agriculture, Ecosystems & Environment, 248*, 123-135. doi:https://doi.org/10.1016/j.agee.2017.07.018

Kleber, M. (2010). What is recalcitrant soil organic matter? *Environmental Chemistry, 7*(4), 320-332.

Kleber, M., Eusterhues, K., Keiluweit, M., Mikutta, C., Mikutta, R., & Nico, P. S. (2015). Mineral–organic associations: formation, properties, and relevance in soil environments. *Advances in agronomy, 130*, 1-140.

Kochiieru, M., Feiziene, D., Feiza, V., Volungevicius, J., Velykis, A., Slepetiene, A., . . . Seibutis, V. (2020). Freezing-thawing impact on aggregate stability as affected by land management, soil genesis and soil chemical and physical quality. *Soil and tillage research, 203*, 104705. doi:https://doi.org/10.1016/j.still.2020.104705

Kocira, A., Staniak, M., Tomaszewska, M., Kornas, R., Cymerman, J., Panasiewicz, K., & Lipińska, H. (2020). Legume cover crops as one of the elements of strategic weed management and soil quality improvement. A Review. *Agriculture, 10*(9), 394.

Kögel-Knabner, I. (2017). The macromolecular organic composition of plant and microbial residues as inputs to soil organic matter: fourteen years on. *Soil Biology and Biochemistry, 105*, A3-A8.

Kopittke, P. M., Dalal, R. C., Hoeschen, C., Li, C., Menzies, N. W., & Mueller, C. W. (2020). Soil organic matter is stabilized by organo-mineral associations through two key processes: The role of the carbon to nitrogen ratio. *Geoderma, 357*, 113974. doi:https://doi.org/10.1016/j.geoderma.2019.113974

Krzywoszynska, A. (2019). Caring for soil life in the Anthropocene: the role of attentiveness in more-than-human ethics. *Transactions of the Institute of British Geographers, 44*(4), 661-675.

Kwiatkowski, C. A., Harasim, E., & Staniak, M. (2020). Effect of catch crops and tillage systems on some chemical properties of loess soil in a short-term monoculture of spring wheat. *Journal of Elementology, 25*(1).

Lal, R. (2006). Enhancing crop yields in the developing countries through restoration of the soil organic carbon pool in agricultural lands. *Land Degradation & Development, 17*(2), 197-209.

Lal, R. (2015). Restoring soil quality to mitigate soil degradation. *Sustainability, 7*(5), 5875-5895.

Lal, R. (2020). Soil organic matter content and crop yield. *Journal of soil and water conservation, 75*(2), 27A-32A.

Lal, R., Mokma, D., & Lowery, B. (2018). Relation between soil quality and erosion *Soil quality and soil erosion* (pp. 237-258): CRC Press.

Larson, W., & Pierce, F. (1991). *Conservation and enhancement of soil quality*. Paper presented at the Evaluation for sustainable land management in the developing world: proceedings of the International Workshop on Evaluation for Sustainable Land Management in the Developing World, Chiang Rai, Thailand, 15-21 September 1991.

Lehmann, J., & Kleber, M. (2015). The contentious nature of soil organic matter. *Nature, 528*(7580), 60-68.

Lehmann, J., Solomon, D., Kinyangi, J., Dathe, L., Wirick, S., & Jacobsen, C. (2008). Spatial complexity of soil organic matter forms at nanometre scales. *Nature Geoscience, 1*(4), 238-242.

Leite Chaves, H. M., Concha Lozada, C. M., & Gaspar, R. O. (2017). Soil quality index of an Oxisol under different land uses in the Brazilian savannah. *Geoderma Regional, 10*, 183-190. doi:https://doi.org/10.1016/j.geodrs.2017.07.007

Li, G., Sun, G. X., Ren, Y., Luo, X. S., & Zhu, Y. G. (2018). Urban soil and human health: a review. *European Journal of Soil Science, 69*(1), 196-215.

Li, H., Feng, W.-t., He, X.-h., Zhu, P., Gao, H.-j., Sun, N., & Xu, M.-g. (2017). Chemical fertilizers could be completely replaced by manure to maintain high maize yield and soil organic carbon (SOC) when SOC reaches a threshold in the Northeast China Plain. *Journal of Integrative Agriculture, 16*(4), 937-946. doi:https://doi.org/10.1016/S2095-3119(16)61559-9

Li, J., Nie, M., & Pendall, E. (2020). Soil physico-chemical properties are more important than microbial diversity and enzyme activity in controlling carbon and nitrogen stocks near Sydney, Australia. *Geoderma, 366*, 114201. doi:https://doi.org/10.1016/j.geoderma.2020.114201

Li, P., Shi, K., Wang, Y., Kong, D., Liu, T., Jiao, J., . . . Hu, F. (2019). Soil quality assessment of wheat-maize cropping system with different productivities in China: Establishing a minimum data set. *Soil and tillage research, 190*, 31-40. doi:https://doi.org/10.1016/j.still.2019.02.019

Li, Y., Song, D., Dang, P., Wei, L., Qin, X., & Siddique, K. H. M. (2020). Combined ditch buried straw return technology in a ridge–furrow plastic film mulch system: Implications for crop yield and soil organic matter dynamics. *Soil and tillage research, 199*, 104596. doi:https://doi.org/10.1016/j.still.2020.104596

Liang, A., Zhang, Y., Zhang, X., Yang, X., McLaughlin, N., Chen, X., . . . Tang, J. (2019). Investigations of relationships among aggregate pore structure, microbial biomass, and soil organic carbon in a Mollisol using combined non-destructive measurements and phospholipid fatty acid analysis. *Soil and tillage research, 185*, 94-101. doi:https://doi.org/10.1016/j.still.2018.09.003

Liang, C., Schimel, J., & Jastrow, J. (2017). The importance of anabolism in microbial control over soil carbon storage, Nat. Microbiol., 2, 17105.

Liu, J., Wang, Z., Hu, F., Xu, C., Ma, R., & Zhao, S. (2020). Soil organic matter and silt contents determine soil particle surface electrochemical properties across a long-term natural restoration grassland. *Catena, 190*, 104526. doi:https://doi.org/10.1016/j.catena.2020.104526

Liu, L., & Basso, B. (2020). Impacts of climate variability and adaptation strategies on crop yields and soil organic carbon in the US Midwest. *PLoS one, 15*(1), e0225433.

Liu, M., Han, G., & Zhang, Q. (2019). Effects of soil aggregate stability on soil organic carbon and nitrogen under land use change in an erodible region in Southwest China. *International journal of environmental research and public health, 16*(20), 3809.

Lorenz, K., Lal, R., & Ehlers, K. (2019). Soil organic carbon stock as an indicator for monitoring land and soil degradation in relation to U nited N ations' S ustainable D evelopment G oals. *Land Degradation & Development, 30*(7), 824-838.

Loveland, P., & Webb, J. (2003). Is there a critical level of organic matter in the agricultural soils of temperate regions: a review. *Soil and tillage research, 70*(1), 1-18.

Luo, Z., Gan, Y., Niu, Y., Zhang, R., Li, L., Cai, L., & Xie, J. (2017). Soil quality indicators and crop yield under long-term tillage systems. *Experimental Agriculture, 53*(4), 497-511.

MacCarthy, P. (2001). The principles of humic substances. *Soil Science, 166*(11), 738-751.

Machmuller, M. B., Kramer, M. G., Cyle, T. K., Hill, N., Hancock, D., & Thompson, A. (2015). Emerging land use practices rapidly increase soil organic matter. *Nature communications, 6*(1), 1-5.

Manna, M. C., Swarup, A., Wanjari, R. H., Mishra, B., & Shahi, D. K. (2007). Long-term fertilization, manure and liming effects on soil organic matter and crop yields. *Soil and tillage research, 94*(2), 397-409. doi:https://doi.org/10.1016/j.still.2006.08.013

Manna, M. C., Swarup, A., Wanjari, R. H., Ravankar, H. N., Mishra, B., Saha, M. N., . . . Sarap, P. A. (2005). Long-term effect of fertilizer and manure application on soil organic carbon storage, soil quality and yield sustainability under sub-humid and semi-arid tropical India. *Field crops research, 93*(2), 264-280. doi:https://doi.org/10.1016/j.fcr.2004.10.006

Manson, A. (2018). Soil organic matter. *Research and Technology Bulletin*, 20017-20018.

Manzoni, S., Schaeffer, S., Katul, G., Porporato, A., & Schimel, J. (2014). A theoretical analysis of microbial eco-physiological and diffusion limitations to carbon cycling in drying soils. *Soil Biology and Biochemistry, 73*, 69-83.

Martini, E. A., Buyer, J. S., Bryant, D. C., Hartz, T. K., & Denison, R. F. (2004). Yield increases during the organic transition: improving soil quality or increasing experience? *Field crops research, 86*(2), 255-266. doi:https://doi.org/10.1016/j.fcr.2003.09.002

Marzaioli, R., D'Ascoli, R., De Pascale, R. A., & Rutigliano, F. A. (2010). Soil quality in a Mediterranean area of Southern Italy as related to different land use types. *Applied Soil Ecology, 44*(3), 205-212. doi:https://doi.org/10.1016/j.apsoil.2009.12.007

Maughan, M. W., Flores, J. P. C., Anghinoni, I., Bollero, G., Fernández, F. G., & Tracy, B. F. (2009). Soil quality and corn yield under crop–livestock integration in Illinois. *Agronomy journal, 101*(6), 1503-1510.

Maurya, S., Abraham, J. S., Somasundaram, S., Toteja, R., Gupta, R., & Makhija, S. (2020). Indicators for assessment of soil quality: a mini-review. *Environmental monitoring and assessment, 192*(9), 1-22.

Mausel, P. W. (1971). Soil quality in Illinois—an example of a soils geography resource analysis. *The Professional Geographer, 23*(2), 127-136.

Mendes, I. C., Sousa, D. M. G., Dantas, O. D., Lopes, A. A. C., Junior, F. B. R., Oliveira, M. I., & Chaer, G. M. (2021). Soil quality and grain yield: A win–win combination in clayey tropical oxisols. *Geoderma, 388*, 114880.

Mendes, R. (2009). VAZ A. *Educação Ambiental no ensino formal: narrativas de professores sobre suas experiências e expectativas*.

Milori, D. M., Martin-Neto, L., Bayer, C., Mielniczuk, J., & Bagnato, V. S. (2002). Humification degree of soil humic acids determined by fluorescence spectroscopy. *Soil Science, 167*(11), 739-749.

Miltner, A., Bombach, P., Schmidt-Brücken, B., & Kästner, M. (2012). SOM genesis: microbial biomass as a significant source. *Biogeochemistry, 111*(1), 41-55.

Mirsky, S. B., Lanyon, L. E., & Needelman, B. A. (2008). Evaluating soil management using particulate and chemically labile soil organic matter fractions. *Soil Science Society of America Journal, 72*(1), 180-185.

Mirzaee, S., Ghorbani-Dashtaki, S., Mohammadi, J., Asadi, H., & Asadzadeh, F. (2016). Spatial variability of soil organic matter using remote sensing data. *Catena, 145*, 118-127.

Mitchell, A. E., Hong, Y.-J., Koh, E., Barrett, D. M., Bryant, D., Denison, R. F., & Kaffka, S. (2007). Ten-year comparison of the influence of organic and conventional crop management practices on the content of flavonoids in tomatoes. *Journal of agricultural and food chemistry, 55*(15), 6154-6159.

Mohamed, H. I., Sofy, M. R., Almoneafy, A. A., Abdelhamid, M. T., Basit, A., Sofy, A. R., . . . Abou-El-Enain, M. M. (2021). Role of Microorganisms in Managing Soil Fertility and Plant Nutrition in Sustainable Agriculture. *Plant Growth-Promoting Microbes for Sustainable Biotic and Abiotic Stress Management*, 93-114.

Mondal, S., Chakraborty, D., Bandyopadhyay, K., Aggarwal, P., & Rana, D. S. (2020). A global analysis of the impact of zero-tillage on soil physical condition, organic carbon content, and plant root response. *Land Degradation & Development, 31*(5), 557-567.

Mulyono, A., Suriadikusumah, A., Harriyanto, R., & Djuwansah, M. R. (2019). Soil quality under agroforestry trees pattern in upper Citarum watershed, Indonesia. *Journal of Ecological Engineering, 20*(1).

Muñoz-Rojas, M. (2018). Soil quality indicators: critical tools in ecosystem restoration. *Current Opinion in Environmental Science & Health, 5*, 47-52.

Murphy, B. (2015). Impact of soil organic matter on soil properties—a review with emphasis on Australian soils. *Soil Research, 53*(6), 605-635.

Mustafa, A., Minggang, X., Ali Shah, S. A., Abrar, M. M., Nan, S., Baoren, W., . . . Núñez-Delgado, A. (2020). Soil aggregation and soil aggregate stability regulate organic carbon and nitrogen storage in a red soil of southern China. *Journal of environmental management, 270*, 110894. doi:https://doi.org/10.1016/j.jenvman.2020.110894

Naab, J. B., Mahama, G. Y., Yahaya, I., & Prasad, P. (2017). Conservation agriculture improves soil quality, crop yield, and incomes of smallholder farmers in North Western Ghana. *Frontiers in plant science, 8,* 996.

Nabiollahi, K., Golmohamadi, F., Taghizadeh-Mehrjardi, R., Kerry, R., & Davari, M. (2018). Assessing the effects of slope gradient and land use change on soil quality degradation through digital mapping of soil quality indices and soil loss rate. *Geoderma, 318,* 16-28.

Nabiollahi, K., Taghizadeh-Mehrjardi, R., Kerry, R., & Moradian, S. (2017). Assessment of soil quality indices for salt-affected agricultural land in Kurdistan Province, Iran. *Ecological Indicators, 83*, 482-494. doi:https://doi.org/10.1016/j.ecolind.2017.08.001

Nguemezi, C., Tematio, P., Yemefack, M., Tsozue, D., & Silatsa, T. (2020). Soil quality and soil fertility status in major soil groups at the Tombel area, South-West Cameroon. *Heliyon, 6*(2), e03432.

Nortcliff, S. (2002). Standardisation of soil quality attributes. *Agriculture, Ecosystems & Environment, 88*(2), 161-168.

Nouri, A., Lee, J., Yin, X., Tyler, D. D., & Saxton, A. M. (2019). Thirty-four years of no-tillage and cover crops improve soil quality and increase cotton yield in Alfisols, Southeastern USA. *Geoderma, 337*, 998-1008. doi:https://doi.org/10.1016/j.geoderma.2018.10.016

Novara, A., Catania, V., Tolone, M., Gristina, L., Laudicina, V. A., & Quatrini, P. (2020). Cover crop impact on soil organic carbon, nitrogen dynamics and microbial diversity in a Mediterranean semiarid vineyard. *Sustainability, 12*(8), 3256.

Novotny, E., Turetta, A., Resende, M., & Rebello, C. (2020). The quality of soil organic matter, accessed by 13C solid state nuclear magnetic resonance, is just as important as its content concerning pesticide sorption. *Environmental Pollution, 266*, 115298.

Nunes, M. R., van Es, H. M., Schindelbeck, R., Ristow, A. J., & Ryan, M. (2018). No-till and cropping system diversification improve soil health and crop yield. *Geoderma, 328,* 30-43. doi:https://doi.org/10.1016/j.geoderma.2018.04.031

Obalum, S., Chibuike, G., Peth, S., & Ouyang, Y. (2017). Soil organic matter as sole indicator of soil degradation. *Environmental monitoring and assessment, 189*(4), 176.

Okur, N., Kayikcioglu, H., Ates, F., & Yagmur, B. (2016). A comparison of soil quality and yield parameters under organic and conventional vineyard systems in Mediterranean conditions (West Turkey). *Biological Agriculture & Horticulture, 32*(2), 73-84.

Oladele, S. O., & Adetunji, A. T. (2021). Agro-residue biochar and N fertilizer addition mitigates CO2-C emission and stabilized soil organic carbon pools in a rain-fed agricultural cropland. *International Soil and Water Conservation Research, 9*(1), 76-86.

Oliver, M. A., & Gregory, P. (2015). Soil, food security and human health: a review. *European Journal of Soil Science, 66*(2), 257-276.

Ondrasek, G., Begić, H. B., Zovko, M., Filipović, L., Meriño-Gergichevich, C., Savić, R., & Rengel, Z. (2019). Biogeochemistry of soil organic matter in agroecosystems & environmental implications. *Science of the Total Environment, 658,* 1559-1573.

Palm, C., Blanco-Canqui, H., DeClerck, F., Gatere, L., & Grace, P. (2014). Conservation agriculture and ecosystem services: An overview. *Agriculture, Ecosystems & Environment, 187,* 87-105.

Pan, G., Smith, P., & Pan, W. (2009). The role of soil organic matter in maintaining the productivity and yield stability of cereals in China. *Agriculture, Ecosystems & Environment, 129*(1), 344-348. doi:https://doi.org/10.1016/j.agee.2008.10.008

Pan, J., Zhang, L., He, X., Chen, X., & Cui, Z. (2019). Long-term optimization of crop yield while concurrently improving soil quality. *Land Degradation & Development, 30*(8), 897-909.

Pan, X., Zhang, S., Zhong, Q., Gong, G., Wang, G., Guo, X., & Xu, X. (2020). Effects of soil chemical properties and fractions of Pb, Cd, and Zn on bacterial and fungal communities. *Science of the Total Environment, 715,* 136904.

Panettieri, M., Berns, A. E., Knicker, H., Murillo, J., & Madejón, E. (2015). Evaluation of seasonal variability of soil biogeochemical properties in aggregate-size fractioned soil under different tillages. *Soil and tillage research, 151*, 39-49.

Parton, W. J., Ojima, D. S., & Schimel, D. S. (2020). Models to evaluate soil organic matter storage and dynamics *Structure and organic matter storage in agricultural soils* (pp. 421-448): CRC Press.

Paul, E., Collins, H., & Leavitt, S. (2001). Dynamics of resistant soil carbon of Midwestern agricultural soils measured by naturally occurring 14C abundance. *Geoderma, 104*(3-4), 239-256.

Pittelkow, C. M., Linquist, B. A., Lundy, M. E., Liang, X., Van Groenigen, K. J., Lee, J., . . . Van Kessel, C. (2015). When does no-till yield more? A global meta-analysis. *Field crops research, 183,* 156-168.

Plassart, P., Prévost-Bouré, N. C., Uroz, S., Dequiedt, S., Stone, D., Creamer, R., . . . Lemanceau, P. (2019). Soil parameters, land use, and geographical distance drive soil bacterial communities along a European transect. *Scientific reports, 9*(1), 1-17.

Prober, S. M., Leff, J. W., Bates, S. T., Borer, E. T., Firn, J., Harpole, W. S., . . . Bakker, J. D. (2015). Plant diversity predicts beta but not alpha diversity of soil microbes across grasslands worldwide. *Ecology letters, 18*(1), 85-95.

Pujol Pereira, E. I., Suddick, E. C., & Six, J. (2016). Carbon abatement and emissions associated with the gasification of walnut shells for bioenergy and biochar production. *PLoS one, 11*(3), e0150837.

Qiu, J.-j., Wang, L.-g., Li, H., Tang, H.-j., Li, C.-s., & Van Ranst, E. (2009). Modeling the Impacts of Soil Organic Carbon Content of Croplands on Crop Yields in China. *Agricultural Sciences in China, 8*(4), 464-471. doi:https://doi.org/10.1016/S1671-2927(08)60233-3

Quiroga, A., Funaro, D., Noellemeyer, E., & Peinemann, N. (2006). Barley yield response to soil organic matter and texture in the Pampas of Argentina. *Soil and tillage research, 90*(1), 63-68. doi:https://doi.org/10.1016/j.still.2005.08.019

Quist, C. W., Gort, G., Mooijman, P., Brus, D. J., van den Elsen, S., Kostenko, O., . . . Helder, J. (2019). Spatial distribution of soil nematodes relates to soil organic matter and life strategy. *Soil Biology and Biochemistry, 136*, 107542.

Raiesi, F., & Salek-Gilani, S. (2020). Development of a soil quality index for characterizing effects of land-use changes on degradation and ecological restoration of rangeland soils in a semi-arid ecosystem. *Land Degradation & Development, 31*(12), 1533-1544.

Ramos, F. T., Dores, E. F. d. C., Weber, O. L. d. S., Beber, D. C., Campelo Jr, J. H., & Maia, J. C. d. S. (2018). Soil organic matter doubles the cation exchange capacity of tropical soil under no-till farming in Brazil. *Journal of the Science of Food and Agriculture, 98*(9), 3595-3602.

Ranjendra, S. V., & Gadekar, D. (2020). Analysis of Chemical Properties of Soil under Sugarcane Crop: A Case Study of Khandala, Shrirampur, Ahmednagar District, Maharashtra State, India. *Our Heritage, 68*(30), 6522-6547.

Rasmussen, P. E., & Parton, W. (1994). Long-term effects of residue management in wheat-fallow: I. Inputs, yield, and soil organic matter. *Soil Science Society of America Journal, 58*(2), 523-530.

Rasool, R., Kukal, S., & Hira, G. (2008). Soil organic carbon and physical properties as affected by long-term application of FYM and inorganic fertilizers in maize–wheat system. *Soil and tillage research, 101*(1-2), 31-36.

Redmile-Gordon, M., Gregory, A., White, R., & Watts, C. (2020). Soil organic carbon, extracellular polymeric substances (EPS), and soil structural stability as affected by previous and current land-use. *Geoderma, 363*, 114143.

Reeves, D. (1997). The role of soil organic matter in maintaining soil quality in continuous cropping systems. *Soil and tillage research, 43*(1-2), 131-167.

Roh, S. W., Kim, K.-H., Nam, Y.-D., Chang, H.-W., Park, E.-J., & Bae, J.-W. (2010). Investigation of archaeal and bacterial diversity in fermented seafood using barcoded pyrosequencing. *The ISME journal, 4*(1), 1-16.

Ruiz-Colmenero, M., Bienes, R., Eldridge, D. J., & Marques, M. J. (2013). Vegetation cover reduces erosion and enhances soil organic carbon in a vineyard in the central Spain. *Catena, 104*, 153-160. doi:https://doi.org/10.1016/j.catena.2012.11.007

Sainju, U. M., Lenssen, A. W., Caesar-TonThat, T., & Evans, R. G. (2009). Dryland crop yields and soil organic matter as influenced by long-term tillage and cropping sequence. *Agronomy journal, 101*(2), 243-251.

Santos-Francés, F., Martínez-Graña, A., Ávila-Zarza, C., Criado, M., & Sánchez, Y. (2019). Comparison of methods for evaluating soil quality of semiarid ecosystem and evaluation of the effects of physico-chemical properties and factor soil erodibility (Northern Plateau, Spain). *Geoderma, 354*, 113872. doi:https://doi.org/10.1016/j.geoderma.2019.07.030

Schjønning, P., Jensen, J. L., Bruun, S., Jensen, L. S., Christensen, B. T., Munkholm, L. J., . . . Knudsen, L. (2018a). Chapter Two - The Role of Soil Organic Matter for Maintaining Crop Yields: Evidence for a Renewed Conceptual Basis. In D. L. Sparks (Ed.), *Advances in agronomy* (Vol. 150, pp. 35-79): Academic Press.

Schjønning, P., Jensen, J. L., Bruun, S., Jensen, L. S., Christensen, B. T., Munkholm, L. J., . . . Knudsen, L. (2018b). The role of soil organic matter for maintaining crop yields: Evidence for a renewed conceptual basis. *Advances in agronomy, 150*, 35-79.

Schjønning, P., McBride, R., Keller, T., & Obour, P. (2017). Predicting soil particle density from clay and soil organic matter contents. *Geoderma, 286*, 83-87.

Schloter, M., Nannipieri, P., Sørensen, S. J., & van Elsas, J. D. (2018). Microbial indicators for soil quality. *Biology and fertility of soils, 54*(1), 1-10.

Schmidt, M. W., Torn, M. S., Abiven, S., Dittmar, T., Guggenberger, G., Janssens, I. A., . . . Manning, D. A. (2011). Persistence of soil organic matter as an ecosystem property. *Nature, 478*(7367), 49-56.

Schnitzer, M. (1978). Humic substances: chemistry and reactions *Developments in soil science* (Vol. 8, pp. 1-64): Elsevier.

Schwilch, G., Bernet, L., Fleskens, L., Giannakis, E., Leventon, J., Maranon, T., . . . Van Delden, H. (2016). Operationalizing ecosystem services for the mitigation of soil threats: A proposed framework. *Ecological Indicators, 67*, 586-597.

Selolo, K. R. (2021). *Effects of tillage and mulching on selected soil properties, growth and yield of sunflower (Helianthus annuus L.).*

Senesi, N., & Loffredo, E. (2018). The chemistry of soil organic matter *Soil physical chemistry* (pp. 239-370): CRC press.

Shahbaz, M., Kuzyakov, Y., & Heitkamp, F. (2017). Decrease of soil organic matter stabilization with increasing inputs: mechanisms and controls. *Geoderma, 304*, 76-82.

Shao, G., Ai, J., Sun, Q., Hou, L., & Dong, Y. (2020). Soil quality assessment under different forest types in the Mount Tai, central Eastern China. *Ecological Indicators, 115*, 106439. doi:https://doi.org/10.1016/j.ecolind.2020.106439

Sharma, K., Mandal, U. K., Srinivas, K., Vittal, K., Mandal, B., Grace, J. K., & Ramesh, V. (2005). Long-term soil management effects on crop yields and soil quality in a dryland Alfisol. *Soil and tillage research, 83*(2), 246-259.

Shen, Y., Zhang, T., Cui, J., Chen, S., Han, H., & Ning, T. (2021). Subsoiling increases aggregate-associated organic carbon, dry matter, and maize yield on the North China Plain. *PeerJ, 9*, e11099.

Sierra, C. A., Trumbore, S. E., Davidson, E. A., Vicca, S., & Janssens, I. (2015). Sensitivity of decomposition rates of soil organic matter with respect to simultaneous changes in temperature and moisture. *Journal of Advances in Modeling Earth Systems, 7*(1), 335-356.

Sims, J., Cunningham, S., & Sumner, M. (1997). Assessing soil quality for environmental purposes: roles and challenges for soil scientists. *Journal of Environmental Quality, 26*(1), 20-25.

Singh, P., & Dhumal, G. (2019). Effect of Pollution on Physical and Chemical Properties of Soil. In A. Kumar & S. Sharma (Eds.), *Microbes and Enzymes* *in Soil Health and Bioremediation* (pp. 75-97). Singapore: Springer Singapore.

Sione, S. M. J., Wilson, M. G., Lado, M., & González, A. P. (2017). Evaluation of soil degradation produced by rice crop systems in a Vertisol, using a soil quality index. *Catena, 150*, 79-86. doi:https://doi.org/10.1016/j.catena.2016.11.011

Sithole, N. J., Magwaza, L. S., & Mafongoya, P. L. (2016). Conservation agriculture and its impact on soil quality and maize yield: A South African perspective. *Soil and tillage research, 162*, 55-67. doi:https://doi.org/10.1016/j.still.2016.04.014

Smith, P., Lutfalla, S., Riley, W. J., Torn, M. S., Schmidt, M. W., & Soussana, J. F. (2018). The changing faces of soil organic matter research. *European Journal of Soil Science, 69*(1), 23-30.

Sofo, A., Mininni, A. N., & Ricciuti, P. (2020). Soil macrofauna: A key factor for increasing soil fertility and promoting sustainable soil use in fruit orchard agrosystems. *Agronomy, 10*(4), 456.

Soinne, H., Keskinen, R., Räty, M., Kanerva, S., Turtola, E., Kaseva, J., . . . Salo, T. (2020). Soil organic carbon and clay content as deciding factors for net nitrogen mineralization and cereal yields in boreal mineral soils. *European Journal of Soil Science*.

Song, W., Tong, X., Liu, Y., & Li, W. (2020). Microbial community, newly sequestered soil organic carbon, and δ15N variations driven by tree roots. *Frontiers in microbiology, 11*, 314.

Soto, R. L., Padilla, M. C., & de Vente, J. (2020). Participatory selection of soil quality indicators for monitoring the impacts of regenerative agriculture on ecosystem services. *Ecosystem Services, 45*, 101157.

Spiegel, H., Zavattaro, L., Guzmán Díaz, M. G., D'Hose, T., Pecio, A., Lehtinen, T., . . . Molendijk, L. (2015). Impacts of soil management practices on crop productivity, on indicators for climate change mitigation, and on the chemical, physical and biological quality of soil.

Spurgeon, D. J., Keith, A. M., Schmidt, O., Lammertsma, D. R., & Faber, J. H. (2013). Land-use and land-management change: relationships with earthworm and fungi communities and soil structural properties. *BMC ecology, 13*(1), 1-13.

Steffan, J., Brevik, E., Burgess, L., & Cerdà, A. (2018). The effect of soil on human health: an overview. *European Journal of Soil Science, 69*(1), 159-171.

Stevenson, F. J. (1994). *Humus chemistry: genesis, composition, reactions*: John Wiley & Sons.

Stockmann, U., Adams, M. A., Crawford, J. W., Field, D. J., Henakaarchchi, N., Jenkins, M., . . . Singh, K. (2013). The knowns, known unknowns and unknowns of sequestration of soil organic carbon. *Agriculture, Ecosystems & Environment, 164*, 80-99.

Stolt, M. H., & Lindbo, D. L. (2010). Soil organic matter *Interpretation of micromorphological features of soils and regoliths* (pp. 369-396): Elsevier.

Sun, B., Chen, X., Zhang, X., Liang, A., Whalen, J. K., & McLaughlin, N. B. (2020). Greater fungal and bacterial biomass in soil large macropores under no-tillage than mouldboard ploughing. *European Journal of soil biology, 97*, 103155.

Sun, T., Wang, Y., Hui, D., Jing, X., & Feng, W. (2020). Soil properties rather than climate and ecosystem type control the vertical variations of soil organic carbon, microbial carbon, and microbial quotient. *Soil Biology and Biochemistry, 148*, 107905.

Sun, Z., Zhang, Z., Zhu, K., Wang, Z., Zhao, X., Lin, Q., & Li, G. (2020). Biochar altered native soil organic carbon by changing soil aggregate size distribution and native SOC in aggregates based on an 8-year field experiment. *Science of the Total Environment, 708*, 134829. doi:https://doi.org/10.1016/j.scitotenv.2019.134829

Sutton, R., & Sposito, G. (2005). Molecular structure in soil humic substances: the new view. *Environmental science & technology, 39*(23), 9009-9015.

Tajik, S., Ayoubi, S., & Lorenz, N. (2020). Soil microbial communities affected by vegetation, topography and soil properties in a forest ecosystem. *Applied Soil Ecology, 149*, 103514.

Tang, J., & Riley, W. J. (2015). Weaker soil carbon–climate feedbacks resulting from microbial and abiotic interactions. *Nature Climate Change, 5*(1), 56-60.

Teimouri, M., Mohamadi, P., Jalili, A., & Dick, W. (2018). Assessing soil quality through soil chemical properties and enzyme activities in semiarid area, Iran.

Terekhova, V., Fedoseeva, E., Kiryushina, A., Caracciolo, A. B., & Verkhovtseva, N. (2021). Effect of an equal dose of polymetallic pollution on the microbiological characteristics of two soils with different organic carbon contents. *Water, Air, & Soil Pollution, 232*(7), 1-14.

Thiele-Bruhn, S., Schloter, M., Wilke, B.-M., Beaudette, L. A., Martin-Laurent, F., Cheviron, N., . . . Römbke, J. (2020). Identification of new microbial functional standards for soil quality assessment. *Soil, 6*(1), 17-34.

Tian, P., Razavi, B. S., Zhang, X., Wang, Q., & Blagodatskaya, E. (2020). Microbial growth and enzyme kinetics in rhizosphere hotspots are modulated by soil organics and nutrient availability. *Soil Biology and Biochemistry, 141*, 107662.

Tiessen, H., Cuevas, E., & Chacon, P. (1994). The role of soil organic matter in sustaining soil fertility. *Nature, 371*(6500), 783-785.

Tisdall, J. (2020). Formation of soil aggregates and accumulation of soil organic matter *Structure and organic matter storage in agricultural soils* (pp. 57-96): CRC Press.

Tresch, S., Moretti, M., Le Bayon, R.-C., Mäder, P., Zanetta, A., Frey, D., & Fliessbach, A. (2018). A gardener's influence on urban soil quality. *Frontiers in Environmental Science, 6*, 25.

Trivedi, P., Singh, B. P., & Singh, B. K. (2018). Soil carbon: introduction, importance, status, threat, and mitigation *Soil Carbon Storage* (pp. 1-28): Elsevier.

Tsiafouli, M. A., Thébault, E., Sgardelis, S. P., De Ruiter, P. C., Van Der Putten, W. H., Birkhofer, K., . . . Brady, M. V. (2015). Intensive agriculture reduces soil biodiversity across Europe. *Global change biology, 21*(2), 973-985.

Valani, G. P., Vezzani, F. M., & Cavalieri-Polizeli, K. M. V. (2020). Soil quality: Evaluation of on-farm assessments in relation to analytical index. *Soil and tillage research, 198*, 104565.

Van Asten, P., Gold, C., Wendt, J., De Waele, D., Okech, S., Ssali, H., & Tushmereirwe, W. (2003). The contribution of soil quality to yield and its relationship with other factors in Uganda. *Farmer-participatory testing of integrated pest management options for sustainable banana production in Eastern Africa*, 100.

Vasu, D., Singh, S. K., Ray, S. K., Duraisami, V. P., Tiwary, P., Chandran, P., . . . Anantwar, S. G. (2016). Soil quality index (SQI) as a tool to evaluate crop productivity in semi-arid Deccan plateau, India. *Geoderma, 282*, 70-79.

Vizioli, B., Cavalieri-Polizeli, K. M. V., Tormena, C. A., & Barth, G. (2021). Effects of long-term tillage systems on soil physical quality and crop yield in a Brazilian Ferralsol. *Soil and tillage research, 209*, 104935. doi:https://doi.org/10.1016/j.still.2021.104935

Waksman, S. A. (1936). Humus origin, chemical composition, and importance in nature: LWW.

Wander, M. (2004). Soil organic matter fractions and their relevance to soil function. *Soil organic matter in sustainable agriculture. CRC Press, Boca Raton, FL*, 67-102.

Wang, Y., Gao, F., Wang, L., Guo, T., Qi, L., Zeng, H., . . . Zhang, R. (2021). Crop yield and soil organic carbon under ridge–furrow cultivation in China: A meta-analysis. *Land Degradation & Development*.

Wang, Y., Liu, L., Luo, Y., Awasthi, M. K., Yang, J., Duan, Y., . . . Zhao, Z. (2020). Mulching practices alter the bacterial-fungal community and network in favor of soil quality in a semiarid orchard system. *Science of the Total Environment*, *725*, 138527.

Waqas, M. A., Li, Y. e., Lal, R., Wang, X., Shi, S., Zhu, Y., . . . Qin, X. (2020). When does nutrient management sequester more carbon in soils and produce high and stable grain yields in China? *Land Degradation & Development, 31*(15), 1926-1941.

Waqas, M. A., Li, Y. e., Smith, P., Wang, X., Ashraf, M. N., Noor, M. A., . . . Liu, S. (2020). The influence of nutrient management on soil organic carbon storage, crop production, and yield stability varies under different climates.

Journal of Cleaner Production, 268, 121922. doi:https://doi.org/10.1016/j.jclepro.2020.121922

Warren Raffa, D., Bogdanski, A., & Tittonell, P. (2015). How does crop residue removal affect soil organic carbon and yield? A hierarchical analysis of management and environmental factors. *Biomass and Bioenergy, 81*, 345-355. doi:https://doi.org/10.1016/j.biombioe.2015.07.022

Wei, X., Zhu, Z., Liu, Y., Luo, Y., Deng, Y., Xu, X., . . . Guggenberger, G. (2020). C: N: P stoichiometry regulates soil organic carbon mineralization and concomitant shifts in microbial community composition in paddy soil. *Biology & Fertility of Soils, 56*(8).

Wen, Z., Zheng, H., Zhao, H., Xie, S., Liu, L., & Ouyang, Z. (2020). Land-use intensity indirectly affects soil multifunctionality via a cascade effect of plant diversity on soil bacterial diversity. *Global Ecology and Conservation, 23*, e01061.

Wendling, B., Jucksch, I., Mendonca, E., & Alvarenga, R. (2010). Organic-matter pools of soil under pines and annual cultures. *Communications in Soil Science and Plant Analysis, 41*(14), 1707-1722.

Wolters, V. (2001). Biodiversity of soil animals and its function. *European Journal of soil biology, 37*(4), 221-227.

Wood, S. A., Tirfessa, D., & Baudron, F. (2018). Soil organic matter underlies crop nutritional quality and productivity in smallholder agriculture. *Agriculture, Ecosystems & Environment, 266*, 100-108.

Wubie, M. A., & Assen, M. (2020). Effects of land cover changes and slope gradient on soil quality in the Gumara watershed, Lake Tana basin of North–West Ethiopia. *Modeling Earth Systems and Environment, 6*(1), 85-97.

Xie, X., Pu, L., Zhu, M., Wu, T., Xu, Y., & Wang, X. (2020). Effect of long-term reclamation on soil quality in agricultural reclaimed coastal saline soil, Eastern China. *Journal of Soils and Sediments, 20*(11), 3909-3920. doi:10.1007/s11368-020-02698-w

Xu, J., Han, H., Ning, T., Li, Z., & Lal, R. (2019). Long-term effects of tillage and straw management on soil organic carbon, crop yield, and yield stability in a wheat-maize system. *Field crops research, 233*, 33-40. doi:https://doi.org/10.1016/j.fcr.2018.12.016

Yaduvanshi, N., & Sharma, D. (2008). Tillage and residual organic manures/chemical amendment effects on soil organic matter and yield of wheat under sodic water irrigation. *Soil and tillage research, 98*(1), 11-16.

Yang, T., Siddique, K. H., & Liu, K. (2020). Cropping systems in agriculture and their impact on soil health-A review. *Global Ecology and Conservation, 23*, e01118.

Yuan, H., Ge, T., Zhou, P., Liu, S., Roberts, P., Zhu, H., . . . Wu, J. (2013). Soil microbial biomass and bacterial and fungal community structures responses to long-term fertilization in paddy soils. *Journal of Soils and Sediments, 13*(5), 877-886.

Zaher, H., Sabir, M., Benjelloun, H., & Paul-Igor, H. (2020). Effect of forest land use change on carbohydrates, physical soil quality and carbon stocks in Moroccan cedar area. *Journal of environmental management, 254,* 109544. doi:https://doi.org/10.1016/j.jenvman.2019.109544

Zarafshar, M., Bazot, S., Matinizadeh, M., Bordbar, S. K., Rousta, M. J., Kooch, Y., . . . Negahdarsaber, M. (2020). Do tree plantations or cultivated fields have the same ability to maintain soil quality as natural forests? *Applied Soil Ecology, 151*, 103536.

Zeraatpisheh, M., Bakhshandeh, E., Hosseini, M., & Alavi, S. M. (2020). Assessing the effects of deforestation and intensive agriculture on the soil quality through digital soil mapping. *Geoderma, 363*, 114139. doi:https://doi.org/10.1016/j.geoderma.2019.114139

Zhalnina, K., Dias, R., de Quadros, P. D., Davis-Richardson, A., Camargo, F. A., Clark, I. M., . . . Triplett, E. W. (2015). Soil pH determines microbial diversity and composition in the park grass experiment. *Microbial ecology, 69*(2), 395-406.

Zhang, H., Goll, D. S., Wang, Y. P., Ciais, P., Wieder, W. R., Abramoff, R., . . . Viscarra Rossel, R. A. (2020). Microbial dynamics and soil physicochemical properties explain large-scale variations in soil organic carbon. *Global change biology, 26*(4), 2668-2685.

Zhang, Q., Pang, X., Chen, X., Ye, J., Lin, S., & Jia, X. (2020). Rain-shelter cultivation influence rhizosphere bacterial community structure in pear and its relationship with fruit quality of pear and soil chemical properties. *Scientia Horticulturae, 269*, 109419.

Zhang, X., Xin, X., Zhu, A., Yang, W., Zhang, J., Ding, S., . . . Shao, L. (2018). Linking macroaggregation to soil microbial community and organic carbon accumulation under different tillage and residue managements. *Soil and tillage research, 178*, 99-107.

Zhang, Y., Xu, X., Li, Z., Liu, M., Xu, C., Zhang, R., & Luo, W. (2019). Effects of vegetation restoration on soil quality in degraded karst landscapes of southwest China. *Science of the Total Environment, 650*, 2657-2665.

Zhao, J., Yang, Y., Zhang, K., Jeong, J., Zeng, Z., & Zang, H. (2020). Does crop rotation yield more in China? A meta-analysis. *Field crops research, 245*, 107659. doi:https://doi.org/10.1016/j.fcr.2019.107659

Zhong, Z., Zhang, X., Wang, X., Fu, S., Wu, S., Lu, X., . . . Yang, G. (2020). Soil bacteria and fungi respond differently to plant diversity and plant family composition during the secondary succession of abandoned farmland on the Loess Plateau, China. *Plant and Soil*, 1-18.

Zhu, M., Yang, S., Ai, S., Ai, X., Jiang, X., Chen, J., . . . Ai, Y. (2020). Artificial soil nutrient, aggregate stability and soil quality index of restored cut slopes along altitude gradient in southwest China. *Chemosphere, 246*, 125687. doi:https://doi.org/10.1016/j.chemosphere.2019.125687

Ziechmann, W. H. (1980). Verlag Chemie: Weinheim, Germany.

Zong, M., Lin, C., Li, S., Li, H., Duan, C., Peng, C., . . . An, R. (2021). Tillage activates iron to prevent soil organic carbon loss following forest conversion to cornfields in tropical acidic red soils. *Science of the Total Environment, 761*, 143253. doi:https://doi.org/10.1016/j.scitotenv.2020.143253

CHAPTER 12

SOLID WASTE STORAGE FACILITY SITE SELECTION WITH GEOGRAPHIC INFORMATION SYSTEMS (GIS): A CASE STUDY IN ADIYAMAN, TURKEY

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INTRODUCTION

Due to immigration and asylum from rural areas and neighboring countries for various reasons, cities now have an excessive population density. Population growth, economic conditions, and the extensive use of technology all contribute to the acceleration of environmental degradation. The environment is threatened by soil, air, and water pollution. The degradation of the environment necessary for human survival is the result of environmental pollution. The increase in human and industrialization-centered activities in urban areas, the shift in consumer patterns, and the expansion of the economy have led to an increase in the quantity and variety of solid waste (Ngoc and Schnitzer, 2009). The disposal of these ever-increasing solid wastes has become an issue for the environment. For this reason, scientists continue to investigate whether the geographical selection of solid waste storage areas causes environmental issues.

Solid waste; domestic garbage, packages, discarded electronic materials, garden wastes, etc., which are created as a result of the production and consumption activities of people or industrial companies and which they want to dispose of solids (Ngoc and Schnitzer, 2009; Bilgili, 2020; Akinci et al., 2012). Economy, ecology, and human health are all intimately tied to the disposal of solid wastes without producing environmental problems and with the least amount of environmental damage possible. In recent years, a substantial amount of work has been devoted to developing immediate and long-term solutions to environmental issues. Due to its economic benefits, landfilling is the most frequent method for the disposal of solid waste; well-designed engineering procedures are employed. The purpose of the construction of regular storage areas is to protect the quality of ground and surface waters, to protect the air quality and to obtain energy with gas collection systems, to use the storage area effectively and for an extended period of time, and to evaluate the site once storage is complete. According to Vaverková et al. (Vaverková et al., 2019), landfills are accepted as a feasible and widespread alternative for solid waste management worldwide. Although in most regions of Turkey solid wastes are disposed of in unmanaged and unregulated landfills, landfill disposal has become a largely accepted option (Ngoc and Schnitzer, 2009; Bilgili, 2020; Akinci et al., 2012). Design and operation of sanitary landfills are contingent on legal site selection criteria and standards that prioritize the prevention of environmental contamination. The site selection for the landfill relates primarily to the city's land use planning and is a crucial aspect of urban planning (Fan et al., 2008). Because the landfill area is strongly associated with a number of disciplines, including soil science, sociology, hydrogeology, land use, and land topography (Sumathi et al., 2008). In addition, the landfill site selection procedure is an issue that tries to establish the locations that will minimize risks to the environment and public health, and also has substantial financial implications (Uyan, 2014).

In addition to meeting the requirements of the applicable laws and regulations, the most acceptable location for landfills is selected using a method that minimizes the environmental, economic, health, and socio-cultural impacts that will emerge from the physical application. Therefore, the location of landfills is a multidisciplinary and complex process that necessitates careful study of a number of environmental factors of the region (Altuntaş et al., 2017; Bosompem et al., 2016; Gbanie et al., 2013). Solid waste landfills are among the undesirable facilities since they are considered as a threat to the health, quality of life and regional ecosystem of the local people. Therefore, site selection; It should be determined by taking into account the possibility of high productivity and social acceptance, and low environmental risk factors. The fact that this complex and multi-actor process can be successfully managed according to the desired criteria for the site selection of landfills, while maintaining the balance of urban and rural life, technically necessitates the use of some information systems (Ertunç et al., 2019). Geographic Information Systems (GIS) is one of the important tools used effectively in the selection of storage areas and in solving problems driven by complex spatial data related to the other environment (Alavi et al., 2013; Ali et al., 2019). Geographic Information Systems (GIS) are more preferred than traditional methods in the design and construction of integrated systems to automate the waste planning and management process, and in site selection studies involving certain criteria such as hospitals, schools, new settlements or regular solid waste landfills (Karadimas and Loumos, 2008). The use of GIS in landfill site selection reduces costs and provides a digital data store for the selected site (Moeinaddini et al., 2010; Donevska et al. 2012; Eskandari et al., 2012). In the literature on this subject, it can be seen that many studies have conducted regular solid waste landfill site selection analysis with the GIS method. A GIS-based site selection was carried out by using the criteria of proximity to roads, wells, archaeological sites and urban areas by creating a land cover and land slope map for the regular solid waste landfill in Konya (Nas et al., 2010). In the Beyşehir Lake Basin (Şener et al., 2010), in Elazığ (Çeliker et al., 2019), and in Edirne (Kuru et al., 2021); various researches were carried out on landfill site selection using similar criteria such as proximity to protected areas, water bodies, roads and settlements, land use, hydrogeology aspect and slope factors with multi-criteria decision analysis and GIS applications. In addition, in other studies conducted in different parts of the world on this subject tried to solve the landfill site selection problem by using GIS method together with AHP and multi-criteria decision (MCDM) methods (Wang et al., 2009; Zelenović et al., 2012; Rathore et al., 2015; Demesouka, et al., 2016; Lokhande et al., 2017).

The Adiyaman Integrated Solid Waste Disposal Facility and Landfill, located in Adiyaman, Central District, Kayaonü in Turkey, became active with the Ministry of Environment and Urbanization's Environmental Impact Assessment (EIA) Report and Decision No. 6614 dated September 17, 2020. Lot 1 began receiving waste in 2021. The location of the Adiyaman Integrated Solid Waste Disposal Facility and Landfill was determined using just conventional techniques, and not GIS or other decision support technologies. In this study, the landfill in question was examined in terms of compliance with regulations and environmental functionality using GIS. In addition, the suitability of the Adiyaman environmental plan's land use framework was reviewed.

MATERIAL AND METHOD

Study area

The study area is approximately 7 kilometers north-northwest of Adiyaman's city center in Turkey's Southeastern Anatolia Region (Fig.1). The area of Adiyaman is 7,337 km^2, whereas the area of the central district is 1,702 km^2; according to TUIK data from 2021, the population of the Central District is 267,131. Over the years, the amount of solid waste collected in the Central District of Adiyaman has increased, as has the necessity for a permanent solid waste storage location (Table 1). With the Adiyaman Solid Waste Landfill Facility, which was established to serve the districts of Adiyaman Center, Kahta, Tut, Samsat, Gölbaşı, Çelikhan, and Besni, as well as the municipalities Kesmetepe, Yaylakonak, Balkar, Pınarbaşı, Şambayat, Bölükyayla, and Harmanlı, as 4 lots, 2nd Class Landfill Facility (road, leachate collection system, energy and lighting system, communication system, parking lot, in-plant roads, waste temporary storage area). The entire facility size is 75,2 hectares and consists of six parcels (Figure 2). The facility will have a total storage capacity (compressed) of 1,120,000 m^3 and a collection storage surface area of 407,910 m^2.

Table 1: Population of The Central District of Adiyaman and Solid Waste Collected by Year (TUIK)

Year	Population	Amount of Solid Waste Collected (Ton/Year)
2008	193,250	152,023
2010	202,735	133,960
2012	217,463	145,052
2014	230,630	150,412
2016	245,446	162,060
2018	254,695	167,293
2020	263,790	172,291
2021	267,131	175,384

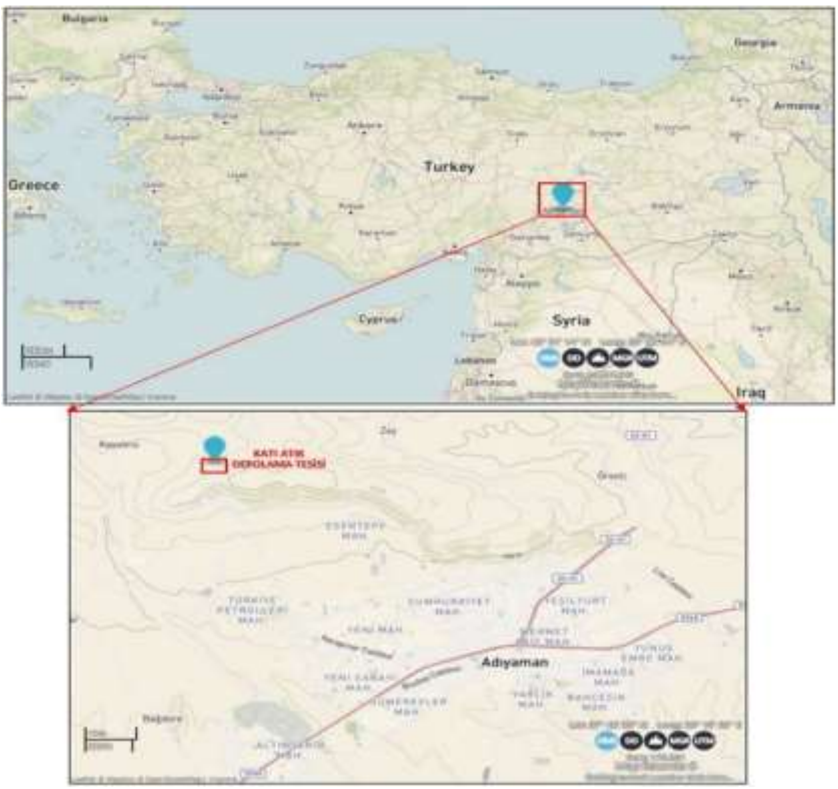

Figure 1. Geographical location of Adiyaman Solid Waste Landfill

Figure 2. Satellite image of the Adiyaman Solid Waste Landfill Area and Disposal Facility parcels

The final EIA Report prepared for the facility predicts that the economic life of the facility will be 6 years for each lot and approximately 29 years after the waste storage procedure is complete. The construction of the waste receiving area of the 2nd class regular storage facility, which is planned to be divided into four lots, is complete, as are the laying of clay, the construction of drainage channels, and the construction of the leachate reservoir for the 1st Lot. Waste has begun to be received into the facility, and the first storage lot has begun to fill. The general view of the facility and the 1st lot storage area are shown in Figure 3.

Figure 3. Adiyaman Solid Waste Landfill Facility general view **(a)** and 1st lot of storage space **(b)**

Waste Disposal Method and Work Flow Chart

The waste problem, which has a significant impact on the environment and is growing exponentially, cannot be solved with a single approach. However, a combination of all strategies should be employed to establish an effective waste management system. This internationally recognized methodology has led to the development of an integrated solid waste management methodology. Integrated waste control seeks to achieve both environmental and economic sustainability by analyzing all aspects of waste management as a whole. In this context, it cannot be assumed that integrated waste management will be limited to a single waste type or source. According to the integrated waste management hierarchy, it is essential to prevent and reduce waste generation and its damages at the source, and when waste management is unavoidable, it is essential to reuse, recycle, and use other processes to obtain secondary raw materials, as well as to recover the horse or use it as a source of energy. Landfill gases and leachate that may be produced during garbage disposal are subjected to a method that protects environmental contamination by limiting their negative impacts on air, soil, groundwater, and surface water. Adiyaman solid waste disposal Facility process flow chart is shown in Figure 4. Domestic solid wastes coming from Adiyaman Center and other districts on a daily basis are taken to the 1st lot of the sanitary landfill. With the aid of a bulldozer, heaps of solid garbage are spread and compacted. On top of these compacted wastes, an intermediate layer of approximately 1 m of clayey material is placed. When the 1st lot field is filled, the second storage step will be exited. When this floor is completed in the subsequent phase, landscaping will commence with the installation of the top layer.

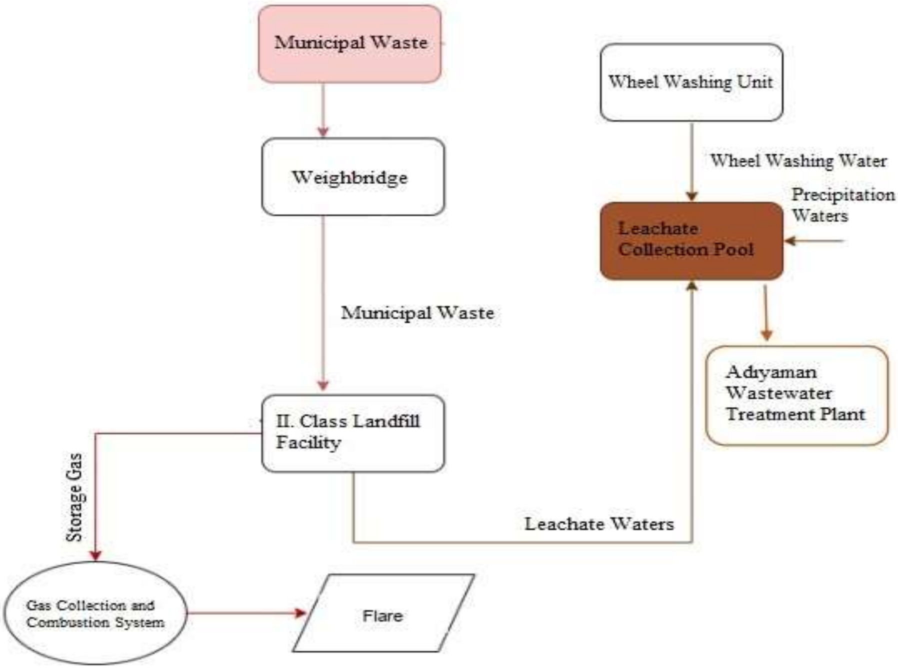

Figure 4. Adiyaman Solid Waste Landfill Facility process flow chart

Criteria for the Site Selection and Legal Legislation

The management of solid wastes in Turkey is conducted in line with the terms of the "Regulation on the Regular Storage of Wastes," which entered into force on 1 April 2010 and was published in the Official Gazette on 26 March 2010 under number 27533. This regulation addresses the technical principles governing the site selection of sanitary landfills, the procedures and principles governing the acceptance of wastes into landfills and the regular storage of wastes, the measures to be taken, the inspections to be conducted, and the responsibilities that must be adhered to. A sanitary landfill facility is defined in the regulation as "units where waste is temporarily stored for recycling, pre-treatment, or disposal within the facility, facilities where waste is stored for less than three years for recovery or pre-treatment, and shall not exceed one year for waste to be disposed." Underground and above-ground sites where wastes are disposed of in compliance with specified technical criteria, excluding plants where wastes are temporarily held. Section 15 of this rule establishes the following criteria for the selection of locations for solid waste disposal facilities:

(1) “The minimum distance between landfill facility borders and residential units for I. class dump facilities is one kilometer; for II. and III. class landfill facilities, this distance must be at least 250 meters.”

(2) “In addition, in the location selection of the sanitary storage facility;”

   a) “Whether the regular storage facility affects air transport security,”
   b) “Distance to protected areas for special purposes such as forest areas, afforestation areas, protection of wildlife and vegetation,”
   c) “Status of underground and surface water resources and protection basins in the region, groundwater level and groundwater flow directions,”

ç) “Topographic, geological, geomorphological, geotechnical and hydrogeological condition of the site,”

d) “Flood, landslide, avalanche, erosion and high earthquake risk,”

e) “Dominant wind direction and precipitation situation,”

f) “Natural or cultural heritage status,”

are taken into account.

(3) “There are no pipelines or high-voltage lines used in the transportation of fuel, gas and potable-use water in the field.”

(4) “After the completion of the environmental impact assessment process, the selected area is included in the relevant plans.”

In this study, it was assessed if the area designated as the solid waste regulatory facility conforms to the environmental plan's land use structure. Then, for the examination of certain site selection criteria for solid waste disposal areas, a digital elevation model (DEM) reflecting the topography of the site and its immediate surrounds and displaying all man-made and natural land features was generated. DEM was generated in QGIS-Geographic Information Systems Software utilizing USGS-United States Geological Survey raster data with a spatial resolution of 28 m. In addition, "distance map to nearest towns," "slope map," "visibility map," "primary wind direction impact map," and "ground water elevation map" were created to determine if specific requirements mandated by the law are met.

Using the digital elevation model, the slope and visibility of the sanitary landfill were analyzed. Slope analysis reveals the slope values of the land's surface based on varied heights. Based on these slope values, it is assessed whether solid waste-carrying heavy-tonnage trucks can approach the dump and whether landslide, flood, and avalanche risks may be mitigated. In addition, slope analysis is essential for estimating the effects of the predominant wind direction on the residential areas that will be exposed to odor, dust, and particles from the solid waste dump (Ertunç et al., 2019). The areas influenced by the predominant wind direction will vary based on the topography of the relevant urban region. Considering this circumstance, slope analysis was used to determine the effects of the predominant wind direction in the study area (Ertunç et al., 2019).

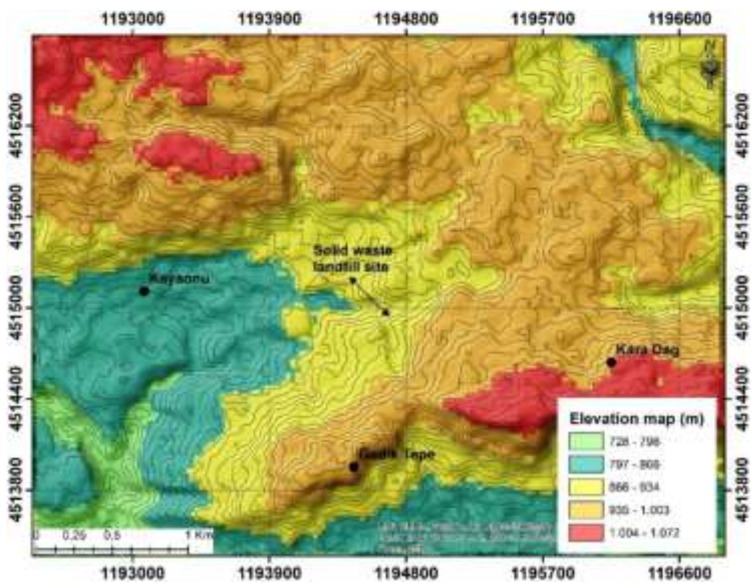

Figure 5. Digital Elevation Model (DEM) of Adiyaman Solid Waste Landfill Facility

The appearance of the solid waste storage area from the city's settlements and transportation network has a negative impact on the urban identity. Visibility analysis analyzes the visible and unseen portions of a solid waste dump from predetermined observation stations in the city area (Bartie et al., 2008). Furthermore, visibility analysis is discussed in research in a variety of fields, including health, archeology, and national security (Delikostidis et al., 2013; Gümüş et al., 2017). The investigation of visibility in solid waste landfills will add to the body of knowledge concerning the consideration of environmental and visual values in solid waste landfill site selection. Finally, the consequences of the solid waste landfill's geological structure on subsurface and surface waters were assessed. On the geologically pertinent geological maps, the ground structure of the solid waste dump is analyzed in terms of whether or not it satisfies the standards outlined in the applicable laws.

FINDINGS AND DISCUSSION

Evaluation of the Facility's Site Selection in terms of Land Use in Urban Planning and Distances to Settlements

In accordance with the Adiyaman environmental plan, the land use structure and the distance between the regular solid waste disposal and the nearest residential areas were assessed in accordance with the applicable legal requirements. Figure 6 depicts the general land use structure of Adiyaman province. Towards accordance with this, residential neighborhoods are situated further south of the city center and main axis, yet they are more dense in the west, north, and northwest.

The modest industrial site is located in the city's west, while the organized industrial hub is located in the city's northwest. As shown in Figure 6, the regular solid waste storage area is depicted with the symbol "KA" in the environmental plan and is included in accordance with the legal requirement that "the selected area is processed in the relevant plans following completion of the environmental impact assessment process." The "KA" area is located outside the urbanization boundary in figure 6, and although it meets the legal distance requirements to the settlements, it is not too far away. Moreover, according to the land use plan and on the ground, this facility is situated in a forest, significantly impacting the city's only extant forest. It also poses a threat to urbanization in the city's northern and northwest quadrants.

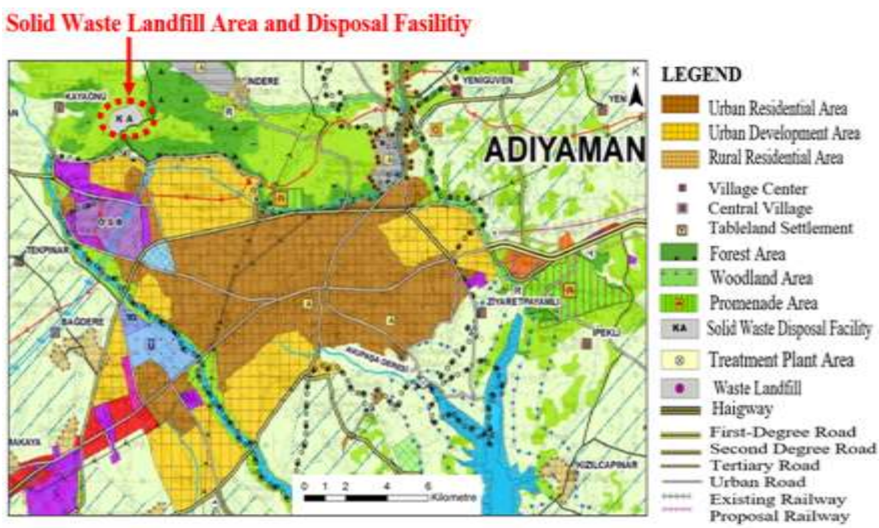

Figure 6. Land use situation in Adiyaman 1/100 000 scale environmental plan

The distances between the Adiyaman landfill area and the settlements are depicted in Table 2, while the distances to the nearest rural settlements are depicted in Figure 7.

Table 2. The distances of existing settlement areas to the solid waste landfill facility according to land use properties in Adiyaman

Settlement Areas	**Distance to the Solid Waste Landfill Facility (Km)**
Urban border	1.044
Central main route	6.10
Nearest housing area	1.37
Bus terminal	12.21
The nearest governmental institution	8.85
The nearest education facility	4.67
The nearest sports area	5.02
The nearest trade area	6.43
İndustrial zones (OSB)	2.26
The nearest afforestation area	0
The nearest forest	0

In Table 2, the distance from the regular solid waste landfill in Adiyaman to the other uses of land in the settlement area is measured. According to the legislation in Turkey, “The minimum distance between landfill facility borders and residential units for I. class dump facilities is one kilometer; for II. and III. class landfill facilities, this distance must be at least 250 meters.”. The distances to land uses such as major access roads, communities, educational facilities, green areas, governmental institutions, commercial areas, sports areas, and bus stops comply with the law, as shown in Table 2. However, as shown in Table 2 and Figure 6, the solid waste landfill site was chosen in the forestry and afforestation region. In the legal legislation, it is stated that “In addition, the distance of the sanitary landfill facility to areas under protection for special purposes such as forest areas, afforestation areas, protection of wildlife and vegetation is taken into account when choosing a location". When evaluated in this context, it can be interpreted that the site selection of the landfill facility does not comply with the legal site selection criteria, since it is directly selected in the forestry and afforestation area.

Evaluation of the Site Selection in terms of Land Use in the Rural Area and the Distances to the Settlement Areas

In Figure 7, the distance between the solid waste disposal and the rural communities is assessed. According to Figure 7, the nearest rural settlement, Kayaonü, is 1.3 kilometers from the sanitary dump. In addition, according to Figure 6 and Table 2, the distance between the facility and the industrial regions is 2.26 kilometers. Accordingly, it can be stated that the distance between the solid waste landfill site and rural communities and industrial facilities complies with the legal requirements.

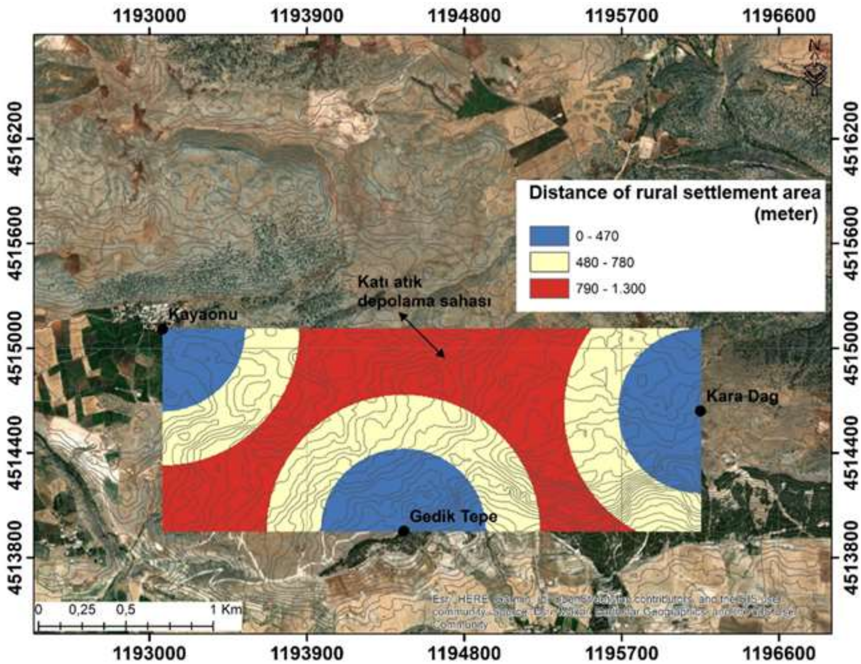

Figure 7. Distances of Adiyaman Solid Waste Landfill Facility to the nearest rural settlements

Evaluation of the Site Selection of the Facility According to the Topographical Slope Condition

Providing easy access to solid waste landfills in all climatic conditions, slope can be seen as an important economic criterion in site selection due to additional costs in road construction. It is suggested that the land slope in solid waste landfills should not be more than 15 percent (Oweis et al., 1990). In the studies carried out, regions with a slope value of 15 percent and below and especially regions with a slope value of 7 percent and below are the most suitable areas in terms of slope in solid waste landfills (Ertunç et al., 2019). The slope map prepared for the slope analysis in and around the solid waste landfill in the study area is presented in Figure 8.

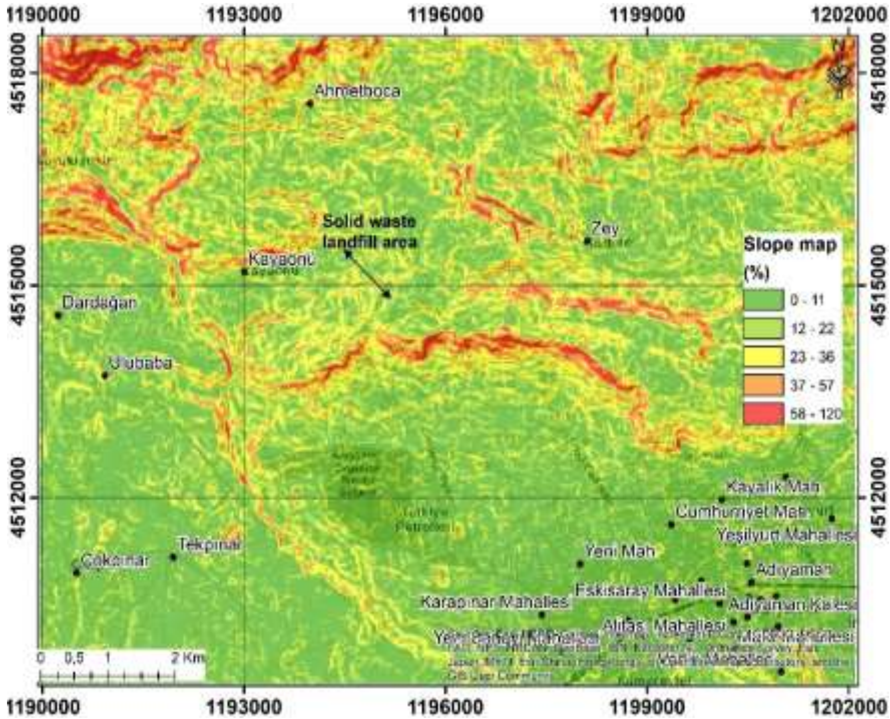

Figure 8. Slope map of the solid waste landfill area

According to the slope map in Figure 8, the solid waste landfill area is located in the region between 12% and 22% slope. It is recommended that the maximum slope should not exceed 10%, especially for the movement of heavy tonnage vehicles in road construction (Kumaş et al., 2012). The land slope has been brought to the desired value with the land leveling done in the facility area. In addition, the existing land slopes are at suitable values in terms of the accessibility of heavy tonnage vehicles that will transport solid waste from the settlements, and the slope values in the legislation can be reached with a road work to be done for a small region in a mountainous area that crosses the border.

Evaluation of the Facility's Visibility

According to Turkish Law, solid waste landfills should not be visible from major highways (Ertunç et al., 2019). In addition, the presence of waste from other urban communities in solid waste storage facilities is indicative of a negative urban character. The visibility of the Adyaman solid waste landfill from urban transportation, ring roads, and major transportation axes has been evaluated for this purpose. The visibility map of Adiyaman Solid Waste Landfill, based on settlements and main access roads, is presented in Figure 9. Although this facility is placed very high (940 m) above the urban residential areas, it is shielded from the south, southeast, and southwest residential areas by a higher mountain range (an extension of the Southeast Taurus). The Solid Waste Landfill Area is therefore not visible from the residential areas and highways depicted in Figure 9. Consequently, it can be asserted that the facility satisfies the legislation's visibility requirements.

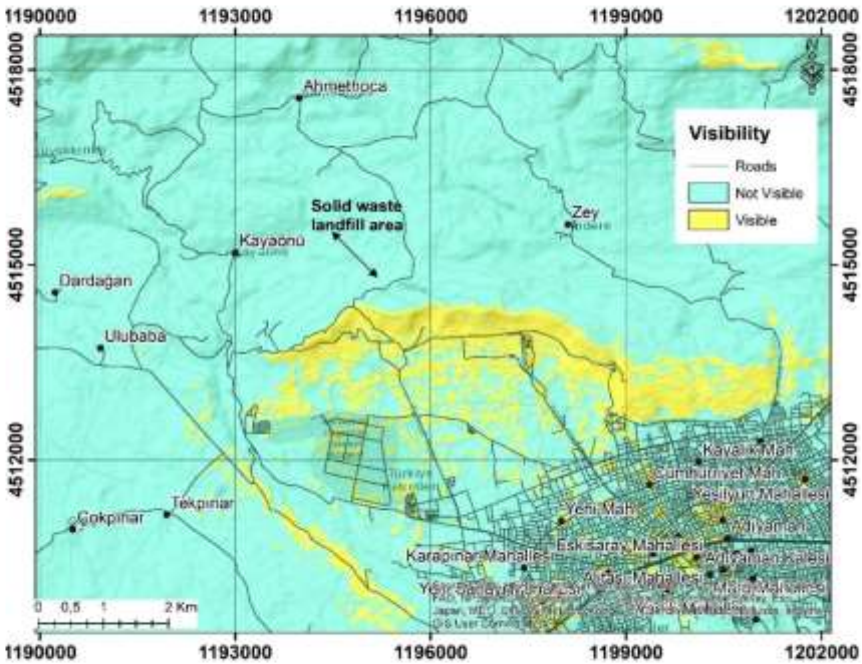

Figure 9. Visibility map of solid waste landfill area

Evaluation of the Location of the Facility According to the Dominant Wind Direction

The prevailing wind is the sort of wind that blows most frequently in a certain geographical region on a daily, monthly, seasonal, or annual basis, and its direction is known as the predominant wind direction (Avcı, 2020). Dust and odor that will be produced by employing impermeable soil on the floors of solid waste landfills must not be exposed to the prevailing wind direction (Ertunç et al., 2019). For this reason, the location of a solid waste storage area must take into account the predominant wind direction. Otherwise, the foul stench emanating from the solid waste storage location will be blown to the surrounding residential areas by the prevailing wind, causing annoyance to the residents. According to Adiyaman Meteorology Station's long-term meteorological data (1963-2019), the first-degree dominant wind direction is north-southeast (N-SE), and the second-degree dominant wind direction is north-south (N-S). The wind directions that dominate the topography of the city are shown in Figure 10. The analysis map made according to the prevailing wind directions is shown in Figure 11. The structured industrial zone is located in the direction of the second prevalent wind direction, the Türkiye Petrolleri Neighborhood and the Altinşehir Neighborhood are located farther south, and the first two neighborhoods are around 1.5 kilometers from the bird's flight. Kayaonü Village, located 1.3 kilometers from the source of the odor, is the other nearby rural settlement. However, this community is located to the west of the odor source and does not face the predominant wind direction. It is inevitable that the landfill would emit odors. In the process of daily storage at a sanitary landfill, daily cover material is applied to the dump in order to limit odor emissions. However, the amount of odor production will rise, particularly during warm weather. Figure 10 shows that the solid waste storage facility is positioned precisely north of the valley between Gedik Tepe and Boge Tepe. The odor emission that will occur in the solid waste storage area will spread through the gorge formed by the valley between these two hills, taking the prevailing wind direction behind it, and spread to almost all of the settlements (Figure 11).

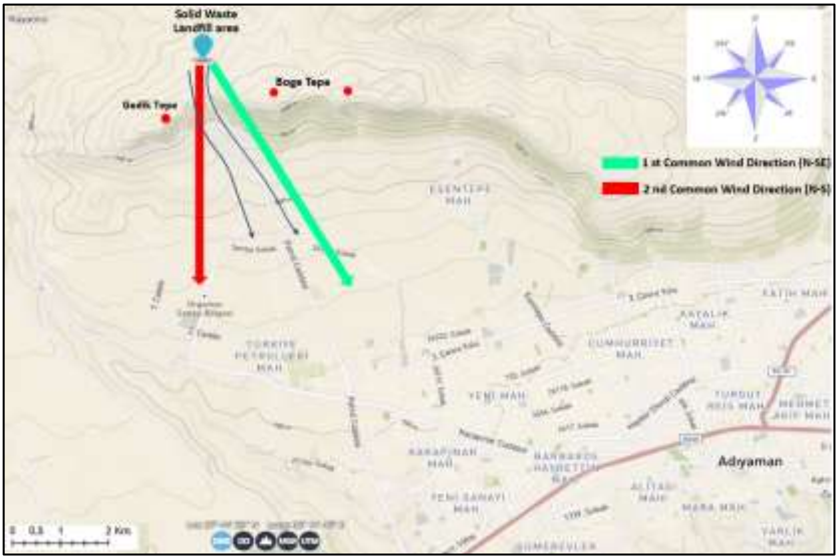

Figure 10. Wind direction map for Adiyaman city center

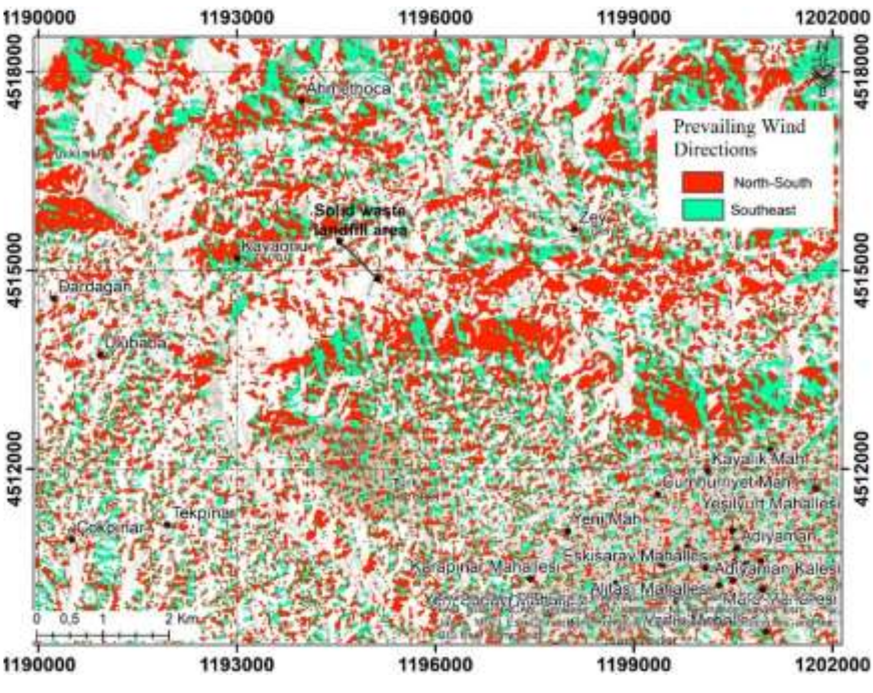

Figure 11. Adiyaman city center settlements affected by prevailing wind directions

Evaluation of the Site Selection of the Facility According to the Geological Structure

The geological structure of the region to be selected as a solid waste landfill is a very important parameter. The structural characteristics of the soil in the selected region are very important in terms of not being affected by groundwater. In addition, the selected ground structure should have an impermeable structure in order to protect groundwater, a structure with granular textured plutonic rocks and massive volcanic and metamorphic rocks should be preferred, and areas with high permeability rocks such as sandstone, conglomerate and basalt should be avoided (Ertunç et al., 2019). Solid waste sanitary landfill is located in Adiyaman, within the borders of the Euphrates-Tigris Basin. The annual average flow for the Euphrates Tigris Basin constitutes 28.5% of Turkey's surface water potential. It is the largest basin of our country with 184,918 km^2 of precipitation. When the geological structure of the region is examined, it is understood that the spring sources are fed from the formation in the region. There is no normal underground water nappe in the region. However, depending on the joints and cracks of the veined limestone cracks, there is an underground formed by the local waters fed by the flat valleys in the west direction. Koçali and Black Mulberry Complexes, which are allochthonous units settled in the region during the Upper Cretaceous, are located in the north of Adiyaman along the thrust belt. Koçali Complex consisting of Upper Jurassic-Lower Cretaceous peridotite, harzburgite, lerzolite, serpentine, basalt and pelagic limestones; Platform Sediments are coming. The limestones forming the Hoya formation in the region to be selected as the solid waste landfill area show the feature of being the most water-bearing and good aquifer in the region. The Eocene Aged Limestones in this area have important groundwater carrying capacities due to their abundant fractures and dissolution gaps and are an important groundwater basin that feeds the entire region. It can be said that the waters filtered from the limestones, which carry very good water and show a very good aquifer feature that feeds the springs and groundwater in the region, cause spring discharges in the semi-permeable Germav formation sandstones and occasionally pebbles and detrital limestones in the region, as in Kırkgöz Water Spring. In addition, since the waters filtered from the limestones of the Hoya Formation feed the Plioquaternary sediments in and around Kayaönü Village, many boreholes for irrigation and drinking water have been drilled in these areas, and it can be said that the solid waste sanitary landfill will adversely affect the groundwater and surface waters. However, this effect can be eliminated with impermeability studies on the floors of the lots.

Adiyaman Regular Solid Waste Landfill and its vicinity are located within the Lower Eocene-Lower Oligocene Hoya formation (Figure 12). The unit, which consists of dolomitic limestones with medium-thick bedded structure, in cream-off-white-light gray colors in general, unconformably overlies the Gercüş Formation at the base, and is unconformably overlain by the Kapıkaya Formation at the top. Besides, the Hoya Formation; It is observed conformably over The Germav

Formation in the fields around Suvarlı-Besni in Adiyaman (Bolat, 2012). The weathering surfaces of the limestones are partially unstable and the unit, which starts with clayey-sandy limestones at the base, passes into dolomitic limestones towards the top. The Hoya Formation is composed of limestones that generally form steep cliffs and widespread dolomites formed by their diagenetic changes in the areas where it outcrops and presents weak-good reservoir rock characteristics (Bolat, 2012). The Hoya Formation was deposited in environments ranging from a limited-semi-confined shallow sea to a shallow normal open sea and shelf edge/front. While wide shelf lagoon, tidal plain and evaporitic environments were active in some parts of the region, shallow, normal open sea shelf edge environments were dominant (Karadoğan and Tonbul, 2013).

The foundation rock of the plant site, which consists of different limestone forms, has different impermeability properties depending on the discontinuity and weathering. In the scope of the study, the hydraulic properties of dolomite and limestones and since there is no rock mass data to reflect these properties, the evaluation of the basement rock in terms of impermeability was made within the scope of field observations and literature data. From this point of view, the permeability of dolomite rocks as solid rock (k, m/s) can be described as medium-low permeability such as 10^{-6} and 10^{-12}, while the permeability coefficient as a rock mass can increase up to 10^{-1} and is in the very high permeability class. (Figure 13).

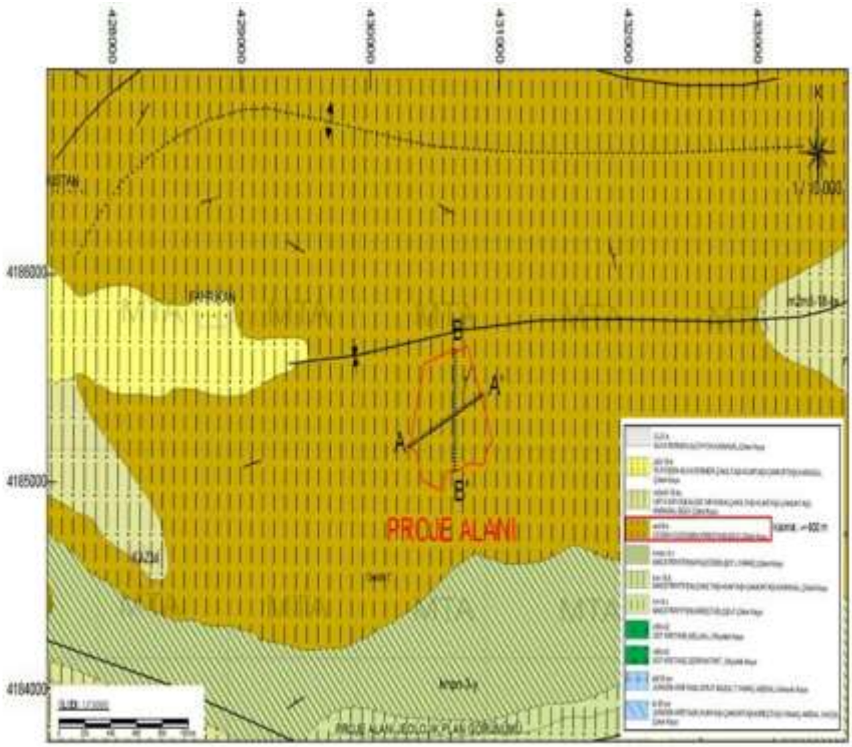

Figure 12. Geological map of Adiyaman landfill and its immediate vicinity (MTA 1/25000 Şanlıurfa M40a3 Geological Map)

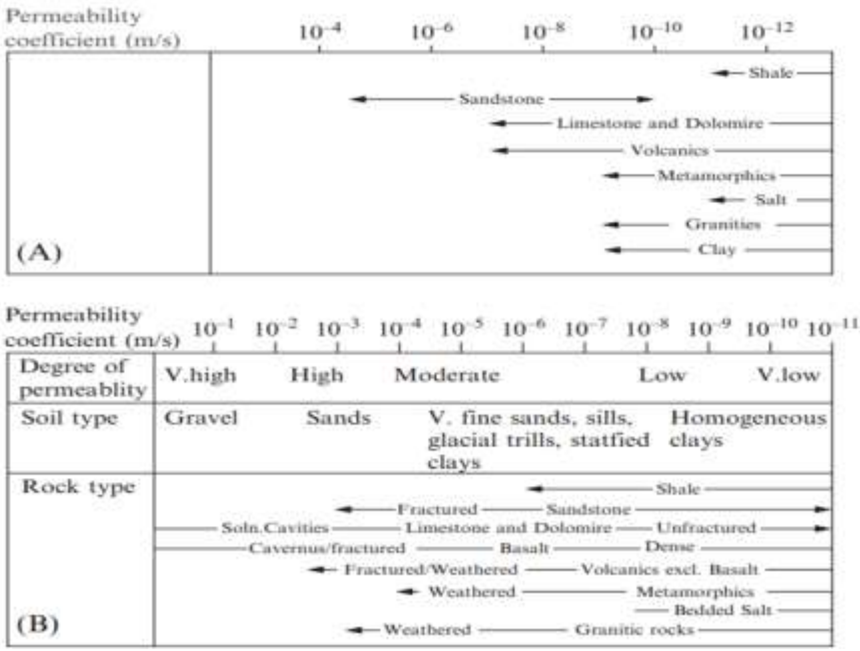

Figure 13. Typical permeability values for solid rock (A) and rock mass (B) (Isherwood, 1979)

In accordance with the 26.12.2019 amendment to matter 16 of the "Regulation on the Regular Storage of Wastes" published in the Official Gazette on 26.03.2010 and bearing the number 27533, an impermeability layer is formed on the bottom and side surfaces of the sanitary landfill facility to prevent leachate from mixing with groundwater. The physical, chemical, mechanical, and hydraulic qualities of the impermeable layer must be such as to protect soil and groundwater from potential storage facility dangers. In addition, the 26.12.2019 amendment to clause 2b of matter 16 specifies a permeability coefficient (K) 1.0 x 10^{-9} m/sec and a clay or clay group impermeable layer at least 1 m thick for a II. Class sanitary landfill site. Given that the proposed project is a II. Class Landfill Facility and that the bedrock is partially weathered, fractured-cracked dolomite and limestone, it is not anticipated that the bedrock will naturally offer the impermeability required by the applicable law.

For this reason, the ground impermeability layer of the sanitary landfill facility was constructed in accordance with the provisions of the "Regulation on the Regular Storage of Wastes" published in the Official Gazette dated 26.03.2010 and numbered 27533. In this context, in cases where 2 m of excavation work is carried out in the field before the filling works and mixing of the leachate with the groundwater cannot be achieved naturally, it has a permeability of K ≤ 1.0 x 10-9 m/s and a compacted at least two layers with a total thickness of at least 50 cm. An impermeability layer was applied in accordance with the section in Figure 14 by using clay or clay group minerals and geomembrane.

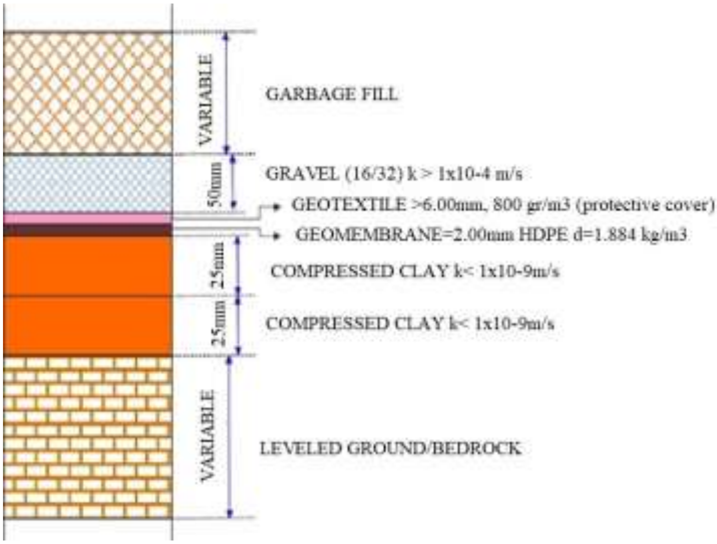

Figure 14. II. Class landfill area base impermeability system (Ministry of Environment and Urbanization, 2014)

Sieve analysis was used to evaluate the appropriateness of the impermeable layer produced on the floor of the sanitary landfill.

Consequently, the impermeable layer is composed of 28.82% clay-silt, 41.27% sand, and 29.18% gravel-sized material (Figure 15). According to the Landfill Facilities Site Management and Operation Guide, the rate of material less than 0.075 mm (clay + silt) must exceed 20 %, whilst the rate of material higher than 4.76 mm must be less than or equal to 30 %. Although the material used in the project area is very close to the limit values in terms of particle size distribution, it provides the conditions required in the guide.

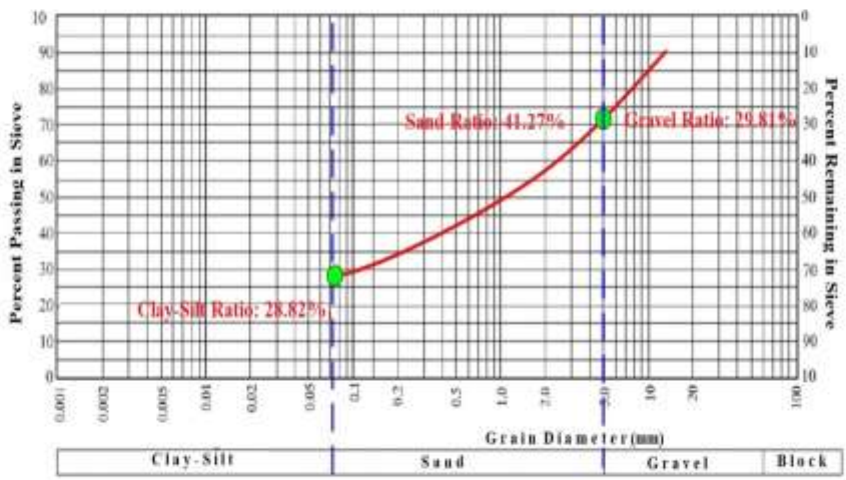

Figure 15. Grain size distribution graph of the impermeable layer

The Regular Solid Waste Landfill Site is located roughly 7 kilometers to the northwest of the city center of Adiyaman, and the topographic altitudes in the project area range from 900 to 1000 meters. Gedik Tepe, Boga Tepe, and Heyik Tepe, all of which have altitudes greater than 1000 meters, border the south of the project site (Figure 16).

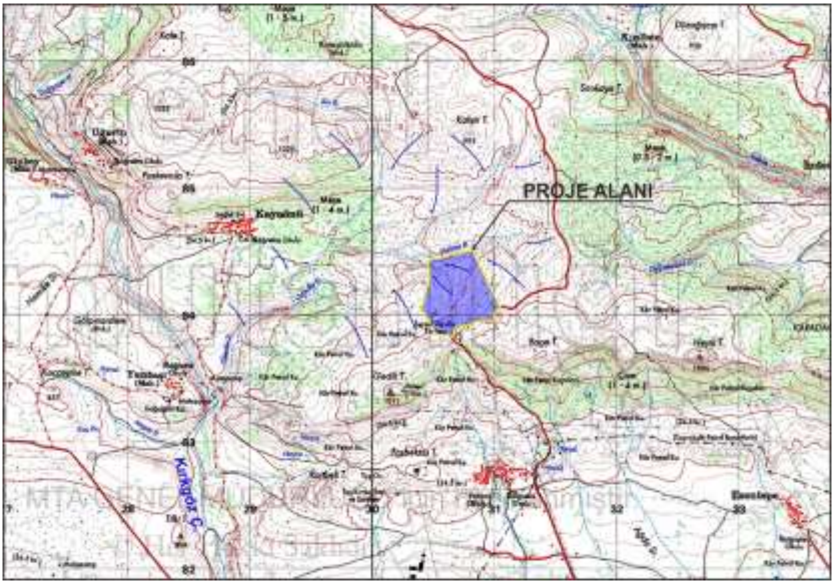

Figure 16. Topographical map depicting the surface waters of Adyaman landfill and its immediate surroundings

Therefore, its interaction with the surface waters in the south of the project is not considered very possible. On the other hand, there are Gömike and Nalısus streams feeding Kırkgöz Stream in the north and northwest of the project site. The creeks in question start at a maximum elevation of 950 m and meet with Kırkgöz Stream at 760 m elevation and in the west of the project area. With this location, "Adiyaman Regular Solid Waste Landfill" is in a position to interact with surface waters if the conditions specified in the regulation are not met. The base excavation level of the 1st Lot of Adiyaman regular solid waste landfill is 910 m. It will not be possible to descend below the groundwater level because the water level of Kırkköz Spring, which is located at 810-830 m elevations of the groundwater level and to the southwest of the solid waste storage area, is 770 m (Figure 17). In this context, it can be said that there will be no negative impact on Kırkgöz Spring.

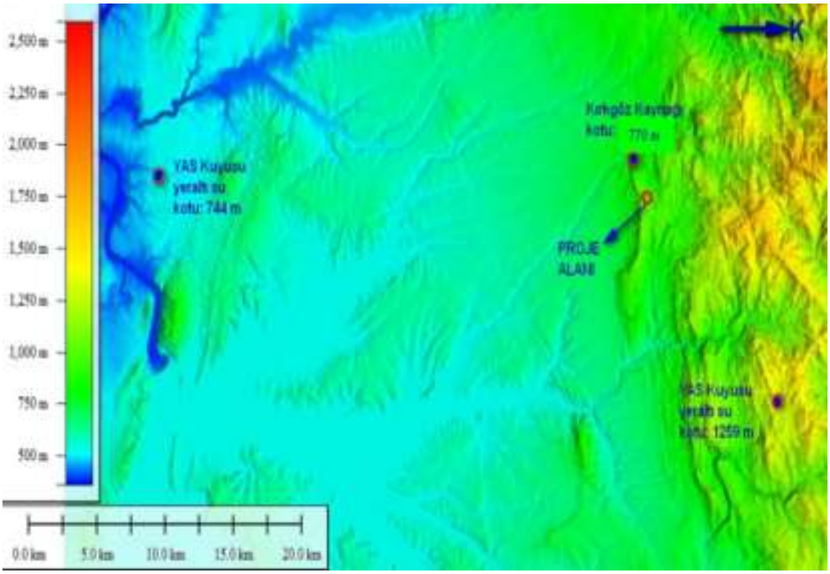

Figure 17. Groundwater elevations of the immediate vicinity of Adiyaman Regular Solid Waste Landfill

Evaluation of the Location of the Facility According to the Water Basins

The border coordinates of the Adiyaman Solid Waste Landfill Facility were examined within the framework of the database of the General Directorate of State Hydraulic Works and it was determined that it is located in the Atatürk Dam Lake Basin (Figure 18), where drinking and utility water is currently supplied to Şanlıurfa. In addition, as a result of the examinations made, it was seen that the entire province of Adiyaman remained within the Atatürk Dam Water basin, and it was determined that a sanitary landfill project to be built for Adiyaman would remain in this basin no matter where it was built.

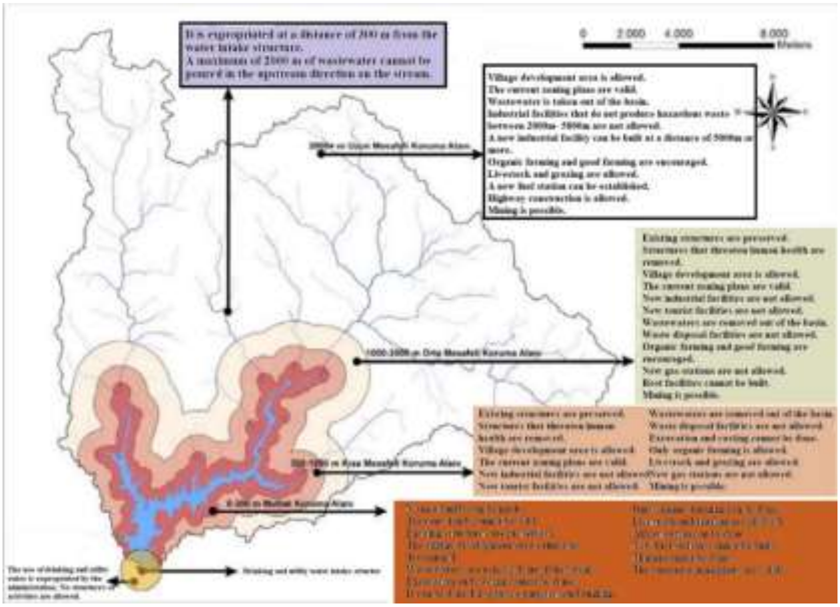

Figure 18. Atatürk Dam Conservation Area

Although the Adiyaman Solid Waste Landfill Area does not have a continuously flowing water source, there is a Kırkgöz spring with an annual average flow of 500 l/sec, approximately 1850 m in the southwest direction, around the impact area of the facility (Figure 17). This source also feeds the Kırkgöz Stream (named Eğri Stream downstream). Eğri Stream, on the other hand, flows directly into the Atatürk Dam Lake. However, the base excavation elevation of the Adiyaman regular solid waste landfill Lot 1 is 910 m, and the elevation of the groundwater level is 810-830 m. Kırkköz Spring, located in the southwest of the solid waste landfill, will not go below the groundwater level since the groundwater level is 770 m. (Figure 17) In this context, it can be said that there will be no negative impact on Kırkgöz Water Source.

Evaluation of the Site Selection of the Facility According to the Distances to the Natural Protection Areas / Protected Areas

Natural parks and protected areas are not suitable for landfill settlement. Storage areas should be located at a distance of 150 m from the buffer zone of such places. The purpose of this is to protect these places from the impact of the landfill and to keep natural areas separate from places under human influence. The protected areas near the Adiyaman Solid Waste Landfill Area were investigated, and it was seen that the closest tomb was the Zeynel Abidin Tomb, which is 435 m away as a bird flight distance (Figure 19). In this case, it can be said that the tomb is far enough from the solid waste storage area and will not be affected by the activities of the facility. In addition, in the letter received from the relevant institution (Provincial Directorate of Culture and Tourism, letter dated 08.12.2021 and numbered 1987895) during the project work of Adiyaman Solid Waste Landfill Facility, it was stated that the tomb was not a registered structure and that there were no movable or immovable cultural assets around it.

Figure 19. Satellite view of the Tomb closest to the landfill

CONCLUSION

Increasing solid waste problem due to dense population living in cities, industrialization and external migration is one of the most important environmental problems to be considered for sustainable urban life. Solid waste landfill is a very risky form of land use for agricultural production areas, urban living areas and residents, and a very important form of land use for future scenarios in urban planning. For this reason, the selection of a location for the solid waste storage area should be decided by taking into account the necessary criteria and as a result of meticulous evaluations. In the literature, it is suggested that the site selection of solid waste landfills should be done with a series of analyzes to be made using Geographic Information Systems at the stage of preparing the environmental plans. However, Adiyaman Solid Waste Landfill, which is discussed in this study, is included in the land uses in the environmental plan, but it has not been determined by making any Geographic Information Systems analysis. In this study; It has been investigated whether the place chosen as Adiyaman Solid Waste Landfill is suitable or not according to the criteria determined in the literature and legislation by using Geographical Information Systems. In this context, it is aimed to contribute to the prevention of environmental problems that may occur by discussing the possible positive and negative situations in the selection of Adiyaman Solid Waste Landfill. In addition, this study will make an important contribution to the evaluation of other existing solid waste landfills in Turkey with Geographical Information Systems and to the selection of new sites. According to the findings obtained in the study, the following results were obtained:

- The location of the existing Adiyaman Solid Waste Landfill Site is located within the land use structure in the environmental plan, and the distances to the urban and rural settlements are within legal limits. However, while it should be at a certain distance from forested areas, it is positioned on a forest-like field. It also poses a threat to urbanization for the north and northwest directions of the city, which are the urbanization direction.

- The current Adiyaman Solid Waste Landfill Site is in compliance with the values in the legislation in terms of site selection, land slopes and accessibility.
- According to the results obtained from the visibility analysis, it has been determined that the existing solid waste landfill is not in a position that may adversely affect the urban identity of Adiyaman in terms of visibility.
- The odor emission, which occurs in the solid waste storage area located at the very mouth of the strait formed by two hills topographically, spreads to almost all of the settlement areas with the effect of the prevailing winds.
- Existing Adiyaman Solid Waste Landfill Site is located on a ground that will adversely affect ground and surface waters in terms of geology. However, this effect has been eliminated with impermeability studies on the floors of the lots.
- Adiyaman Solid Waste Landfill Site is located within the Atatürk Dam Lake Basin.
- Adiyaman Solid Waste Landfill is not located in any protected area.

The results of the site selection of the solid waste landfill for the city of Adiyaman are very important for the city's future land use planning and strategies. Because solid waste landfills are high-cost projects that are planned to serve the city in the long term rather than the short term. In addition, the location selection of such facilities plays an active role in the emergence of results that will positively or negatively affect the development direction, urban identity and livability of the city. This study aims to guide other studies to increase the success of implementation for the future of cities and the location selection of new projects to be prepared by practitioners by expanding the scope of the criteria to be examined in the Geographical Information Systems environment related to the site selection of solid waste landfills.

REFERENCES

Akinci, G., Guven, E. D., & Gok, G. (2012). Evaluation of Waste Management Options and Resource Conservation Potentials According to The Waste Characteristics and Household Income: A Case Study in Aegean Region, Turkey. *Resources, Conservation and Recycling*, *58*, 114–124. doi: 10.1016/j.resconrec.2011.11.005

Alavi, N., Goudarzi, G., Babaei, A. A., Jaafarzadeh, N., & Hosseinzadeh, M. (2013). Municipal Solid Waste Landfill Site Selection With Geographic Information Systems and Analytical Hierarchy Process: A Case Study in Mahshahr County, Iran. *Waste Management and Research*, *31*(1), 98–105. doi: 10.1177/0734242X12456092

Ali, S., Taweekun, J., Techato, K., Waewsak, J., & Gyawali, S. (2019). GIS Based Site Suitability Assessment for Wind and Solar Farms in Songkhla, Thailand. *Renewable Energy*, *132*, 1360–1372. doi: 10.1016/j.renene.2018.09.035

Altuntaş, S., Hapoğlu, H., Ertunç, S., & Alpbaz, M. (2017). Experimental Self-Tuning Proportional Integral Derivative pH Control: Application to A Bioprocess. *Acta Physica Polonica A*, *132*(3), 1006–1009. doi: 10.12693/APhysPolA.132.1006

Avcı, S. (2020). Software Proposal for Determining the Prevailing Wind Direction: PrevailingWindRUB 1.0. *Journal of Geography*, 41, 209–219. doi: 10.26650/jgeog2020-806385

Bartie, P., Mills, S., & Kingham, S. (2008). An Egocentric Urban Viewshed: A Method for Landmark Visibility Mapping for Pedestrian Location Based Services. *Geospatial Vision*, 61–85. doi: 10.1007/978-3-540-70970-1_4

Bilgili, M.Y. (2020). Some Concepts and Their Explanations Used in Solid Waste Management. *Eurasscience Journals,* 8(2), 88–97.

Bolat, A. (2012). *The Geology of Northern Adıyaman Province and Its Petroleum Possibilities*. MSc thesis, Çukurova Unıversıty Instıtute of Basic and Applied Sciences Department of Geological Engineering, pp 112.

Bosompem, C., Stemn, E., & Fei-Baffoe, B. (2016). Multi-Criteria GIS-Based Siting of Transfer Station for Municipal Solid Waste: The Case of Kumasi Metropolitan Area, Ghana. *Waste Management and Research*, *34*(10), 1054–1063. doi: 10.1177/0734242X16658363

Çeliker, M., Yıldız, O., & Koçer, N. N. (2019). Evaluating Solid Waste Landfill Site Selection Using Multi-Criteria Decision Analysis and Geographic Information

Systems in The City of Elazığ, Turkey. *Pamukkale University Journal of Engineering Sciences*, *25*(6), 683–691. doi: 10.5505/pajes.2018.70493

Delikostidis, I., Engel, J., Retsios, B., Van Elzakker, C. P. J. M., Kraak, M. J., & Döllner, J. (2013). Increasing The Usability of Pedestrian Navigation Interfaces By Means of Landmark Visibility Analysis. *Journal of Navigation*, *66*(4), 523–537. doi: 10.1017/S0373463313000209

Demesouka, O. E., Vavatsikos, A. P., & Anagnostopoulos, K. P. (2016). Using MACBETH Multicriteria Technique for GIS-Based Landfill Suitability Analysis. *Journal of Environmental Engineering*, *142*(10), 1–11. doi: 10.1061/(asce)ee.1943-7870.0001109

Donevska, K. R., Gorsevski, P. V., Jovanovski, M., & Peševski, I. (2012). Regional Non-Hazardous Landfill Site Selection By Integrating Fuzzy Logic, AHP and Geographic Information Systems. *Environmental Earth Sciences*, *67*(1), 121–131. doi: 10.1007/s12665-011-1485-y

Ertunç, E., Bozdağ, A., & Gökçek, Ö. B. (2019). Investıgatıon of The Solid Waste Landfill Site Selection Using The Geographic Information System in The City of Niğde. *Konya Journal of Engineering Sciences*, *7*(4), 822–838. doi: 10.36306/konjes.654955

Eskandari, M., Homaee, M., & Mahmodi, S. (2012). An Integrated Multi Criteria Approach For Landfill Siting in A Conflicting Environmental, Economical And Socio-Cultural Area. *Waste Management*, *32*(8), 1528–1538. doi: 10.1016/j.wasman.2012.03.014

Fan, R., Chang, K., Hsieh, C., Wang, X., & Lin, C. (2008). : A Library for Large Linear Classi Cation. *Corpus*, *9*, 1871–1874.

Gbanie, S. P., Tengbe, P. B., Momoh, J. S., Medo, J., & Kabba, V. T. S. (2013). Modelling Landfill Location Using Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA): Case Study Bo, Southern Sierra Leone. *Applied Geography*, *36*, 3–12. doi: 10.1016/j.apgeog.2012.06.013

Gümüş, M. G., Savaş Durduran, S., Bozdag, A., & Gümüş, K. (2017). GIS Investigation of Site Selection of Historical Structures: The Case of Knidos (Datça, Turkey). *Mediterranean Archaeology and Archaeometry*, *17*(2), 149–157. doi: 10.5281/zenodo.810819

Isherwood, D. (1979). *Geoscience Data Base Handbook for Modeling Nuclear Waste Repository, 1,* (p. 114).

Karadimas, N. V., & Loumos, V. G. (2008). GIS-Based Modelling For The Estimation of Municipal Solid Waste Generation and Collection. *Waste Management and Research*, *26*(4), 337–346. doi: 10.1177/0734242X07081484

Karadoğan, S., Tonbul, S. (2013). Geomorphological Properties of Adiyaman Basin. *The Journal of Academic Social Science, 1*(1), 182–217. doi: 10.16992/ASOS.32

Kumaş, H., Gencer, C., Maraş, H. (2012). Determination Fastest Path for Heavy Vehicles Taking into Account Road Slope and Horizontal Curve Radius. *Journal of the Faculty of Engineering and Architecture of Gazi University*, *27*(2), 385–395.

Kuru, A., Tok, E., Guroglu Aktas, M., Demir, H. H., Özcan, H. K., & Demir, G. (2021). GIS and Multicriteria Decision Analysis for Landfill Site Selection in Edirne Province, Turkey. *Journal of the Institute of Science and Technology*, *11*(2), 969–981. doi: 10.21597/jist.792249

Lokhande, T. I., Mane, S. J., & Mali, S. T. (2017). Landfill Site Selection using GIS and MCDA Methods : A Review. *International Journal of Research in Engineering, Science and Technologies*, *3*(3), 25-30.

Moeinaddini, M., Khorasani, N., Danehkar, A., Darvishsefat, A. A., & zienalyan, M. (2010). Siting MSW Landfill Using Weighted Linear Combination and Analytical Hierarchy Process (AHP) Methodology in GIS Environment (Case Study: Karaj). *Waste Management*, *30*(5), 912–920. doi: 10.1016/j.wasman.2010.01.015

Nas, B., Cay, T., Iscan, F., & Berktay, A. (2010). Selection of MSW landfill Site for Konya, Turkey Using GIS and Multi-Criteria Evaluation. *Environmental Monitoring and Assessment*, *160*(1–4), 491–500. doi: 10.1007/s10661-008-0713-8

Ngoc, U. N., & Schnitzer, H. (2009). Sustainable Solutions for Solid Waste Management in Southeast Asian Countries. *Waste Management*, *29*(6), 1982–1995. doi: 10.1016/j.wasman.2008.08.031

Oweis, I., Smith, D.A., Ellwood, R.B., Greene, D. S. (1990). Hydraulic Characteristics of Municipal Refuse, Journal of Geotechnical Engineering. *Journal of Geotechnical Engineering*, *4*, 116.

Rathore, S., Ahmad, S. R., & Shirazi, S. A. (2015). Application of GIS Based Model in Landfill Site Selection: A Case Study of Lahore, Pakistan. *Pakistan Journal of Science, 67*(4), 359–364.

Şener, Ş., Şener, E., Nas, B., & Karagüzel, R. (2010). Combining AHP With GIS for Landfill Site Selection: A Case Study in The Lake Beyşehir Catchment Area (Konya, Turkey). *Waste Management*, *30*(11), 2037–2046. doi: 10.1016/j.wasman.2010.05.024

Sumathi, V. R., Natesan, U., & Sarkar, C. (2008). GIS-Based Approach for Optimized Siting of Municipal Solid Waste Landfill. *Waste Management*, *28*(11), 2146–2160. doi: 10.1016/j.wasman.2007.09.032

Uyan, M. (2014). MSW Landfill Site Selection by Combining AHP With GIS for Konya, Turkey. *Environmental Earth Sciences*, *71*(4), 1629–1639. doi: 10.1007/s12665-013-2567-9

Vaverková, M. D., Maxianová, A., Winkler, J., Adamcová, D., & Podlasek, A. (2019). Environmental Consequences and The Role of Illegal Waste Dumps and Their Impact on Land Degradation. *Land Use Policy*, *89*(March). doi: 10.1016/j.landusepol.2019.104234

Wang, G., Qin, L., Li, G., & Chen, L. (2009). Landfill Site Selection Using Spatial Information Technologies and AHP: A Case Study in Beijing, China. *Journal of Environmental Management*, *90*(8), 2414–2421. doi: 10.1016/j.jenvman.2008.12.008

Zelenović Vasiljević, T., Srdjević, Z., Bajčetić, R., & Vojinović Miloradov, M. (2012). GIS and The Analytic Hierarchy Process for Regional Landfill Site Selection in Transitional Countries: A Case Study From Serbia. *Environmental Management*, *49*(2), 445–458. doi: 10.1007/s00267-011-9792-3

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