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Preface I

Dear colleagues,

The Federation of Eurasian Soil Societies (FESSS) and the Erasmus Mundus Soil Science Program (emiSS) welcome you to "Soil Science and Plant Nutrition" (EURASIAN SOIL Symposium 2021). It is a great pleasure for us to see you at this great event. We hope that the speeches that will take place here in the field of soil science will be of great importance. It is a great honor for us to represent our country here.
The symposium "Soil Science and Plant Nutrition" is about applied research and new approaches to integrating soil, plant and environmental aspects across different ecosystems for the integration of scientific data and the physical, chemical and biological properties of soil, plant nutrition. and topics related to fertility mechanisms and processes under study. will cover topics of different scales - from molecular to field - on the diversity of experiences, opinions and scientific knowledge. The symposium will provide a great opportunity to learn and discuss the latest achievements in the field of soil science in general, and to establish contacts and cooperation with various participants. The symposium will focus on a multidisciplinary approach to soil science, with a particular interest in key research, the latest and most technological research. Scientific sessions will also highlight key concepts about land. The symposium will also provide numerous opportunities for interaction between public and private scientists.

Prof.Dr.Garib Mamadov
President, FESSS

Preface II

Respected guests, welcome to the international symposium organized in partnership with the Federation of Eurasian Soil Science Societies and Erasmus Mundus Joint Master Degree in Soil Science Program (emiSS). We are all in the process of a Corona virus epidemic that has a significant impact on all of our lives. This pandemic has been a shocking reminder to all segments of society how valuable it is to life to have enough food, enough water and also a clean environment. The pandemic disease has shown the importance of being self-sufficient to all sectors, and more importantly to the whole society, in a way that must be taken very seriously. Soil; the great connector of our lives now and beyond COVID-19. Achieving global food security is a complex and pressing issue

Turkish Soil Science Society (SSST) is a Non-Governmental Organization that was established in 1964 and started its activities in order to develop, disseminate and adopt soil science in theoretical and applied fields in Turkey. Our society, which is not a political organization, has more than nine hundered members with academic and research backgrounds. It carries out different activities in order to convey the message that soil, which is the basis of life, is a fragile and destructible entiti, and to spread the awareness that soil is an asset that needs to be protected in the society.

SSST is a member of the committee on combating desertification and erosion. In this context, we took part in the preparation of the Corrent National Action Program to Combat Desertification in 2005 and taking part in to rivays UNCCD NAP in 2014. It is committee member of the Grand National Assembly of Turkey, member of Agricultural Drought Management Coordination Board and taking part as a National committee member in GEF UNDP Small Grand Project from 2011 to continues. One of SSST activities is to organize an international congress every 2 years. We organized a total of 24 congresses, 13 national and 11 international. In the congresses we have organized, we aim to discuss the problems and future of the soil, which has a very important position in terms of the continuity of life in the world, to create universal messages on desertification, land degradation, what needs to be done against erosion, recycling policies, correct energy sources and carbon management, and sustainable use of soil. SSST is a founding member of the Federation of Eurasian Soil Science Societies and organized Soil Congress in 2014 in Antalya. SSST was the president of Federation of European Soil Science till 2012-2016 and organized sixty Eurosoil meeting in Istanbul. Finally, in 2019, we organized an international congress on LDN in Ankara with the Ministry of Agriculture and Forestry. Due to the pandemic that started in 2020, we could not organize an international congress yet. However, in this process, we have made and will continue to do serial soil panels on the national platform where soil threats such as salinity, erosion, pollution, biodiversity, acidity, lost of carbon are discussed. Every year on December 4 we celebrate the world soil day both in the academic framework and together with the students at the eco festival. SSST makes publications on the soil science, has online Journal of Soil Science and Plant Nutrition in Turkish, has the International Journal 'Mediterranean Soil Ecosystems published by Spinger and Booklet for children on Soil Biodiversity.

Ladies and gentlemen, the symposium will provide a great opportunity to learn and discuss ricınt advances in the soil science in general and to establish contacts and collaboreyşins with participants from many different parts of the World. Before I finish, I would like to thank, Dr Rıdvan Kızılkaya, Dr Coşkun Gülser, and Dr Orhan Dengiz for giving me the opportunity to speak on behalf of SSST in the opening speeches. And Special thanks to Dr Garip Mammadov. I greet you all with love and respect.

Prof.Dr.Ayten Namlı
President, Soil Science Society of Turkey

Preface III

Distinguished colleagues and friends,

Good morning and on behalf of Federation of Eurasian Soil Science Societies (FESSS) welcome to this Symposium on the "Soil Science and Plant Nutrition".
Let me begin by thanking our co-organizer, Erasmus Mundus Joint Master Degree in Soil Science Programme (emiSS) and its Coordinator, Dr Coskun Gulser for being here with us. This is the 6th International Scientific Meeting under our federation (FESSS) structure and the first we have co-organised with emiSS. Also, FESSS is the associate partner in emiSS Project. I am pleased to welcome again our colleagues from Southern Federal University in Russia, University of Agriculture in Krakow in Poland, Agricultural University Plovdiv in Bulgaria and participants from many countries participating in the symposium. I believe this event has helped that collaboration develop.
In this symposium, this year we will discuss the importance of Soil Science and Plant Nutrition with 77 different topics submitted by 33 different countries from all over the world. The symposium titled "Soil Science and Plant Nutrition" sets up the ambitious goal of integrating scientific background, applied research and novel approaches to link soil, plant and environmental aspects over various ecosystems. Physical, chemical and biological soil properties, plant nutrition and fertility mechanisms and processes studied at different scales - from molecular to field - will feed the diversity of experiences, opinions and scientific knowledge.
Federation of Eurasian Soil Science Societies (FESSS) with its unique organization of 8 Member countries, can help in the critical areas of Soil Science and Plant Nutrition. The Federation of Eurasian Soil Science Societies was established by the collaboration of Soil Science Societies of four different countries which are Turkey, Russia, Azerbaijan and Kazakhstan in 2012. After 2016, Romania, Kyrgyzstan, Bosnia & Herzegovina and Serbia Soil Science Societies joined to FESSS. The primary goal of the Federation is to share knowledge on the most dynamic part of earth-soils and to "bridge the gap" between soil science, policy making, and public knowledge both nationally and internationally in the region.
I would like to thank our programme steering committee for arranging an excellent line-up of speakers, and I thank the speakers and moderators for their contribution. Let me also thank all of you the participants. As always, we appreciate your support and look forward to your contribution to the discussion.
I wish you all a most enjoyable and productive symposium.
Thank you

.

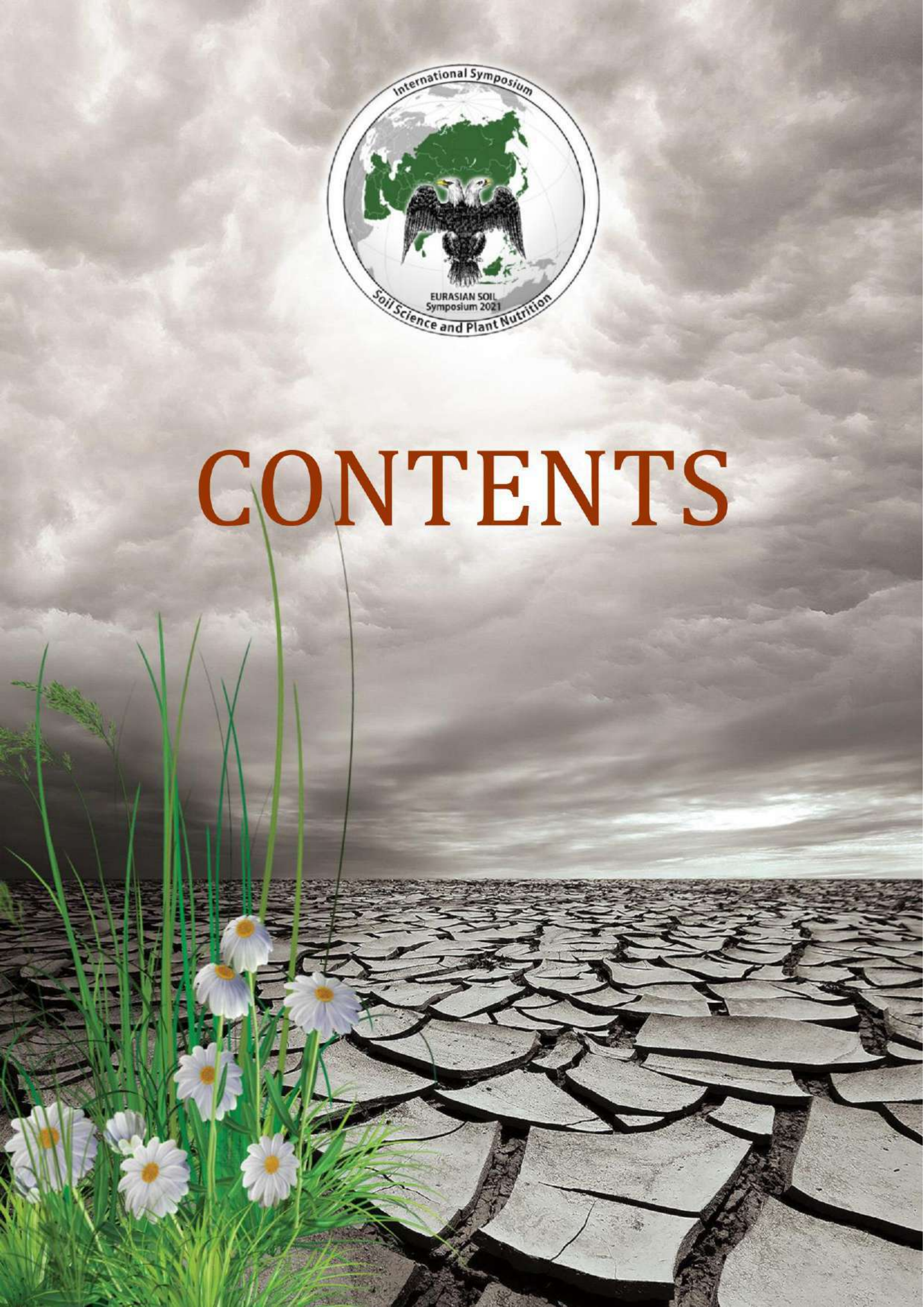
Prof.Dr.Rıdvan Kızılkaya
Chair, Organization Committee

Preface IV

Dear participants,

It is my great pleasure to attend the International Soil Symposium on "Soil Science & Plant Nutrition" as a part of organizing committee. This symposium has been organized by the Federation of Eurasian Soil Science Societies (FESSS) collaborating with ERASMUS MUNDUS Joint Master Degree in Soil Science (emiSS) programme. I would like to express my grateful thanks to FESSS and Prof. Dr. Ridvan Kizilkaya, who is the Chairman of the Symposium, giving us s chance to represent emiSS programme in this International Symposium. The emiSS programme has been founded with the support of the Erasmus+ Programme of the European Union and organized by a consortium of the five Universities: Ondokuz Mayıs University (OMU-Turkey), University of Agriculture in Krakow (UAK-Poland), Agricultural University Plovdiv (AU - Bulgaria), Southern Federal University (SFedU - Russia) and Jordan University of Science and Technology (JUST- Jordan) in 2019. The aim of emiSS programme is to raise and meet the need for qualified and skilled soil scientists at the master level through a higher educational programme under the training in soil science, soil management, soil fertility, soil ecosystem with intercultural competence and language skills. So far, it has 34 international students from the different geographical parts of the World. Some of emiSS students will be among us and make an oral presentation during the Symposium. I think that the mission of the symposium will be successful with sharing novel access that fulfill the needs of applications in soil science and plant nutrition field, and identifying new directions for future researches and developments in soil science area. At the same time, this symposium will give researchers and participants a unique opportunity to share their perspectives with others interested in the various aspects of soil science. I hope this symposium also will be helpful to increase young soil scientists' knowledge and their presentation skills front of the audience. Once more I would like to thank the organizing committee and all participants to their helps and sharing their scientific knowledge in this symposium.

Prof.Dr.Coşkun Gülser
emiSS Coordinator



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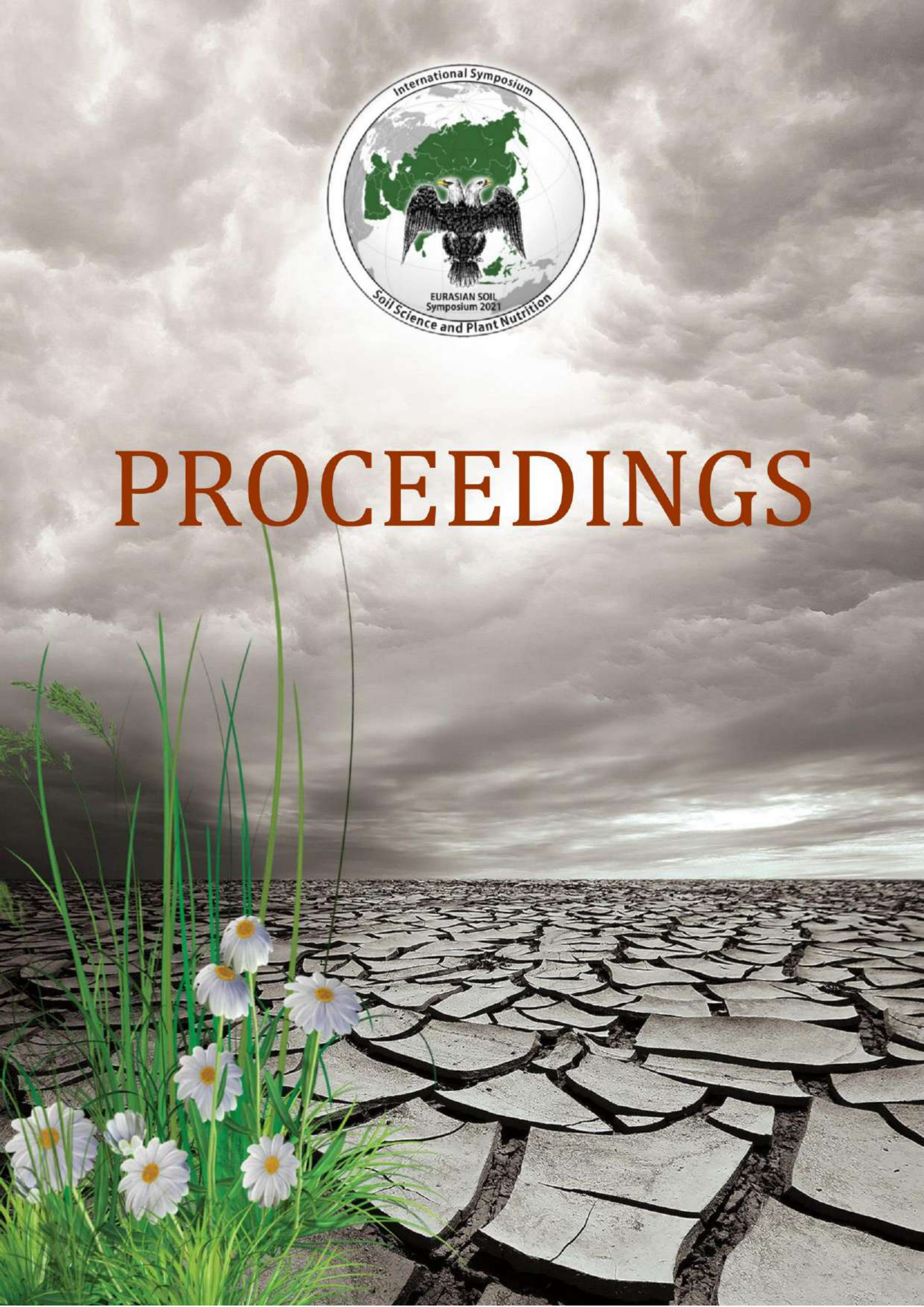
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PROCEEDINGS

The effect of vermicompost addition and soybean planting on soil physical properties

Dorcas Ojeade [a,*], Coskun Gulser [a], Nazeir Elnaker [b], Hadeer Elgendy [c], Belkis Karapicak [a]

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Abstract

Soil physical properties play a crucial role in determining soil suitability and sustainability in agricultural production. In recent years, legume crops have been found to be highly effective in enhancing soil physical parameters. In this study, soil physical parameters were observed under soybean cultivated plots and 2% vermicompost addition in a controlled environment.

A greenhouse experiment was carried out using clay soil with four treatments including soil (S) as a control treatment, soil+2% vermicompost (SV), soil + planting (SP), and soil+planting+2% vermicompost (SPV) in 10 cm soil depths of cylinders. Physical soil properties bulk density, porosity, and saturated hydraulic conductivity (Ks) were determined after 24days and 72days of the experiment respectively. Bulk density values after 72days were higher relative to the values recorded after 24days in all treatments. The bulk density values in control soil were almost the same (0.99 g/cm3), the percentage increase rate for SP, SV, and SPV treatments was 3.26%, 3.13%, and 2.13%, respectively while total porosity decreased at the same rate. The highest Ks value obtained was 1.86 cm/min in SPV treatment at 24 days while the lowest was 0.23 cm/min recorded in SV treatment at 55 days. Generally, the SPV treatments had the highest Ks value in this experiment. The Ks values for S, SP, SV and SPV treatments decreased from 24 to 72 days as 57.3%, 65.5%, 84.9% and 60.2%, respectively. The results showed that soybean planting treatment had a greater effect on soil measured physical properties than vermicompost alone treatment. Addition of vermicompost to the soil when planting soybean improved soil permeability in the clay soil.

Keywords: Clay soil, Soil Physical Properties, Soybean, Vermicompost.

Introduction

Being an inherent and static soil property, soil texture affects other soil physical parameters like soil porosity, bulk density and water movement. These physical properties do not only determine the suitability and sustainability of soil for agricultural purpose, they are also significant indicators for soil physical quality (Almendro Candel et al., 2018). Clay soils are the most difficult soil to work with due to its high preponderance of micro pores leading to poor drainage and poor root growth. Addition of organic amendment and cover cropping generally improve the physical quality of the soil and therefore food production (Blouin et al., 2019). More so, soybean planting is a sustainable way of reducing the emissions of CO_2 (Siamabele, 2021).

Vermicompost as a soil amendment is formed when overhead earthworms consume organic residues and convert them into a finely divided, mature peat-like material with porosity, aeration, drainage, WHC, and activities microbial (Xu and Mou, 2016; Biouin et al., 2019).

Addition of un-composted organic residues to the soil could facilitate the liberation of CO_2 and waste could cause environmental pollution (Navarro-Pedreño, 2021). Vermicompost is "exceptionally superior" to global brands of conventionally prepared and marketed compost. It is at least four times more nutritious than conventional compost made from cow manure and seven times richer than conventional compost in nutrients and growth-promoting values (Thakur et al., 2021). This can be attributed to the rapid production of humus by earthworms in vermicompost (Canellas et al., 2002).

Studies show that legume cropping helps to improve soil physical quality (Gülser, 2004; Demir et al., 2019; Gülser and Gülser, 2021), increase the capacity of carbon sequestration (Kumer et al., 2019, 2020), maintain soil fertility, and control soil erosion (Garcia Estringana et al., 2013). It adds organic matter to the soil which has significant impacts on the physicochemical attributes of the soil, improving soil porosity, therefore, having indirect effects on the hydraulic properties (Demir and Işık, 2019).

Being the most important crop worldwide, soybean has risen as one of the top traded commodities with multiple uses (GAIN, 2021). It could combat world hunger and reduce environmental footprint caused by the excessive use of chemical fertilizer as the interaction between soybean plant and Rhizobium bacteria helps to fix nitrogen, converting it to ammonia; a compound necessary for plant growth and development.

The objective of this study is to determine the effects of soybean planting and vermicompost application on some physical properties of a clay soil.

Material and Methods

The experiment was carried out using clay soil, soybean seed, and vermicompost. A clay textured soil and soybean seeds were obtained from the Faculty's experimental field and Department of Field Crop, Ondokuz Mayis University, respectively. Vermicompost was produced from manure by the *Eisenia fetida* species earthworms for eight weeks in the greenhouse. Properties of vermicompost and soil used in the experiment is given in Table 1.

Table 1. Some properties of Vermicompost used in the Study

	Sand, %	Silt, %	Clay, %	pH	EC, dS/m	OC, %	N, %	C/N
Vermicompost				8.15	0.600	22.7	1.9	11.92
Soil	21.24	22.24	56.38	6.28	0.625	2.00		

The soil was air-dried in a laboratory and sieved through 4 mm screens. Particle size distribution was done by hydrometer method (Day, 1965), soil reaction (pH, 1:1 (w:v) soil: water suspension) by pH meter, electrical conductivity ($EC_{25°C}$) in the same soil suspension by EC meter and organic carbon by Walkey Black Method. Analysis revealed that vermicompost was slightly alkaline, non-saline, and low C/N ratio while the soil was clay textured, slightly acidic, non-saline, and high in organic matter content (Soil Survey Staff, 1993).

The research was carried out in the greenhouse of Ondokuz Mayis University's Agricultural Faculty between August 9 and October 5, 2021. There were four treatments including soil (S) as a control treatment, soil+2%vermicompost (SV), soil+soybean planting (SP), and soil+soybean planting+2% vermicompost (SPV) in 10 cm soil depths of cylinders with four replications. Soybean seeds were sown two seeds per cylinder for treatments SP and SPV and were thinned to one seedling per cylinder. Half of the experiment was terminated 24 days after it began while the second half of the experiment was terminated after vegetative maturity (72 days).

At the end of each period, bulk density was determined by gravimetric analysis, using the sample dry weight and the corresponding volume of the cylinder. Total porosity (F) was estimated from equation 1

$$F = 1 - \frac{\text{soil bulkdensity (g/cm}^3)}{2.65\ (\text{soil particle density(g/cm}^3)} \qquad (1)$$

Saturated hydraulic conductivity (Ks) values of the soil samples were measured according to the constant head method using a Mariotte bottle device. Outflow volumes obtained from the bottom of soil columns were used in Darcy's equation (2) to find saturated hydraulic conductivity (Ks, cm/min).

$$K_S = \frac{Q}{At}\left(\frac{S}{S+H}\right) \qquad (2)$$

Where, Q: outflow volume (cm^3), A: cross-sectional area of soil column (cm^2), t: time (minutes), S: length of soil column (cm), H: height of pounded water at the top of soil column (cm).

Using descriptive statistics, data were compared among the treatments.

Results and Discussion

In Fig 1, Bulk density values varied between 0.92 and 0.99 g/cm3, within the range of an ideal soil bulk density for clay soil. It has been reported that clay soil supports bulk density less than 1.10 g/cm3 for root growth (Soil Quality Staff, 1999). Bulk density values after 72days are higher relative to the values recorded after 24days in all treatments, except for control soil which is lower but approximately the same (0.99 g/cm3).

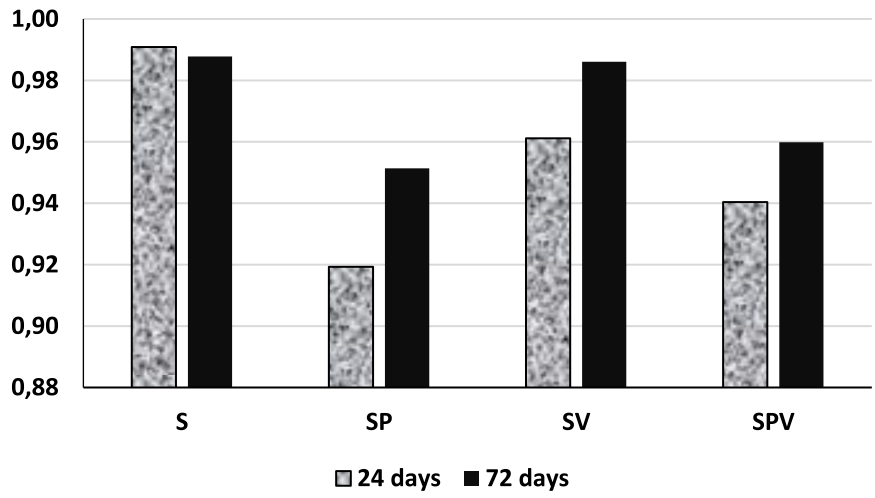

Fig 1. Bulk Density of Treatment after 24 and 72 days

Lower bulk density of control treatment is due to the formation of well-structured soil after wetting and drying process. The constant wetting and drying process had more effect on control treatment as the presence of plants and or vermicompost in the other treatments disallowed the formation of the characteristics crack patterns that occur in clay soils during wetting and drying processes. This is concurrent to Tang et al. (2016) findings. They conducted laboratory tests to investigate the consequence of wetting-drying cycles on the initiation and propagation characteristics of desiccation cracks on the soil surface, and observed that the applied wetting drying cycles are accompanied by a continual reconstruction of soil structure and thus a decrease in bulk density.

An increase in bulk density values for SP, SV, and SPV after 24 days is mostly attributed to compaction that resulted from the constant movement of glass cylinders during the period of the experiment. The percentage increase rate for SP, SV, and SPV treatments was 3.26%, 3.13%, and 2.13%, respectively. However, a high rate of increase in SV is a result of high EC in treatment after 72days which increased the bulk density rate (Fig 2). EC is the measure of soluble salts in the soil. Tejada et al. (2006) observed a 23% increase in bulk density after the saline soils are exposed to organic manure and organic matter for about 5 consecutive years. Absorption of ions occurred with the presence of soybeans plant roots and thus lower rate of bulk density increased with SPV. High EC value can be attributed to the vermicompost source (Cattle Manure). In their findings, Mahboub-Khomam, et al. (2021) recorded that the chemical composition of cattle dung causes an increase in bulk density. Though increasing doses of organic amendment to the clay textured can soil decrease bulk density (Anikwe, 2000 and Gulser, 2021), the source of the organic amendment is adequately essential.

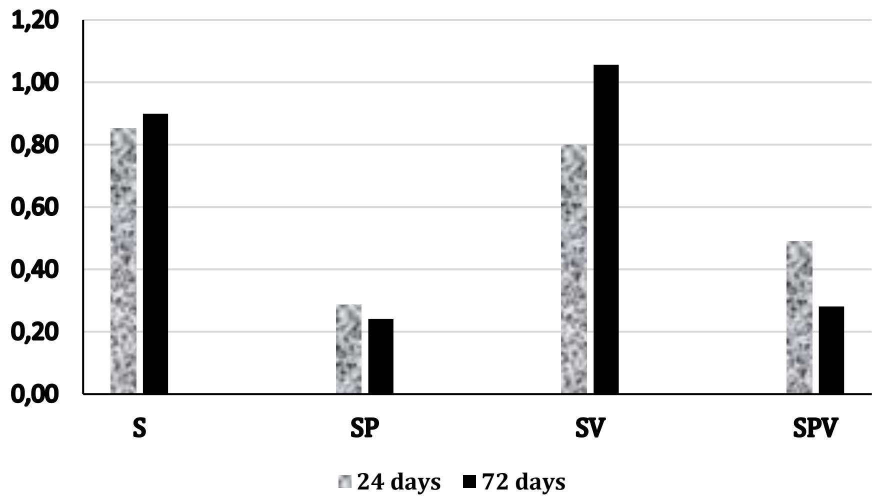

Fig 2. Electrical Conductivity (dS/m) of Treatments at 24 and 72 days

Bulk density affects the pore diameter and its distribution, decreasing macropores and increasing meso and micropores, thus the resultant effects on the soil hydraulic properties (Fuentes et al., 2004; Horn and Smucker, 2005; Buczko et al., 2006; Dec et al., 2008).

Being a dependent soil property, total porosity values decreased with increasing bulk density. Values after 24days is relatively higher compared to the values recorded after 72days in all treatments, except for control soil. Values ranged between 0.63 and 0.65; with S having the least, SP and SPV having the highest. The percentage rate of decrease for SP, SV and SPV treatments were, 1.54%, 1.56% and 1.54% respectively (Fig 3). Decreased porosity due to the addition of vermicompost has been reported by several authors (Ingelmo et al., 1998; Guerrero et al., 2002) with materials such as peat, pine bark, sewage sludge.

Clay soils generally have high total porosity because of the preponderance of micropores leading to poor drainage and poor root growth, however, plant root network improved porosity of soil by increasing the number of large gaps in the soil where roots are distributed.

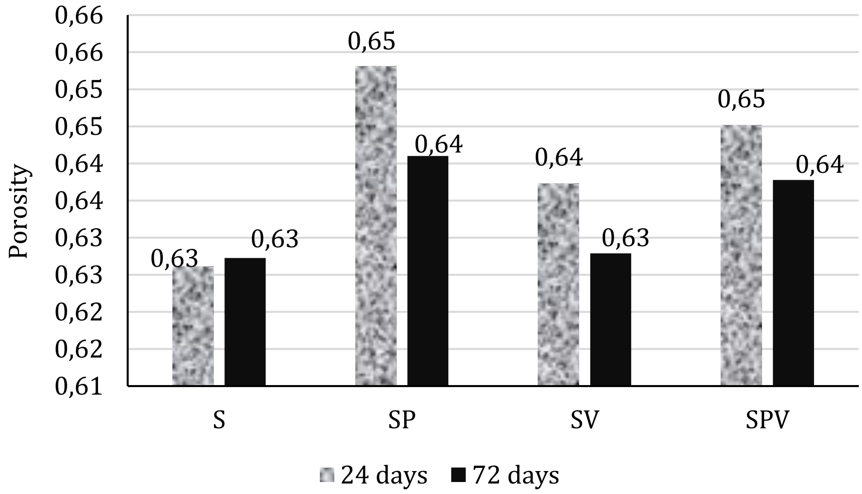

Fig 3. Porosity of Treatment after 24 and 72 days

The rate of water flow is increased in the first month compared to the second month. Addition of vermicopost and planting had highest effect on soil hydraulic conductivity. In the present study, soybean planting increased Ks values (cm/min) in both periods (Fig 5). Demir and Isik (2019) reported significant improvements in soil hydraulic properties with cover crop in a clay soil of a persimmon orchard. Another study with leguminous crop increased soil physical properties in an apricot orchard with clay soil.

The hydraulic properties of soil are directly influenced by crack networks in the control treatment. SP treatment had the highest increase rate.

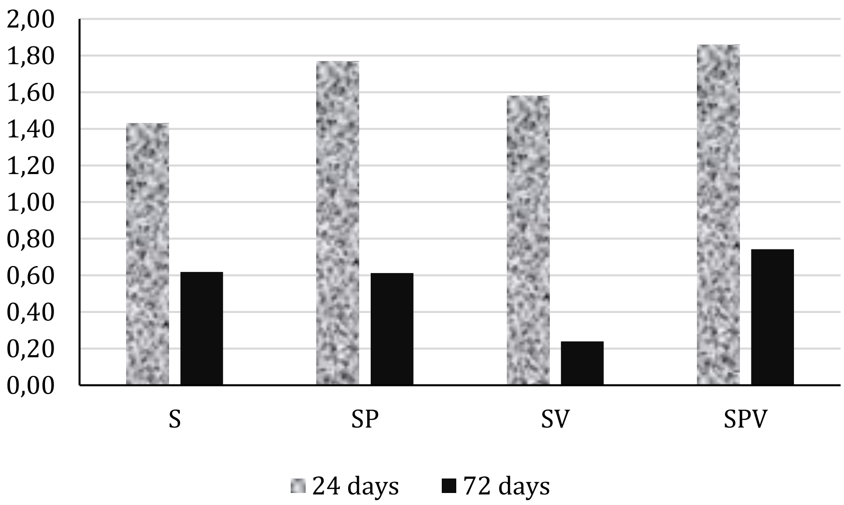

Fig 4. Saturated Hydraulic Conductivity Ks (cm/min) of Treatment after 24 and 72 days

Fig 5 showed a positive linear relationship between porosity and hydraulic conductivity. This implies that the higher the pore space, the higher the rate of flow and vice versa

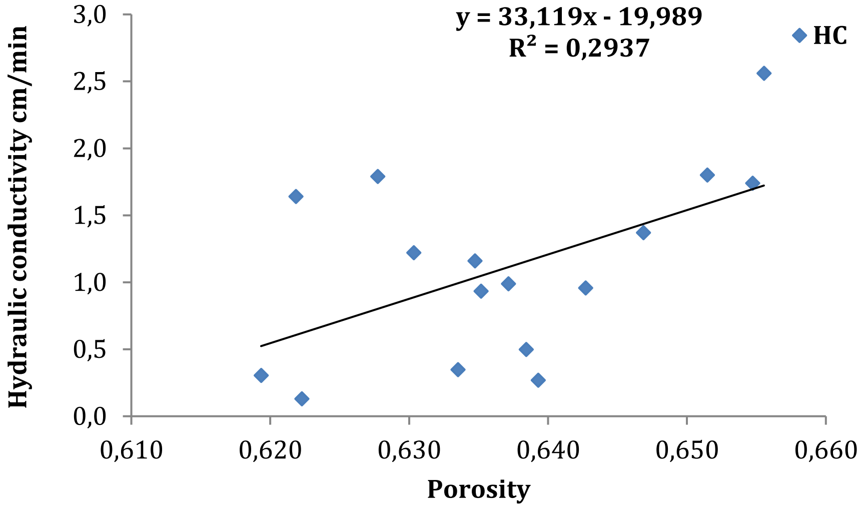

Fig 5. Correlation between Porosity and Permeability

Conclusion

Soybean planting impacted physical properties of clay soil better than sole addition of vermicompost. Vermicompost made from cattle dung when added to the soil had negative effect on soil properties. However, addition of vermicompost to soil when planting soybean improved permeability in the clay soil. Source of material for vermicomposting is a crucial consideration to be looked into because it goes a long way to alter soil physical characteristics. Further studies should be done on the effect of various sources of vermicompost on soil properties.

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Artificial intelligence and remote sensing as a tool for sustainable agriculture: a review

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Abstract

Artificial Intelligence (AI) and Remote Sensing (RS) applications have become a point of interest in agricultural research. The current RS research trend on agriculture changed its focus from the land-use/land-cover classifications to evaluating biophysical properties. The advances in spatial and temporal resolutions of sensors, the introduction of UAVs, cloud computing, and machine learning algorithms have caused an exponential growth in the number of scientific reports about the application of RS in agriculture. This study reviewed the current and potential applications of RS and AI in agriculture. Several studies revealed that RS has vital applications to assess and monitor agricultural activities using the spectral response of plants and soils within the visible and Near-Infrared (NIR) spectral regions. The vegetation indices (such as RVI, NDVI, NDWI, PRI) developed based on the difference in spectral responses have been validated to evaluate the soil and crop conditions. According to the review, RS has been successfully used to estimate the nutrient and soil moisture conditions, enabling valuable farm-based nutrient and soil moisture management. The presence of plant pathogens and weeds can also be detected using RS. Despite its potential, the RS application for precision farming is still limited due to several factors. Moreover, AI is an emerging technology that brought a novel revolution in agriculture. AI has various applications in agriculture: weather forecasting, monitoring soil and crop condition, detecting weed and pests, precision farming, automation, and robotics. AI helps producers automate their agriculture and shift to precision farming, promoting maximized output and enhanced quality with low agricultural inputs. In summary, the reviewed reports revealed that RS, along with AI, is redefining the conventional farm model, and their future is increasingly evolving.

Keywords: Artificial intelligence; crop; precision farming; remote sensing; soil

Introduction

Agriculture has evolved for over a thousand years since the beginning of the farming practice. Over the last two centuries, agricultural practices have become modernized following the introduction of the industrial revolution in the late 18th century (Thrall et al., 2010). Agricultural machinery, pesticides and fertilizers, improved cultivars, and other technologies have substantially improved farm production and productivity (Liaghat and Balasundram, 2010).

The global population is projected to boost from the current 7.5 billion to above 10 billion by the end of 2050. Advancements in agricultural production are essential to meet the food and fiber demands of the global community and maintain sustainable agricultural production (Liaghat and Balasundram, 2010). Traditional farming practices will not meet this goal. Technological advancements and automation have a significant role in achieving sustainable agricultural production (Ennouri et al., 2021).

Several sectors have benefited from technological advancements, while the agriculture sector has a limitation of harnessing the potential benefit of these technologies (World Economic Forum, 2021). Agriculture practice is highly dependent on information technologies related to different farming practices. The updated weather information, the forecasted extreme events (floods, droughts), and the latest farming approaches have improved agricultural production and productivity despite some environmental and economic concerns (Darnhofer et al., 2010).

Artificial Intelligence and Remote Sensing (RS) have become a point of interest in recent agricultural researches (Moussaid et al., 2021). RS is the method of collecting and analyzing information from a remote location without having direct contact with the target objects or areas (Ray, 2016). Remote sensing allows analysis of the spectral images with different bands. This approach enables monitoring the agricultural practices, identifying the abiotic and biotic plant stresses, and making practical decisions to maximize agricultural yield (Moussaid et al., 2021; Ray, 2016). The AI also helps identify and anticipate several factors that will maintain sustainable agricultural production (Ray, 2016).

Remote Sensing in Agriculture

RS is a tool used to monitor the planet's resources based on synoptic satellite observation (Moussaid et al., 2021). The main principle of the remote sensing approach is using the electromagnetic spectrum to identify the target features. The electromagnetic spectrum can be classified as visible, infrared, and microwaves based on their wavelength. Each target objects or areas have a different response to these wavelength ranges. This enables distinguishing the target features such as vegetation, soil, or water (Shanmugapriya et al., 2019).

The research trend of RS has changed its focus from land use/land cover classification to an assessment of plant and soil biophysical properties (Shanmugapriya et al., 2019). The number of scientific reports about the application of Remote Sensing in agriculture showed an exponential growth trend over the last two decades (2000 to 2019), as depicted in Figure 1. This is due to a significant technological advancement, including spatial, temporal, and spectral resolutions of sensors, Unmanned Aerial vehicles (UAV), and the progressive growth of cloud computing and machine learning applications (Khanal et al., 2020).

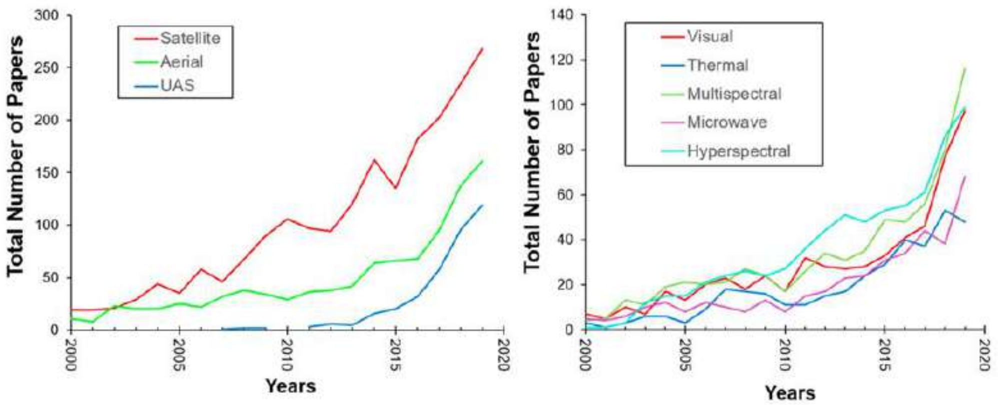

Figure 1: Number of studies about remote sensing applications in agriculture between 2000 and 2019 (Khanal et al., 2020)

Remote sensing can revolutionize agricultural practices (Ray, 2016). Some RS applications in agriculture include providing data (weather, area, yield), monitoring crop growth, soil moisture content, weed and crop diseases infestations (Liaghat and Balasundram, 2010; Shanmugapriya et al., 2019; Khanal et al., 2020)

Assessment of Crop Conditions and classifications

Frequent monitoring of the crop condition is essential during the crop growth period. Several studies showed that RS could assess crop conditions. Digital image analysis based on supervised or unsupervised classification algorithms is commonly used to prepare crop classification maps (Shanmugapriya et al., 2019). The vegetation conditions can be evaluated by developing different indices based on various multi-spectral bands and the related plants' responses (Xue and Su, 2017). The vegetation indices such as Reflectance Ratio, Normalized Difference Vegetation Index (NDVI), Vegetation Condition Index (VCI), Leaf Area Index (LAI), and Greenness Index has been validated as a reliable approach to determining the growth of the plant and its related conditions (Shanmugapriya et al., 2019). The water content can be determined using a Normalized Difference Water Index (NDWI) (Gao, 1996). Chlorophyll Index (CI) is also used to estimate the chlorophyll content (Bausch and Khosla, 2010). The Photochemical Reflectance Index (PREI) can determine the rate of photosynthesis (Gamon et al., 1992). Despite its vast potential, according to (Bégué et al., 2019), only less than 10% of the scientific studies are about the application of remote sensing on agriculture focused on assessing crop conditions.

Nutrient and Soil Moisture Status

RS has vital applications for estimating the nutrient and soil moisture conditions, enabling precision farm-based nutrient and soil moisture management (Shanmugapriya et al., 2019). The nutrient and water stress can be detected by RS using the vegetation indices. According to Shanmugapriya et al. (2019), the reflectance in the visible spectral region is higher in the water-stressed crop than the non-stressed. Consequently, the vegetation indices (such as NDVI, RI, PVI, and GNDVI) have lower values in the water-stressed crops. A microwave sensor data has been used by Casanova et al. (2006) to refine soil moisture estimates, while Verstraeten et al. (2006) used a combination of optical and thermal sensor data (METEOSAT) to determine thermal inertial relative to soil moisture content.

The remote sensing approach also has applications for assessing nutritional stress. Bajwa and Tian (2005) presented the application of aerial visible/infrared hyperspectral imagery to differentiate soil fertility factors in the US Midwest. The result showed a higher degree of variability in Ca, Mg, P, and K parameters, while the variability is less for pH parameters. Miao et al. (2009) used multi-spectral and hyperspectral data to estimate the chlorophyll. The study was based on digital image analysis and in-situ field measurement. The study revealed that each multi-spectral and hyperspectral band (vegetation index) could explain 71–86% and 73–88% variability in corn's field-based chlorophyll measurements, respectively. Peng et al. (2020) have shown the use of hyperspectral indices to estimate leaf N, P, and K content is promising. Mahajan et al. (2021) used remote sensing and machine learning algorithms to characterize the nutrient status of the mango foliage. The study showed that a combination of Partial Least Square Regression (PLSR) with a machine learning model predicts the leaf nutrient requirements at acceptable accuracy.

Monitoring Crop Health

The presence of plant pathogens can be characterized by either the loss of leaves and shoot area or leaf color changes related to the reduction of photosynthetic activity. Plants infected with a pathogen could be differentiated from the healthy ones using their spectral responses within the Visible and Near-Infrared spectral region (Lorenzen and Jensen, 1989). A more recent study revealed that the availability of machine learning algorithms and high-resolution spectral data enables detecting plant pathogens at early infestation stages (Barbedo, 2016).

Weed Identifications

RS enables the identification of weeds from the crop based on their difference in spectral reflectance properties (Lamb et al., 1999). It would help prepare a weed map to apply site-specific herbicide on the delineated area. Kaur et al. (2014) pointed out that the value of radiance ratio and NDVI were higher in pure wheat (the crop) and lower in solid weed. Using the indices (RR, NDVI), it was possible to distinguish pure wheat from weed. López-Granados (2011) used a multi-spectral aerial imagery analysis to detect weeds and prepare a weed map for site-specific weed management. Li et al. (2021) assessed the potential application of hyperspectral data and three machine learning algorithms for the reliable and rigorous identification of weeds in pastures. The study showed a reliable detection of four weeds using both Av and Sp spectra within acceptable accuracy (70% to 100%).

Crop Yield Estimation

The crop yield depends on multiple factors, including variety, soil fertility, an infestation of weeds and pests, and climate factors (Shanmugapriya et al., 2019). The spectral response depends on these yield affecting factors. The difference in spectral responses can characterize the crop condition and predict its yield. RS has a demonstrated application to prepare fine resolution yield maps (Geipel et al., 2014). These maps help assess yield variability within the field and predict overall production and productivity. Ferencz et al. (2004) forecasted crop yields based on Hungary's multi-spectral satellite imagery data and a novel vegetation index (GYURI). The study showed that the yield estimated using RS and field measurement was strongly correlated with the coefficient of determination (R2) of 0.75 at the field level and 0.93 at the country level. Prasad et al. (2006) have used NDVI, soil, and weather parameters (moisture, temperature, and rainfall) to estimate the Iowa state yields for 19 years using a piecewise linear regression approach. The study indicated that there had been a strong correlation between predicted and observed yield for corn (R2= 0.75) and soybean (R2= 0.86). However, the accuracy of crop yield maps depends on the crop development stages (Khanal et al., 2020).

Precision Farming

Precision farming is a novel practice that combines different management strategies to site-specific soil and crop condition, fertilizer, herbicide, and pesticide applications, which are required to improve farm efficiency and reduce environmental pollution. This approach relies on applying GIS, GPS, and RS (Khanal et al., 2020).

Aerial imagery has the potential to delineate management zones, prepare a field, assess the soil conditions and their variability from place to place (Schepers, 2002). UAVs (drones) have also been introduced for monitoring large-scale farming practices precisely. Daponte et al. (2019) applied UAV successfully to assess site-specific water deficiency, nutrient stress, or disease, vital to support crop management decisions. Selecting suitable sensors for agricultural data collection depends on the objective (nature of the problem) and economy. While other geospatial technologies, especially GPS and GIS, are frequently used in precision farming, the application of the RS approach remains limited due to several factors, including cost of imagery acquisition, spatial and temporal resolutions, and the required level of skills (Khanal et al., 2020).

The Role of Artificial Intelligence in Agriculture

Due to the dramatic global population growth, the agricultural sector is in crisis, and AI can provide a sustainable solution. AI is based on the hypothesis that machines can easily mimic human intelligence and execute different tasks using different algorithms. It brought a novel revolution in the agriculture industry (Talaviya et al., 2020). AI has various applications in agriculture, including weather forecasting, monitoring soil, and crop conditions, detecting weeds and pests, precision farming, automation, and robotics (Jain, 2020). It enables the farmers to produce more with optimized agricultural inputs and helps to enhance the quality of the farming products, and promotes a strong market value chain (Talaviya et al., 2020). According to Hunt (2021), the applications of AI in agriculture focus primarily on four goals: improving yield, reducing cost, maximizing profit, and sustainability.

AI can be applied successfully to different agricultural practices (Jain, 2020). Talaviya et al. (2020) discuss that AI helped select improved crop varieties that have enhanced production. This has been assessed by analyzing the response of varieties for different soil and climate conditions. AI enables yield prediction and mapping, evaluation of the market trend, annual outcomes, and consumer preference; thus, farmers could maximize their profits (Talaviya et al., 2020). AI also has practical applications for precision farming that help to improve harvest quality and accuracy using different probabilistic models. It detects plant diseases, pests, weeds, nutritional stress, and water deficiency. AI optimizes farm management by supporting soil and crop management decisions based on reliable predictions (Hunt, 2021). The machine learning algorithms enable satellite and aerial imagery analysis that helps forecast the weather and evaluate soil and plant conditions. A German-based technological company, PEAT, developed an AI algorithm application to detect nutrient deficiency and plant health (Jain, 2020). AI with machine learning algorithms helps develop a chatbot, a conversational virtual assistant for farmers, that enhances the capacity and skills of farmers (Talaviya et al., 2020).

The traditional farming practices is labor-intensive as it requires massive workforces to grow and harvest crops. Particularly in the US, the number of people participating in farming practices decreases significantly. AI-based agricultural robotics offer alternative solutions for this challenge by harvesting a massive volume of products at minimized durations than human labor. The introduction of smart tractors enables planting seeds remotely. IoT devices monitor the soil and crop conditions (Jain, 2020; Talaviya et al., 2020). Talaviya et al. (2020) indicated that smart irrigation would replace the manual irrigation method with automated irrigation scheduling technologies with enhanced production at minimum labor. It also enables farmers to locate water leakage, optimize the irrigation schemes and evaluate the irrigation efficiency. AI also offers an efficient method to monitor plant health or any abiotic plant stresses. With the help of a machine and deep learning algorithms, several applications are being developed to analyze crop health patterns (Hunt, 2021).

Conclusion

Due to several factors, the agricultural sector is in crisis in meeting the food and fiber demands of the present and future generations in a sustainable way. AI and RS can provide alternative solutions for promoting sustainable agricultural production. Several studies have shown that RS can be used to assess crop conditions, nutrient and soil moisture status, weeds, and plant health conditions. The RS application for precision farming remains limited due to several factors, including the cost of imagery acquisition, spatial and temporal resolutions, and the level of skills required to apply RS at the farm level.

AI solutions enable the farmers to produce more with optimized agricultural inputs and help to enhance the quality of the farming products and promote a strong market value chain. The applications of AI in agriculture focus primarily on improving yield, reducing cost, maximizing profit, and sustainability. The review showed that RS, along with AI, has the potential to promote sustainable agricultural practices.

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Variability of crust formation under various land use and land cover

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Abstract

It is one of the indispensable elements in the transportation and industry sectors, as well as the use of soil, agriculture, forest and pasture. With direct or indirect human influence, million tons of soils are destroyed every year, affecting life negatively. Erosion plays an important role in disasters. The soil, which is lost as a result of erosion and transport of its upper layer by the effect of precipitation or wind, also loses its productivity functions. Soil's resistance to abrasion is closely related to its physical and chemical properties as well as to vegetation. This study was carried out in Tekkeköy district of Samsun province, which is located in the Central Black Sea Region. The study covers about 22563 km^2, where has been intensively used as agriculture, forest and pasture. Total 328 soil samples were taken from the surface (0-20 cm) at agricultural, forest and pasture lands. After taking laboratory results and field observations, it was produced crust formation map and evaluated relationship between soil crust formation and land cover-land use. Finally, in this study, it was observed that there was no physical deterioration due to the high soil crust formation in 10.98% of the soils, and very severe physical deterioration was observed in 55.79% of them.

Keywords: Soil crust formation, Land use, Land cover, Tekkeköy district

Introduction

In recent years, climate change has been experienced with the effect of global warming and as a result of this change, irregularities are observed in weather events. Air temperatures above seasonal averages, excessive and irregular precipitation, and disasters such as fire, flood, erosion, landslide and landslide bring with them. The Black Sea region is sensitive to almost all of these disasters due to its topographic and geological structure. In the region where the slope is an effective parameter in terms of risk, improving the physical properties of the soil is of great importance in terms of preserving its existence (İmamoğlu and Dengiz, 2020).

Erosion and landslides show their effects as a result of heavy rain and long-term precipitation. In particular, the soils devoid of vegetation and vulnerable to raindrops are quite suitable for erosion and then to be transported by moving in the direction of the slope. Soil erosiveness is a combined expression that affects the physical, chemical and mechanical properties of the soil, such as the disintegration and transport of soil particles by erosive processes (water, wind, gravity, etc.) (Houghton and Charman, 1986).

Soil crust is called the surface soil layer, which has become harder than the underlying layer and can be separated physically and biologically (Han et al., 2016). The crust layer formed on the surface of the soil is mostly formed by the effect of rain (McIntyre, 1958). In sloping areas devoid of vegetation, the crust/cream layer, which is effective in preventing or reducing the penetration of rain and irrigation water into the soil, causes surface flow and causes erosion (İmamoğlu et al., 2018). The formation of crust in the soil directly affects the seed emergence rate and germination time in agricultural soils, and the time elapsed until the soil surface is covered with vegetation in forest and pasture lands. The tendency of soils to erode and their structural durability are important in terms of soil management practices as well as plant cultivation (Sönmez and Özdemir, 1987). The high soil structure increases the aeration and water holding capacity of the soil, as well as facilitating the uptake of nutrients and increasing its resistance to erosion (Turgut and Aksakal; 2010).

Many factors have an effect on crust formation in the soil. Organic matter is one of the most effective of these factors, as it physically increases the water holding capacity of the soil, increases aeration, increases the uptake of nutrients, and contributes to the infiltration of water in the soil. The higher the tendency of soils to crust, the lower the aeration and water permeability of the soil, as well as its resistance to abrasion (Sönmez and Özdemir, 1987). The low organic matter content in the soil increases the tendency of soil aggregates to break down easily with the impact of raindrops and crusting of the soil surface (Öztürk and Özdemir, 2006). This study, which was carried out in the lands of Tekkeköy district of Samsun province, is to determine the relationships between different land use by calculating the crust formation in the soil as a result of the organic matter and structural stability index analyzes made on soil samples taken from agricultural forest, pasture, etc.

Material and Methods

Characteristics of the study area

It is located between 4550000-4570000 m North, 278000-29600 m East (WGS 1984, 37 Zone) coordinates in Tekkeköy town of Samsun province. 1 km to the south on 13 km of the Samsun - Ordu highway (Figure 1). It is located inside and the District area is 22563 km^2. It was opened in the section where Tekkeköy creek opens into the coastal plain. One third of the district's lands are located in the Çarşamba plain. In the study area, where the Black Sea climate characteristics are observed, summers are hot and partly rainy, and winters are cold and rainy (Dengiz et al., 2009). The average annual precipitation of the area is 831 mm, and the annual average temperature is 15.2 0C. Soil temperature and moisture regimes produced using the Newhall simulation model were determined as Mesic and Ustik, respectively (Turan et al., 2018). The study area includes artificial areas such as agriculture (45.5%), forest(22%), pasture (22%) and settlement (10.6 %). While agricultural areas cover the largest area with 167 km in a total area of 368 km, the lowest area covers the artificial areas, including the settlements, with 39 km^2 (Figure 1).

Laboratory analyzes to determine soil erosion are parameters used to indirectly predict soil quality (and Wakindiki, 2015). Soil samples were taken from a total of 328 points, from 0-20 cm depth, representing agriculture, forest, pasture and artificial areas within the study area. The texture analysis (Bouyocous, 1951), organic matter analysis (Jackson, 1958) and the structural stability index (Atalay, 2006), which is the erosion susceptibility parameter, were made in the soil samples taken according to Equation 1.

SSI= ∑ Silt and clay fractions obtained by mechanical analysis -∑ Silt and clay fractions dispersed from aggregates to suspension (Eq. 1)

The layer formed on the upper part of the soil surface, which occurs under various soil types and climatic conditions, affects seedling emergence and causes water and product loss (Awadhwal and Thierstein, 1985), is called soil crust. Texture, OM and SSI analyzes were performed on soil samples taken from a total of 328 points, and TKI values were calculated (Equation 2). Soil crust formation was calculated with the help of Equation 2 according to Pieri (1989) and class intervals are given in Table 1.

$$SCI = OM\ (\%) \times \frac{100}{C\ (\%)} + Si\ (\%) \qquad \text{(Eq. 2)}$$

SCI: Soil Crust Index, OM: Organic matter, C: Clay, Si: Silty

Table 1. Soil Crust Index classes and values.

Definition	Class values	Class range
Very severe physical impairment	1	SCI <5
Severe physical impairment	2	5 <SCI <7
Low physical impairment	3	7 <SCI <9
No physical impairment	4	SCI> 9

Spatial distributions of SCIs were obtained as a result of applying 14 different interpolation models by using the Geostatistical analyst module in ArcGIS program. In the comparison of the methods discussed, different models were used in order to question the relationship between the measured values and the estimated values, and to select the model that gives the closest result to the measured values. Distribution maps were produced by selecting the values with the lowest mean square error (RMSE) among the models discussed in the study (Table 3). The method that gave the lowest RMSE value was evaluated as the most appropriate method. The Sperman correlation coefficient was used to determine the correlation relations. Depending on the difference in land uses, the change in soil properties was evaluated with the TUKEY multiple comparison test. Statistical evaluations were made in the IBM SPSS Statistic 23 package program.

Results and Discussion

Statistical and Geostatistical Evaluation

Correlation coefficients of soil properties are given in Table 2. There was a positive statistically significant correlation between SCI and om (r:0.858) and sand (r:0.459), and a negative statistically significant correlation with SSI (r:-0.388) and clay (r:-0.491) for SCI. A similar situation is valid for SCI index. The changes in the contents of SCI, SSI and OM due to land uses are given in Table 3. If P value < 0.05, it is seen that the considered parameter changes depending on the land use conditions and this change is statistically significant.

Table 2. Correlation coefficients of soil properties

	OM	SSİ	Sand	Silt	Clay	SCI	SCI index
OM	1.000	0.071	0.003	0.213**	-0.066	0.858**	0.753**
SSİ		1.000	-0.986**	0.264**	0.937**	-0.388**	-0.359**
Sand			1.000	-.281**	-0.944**	0.459**	0.416**
Silt				1.000	0.001	0.027	0.027
Clay					1.000	-0.491**	-0.460**
SCI						1.000	0.903**
SCI index							1.000

OM= Organic matter, SSI= Structure stability index, SCI = Soil Crust index **. Correlation is significant at the 0.01 level

Table 3. Change in soil properties depending on the difference in land uses

Land Use	SCI	SSİ	OM %
Agriculture	4.28c*	61.22a*	2.719b*
Pasture	5.62b	54.49b	3.183b
Forest	6.96a	56.49b	4.159a

SCI= Soil Crust index, SSI= Structure stability index, OM= Organic matter, *: P =0.000

The fact that the lettering is different from each other, it is seen that the formations of the crust index depending on the applications or land uses are different from each other. The highest crust formation was 6,962 for the forest use type. The organic matter contents of the agricultural and pasture soils are similar to each other since there is no significant difference. However, the organic matter content of forest soils was the highest and differed from agricultural and pasture land uses. While the structure stability index values between pasture and forest soils are similar to each other, the highest value belongs to agricultural soils with 61.22. İmamoğlu and Dengiz (2018) examined soil crust formation in soil samples taken from a total of 995 points including agriculture, forest and pasture areas. Accordingly, they stated that the SCI factor was statistically significant in the use of Agriculture-Forest, Agriculture-Pasture, but the correlation value between Forest-Pasture uses was statistically insignificant, and accordingly, SCI mostly poses a problem in agricultural areas.

The RMSE values of the geostatistical methods produced using the Arc-GIS program are given in Table 4 and the distribution maps produced in the server are given in the Figure…. Among the models applied, Kriging-Simple Kriging-Gaussian for OM item analysis, Kriging-Universal Kriging-Gaussian SCI analysis for SSI analysis, and Level 1 of Inverse Distance Weighting model was found suitable.

Table 4. Geostatistical models and RMSE values

Geostatistical Methods			OM	SSI	SCI
Inverse Distance Weighting IDW		1	1,419	11,078	**2,738**
		2	1,509	11,187	2,864
		3	1,619	11,563	3,062
Radial Basis Functions RBF		Thin Plate Spline	1,934	13,909	3,657
		Completely Regularized Spline	1,450	11,125	2,774
		Spline With Tension	1,440	11,100	2,761
Kriging	Ordinary Kriging	Gaussian	1,457	11,014	2,768
		Exponential	1,438	11,094	2,741
		Spherical	1,456	10,978	2,769
	Simple Kriging	Gaussian	**1,413**	11,027	2,844
		Exponential	1,417	11,087	2,841
		Spherical	1,414	10,991	2,843
	Universal Kriging	Gaussian	1,457	**11,012**	2,768
		Exponential	1,438	11,094	2,740
		Spherical	1,456	10,979	2,769

OM: Organic matter, SSI: Strücture stability index, SCI: Soil crust index

Distribution maps of SSI, OM and SCI are shown in Figure 1. According to Leo (1963), as the structural stability index values of soils get smaller, their tendency to erode increases. Accordingly, the erosion tendency of the soils especially in the northwest of the study area is relatively high compared to other regions. Considering the distribution of organic matter, it is seen that it is higher in the areas that are difficult to process due to the slope in the southern part of the area. According to Öztürk and Özdemir (2006), they stated that for the solution of the soil crust layer, considering the climate and soil characteristics, increasing the soil organic matter level, covering the soil surface with vegetation and improving the irrigation method.

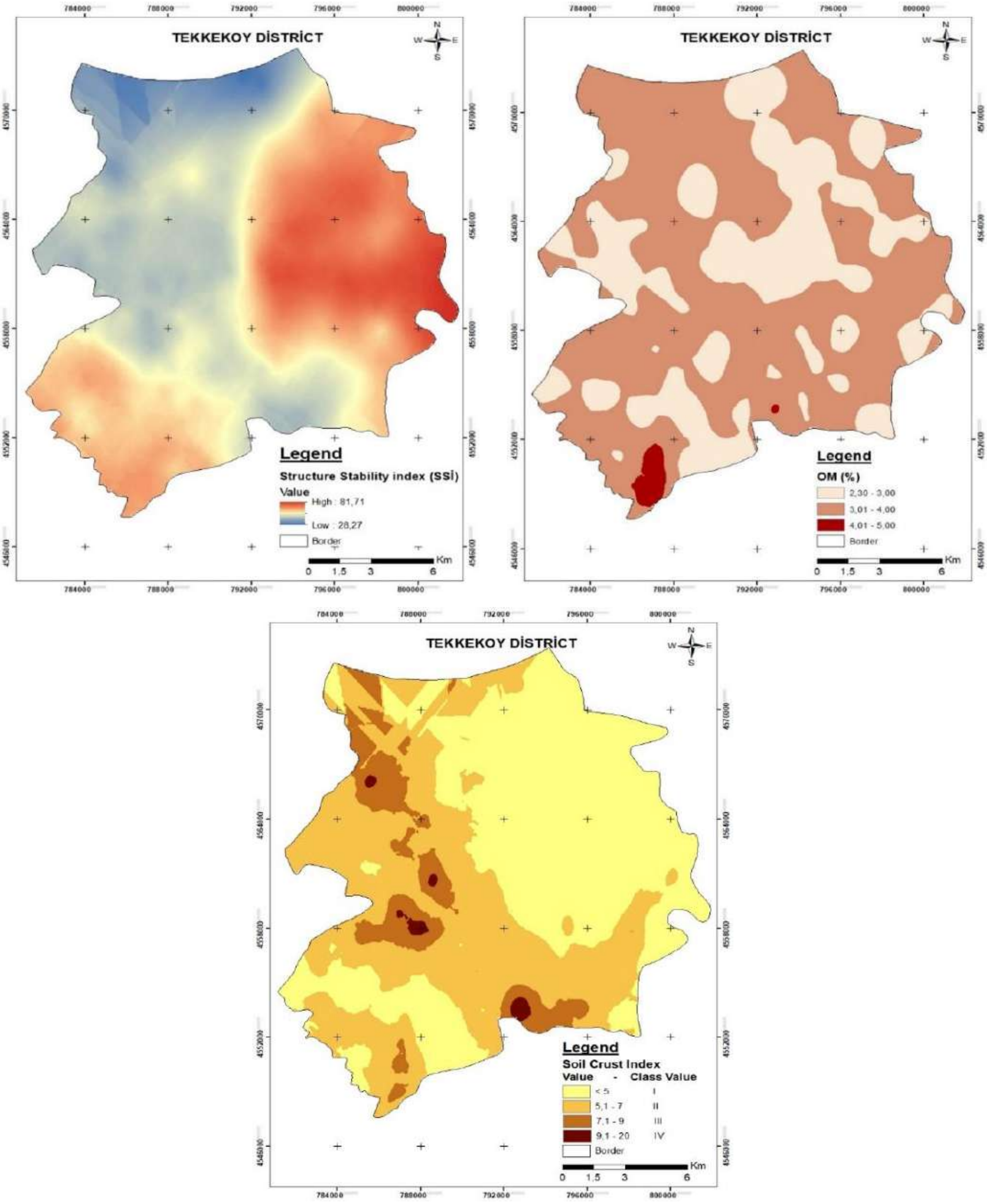

Figure 1. Distribution maps of SSI, OM, SCI

In the areas in the northeastern part of the study area, very severe physical deterioration is observed due to the fact that the slope is flat and level. Besides, the western and southwestern parts of the Area have relatively severe degradation. Among the samples taken from a total of 328 points, 55.79% area represented by 183 points is exposed to severe physical deterioration, while areas representing 10.98% do not have physical deterioration. İmamoğlu et al., (2018) investigated the relationship between some soil properties and soil crust formation in the study they conducted on a total area of 16645 ha in the Ilıcak and Kumçayı sub-basins in the Gediz Basin. They determined a significant relationship at the $p<0.05$ level between crust formation and texture properties in the soil. As a result of the study, they stated that a high rate of crust formation occurred in approximately 80% of the area. Han et al., (2016) investigated the relationship between soil aggregate stability and wetting rate and soil crust formation. In the study, they determined that the soil had higher bulk density, stronger crustal strength and lower infiltration rate in the rapid wetting process. In the areas in the northeastern part of the study area, very severe physical deterioration is observed due to the fact that the slope is flat and level. Besides, the western and southwestern parts of the Area have relatively severe degradation. Among the samples taken from a total of 328 points, 55.79% area represented by 183 points is exposed to severe physical deterioration, while areas representing 10.98% do not have physical deterioration.

Conclusion

In the study area, surface soil was taken from 328 areas belonging to 4 different types of use, including pasture, agriculture, forest and artificial areas, and OM, SSI, SCI index analyzes were made and the relationship between them was revealed. 165 of these samples represent agriculture, 108 of them are pasture and 55 of them are forest areas. The formation of crust in the soil, which prevents the entry of water into the soil profile by forming an impermeable layer on the soil surface, is an important problem affecting soil health. In order to eliminate this problem, the bare soil surface should be broken up with a cultivator, especially in the periods when the weather warms up rapidly following the precipitation period. In addition, increasing the organic matter in the soil will also contribute to the prevention of erosion to a certain extent, as it will affect the increase in the structural stability values.

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Impact of soil-applied biochar and foliar application of ZnO NPs on plant growth in PAHs contaminated soils

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Abstract

Polycyclic aromatic hydrocarbons (PAHs) are a resilient class of pollutants, their accumulation on soil surface/sediment caused carcinogenic and mutagenic effects to all living organisms, thereby being considered a global environmental problem. Biochar has shown promising results for PAHs soil amendment, whether through their high adsorptive reactive surface or enhancement of the bacterial degradation to PAHs. As for ZnO nanoparticles, they worked on improving the physiological and biochemical parameters of the plants. Previous studies on ZnO nanoparticles application to plants under biotic or abiotic stress showed high concentrations of antioxidant enzymes synthesis in plants, especially malondialdehyde, superoxide dismutase, Catalase, and peroxidase. ZnO nanoparticles foliar application proved higher Zn concentrations in shoots and roots, in comparison with direct to the soil. For the first time, the action of biochar and zinc oxide nanoparticles (ZnO NPs) foliar application on plants grown in polyaromatic hydrocarbons (PAHs) are assessed both separately and combined. In the study, we expect that the use of biochar and ZnO nanoparticles on plants grown in PAHs contaminated soil will provide an insight into their interactive effect on PAHs in soil and their uptake by plants.

Keywords: Biochar-Foliar Application -Polyaromatic Hydrocarbons (PAHs)-Plants- ZnO Nanoparticles.

Introduction

The fast urbanization and uncontrolled industrialization have caused a rapid increase of polycyclic aromatic hydrocarbons (PAHs) in the environment (1). Their hydrophobic nature contributes to their strong adsorption to organic matters in soil/sediment (1). PAHs are persistent pollutants, they can accumulate in water and soil for months causing toxicity and even death to many living organisms (1). Long-term exposure of PAHs to humans may cause breathing problems, kidney and liver damage, skin irritation and in chronic stages, it may lead to cancer (1). The USEPA has categorized 16 of the PAHs as priority-contaminants, based on their possible human exposure, toxicity, occurrence frequency at hazardous waste sites, and the extent of information available. These 16 PAHs include acenaphthene, benzo[ghi]perylene, chrysene, acenaphthylene, benzo[a] anthracene, benzo[b]fluoranthene, anthracene, benzo[k]fluoranthene, benzo[a]pyrene, fluoranthene, Indeno[1,2,3- cd]pyrene, naphthalene, phenanthrene, dibenz[a,h]anthracene, fluorene, and pyrene (1). Remediation of PAHs contaminated sites had become a matter of global concern, therefore various physical, chemical, and biological remediation approaches were developed (2). Biochar has attracted great attention as an amendment for organic pollutants in soil. The porous structures and large surface area of biochar, contribute to their high adsorption capability for PAHs. Sorption of PAHs to biochar reduces their bioavailability to plants and microorganisms in the soil (3). On the other hand, The use of nanotechnology in the detoxification of pollutants in the soil is applied globally in various research projects. Foliar-applied NPs are a novel technique for solving production challenges in agriculture, they are used as herbicides, fertilizers, plant nutritional supplements (4). However, their sorption capability for PAHs in the soil is still not well covered in the literature. This review will cover the known facts on the use of biochar and ZnO NPs foliar application in soil amendment and the sensitive biochemical changes in plants grown in PAH contamination.

Source of PAHs in Soil

Two main pathways release PAHs into the environment, a natural pathway from forest fires and volcanic eruptions and an anthropogenic pathway due to the incomplete combustion of organic matter (2). Soils/sediments are the final sinks for PAHs pollution, more than 50% of the total atmospheric PAHs end up stored in soil/sediment (5). Petrogenic PAHs are formed during crude oil maturation and similar processes such as oceanic and fresh-water oil spills (6). Whereas Pyrogenic PAHs are produced from coal and petroleum during their pyrolysis in industrial power plants or indoor heating. They are usually found in higher concentrations in locations near urban areas or in proximity to a long-term emission source (6)(2). PAHs like Fluoranthene, pyrene, chrysene and benzo[a]pyrene are frequently found in high concentrations in sites of wood combustion, gasification/ liquefication of fossil fuels, burning of tires/coal/refuse, incineration, asphalt production, and use. Even in places where there was no industrial activity, PAHs were detected. Where naphthalene, phenanthrene, and perylene are most abundant in tropical soils, even at a higher concentration than temperate soils which are dominated by HMW PAHs such as benzo[a]fluoranthene (2).

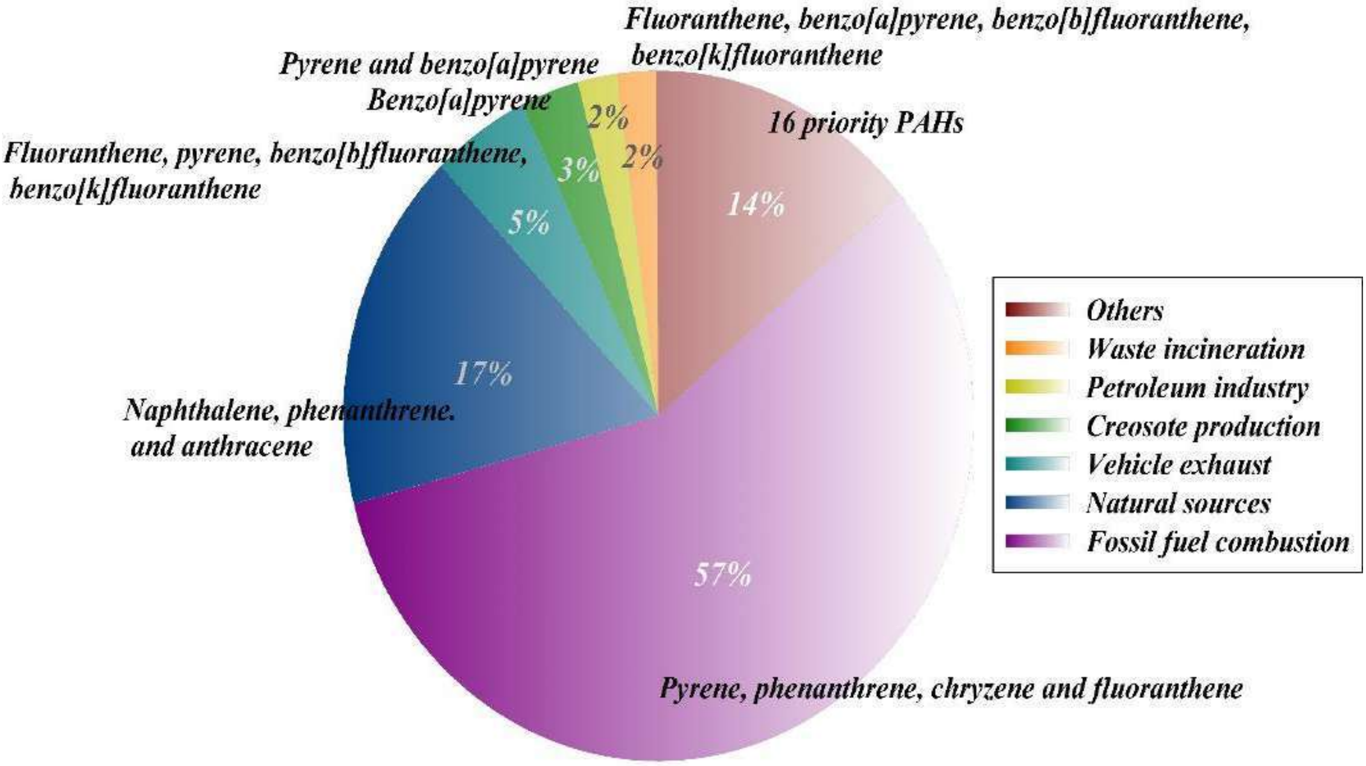

Figure (1): Types of PAHs found in contaminated sites based on Kuppusamy et al., 2017(2).

Effect of PAHs on plants

Even though abiotic stresses have a reducing impact on plant health and cause yield production problems, not enough studies consider PAHs stress compared with other soil-borne contaminants. PAHs with low molecular weight are found to be more water-soluble and bioavailable, thereby more toxic to plants than high molecular weight PAHs (7). PAHs can induce oxidative stress in plants tissues, reduce plant growth and lead to leaf necrosis and deformation. A high concentration of PAHs (400 mg kg) to soils with rice plants resulted in a decrease in plant biomass, chlorophyll content, and an increase in water content as well as chlorophyll a/b ratio (8). Increasing Fluoranthene (FLT) concentration inhibited the germination energy and the germination rate of seeds of all plant species (8). Arabidopsis (Arabidopsis thaliana) exposed to phenanthrene exhibited root and shoot growth reduction, late flowering, and white spots, that eventually developed into necrosis. The oxidative stress of phenanthrene resulted in localized H_2O_2 production which led to cellular death (9). Modification in PAHs as a result of aging, biodegradation, and weathering may result in a more toxic byproduct. Photoinduced PAHs are highly soluble therefore their toxicity is enhanced (7). Total chlorophyll is reduced in comparison with chlorophyll a/b ratio in C3 and C4 plants in presence of PAHs (7). PAHs are usually stored in thylakoid membranes, therefore they might interfere with the electron transport of Photosystem II, blocking the electron flow from PSII to PSI in case of change in solubility (8). It was found out that Anthracene inhibits the photosynthetic activity of green algae. Through lowering the activity of oxygen electron complex (OEC) in anthracene treated algal cells (8). Phragmites australis Cav. Exposed to Fluoranthene (FLT) exhibited ultrastructural changes. For instance, in the root cells, the integrity of the tonoplasts was disturbed, the central vacuole penetrated the cytoplasm, the mitochondrial matrix was condensed with flattened cristae, the severe cellular damage made it hard to identify other cytoplasmic organelles (10).

Role of biochar amendment in PAHs polluted soil

Few factors control the properties of the produced biochar, which are type and composition feedstock, pyrolysis temperature, and time (11). The unique physicochemical properties of biochar have encouraged its application for the mitigation of greenhouse gases (GHGs) and organic pollutants in soil (12). Biochar lowers the rate of PAHs biodegradation due to their sorption on biochar. Thereby, its application showed a negative effect on bioaugmentation and phytoremediation (13). In one of the studies, the application of conifer biochar reduced the bioavailability and phytotoxicity of phenanthrene and pentachlorophenol (3). The detailed steps of biochar, soil, and plant interaction were explained in Joseph et al., (2021) review, by dividing it into 3 periodic intervals (short, medium, and long term) according to the plant's different growth stages (14). Soil amendment with 1% biochar increased the antioxidant response of quinoa grown under drought and salinity stress through sorption of salts, enhancement of plant-growth-promoting hormones, and reducing Na+ and K+ uptake by plants (12). In benzopyrene (BaP) spiked soil, the application of 5% biochar to soil contaminated with 1200 μg kg-1 reduced both benzopyrene and total PAH by 47% and 30%, respectively as well as in plants by 37048% (15).

The most sensitive biochemical indicators in Plants for PAHs pollution

PAHs induce oxidative damage inside the plant tissue through reactive oxygen species (ROS) production. This change in cellular integrity affects phytohormones synthesis and metabolic activity (7). Comparative microarray analyses indicated that the plant's exposure to phenanthrene, induced responses closely related to pathogen defense conditions. A number of glutathione S-transferase which signals for xenobiotics accumulation in the vacuole was enhanced (8). Rice plants grown under artificial PAHs contamination showed enhanced Superoxide dismutase (SOD) activity and soluble protein content. However, water content and SOD activity were the most sensitive indicators to PAHs stress (8). Another study on rice resistance to PAHs showed that SOD activity was enhanced by 8%, 46%, and 150% to 100, 200, and 400 mg kg^{-1} respectively of PAHs contamination (16). The maximum concentration of polyphenol (0.909 mg g^{-1}) and proline (0.732 μmol g^{-1}) was indicated in Helianthus annus under 100 mg kg^{-1} PAHs. Also, the concentration of ascorbate peroxidase, peroxidase, and superoxide dismutase increased by 20.37 Unit g^{-1} FW, 0.212 Unit g^{-1}, and 2.13 Unit g^{-1} FW respectively (17).

Impact of foliar application of ZnO nanoparticles

It is well documented that; the foliar spray of NPs increases the efficiency of plant protection technique when compared to the traditional soil–root application. The foliar sprayed NPs enter the plants through, stomata, hydathodes or shoot wounds. Later, they are transported to other plant parts by two pathways, apoplastic and symplastic pathways (18). In one of the studies, ZnO NPs were applied to reduce the oxidative effect of Cd and Pb in Leucaena leucocephala. The results showed enhanced seedling growth and increased photosynthetic pigments and total soluble protein in leaves (19). Also, the foliar spray of ZnO NPs of concentration 10 mg/L on a 14-day-old cluster bean plant was studied. It was observed that plant biomass, shoot length, root length was enhanced by 27.1, 31.5, 66.3 % respectively (20). Similarly, the foliar spray of ZnO NPs on Coffee arabica L. increased the fresh and dry weight of roots, leaves, shoot, and net photosynthetic rate (21). It was noted that not enough work is done in the concern of NPs foliar application to plants under abiotic stresses especially for PAHs, therefore this knowledge gap requires our attention.

Remediation Approaches for PAHs polluted soil

Enzyme-mediated bioremediation and NPs-based eco-engineered bioremediation are innovative research fields that deal with PAHs pollution in different matrices such as soil, sediment, surface water, and groundwater. Bioremediation of soil with isolated microbial enzyme-mediated bioremediation is an efficient and selective method for PAHs removal. It was proven that fungal ligninolytic enzymes (lignin peroxidase, Manganese-dependent peroxidase, laccase) are less substrate-specific enzymes thereby more applicable (22). One of the major drawbacks of this method is the costs of enzyme production, extraction, and purification (2). The utilization of NPs of biomolecules such as enzymes, proteins, DNA, humic acids, and biosurfactants offers nano-adsorptive and catalytic degrading properties to remove PAHs from the polluted environment (23). Iron hexacyanoferrate (FeHCF) NPs (10-60 nm in size) were synthesized by from plant origin biosurfactant(saponins) that was extracted by water from Sapindus mukorossi (2). The produced nanoparticles were able to degrade anthracene and phenanthrene to 80–90%, while fluorene, chrysene, and benzo(a)pyrene to 70–80% in water and soil under the optimized experimental system, (pH 7, catalyst 25 mg, PAHs 50 mg/L, and solar radiation) and eventually, all PAHs were converted into low-molecular-weight non-toxic metabolites after treatment.

Conclusion

Even though abiotic stresses are of great importance to plant health; not enough work is done on PAHs stresses and their responses. Their accumulation in the soil is becoming inevitable and their entrance into the food chain is uncontrolled. It has been well documented in literature the ability of biochar as a sustainable solution for soil remediation with a focus on their reducing effect of PAHs bioavailability. Whereas the foliar application of ZnO NPs on plants grown under PAHs contamination wasn't covered in literature before, along with their dual impact on different PAHs pollution levels. The combined application of ZnO NPs and biochar potential was only studied in very few research experiments hence, their remediation of PAHs contaminated soils is still unexplored.

Acknowledgement

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Effect of PAHs and heavy metal co-contamination on soil microbial communities and their metagenomics studies

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Abstract

One of the serious challenges the world is facing is environmental pollution and soil is the most critical component of our environment. Soil contamination is a major threat to humanity and it is getting polluted day by day with different anthropogenic sources. Among these notable persistent pollutants are polyaromatic hydrocarbons (PAHs) and heavy metals. These contaminants produce alterations in the metabolic system of microbes, which are considered signals for prevailing contamination in the surrounding ecosystem. Co-existence of PAHs with heavy metals cause to decrease the efficacy of microflora to biodegrade the contaminants. Hence, these chemical mixtures are influencing the whole soil microbial community. Different soil biological properties such as dehydrogenase, urease activity, nitrification, microbial biomass carbon, microbial respiration, metabolic quotient (qCO2), lipase, acid phosphatase and arylsulfatase activity have been observed. Biodiversity indices are good indicators to check the quantity of microbial community and species through different indices such as Shannon-Weaver (H'), evenness index (E) and Simpson's index (D). Recent developments have facilitated researchers to know more about microbial diversity, its composition and structure. New approaches are coming now-a-days and one of the powerful tools is metagenomics, which researchers are using to investigate the soil microbiome. The most common and cheap analysis is 16s rRNA analysis which researchers widely use to explore microbial community and visualize phylum interaction in the presence of co-contamination. Metagenomics studies give an insight into the evolutionary and ecological changes in microorganisms. Different bioinformatics tools are performed on raw data to study biodiversity. This review article includes that how co-contamination is effecting soil community and metagenomic studies are contributing to detect effect in terms of diversity and structure of soil microbiota. Co-contamination decrease some phyla but increase the number of some species which show tolerance under specific heavy metals and degrade PAHs.

Keywords: Co-contamination, PAHs, Heavy metals, soil microbes, microbial community, metagenomics studies.

Introduction

One of the serious challenges world is facing is the environmental pollution and soil is the most critical component of our environment. According to FAO (2015), soil is a non-renewable resource because it cannot recover easily it's degradation and loss within a lifespan of human. Soil contamination is a major threat to humanity and it is getting polluted day by day with different anthropogenic sources. Among these, notable persistent pollutant is poly aromatic hydrocarbons (PAHs) and heavy metals (HMs) (Zhang & Chen, 2017). PAHs are considered as widespread and harmful pollutant because of their persistent nature, toxicity and carcinogenic properties. These pollutants are characterized by their specific benzene ring structure and further they are classified as low molecular weight (LMW) having 2 and 3 benzene ring and high molecular

weight (HMW) with 4,5 and 6 benzene rings. List of 16 priority PAH from US Environmental Protection Agency is commonly used to assess these PAH in contaminated soil sites.
Both HM and PAH are notorious for their persistent nature and toxicity in soil as well as for plants. Heavy metals are occurring in nature and part of earth's crust but many of them such as Zinc (Zn), Copper (Cu), Cadmium (Cd), Chromium (Cr), Mercury (Hg), Lead (Pb), and Arsenic (As) are widespread in our agriculture and urban industries. Heavy metals don't itself a problem in soil because a specific amount is required in soil for plant growth but if it exceeds from threshold level, increase their bioavailibity in soil and thus interfere with the normal metabolic processes.
Recently, research community is showing a great an interest in soil microbial community. They are manipulating soil microbiome to replenish the disturb ecosystem which has been occurred due to PAHs and HMs contamination. Soil microbes are providing different services including the fixation of carbon, nitrogen, degrading of hydrocarbons and reducing the bioavailability of heavy metals (Jansson & Hofmockel, 2018). Hence, in this domain, metagenomics is helping the researchers in exploring the soil microbial community by providing them analysis and bioinformatic tools to visualize soil microbiome.
Metagenomics provide functional characterization and taxonomic profiling of soil microbiota in different contaminated soils based. Several soil microorganisms have been studied and strains are isolated from the contaminated sites which are involve in degrading PAH and metal resistant. Most bacterial genus are key players and perform well in co-contaminated sites and biodegrade hydrocarbon in presence of heavy metals (Czarny et al., 2020). Metagenomics a major contribution whose analysis showed that microbial community efficiency in degrading PAH and presenting a change in pattern of alpha and beta diversity (Sazykina et al., 2021).

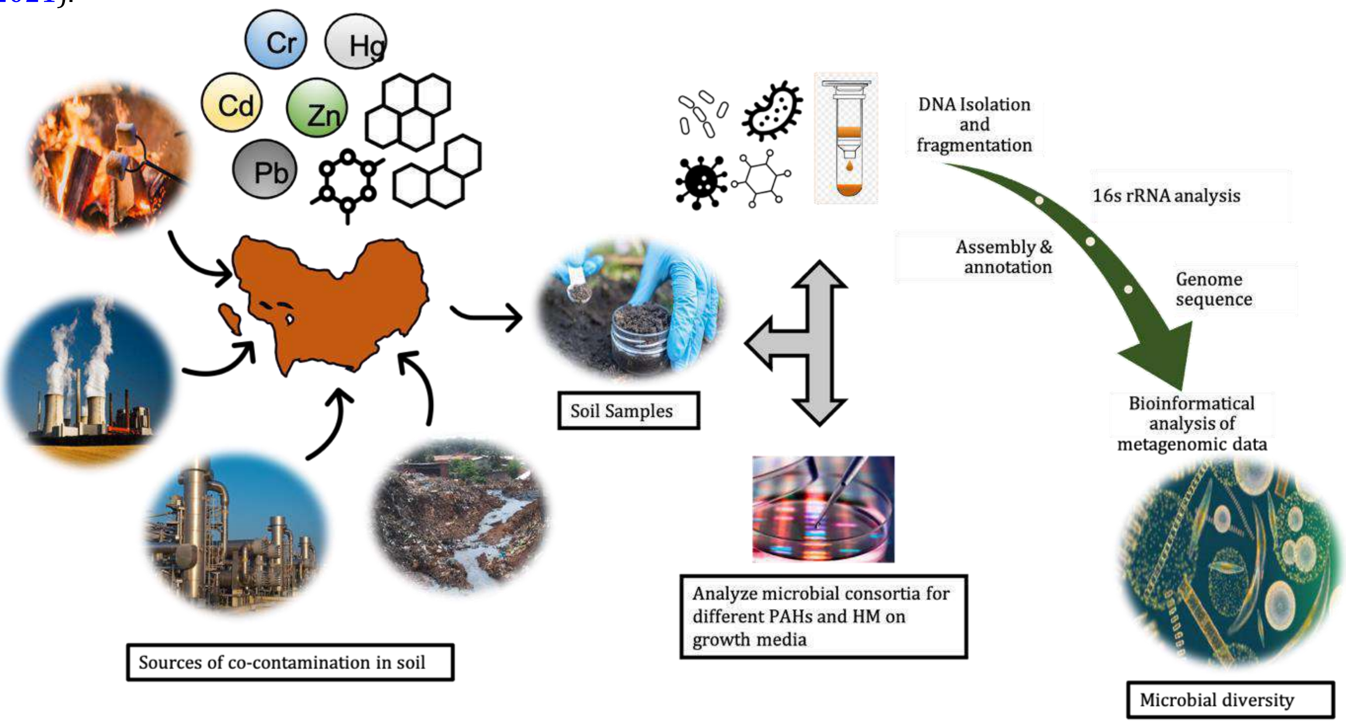

Figure 1: Comprehensive cycle to show sources of contamination in soil, extraction of soil microbial DNA and study metagenomics data to see effect on soil microbial biodiversity.

This review will be focusing on the presence of the PAHs and Heavy metals in soil, co-contamination and sources of this mixed contamination. It includes how this mixed contamination is effecting on soil microbial community. In the meantime, this review will also be focusing ton metagenomic studies of co-contaminated soils and effect of these contamination on soil microbiome in terms of their structure and composition.

PAHs and Heavy Metal Co-Contamination in Soil

Sources of PAH in environment can be natural or anthropogenic activities. In our environment, these are usually found and analyzed in the contaminated soil sites (Gorovtsov et al., 2021). Extensive research studies are done on phenanthrene, benzo[a]pyrene and 7,12-dimethylbenzo anthracene. Total content of PAHs should not be more than 200 mg kg-1 but most of studies on PAH showed that soils are contaminated by industries have PAH total content upto 6000 mg kg^{-1} (Sushkova et al., 2021).

Most of them found in urban areas resulted from industrialization because of high usage of crude oil, fresh fuel, diesel oil, coal tar and petroleum (Lee et al., 2018). PAHs are releasing into the soil through several gas manufacturing plants, petrochemical sites, oil refineries, coking and coal fired thermal power plants (F. Li et al., 2020). In the same way, heavy metals are also polluting soils and main anthropogenic source in urban soils is waste disposal, sewage sludge, metal mining, smelting, transportation, industrial effluents and vehicle exhaust while typical sources of HM in rural soils is pesticides, fertilizers application, agrochemical impurities, animal/livestock manure, mineral ore extraction and distribution by surface runoff. Mostly some industries are reason of both PAHs and heavy metal contamination such as on manufactured gas plants, where Cd and Pb contamination present in long term contaminated soils.

Co-Contamination Effect on Soil Microbial Community Diversity

Contaminations produce alterations in the metabolic system of microbes. Such as presence of the heavy metal like Pb, Cr, Cd and hydrocarbons create more CO_2 production and it is indication of high metabolic activities of soil microbes and a reaction to stress. This is a clear evidence that soil pollutants have a significant impact on its soil microbiota (Gorovtsov et al., 2021). Thus, co-existence of PAHs with heavy metals are caused to decease the efficacy of microflora to biodegrade the contaminants (Thavamani et al., 2012).

Soil enzymatic activities can be a one of the indicators which are often estimated to check the soil microbial activity under contamination. They are playing their role in mitigation of organic compounds like PAHs and converting toxic heavy metals to least toxic or nontoxic form. Soil biological properties include dehydrogenase (DHA), urease activity (UR), nitrification, microbial biomass carbon (MBC), microbial respiration, metabolic quotient (qCO_2), lipase, acid phosphatase and arylsulfatase activity which observed in laboratory on soil samples. Long-term highly contaminated soils with PAH and heavy metals showed high dehydrogenase activity (DHA) while some showed low DHA in presence of crude oil and chromium and copper (Lu et al., 2013).

Besides this, low urease activity (UR) and microbial biomass carbon (MBC) was found. While nitrification was low in all samples (no significant variation). In study of Lu, Xu, and Chen (2013), high basal respiration (CO_2) and metabolic quotient (qCO_2) has been observed. Cadmium exposure caused low biological activities overall and production of less microbial mass (dos Santos et al., 2012). It is evident from study that lower activity of aryl sulfatase, lipase activity and lower acid phosphatase activity in contrast to other study. Overall, respiration increased in mixed contamination which showed that there is a declined in population but some selected members increased in population and in activity.

Soil biodiversity indices are measured to check the quality of microbial community, in which most common are Shannon-Weaver (H'), evenness index (E) and Simpson's index (D). Various analysis methods are used for microbial diversity such as denaturing gradient gel electrophoresis (DDGE), fluorescence in-situ hybridization (FISH), Phospholipid fatty acid analysis (PFLA) and quantitative PCR (qPCR) been designed and developed to study genetic structure and diversity of soil microorganisms (Dubey et al., 2020).

Thavamani (2012) revealed low Shannon index and evenness but high Simpson's index which explained that few genotypes are dominant in community because of death of some microbes due to contamination and survival of selected members. But on other side, Li (2017) observed no significant differences in samples. While high level of Shannon and Simpson index was observed in (Gorovtsov et al., 2021) samples and negatively correlated with PAH which indicates the impact of contamination on soil microbial community.

Metagenomic Studies on Co-Contaminated Soils

Since it is difficult to isolate and identify the bacteria through media culture so there was need to use that approach which is free of these constraints. New approaches are coming now-a-days and one of the powerful tools is metagenomics, which researchers are using to investigate the soil microbiome (Hemmat-Jou et al., 2018). Therefore, metagenomics is fulfilling these criteria in any every way and providing metagenomic profiling of microbial community.

Metagenomics is a hub of omics approaches to understand clearly and closely about evolutionary and ecological changes occurring in microorganisms. It offers a full package (Table 1) to identify microbiome complete profile, show their evolutionary history in form of phylogenetic tree, species abundance, composition and their diversity (Fig 2). Various methods are used to analyze different levels of microbial community. Most popular, cheap and common method is 16s rRNA used by researchers. Other methods such as whole-genome shotgun analysis (WGS) and whole-transcriptome (metatranscriptome) shotgun are also used to understand gene sequences, taxonomic profiling and phylogeny of soil microbes.

Date Analysis	Software	Availability	Package	Web address
16S rRNA amplicon analysis	QIIME	Open sources, tutorial and database	Yes	http://qiime.org/
	UPARSE	Tutorial	-	http://drive5.com/uparse/
	MED	Basic and tutorial	-	http://merenlab.org/software/med/
Species-level metagenomic data analysis	MetaPhlAn2	Open source, basic and tutorial	Yes	http://segatalab.cibio.unitn.it/tools/metaphlan2/
	CLARK	Open source, basic and tutorial	Source code	http://clark.cs.ucr.edu/
	SUPER-FOCUS	Open source, basic and tutorial	Source code	http://edwards.sdsu.edu/superfocus/
	MG-RAST	Open source	-	http://metagenomics.anl.gov/
Strain-level metagenomic data analysis	StrainPhlAn	Open source and tutorial	Yes	http://segatalab.cibio.unitn.it/tools/strainphlan/
	PanPhlan	Open source and tutorial	Yes	http://segatalab.cibio.unitn.it/tools/panphlan/
	Sigma	Open source and tutorial	-	http://sigma.omicsbio.org/

The most dominated phylum is Proteobacteria present in contaminated soils with the abundance rate of more than 70% (Tipayno et al., 2018). 16s rRNA analysis of diesel and heavy metal contaminated soils showed relative abundant composition of bacterial community; Proteobacteria, Bacteroidetes, Actinobacteria, Chloroflexi, Acidobacteria and they isolated Sphingobium spp. having high capacity to degrade PAHs under the presence of cadmium and chromium (Gran-Scheuch et al., 2020). Burkholderia fungorum FM-2 strain is also found capable to degrade phenanthrene in acidic contaminated soils under high levels of Zn (Rahman, 2020). Exploration of metagenomic data revealed different microbial species are dominated in co-contaminated soils. Many of them are reported Actinobacteria spp., Pseudonocardia spp. Halomonasspp spp., Mycobacterium spp., Streptomyces spp. Nocardia spp., Dietzia spp., Rhodococcus spp. Aeromicrobium spp., Pseudoxanthomonas spp. and Bacillus spp. in contaminated sites (Khudur et al., 2018).

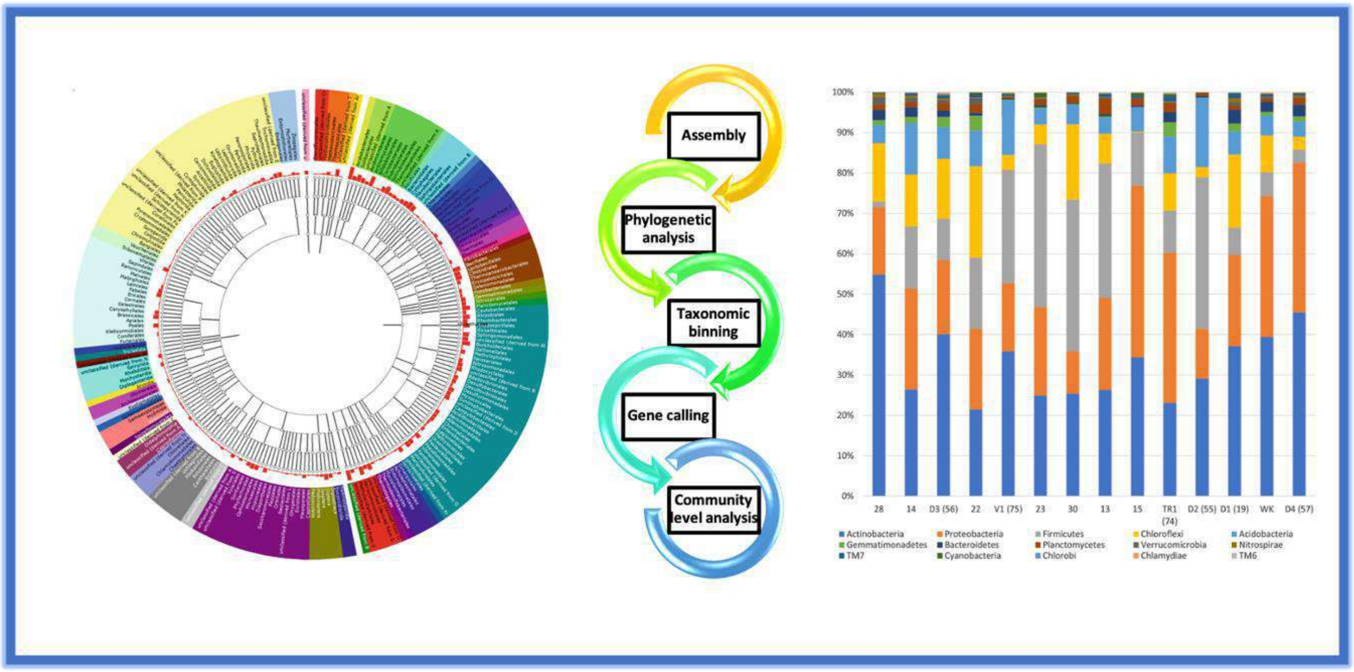

Figure 2: (a) Illustration of phylogenetic tree, (b) process to visualize metagenomic data, (c) relative abundance of soil microbes (diversity) in samples

Phylogenetic studies of topsoil microbial community metagenomic data revealed the same relative abundance of Actinobacteria and Proteobacteria in contaminated lake soils under Zn metal pollution. Some phyla Gemmatimonadetes, Verrucomicrobia, and Nitrospira have a negative relation with total PAHs level (Gorovtsov et al., 2021). Presence of these bacteria phyla abundance could be helpful in degrading PAHs and specific heavy metal because they contain degrading and metal resistant genes. These studies give benefit to locate different bacterial consortia which can be used for soil reclamation in result of different potential toxic elements and heavy metals pollution.

Conclusion

All in all, this review paper is addressing contamination sources in soil and how different kinds of polyaromatic hydrocarbons (PAHs) and heavy metals are disturbing soil bacterial community. This co-contamination has an effect on soil microbiota composition as well as their diversity. Effect can be measured in term of soil biological properties which includes enzymatic activities of microbes. Secondly, metagenomics is playing a robust role in defining profiling of different bacterial species within contaminated soils with the help of bioinformatic tools. Metagenomics revealing phylogenetic, taxonomic and functional characterization of different phyla and thus paving a way to reclaim these contaminated soils with use of microorganism as these PAHs degrading and metal degrading bacteria are useful for bioremediation.

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Effect of organic manures application on soil physicochemical properties of coarse-textured Ultisol and Okra productivity in Nsukka, Southeastern Nigeria

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Abstract

The greenhouse and field studies were carried out to assess the effect of different rates of poultry manure (PM), pig slurry (PS) and the recommended NPK fertilizer on some soil physico-chemical properties and okra yield of coarse-textured Ultisols in Nsukka, southeastern Nigeria. The PM and PS were applied at three different rates (10, 20 and 40 t ha-1) as well as no amendment as control and the recommended NPK fertilizer (300 kg/ha) and replicated five times. Soil and agronomic data collected were analyzed for variance (ANOVA) using Genstat 4.0. The PM and PS significantly ($p<0.05$) improved soil pH, soil organic matter, available phosphorous, total nitrogen, aggregate stability, mean weight diameter, bulk density, porosity and saturated hydraulic conductivity in greenhouse and field studies. Significant improvement in CEC was obtained in the field study. The PM and PS significantly ($p<0.05$) improved agronomic parameters e.g. plant height, number of leaves, biomass weight and yield of okra than the control. Poultry manure showed its superiority over other amendments in improving soil and agronomic properties. The study recommended 20 t ha-1 of PM and 40 t ha-1 of PS for sustainable soil and optimum productivity of okra in Nsukka, southeastern Nigeria.

Keywords: Agronomy, Organic manure, Productivity.

Introduction

Sustainable nutrient management is necessary for maintaining good agronomic production as well as soil quality (Jagdish, 2015). This is even more relevant now that soil degradation is seen as one of the 21st century global problem with its severe impact felt more in the tropics and sub-tropics (Lal, 2015). Inherent low soil nutrient has been a major constraint to crop productivity of most arable soils in Nigeria especially those of Nsukka ecological zone (Igwe, 2004). These soils are further degraded owing to continuous cultivation, deforestation and inappropriate farming practices (Oshunsanya, 2011). These unsustainable land use practices often result to low soil organic matter (SOM) content that makes the fragile soil become more prone to compaction and erosion (Alyelari and Oshunanya, 2008). Okra (Abelmoschus esculentus L.) is one of the most important vegetables grown in Africa, Asia as well as in tropical America and perhaps Australia (NRC, 2006). It is grown mainly as fruit vegetables in the tropics and consumed in both green and dried state (Awurum and Okorie, 2011). The production and productivity of okra have declined recently due to low soil fertility (Adeyemi et al., 2008), poor soil management and cultural practices by the farmers. In order to ensure high and sustainable okra yields, good soil fertility management is required to facilitate its production. The use of organic manures and inorganic fertilizers improved SOM, soil structure and water holding capacity, nutrient cycling and maintain soil nutrient status (Saha et al., 2008). However, high cost of inorganic fertilizer and its scarcity, poor technological expertise, increased soil acidity and nutrient imbalance have hindered its sustainable use (Ojeniyi, 2000). In addition, there are growing concerns about the negative implications of conventional agriculture involving use of chemical fertilizers and pesticides to human health and the environment. On the other hand, it has been reported that organic manures improve the growth and yield parameters of crops when the required amount is judiciously used (Senjobi et al., 2010). However, information on the recommended rate of organic manures application for okra production in the derived savanna region of southeastern Nigeria is scarce. Therefore, the objective of this study was to compare the effect of different rates of organic manures and the recommended rate of NPK 15-15-15 fertilizer on soil physico-chemical properties and okra yield in Nsukka, southeastern Nigeria.

Material and Methods

Description of experimental site

The study was carried out at the Department of Soil Science Teaching and Research Farm, University of Nigeria, Nsukka. The location falls within the derived savannah agroecological zone of Nigeria (6◦51' N, 7◦25' E) at an average elevation of about 436 m above sea level. The rainy season starts from April to October while the dry season begins from November to March. There is usually a short break in the month of August. The average annual rainfall amount is about 1600 mm and 85% of this takes place during the rainy season. The average minimum and maximum temperatures are about 22◦C and 30◦C respectively. The relative humidity was rarely below 60% (Asadu, 2002). The soils of the area are mostly Ultisols which belongs to Nkpologu series (Nwadialo, 1989). The soil is very deep, dark-reddish brown at the top layer and reddish in the subsoil. It is coarse to medium sandy loam (clay content ranged from 5-25%), acid in reaction (pH range of 4-7) and low in nutrient status.

Greenhouse study

The soil used for the greenhouse study was collected from the Teaching and Research farm of the Department of Soil Science, University of Nigeria, Nsukka. Air-dried sieved (2 mm) soil (3.5 kg) was placed in each perforated pots following CRD with eight (8) treatments replicated five times. Poultry manure and pig slurry were added at 10, 20 and 40 t ha-1. All the pots were watered to field capacity for two weeks (3 times per week). At the end of two weeks, the okra (Spineless species) seeds were planted at the rate of two seeds per pot. The germinated seedlings were thinned down to one per pot two weeks after planting (WAP). The recommended rate of NPK 15-15-15 fertilizer (300 kg ha-1) was applied two weeks after planting (WAP) to five pots while the remaining five pots with no amendment served as the control. The okra plants were harvested at eight WAP.

Field study Data collection and soil sampling

The field evaluation was carried out from 10thApril, 2018 to 15th July, 2018 at the Teaching and Research Farm of the Department of Soil Science, University of Nigeria, Nsukka. Each of the plots (3m x 1.5m) were properly demarcated using earthen bunds with a spacing of 0.5 m between each plot and a spacing of 1 m between each blocks. There were 40 experimental plots under randomized complete block design (RCBD) with five replications. The plots were manually tilled to 20 cm depth using hand hoe. The poultry manure and pig slurry at 10, 20 and 40 t ha-1were thoroughly mixed in plots as per treatments before planting. The okra (Spineless species) seeds were planted at the rate of two seeds per hole using a plant spacing of 60 cm x 50 cm and thinned to one, two weeks after planting. The recommended NPK 15-15-15 fertilizer (300 kg/ha) was applied two weeks after planting to five plots while the remaining five plots without any amendment served as control. Weeding was done by hand and hand hoe picking. Subsequent weed controls were done by a combination of hand picking and use of hand hoe method at two weeks interval.

Data collection and soil sampling

The agronomic parameters such as plant height and number of leaves were measured at 2, 4, 6 and 8 weeks after planting (WAP) in greenhouse and field studies. Fresh and dry matter yields were also measured. Both disturbed and undisturbed soil samples were collected at 0-15cm depth with the help of core samplers and soil auger. The soil samples were collected in black polyethylene bags. The disturbed soil samples were air dried, sieved with 2 mm sieve while the core samples were trimmed with spatula and saturated for at least 48 hours before analysis. The soil samples were analyzed using standard laboratory procedures.

Laboratory analysis

Particle size distribution of the soil was determined using the Bouyoucous hydrometer method as described by Gee and Bauder (1986). Bulk density was determined by core method as described by Blake and Hartge (1986). Saturated hydraulic conductivity (Ksat) was determined by the constant head permeameter method (Klute and Dirksen, 1986).Total porosity (P) was computed from bulk density (Bd).

The size distribution of water stable aggregates (WSA) was determined by the wet sieving method (Kemper and Rosenau, 1986). The MWD of WSA was calculated based on the equation proposed by Chaney and Swift (1984). Soil pH was determined using digital pH meter in a soil solution ration of 1:2.5. Organic carbon was determined using the modified Walkley and Black method as described by Nelson and Sommer (1996). The soil organic matter was obtained by multiplying with a correction factor of 1.724. Total nitrogen was determined using the Kjeldhal method as described by Bremner (1996). Available phosphorus was determined using Bray II method as described by Bray and Kurtz (1945). Exchangeable calcium, magnesium, sodium and potassium were extracted with NH4OAc. Calcium and magnesium were determined using Ethylene Diamine Tetraacetic acid (EDTA) titration method while potassium and sodium were determined using flame photometer. Cation exchange capacity was determined titrimetrically using 0.01N NaOH. Exchangeable acidity was determined titrimetrically using 0.05 N NaOH.

Data analysis

The soil and agronomic data were analyzed for variance (ANOVA) in RCBD and in CRD for the field and the greenhouse study respectively as outlined by Steel and Torrie (1980) using GENSTAT 4.0. Separation of treatment means was done using the F-LSD at 5% probability level as described by Obi (2002).

Results and Discussion

Effect of poultry manure, pig slurry and NPK on soil physical properties

The result of greenhouse and field studies (Tables 1 and 2) indicated that the rates of poultry manure and pig slurry significantly ($p<0.05$) improved soil physical properties than the control and the recommended rate of NPK 15-15-15 fertilizer. The results are in agreement with the findings of different researchers reporting that organic manure improved the stability of soil aggregates (Ardeshir et al., 2010), increased total porosity and reduced bulk density (Mahmood et al., 2017) and improve mean weight diameter (Mbah and Onweremadu, 2009).

Table 1: Effect of poultry manure and pig slurry rates and NPK on soil physical properties (Greenhouse study).

Treatment	AS (%)	Ksat (cm hr^{-1})	MWD (mm)	Porosity (%)	BD (mg m^{-3})	CS (g kg^{-1})	FS (g kg^{-1})
PM_{10}	26.67	20.23	0.75	44.15	1.48	392.0	447.60
PM_{20}	33.86	22.72	0.71	46.80	1.41	414.0	415.60
PM_{40}	38.13	34.84	0.79	47.20	1.40	466.0	303.00
PS_{10}	25.29	15.65	0.65	41.10	1.56	414.0	425.60
PS_{20}	36.37	17.84	0.96	43.00	1.51	410.0	414.90
PS_{40}	39.15	35.69	0.85	43.40	1.50	430.0	399.60
NPK	24.36	10.60	0.60	37.00	1.67	360.0	479.60
CONTROL	24.68	9.76	0.49	35.20	1.71	438.0	401.60
LSD(0.05)	4.379	5.424	0.1052	1.85	0.05	ns	ns

PM10 = 10 t/ha poultry manure, PM20 = 20 t/ha poultry manure, PM40 = 40 t/ha poultry manure, PS10 = 10 t/ha pig slurry, PS20 = 20 t/ha pig slurry, PS40 = 40 t/ha pig slurry, AS=aggregate stability, Ksat= saturated hydraulic conductivity, MWD= mean weight diameter, BD= bulk density, FS = fine sand, CS =coarse sand, ns = non-significant.

Table 2: Effects of poultry manure and pig slurry rates and NPK on soil physical properties (Field study).

Treatment	AS (%)	Ksat (cm hr^{-1})	MWD (mm)	Porosity (%)	BD (gcm-3)	CS (g kg-1)	FS (g kg-1)
PM_{10}	47.58	29.46	1.56	45.70	1.44	390.0	419.60
PM_{20}	66.82	35.35	2.11	46.40	1.42	396.0	422.93
PM_{40}	86.33	47.47	2.67	47.60	1.39	385.3	424.27
PS_{10}	56.92	25.25	1.96	44.50	1.47	380.0	429.60
PS_{20}	69.87	32.66	2.44	46.00	1.43	388.0	421.60
PS_{40}	77.19	43.60	2.53	46.80	1.41	382.7	429.60
NPK	58.26	20.70	2.02	43.00	1.51	394.0	425.60
CONTROL	38.35	21.21	1.38	40.80	1.57	356.0	463.60
LSD(0.05)	5.193	6.923	0.4056	2.30	0.08	14.18	3.045

PM10 = 10t/ha poultry manure, PM20 = 20 t/ha poultry manure, PM40 = 40 t/ha poultry manure, PS10 = 10 t/ha pig slurry, PS20 = 20 t/ ha pig slurry, PS40 = 40 t/ha pig slurry, AS =aggregate stability, Ksat= saturated hydraulic conductivity, MWD= mean weight diameter, BD= bulk density, TS=total sand, FS = fine sand, CS =coarse sand, ns = non-significant.

Effect of poultry manure, pig slurry and NPK on some soil chemical properties

The result of greenhouse study showed that different levels of poultry manure and pig slurry applications significantly ($p<0.05$) improved the soil chemical properties except CEC than the control plot with no amendment (Table 3). Similarly, the results of the field study (Table 4) showed that different levels of poultry manure and pig slurry applications significantly ($p<0.05$) improved the soil chemical properties; soil pH, SOM, TN, Av.P and CEC than the control plot with no amendment. The results are in conformity with the findings of Mbah and Onweremadu (2009). Han et al. (2016) noted that organic manure increased soil pH while NPK fertilizer decreased soil pH.

Table 3: Effect of poultry manure and pig slurry rates and NPK on some soil chemical properties (Green house study).

Treatment	pH	SOM (g kg^{-1})	TN (g kg^{-1})	Av.P (mg kg^{-1})	CEC (cmol kg^{-1})
PM_{10}	5.2	18.75	0.980	27.97	12.0
PM_{20}	5.6	18.75	1.050	40.10	12.2
PM_{40}	5.7	18.80	1.260	63.42	14.0
PS_{10}	4.4	17.80	0.910	20.98	9.2
PS_{20}	4.7	17.80	1.030	27.51	10.2
PS_{40}	4.9	18.75	1.120	28.91	10.8
NPK	4.0	15.60	0.960	13.44	10.4
CONTROL	4.3	15.45	0.910	15.39	8.8
LSD(0.05)	0.333	1.506	0.1285	5.643	ns

SOM = soil organic matter, TN = total nitrogen, Av.P= available phosphorus, CEC = cation exchange capacity, ns = non-significant.

Table 4: Effect of poultry manure and pig slurry rates and NPK on some soil chemical properties (Field study).

Treatment	pH	SOM (g kg^{-1})	TN (g kg^{-1})	Av.P (mg kg^{-1})	CEC (cmol kg^{-1})
PM10	6.4	17.20	0.980	45.70	9.40
PM20	6.4	17.80	1.120	51.29	12.0
PM40	6.5	19.63	1.190	58.28	15.8
PS10	5.4	17.80	0.840	36.31	10.13
PS20	5.4	18.73	0.980	46.63	13.60
PS40	5.5	19.03	1.050	54.56	10.40
NPK	4.5	15.90	0.980	33.57	9.80
CONTROL	4.8	15.90	0.840	28.91	8.80
LSD(0.05)	0.363	1.055	0.0927	6.87	4.50

SOM = soil organic matter, TN = total nitrogen, Av. P= available phosphorus, CEC = cation exchange capacity, ns = non-significant

Effect of poultry manure, pig slurry and NPK on the yield component of Okra

The results of greenhouse and field studies showed that the biomass (fresh and dry matter), fruit yield, number of leaves and plant height were significantly ($p<0.05$) improved due to increasing levels of poultry manure and pig slurry (Tables 5 and 6). These results are in agreement with the findings of Premsekhar and Rajashree (2009). Adesina et al. (2014) had also reported that plant height and number of leaves increased with increase in the rate of organic manure applied. The significant influence on growth and yield characteristics of okra may be due to the improvement in soil physical properties and enhanced uptake of nutrients by the applications of poultry manure and pig slurry. However, poultry manure showed its superiority over pig slurry. Poultry manure has been reported to increase the fruit yield and plant height of okra compared to other sources of organic manure (Fagwalawa and Yahaya, 2016). It has been reported that poultry manure contains high amount of nutrients especially nitrogen and phosphorus that are easily taken up by plants for fast growth (Awodun; 2007).

Table 5: Effect of poultry manure and pig slurry rates and NPK on Okra growth and Yield (Greenhouse study).

Treatment	NL 2WAP (cm)	NL 4WAP (cm)	NL 6WAP (cm)	NL 8WAP (cm)	PH 2WAP (cm)	PH 4WAP (cm)	PH 6WAP (cm)	PH 8WAP (cm)	BFW (g)	BDW (g)
PM10	4.00	5.00	6.00	7.67	17.73	28.0	35.67	40.17	10.67	5.80
PM20	4.00	4.67	5.67	7.33	19.47	28.73	36.67	38.30	15.93	8.53
PM40	4.00	6.00	7.00	7.67	21.40	32.67	45.33	48.50	22.43	13.00
PS10	3.00	4.00	5.00	6.33	13.03	19.47	26.33	30.33	3.07	1.90
PS20	3.67	5.67	6.67	7.00	14.77	21.23	28.33	34.40	5.47	3.17
PS40	4.00	5.33	6.33	7.00	13.70	22.77	37.17	43.83	12.10	7.87
NPK	3.00	3.33	4.33	5.33	12.87	13.10	24.67	25.83	2.00	2.23
CONTROL	2.33	3.33	4.33	4.67	12.93	17.93	18.50	19.50	1.80	1.23
LSD(0.05)	0.790	Ns	1.694	1.368	2.929	6.212	3.934	5.090	3.446	2.419

NL= number of leaves, PH =plant height, 2WAP= 2weeks after planting, 4WAP = 4 weeks after planting, 6WAP=6 weeks after planting, 8WAP = 8 weeks after planting, BFW = biomass fresh weight, BDW= biomass dry weight.

Table 6: Effect of Poultry manure and Pig slurry rates and NPK on the growth and Yield of Okra (Field study)

Treatment	NL 2WAP (cm)	NL 4WAP (cm)	NL 6WAP (CM)	NL 8WAP (cm)	PH 2WAP (cm)	PH 4WAP (cm)	PH 6WAP (cm)	PH 8WAP (cm)	FG (cm)	FL (cm)	FY (t/ha)
PM10	3.33	7.67	12.00	20.00	6.37	13.80	31.00	56.00	9.23	9.82	2.15
PM20	3.33	7.67	14.33	24.00	7.70	15.85	35.70	66.30	9.75	10.03	3.93
PM40	3.67	9.33	17.67	24.67	7.13	22.43	45.30	75.70	11.37	11.35	4.97
PS10	4.00	6.67	12.33	19.33	7.47	14.17	27.50	47.30	8.77	10.88	2.07
PS20	3.00	8.33	17.00	24.00	7.07	17.33	42.00	72.30	9.80	10.67	2.65
PS40	3.67	8.67	14.33	24.33	8.10	18.23	39.30	64.70	9.97	12.43	4.62
NPK	3.00	7.33	10.33	15.67	4.90	12.73	27.20	53.30	8.17	10.00	0.89
CONTROL	2.33	4.67	6.00	5.67	3.17	7.33	11.30	16.70	8.52	8.87	0.62
LSD(0.05)	ns	1.798	4.809	6.885	2.582	7.643	19.39	27.79	ns	ns	2.310

NL= number of leaves, PH =plant height, 2WAP= 2 weeks after planting, 4WAP = 4 weeks after planting, 6WAP= 6weeks after planting, 8WAP = 8 weeks after planting, FG= fruit girth, FL=fruit length, FY = fruit yield.

Conclusion

The improvement in soil physical and chemical properties through the applications of poultry manure and pig slurry led to significant ($p<0.05$) improvement in the uptake of nutrients and in turn, growth and yield of okra. However, poultry manure have greater influence on soil properties and okra productivity than pig slurry. It may be concluded that the addition of 20 t ha-1 of poultry manure and 40 t ha-1 of pig slurry is best for sustainable soil management and optimum productivity of okra in the coarse textured Ultisols in Nsukka, southeastern Nigeria.

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Composting with microorganisms: to improve available nutrient contents in sustainable soil management

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Abstract

Achieving zero hunger and food security are considered as two core concerns for a better future, but the enhancement of world population, unplanned urbanization, and multiple climatic pressures have made agriculture practices more challenging. Besides, traditional agronomy systems, injudicious use of chemical fertilizers, and lack of technical expertise have led to soil fertility degradation and increased soil pollution. In this situation, it is indispensable to manage our soil smartly through sustainable and eco-friendly approaches. Beneficial microorganisms can contribute in diverse ways (nitrogen fixation, carbon sequestration, phosphate solubilization, phytohormone, and enzyme production) to soil fertility and crop production improvement. Several types of research on heavy metal and hydrocarbon pollution have shown that some microorganisms are remarkably versatile at catabolizing these recalcitrant compounds. Compost is a big source of microorganisms comprising bacteria, fungus, and actinomycetes, that has the ability to degrade contaminants to harmless compounds. These microorganisms can also biotransform pollutants into low-toxic substances and hence can lessen pollutant bioavailability. Recently, compost application with selective microorganisms has got much attention to boost the nutrient availability in soil. This review reports on the integrated utilization of compost and microorganisms contributing sustainably to improving soil health by forming positive impacts in both crops and the environment.

Keywords: Beneficial microorganisms, compost, integrated utilization, nutrient availability, pollution, soil health

Introduction

The ever-growing demand for food coupled with the reduction of cultivable lands and resources have raised massive challenges for tomorrow's agriculture. There is an urgent need to strengthen crop production with modern agricultural techniques and approaches. For the past few decades, farmers have been using chemical fertilizers in their fields for better crop yield, but in the long term, this fertilization has led to nutrient removal from soil which is higher than nutrient addition. This situation is a big threat to global soil health that has already made a serious economic loss for farmers (Solanki et al., 2015). So, to intensify agriculture, we need to choose sustainable ways through the use of efficient agro-biosystems which consider the entire agroecosystem biochemical diversity and their potential to mitigate the adverse impacts of less soil fertility, abiotic stress, pathogens, and pests (Timmusk et al., 2017).

Compost is considered as a comprehensive source of diverse beneficial microorganisms (e.g., bacteria, actinomycetes, yeasts, and fungi) (Boulter et al., 2002). In agriculture, these beneficial microorganisms encompass immense importance through boosting plant growth and yield via multiple regulatory biochemical pathways (direct and indirect mechanisms) that manipulating plant hormonal biosynthesis, increasing the availability of soil nutrients (N, P, K, and essential micronutrients), alleviating osmotic (salinity and drought) stress in plants, supporting bioremediation of heavy metals and preventing soil-borne pathogens (Munees and Mulugeta, 2014; Jacoby et al., 2017). Hence, the application of compost creates significant effects on nutritional availability to the plants through the action of different microbial activities in soil (Chenu, Le, Bissonnais, and

Arrouays, 2000; Candemir and Gülser 2011). Moreover, this is an excellent alternative for waste management that can recover crop production by increasing soil fertility status. Its major contribution is the high organic matter fraction which reduces the use of inorganic fertilizers in soil (Eneji et al., 2001). Additionally, compost application improves soil structure, reduces soil erosion, and enriches water holding capacity (Diacono and Montemurro, 2010; Demir and Gülser, 2021).

Compost is produced from organic wastes through the aerobic process, performed at a large scale in piles or at a local scale with a home composter (Andersen et al. 2011). Microbial and enzymatic activities can degrade and transform these organic wastes to CO2, H2O, mineral ions, and humic substances through specific stages (Lu et al., 2014; Bialobrzewski et al., 2015).

Numerous studies have represented the versatile benefits of composts in soil health improvement. Regrettably, some researchers feel wary of the large-scale application of compost in agriculture as compost may induce some negative consequences, such as heavy metal accumulation, soil salinization, and alkalization with groundwater pollution (Carbonell et al., 2011; Sharifi and Renella, 2015). To overcome this critical situation, implementing compost with beneficial microorganisms can bring an effective solution (Ahmad et al., 2018). At the same time, this co-application strategy in crop fields can also enhance nutrient (N, P, K) availability in soil, accelerate bioremediation of hydrocarbons, and initiate better protection against many soil-borne pathogens (Muhammad et al., 2017; Osei-Twumasi et al., 2020).

This review aims to represent different beneficial microorganisms used during compost application and to evaluate their effects on soil nutrient accessibility and successful crop growth.

Application of compost and microorganisms to improve available nutrient status in soil

Impacts on soil nitrogen (N) availability

One of the major issues during composting is the emission of ammonia (NH3). This emission is responsible for nitrogen loss (about 21%-77% of total nitrogen) in compost and adversely affects the surroundings (Yang et al., 2019). Interestingly, Zhao et al. (2020) revealed that the combinatory application of thermotolerant nitrifying bacteria (TNB) and sewage sludge compost reduced ammonia emission (29.7%), lessened the nitrogen loss, and increased nitrifying bacteria population in soil with overall improving the performance of compost (temperature, pH, C/N ratio, organic matter status, and germination index). Another study showed that inoculation of Bacillus cereus GS6 with compost significantly enhanced nodulation and nodule efficiency as well as ensured higher accumulation of NPK contents in grain, shoot, and nodule biomass of soybean (Muhammad et al., 2017). Improvement of nitrogen in soil has also been reported by Jiang et al. (2015), where they used some specific bacterial agents (nitrobacteria, Azotobacter) and pig manure compost together. The nitrogen status of compost can also be improved by adding nitrogen-fixing bacteria (Azotobacter chroococcum and Azotobacter lipoferum) (Kumar and Singh, 2001). Besides, they reported that in addition to enhancing phosphorus status, mixing phosphate-solubilizing bacterium (Pseudomonas striata) in compost also improved N availability in soil.

Impacts on soil phosphorus (P) availability

Composting is a special biological method that causes organic matter stabilization and humification (Zhao et al., 2017). This increasing humic matter status can directly affect the P availability in soil through biofixation of phosphates (Borggaard et al., 2005). This problem can be solved effectively by applying plant growth promoting rhizobacteria, especially phosphate solubilizing bacteria (PSB), in compost (Vessey, 2003).

Impacts on other soil nutrients

At present, different beneficial exogenous microorganisms are inoculated to minimize the composting time and maximize the effectiveness of compost (Zhao et al., 2017). Bioaugmentation of compost with some selected agriculturally useful microbes (Candida tropicalis, Phanerochaete chrysosporium, Streptomyces globisporus, Lactobacillus sp., and photosynthetic bacteria) was found effective to improve organic carbon, available nitrogen status, and microbial activity in the soil. Besides, the lycopene and carotenoid contents of tomato, marigold, and calendula were also reported to be increased significantly in those studies (Verma et al., 2015; Sharma et al., 2017). Likewise, the availability and uptake of some micronutrients (Fe, Mn, and Zn) have been found to increase through the combined application of compost and bacteria (Shahzad et al., 2008). Furthermore, researchers (Shoghi-Kalkhoran et al., 2013) have observed that the grain yield, fatty acid percentage, and oil contents of sunflower crop enriched due to the application of farmyard manure compost with plant growth-promoting rhizobacteria (including Azotobacter and Azospirillium).

Table 1. Positive impacts of integrated application of composts and P solubilizing microorganisms on crops and soil

Composts	P solubilizing microorganisms	Crops	Impacts on soil and plant	References
Sugarcane waste compost	*Bacillus* sp. BACBR04, *Bacillus* sp. BACBR06, and *Rhizobium* sp. RIZBR01	Sugarcane	Improved phytate-degrading enzyme activity that was interrelated with the improvement of organic P content in soil. This study also showed enhancement of N and K content in plant tissue.	Estrada-Bonilla et al., 2021
Kitchen waster compost	*Bacillus* sp. P6	Cucumber	Increased Olsen P content, organic matter degradation, and bacterial diversity. Enhanced the activity of P-mobilization bacterial genera.	Zhang et al., 2021
Phospho compost	Arbuscular Mycorrhizal Fungi (AMF): *Acaulospora scrobiculata, Glomus deserticola, Glomus intraradices and Glomus versiforme* Bacteria: *Myroides odoratus*, *Alcaligenes feacalis*, *Alcaligenes* sp., and *Alcaligenes* sp.	Tomato	Increased alkaline phosphatase activity in soil, improved plant growth and phosphorus solubilization.	Maaloum et al., 2020
Fruit and vegetable waste compost	*Bacillus* sp. CIK-512	Radish	P availability in soil increased.	Ahmad et al., 2018
Food and fruit waste compost	*Bacillus cereus* GS6	Soybean	Reflected significant role in nodulation. Dehydrogenase and phosphomonoesterase activity increased because of high microbial P cycling in soil.	Muhammad et al., 2017
Rock phosphate enriched compost	*Burkholderia cepacia* and *Klebsiella pneumoniae*	Maize	Increased maize growth and P nutrition availability in soil.	Iqbal et al., 2016

Application of compost and microorganisms to bioremediate soil pollutants (heavy metals and hydrocarbons) for better nutrient utilization

Bioremediation of heavy metals from soil

Bacteria, fungi, and actinomycetes are considered as the major bioagents in compost that are pretty active to degrade heavy metals in polluted soil (Chen et al., 2015). It is reported that the merged application of compost and Bacillus sp. CIK-512 ameliorated the lead (Pb) toxicity in radish (Ahmad et al., 2018). Compost can provide a favorable environment for the growth and development of Bacillus, where these bacteria, in turn, assist crops in escaping heavy metal stress through certain enzymatic activities. Moreover, they suggested that this synergistic application might expand the root surface area that enhanced water absorption ability which finally resulted in better growth of plants. Likewise, other studies also supported the aggregated use of bacteria and compost to improve plant physiology by reducing membrane leakage under heavy metal stress conditions (Rajkumar et al., 2012).

Bioremediation of hydrocarbons from soil

As a safe and eco-friendly choice, bioremediation cleans up the polycyclic aromatic hydrocarbons contaminated fields (Wolf et al., 2020). Using compost as co-substrates facilitates the bioaugmentation and biostimulation processes, which are bioremediation practices and applied to sites contaminated with polycyclic aromatic hydrocarbons, pesticides, and petroleum products (Mihai et al., 2021). According to the recent study of Osei-Twumasi et al. (2020), the application of compost and bacteria (Brevibacterium casei and Bacillus zhangzhouensi) together is remarkably effective to remediate TPH (total petroleum hydrocarbon) in hydrocarbon-contaminated drill mud waste. Similarly, Hussain et al. (2018) demonstrated that the synergic use of compost and bacterial strains (Pseudomonas poae, Actinobacter bouvetii, Stenotrophomonas rhizophila, and Pseudomonas rhizosphaerae) very effectively (84%) removed petroleum hydrocarbon from polluted soil and improved the nutrient status. Very interestingly, this dual combined application (compost + bacterial strains) showed a statistically similar result with the tri combination (compost + biochar + bacterial strains).

Conclusion

The integrated application of compost and microorganisms is recommended based on the related studies in enhancing macro and micronutrients with enzyme activities in soil, contributing to microbial life, mitigating heavy metal and hydrocarbon pollution, and ultimately escaping long-term risks in soil health. This ecofriendly approach may ensure significant changes in sustainable soil management and eventually accomplish resilient agricultural practices.

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Evaluating Splintex 2.0 for estimating the soil hydraulic properties in the western mediterranean region

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Abstract

Soil hydraulic properties are very important for the soil-plant-water relationship. Soil water retention curve (SWRC) is a property that is difficult to measure. For this reason, the use of pedotransfer functions (PTFs) in the estimation of moisture constants is quite common. One of the most widely used equations to describe soil hydraulic properties was developed by van Genuchten (1980). Splintex 2.0 is a physically-based computer model developed to estimate the parameters that comprise the van Genuchten's (1980) equations. Splintex 2.0 uses particle size distribution, bulk density, particle density, and optionally one or two measured points of the SWRC to predict the parameters of SWRC and unsaturated hydraulic conductivity by two simulation options (Simulations A and B). In this study, some soil moisture constant estimation was evaluated using the Splintex 2.0 model in the Western Mediterranean region. In the evaluation made with simulation A and simulation B, the RMSE values obtained in the estimation of the moisture content of the soils at 10 kPa matric suction head were respectively 0.056 and 0.097 cm^3 cm^{-3}. The highest error rate was found at 33 kPa matric suction head. The RMSE values found at 1500 kPa matric suction head were respectively 0.052 and 0.118 cm^3 cm^{-3}. As a result of the study, the error rate of the moisture constants was lower with Simulation A. It is suggested that the Splintex program can be successfully used for this region.

Keywords: Moisture constant, pedotransfer function, soil hydraulic properties, van Genuchten.

Introduction

Global warming caused by greenhouse gases intensely released into the atmosphere by industrializing countries; It causes climatic changes with differences in precipitation and temperatures, and drought with the decrease of water resources. According to the drought scenarios expected in the future, the importance of water, which is the most basic need of agriculture, will increase day by day [7]. Today, in order to provide improvements in areas such as soil water conservation, development of irrigation programs, improvement and drainage studies, plant-water stress; It will be useful to determine the soil-water relations.

The water retention curve in the soil forms a sigmoid curve in case of wetting and drying. The curve has two inflection points, the residual water tension (residual) and the air entry value. The matric potential of the soil water when the air starts to enter the large pores in the soil (beginning of drainage) or when all the air is expelled at some point (during wetting) is expressed as the air entry value. On the other hand, after a certain point, the point where the soil water content remains unchanged despite increasing the negative water potential applied to the soil; expressed as the resudial water content (θr). Determining these parameters is laborious and time consuming. Today, alternative estimation methods are used instead, often a new concept such as —Pedotransfer functions (PTFs)[4, 6, 14]. It is revealed by the studies that the PTFs used and the low error rate estimations are made[1]. Estimations can be made directly with the available parameters to determine the hydraulic properties such as water retention curve and hydraulic conductivity in the soil. Numerous empirical equations have been developed expressing soil water retention curves as a function of pressure load or water content. One of the most widely used is that developed by van Genuchten (1980). There are software programs that use the van Genuchten equation parameters for estimation from experimental data and accurate construction of the water retention curve. Splintex 2.0 is a computer program that can estimate van Genuchten (1980)-Mualem (VGM) parameters to determine both water retention and unsaturated hydraulic conductivity properties. Splintex 2.0 has 2 different outputs as simulation A and B to determine SWRC. Splintex 2.0 uses particle size distribution, bulk density, particle density, and optionally one or two points of the SWRC to predict the parameters of SWRC and unsaturated hydraulic conductivity. It has been determined in studies that the Splintex 2.0 version exhibits a successful performance in the estimation of the water retention curve[11] . However, there are limited studies on the evaluation of this program for different regional lands.

Turkey is located in a strategic region with its geographical location. It is a country with four seasons. It is located in the temperate zone. In this study, some soil moisture constant estimation was evaluated using the Splintex 2.0 model in the Western Mediterranean region.

Material and Methods

The study was carried out on an area of approximately 250 hectares between Isparta - Eğirdir highway and Isparta-Keçiborlu highway at the coordinates of WGS 1984 UTM Zone 36N 4187863-4188514 north and 283384- 285593 east latitudes. There are different types of land use in the region such as dry farming, orchards, vineyards and pastures. According to the meteorological data of the study area for many years (1960-2020), the semi-arid climate type is dominant in the region. The annual mean temperature, precipitation and evapotranspiration are 12.5 ºC, 466.8 mm and 724.58 mm, respectively[13]. According to the Newhall simulation model for the soil climate regime, the soil temperature and moisture regimes of the study area are mesic and xeric[15]. Disturbed and undisturbed soil samples were taken from 40 sampling points (0-20 cm depth) in the region.

The sand, silt and clay % contents of the soils were determined by the Bouyoucos hydrometer method[3]. The bulk density was found with undisturbed sampling cylinders with a volume of 100 cm^3. Moisture content at saturation was determined by making the undisturbed samples saturated.

Moisture contents of 10kPa(θ_{10kPa}), 33 kPa(θ_{33kPa}) and 1500kPa ($\theta_{1500kPa}$) matric suction were determined volumetrically with the help of ceramic plated pF set (U.S.A, Soil Moisture Equipment Corp.). Particle density was obtained by the pycnometer method [5]. Soil moisture content was estimated by the equation developed by van Genuchten (1980). Equation parameters were obtained with the Splintex 2.0 algorithm.

The Splintex 2.0 computer model[11,12] was applied to estimate the van Genuchten's (1980)-Mualem (VGM) parameters that describe both water retention (Eq 1.) and unsaturated hydraulic conductivity functions (Eq. 2).

$$\Theta = \frac{\theta - \theta_r}{\theta_s - \theta_r} = \left[\frac{1}{1 + (\alpha h)^n} \right]^m \quad \text{Eq. (1)}$$

$$K(\theta) = Ks\, \Theta^{\lambda} [1 - (1 - \Theta^{1/m})^m]^2 \quad \text{Eq. (2)}$$

in which θ is the volumetric soil water content ($m^3\ m^{-3}$) as a function of the soil water pressure head (h), Θ is the effective saturation, θ_r and θ_s are respectively the residual and saturated water content ($m^3\ m^{-3}$), Ks is a fitted-matching point at saturation ($cm\ d^{-1}$), α (m^{-1}), λ, n and m ($m = 1–1/n$) are empirical curve shape parameters. The flow diagram of the Splintex 2.0 algorithm is given in Figure 1.

The output of the VGM parameters are presented in three ways; simulation A: θs was set as its measured value and θr, α, n and m estimated; simulation B: all parameters θs, θr, α, n and m estimated; simulation C: all parameters θs, θr, λ, m and Ks estimated; PSD: particle size distribution [6].

Estimated values were obtained with the equation coefficients obtained from the Splintex 2.0 algorithm. Root mean square error (RMSE), mean absolutely error (MAE), mean absolutely percentage error (MAPE) features were used in the evaluation of the model.

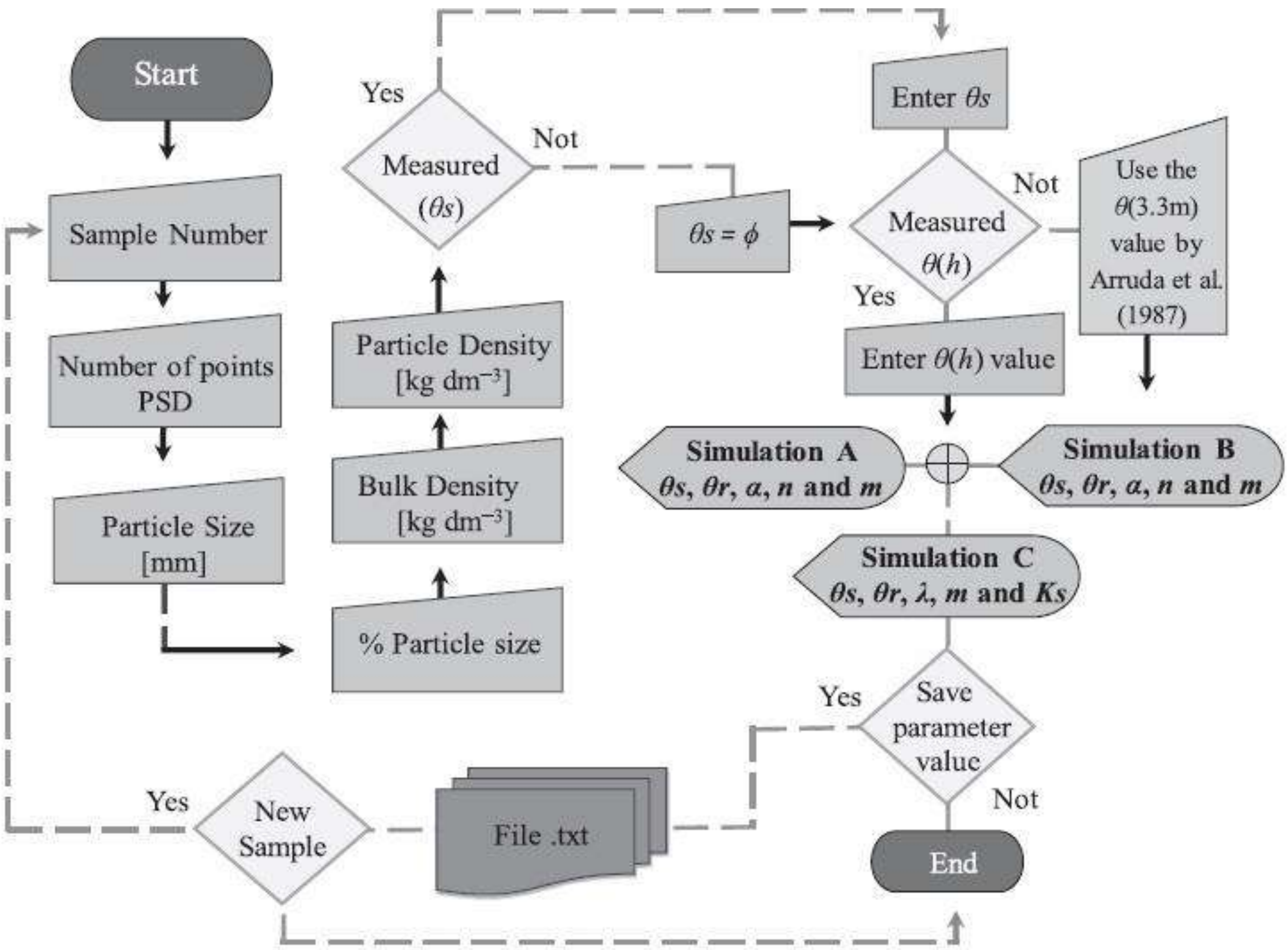

Figure 1. Flowchart of the Splintex 2.0 algorithm [11]

Results and Discussion

The descriptive statistics of the soil properties and the properties obtained for simulation A and B are given in Table 1. The sand, silt and clay contents of the soils were determined in the ranges of 16.84-78.69%, 16.50-49.81%, 8.59-60.95%, respectively. Medium texture group generally dominates in the soils. While the saturated water content (θs) of the soils was between 0.47-0.80 $cm^3\ cm^{-3}$, the water contents held at θ_{10kPa}, θ_{33kPa} and $\theta_{1500kPa}$ were determined as 0.42-0.71 $cm^3\ cm^{-3}$, 0.28-0.55 $cm^3\ cm^{-3}$ and 0.12-0.39 $cm^3\ cm^{-3}$, respectively. While the distribution of soil properties is close to normal, the properties that show the furthest distribution from the normal are sand and bulk density. The water retention curve is significantly affected by the particle size distribution and soil structure. At low tensions, the amount of water retained in the soil changes depending on the capillarity and pore size distribution. Thus, the retained water is strongly influenced by the soil structure. However, as the amount of absorption applied to the soil increases at high tensions, it has been revealed that soil texture and surface area are more effective than soil structure. As the clay content of the soils increases, the amount of moisture retained at any matric potential in the water retention curve increases and the slope change of the drawn curve becomes less. Since most of the pores are large in sandy soils, drainage starts rapidly after the air entry value as the applied tension increases, most of the water held in the large pores is immediately discharged, and only some water remains in the small pores [9].

Residual water content (θr) was estimated between 0.01 -0.27$cm^3\ cm^{-3}$ with Sim-A and 0.01-0.11 $cm^3\ cm^{-3}$ with Sim-B. The α coefficient varied between 0.01-0.04 cm^{-1} with Sim-A and between 0.01-0.07 cm^{-1} with Sim B. 1/ α is defined as the air entry value (cm) according to van Genuchten. n and m are the empirical shape-defining parameters in the van Genuchten equation (dimensionless). In both simulations, n and m coefficients were determined similar to each other. n and m are shape parameters and are based on minimizing the difference between the estimated volumetric water content and the measured water content value. Estimation accuracy of Splintex 2.0 algorithm was determined for different matric suction (Figure 2). While the RMSE obtained with θ_{10kPa}, which was estimated as a result of the equation parameters obtained with Sim-A, was 0.056 $cm^3\ cm^{-3}$, this value was found to be 0.080 $cm^3\ cm^{-3}$ in Sim-B. Again, while the RMSE values obtained at θ_{33kPa} are 0.097 $cm^3\ cm^{-3}$ and 0.153 $cm^3\ cm^{-3}$, they are 0.041 $cm^3\ cm^{-3}$ and 0.153 $cm^3\ cm^{-3}$ at $\theta_{1500kPa}$.

Table 1. Statistical parameters for soil properties and equation parameters

Variable	Mean	StDev	CoefVar	Minimum	Maximum	Skewness	Kurtosis
Clay %	31.19	12.35	31.61	8.59	60.95	0.28	0.33
Silt %	32.20	8.15	20.30	16.50	49.81	-0.15	-0.79
Sand %	36.62	15.11	40.26	16.84	78.69	0.72	0.07
BD g cm^{-3}	1.21	0.14	10.98	1.10	1.72	0.73	-0.33
PD g cm^{-3}	2.71	0.03	1.95	2.68	2.78	0.28	0.33
θs cm^3 cm^{-3}	0.59	0.08	13.57	0.47	0.77	0.15	-0.69
θ_{10kPa} cm^3 cm^{-3}	0.56	0.09	15.37	0.42	0.71	0.39	0.11
θ_{33kPa} cm^3 cm^{-3}	0.42	0.07	18.68	0.28	0.55	0.04	-0.59
$\theta_{1500kPa}$ cm^3 cm^{-3}	0.27	0.06	20.54	0.12	0.39	-0.17	0.17
Sim-A							
θs cm^3 cm^{-3}	0.59	0.08	13.57	0.43	0.77	0.15	-0.69
θr cm^3 cm^{-3}	0.11	0.08	75.22	0.01	0.27	0.13	-1.27
α cm^{-1}	0.01	0.01	45.54	0.01	0.04	1.53	2.09
n	2.22	0.67	30.31	1.16	3.04	-0.38	-1.52
m	0.50	0.18	36.49	0.14	0.67	-0.73	-1.16
Sim-B							
θs cm^3 cm^{-3}	0.60	0.08	13.02	0.44	0.78	0.17	-0.63
θr cm^3 cm^{-3}	0.01	0.02	389.23	0.01	0.11	4.44	19.11
α cm^{-1}	0.02	0.01	54.58	0.01	0.07	2.12	6.58
n	1.46	0.32	21.94	1.14	2.81	2.97	9.79
m	0.29	0.11	36.25	0.12	0.64	1.59	3.48

$m=1-1/n$ (13), α: equation parameter cm^{-1} θr: residual water content, θs: saturated water content, BD: bulk density, PD: Particle density, Sim-A: Simulation A, Sim-B: Simulation B

Although the MAPE values were similar to each other, the error rates were higher in the 33 kPa estimations in Sim B. The lowest error rate was found in Simulation A at 1500kPa estimation. The most linear relationship between observed and estimated values is seen at the wilting point (1500kPa). While the error rates were similar in both simulations for 10 kPa and 1500 kPa, Sim-A determined approximately 6% lower error rate than Sim B at 33 kPa. Silva et al. (2020) stated that the version of Splintex 2.0 exhibits a successful performance in the estimation of the water retention curve. In addition, the use of saturated water content in Sim-A can lead to a lower determination of the error rate, such as a calibration. Properties such as clay amount, clay type, organic matter content are effective in retaining water in soils. In addition, depending on the pore structure, the amount of water held at low matric potential also causes variability due to soil compaction (2, 8). In these estimates, the high error rates at low matric potential compared to 1500 kPa may be due to the difference in the pore geometry.

Conclusion

In this study, the usability of the Splintex 2.0 algorithm was investigated in soils under semi-arid climate. The estimated values of water content obtained at 10 kPa, 33 kPa and 1500 kPa matric suction head were compared. As a result of the study, while the error rates of the values obtained with Sim-A and Sim-B at 10 kPa and 1500 kPa were close to each other, Sim A was determined to have more successful predictive accuracy at 33 kPa. It was revealed that the error rate of the estimations obtained with Simulation A was lower than with Simulation B. More successful results were obtained, especially at the permanent wilting point. It is suggested that Splintex 2.0 Simulation A can be used successfully for determining the SWRC for the study area.

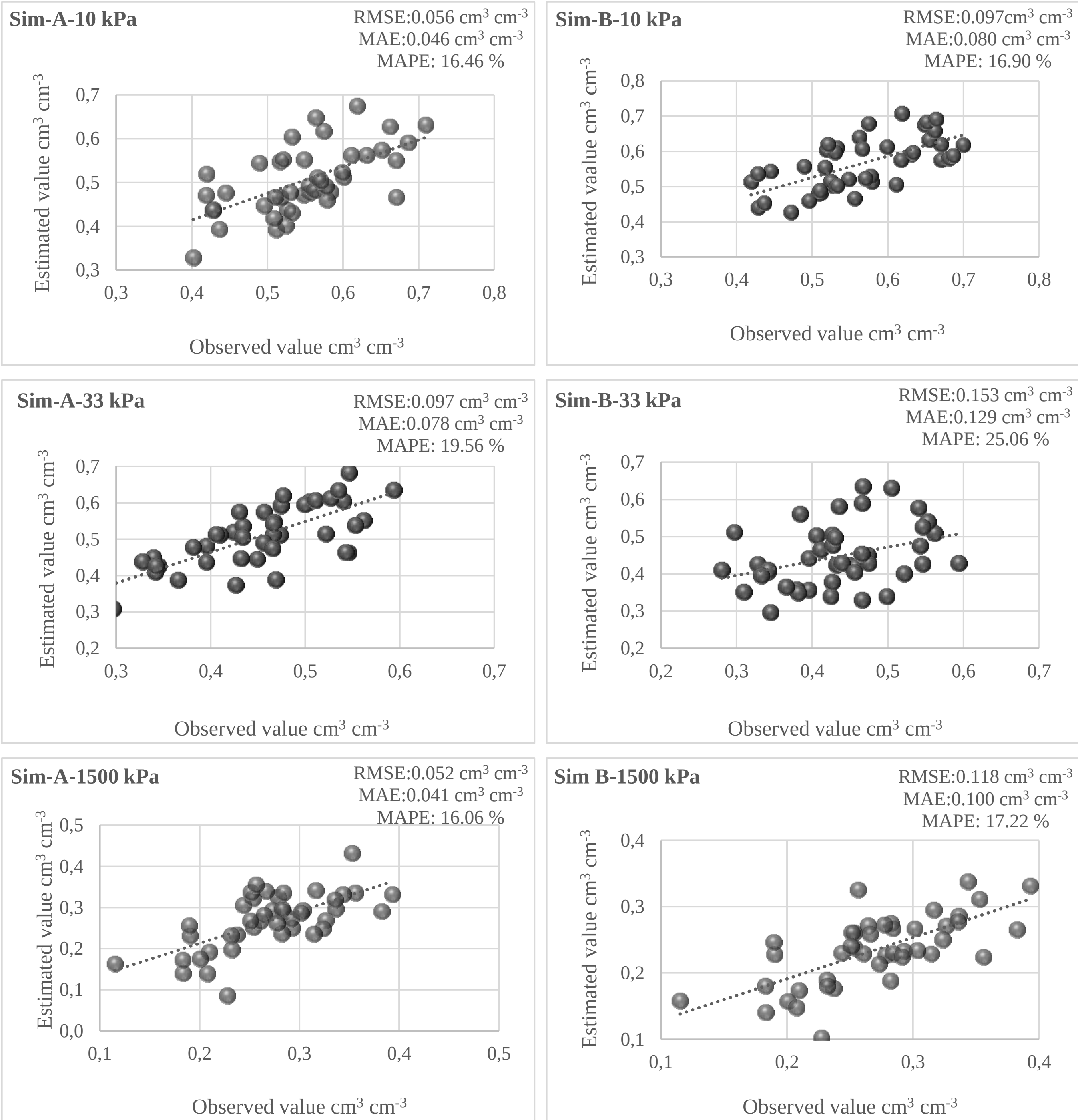

Figure 2. Estimation accuracy of Splintex 2.0 algorithm

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Soil management assessment framework (SMAF) in assessment soil quality

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Abstract

Made in order to achieve maximum efficiency from the unit area in agriculture; unsustainable agricultural practices and the problems brought about by the rapid growth of the population; it irreversibly loses its properties, causing the loss of workable agricultural areas. In recent years, scientists who have realized this danger have done many studies in order to understand and protect the soils and have put forward the concepts of soil health and quality. Many scientists from the past to the present have offered different opinions about soil quality and developed different methods to determine this quality and to monitor their differences over the years. The aim of this paper is to introduce SMAF model for soil quality approach.

Keywords: Soil Quality, Soil Quality Methods, SMAF

Introduction

The soils; living and breathing at the top of the earth's crust, which contains a wide realm of living things on and inside; they are natural resources consisting of the decomposition of rocks, organic waste and residaces, which have an important, non-renewable, three-dimensional structure. The concept of soil quality or health, which has become increasingly important in recent years in order to protect the land, which is the most important thing for human beings to survive; it is a key factor needed to achieve sustainable agricultural systems that will meet our growing demands for food, feed, fiber and fuels. Therefore, the concept of soil quality has been discussed worldwide in recent years and has become an important agenda item for scientific communities (Karlen et al., 2008).

Soil quality was defined by Karlen and his colleagues in 1997 as the capacity to maintain the productivity of a particular type of soil within the boundaries of a natural or managed ecosystem, to maintain or improve water and air quality, and to maintain its functions in order to support human health and settlement. It is possible for the soil to perform its functions, which are very important for human and environment in general, in a sustainable way, with an accurate understanding and monitoring of its quality.

What is Soil Quality?

Many different definitions have been made about soil quality from the past to the present. The most important reasons for the differentiation of definitions are the diversity of land, the difference of land use from region to region, social environmental factors, schools providing scientific education, languages and many other factors differ regionally. Soil quality was initially described by the FAO (Food and Agriculture Organization of the United Nations) in 1976 as a "complex feature of the land" and emphasized that land use has a different degree of impact on the sustainability of the land. In order to adequately explain the term soil quality, it is necessary to know the functions of the soil and to understand well the relationship between agricultural activity and soil quality. These functions are characteristic features that exist in the nature of the soil itself and differ from soil to soil depending on the physical, chemical and biological properties of the soil (Obade and Lal, 2016).

Soil quality is determined by the characteristics and dynamic variability of the soil. These changes are the result of agroclymatic factors, hydrogeology and production techniques. There are many factors that affect soil quality such as soil depth, water retention capacity, volume weight, amount of nutrients available, amount of organic matter, microbial biomass, carbon and nitrogen content, technology and infiltration rate (Pacci et al., 2021). Organic matter and microbial activities, which are dynamic properties of the soil; agricultural applications are very sensitive to land use changes and any adverse impact these changes will have on soil functionality (Emadi et al., 2009).

Dengiz et al. (2005) aimed to determine the quality status of Kahramanmaraş agricultural enterprise lands by parametric method, and the proportional values of the factors evaluated were determined after the land quality index values were calculated with the help of the complex square root formula. 55.1% (1099.1 ha), which constitutes the majority of the area, is very good and good in terms of agricultural and quality characteristics of the land (S1 and S2), 16.5% (329.9 ha) is medium good (S3) and 27.9% (555.6 ha) is not suitable for agricultural use (N). In addition, soil database of the study area was created using the GIS system.

Assessment of Soil Quality

In order to practically determine the current state of the territory, all basic soil functions in a region must be taken into account (Andrews et al., 2004). Complexity in the selection and evaluation of soil functions; Due to the significant impact of management activities and land use on soil quality, the creation of a soil quality minimum data set based on monitoring soil use and management has been proposed by many researchers (Askari and Holden, 2014). The data set consisting of a sufficient number of indicators used to determine the capacity of the soil to show various functions is called the "minimum data".

Determining the most appropriate indicators for creating a minimum data set (MDS) is an important step in determining the soil characteristics that affect soil quality and how much they affect them. The creation of MDS provides the selection of indicators associated with the functions in which the quality calculation will be determined. When determining minimum data sets consisting of the minimum number of soil indicators to measure the amount of realization of soil functions, it is important that indicators are selected on a large scale to include both chemical, physical and biological soil properties and functions in complex systems (Karlen et al., 2003).

Methods Used in Soil Quality Assessment.

Although there are many parameters at different levels that affect soil quality, it is almost impossible to use all of these parameters in the evaluation of land quality. For this purpose, the process of selecting the most suitable parameters for determining the quality of land requires great diligence. In order to determine land quality scores over the last 20 years; land use capability classes (Klingebiel and Montgomery, 1961), land quality index method (Doran and Parkin, 1994), dynamic multivariate land quality method (Larson and Pierce, 1994), terrain quality cards and test kits (Ditzler and Tugel, 2002), SMAF (Soil Management Assessment Framework) (Andrews et al., 2004) and CSHA (Cornell Soil Health Assessment) (Gugino et al., 2009) methods were developed.

- AEPAT: Agroecosystem Performance Assessment Tool
- SCI: Soil Conditioning Index
- Cornel Soil Health Test
- SMAF: Soil Management Assessment Framework

SMAF: Soil Management Assessment Framework

Significant improvement in germination percentage was observed in primed seed (95.50) compared to normal seed (78.50) (Figure 1). There were no significant differences in percent germination among the salinity levels (Figure 2). The mean value showed that the maximum germination percent (90%) was observed in salinity level 2g/L and 8g/L, whereas the minimum germination percentage (82.5) was reported when the salinity level was 6g/L.

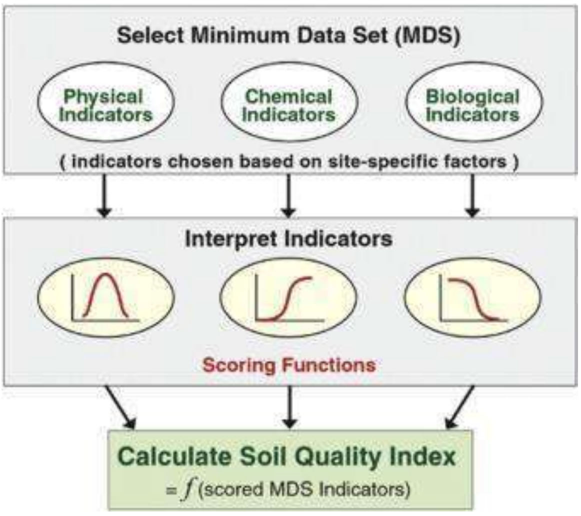

Figure 1. Stages of calculation of soil quality index.

SMAF; the soil contains 13 indicators including macroaggregate stability, available water capacity, bulk density, β-glucosidase activity, electrical conductivity, soil test potassium, microbial biomass carbon, soil solution pH, potentially mineralizable nitrogen, soil test (extractable) soil phosphorus, soil adsorption ratio, total organic carbon, water – filled pore space. Since the definition of soil quality for any area depends on the management objectives, climate, products and soil type, the SMAF method is used as a framework approach for determining the soil quality index. This framework provides information about the ability of soil to perform functions for the desired land use purpose with calculated quality values, giving the ability to make purposeful comments on the studied area for the calculated indicator results (Andrews et al., 2004).

The minimum data sets prepared for any region cannot be used for soils in different regions due to the variability depending on the distance. Therefore, Nortcliff (2002) states that in order to determine the soil quality, the selected indicators should be selected in accordance with the targeted soil quality functions and the region. However, with the use of evaluation methods such as SMAF that take into account soil taxonomy, it is possible to apply data sets prepared for soils in certain taxonomic classes to the same soil classes located in different parts of the world.

In the study titled "Soil Quality Assessment using SMAF Model in Pasture Land located in Van Basin", Pacci et al. (2021) determined the physical, chemical and biological quality index values and total soil quality characteristics of the soils distributed in the pasture lands in the Van basin using the SMAF model and their distribution maps were given in Figure 2. To this end, they studied 150 surface (0-30 cm) soil samples representing a research area of 6024 ha. 11 indicators were used in the model consisting of 13 indicators, apart from potentially mineralizable nitrogen and βeta-Glucosidase activity. According to the results obtained, it was determined that the chemical quality index of pasture soils is in a low class and the biological quality index is in the high class. Physical soil quality and total quality index values were determined to be moderate. Especially the biological quality index; they have shown that all quality classes vary highly in terms of their distribution within the field. It was determined that the middle parts of the research area were low for all quality classes and this was especially due to excess slope and high erosion.

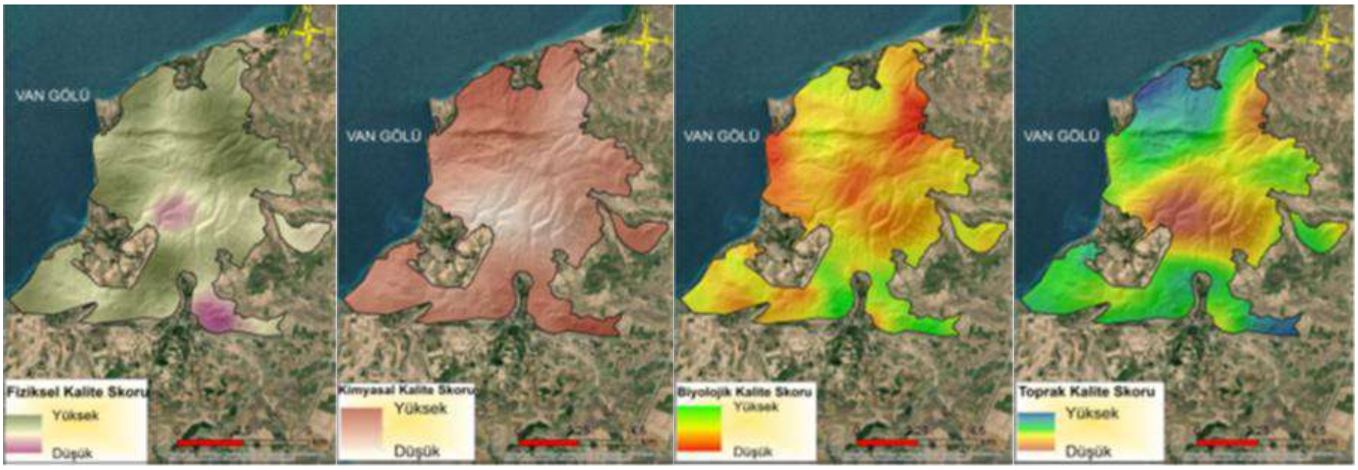

Figure 2. Distribution maps of the physical, chemical, biological and soil quality scores of pasture soils.

Scoring Quality Indicators in the SMAF Model.

Scoring indicators is necessary in interpreting how the relevant soil function can be associated with each measurement and incorporating it into an index that eliminates unit differences of indicators. In general, nonlinear scoring functions are used in scoring. Scoring functions are widely used in many uses. By using index values obtained for soil quality, it becomes possible to monitor the change occurring over time in an area and compare the different managements applied (Andrews et al., 2003).

Soil quality scoring functions allow high-precision laboratory assessment of changing soil health indicators using a cumulative normal distribution curve to be converted to percentage with 1 (100) being a high, good optimum result and 0 as a low, weak result. In addition to the ranking of percentage thresholds, ratings are given a nominal color rating that is appropriate for ease of identification. These are very low (score <20, color red), low (> 20 <40, color orange), medium (> 40 <60, yellow color), high (> 60 <80, color green) and very high (> 80, dark green). The scoring functions are as follows; more is better, the less is better, and the optimum area (Figure 3). SMAF uses the same technique and allows variability in the shape of the curve.

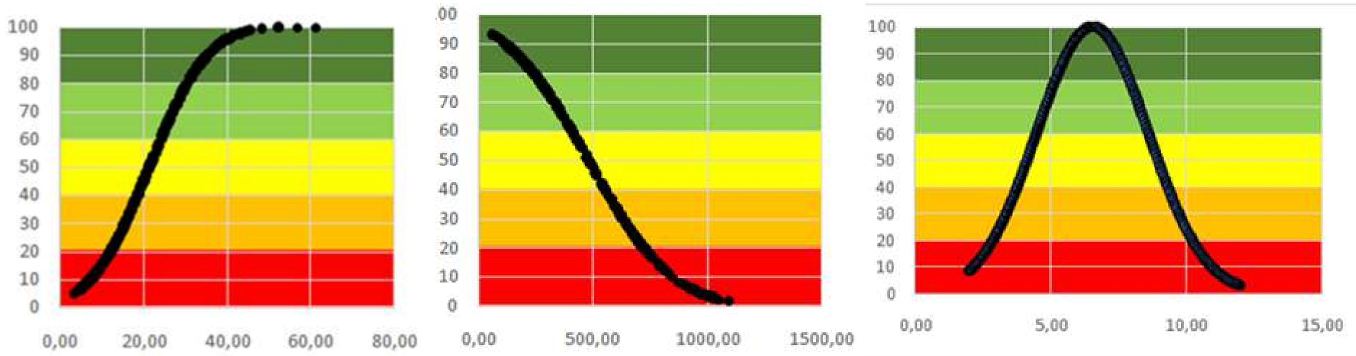

Figure 3. More is better Less is better Optimum area

More is better should applied in indicators that improve soil structure, such as good aggregate stability (Figure 4b.); Less is better should applied in indicators that disrupt the soil structure if it is as high as volume weight (Figure 4a.). Optimum area should be applied for indicators where extreme values such as low or high pH are not desired (Figure 4c.) (Andrews et al., 2004).

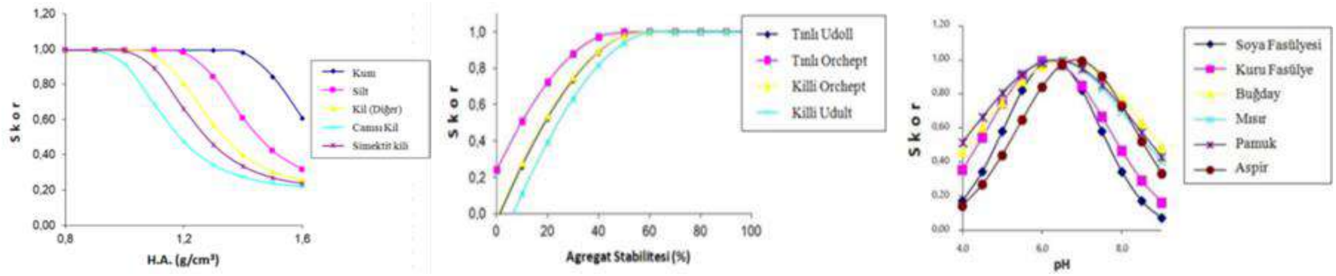

Figure 4. A B C

Depending on the product grown, the scoring values of some of the indicators may vary. The value of an indicator for a soil can get the highest score at the optimum value. For example, the optimum score for soil pH varies depending on which crop will be grown. The scoring of indicators is mostly specific to that place and their interpretation is usually based on soil properties that are the product of soil formation; some properties may differ depending on that place.

In indicator interpretation, various factors are used to regulate the threshold value in the scoring curve (e.g. organic matter, texturing, climate, terrain slope, region, mineralogy, decomposition class, product sampling time and analytical method). Scoring curves are then used to rate each type of data collected proportionally between 0 and 1.0 (Andrews et al., 2004). After the scoring of each indicator is completed, these scores are combined to obtain the soil quality index. Taking into account the quality scores obtained, the soil is general; physical, chemical and biological quality conditions are determined and evaluated. According to this result, the management studies to be carried out on the land are determined. The purpose of these studies is to protect the land in good condition and to regulate those in bad condition.

Conclusion

Recently, many different models have been used to determine soil quality. Compared to other models, the advantage of the SMAF model has the flexibility to meet field-specific differences arising from soil structure, region climate, agricultural applications and other factors in the scoring curves. In other models that determine soil quality, many parameters are used and a minimum data set is extracted, but SMAF avoids possible confusions and disagreements by using fixed parameters when performing quality assessment and interpreting these parameters according to certain standards.

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The relationships between tobacco quality and yield with engineering properties of Akhisar Region soils of Turkey

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Abstract

The research was carried out in Akhisar environs where tobacco is very popular. Ten fields were selected in 5 different villages which are known to show differences in terms the quality and yield. In this study some basic soil properties and engineering properties of soils were examined and the relationships between tobacco quality and yield and some engineering properties of soil were determined. The positive relationships were found between wilting point of soil and total reducing sugar as statisticaly significant. Negative relationships between reducing sugar and yield with bulk density were also determined, but it was not statisticaly significant. It was found that there were positive correlations between raw ash and total reducing sugar of tobacco and plastic and liquid limit as soil engineering properties. It is recommended that low raw ash and high sugar content are required for tobacco quality. With this content, for the quality of tobacco, it can be recomended that soils for tobacco production should have high liquid limit and plastic limit values. Further studies should be done in several years for having more relationships between tobacco quality and yield with engineering properties of soil.

Keywords: Akhisar, Tobacco, Soil Properties, Quality, Yield

Introduction

Tobacco is a cultivated plant with a pleasurable feature that became widespread in the world with the discovery of the Americas by Christopher Columbus in 1492 (Collins and Hawks, 1993). Tobacco is in the Solanaceae family, Nicotiana genus in plant systematics. There are about 65 species included in the genus Nicotiana. Of these species, only Nicotiana tabacum and Nicotiana rustica species can be found in cigarettes, cigars, pipes, etc. It is a culture form whose leaves are used in the production of tobacco products (Otan and Apti, 1989). The importance of tobacco, which is one of the most important agricultural products in the world, is not due to its usefulness to people, but to the economic gains of those who produce and trade tobacco and tobacco products (Kevseroğlu, 2000). Oriental Tobacco production in the world is approximately 180 thousand tons and approximately 35% of this belongs to Turkey.Tobacco production in Turkey is carried out with a contracted production model.In 2020, the amount of leaf tobacco produced by 57,296 tobacco producers on an area of 95,000 hectars was 82.7 thousand tons. Although its natural ecology is sloping barren and non-fertilized lands, tobacco has shifted from arid land to irrigated land due to the high price policies applied from time to time. Although its yield has reached high levels in the base land, its quality has deteriorated drastically.

In a study conducted in the western part of Turkey, it was determined that the best quality tobacco was grown on second and third class agricultural lands, the quality decreased in first class lands, and both quality and yield decreased in fourth class lands (Tuncay et al., 1985). Soil properties have a great influence on the taste and smell of tobacco (Purseglove, 1968). Tuncay et al. (1985) examined the relationship between tobacco quality and soil properties and reported that there was no relationship between soil nitrogen, phosphorus, potassium and organic matter content and quality characteristics in tobacco, whereas there was a significant relationship between soil physical properties and micronutrient content and quality.

Material and Methods

This study was carried out in 10 different fields in 5 villages, namely Hacıosmanlar, Dereköy, Arabacıbozköy, Mecidiye and Süleymanlı, in Akhisar district of Manisa province, located in the Aegean Region of Turkey (Table 1). The research material consisted of soil and tobacco samples taken from the fields where tobacco is grown in these villages. Tobacco grown in the research area belongs to Sarıbağlar variety.

Table 1. Villages, field numbers and symbols where the study was carried out

						Total
Villages	Hacıosmanlar	Arabacıbozköy	Dereköy	Mecidiye	Süleymanlı	5
Field number	3	2	1	2	2	10
Symbols	(H-8; H-9; H-10)	(A-4; A-5)	(D-3)	(M-1;M-2)	(S-6; S-7)	

Determination of Atterberg limits (liquid limit, plastic limit and plasticity index) in soils (Özaydın, 1997); grain size distribution (Bouyoucos, 1962); volume-weight (Black, 1965) analyzes; total N in tobacco leaves (Kacar, 1972); total reducing sugar (Lindsay, 1973); total alkaloid (nicotine) (Anonymous, 1977); raw ash (Gaines, 1971); yield (kg da^{-1}) and efficiency values were determined.

Tobacco cultivation practices in villages selected for research

Although the villages where the research was conducted have similar characteristics in terms of tobacco cultivation, they may show differences in terms of planting time and cultural processes.

Yield and quality are low in Mecidiye village. In Dereköy and Arabacıbozköy villages, tobacco quality is high, but yield is low. Tobacco yield in Süleymanlı village is high but its quality is low. The quality and yield of tobacco grown in Hacıosmanlar village is high.

Results and Discussion

Some quality characteristics, efficiency and yield values of tobacco samples are given in Table 2.

Table 2. Some quality characteristics and efficiency and yield values of tobacco samples

Field number	Quality properties of tobacco					Yield (kg da^{-1})
	Total alkoloid (nicotine) (%)	Total redusing sugar (%)	Total N (%)	Raw ash (%)	Efficiency	
M-1	0,650	21,92	1,73	19,50	S	87
M-2	0,557	22,07	1,86	20,02	S	80
D-3	0,346	24,20	1,48	18,05	75	63
A-4	0,220	28,45	1,19	20,04	70	108
A-5	0,545	27,65	1,35	18,12	65	99
S-6	0,815	25,80	1,93	22,40	S	75
S-7	0,922	19,06	2,79	18,95	KK	87
H-8	0,457	28,94	1,28	12,05	65	108
H-9	0,665	27,73	1,34	13,30	60	115
H-10	0,530	25,11	1,44	12,25	60	100
Average	0,5707	25,093	1,639	17,468		92,2

Nicotine is an important quality criterion in tobacco and neither high nor low nicotine amounts are required in terms of high quality. Abdallah (1970) states that high levels of nicotine give smoking a hard and burning feature, while low levels of nicotine cause poor taste and physiological dissatisfaction. İncekara (1979) states that nicotine should be within the limits of 0.25-1.79% for Aegean Region tobacco in order to have good quality in Oriental tobacco. Nitrogen element affects the smoking quality (hardness-softness) in tobacco plant. In this context, high N gives smoking a hard character, and low N gives it a soft feature. Mecidiye and Süleymanlı villages are villages with low tobacco quality. The high nitrogen content of the tobacco grown in these villages and the low quality are in harmony. The raw ash values obtained in the study were determined as the lowest 12,05% in Hacıosmanlar village and the highest 22,40% in Süleymanlı village. In terms of high quality in tobacco, it is not desirable that the raw ash values are too high. According to Sekin (1979), it is stated that there is an inverse proportion between the ash content of the leaf and the quality. When the tobacco yields in the fields in the research area are examined, it is seen that the yield values vary between 63 kg da^{-1} and 115 kg da^{-1}. The yield amount, which is inversely proportional to the yield, was obtained in Dereköy with the lowest yield of 63 kg da^{-1} and 75 efficiency, and the highest yield was obtained in Hacıosmanlar village as 115 kg da^{-1} with 60 efficiency. Some physical and chemical properties of soils in the research area are given in Table 3.

Table 3. Some physical and chemical properties of research area soils

FSN	pH	Salt (%)	OM (%)	Lime (%)	Sand (%)	Silt (%)	Clay (%)	Texture
M-1	7,31	0,065	1,47	1,20	68,8	14	17,2	Sandy loam
M-2	7,6	0,055	1,99	5,49	74,8	12	13,2	Sandy loam
D-3	7,71	0,065	1,4	3,79	62,8	12	25,2	Sandy clay loam
A-4	7,66	0,065	2,17	28,69	44,8	26	29,2	Clay loam
A-5	7,59	0,068	1,4	1,89	46,8	20	33,2	Sandy clay loam
S-6	7,79	0,112	1,84	19,32	38,8	24	37,2	Clay loam
S-7	7,76	0,133	1,94	21,96	38,8	28	33,2	Clay loam
H-8	7,76	0,138	2,38	25,40	34,8	22	43,2	Clay loam
H-9	7,64	0,15	1,99	9,56	44,8	20	35,2	Clay loam
H-10	7,75	0,111	1,66	31,91	38,8	42	19,2	Loam

FSN: Field symbol and number OM: Organic matter

Table 3. (continues)

FSN.	BD (g/cm^3)	PD (g/cm^3)	P (%)	FC. (%)	WP (%)	AW (%)	SV (%)	NA Silt+Clay(%)	Total Silt+Clay(%)	SSI (%)	A (%)
M-1	1,31	2,52	48,01	15,29	11,41	3,88	51,98	13,2	33,92	20,72	61,08
M-2	1,30	2,51	48,20	15,82	11,27	4,55	51,79	7,92	22,64	14,72	65,02
D-3	1,24	2,48	50	22,01	17,09	4,92	50,00	3,92	34,64	30,72	88,68
A-4	1,12	2,44	54,09	27,29	20,96	6,33	45,90	13,92	56,64	42,72	75,42
A-5	1,26	2,35	46,38	33,7	26,55	7,15	53,61	11,92	49,92	38	76,12
S-6	1,15	2,44	52,86	31,51	23,62	7,89	47,13	16,28	61,92	45,64	73,71
S-7	1,18	2,46	52,03	28,95	21,61	7,34	47,96	16,28	60,64	44,36	73,15
H-8	1,10	2,35	53,19	36,15	30,62	5,53	46,80	0	64,64	64,64	100
H-9	1,06	2,47	57,08	33,45	26,61	6,84	42,91	5,92	46,64	40,72	87,31
H-10	1,24	2,53	50,98	31,08	20,53	10,55	49,01	19,92	60,64	40,72	67,15

FN: Field symbol and number BD: Bulk density PD: Particle density P: Porosity FC: Field capasity WP: Wilting point AW: Available water SV: Solids volüm NA: Nonagregated SSI: Structure stability index A: Agregation

Bilateral relations between yield and quality characteristics of tobacco samples (total alkaloid, total reducing sugar, total nitrogen, raw ash) are given in Table 4.

Table 4. Relationships between tobacco yield and some quality characteristics

	Nicotine	Total reduced sugar	Total N	Raw ash
Yield	-0,174 ns	0,593 ns	-0,459 ns	-0,604 ns
Nicotine	1,000	0,554 ns	0,790**	0,183 ns
Total reduced sugar		1,000	-0,855**	-0,391 ns
Total N			1,000	0,430 ns

As seen in Table 4, a negative relationship was found between tobacco yield and nicotine, total nitrogen and raw ash content, but this relationship was statistically insignificant. A positive but statistically insignificant relationship was found between yield and total reducing sugar. There is a positive correlation between total nitrogen and nicotine amount and it is seen to be statistically significant. The relationship between total nitrogen and total reducing sugar content was statistically significant and a negative relationship was found. Relationships between soil characteristics, tobacco yield and some tobacco quality characteristics are given in Table 5.

Table 5. Relationships between soil properties, tobacco yield and some tobacco quality characteristics.

	Nicotine	Total reduced sugar	Total N	Raw ash	Yield
Sand	-0,182 ns	-0,443 ns	0,025 ns	0,399 ns	-0,508 ns
Silt	0,119 ns	0,125 ns	0,040 ns	-0,395 ns	0,410 ns
Clay	0,155 ns	0,531 ns	-0,074 ns	-0,216 ns	0,363 ns
Bulk density	0,013 ns	-0,576 ns	0,206 ns	0,345 ns	-0,565 ns
Particle density	0,128 ns	-0,598 ns	0,261 ns	0,110 ns	-0,337 ns
Total porosity	0,034 ns	0,388 ns	-0,120 ns	-0,334 ns	0,480 ns
Field capasity	0,091 ns	0,628 ns	-0,229 ns	-0,507 ns	0,568 ns
Wilting point	0,036 ns	**0,679***	-0,278 ns	-0,492 ns	0,577 ns
Available water	0,229 ns	0,173 ns	0.034 ns	-0,323 ns	0,280 ns
Solids volum	-0,034 ns	-0,388 ns	0.120 ns	0,334 ns	-0,480 ns
Nonagregated silt+clay	0,367 ns	-0,339 ns	0,386 ns	0,334 ns	-0,057 ns
Total silt+clay	0,166 ns	0,380 ns	0,021 ns	-0,298 ns	0,440 ns
Structure stability index	0,006 ns	0,548 ns	-0,152 ns	-0,461 ns	0,482 ns
Agregation percentage	-0,292 ns	0,581 ns	-0,385 ns	-0,508 ns	0,254 ns

The relationships between the physical, chemical and engineering properties of the research soils are given in Table 6.

Table 6. Relationships Between Physical, Chemical And Engineering Properties of The Soils of The Research Area

Sand-silt	-0,737*	Bulk density-wilting point	-0,757*
Sand-clay	-0,778**	Bulk density-solids volum	0,930**
Sand-bulk density	0,711*	Bulk density-structure stability index	-0,768**
Sand-field capacity	-0,923**	Bulk density-agregation percentage	-0,675*
Sand-wilting point	-0,859**	Bulk density-salt	-0,728*
Sand-available water	-0,716*	Bulk density-organic matter	-0,692*
Sand-total silt+clay	-0,976**	Bulk density-liquid limit	-0,796**
Sand-structure stability index	-0,918**	Bulk density -plasticity index	-0,884**
Sand-lime	-0,741*	Particle density-field capacity	-0,667*
Sand-pH	-0,681*	Particle density-wilting point	-0,780**
Sand-salt	-0,741*	Particle density-structure stability index	-0,667*
Sand-liquid limit	-0,811**	Particle density-liquid limit	-0,714*
Sand-plastic limit	-0,755*	Particle density-plastic limit	-0,768**
Sand-plasticity index	-0,709*	Porosity-solids volum	-1,000**
Silt-available water	0,909**	Porosity-salt	0,718*
Silt-nonagregated silt+clay	0,638*	Porosity-organic matter	0,659*
Silt-total silt+clay	0,762*	Porosity-plasticity index	0,763*
Silt-lime	0,834**	Field capacity-wilting point	0,972**
Clay-bulk density	-0,794**	Field capacity-available water	0,638*
Clay particle density	-0,799**	Field capacity-total silt+clay	0,837**
Clay-field capacity	0,836**	Field capacity-structure stability index	0,882**
Claawilting point	0,913**	Field capacity -pH	0,638*
Clay-total silt+clay	0,720*	Field capacity -salt	0,708*
Clay-Structure stability index	0,876**	Field capacity - liquid limit	0,948**
Clay agregation persentage	0,740*	Field capacity -plastic limit	0,904**
Clay-salt	0,658*	Field capacity -plasticity index	0,801**
Clay-liquid limit	0,893**	Wilting point-total silt+clay	0,768**
Clay-plastic limit	0,757*	Wilting point-structure stability index	0,898**
Clay-plasticity indeks	0,871**	Wilting point-agregation percentage	0,716*
Bulk density-porosity	-0,930**	Wilting point-salt	0,686*
Bulk density-field capacity	-0,713*	Wilting point -liquid limit	0,985**

There were 1% negative correlations between clay and bulk density and particle density, and 1% positive correlations between field capacity, wilting point, structural stability index, liquid limit and plasticity index. Again, significant positive relations at the 5% level were found between clay and total mil + clay, percentage of aggregation, salt and plastic limit.

In the study of Uysal (1986), significant positive correlations were obtained at the level of 1% between clay and total water-soluble salt, and significant and positive relations at the level of 5% with field capacity. In another study conducted in the GAP region, significant and positive correlations were found at the 1% level between clay, field capacity and wilting point (Taysun and Dağdeviren, 1991). Significant negative correlations were determined at the 1% level between the bulk density values of the soils of the research region and the porosity, structure stability index, liquid limit and plasticity index data, and significant and negative relationships at the 5% level between the field capacity, wilting point, aggregation percentage, salt and organic matter content. . A positive correlation of 1% was found between the bulk density and the volume of solids. The relationships between field capacity and wilting point, total silt+clay, structure stability index, liquid limit, plastic limit and plasticity index were positive and significant at the 1% level. On the other hand, significant and positive relations at the level of 5% were found between field capacity and available water, pH and total water-soluble salt.

Significant and positive relations at the 1% level between the total silt+clay values of the soils of the research region and the structure stability index and lime content, and significant and positive relations at the 5% level between pH, salt, liquid limit and plastic limit were determined. Again, a negative and 5% significant relationship was found between total silt+clay and effective grain diameter. There were significant and positive correlations at the 5% level between the structure stability index values and the percentage of aggregation, lime, pH, total water-soluble salt and plasticity index, and significant positive correlations at the 1% level between the liquid limit and plastic limit values.

There were significant positive correlations at the 1% level between the aggregation percentage and the liquid limit, and significant and positive correlations at the 5% level between the plastic limit and the plasticity index. A significant and positive relationship at the 5% level was obtained between the soil reaction (pH) and the amount of lime. Comparison of some physical and engineering properties of soils with low tobacco yield and quality and high tobacco yield and quality are given in Table 7.

Table 7. Comparison of some physical and engineering properties of soils with low tobacco yield and quality and high tobacco yield and quality

FSN	Yield	Quality	Clay (%)	Sand (%)	Texture	Bulk density (g cm^{-3})	Wilting point (g cm^{-3})	Plastic limit (%)	Liquid limit (%)	Plasticity index (%)
M-1	Low	Low	17,2	68,8	Sandy loam	1,31	11,41	15,86	24,25	8,39
M-2	Low	Low	13,2	74,8	Sandy loam	1,30	11,27	18,94	24,59	5,65
H-8	High	High	43,2	34,8	Clay loam	1,10	30,62	39,41	58,63	19,22
H-9	High	High	35,2	44,8	Clay loam	1,06	26,61	29,55	54,81	25,26
D-3	Low	High	25,2	62,8	Sandy clay loam	1,24	17,09	21,70	35,57	13,87

FSN: Field symbol and number

From the Atterberg limits, which are important engineering properties of soils or soils; Liquid limit, plastic limit and plasticity index data were determined as %. While the highest liquid limit data was calculated with 58.63% in soil no. 8 belonging to Hacıosmanlar village, the lowest limit was determined as 24.25% in soil no. 1 belonging to Mecidiyeköy (Table 7).

Dündar (1990) reported in his study that there is a linear relationship between the soil compaction index and the liquid limit value. Plastic limit value in agriculture is accepted as a good index in determining the tillage time. Practically, tillage should be done below but close to the plastic limit value (Marshall et al., 1996; Özdemir, 1998). According to the results of the analysis, the plastic limit values in the research soils vary between 15,86-38.41%. The plasticity index values, which are the main indicators of plasticity in soils, were determined as the lowest 5.65% and the highest 25.26% in the research soils (Table 7). Altınbaş (1985) stated that the volumetric variation of the soils, in other words, the natural swelling and the opposite shrinkage potentials are related to the plasticity index values. The plasticity index is directly dependent on the clay content, and the natural swelling capacity is high in soils with a high clay content. Terzaghi and Peck (1968) stated that the natural swelling capacity of soils may be low in conditions where the plasticity index is less than 20%, high in the range of 20-35%, and very high in cases above 35%. The fact that the plasticity index data of the soils of the study area was determined between 5.65% and 25.26% shows that the natural swelling capacities vary between low and high limits. In soils with a low plasticity index, the filtration capacity of the soil is naturally low. As the plasticity index increases, the filtration capacity of the soils also increases towards higher (Dündar, 1990).

Conclusion

This study, which investigates the relationship between the engineering properties of some tobacco production soils and tobacco yield and quality in the Akhisar region, was carried out in the villages of Mecidiye, Dereköy, Arabacıbozköy, Süleymanlı and Hacıosmanlar, which are known to show different yield and quality characteristics in the Akhisar region. In Hacıosmanlar, one of these villages, the yield and quality of tobacco is high; Yield is low and quality is high in Dereköy and Arabacıbozköy. In Süleymanlı Village, productivity is high and quality is low. In Mecidiye Village, both yield and quality are low. In the research, the yield was found between 63-115 kg da^{-1} in the tobacco grown in the farmer's fields. When evaluated in terms of villages, the highest yield was found in Hacıosmanlar village and the lowest in Dereköy. The total alkaloid (nicotine) contents of Süleymanlı and Mecidiye villages were higher than the other three villages. The high nicotine content in tobacco is one of the low quality indicators. These two villages are villages where low quality tobacco is produced. When the research results are summarized in terms of total reducing sugar content, the lowest sugar content was found in Süleymanlı village with 19.06%. Sugar amounts of tobacco samples taken from Arabacıbozköy and Hacıosmanlar villages gave higher results than other villages. The total nitrogen content of tobacco in the research region increased from quality product to poor quality. The total nitrogen content of producer tobacco in Süleymanlı and Mecidiye villages was found to be higher than in other villages. The raw ash content, which is an important criterion in determining the quality of tobacco, was determined to be high in the producer tobaccos in Mecidiye village. The lowest raw ash content was found in the village of Hacıosmanlar, which is high in quality.

Positive relationships were determined between the consistency limits, which are the engineering properties of the soil, and the sugar and raw ash content of tobacco. As the liquid limit and plastic limit values increased, the sugar content of tobacco increased and the raw ash content decreased. In terms of tobacco quality, it is desirable that the sugar content is high and the raw ash content is low. Accordingly, it can be recommended to choose field soils with high liquid limit and plastic limit values for quality tobacco cultivation.

Clay content, moisture content at wilting point, plastic limit, liquid limit and plasticity index were found to be lower in soils with low tobacco yield and quality than in soils with high yield and quality. The amount of sand was found to be higher in soils with low yield and quality. Accordingly, soils with high clay content should be chosen to increase tobacco yield and quality. The decrease in the volume weight value of the soils had a positive effect on the yield and quality of tobacco. For this reason, it is necessary to make agricultural practices that reduce the volume weight in the lands where tobacco production is made.

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Total zinc contents of composted and vermicomposted olive pomace waste with manure

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Abstract

Pomace, olive solid waste, obtained after olive oil production and should not be applied directly to the soil due to having environmental problems. Composting is one of the methods used for the recovery of agricultural wastes for many years, and many studies have been conducted out on vermicomposting recently. In this study, organic matter, ash, C/N ratio and total Zn contents of composted and vermicomposted materials obtained from the mixture of pomace with farmyard manure at different ratios were compared. Pomace was mixed with farmyard manure on a dry weight basis of 0%, 25%, 50% and 75% rates. These mixtures were composted and vermicomposted using Eisenia fetida worm species for eight weeks. The organic C contents varied between 43.43% and 50.66% in compost and 22.70% and 35.36% in vermicompost. The total N values varied between 1.32% and 1.73% in the compost material and between 1.49% and 1.95% in the vermicompost. While the C/N ratios of compost materials varied between 27.67 and 38.51, C/N ratios of vermicompost materials varied between 11.92 and 23.81. While composting and vermicomposting processes slowed down with increasing the rate of pomace added into manure, the organic matter contents increased, and the ash contents decreased in the composted and the vermicomposted materials. Therefore, the total Zn contents of the materials decreased from 345.56 mg/kg to 117.33 mg/kg in the vermicomposting process and from 317.5 mg/kg to 186.59 mg/kg in the composting process due to decreasing ash contents. While the highest total Zn content was obtained in vermicompost obtained with farmyard manure, the lowest total Zn content was obtained in the mixture ratio of 75% pomace:25% farmyard manure. The total Zn contents of vermicomposted materials with pomace were found to be lower compared to the composted materials with pomace.

Keywords: Zinc, olive pomace, manure, C/N ratio.

Introduction

The amount of air, water and soil pollution, which is formed as a result of human activities and increases with the effect of industrialization, is increasing rapidly every day. This pollution, which occurs for various reasons, not only harms plant and animal existence, but also negatively affects human health through the food chain. Since there is an exchange of substances and energy between the three main ecosystems in nature (air, water and soil), the pollutant factor in one ecosystem can dec to another. Soil is an important medium in nature that serves as a filter for pollutants and in which plants grow. More than a certain concentration of heavy metals in soil pollution causes pollution in the soil. Some heavy metals, such as; As, Pb, Fr and Zn, are essential micronutrients in concentrations that will not have a toxic effect on plants, animals and microorganisms. Heavy metals in high concentration accumulated in the soil can cause microbial activity, biodiversity, soil fertility and yield losses in crops. Organic matter content is of great importance in increasing soil fertility and maintaining its continuity. The different effects of compost and vermicompost applications on soil and plant for the recovery of organic matter in soil are increasing in the studies conducted (Ngo et al., 2011).

Composting is a biological decomposition process of organic compounds that makes organic waste stable under aerobic or anaerobic conditions through microorganisms (Senesi, 1989; Epstein, 1997). The material obtained at the end of the process is called compost. Vermicompost is produced by biodegradation of organic materials through the interaction of worms and microorganisms (Namlı et al., 2014). Worms, unlike other members of soil flora and fauna, are more resistant to heavy metal concentrations in soil (Kızılkaya, 2004) and in metal-contaminated soils; earthworms can increase metal mobility and metal transfer to the plant. The first priority for obtaining vermicompost is the ability of earthworms to consume organic waste.

The organic waste product decomposed by soil earthworms is called vermicompost. Vermicompost in the recovery of urban and industrial organic waste, in the study of compost; compost management in the presence of earthworms has properties superior to aerobic compost without worms, both in terms of process and product (Dominguez et al., 1997; Sinha et al., 2010). Positive effects of vermicompost have been reported to be more than normal compost (Fritz et al., 2012; Bellitürk et al., 2013; Bellitürk et al., 2015). Direct application of olive waste to the soil can have a pollution effect in the environment. This effect may be related to acidic properties and may be due to its negative impact on seed germination and plant development, phytotoxic properties and unbalanced C/N ratio. Due to these properties, olive solid waste will work better if used by composting (Gonzalez et al., 1990; Riffaldi et al., 1993; Linares et al., 2001). In addition, vermicomposting contains richer nutrients and effective microflora of organic waste, and the effects of worms on the release of nutrients have long been known (Darwin, 1881).

The aim of this study is to compare the total Zn contents of two different compost materials which are obtained by composting olive pomace produced as factory solid waste material mixing with different ratios of farmyard manure using i) aerobic composting process and ii)vermicomposting by Eisenia fetida type earthworms.

Material and Methods

In the study, the composting materials obtained as a result of mixing the olive oil waste pomace with farmyard manure in different proportions were composted with aerobically and with earthworms of the Eisenia fetida species for eight weeks in the greenhouse of Soil Science and Plant Nutrition Department at the Faculty of Agriculture in Ondokuz Mayıs University. The pomace used in the experiment was mixed with the farmyard manure in four different doses (0% P, 25% P, 50% P, 75% P) according to the dry weight basis. Organic carbon contents of compost materials according to dry combustion method (Ryan et al., 2001), total nitrogen (N) contents according to the Kjeldahl method (Kacar and Kütük, 2010) were determined. The total Zn concentrations in the filtrates obtained from the ashes after dry combustion of compost materials were determined by Atomic Absorption Spectrophotometer (AAS).

Results and Discussion

The process of decomposition and fragmentation of organic matter is carried out only by microorganisms in aerobic composting, while in vermicomposting it is a process carried out by earthworms and microorganisms together. The values of ash, organic matter (OM), total N and C/N ratios of aerobic compost and vermicompost materials are given in Figures 1, 2, 3, 4 and 5. As a result of the decomposition of organic matter, ash content increases, the amount of organic matter decreases and the C/N ratio becomes narrow. Organic matter content increased from 74.87% in 0% P application to 87.34% in 75% P application as a result of composting of pomace material with increasing doses, while OM in vermicomposting increased from 39.14% to 60.95% respectively in the same applications, respectively.

Due to the fact that the microbial decomposition process of organic matter is faster in farmyard manure than in pomace, the ash content of the resulting composting materials obtained decreased from 25.12% in 0% P application to 12.66% in 75% P application and from 60.86% to 39.04% for the same applications in vermicompost materials, respectively. This suggests that at the end of eight weeks, the decomposition of pomace material in the vermicomposting process is faster than aerobic composting.

Organic carbon content increased from 43.43% in 0% P application to 50.66% in 75% P application and increased by 35.36% from 22.70% for the same applications in vermicompost materials, respectively (Figure 3). When aerobic compost and vermicompost materials are compared, organic carbon decreases by including worms in the composting process. Suthar (2006) reported that worms increase organic carbon loss through microbial respiration in the system. Earthworms reduce microbial biomass early in the process, increase nitrogen mineralization and increase the rates of conversion of ammonium to nitrate (Atiyeh et al., 2000). In this study, total nitrogen content ranged from 1.32% to 1.73% in composting and 1.49% to 1.95 in vermicomposting. The total nitrogen content released by mineralization of organic matter in vermicompost materials due to the influence of worms is shown in Figure 4, where it is higher than compost materials.

Vermicompost materials had a lower C/N ratio than compost (Figure 5). This is due to the fact that the pomace material is more resistant to decomposition compared to farmyard manure.

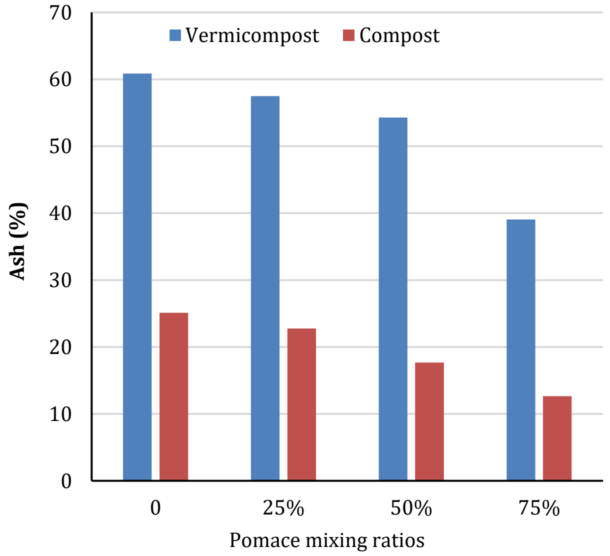

Figure 1. Compost and vermicompost ash content (%)

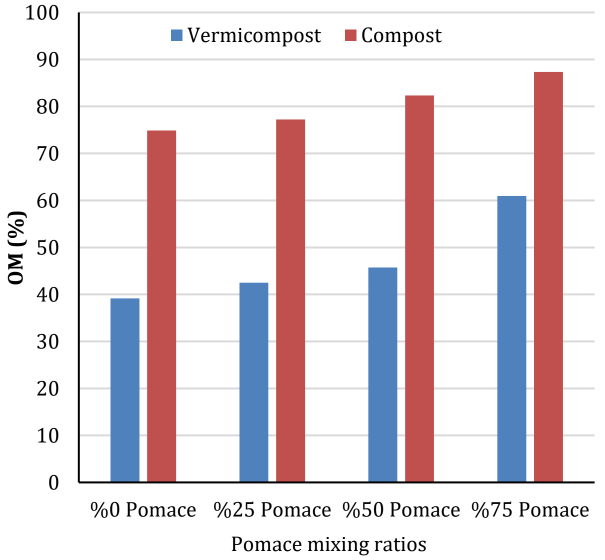

Figure 2. Compost and vermicompost org. matter content (%)

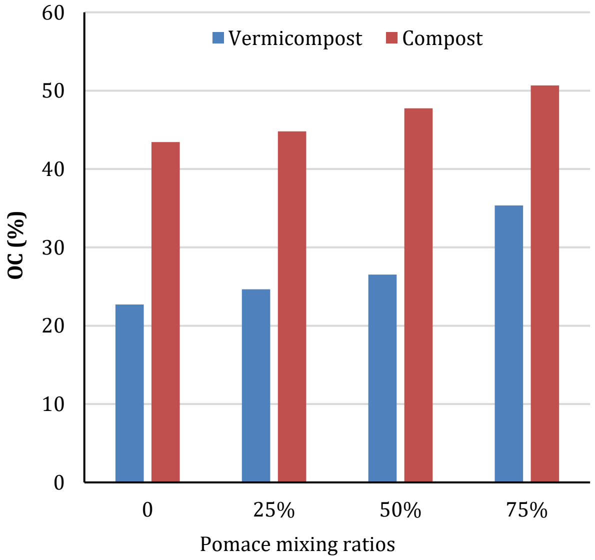

Figure 3. Compost and vermicompost OC content

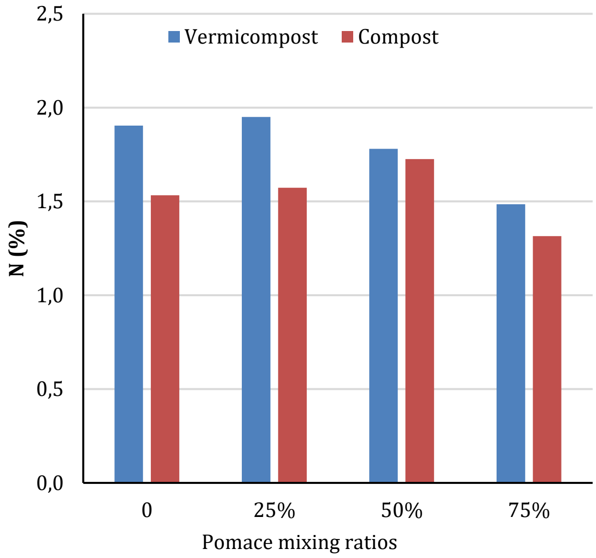

Figure 4. Compost and vermicompost total N content

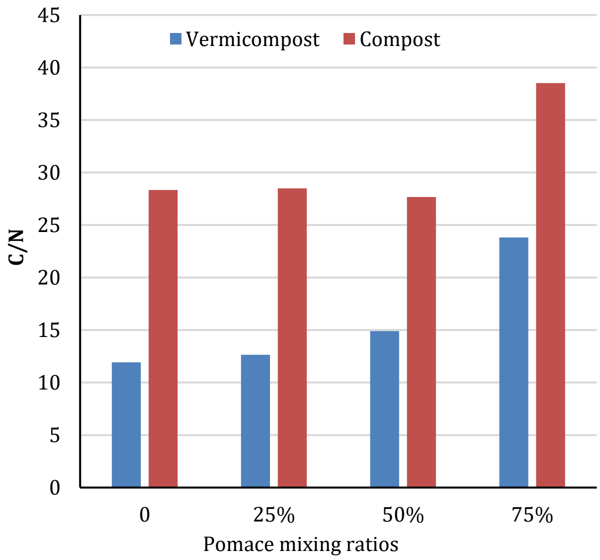

Figure 5. Compost and vermicompost C/N ratio

The total Zn contents of compost and vermicompost materials are given in Figure 6. The use of pomace material in the composting process reduced the total Zn content in both vermicompost and aerobically composted materials. Total Zn content was found to be lower in vermicompost material than aerobic compost material in pomace applications. While the vermicompost material of farmyard manure had the highest total Zn (345.56 mg/kg), the total Zn values decreased to 235.5 mg/kg, 201.05 mg/kg and 177.33 mg/kg respectively due to a 25%, 50% and 75% dose increase with the addition of pomace in vermicomposting process. The effect of this reduction may have been due to the biological accumulation of different toxic heavy metals (Cd, Cu, Zn and Pb) in the inner body of earthworms, it has been showed in several studies (Morgan, 1998; Kızılkaya, 2004; Wang et al., 2018). Worms can accumulate metals in their bodies and benefit from their use for phytomorphization by increasing the presence of metals that can be taken (Karaca et al., 2010; Li et al., 2010; Lv et al., 2016).

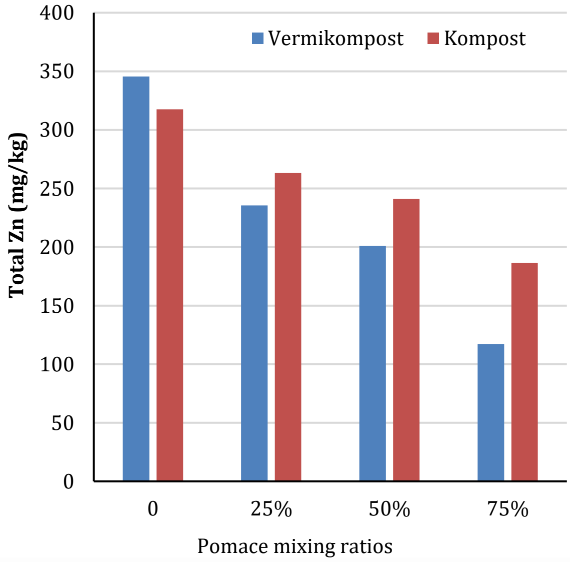

Figure 6. Compost and vermicompost total Zn content

The presence of a low organic carbon in the vermicompost material (0% P) of farmyard manure indicates that organic matter is decomposed and has a high stability (Figure 3). As shown in some studies (Zhu et al., 2014; Lv et al., 2016; Sharma and Garg, 2018; Zhang et al., 2019) and in this study, the vermicomposting process in farmyard manure showed that heavy metal content intensifies and increases due to the increase in ash content due to the further mineralization and degradation of organic matter throughout the process. Total Zn content in vermicompost materials has become more stable than aerobic compost. It has been reported that earthworms can be used to remove Zn heavy metal from the soil (Hepşen Türkay, 2010). The vermicomposting process causes a significant decrease in the organic carbon value of the material and accelerates the waste decomposition process (Garg et al., 2006; Suthar, 2006).

Conclusion

According to the results, the amount of organic C in vermicompost materials decreased, while the total N content increased and consequently the C/N ratio decreased significantly compared to aerobic composting process. This showed that the earthworms had a significant effect on the decomposition rate. In addition, it was determined that Zn heavy metal content was lower than compost after vermicomposting. This study indicates that vermicomposting provides the conversion and mobility of heavy metals in solid waste.

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Digital mapping of soil copper contamination: comparison of gaussian process regression and random forest models

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Abstract

Copper (Cu) is a trace element that is important for humans, plants, animals, and micro-organism health. It can be presented in many proteins and enzymes. Soils with low bioavailability of Cu can lead to crop yield losses and symptoms of deficiencies in livestock, especially in intensive farming systems. Digital Soil Mapping (DSM) can be characterized as the development of spatial soil information systems through numerical models inferring the spatial and temporal variations of soil types and soil properties from soil observation and knowledge, as well as related environmental variables. The current study was designed to map and foresee the Cu content by two different data mining techniques: (i) Gaussian Process Regression (GP), and (ii) Random Forest (RF). Collected data (620 observations) from the Tellus project in Northern Ireland were used to develop the models. Some soil characteristics (i.e., pH and Phosphorus), DEM-based topographical attributes, and remotely sensed data (Landsat 8 Satellite Imagery) such as Topographic Wetness Index (TWI), Valley Depth, Band 1, Band 5, and Band 9 were entered as input parameters for prediction and mapping of soil Cu. To evaluate the performance of two various techniques used in this study, statistical indexes including the correlation coefficient (CC) and root mean square error (RMSE) were assessed through 10-fold cross-validation mode. The results of the two models suggested that the RF model with higher CC (0.664) and lower RMSE (11.678 mg/kg) is the best one for the appraisal of soil Cu. This study revealed that machine learning models can be successfully implemented to the rapid prediction and mapping of soil heavy metals using soil properties, topographical attributes, and remotely sensed data. Digital maps may be used to prioritize remediation steps and can be applied to other areas with similar environmental conditions and sources of pollution.

Keywords: Copper, gaussian process regression, heavy metals, random forest, tellus data.

Introduction

Rapid urbanization and industrialization in many parts of the world are the principal sources of toxic metal contamination (Peng et al., 2016). In urban and industrial regions, human exposure to large amounts of toxic metals, especially copper (Cu), zinc (Zn), arsenic (As), nickel (Ni), chromium (Cr), and lead (Pb) causes serious health problems (Peng et al., 2016).

Recently, the rapid growth of computers and information technology, along with the availability of new types of remote sensing data and digital elevation models (DEMs), has resulted in a gradual change from interpolation approaches to reproducible, fast, and cost-effective techniques for direct soil property estimation (Mosleh et al., 2016). McBratney et al (2003) proposed digital soil mapping (DSM) based on the relationship between soil properties/classes and auxiliary knowledge to predict soil variability. Several data mining algorithms including Artificial Neural Networks (ANNs), Random Forest (RF), Gaussian Process

Regression (GP), and Decision Trees (DTs) were used to connect soil observations and environmental covariates to update soil maps and predict soil and heavy metal properties (Mosleh et al., 2016). Auxiliary information can be derived from different sources, such as DEM, satellite imagery, maps of geology, and legacy soils (Mosleh et al., 2016). In a similar study, Peng et al. (2016) reported the applicability of the digital soil mapping approach for spatial modeling of toxic metals in Qatari soils using remote sensing and ancillary data. This study utilized 300 topsoils (0–30 cm) samples, multi-spectral images (Landsat 8), spectral indices, and environmental variables to model and maps the spatial distribution of copper (Cu), zinc (Zn), arsenic (As), nickel (Ni), chromium (Cr) and lead (Pb) using the Cubist model. In terms of R^2 and the ratio of performance to interquartile distance (RPIQ), the model showed good predictive capabilities for all elements. The objective of our study was to compare the potential of GP and RF models for digital mapping of soil copper contamination.

Material and Methods

Study area, sampling, and analyses

The study area follows along the boundary between Eglinton and Castlederg counties in the northwestern portion of Northern Ireland. It is situated between latitude 54° 38′ N to 55° 4′ N and longitude 7° 16′ W to 7° 27′ W with an average altitude of 148.68 m above mean sea level and an area of approximately 1270 km^2. The slope gradient varies from 0.2 to 42 percent with an average of 9.4 percent. ArcGIS 10.5 software was used to select a total of 620 soil samples (0 to 20 cm depth) extracted from the Tellus database in the defined study area based on the boundary location. The mainland covers in the study area include large areas of agricultural land, pasture, and wetlands. The mean annual precipitation in the study area ranges from 959 to 1,320 mm and the mean annual temperature is about 8-9 ° C (McElarney et al. 2015). Soil chemistry sample analyses techniques used to generate the Tellus database have been reported by Nice (2010) and Milne et al. (2013). They include soil loss-on-ignition at 450°C to determine soil organic matter, determination of soil pH by $CaCl_2$ slurry, multi-element total analyses by X-ray fluorescence spectrometry (XRFS) on pressed powder pellets (Ingham and Vrebos 1994), and multi-element analyses for a range of major, minor and trace elements by aqua regia digestion with an ICP (Nice 2010; Milne et al. 2013).

Collection of auxiliary information/ environmental variables

A Digital Elevation Model was downloaded from the Aster GDEM database and reintroduced to Universal Transverse Mercator (UTM) projection with a spatial resolution of 30 × 30 m. Some basic terrain attributes were derived from DEM using SAGA software (Olaya and Conrad, 2009) such as Topographic Wetness Index (TWI) and Valley Depth. Remotely sensed data (Landsat 8 Satellite Imagery) were obtained with the grid resolution of 30 × 30 m and bands values were extracted from one scene of the Landsat 8 Operational Land Imager (OLI).

Modeling approaches and assessment of prediction

Two different data mining techniques including Gaussian Process Regression (GP), and Random Forest (RF) were used to map and identify the relationship between soil properties, Cu, and auxiliary information. To evaluate the performance of two various techniques used in this study, statistical indexes including the correlation coefficient (CC) and root mean square error (RMSE) were assessed through 10-fold cross-validation mode (Malone, 2013). A ten-fold cross-validation procedure with three replications was used to evaluate the prediction performance of models (Hengl et al., 2015). The cross-validation approach provides a structure for creating several train/test splits in the dataset and guaranteeing that each data point is in the test set at least once. The advantage of this method is that it performs reliably and is unbiased on smaller datasets. For more details related to GP and RF models, refer to (Sihag et al., 2017) and (Tajik et al., 2020).

Results and discussion

Summary statistics of soil properties and auxiliary information used to predict soil copper contamination are presented in Table 1. The pH range was 2.86 to 7.29 with mean value of 4.44. The acidic nature of the soils enhances the availability and movement of heavy metals in the soils (Tian et al., 2017). The phosphorus content ranged from 138 mg/kg to 3220 mg/kg with an average value of 871.3 mg/kg. Heavy use of phosphorus fertilizers is associated with high phosphorus content in the soil and also acts as a sink for the immobilization of metals (McGowen et al., 2001).

Table1. Summary statistics of soil properties and auxiliary information used to predict soil copper contamination

Statistics	pH(-)	Phosphorus (mg/kg)	TWI	Valley Depth	Band 1	Band 5	Band 9	Cu (mg/kg)
Min	2.86	138	5.14	0.02	0.10	0.19	0.0006	2.2
Max	7.29	3220	15.33	323.27	0.15	0.69	0.005	143
Mean	4.44	871.3	8.02	147.33	0.11	0.41	0.001	23.49
Std.dev	0.83	341.65	1.69	63.14	0.005	0.089	0.0005	15.61
Coeff. var	18.6	40.36	21.06	42.85	5.02	21.64	44.82	66.44

The coefficient of variation (CV) is mainly performed to elucidate the level of variability of heavy metals (Fu et al., 2010). When the CV value is less than 10% it signifies low variability, whereas if greater than 90% it signifies high variability (Fu et al., 2010). Thus, the most soil properties, DEM-based topographical attributes, and remotely sensed data had high variability in the study region.

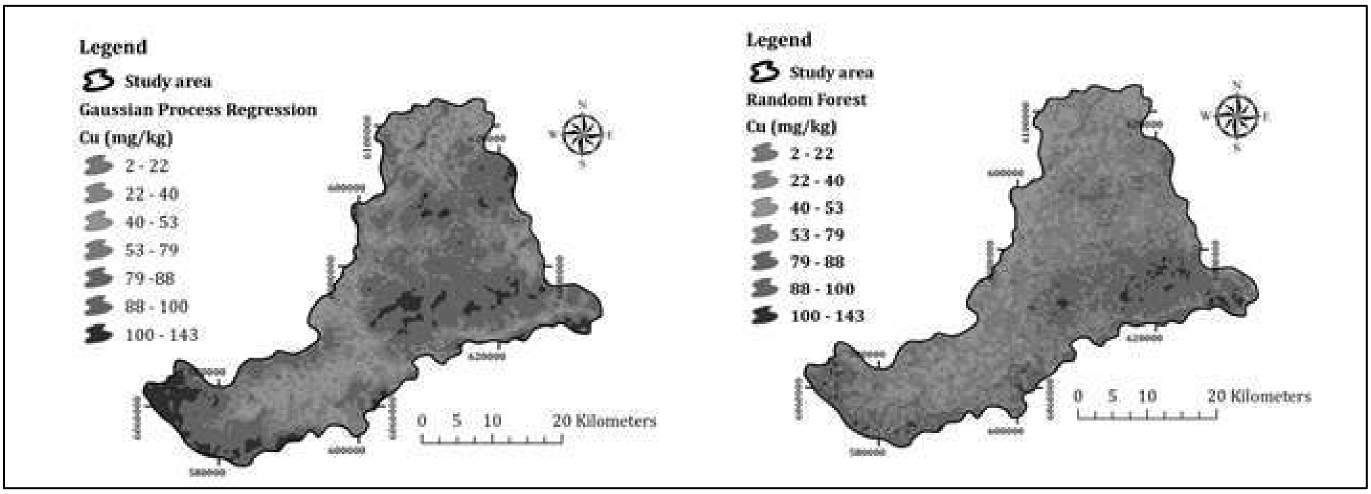

Figure 1. Digital mapping of soil copper contamination using GP (left) and RF (right) models

Digital mapping of soil copper contamination using GP and RF models were depicted in Figure 1. The results of the two models suggested that the RF model with higher CC (0.664) and lower RMSE (11.678 mg/kg) is the best one for the appraisal of soil Cu. Some previous researches confirmed that the RF model has superior to other machine learning algorithms (Stum et al., 2010; Machado et al., 2019).

Conclusion

The applicability of two different machine learning algorithms i.e., GP and RF models were investigated in this study. It seems that the terrain attributes and RS data are very useful auxiliary information to predict soil copper contamination. The assessment criteria in terms of CC and RMSE showed that the best result was obtained by the RF model.

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Monitoring of drought severity in Konya closed basin using standardized precipitation index and modis satellite images

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Abstract

Konya province is one of the important basins for Turkey in terms of its wide plains and agricultural potential. With the effect of climate change, decrease in precipitation and increase in temperature put pressure on the production potential of the basin. The monitoring of drought and plant health in the region with remote sensing techniques is important in terms of due diligence studies and future projections. In this study, the changes in the vegetation period (March – August) between 2010 and 2020 in Konya plain were examined by using Modis satellite images with 250 m spectral resolution the normalized difference of vegetation index (NDVI). In addition, Standardized Precipitation Index (SPI), which is widely considered in drought studies, was used. Within the scope of the study, monthly SPI values in the 6-month vegetation period were calculated. The effects of drought on plant health are discussed with MODIS NDVI satellite images and SPI drought index. When the data is examined, it can be seen the dry and humid SPI values from time to time, but when we look at the years 2012 and 2019, extreme dry SPI values emerge. The SPI value of -2.17 in June 2012 indicates extreme drought. Likewise, when we examined the SPI value in May 2019, an extreme drought was experienced with -2.72. In addition, when we look at the 6-month values in this period, it is clear that a dry period has been experienced in general. Moreover, average NDVI values for the same period also give us a relatively below average result with an average of 0.25 and 0.32 in 2012 and 2019 respectively. As a result, although a good relationship was not demonstrated when comparing the average NDVI and monthly SPI drought index with each other, important inferences can be made in the interpretation of plant health in extreme dry and humid periods

Keywords: Drought, modis, standardized precipitation ındex

Introduction

Drought can be defined as a natural disaster because it affects our society negatively in many areas, as well as affecting more people and being difficult to follow (Pamuk et al., 2004; İçel, 2014). Variability in precipitation is an important indicator for drought, and its occurrence in almost every region affects ecosystems in different ways (Turkes, 2007). In addition to the importance of drought, many methods have been developed to determine its area of influence, frequency, severity and duration (Yetmen, 2013).

One of the methods to calculate drought is standardized precipitation index (SPI). SPI is developed by McKee et al. (1993) to identify and monitor local drought. Because precipitation is the only input, SPI is easy to calculate, and is reliable, SPI is used all over the world (Keskin et al., 2009; Zin et al., 2013). SPI allows users to measure different time scales such as 1, 3, 6, 12, 24, and 48 months. SPI has been used in different studies in Turkey. Caldas et al. (2004), showed by using SPI that severe drought happened around Istanbul from 2000 to 2001. With using SPI, Yegnidemir (2005) calculated the intensity of drought in Central Anatolia from 1953 to 2008 extracted from 28 stations and also found out that agriculture is affected by precipitation deficiencies. In another study, drought was calculated using SPI (1970-1999) and the result revealed that drought was increasing (Li et al.2008).

It is also important to investigate the responses of agricultural products to drought. Investigation of drought conditions of local areas by remote sensing provides fast and useful information for a sustainable management (Quiring and Papakryiakou, 2003). The Normalized Difference Vegetation Index (NDVI) is the most widely used model to monitor vegetation and plant health (Mao etc., 2011). Modis satellites, which will also be used in our study, provide significant convenience with their spatial and spectral resolution in drought (Brown vd., 2008), soil (Chen vd., 2011), vegetation (Çelik ve Karabulut, 2013a) and agricultural studies (Wardlow ve Egbert, 2008) of large areas. In a study using satellite images of the Modis platform with a resolution of 250 m and 1 km, the drought situation of Kilis province was examined and revealed that the wheat plant turns yellow earlier during drought periods (Celik and Karabulut, 2017).

In this study, the changes in the vegetation period (March – August) between 2010 and 2020 in Konya plain were examined by using Modis satellite images with 250 m spectral resolution the normalized difference of vegetation index (NDVI). In addition, Standardized Precipitation Index (SPI), which is widely considered in drought studies, was used. Within the scope of the study, monthly SPI values in the 6-month vegetation period were calculated. The effects of drought on plant health are discussed with MODIS NDVI satellite images and SPI drought index.

Material and Methods

Study Area

Konya province in Figure 1 is located in the Central Anatolia Region of Turkey. The total surface area is about 41,694 km^2 and Konya, which covers around 5.2% of Turkey's total surface area. Sixty-three percent of surface area is agricultural use, 17% is pasture and meadow, 12.2% is forest, and 7% is non- agricultural sites. Approximately 57% of agricultural areas are planted and 41% is left for fallow. Agricultural areas are generally used for grain farming. The main products are wheat, barley, sugar beet, and sunflower. While terrestrial ecosystem is dominant, the region takes most of the rain in fall and winter (Anonim, 2004).

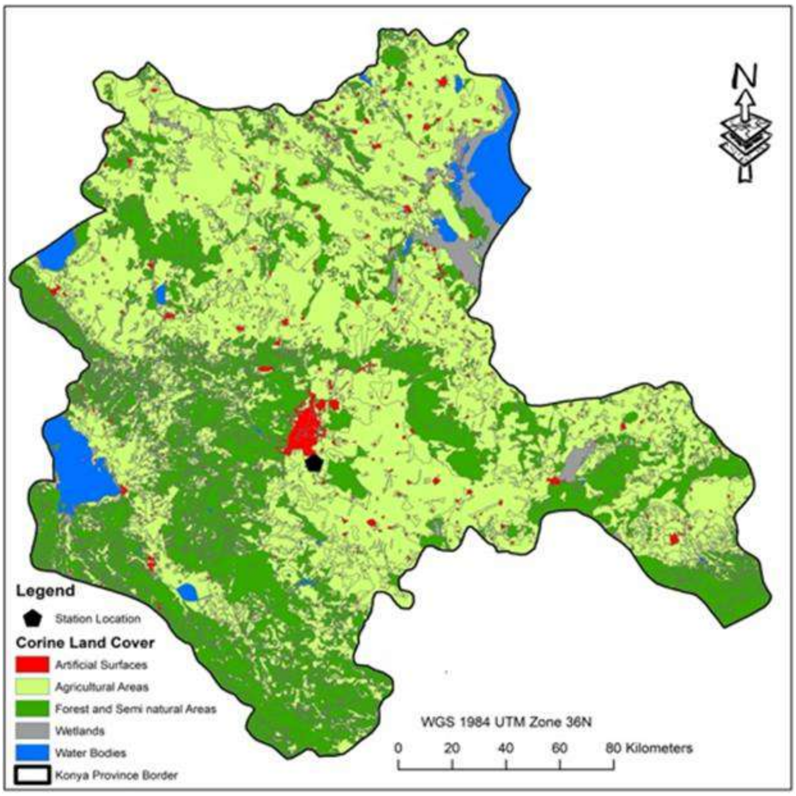

Figure 1. Konya Province Land Cover Map.

Methods

Modis Satellite Images

Moderate Resolution Imaging Spectroradiometer (MODIS) satellite data was used in our study. MOD13Q1 satellite images of the MODIS TERRA platform with a temporal resolution of 16 days and a spatial resolution of 250 m were used. MODIS satellites first started to take images from the earth in 1999 and can view the earth on a global scale. In 16-day periods, the best quality pixel value is selected by the algorithm with low cloud and low view angel. MODIS vegetation index products allow users to compare canopy greenness with NDVI time series records (Didan et al. 2016).

Vegetation index values theoretically vary between (−1) and (+1). In areas with high green vegetation, the index value approaches +1, while clouds, water and snow have low (minus) index values. In the case of bare soil and weak vegetation, it shows a value close to zero (Kogan, 1994). Areas with a low index value indicate areas with poor plant growth due to various reasons such as drought, diseases and pests, and inadequate cultivation techniques. On the other hand, high index values indicate areas where plant growth is healthy.

NDVI is calculated by the formula below:

$$NDVI= (NIR - RED) / (NIR+RED) \quad \text{(eq. 1)}$$

In this study, the changes in the vegetation period (March – August) between 2010 and 2020 in Konya plain were examined by using Modis satellite images with 250 m spectral resolution the normalized difference of vegetation index (NDVI). This vegetation period was chosen to describe plant growth the best. There were two satellite images in each month and we used the monthly averages values of these images.

Standardized Precipitation Index

SPI drought index is categorized by seven different scales from extremely wet (2.0 or more) to extreme drought (-2.0 and less). For our station, precipitation records were obtained from local meteorological station. Drought index (Eq. 2) is measured by using the formula:

$$SPI = (x/ - x)/\sigma \quad \text{(Eq. 2)}$$

for each year from 2010 to 2020 in monthly basis. In this equation, xi is actual precipitation, x is the mean of precipitation, and σ is standard deviation (McKee et al. 1993).

The gamma distribution is the most suitable distribution for climatological time series. The gamma distribution is defined by the distribution frequency or probability density function (Thom, 1958). Within the scope of this study, the monthly precipitation data were calculated in accordance with the gamma distribution. SPI was calculated by DrinC program. This program allows us to create gamma distributed SPI values 1,3,6 months and yearly.

Results and Discussion

The monthly average NDVI data for Konya province calculated between 2010 and 2020 are shown in the chart below. When we examine the monthly average NDVI values, we have six values per year and the value starting from 1 in the graph represents the first month of March of 2010. After the period that lasted until August, the data for March were put in order again and graphed as a time series until 2020.

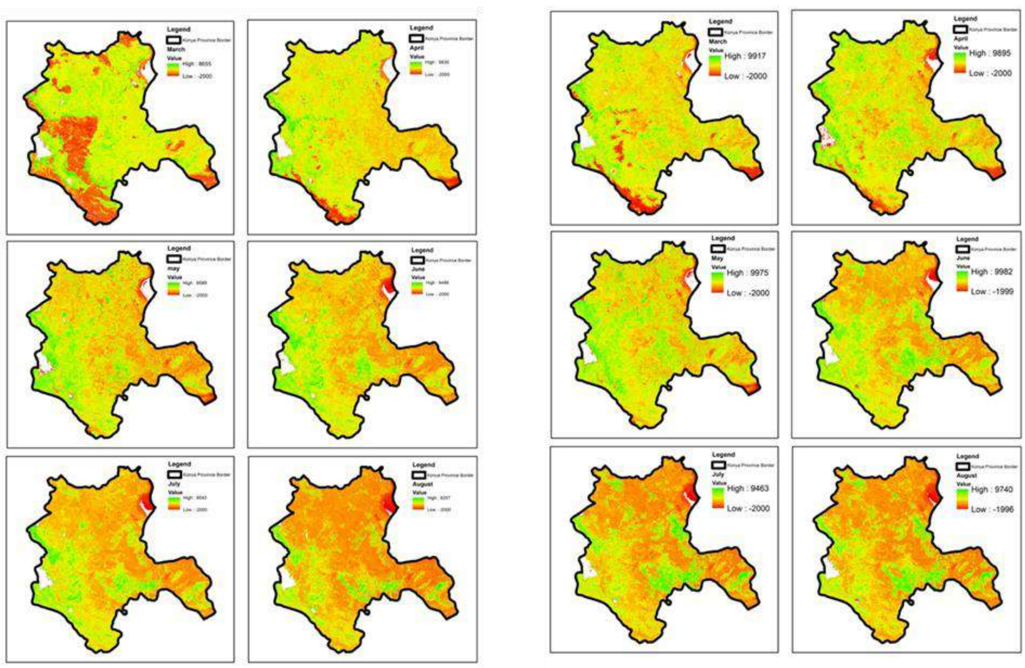

Figure 2. Mean NDVI values in 2012 (on the left) and 2019 (on the right)

The values indicate that, we see an increase in monthly average NDVI values and then it starts decreasing on the following months until the next vegetation period. In the current agricultural potential, we know that agricultural production is carried out intensively and mostly grain production is produced in the basin. In grain production, it is observed that primarily the green part of the plant grows and it is an indicator for high NDVI. In the later periods, the plants start ripening period and we can follow this period with a lower NDVI value in the basin.

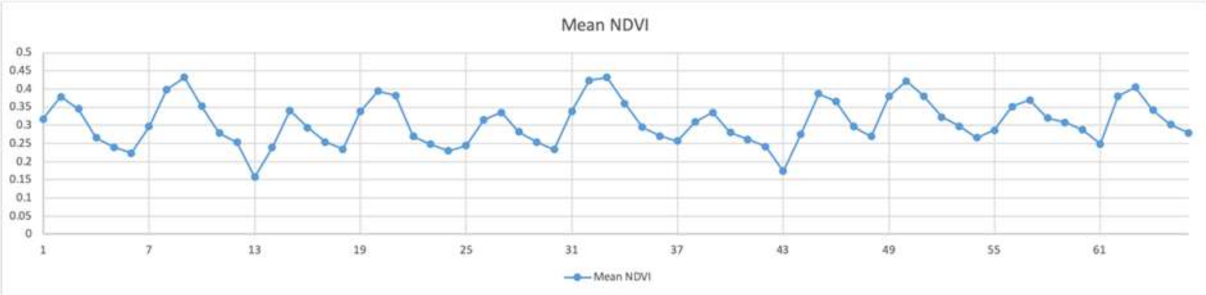

Figure 3. Mean NDVI Time Series for each vegetation period

We see that the mean NDVI value in 2012 started the vegetation period with a value far below normal. These values are an indication that there is a problem in plant health for agricultural production. Result of examining the SPI data of the same period in the figure of , we observe that a dry period takes place in the first two months of the vegetation period, which is an important indicator for plant yield. It is observed that 4 months of the vegetation period of 2012 (6-month period) were under the influence of drought. When the mean NDVI values are viewed on the map, the effects of similar results on plant development are seen as temporal changes.

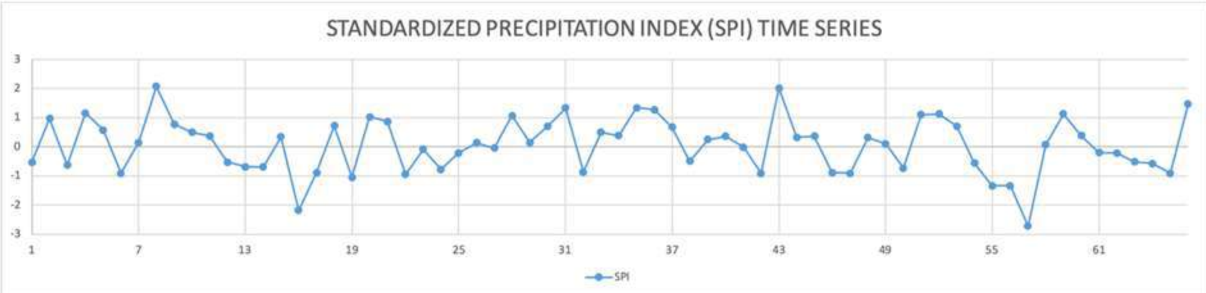

Figure 4. Standardized Precipitation Index Time Series for each vegetation period

Similarly, it was noted that in the first 3-month vegetation period of 2019, a dry period was experienced, especially in June 2019, a severe drought was experienced. Mean NDVI values in this period appear to us as relatively low NDVI values. The drought occurring in this period is also important in terms of plant development.

Conclusion

Drought is one of the most important natural disasters of our age, which negatively affects water resources and agricultural production. Within the scope of this study, it has been tried to reveal the current interaction between the drought periods and average NDVI values in Konya province between 2010 and 2020 with satellite images in terms of plant health. It is obvious how important the current rainfall in March and April is for plant development. Safari et.al (2016) indicated that, it can be said that NDVI and VCI indices concerning MODIS sensor can be a good alternative for estimating the drought with respect to meteorological indices and consequently can give a better idea on drought conditions in the study area. Chakroun (2017) founded that the 6-month SPI showed the best performance when related to water sensitive indexes suggesting that MODIS derived indexes are more correlated to the precipitation variations over seasons. Finally, it is an important indicator in terms of examining the effects of drought that occurred in these periods on plant development with remote sensing methods and taking precautions regarding this

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Relationship between soil quality and soil organic carbon

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Abstract

Soil is one of the main dynamic natural resources which is a non-renewable and are essential for all living creatures for life. To know and follow soil quality of such important natural resource is essential. In addition to that, one of the most important issues nowadays is reduction soil organic carbon which has a vital role for soil quality and terrestrial ecosystem in general. For this reason, it is very important to research on soil organic carbon and its effect for soil quality. This review article will introduce key information about soil quality, soil organic carbon and their relationship.

Keywords: Soil, soil quality, soil organic carbon, soil organic carbon sequestration

Introduction

Soil is one of the most important natural resource which has indispensable part of sustaining life in the Earth and has a vital role mostly in every ecosystem. Furthermore, soil has many important functions such as biomass production, physical infrastructure support, water quality maintenance, biological habitat, raw materials for human use, and maintaining cultural heritage (Balum et al., 204). Most of the people knows about the soil function for growing the food, however, here are much more functions provided by soil. Soils also provide fiber for paper and clothing, main material for buildings and roads, fuelwood production. Less known functions which soils provide are groundwater recharge, a medium to attenuate pollutants and excess water nutrient cycling, habitat for microorganisms and biota. Soils besides it have many indirect uses such as ingredients in pharmaceuticals, insecticides, makeup, inks and material for artworks (Schoonover and Crim, 2015).

Soil is one of the main dynamic natural resources which is a non-renewable and are essential for all living creatures (Schoonover and Crim, 2015). To know and follow soil quality is essential. One of the most major question currently is reduction soil organic carbon and how to stop it. Moreover, the soil organic carbon is one of the most important components of the soil quality. For this reason, it is very important to investigate relationship between soil organic carbon and soil quality and try to find the best practices for prevent soil organic carbon decrease.

Soil Quality

Environmental quality contains three components: air quality, water quality and soil quality. Soil quality is not easy to describe as water and air quality because it is much more complex. The soil quality is usually defined broadly as "the capacity of a soil to function within ecosystem and land-use boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health". Because of broad definition soil quality practical interpretation can differentiate (Bünemann et al., 2018).

Soil quality can be generally separated into two categories inherent quality and dynamic quality which is affected by soil management. Measurement of soil quality is not easy process which requires careful selection of indicators by which soil quality will be measured. Indicators are chosen for follow specific soil functions which can vary depending on soil use and other aspects. After establishment of the soil function the indicators of chemical, physical, and biological soil properties can be selected. The measurement of soil quality lets design the sustainable land management systems (Carter et al., 1997).

Soil quality researchers now a days working on how to select right soil quality indicators and evaluate them. However, here are no one single group of indicators of soil quality which has been agreed by scientific community. Scientific community just have common sense on concept that soil quality should be evaluated based on multiple biological, chemical, and physical attributes (Karlen et al., 2003). The most used soil quality indicators are organic carbon and pH. Other frequently used soil quality indicators are available phosphorus, bulk density, texture, total nitrogen, available potassium, and various indicators of water storage. The most use soil physical indicators are related to water storage. Soil chemical indicators related to soil organic carbon content, total N, available P and K, pH, cation exchange capacity, electrical conductivity. Mostly used biological indicators were soil respiration, N mineralization, earthworm density and microbial biomass. In most soil quality minimum datasets at least one indicator of each group (physical, chemical, and biological) was used, but in some biological indicators were not used (Bünemann et al., 2018).

Soil Organic Carbon

Soils organic carbon (SOC) is one of the most important indicators of soil quality, vitally essential to climate change and sustainable food production. A high amount of SOC in soil increase soil fertility which results in the higher food productivity. SOC enhance soil structural stability, porosity which leads to quality plants grow with sufficient aeration and water infiltration. Moreover, SOC rases the water filtration capacity of soils and improves the supply of clean water (Lefevre et al., 2017).

The amount of soil organic carbon in the world soils is unclear, however the estimation are 677 Pg to 0.3 meter, 993 Pg to 0.5 meter, and 1 505 Pg for the topmost 1 m (Lal, 2018). In addition, as a result of the Turkey Soil Organic Carbon Project, a high-resolution and detailed Turkey Soil Organic Carbon Stock Map has been prepared (Figure 1). The total amount of organic carbon stock in the 30 cm depth of the soils in Turkey is calculated as 3.5 billion tons. The amount of carbon stored per hectare is approximately 56 tons in forests, 50 tons in pasture areas and 36 tons in agricultural areas (ÇEM, 2018).

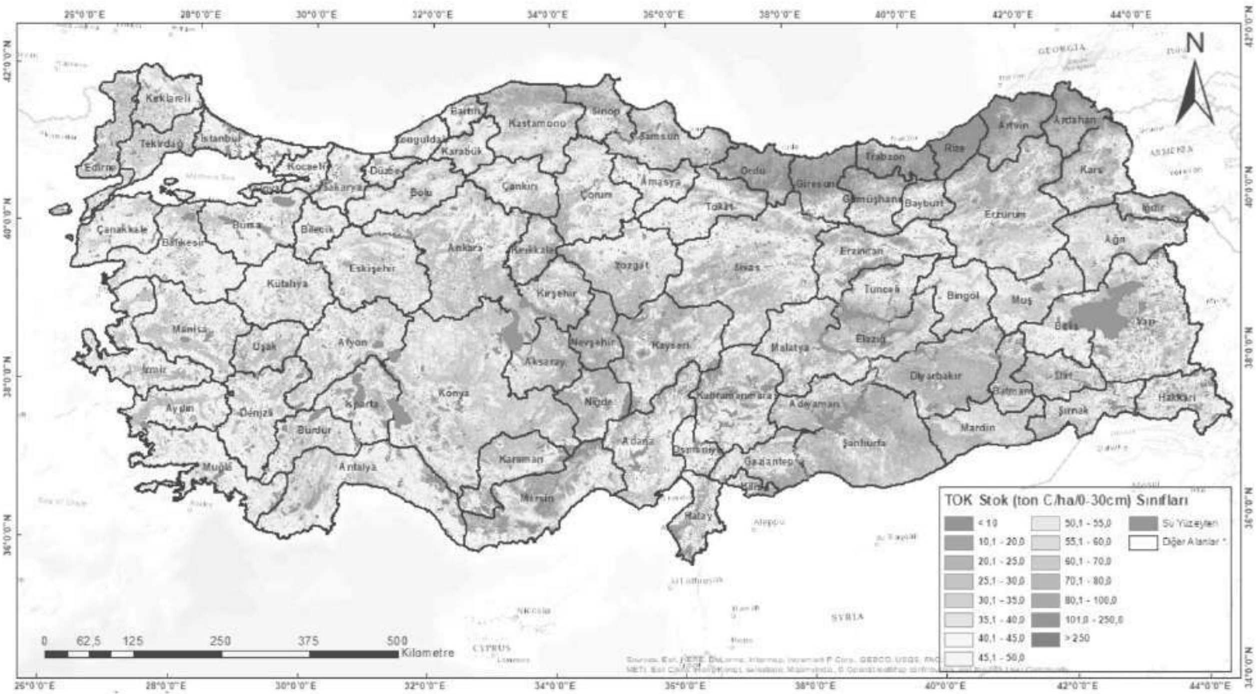

Figure 1. Soil Organic Carbon Stock Map of Turkey (ÇEM, 2018)

The amount of SOC is differentiating depending on soil type, climatic conditions, and land use. The most organic carbon has peatlands and organic soils which hold 30 % of the Earth's soil carbon but only cover 3 % of the world's territory. The forest and grassland also carry decent amount of the SOC, in the agriculture lands SOC is decreasing and in dry soil is very small amount (Lefevre et al., 2017). Land use change, cultivation of the grasslands, burning forest, deforestation, drainage of the land, land use changes and other ways of degradation soil results in loss of soil organic carbon in the world soils and set free CO_2 to atmosphere. CO_2 is one of the greenhouse gasses which cause the rise of atmosphere temperature and results in global climate change (Sommer and Bossio, 2014).

To stop soil organic carbon decrease is the main goal of the scientist worldwide. However, there are many challenges for scientist working on SOC sequestration and preservation. It is complicated define carbon sequestration; however, it can be explained as the uptake of C-holding materials such as CO2 into another place of storage with a longer residence time (Lorenz and Lal, 2014). Many different SOC sequestration ways are tried by researchers. The Olson suggests practices such as use of crops cover, agroforestry, compost, crop rotations, organic fertilizer, manure, and other sustainable agricultural systems (Olson, 2013). The Lal suggest use of organic amendments, conservation agriculture, restoration or degraded lands and creation of complex farming systems by integration of cropping (Lal, 2016b). However, here is no one best way for soil organic carbon sequestration. The future researchers must work on this topic more and found the solutions for reducing soil organic carbon lost, global warming and secure the food supplies for future generations.

Relationship Between Soil Quality and Soil Organic Carbon

Soil quality properties are directly related with soil organic carbon amount in the soil. The decline of soil organic carbon in the soil results in worsening of soil quality indicators (Li et al., 2007). The research conducted by Blanco-Canqui and Benjamin (2013) states that agriculture practices which are regulating SOC amount in soil have strong effect on soil physical properties. Reduction in soil organic carbon amount in soil strongly reduces aggregate stability and strength, expends soil compaction, lowering water repellency, lessens macroporosity, water retention, and hydraulic conductivity (Blanco-Canqui and Benjamin, 2013). Soil organic carbon has also strong effect on soil chemical and biological properties. It increases amount of plant nutrients and CEC. Moreover, increases soil biodiversity and bioactivity (Lal, 2016b). For preserving high soil quality proper agriculture management practices which improve SOC concentration are necessary.

Conclusion

Soil is one of the most important natural resources which is a non-renewable has indispensable part of sustaining life in the Earth and has a vital role mostly in every ecosystem. For securing sustainable agriculture production is essential to follow the soil quality. The one of the most important soil quality indicators is soil organic carbon which decreases because of unsustainable agriculture practices. It is very important to stop decrease of SOC and in same time stop global warming. Soil organic carbon have direct connection with soil properties and soil quality.

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Uptake of biogenic elements by corn plants depending on the effect of trial factors

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Abstract

For the growth, development and formation of grain corn requires a significant availability of basic nutrients in the soil. Thus, the maximum accumulation of nitrogen occurs within 2-3 weeks before the initiation of panicles, that of phosphorus - in the phase of 4-6 leaves (setting of future inflorescences) and in the phase of grain formation and ripening. Corn plants absorb up to 90% of potassium before the beginning of panicle initiation, the absorption of this element ceases after flowering.

It was found out that a vegetative part of corn plants accumulated 95.8 kg/ha of nitrogen, 29.1 kg/ha of phosphorus, but the amount of these elements in grain was much higher - 151.3 kg/ha, 58.4 kg/ha, respectively. The research results indicate that the vegetative part of corn plants accumulated 197.2 kg/ha of potassium, but in grain potassium amount was much less - 41.5 kg/ha. The studies of the hybrids of different maturity groups show that despite the formation of different conditions for the nutrient uptake and a significant accumulation of dry matter by plants per unit area, the uptake of these elements increases accordingly. Therefore, the determination of the optimal parameters of corn fertilizer systems should be approached carefully, taking into account its biological needs, the availability of nutrients in the soil and the capabilities of different fertilizer systems.

Keywords: biogenic elements, corn, fertilizer system, hybrids, plants density, uptake.

Introduction

Corn requires a sufficient amount of the main nutrition elements in the soil for its growth, development and grain formation. The highest accumulation of nitrogen occurs within 2-3 weeks before panicle initiation, that of phosphorus takes place in the phase of 4-6 leaves (the setting of future inflorescences) and in the phase of grain formation and maturation. Corn plants absorb 90 % of potassium before panicle initiation, the absorption of this element ceases after flowering [1-5].

It has been found out that to form the grain yield equal to 8.0-10.0 t/ha, corn plants uptake the following amount from the soil: nitrogen – 190-220, phosphorus - 80-100 and potassium 200-230 kg/ha [6].

Accordingly, if there is a deficit of at least one nutrition element, the growth rates, the formation of vegetative and regenerative plant organs worsen, grain underdevelopment is recorded [7-11].

When estimating the effect of nutrition elements separately, it turns out that due to the lack of nitrogen the corn yield capacity decreases by 25-35 % [12]. The lack of phosphorus worsens the development of reproductive organs [13], the lack of potassium slows down the plant photo-synthetic processes [12]. The research carried out in the USA showed the efficiency of the application of $N_{120-150}$ in the following pattern: before sowing N_{50-60} and N_{70-90} top dressing. But the increase of the rate up to N_{180} appeared to be undesirable for the plants [14-15]. Besides, the works of other researchers contain much higher application rates of fertilizers as optimal ones: $N_{170-280}P_{50-135}K_{35-135}$[16] and $N_{45-200}P_{0-170}K_{0-170}$ with a mandatory diagnostics of the deficit of the main nutrition elements [17]. In the conditions of India, the application of fertilizers at rate N_{240} provided the best result, in Pakistan the top dressing at rate $N_{300}P_{150}$ was a success [18]. In Turkey the application rate N_{320} facilitates the yield increase of corn ears by 59.4 %, as compared with the control – N_{120} [19].

In the conditions of Poland, the best results were received when 30 t/ha of manure were applied as well as a summary application of mineral fertilizer at rate $N_{100\text{-}150}P_{70\text{-}90}K_{150\text{-}200}$. And in the conditions of northern Germany $N_{80\text{-}110}$ and $P_{60\text{-}90}$ were the best application rates [20].

The role of balanced organic-mineral plant nutrition should be mentioned. It has been established that such method of the fertilizer application makes it possible to considerably increase plant resistance to diseases and pests, to decrease yield losses caused by damages.

It has been identified that in the conditions of the Southern Steppe-zone of Ukraine it is advisable to apply not less than $N_{20\text{-}150}$ та $P_{60\text{-}120}$ [12]. And in the southern chornozem soils the yield increase of corn grain was 37.0-57.0 % at a combined nitrogen and phosphorus application [13].

To study the peculiarities of the application of organic fertilizers is a very significant fertilization issue. For instance, provided the application of mineral top dressing $N_{60}P_{60}$ and 20 t/ha of manure was studied, the yield capacity amounted to 9.23 t/ha when organic fertilizers were applied, as compared with the control – 6.70 t/ha [13].

The research conducted in the conditions of the Right-bank Forest-steppe zone of Ukraine proved that due to a mineral fertilization system the corn yield capacity increased by 21-42 %, due to an organic fertilization system the indicator was 20-34 %, and due to an organic-mineral system it increased by 24-46 % [10].

And in the conditions of Bilhorod region, during the two years under study the highest corn yield capacity – 7.03 t/ha was recorded in the treatment when poultry manure/compost 20 t/ha + N_{60} were applied. [10].

Therefore, the results of the research carried out by other scientists confirm both a high demand of corn for nutrition elements and the necessity to work out complex treatments of the application of fertilization systems. After all, the use of mineral fertilization alone is expensive and unreasonable in the conditions of soil droughts. Also, it is not easy to find classical organic fertilizers in the recommended application rates which can be applied in the industrial scales.

Material and Methods

In 2017-2019 field trials were carried out in the experimental field of SPC of Bila Tserkva NAU, situated in the Right-bank Forest-steppe zone – in Bug-Middle Dnipro area. The relief of the experimental field is a slightly-wavy plain with a small slope of the surface from the south to the south-west. Recommended corn hybrids and elements of their cultivation technology were the objects of the research. The effect of the plant density and the fertilization system on the formation of yield capacity of corn hybrids was studied: DN PYVYKHA, FAO 180 (early-ripening), DN ORLYK, FAO 280 (medium-ripening), DN SARMAT, FAO 380 (medium-ripening). The fertilization system implied the following application: 1. $N_{240}P_{120}K_{40}$, 2. $N_{120}P_{60}K_{20}$+ 3.5 t Organic compost 3. Organic compost, 7 t/ha, 4. Manure 40 t/ha.

In the years when the research was conducted (2017-2019) weather conditions differed from long-term indicators. However, generally they were favorable for the growth and development of corn.

To reach the goal the following techniques were used: a field method – to identify the correlation of the plant with biotic and abiotic factors; a calculation method – to keep records of plant density by vegetation on replication plots I and III with the length of 14.3 m; a weighing method – to keep records of corn yield capacity, in the phase of total maturation from each plot; a statistical analysis of the research results was made with help of variation, disperse, correlation and regression methods using applied computer software Statistica.

Results and Discussion

The uptake and assimilation of the main biogenic nutrition elements are the important indicators which are used to determine the efficiency of the application of fertilization systems of corn.

According to our researches and the works of other scientists, in the first two months corn plants grow very slowly. During this period it is necessary to maintain a sufficient concentration of nutrient substances in the upper soil layers where the main mass of the root system of young plants is situated. As the corn plant grows and develops, its roots penetrate into deeper soil layers, and the plant can use nutrients from the soil layers at the depth of 1.01.6 m [21].

There are two kinds of the uptake: a biological one – general costs for the formation of a vegetative mass and grain, an economic uptake of nutrition elements – costs for the formation of corn grain only. However, as the practical experience proves, nutrition elements which are in by-products not always return to the soil. They are lost completely from the circulation of nutrition elements when plant residues are processed into bio-fuel.

For instance, plants require large amounts of nitrogen and they assimilate more than 200 kg/ha to form such yield capacity of corn as 7 t/ha. Plants assimilate nitrogen unevenly and before the 6th leaf appears they require 5 % of it from the required amount. And from the phase of the 6th leaf to panicle initiation (within a month) corn plants assimilate about 60 % of the required nitrogen, i.e., 100-120 kg/ha. They keep assimilating the rest of nitrogen almost till the beginning of corn ear maturation [22-23]. The peculiarities of nitrogen uptake by corn hybrids depending on the effect of trial factors are presented in Table 1.

Table1. Nitrogen uptake by corn hybrids depending on the effect of trial factors, average in 2017-2019, kg/ha

Hybrid	Density at harvesting, th. pcs.	Fertilization system	Vegetative mass	Grain	Total
DN PYVYKHA, FAO 180 (early-ripening)	55	$N_{240}P_{120}K_{40}$	68.68	109.92	178.60
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	83.27	133.16	216.43
		Organic compost, 7 t/ha	81.25	128.61	209.86
		Manure 40 t/ha	77.10	121.92	199.02
	65	$N_{240}P_{120}K_{40}$	81.38	129.43	210.82
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	99.47	158.13	257.60
		Organic compost, 7 t/ha	96.75	151.08	247.83
		Manure 40 t/ha	90.64	143.78	234.42
	75	$N_{240}P_{120}K_{40}$	88.61	139.76	228.37
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	106.89	170.40	277.30
		Organic compost, 7 t/ha	103.14	161.73	264.88
		Manure 40 t/ha	97.62	154.46	252.08
DN ORLYK, FAO 280 (medium early-ripening)	55	$N_{240}P_{120}K_{40}$	71.66	113.55	185.22
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	88.28	136.92	225.20
		Organic compost, 7 t/ha	83.99	132.79	216.78
		Manure 40 t/ha	79.01	125.54	204.55
	65	$N_{240}P_{120}K_{40}$	83.71	133.79	217.50
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	102.86	163.83	266.69
		Organic compost, 7 t/ha	99.88	157.11	257.00
		Manure 40 t/ha	93.97	148.30	242.27
	75	$N_{240}P_{120}K_{40}$	90.96	144.30	235.26
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	112.66	175.63	288.29
		Organic compost, 7 t/ha	107.61	169.19	276.80
		Manure 40 t/ha	102.07	160.26	262.32
DN SARMAT, FAO 380 (medium early-ripening)	55	$N_{240}P_{120}K_{40}$	81.59	129.02	210.61
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	100.18	159.68	259.86
		Organic compost, 7 t/ha	96.07	153.33	249.40
		Manure 40 t/ha	92.12	144.12	236.24
	65	$N_{240}P_{120}K_{40}$	98.67	155.35	254.02
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	119.44	188.84	308.27
		Organic compost, 7 t/ha	115.82	183.15	298.97
		Manure 40 t/ha	111.38	173.29	284.67
	75	$N_{240}P_{120}K_{40}$	97.39	154.87	252.26
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	119.73	187.45	307.18
		Organic compost, 7 t/ha	114.70	181.10	295.80
		Manure 40 t/ha	108.59	171.91	280.50
$HIP_{0.05}$			4.3	7.0	9.8

The research proved that on the average in the trial a vegetative part of corn accumulated 95.8 kg/ha of nitrogen, its amount in corn grain was much higher – 151.3 kg/ha.

The highest nitrogen uptake was recorded in the treatment when the organic-mineral fertilization system was applied; the plant density was 75 th. pcs./ha in hybrids DN PYVYKHA and DN ORLYK, the plant density was 65 th. pcs./ha in hybrid DN SARMAT.

The average data concerning nitrogen uptake depending on a corn hybrid is shown in Figure 1.

Among all the studied hybrids, late-ripening ones accumulated nitrogen the most as they formed a larger vegetative and grain mass: DN ORLYK and DN SARMAT.

Biogenic phosphorus ensures a good growth of a root system and facilitates a fast formation of shoots and leaves. In the first 4-10 weeks of growth corn has a high demand for easily accessible phosphorus forms. Phosphorus uptake by corn hybrids depending on the effect of the trial factors is presented in Table 2.

Table 2. Phosphorus uptake by corn hybrids depending on the effect of trial factors, average in 2017-2019, kg/ha

Hybrid	Density at harvesting, th. pcs.	Fertilization system	Vegetative mass	Grain	Total
DN PYVYKHA, FAO 180 (early-ripening)	55	$N_{240}P_{120}K_{40}$	21.02	42.39	63.41
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	25.54	51.26	76.80
		Organic compost, 7 t/ha	24.79	49.39	74.18
		Manure 40 t/ha	23.33	47.03	70.36
	65	$N_{240}P_{120}K_{40}$	24.77	49.62	74.39
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	30.42	60.88	91.30
		Organic compost, 7 t/ha	29.13	58.77	87.90
		Manure 40 t/ha	27.61	55.49	83.11
	75	$N_{240}P_{120}K_{40}$	26.70	54.01	80.72
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	32.57	65.21	97.78
		Organic compost, 7 t/ha	31.31	62.99	94.30
		Manure 40 t/ha	29.70	59.56	89.26
DN ORLYK, FAO 280 (medium early)	55	$N_{240}P_{120}K_{40}$	22.03	43.31	65.35
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	26.98	53.25	80.24
		Organic compost, 7 t/ha	25.44	51.06	76.50
		Manure 40 t/ha	24.09	48.30	72.39
	65	$N_{240}P_{120}K_{40}$	25.52	51.91	77.43
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	31.53	63.06	94.59
		Organic compost, 7 t/ha	30.35	61.17	91.52
		Manure 40 t/ha	28.82	57.30	86.12
	75	$N_{240}P_{120}K_{40}$	27.69	55.66	83.35
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	33.93	67.75	101.68
		Organic compost, 7 t/ha	32.75	64.59	97.34
		Manure 40 t/ha	31.15	61.86	93.01
DN SARMAT, FAO 380 (medium-ripening)	55	$N_{240}P_{120}K_{40}$	24.69	49.58	74.27
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	30.46	60.96	91.42
		Organic compost, 7 t/ha	29.15	58.92	88.07
		Manure 40 t/ha	27.87	55.81	83.69
	65	$N_{240}P_{120}K_{40}$	29.74	60.57	90.31
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	36.04	72.75	108.79
		Organic compost, 7 t/ha	35.22	71.12	106.34
		Manure 40 t/ha	33.70	67.02	100.72
	75	$N_{240}P_{120}K_{40}$	29.75	59.52	89.27
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	35.91	72.78	108.68
		Organic compost, 7 t/ha	34.92	70.20	105.12
		Manure 40 t/ha	32.88	67.19	100.07
$HIP_{0.05}$			1.8	2.7	3.3

It was found out that on the average in the trial a vegetative part of the corn plant accumulated 29.1 kg/ha of phosphorus, and its amount in grain was much higher – 58.4 kg/ha.

The highest phosphorus uptake was recorded in the treatment when the organic-mineral fertilization system was applied; the plant density was 75 th. pcs./ha in hybrids DN PYVYKHA and DN ORLYK, the plant density was 65 th. pcs./ha in hybrid DN SARMAT.

Similar results confirmed that, among all the studied hybrids, late-ripening ones accumulated phosphorus the most as they formed a larger vegetative and grain mass: DN ORLYK and DN SARMAT.

Corn plants need potassium in large amounts, leaves and stems absorb its greater part; it is required the most when stems grow and absorb it faster than any other element [24-25]. The peculiarities of potassium uptake by corn hybrids depending on the effect of trial factors are presented in Table 3.

Table 3. Potassium uptake by corn hybrids depending on the effect of the trial factors, average in 2017-2019, kg/ha

Hybrid	Density at harvesting, th. pcs.	Fertilization system	Vegetative mass	Grain	Total
DN PYVYKHA, FAO 180 (early-ripening)	55	$N_{240}P_{120}K_{40}$	141.86	30.15	172.01
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	172.32	36.88	209.20
		Organic compost, 7 t/ha	166.07	35.15	201.22
		Manure 40 t/ha	158.47	33.54	192.01
	65	$N_{240}P_{120}K_{40}$	169.22	35.58	204.80
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	205.53	43.05	248.57
		Organic compost, 7 t/ha	197.32	40.87	238.19
		Manure 40 t/ha	184.90	39.39	224.28
	75	$N_{240}P_{120}K_{40}$	181.56	38.16	219.73
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	220.65	46.35	267.01
		Organic compost, 7 t/ha	212.49	44.67	257.16
		Manure 40 t/ha	202.26	42.37	244.63
DN ORLYK, FAO 280 (medium-early)	55	$N_{240}P_{120}K_{40}$	146.86	30.80	177.66
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	182.54	38.03	220.57
		Organic compost, 7 t/ha	171.71	36.26	207.97
		Manure 40 t/ha	163.61	34.38	197.99
	65	$N_{240}P_{120}K_{40}$	172.53	36.49	209.02
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	212.70	44.20	256.90
		Organic compost, 7 t/ha	207.11	43.00	250.11
		Manure 40 t/ha	193.69	40.81	234.50
	75	$N_{240}P_{120}K_{40}$	188.45	39.73	228.18
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	231.09	48.35	279.45
		Organic compost, 7 t/ha	220.57	46.29	266.86
		Manure 40 t/ha	212.34	43.24	255.58
DN SARMAT, FAO 380 (dedium-ripening)	55	$N_{240}P_{120}K_{40}$	166.88	35.33	202.22
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	205.70	43.47	249.17
		Organic compost, 7 t/ha	197.25	42.26	239.50
		Manure 40 t/ha	187.08	39.95	227.02
	65	$N_{240}P_{120}K_{40}$	202.25	43.05	245.29
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	246.08	52.47	298.55
		Organic compost, 7 t/ha	238.89	50.13	289.02
		Manure 40 t/ha	227.44	47.55	274.99
	75	$N_{240}P_{120}K_{40}$	200.64	41.81	242.44
		$N_{120}P_{60}K_{20}$+ 3.5 t Organic compost	245.90	51.83	297.73
		Organic compost, 7 t/ha	238.11	49.76	287.87
		Manure 40 t/ha	225.73	47.68	273.41
$HIP_{0.05}$			10.1	1.7	16.0

The research results proved that on the average in the trial a vegetative part of corn plants accumulated 197.2 kg/ha of potassium, its amount in corn grain was much less – 41.5 kg/ha.

As to the total potassium uptake, its highest parameters were recorded in the treatment when an organic-mineral fertilization system ($N_{120}P_{60}K_{20}$+ 3.5 t Organic compost) was applied; the pre-harvesting plant density was 75 th. pcs./ha in DN PYVYKHA (267.01 kg/ha) and DN ORLYK (279.45), the plant density was 65 th. pcs./ha in hybrid DN SARMAT, the rest of the trial indicators were similar – 298.55 kg/ha.

When analyzing the average data of potassium accumulation in the corn plants by hybrids, one could see that its smallest amount was in grain (38.85 kg/ha) and in vegetative mass (184.4 kg/ha) in hybrid DN PYVYKHA, hybrid DN ORLYK took the second place – 40.13 and 191.9 kg/ha, hybrid DN SARMAT was the leader/had the highest potassium amount in grain and vegetative mass – 45.44 and 215.2 kg/ha. All this corresponds to the peculiarities of the dry matter accumulation by the corn plants of the hybrids of various maturation groups

Conclusion

The research conducted on the hybrids of various maturation groups show that despite the creation of different conditions for the uptake of biogenic nutrition elements and a considerable plant accumulation of dry matter per area unit, the uptake of these elements increases accordingly. Hence, there should be a reasonably careful approach to the determination of the optimal parameters of the fertilization systems of corn taking into consideration its biological needs, the availability of nutrition elements in the soil and the feasibility of various fertilization systems.

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Digital soil mapping of AWC in arable lands: a comparison of different machine learning models

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Abstract

The available water content (AWC) for plants can be defined as the amount of water retained in the soil resulting from the difference between the field capacity (FC) and the permanent wilting point (PWP). Both soil texture and structure affect the soil matrix potential on which the available water capacity to absorb water by plants depends. In arid and semi-arid environments, AWC has large variations in soil due to changing water balances and ongoing changes between water incomes and demand for vegetation type. Spatial high-accuracy estimation of available water capacity in water-scarce-affected areas such as the Mediterranean belt can support the efficient use of water. Digital Soil Mapping (DSM) is a method for the generation of spatial soil information through numerical models which are extracted spatial variations of soil properties from observation and environmental covariates that digitally represent soil formation factors. This study was designed to generate prediction maps for AWC using 3 different machine learning techniques: (i) Multiple Linear Regression (ii) Support Vector Regression (SVR), and (iii) Random Forest. Data collected from the Alluvial plain in Southwest Turkey (91 observations) were used to develop the models. In the estimating and map drawing of AWC, the spectral indices produced from Sentinel 2A images, topographical variables obtained from DEM, and the most recently CORINE land cover classes map were used as input parameters of the models. In the determination of mapping performance of the machine learning techniques for AWC, Lin's concordance correlation coefficient (LCCC) and root mean square error (RMSE) was used for data splitting (70%-30%) and the k-fold cross-validation (n:5, repeated:3) was used. The results of the 3 models showed that the SVR model with higher LCCC (0.19) and lower RMSE (Test set: 2.72; cross-validation: 2.33; %) was the best for AWC prediction. This study revealed that it can be applied by considering the comparative results of machine learning models to quickly predict and mapping of AWC using open-source accessible remotely sensed data. These digital maps can be used practically for monitoring soil water content, prioritizing irrigation schedules, and applied to other areas with similar environmental conditions.

Keywords: Available water content, digital soil mapping, multiple linear regression, support vector regression, random forest, semi-arid

Introduction

Soil water affects almost every aspect of ecosystem behavior, from organic matter decomposition to soil fertility and plant growth (Malone et al., 2020). Spatial characterization of soil water, such as available soil water content, plays a key role in the efficient use of scarce water resources available in agricultural production; however, for multiple locations in the field, their direct measurement is not always possible due to time and cost constraints (Santra et al., 2018). Both soil texture and structure affect the soil matrix potential, which is dependent on the capacity to absorb water by plants. Spatial high-accuracy estimation of available water capacity in water-scarce-affected areas such as the Mediterranean belt can support the efficient use of water (Cramer et al., 2018; Sillero-Medina et al., 2021).

It is possible to use a model-based approach in producing spatial maps of soil properties using information and processing technologies that have the ability to represent soil formation factors with high spatial accuracy. Modeling processes are performed by representing the existing soil formation factors within the framework of digital soil mapping (McBratney et al., 2003).

Machine algorithms such as Multiple Linear regression (MLR) and Random Forest (RF) are used to correlate soil observations and environmental variables in the models of soil water content (Vasques et al., 2016, Malone et al. 2020).

In digital soil mapping, land cover classes are particularly used as categorical environmental variables to reflect the human influence. This gives us an opportunity to estimate different soil properties (Wiesmeier et al., 2019). In this study; there is a comparison of the 3 machine learning algorithms to capture different relationships in the production of digital maps of soil available water content in an alluvial plain.

Material and Methods

Study area, sampling, and analyses

The study area was located in the western Mediterranean region of Turkey. This covers an area of approximately 100 km^2 located between the coordinates of UTM Zone 36, epsg:32636, 4192000 to 4204000 North, and 298000 to 304000 East (Figure 1-a). According to the Java Newhall Simulation Model, the study area has the Mesic soil temperature regime and the Xeric soil moisture regime (Figure 1-b) (Van Wambeke, 2000). Isparta Atabey plain is an agricultural plain that was irrigated for a quarter of a century (GDSHW 2020). According to Newhall Simulation Model, the average annual air temperature, mean annual precipitation, and annual total potential evapotranspiration are estimated as 12.20 °C, 570.20 mm, 710.15 mm, respectively. In terms of geomorphology, the alluvial plain of Atabey is affected by the sediments of the Akçay River. The land use of this area is barley, wheat, sugar beet, cherry, walnut, and apple.

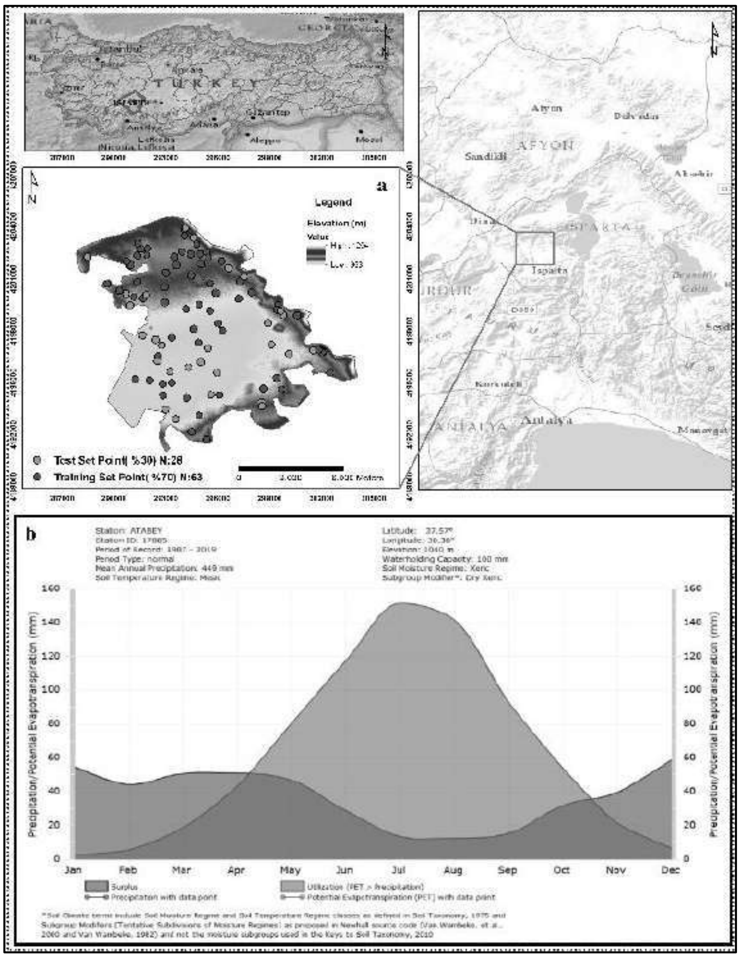

Figure 1. The study area in Southwest Turkey in the figure and the spatial distribution of the soil samples training and test set overlaid on a Digital elevation model (a), Climograph produced using jNSM v1.6.0 (b)

The soil surface sampling scheme (0 to 30 cm) was performed by applying a stratified random method, considering the soil phases in the study area (Soil Science Division Staff, 2017). The soil available water content has calculated the difference between field capacity (FC) and permanent wilting point (PWP). Equation 1 to calculate available water capacity per soil surface (0 to 30 cm) using

$$AWC_{\%} = (FC_{\%} - PWP_{\%}) \qquad (2.1.)$$

where $AWC_{\%}$ is the available water capacity of soil in %, and $FC_{\%}$ and $PWP_{\%}$ are the reported soil water content at 1/3 bar and 15 bar, respectively, in the gravimetric unit (%, g/g). FC and PWP, 1/3 bar and 15-bar moisture content of the soil samples are determined with pressure membrane apparatus (U.S.A, Soil Moisture Equipment Corp.) in the gravimetric unit (%, g/g), respectively (Soil Survey Staff, 2014).

Covariates used for DSM

The topographic features of the study area were derived from a digital elevation model (DEM) with a resolution of 30x30 m (https://search.asf.alaska.edu/) and reintroduced to Universal Transverse Mercator (UTM North Zone 36, EPSG:32636) projection with a spatial resolution of 30 × 30 m (ALOS PALSAR, 2021). Terrain attributes of elevation (m), profile curvature, slope (%), planform curvature, and topographic wetness index were derived from DEM using ArcGIS 10.8 (ESRI, 2021) software and used as the predictive-independent variables in the modeling (Hengl and Reuter., 2008).

Soil formation factors were generated from multiple digital sources while predicting functional soil available content. To assess the soil organism factor, Topsoil grain size index (TGSI) (Xiao et al., 2006), Brightness index (BI) (Hounkpatin et al., 2018), Normalized clay index, Normalized difference vegetation index (NDVI) (Brown et al., 2017), indices derived from the satellite image (Downloaded from Copernicus Open Access Hub "https://scihub.copernicus.eu" within the framework of T36STH dated 16/11/2019. Registration number S2A_MSIL2A_20191116T085231_N0213_R107_T36STH) obtained near the date of soil samples were taken from the Sentinel 2A MSI satellite. The spatial and spectral resolution of the satellite image was given in Sentinel-2 User Handbook (ESA, 2015).

Corine land cover classes 2018 V 2.0 data was downloaded from https://land.copernicus.eu/pan-european/corine-land-cover (European Union, Copernicus Land Monitoring Service, 2018). CORINE Land Cover Class for all categorical predictors were recoded into dummy variables (FAO, 2018).

All covariates used in this study were aligned to the same grid cell resolution and extent using ArcGIS 10.8 (ESRI, 2021). A grid with 30m was used and was performed to align using nearest neighbor resampling where needed. The coordinate reference system used in this study was WGS 1984 UTM zone 36N (EPSG:32636).

Modeling approaches and assessment of prediction

Multiple Linear Regression (MLR), Support Vector Regression (SVR), and Random Forest (RF) were used to digital mapping and identify the relationship between soil available water content and covariates information.

A map of a continuous, two-dimensional spatial distribution of available soil water content that can be used to develop best management practices on a regional scale was produced as an output. Comparative modeling approaches were applied for different algorithms to reveal different relationships in a particular field (Wadoux et al., 2021). We compared the spatially generated AWC maps and prediction accuracies of multiple linear regression (Hengl and Macmillan, 2019), which can detect only linear relationships, and random forest (Breiman et al, 2001) and support vector machine (Cortes and Vapnik 1995) algorithms, which can detect nonlinear relationships.

To evaluate the performance of three various techniques used in this study, statistical criteria including Lin's concordance correlation coefficient (LCCC) and root mean square error (RMSE) were assessed through data splitting (70%; N:63-30%; N:28) (FAO, 2018) and 5-fold cross-validation mode (Sakhaee et al., 2021). A 5-fold cross-validation procedure with three replications was used to evaluate the prediction performance of models. Because the data splitting method for sparse datasets may be inefficient as the information in the datasets is not fully used for training and validation (FAO, 2018), comparative data splitting and cross-validation results can facilitate the interpretability of model results. R Core Environment and related packages were used for environmental variable extraction, modeling, and spatial mapping (R Core Team, 2021).

Results and Discussion

Results of descriptive statistics

Descriptive statistics of soil available water content were presented in Table 4. The observed AWC was ranged from 1.78 to 16.09 % with a mean of 7.48 % and a CV of 37.27 % in the training set; AWC was ranged from 1.36 to 13.18 % with a mean of 7.27 % and a CV of 40.15% in the testing set. The coefficient of variation is greater than 36% in both data sets for AWC. The coefficient of variation (CV) is mainly performed to express the level of variability of soil properties. When the CV value is high than 36% it signifies high variability, whereas if greater than 15% it signifies less variability (Wilding, 1985). Thus, the AWC was high variability in the study region. The training and testing set of AWC was represented with good and comparable data distribution, considering the similarities in the coefficients of variation (Table 1). In the modeling process, our data splitting procedure is appropriate (Adhikari et al., 2021).

Table 1. Descriptive statistics of soil available water content

Variable		Mean	SD	CV	Min.	Q1	Med.	Q3	Max.	Ske.	Kurt.
Available Water Content (%)	Training (N:63)	7.48	2.78	37.27	1.78	5.43	7.35	9.43	16.09	0.42	0.51
	Testing (N:28)	7.27	2.92	40.15	1.36	6.16	7.21	8.83	13.18	-0.18	0.28
	All Data	7.41	2.81	37.95	1.36	5.81	7.23	9.12	16.09	0.22	0.39

Abbreviation: N: Sample Number, SD: Standard Deviation, CV (%): Coefficient of Variation, Ske.: Skewness, Kurt.: Kurtosis

Model performance analysis

Table 2 lists the model performance measures values for the training and test dataset for the AWC predictions. For test data that was not used in model calibration, SVR had the highest LCCC (0.19) for AWC, while SVR and RF had the same RMSE (2.72%). For the training set, AWC had the highest LCCC (0.78) in using the random forest algorithm, furthermore, for AWC the lowest RMSE (1.40%) was obtained with RF. The results suggested that different algorithms have different capabilities for AWC estimation at unsampled locations.

Table 2. Performance statistics of the regression models used for predicting soil available water content

		Training		Testing		Cross-Validation
Variable	Model	LCCC	RMSE	LCCC	RMSE	RMSE
Available Water Content (%)	MLR	0.42	2.36	0.08	3.30	3.14
	SVR	0.60	1.94	0.19	2.72	2.33
	RF	0.78	1.40	0.18	2.72	2.61

Abbreviation: LCCC: Lin's Concordance Correlation Coefficient, RMSE: Root Mean Square Error

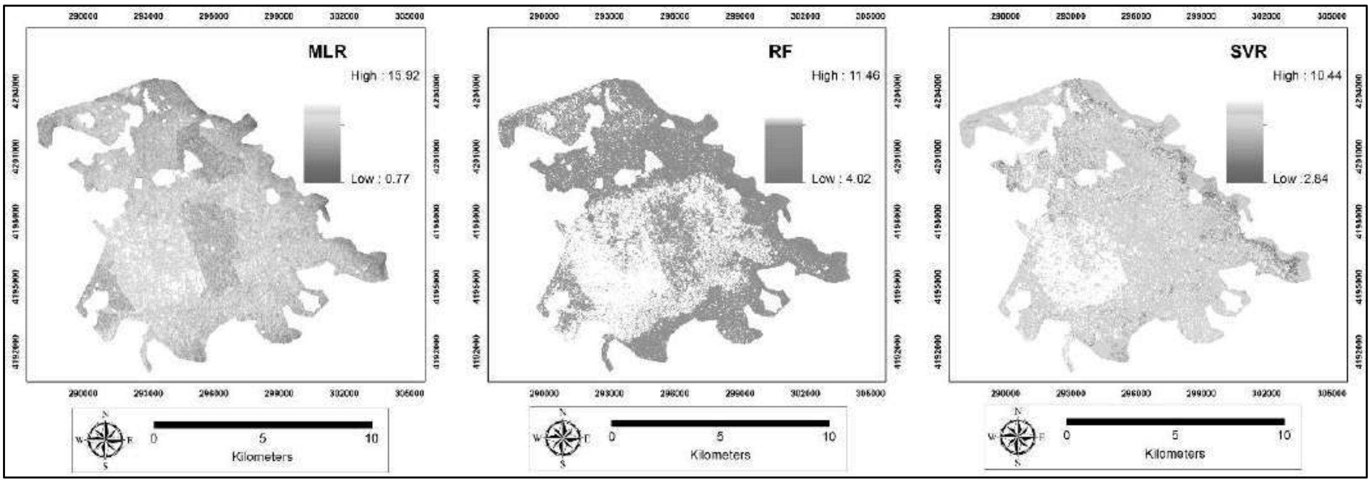

Figure 1. Soil available water content maps produced with different models

Soil available water content maps were depicted in Figure 1. In the southwestern parts of the study area, the available water content in the old stream beds region was high by the three algorithms. The MLR model was considerably influenced by the land cover data and spatially produced the linear relationship between certain land cover classes and AWC. SVR was produce lower RMSE values than both the test set and the cross-validation validation results. SVR has also reflected the minimum AWC values better. Thus, SVR has become the preferred method for the study area.

The relative importance of environmental variables in MLR, SVR, and RF models in AWC estimation were shown in figure 2. Elevation was the most important variable in both MLR and RF. The most important variable in the SVR algorithm was the topographic wetness index (Figure 2-c). Mehrabi-Gohari et al. (2019), described the topographic wetness index as an important topography variable that affects the amount of moisture accumulation in the soil.

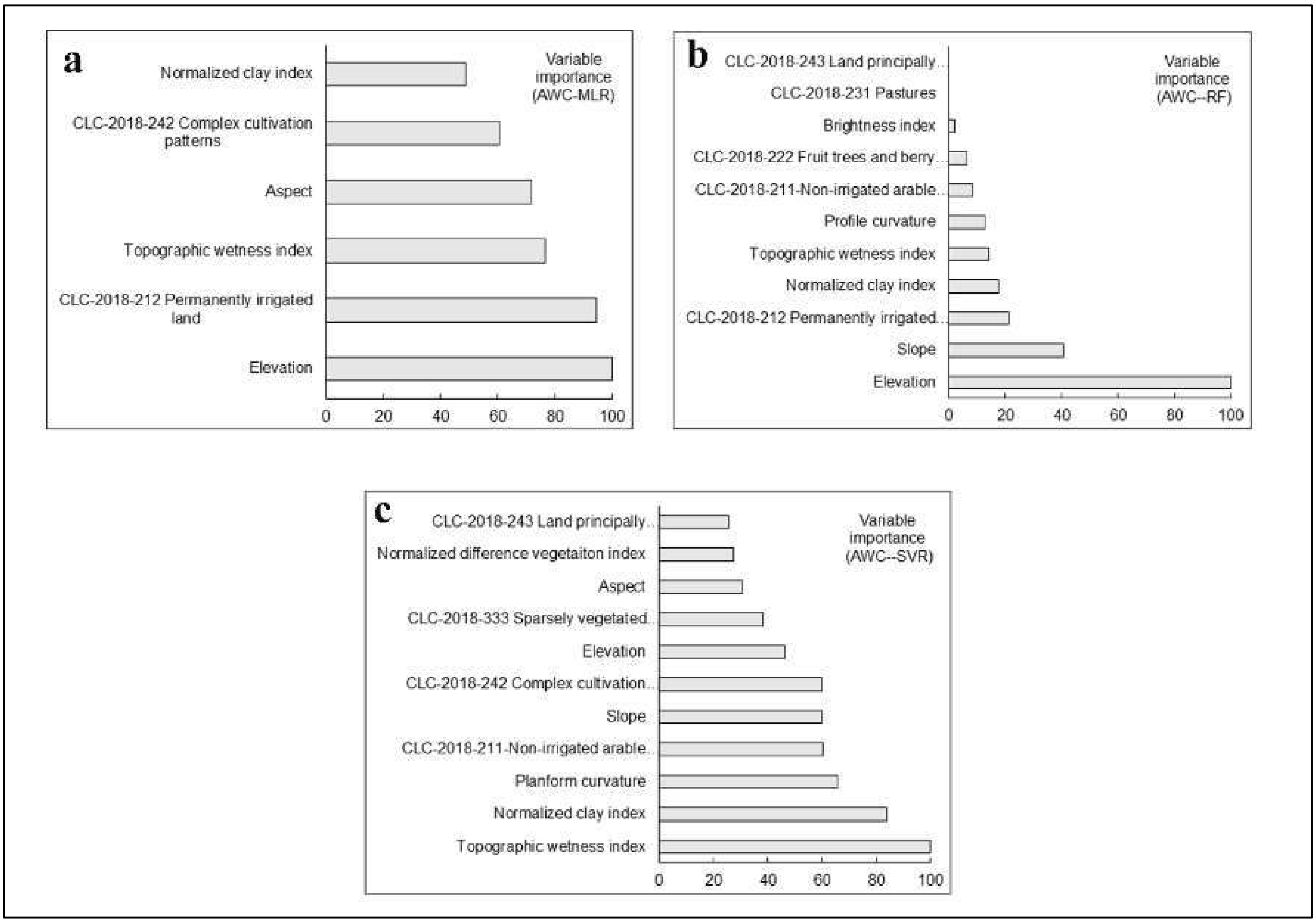

Figure 2. Variable importance of the environmental variables used to predict the available water content using MLR (a), RF (b), and SVR (c) models

Conclusion

The applicability of MLR, SVR, and RF models for AWC estimation was investigated in this study. Terrain attributes and categorical CORINE data are very useful auxiliary information to predict soil AWC. The best result was obtained by the SVR model according to assessment criteria in terms of LCCC and RMSE. Furthermore, SVR was recommended for digital mapping in similar environmental conditions.

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Detection of different agricultural crops on the same land parcel with soil moisture analysis by using remote sensing in part of Central Bohemia Region, Czech Republic

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Abstract

Agricultural land in the Czech Republic was significantly affected by collectivization after the WW II. Within the process of uniting the farmland were removed landscape elements such as balks, shrubberies etc. Thus the Czech Republic has one of the largest land parcels in Europe. As a consequence, the ecological stability has been disrupted, the landscape has become vulnerable and this problem persists in terms of susceptibility to water erosion, loss of organic matter, influence on microclimate and biodiversity. Currently a new standard of good agricultural and environmental conditions (GAEC) related to the Cross Compliance has been applied by the Czech Ministry of Agriculture, which constraints a continuous area of single crop up to 30 ha since 2020. In other words, when the land parcel is physically larger than 30 ha, the farmer has to virtually divide the parcel by growing different crops. Rapid development of satellite technologies provides many advantages of application in observing the Earth and getting reliable information faster than from field measurements by remote sensing (RS). Also, distinguishing different agricultural crops from each other can be easily detected by RS satellites which have skills to detect electromagnetic energy at different wavelengths on spectrum. In this study, the application of the new standard was examined by RS data analysis, with focus on water and temperature regime of the land. Landsat_8 Level_1 combining RS data with 30 m spatial resolution for operational land imager and 100 m spatial resolution for thermal infrared sensor was used to discriminate different crop types on the same land parcel by calculating land surface temperature and soil moisture values which play an important role in understanding the soil water regime. Time ranges of satellite images were decided in Junes between 2018 to 2020 in part of the central Bohemia region and preliminary results are presented.

Keywords: Land surface temperature, Soil moisture, Vegetation index, Water index

Introduction

Due to political changes in former Czechoslovakia after the World War II the landscape, including the agricultural land, underwent significant changes. The process of the so called collectivization of agriculture had taken place mainly between years 1948-1960. The individual ownership was transformed into collective state ownership. Within the process of uniting the farmland the space diversification of the landscape was altered to large land parcels by removing landscape elements such as balks, shrubberies and groves (Sklenicka et al, 2009). The structure of the landscape has been simplified (Figure 1). These elements have great effect on reducing the soil erosion and surface runoff and thus retention of water in the landscape and soil. Additionally, in order to increase area of agricultural lands, agricultural drainage systems in the Czech

Republic (CR) were built overall on 1,078,000 ha, which is about 25% of agricultural land (Kulhavý and Fučík, 2015).

Consequently, the ecological stability has been disrupted, the landscape has become vulnerable and this problem persists in terms of susceptibility to water erosion (Vláčilová and J. Krása, 2016, Vopravil et al, 2007, Žížala et al, 2017), loss of soil organic matter, influence on microclimate and biodiversity. Other consequence of collectivization was the disruption of man's relationship to the landscape. Soil became just a tool for industrial food production. Property restitution after 1989 has not solved the problem. CR belongs among the countries with the highest level of land-ownership fragmentation, but at the same time it is the country with the highest average area (89.3 ha) of production blocks in the EU, where the average block size is about 26 ha. Very small parcels are economically not feasible thus tend to be rented to large farmers and create large production blocks. The land-use pattern is then significantly homogenous. Thus the extreme land-ownership fragmentation phenomenon can be considered as a significant form of land degradation (Sklenicka et al, 2014). Soils are cultivated mostly by tenants and due to often bad adjustment of the relationships between owners and tenants the degradation of soils continues as the tenants are not fully interested in sustainable soil management.

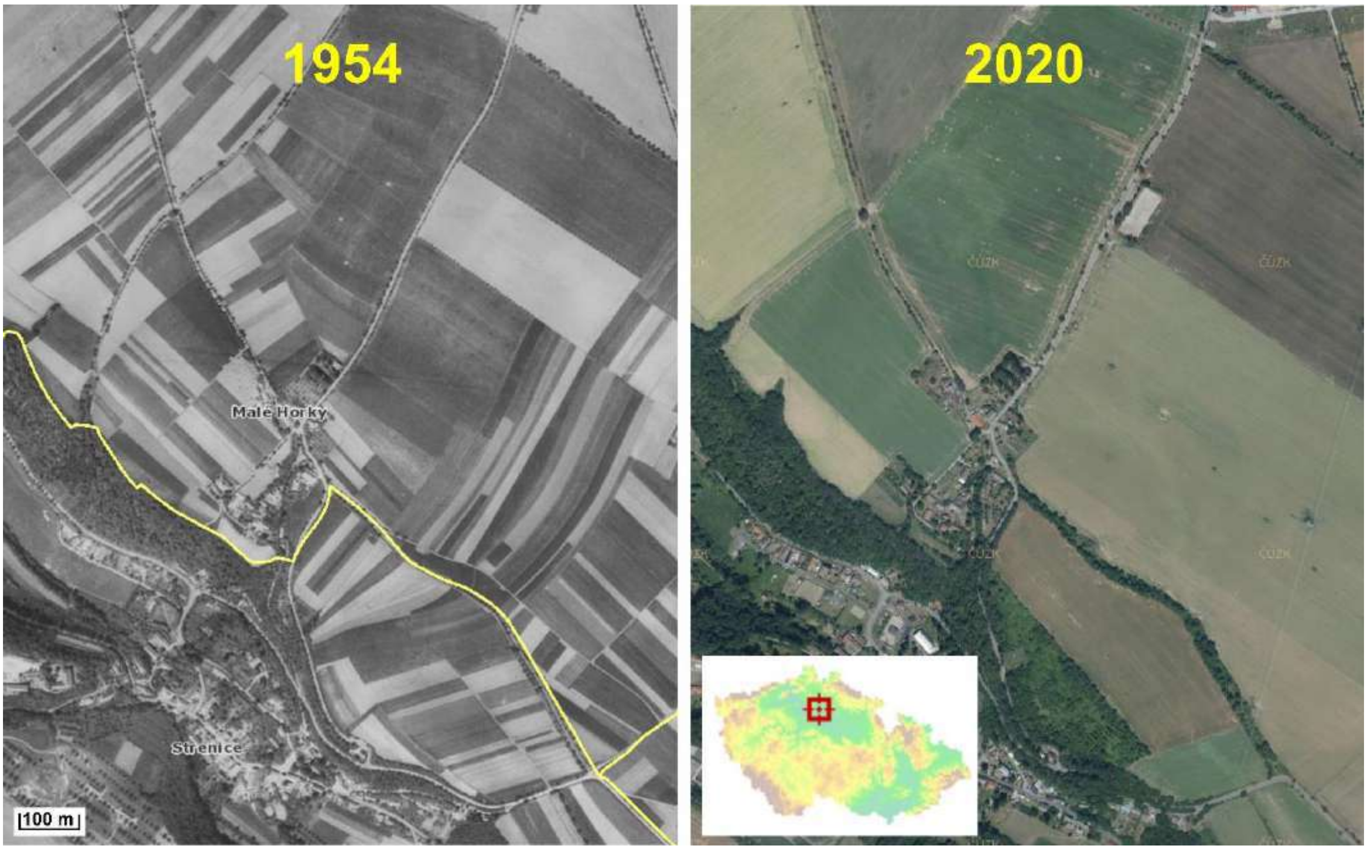

Figure 1. Example of uniting the farmland in the Czech Republic (Malé Horky village in Mladá Boleslav district). Source of maps: https://geoportal.gov.cz/web/guest/map.

Mitigation of negative impact of agriculture in EU's Common Agricultural Policy involves Cross Compliance, which is among others carried out through standards of good agricultural and environmental conditions (GAEC) (EU, 2013). Currently a new GAEC 7d has been applied by the Czech Ministry of Agriculture, which constraints a continuous area of single crop up to 30 ha since 2020. In other words, when the land parcel is physically larger than 30 ha, the farmer has to virtually divide the parcel by growing two or more different crops, or put a protection stripe minimum 22 m wide sown by protection crops. The GAEC 7d should be applied since 2020 to land parcels susceptible to soil erosion, and since 2021 to all land parcels. (Based on amendment to government regulation No. 48/2017 the concern of single crop constraint up to 30 ha passed to GAEC 5g, unchanged.) Management in accordance with GAEC standards is one of the conditions for providing the full amount of direct support to farmers. Rapid development of satellite technologies provide many advantages for users to observe the Earth and get reliable information about environmental issues by using remote sensing such as disaster management, agricultural activities, soil quality analysis and climate changes. Remote sensing satellites have skills to detect electromagnetic energy at different wavelengths on electromagnetic spectrum. Land surface temperature and soil moisture index can be measured by using remote sensing satellites or ground sensors. Although, ground sensors are used to make estimation of soil moisture and land surface temperature in limited areas, remote sensing technology has advantage to observe oversize areas on Earth surface (Parida et al, 2008).

What impact has the application of this GAEC on agricultural management and agricultural landscape? Limitation of large monocultures in agricultural practices assumes to positively influence biodiversity, decrease soil erosion, increase infiltration of water to the soil and stabilise the water and temperature regime of the agricultural landscape. Thus aims of this preliminary study are to i) detect changes in land cover in the first year of the GAEC 7d application by remote sensing and ii) select the most suitable indices for assessment of the GAEC impact.

Material and Methods

Study Area and Datasets

Mlad Boleslav and Nymburk districts are located in central Bohemia region, CR, and these two districts were chosen as study area due to large areas of agricultural lands. They are located north-east of Prague (see Figure 2). While the area of Mlada Boleslav has 102245 ha, area of Nymburk is 84990 ha. Landsat 8 Operational Land Imager and Thermal Infrared sensors (OLI and TIRS) Level 1 data were used for this study. The data obtained from USGS's Earth Explorer for three different years on June 7, 2018, June 26, 2019 and July 30, 2020 were used. The data were less than 10% cloudy. Landsat 8 (OLI & TIRS) contains 11 bands and two of these bands are for thermal sensing. In addition, Operational Land Imager sensor has 30 m spatial resolution for visible and infrared bands and thermal sensor has 100 m spatial resolution for band 10 and band 11. Thermal properties of the sensor have important role for calculation of land surface temperature and soil moisture index. Moreover, polygon shape of 11833 agricultural land parcels with the total area of 112997 ha (covering 60 % of the study area) were obtained from Czech Ministry of Agriculture in the study area. 737 land parcels of 11833 are bigger than 30 ha and area of these parcels is 37793 ha. These 737 land parcels cover 33 % of the agricultural land and 20 % of the total area of the two studied districts (Figure 2).

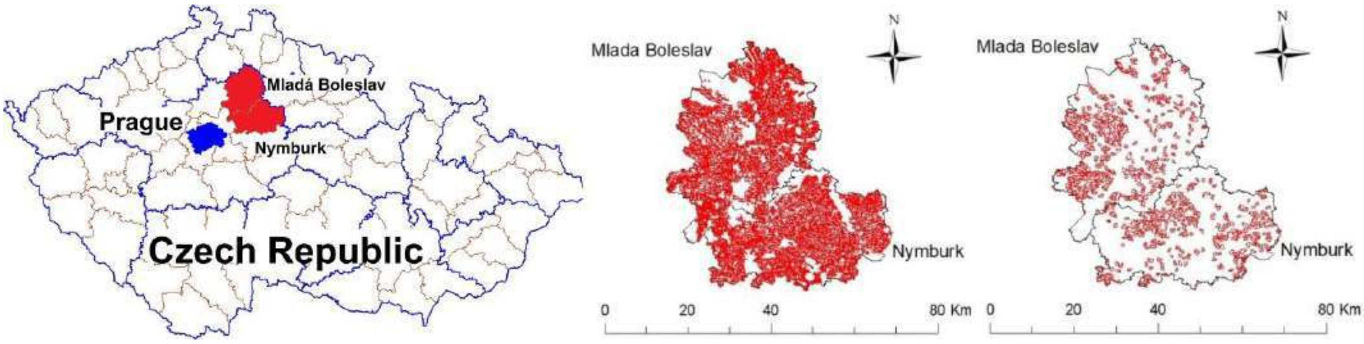

Figure 2. Location of study area (on the left), polygons of all land parcels (in the middle) and land parcels bigger than 30 ha in the study area (on the right).

Methodology

TIRS bands are used to calculate land surface temperature (LST) and soil moisure index (SMI) but Landsat thermal data has stored digital numbers (DN) and these values are not calibrated and do not represent meaningful units. DN have to be converted to spectral radiance values to obtain meaningful units. Radiance values were calculated for both thermal bands by using equation 1 which is (USGS LM, 2016):

$$L_\lambda = M_L * Q_{CAL} + A_L \quad (1)$$

where L_λ is top of atmospheric (TOA) spectral radiance, M_L is the band specific multiplicative rescaling factor from metadata and A_L is the band specific additive rescaling factor from metadata. Q_{CAL} represents thermal bands such as band 10 and band 11 for Landsat 8 TIRS data. Brightness temperature (BT) values are calculated by using thermal conversion constant of bands and spectral radiance (TOA) values and cell statistics are done for both bands. Equation adjusted absolute zero to obtain brightness temperature values in °C (0°C = 273.15 K). Equation of BT calculation is (2):

$$BT = (K_2 / (\ln (K_1 / L) + 1)) - 273.15 \quad (2)$$

where L is spectral radiance (TOA) and K_2 and K_1 are thermal conversion constants for each bands which are shown below(USGS LM, 2016).

$Band_{10}$ (K_2=1321.0789, K_1=774.8853)

$Band_{11}$ (K_2 =1201.1442, K_1=480.8883)

Normalized Difference Vegetation Index (NDVI; eq 3) is calculated by using red and near infrared bands on Erdas Imagine and ArcGIS 10.8 softwares because NDVI values are used to obtain proportion of vegetation (PV) which is related to land surface emissivity (eq.5).

$$NDVI = (NIR - RED) / (NIR + RED) = (Band_5 - Band_4) / (Band_5 + Band_4) \quad (3)$$

Proportion of Vegetation can be obtained by formula (4):

$$PV = ((NDVI - NDVI_{min}) / (NDVI_{max} - NDVI_{min}))^2 \quad (4)$$

Proportions of vegetation values are used to estimate land surface emissivity calculated by equation (5) proposed innitaly by (Sobrino et al, 2004):

$$\varepsilon = 0.004*PV + 0.986 \quad (5)$$

where ε is land surface emissivity and 0.986 corresponds to the correction of the equation.

BT and land surface emissivity are used for estimation of land surface temperature (LST) by formula (6):

$$LST = (BT / (1 + (\lambda * BT / \rho) * \ln(\varepsilon))) \quad (6)$$

where λ is average wavelenght of the emitted radiance, ρ is Planck's constant which is law of blackbody [11]. Soil moisture index estimation based on LST values on this technique. Formula of SMI is shown below (7):

$$SMI = (LST_{max} - LST) / (LST_{max} - LST_{min}) \quad (7)$$

Normalized Difference Water Index (NDWI) values (eq. 8) were obtained by the use of green and near infrared bands to addition of classification in further process to relate with temperature values (Guha and Govil, 2021).

$$NDWI = (GREEN - NIR) / (GREEN + NIR) \quad (8)$$

Results and Discussion

Results of remote sensing data demonstrated that agricultural crops can be discriminated by using land surface temperature values (Figure 3) and soil moisture index (Figure 4). Acording to the temperature results (Figure 3), the highest temperature was found in June, 2019, which is in agreement with (Xu et al, 2020) and (ČHMÚ, 2019). Areas with high temperature correspond very well with areas which have low SMI, typically bare soil and civil constructions (indicated by red color), and vice versa. Similar results were found by (Saha et al, 2018).

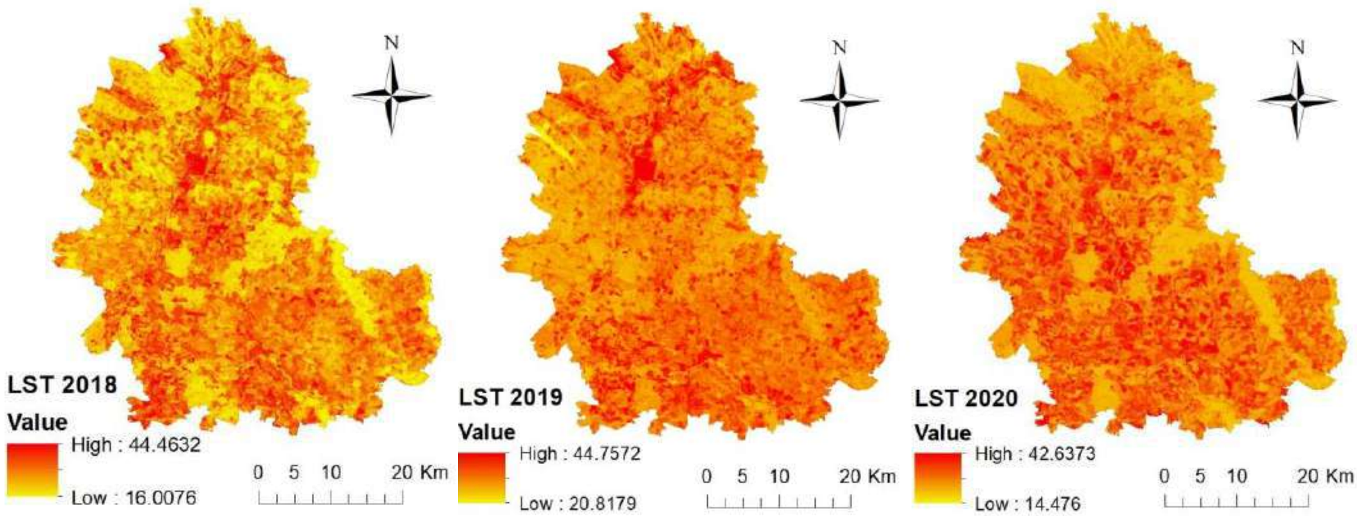

Figure 3. Land Surface Temperature Distribution in the Study Area.

Detailed comparison of year-to-year changes in land cover on the same land parcel demonstrated on SMI is shown in Figure 5; in the upper row the land parcels bigger than 30 ha are indicated with red borders. Different crop patterns can be detected. Also, soil moisture can provide estimations about crop use of parcels but precipitation ratio of region and type of planted crops have to be known for every year.

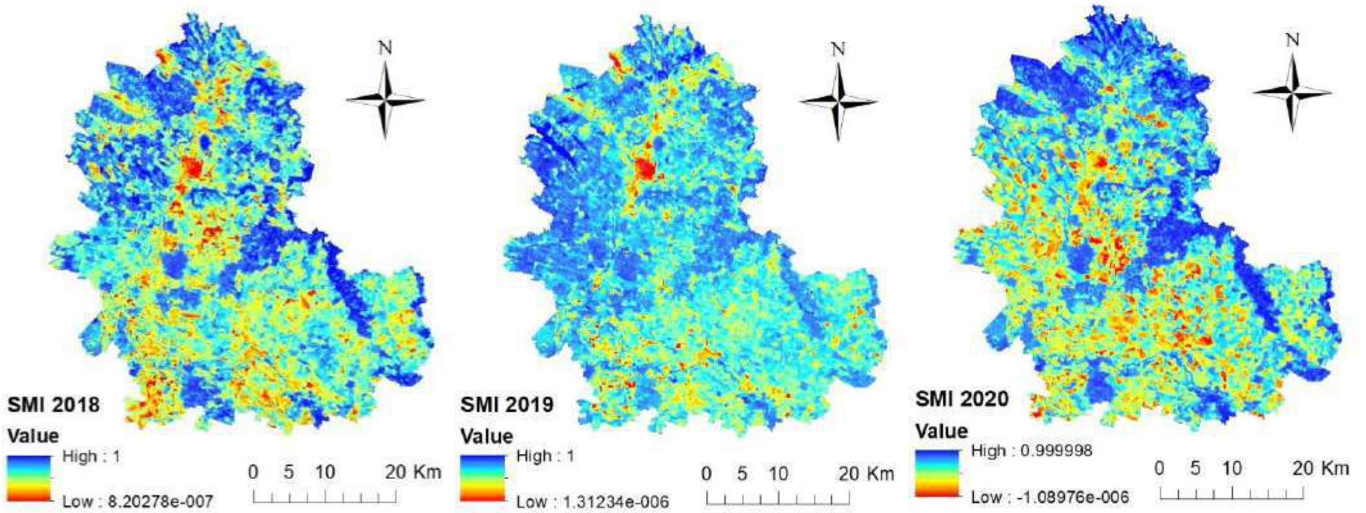

Figure 4. Soil Moisture Index Distribution in the Study Area.

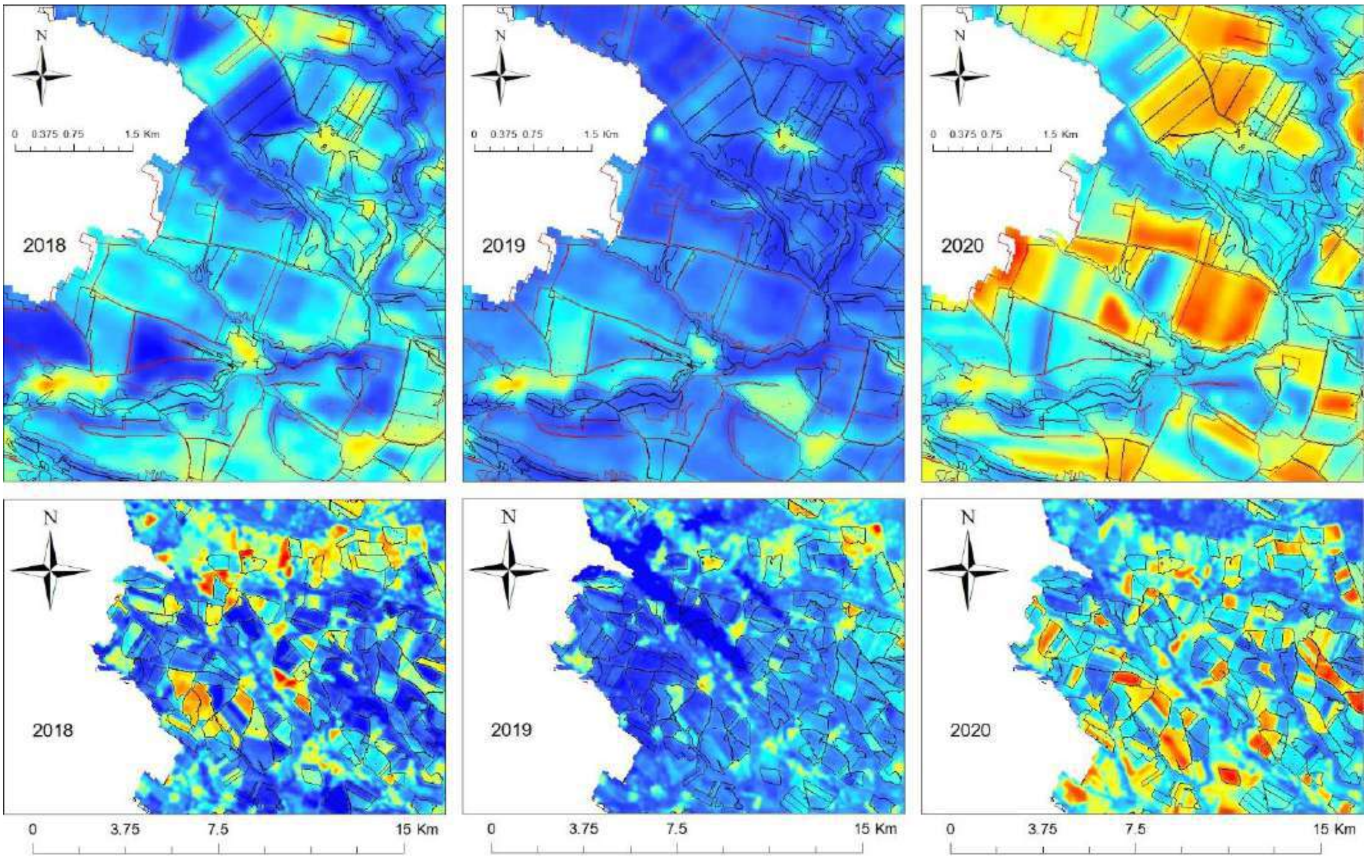

Figure 5. Comparison of Soil Moisure Index between years on detailed parcels.

NDVI results (see Figure 6) of the study area showed less vegetation in July 2020 than other years, which is indicated by red colour; this is due to harvest time in progress in that time. In this case, comparison of changes between 2019 and 2020 on the same agricultural land cannot be reliable without knowledge of planted crops on lands due to harvest time of different crops.

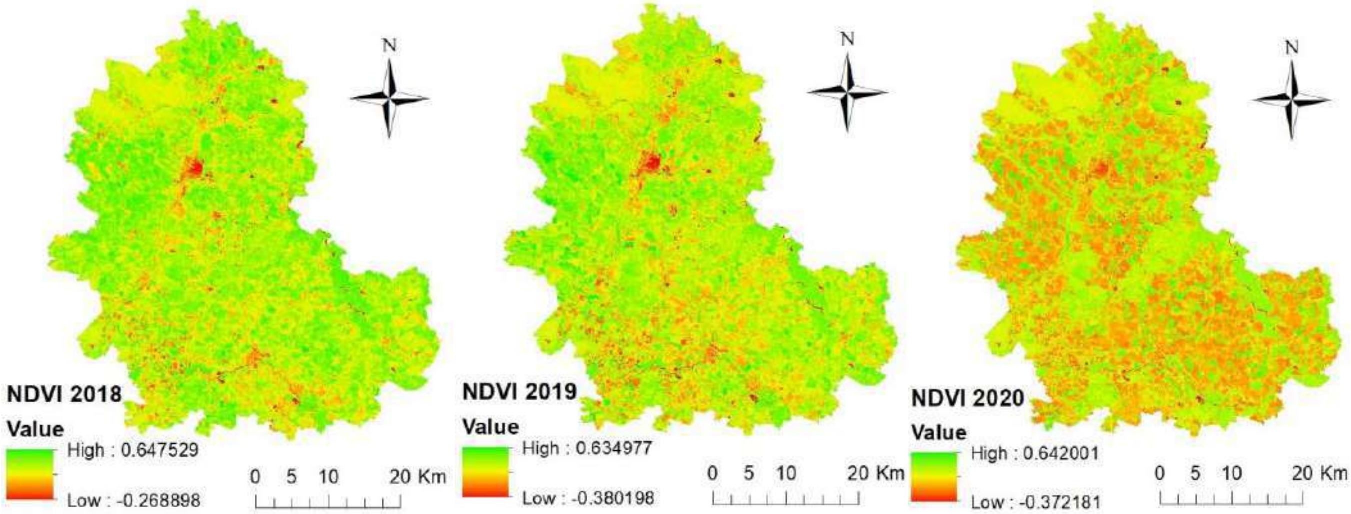

Figure 6. NDVI Distribution in the Study Area.

NDWI values represent water bodies' structure of the area (see Figure 7). These NDWI values can be interpreted similarly as NDVI. However; according to (McFeeters, 2013) values above 0.33 can also be taken as water area and this thresold value can provide correct interpretation in urban areas.

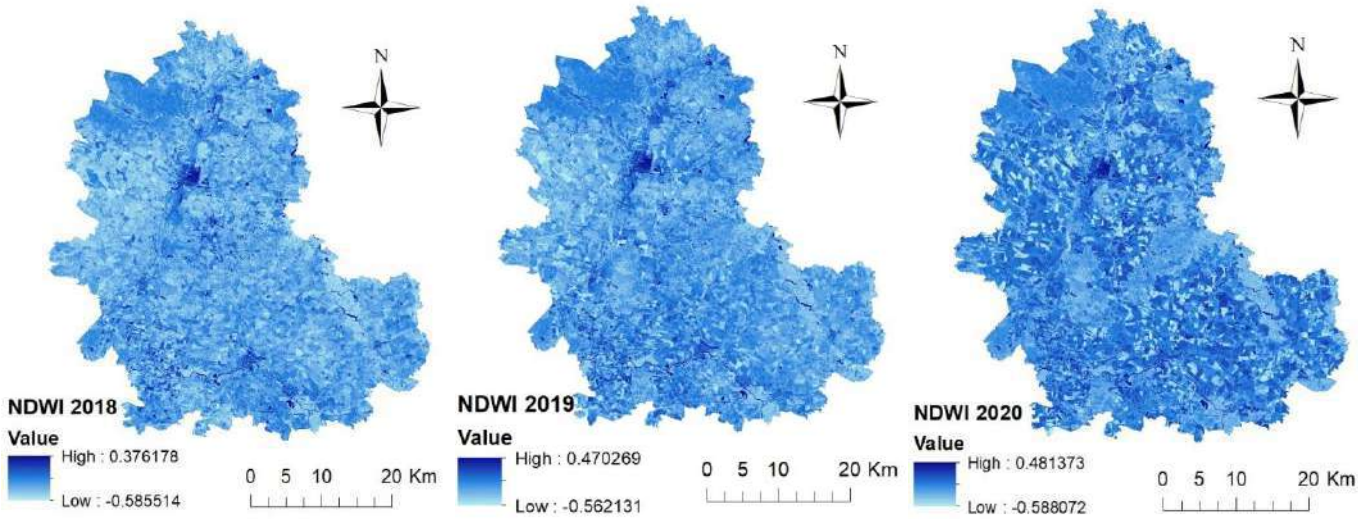

Figure 7. NDWI Distribution in the Study Area.

Conclusion

In this study, LST and SMI along with NDVI and NDWI values were calculated to observe changes in farming practices related to sowing area after application of the new standard of good agricultural and environmental conditions on individual land parcels in 2020. Preliminary results show, that changes in all calculated indices can be detected by using remote sensing technology on parcels. However, for better evaluation about detailed changes on parcels, spectral reflectance curves have to be known for each crop types. NDVI and LST images show that date of images from each year must be corresponding in order to have better understanding of soil moisture index on the same parcels or information about crop types on each parcel are required.

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Responses of cytokines in strawberry (*Fragaria ananassa*) to Zinc application

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Abstract

The aim of this study was to determine the effects of zinc applications on levels of trans-Zeatin-Riboside (t-Z), and Gibberallic acid (GA3) hormones at cytokinin groups in strawberry (Fragaria ananassa). This study was carried out with the application of four different doses (Control (Zn_0):0, Zn_1:75, Zn_2:150 and Zn_3:225 mg per plot having 15 plants) of Zintrac (7% Zn) to soil in a randomized factorial experimental design with three replications at the Experimental Field of Agricultural Faculty in Van Yüzüncü Yil University, Van-Turkey. Gibberallic acid levels in plants decreased with increasing Zn doses. The highest gibberallic acid level was determined as 602.3 mg GA/kg in control (Zn_0) while the lowest mean value was 231.0 mg GA/kg in Zn_3 application. Increasing doses of zinc up to Zn_3 dose leaded unregulated increases in trans-Zeatin-Riboside levels. The lowest trans-Zeatin-Riboside mean was obtained as 26.30 mg/kg in Zn_0 dose while the higher trans-Zeatin-Riboside mean values were determined as 58.26 mg/kg and 49.26 mg/kg in Zn_1 and Zn_2 application dose, respectively. As a result, increasing Zn application doses increased trans-Zeatin-Riboside levels and reduced gibberallic acid levels in strawberry.

Keywords: Zinc, fertilization, plant hormone, cytokines, strawberry.

Introduction

Plants during their growing period are influenced by a lot of factors which are classified as internal factors such as; hormones, vitamins, enzymes and proteins, and external factors such as; light, temperature, humidity and soil structure. Micronutrients are one of the most important external factors even though they are required in small concentrations for plants (Sandman and Böger, 1983). Micronutrient fertilization is necessary to reach a high qualitative yield if micronutrient contents are low in soils. High soil pH and lime content have a negative effect on available zinc content in soils. Zinc has an important effect on enzyme activation, carbonhydrate, protein, oxyn metabolism, membrane quality and plant growth (Kacar and Katkat, 1998). It has been reported that soils of 30% in the world (Alloway, 2008) and 50% in Turkey (Eyüpoğlu et al., 1995) show zinc deficiency. Zinc deficiency is also a common problem in strawberry growth (Türemiş et al., 2000).

Hormones effective in all biological processes are also important for plant growth and development (Sembdener and Parthier, 1993). Cytokinin can be influenced by changes in plant nutrition at different levels (Kudoyarova et al., 1990). Hormone synthesis as a physiological process is influenced by excess or low nutrient contents in soils during the plant growth periods (Amzallog et al., 1992). Hormones in cytokinin group influence plant growth and development at different stages (Dominov et al., 1992). It has been reported that cytokinins are effective on cell division, cell expanding, shoot and root regeneration, nutrient uptake and transfer, protecting dormancy, chloroplast development, chlorophyll, protein and enzyme synthesis, flowering, fruit and seed production, controlling some genes, tolerance to pathogens in plants (Benkova et al., 1999; Silver et al., 1996; Clarke et al., 1999). It has been similarly reported that Gibberellic acid affects plant growth and development (Emongor, 2007; Famiani et al., 2007; Yoshida et al., 2007; Jamil and Rha, 2007; Bora and Sarma, 2006). Hormone synthesis as a physiological process is influenced by excess or low nutrient contents in soils during the plant growth periods (Amzallag et al., 1992). According to Andreini and Bertini, (2012) zinc plays an important role as a cofactor in defining the structure and function of more than 300 enzymes, such as Cu/Zn superoxide, carbonic anhydrase, and sorbitol dehydrogenase in plants. Zinc plays a vital role in plant photosynthesis, carbohydrate metabolism, and phytohormones regulation (Broadley et al., 2007; Alloway, 2008; Gupta et al., 2011). Cakmak et al. (1989) and Sekimoto et al. (1997) reported that zinc directly participates in the biological synthesis of auxin (IAA) and gibberellin (GA3).

Despite of increasing human population in the world rapidly, agricultural lands are becoming limited or degraded by erosion, pollution or salinization. Therefore, studies related to yield productivity in agriculture are becoming more important nowadays. Metabolic activities of plants influenced by nutrients should be known in order to determine effective fertilization program. Rashid (2018) reported that strawberry, belongs to the family Rosaceae, is one of the most delicious, delicate flavored, refreshing, and attractive red fruit of the world. It has bioactive compounds including vitamin C, E, b-carotene and phenolic compounds (phenol acids, flavan-3-ols, flavonols, and anthocyanins), folate and potassium, and is relatively low in calories (Kazemi, 2014). The aim of this study was to determine the effects of zinc on levels of trans-Zeatin-Riboside and Giberallic acid (GA3) hormones in cytokinin groups in strawberry.

Material and Methods

This experimental study was carried out with the application of four different doses (Control (Zn0):0, Zn1:75, Zn2:150 and Zn3:225 mg per plot having 15 plants) of Zn to soil in a randomized factorial experimental design with three replications in 48 plots at the Experimental Field of Agricultural Faculty in Van Yüzüncü Yil University, Van-Turkey. Zintrac including 7% of Zn content was used as a zinc fertilizer. There were 15 strawberry (*Fragaria ananassa*) plants in each plot. Frigo seedlings were planted with a planting spacing of 1.0x0.5 m. During the development period, the necessary cultural processes (irrigation, fertilization, weed removal) were carried out regularly.

Some physical and chemical soil properties of the field were determined in soil samples taken from 0 – 20 cm depth as follows: particle size distribution by Bouyocous hydrometer method (Demiralay, 1993); lime content by Scheibler Calsimeter, soil reaction (pH) in 1:1 (w:v) soil:water suspension by pH meter and soil salinity by EC meter in the same suspension; organic matter content by Walkley-Black method, exchangeable cations by ammonium acetate extraction; available phosphorus by Olsen's method. The available Fe, Zn, and Cu were made by using AAS (Themo ICE 3000 series) with a DTPA-TEA extraction solution recommended for calcareous soils (Kacar, 2009).

The analysis of zinc was performed in leaf samples collected from the strawberry plants in each plot at the flowering time. The leaf zinc content was determined by atomic absorption spectrophotometer (Themo ICE 3000 series) (Kacar and Inal, 2008).

The analysis of trans-Zeatin-Riboside (t-Z), and Giberallic acid (GA3) were performed leaf samples collected from the strawberry plants in each plot at the flowering time. The analysis of trans-Zeatin-Riboside (t-Z), and Giberallic acid (GA3) was performed according to Kuraishi et al (1991) and Battal et al (2004). One gram of frozen leaf sample was powdered in liquid nitrogen. Then cold methanol was added and stored at 4°C for 24 h in dark. The samples were homogenized in an Ultra Tissue Lysis (Ultrasonic Processor, Jenway Ltd. Essex, UK) and filtered through a filter paper (Whatman No. 1). Then the filtrates were collected. The residue was reprocessed in the same way as mentioned above and combined with the former one in order to minimize the loss of phytohormones. The filtrates were filtered through PTFE filters (0.45 *l*m). Methanol was removed at 35°C under reduced pressure. The extracts were redissolved in K_2PO_4 buffer (pH 8.5) and centrifuged at 10,000 g for 1 h at 4°C. Then, the supernatants were put in flask (25 cm^3), each containing 1 g polyvinylpolypyrolidone (PVPP, Sigma Chemical Co. UK), well mixed and filtered through Whatman fitler paper (No. 1). The filtrates were introduced to Sep-Pak C18 cartridges (Waters, Hichrom Ltd. UK) (Machackova et al., 1993). The hormones were adsorbed by cartridges and the remnants were removed. The hormones were eluated from cartridge with 80% methanol and collected in vials. The hormone extracts were injected into High Performance Liquid Chromatography (HPLC) to detect t-Z, trans-Zeatin-Riboside and GA3.

The statistical evaluation of the data obtained from this study was performed using the SAS package program (SAS, 2013).

Results and Discussion

Some physical and chemical properties of the experimental soil are given in Table 1. The experimental soil was found assandy-clay-loamy textured, in neutral reaction, non-saline, limely and insufficient in terms of organic matter, phosphorus, iron and zinc contents.

Table 1. Some physical and chemical properties of the experimental soil

Depth	Sand	Silt	Clay	pH	EC	Lime	Organic Mater	P	K	Fe	Cu	Zn
cm		%			dS/m	%	%			mg/kg		
0-20	62	15	23	7.2	0.067	6.40	2.03	2.04	459	0.23	0.82	0.58

The effects of zinc applications were found statistically significant for leaf zinc content (P<0.05) gibberallic acid (GA3) (P<0.01) and trans-Zeatin-Riboside (P<0.01) levels (Table 2).

Table 2. The results of F values in variance analysis about effects of zinc applications on leaf zinc contents and hormone levels.

Variation Sources	df	Leaf Zinc Content	GA3	trans-Zeatin-Ribozid
Zn	3	2.96 *	24.48**	26.33**
Error	6			

*: P<0.05, **: P<0.01

The means zinc contents, gibberallic acid and trans-Zeatin-Riboside contents obtained in different zinc applications were given in Table 3 and in Figures 1, 2 and 3.

Table 3. The means of leaf zinc contents and hormone levels obtained in different zinc applications.

Zinc, mg/kg	Zinc	GA3	trans-Zeatin-Ribozid
		mg/kg	
Control	12.60 b	602.3 a	26.30 b
75	13.90 ab	273.7 b	58.26 a
150	13.97 ab	251.3 b	49.96 a
225	15.60 a	231.0 b	29.51 b
LSD (p<0.05)	2.46	123.1	10.49

a, b; values followed by the different letter are significantly different

The leaf zinc contents increased by zinc applications (Figure 1). The lowest and highest leaf zinc means were obtained as 12.60 mg/kg and 15.60 mg/kg in control and Zn_3 applications respectively. It was shown that zinc applications caused decreases in the giberallic acid content of strawberry (Figure 2). The highest giberallic acid mean was determined as 602.3 mg GA3/kg in control while the lowest mean was 231.0 mg GA3 kg^{-1} in Zn_3 application. Increasing doses of zinc up to Zn_3 dose leaded an unregulated increase in trans-Zeatin-Riboside levels. The lowest trans-Zeatin-Riboside mean was obtained as 26.30 mg kg^{-1} in Zn_0 dose while the highest trans-Zeatin-Riboside means were 58.26 mg/kg and 49.26 mg/kg in Zn_1 and Zn_2 doses, respectively.

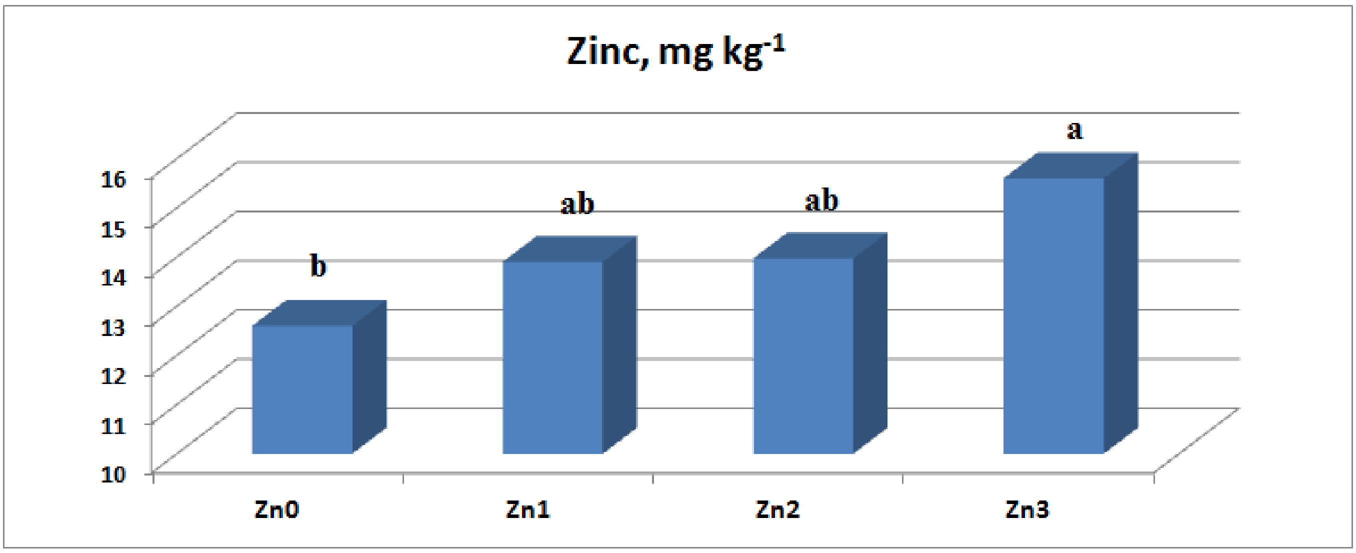

Figure 1. The effect of increasing zinc applications on the zinc content of strawberry plant, Zn0; 0 mg Zn kg^{-1}, Zn1; 75 mg Zn kg^{-1}, Zn2; 150 mg Zn kg^{-1}, Zn3; 225 mg Zn kg^{-1}

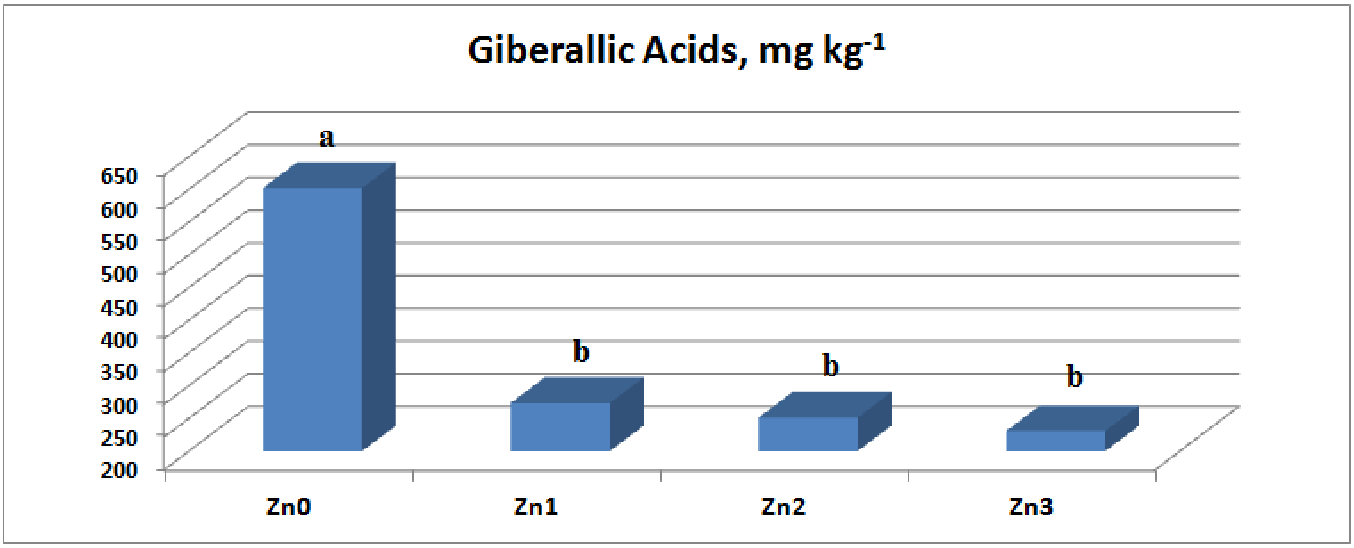

Figure 2. The effect of increasing zinc applications on the Giberallic acids content of strawberry plant, Zn0; 0 mg Zn kg^{-1}, Zn1; 75 mg Zn kg^{-1}, Zn2; 150 mg Zn kg^{-1}, Zn3; 225 mg Zn kg^{-1}

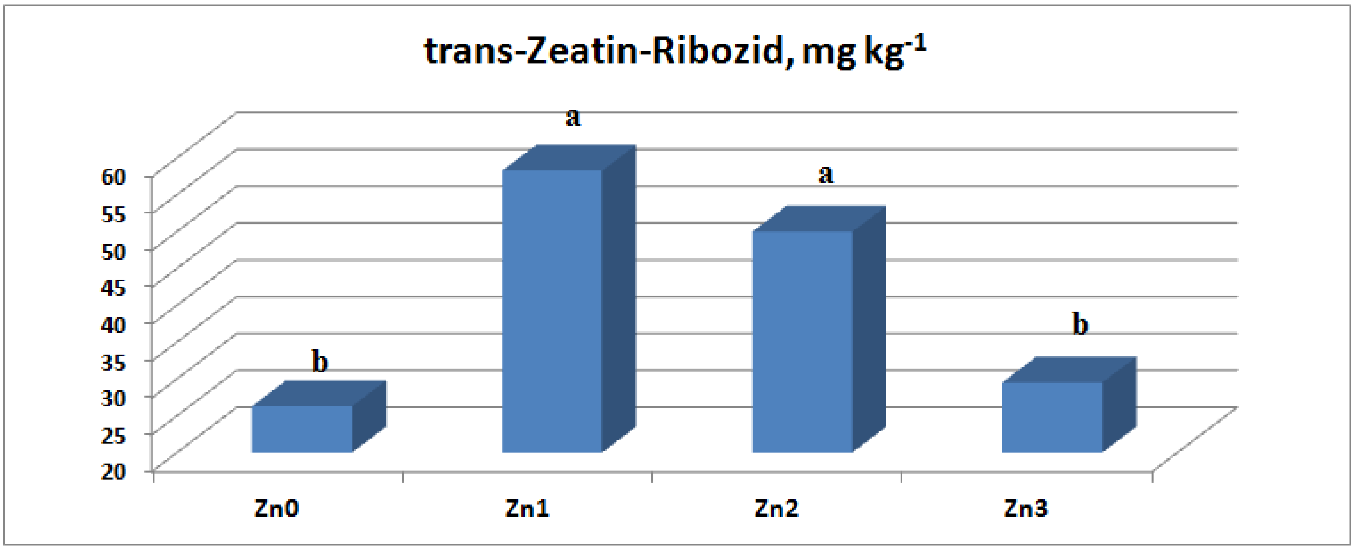

Figure 3. The effect of increasing zinc applications on the trans-Zeatin-Ribozid contents of strawberry plant, Zn0; 0 mg Zn kg^{-1}, Zn1; 75 mg Zn kg^{-1}, Zn2; 150 mg Zn kg^{-1}, Zn3; 225 mg Zn kg^{-1}

At this study generally increasing Zn doses increased trans-Zeatin-Riboside while gibberallic acid levels decresed in strawberry (Figure 3). There are the reports that the ions of heavy metals, including zinc affect the genetic material (Glass,1955; Moustchen-Dahmen, 1965). Masev and Kutacek (1965) reported that at high concentrations of zinc the content of gibberallin like substances fell to below that of the controls.

Conclusion

Increasing zinc doses up to Zn_3 dose increased trans-Zeatin-Riboside levels of strawberry. Zinc sulfate applications increase the auxin content in plants (Hossain et al, 1998). Zinc is involved in the regulation of auxin synthesis through the activation of tryptophan synthetase, because tryptophan is known to be a precursor of IAA (Karakis et al., 1990). Zinc prevents auxin oxidation. An enzyme system catalyzing auxin oxidation was more active in the absence of zinc (Hossain et al., 1998). In this study generally increasing Zn doses increased trans-Zeatin-Riboside while gibberellic acid levels decreased in strawberry.

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Role of Metal-Based Nanomaterials in Plant Growth

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Abstract

Food security and sustainable agriculture are major challenges of the current era. As the world population is continuously increasing, and more effort is required to boost agriculture production in a sustainable way to ensure food safety. Heavy metals have shown inhibitory toxic effects on plant growth and their accumulation in edible crops. Scientists have put in a lot of efforts to improve the existing approaches, however, in recent years, nanotechnology has shown promising results to improve food production. A large number of nanoparticles (NPs) were used to enhance plant growth; however, less is explored in stress conditions; especially metal pollution. Thus, in the present experiment, the plants i.e., barley was grown in heavy metal polluted soils. The foliar application ZnO and CuO NPs were applied to the barley. Results showed, the joint application of NPs enhanced plant growth under metal stress, however, less is known on the combined foliar application of these particles. Therefore, in-depth and several experiments are required to conclude that these foliar applications of NPs might be an effective approach to reduce the toxic effects of heavy metals. The results of the present experiment will be the addition of nanotechnological approaches for sustainable agriculture.

Keywords: CuO and ZnO foliar, heavy metals, metal-based NPs., spring barley, sustainable agriculture

Introduction

Recently, nanotechnology emerged due to its wide Potential to improve food security (Rajput et al., 2021b). Nanoparticles (NPs) are small particles with a high surface area. Nanoparticles (NPs) have many beneficial applications due to their small sizes (1–100 nm), such as in agriculture, pharmaceutical, catalysis, energy, material, and plant science etc (Jeevanandam et al., 2018). Heavy metals have been shown to have toxic inhibitory effects on plant growth and accumulation in edible crops. Heavy metals impact negatively on plant tissues.

Heavy metals have detrimental impacts on plants that include low biomass accumulation, chlorosis, growth and photosynthetic inhibition, disturbed water balance and nutrient assimilation, and oxidative stress, all of which resulted in plant death (Singh et al., 2016) Plants use two methods to manage the harmful effects of HMs and safeguard their organs, namely, limiting the absorption and concentration of HMs through tolerance method applications. Plants accumulate HMs within their cells, thereby their mitigation is conceivable. For example, *Triticum aestivum* L. plants have been shown to prevent the uptake of HMs, allowing crops to be grown without accumulating significant levels of HMs in the plant biomass (Noman et al., 2021). In other study, the NP treatment was found to be efficient in decreasing reactive oxygen species (ROS) synthesis as well as Cr transfer into the plant during Cr stress by considerably immobilizing it in the soil. Similar studies on microbially fabricated Cu-NPs that ameliorated Cr-induced toxicity and reduced metal immobilization in plants' organs, resulting in an increase in nutrient absorption and biomass, were also reported (Rajput, Minkina, et al., 2021).Recently, the utilization of Fe_2O_3-Nps proved that they can be used to mitigate the growing issues related with Cd phytotoxicity in *Oryza sativa* L. (Ahmed et al., 2021).

In order to effectively manage HM-contaminated agricultural fields and achieve better plant growth and development, researchers have suggested the use of biosynthesized NPs. To counteract the effects of Cd on *Zea mays*, it was noticed that foliar spray of TiO_2 was more efficient than root supplementation in a field experiment. Also, several studies indicated that antioxidant defence enzymes, the expression of metal transporter genes, the regulation of key metabolic pathways, the amount of metal retained, the amount of chlorophyll in plants, and the growth inhibition caused by metal stress can all be reduced by the foliar applications of NPs (Bidi et al., 2021).

Metal-based NPs such as copper (Cu), zinc (Zn), aluminum (Al), , iron (Fe), silica (Si), gold (Au), and silver, as well as their oxides such as zinc oxide (ZnO), copper oxide (CuO) titanium dioxide (TiO2), and cerium oxide (Ce_2O_3), have been synthesized for a variety of applications such as environmental remediation, energy storage, catalytic reactions, photo-catalytic applications, fuel cells, sensors Cu metal nanoparticles are well-known antibacterial agents (Sharma et al., 2019). They can cause cell death through a variety of mechanisms, including membrane disruption, DNA damage, protein synthesis inhibition, and blockage of various biochemical pathways. Zn NPs have antibacterial properties as well, though to a smaller extent than Cu. Zn's bioavailability and low toxicity make it an excellent substitute for toxic metals. (Ashfaq et al., 2016). NPs are now widely used in agriculture to increase crop productivity and protect crops from disease. The activation of plant defence systems by NPs reduces the damage caused by abiotic stress (Rajput et al., 2021a).

Plants benefit from NP application in the form of a foliar application in general, foliar applications of NPs provide sufficient nutrient elements for plant growth, aid in the fight against diseases or pathogens, quickly replenish nutrients in nutrient-deficient plants, and provide essential elements that are difficult to absorb in the roots, supplement elements that are difficult to obtain from deficient soil, and provide micronutrients that play important roles in plant metabolism (Hong et al., 2021). Foliar exposure to ZnO-NPs boosted leaf chlorophyll content while simultaneously decreasing oxidative stress and enhancing the activities of superoxide dismutase and peroxidase in the leaves, as compared to the control. Likewise, the foliar application of ZnO-NPs may be an efficient strategy to increase wheat development and production with maximal Zn and minimum Cd levels while decreasing NP migration to other environmental compartments (Adrees et al., 2021). Foliar-applied micronutrients are more useful for the response of plants at the field level because they are less toxic than soil application, which may cause toxicity when the same microelements are added (Semida et al., 2021). Some crop plants *viz*., sorghum, soybean, and rice have recently been supplemented with zinc oxide nanoparticles (ZnO-NPs), bulk zinc oxide (ZnO-B), and zinc salts (Zn^{2+}) as foliar nutrients; however, the ZnO-NPs form surpassed the other forms in terms of plant growth, physiology, biochemistry, antioxidant defence system, and productivity under adverse stress conditions (Awad et al., 2021). Therefore, with this background, in order to obtain in-depth knowledge on single and binary applications of CuO- and ZnO-NPs on crop plants' growth indices, this study is designed. The findings of the current study will be useful in illustrating the mechanisms of NPs for reducing the negative repercussions of abiotic stresses in order to increase agricultural production as a realistic way to improving agricultural output.

Zn Based Nanoparticles

The usage of ZnO NPs as a Zn supplement was examined. ZnO NPs were coated on the seeds of numerous plants (*Zea mays, Glycine max, Cajanus cajan, and Abelmoschus esculentum*). When germination tests were conducted with coated and uncoated seeds, the ZnO coating resulted in a higher germination percentage (93–100%) when compared to uncoated seeds (80 percent). A pot culture experiment with coated seeds demonstrated that crop growth with ZnO coated seeds was comparable to that seen with soluble Zn treatment applied as zinc sulphate heptahydrate (Adhikari et al., 2016). As a result, lower doses of ZnO NPs might be considered preferable to plants. Zn is a vital component for plant growth and development as ZnO-NPs were found to impart several positive benefits such as promoted germination, stem and root growth, *etc*. ZnO-NPs are widely documented for their ability to boost plant growth and biomass production. For example, Umar et al., 2020 studied the influence of ZnO-NPs on maize plant growth and development and observed better growth, increased yield, and increased Zn content in grains following foliar and soil application. When ZnO-NPs were applied to the plants foliar, the shoot fresh weight increased by 31% when compared to control plants. The chlorophyll content of ZnONPs supplemented plants via foliar and soil application.

Cu Based Nanoparticles

Cu is an essential micronutrient since it is found in a wide variety of proteins and enzymes and hence plays a critical function in plant physiology. Hence Copper nanoparticles (Cu-NPs) are frequently employed in a wide variety of commercial applications. Copper oxide nanoparticles (CuO-NPs) are anticipated to be more harmful than Cu NPs due to their oxidative nature. CuO-NPs have been shown in studies to have a stimulatory effect on *Elodea densa* (waterweed) and enhance photosynthesis, while at low concentrations they have been shown to increase the production of reactive oxygen species in plants (Nair and Chung, 2014).

Cu/CuO NPs are used in optoelectronics, catalysis, solar cells, like semiconductors, they're also applied as fungicides and pigments (Dimkpa et al., 2015). Cu is frequently used as a fungicide in vineyards and organic farming (Gogos et al., 2012) Cu NPs absorbed in chitosan hydrogel showed good impacts on tomato growth and quality, according to a recent study. Some enzymes' activity can rise (like catalase) or decrease (like ascorbate peroxidase) throughout this process. CuNPs' stimulatory actions are thought to be linked to the stimulation of antioxidant activity (Juárez-Maldonado et al., 2016). The foliar application of Cu NPs increased vitamin content, fruit firmness, and antioxidant enzyme, Similarly, foliar TiO_2 NPs improved plant tolerance to abiotic stresses like drought, salinity, and submergence, increased water and fertilizer uptake, and increased photophosphorylation and yield in barley (*Hordeum vulgare*) (Janmohammadi et al., 2016).

Iron-Based Nanoparticles

Fe_2O_3 NPs can be used instead of Fe fertilizers in agriculture (Ali et al., 2016). In a pot experiment, the effects of Fe_2O_3 NPs and EDTA chelated-Fe fertilizer on the growth and development of peanut, a crop that is sensitive to Fe deficiency. In this work, Fe_2O_3 NPs improved root length, plant height, biomass, and soil-plant analysis development values in peanut plants, according to the findings. By modulating phytohormone levels and antioxidant enzyme activity, Fe_2O_3 NPs aided peanut growth. Fe levels in peanut plants treated with Fe_2O_3 NPs and EDTA-Fe were greater than in the control group. The experiment looked at the effect of Fe NPs on mung bean growth (*V. radiata*). Seeds exposed to FeNPs had longer radicals and more biomass than seeds exposed to ions (Raju et al., 2016).

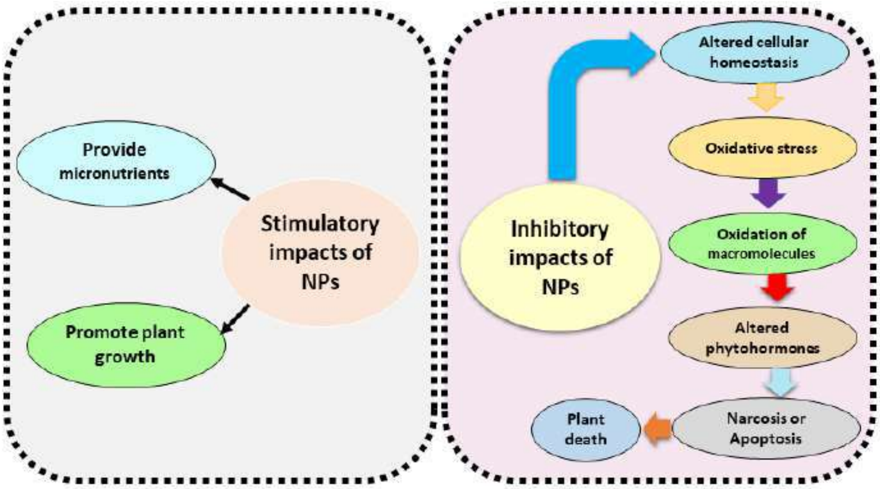

Figure 1. The interaction of nanoparticles with plants can have a variety of effects, as seen in this diagram.

Impacts of NPs on Plant Growth and Development

Plant growth and development is a broad and comprehensive concept that covers stages ranging from seed germination to plant senescence (Gutiérrez-Ruelas et al., 2021). Metal oxides and pure metals are the two types of metallic nanoparticles applied in plant growth and development research. All metal oxide NPs have the potential to influence plant growth and development.

Seed germination, shoot/root growth, biomass production, and physiological/biochemical activities all show both beneficial and detrimental effects (Siddiqi and Husen, 2017). The influence of metal and metal oxide nanoparticles on plant growth was researched by several study groups and shown to be positive, negative, and neutral. This could be due to various factors such as size, concentration, physicochemical features of nanoparticles, and plant species type (Zhao et al., 2020). Many metals serve as micronutrients for plant growth, and therefore metal nanoparticles have been shown to be effective plant growth promoters. Metal oxide nanoparticles are preferred as plant growth promoters among metal nanoparticle NPs This is due to the fact that they may quickly release metals as micronutrients in the vicinity of plant roots, allowing them to be easily absorbed by plants for further metabolism. As a result, research into the effects of various nanoparticles on plant growth is required. Fungicides, pesticides, herbicides, and fertilizers are now applied in excessive amounts to soil via foliar application. Fungicides, pesticides, and herbicides are chemical substrate mixtures that can be used to limit, inhibit, or kill pests, pathogens, or undesirable herbs that attack crops and reduce crop yield. Algicides, herbicides, fungicides, pesticides, and plant disinfectants are the most common nano-enabled crop protection products used currently (Rajput et al., 2021).

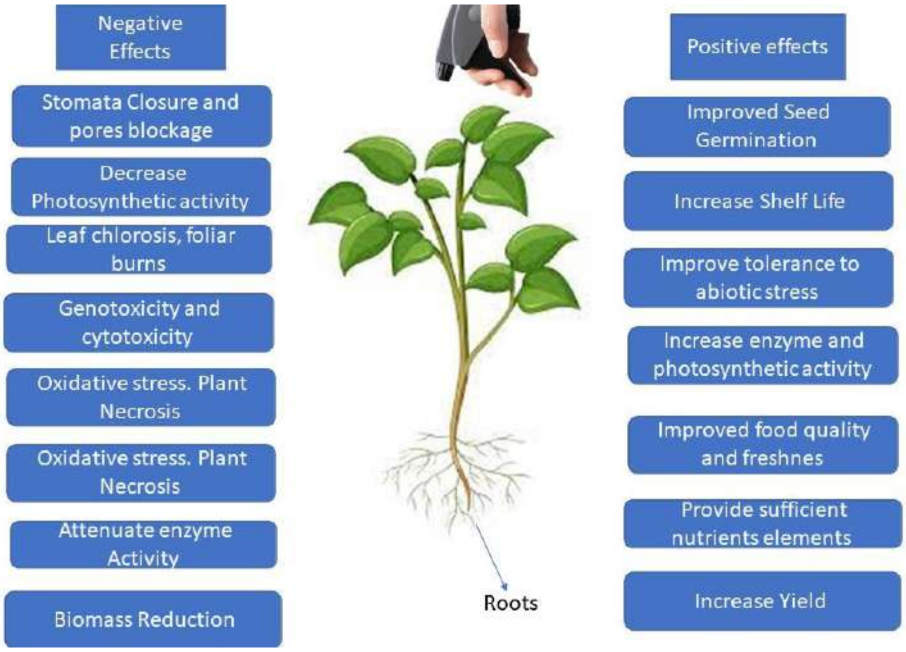

Figure 2. Positive and Negative effects of Foliar Application of Nanoparticles

Conclusion and Future Perspective

Many different types of nanoparticles have been indicated to be useful for this purpose. Some metals and metal oxides are used as micronutrients to help plants growth. They can be absorbed by plants when mixed with soil. Similarly, metal nanoparticles and metal oxide nanoparticles can be important for plant growth. The advantage of using nanoparticles of corresponding metals and metal oxides is that they have a substantial influence with a smaller amount. These nanoparticles can help plants grow. On the contrary, if they are used in excess of certain concentrations, they can interrupt the soil ecosystem, limiting the growth of soil microorganisms and plants. As a result, the negative consequences must be considered.

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Applicability of a mathematical approach to evaluate of soil temperature in the plant root zone

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Abstract
Plant growth, along with other soil properties, is strongly related to optimum soil temperature in the plant-root zone. In this research, the theoretical expression obtained based on the conservation of energy for soil heat flow and the Fourier law was used to evaluate the temperature in the plant-root zone. It has been shown that the temperature values in the spherical soil area surrounding the plant root medium depend on the separated heat flux, the conductivity coefficient, the average surface temperature of the spherical medium, and the radius of the root zone. When compared with the average surface temperature, a decrease in temperature values towards the center of the plant-root zone and an increase in distances greater than the radius were determined. The surface heat flux of the spherical soil medium surrounding the root zone is shown in the form of an expression of the law of energy conservation.
Keywords: Spherical soil media, heat flux, soil temperature, energy conservation, Fourier's law.

Introduction

Plant growth is significantly affected by soil properties and various environmental factors, as well as temperature change in the plant root zone. Experimental and theoretical evaluation of the temperature in the root zone helps to apply the necessary agricultural practices to maintain soil temperature at the optimum level.

Different approaches are used to determine the change in root zone temperature in various plant systems and the effect of this change on plant growth (Bai et al., 2002; Quadir et al., 2011; Yan et al., 2012; Yong et al., 2014; Zhao et al. , 2021). The plant root system is more sensitive to the deviation of the temperature from the optimum level than the aboveground parts (Hao et al., 2012; Kawasaki et al., 2014; Sakamoto and Suzuki, 2015), it alters various physiological and metabolic processes in cells and causes a number of stresses in plants, especially during the reproductive phase (Wang et al., 2008; Hemming et al., 2012; Nakano et al., 2013; Matschegewski et al., 2015; Gonzalo et al., 2020).

The evaluation of the temperature in plant root zone is based on the variation of the heat flux and the Fourier law. According to Xie et al. (2022), the heat flow variation and heat conductive equation were used to determine plant root parameters. The estimation of the temperature change in the soil layers is also related to soil heat zone including heat flow and soil temperature (Chen et al., 2006; Usowicz et al., 2017; Ekberli and Gülser, 2015; Kayaci and Demir 2018; Gülser et al., 2019; Ekberli et al., 2020; 2021a,b). Determination of the soil heat zone is critical in regulating physical, chemical and biological processes in the plant-root zone. For this reason, many researchers (Heusinkveld et al., 2004; Foken, 2008; Sayılğan, 2016) show the necessity of determining the soil heat zone under suitable plant, environment and climatic conditions. Examining the applicability of theoretical models in the evaluation of temperature in plant root zone helps to partially eliminate this problem.

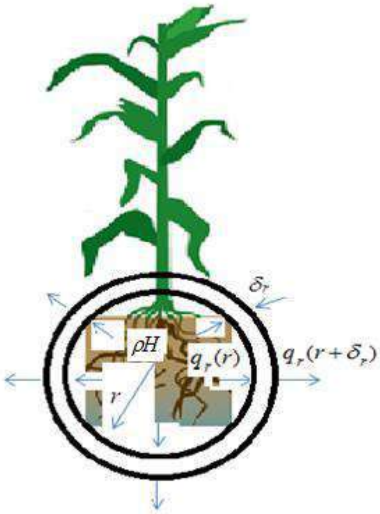
The aim of this study is to mathematically evaluate the temperature in the plant-root zone depending on the conservation of energy and Fourier's law.

Material and Methods

The expression of the heat flow leaving from a thin layer of the spherical soil area depending on the law of energy conservation, and the equation obtained according to the Fourier law to determine the soil temperature constitute the material of this study. The mathematical modeling method was used as the research method (Ekberli, 2008).

Results and Discussion

The formation and change of the temperature area in the plant root zone has an important effect on supplying the optimum levels of soil properties. Quantitative evaluation of soil temperature also helps to apply necessary agricultural methods depending on plant variety and development. Analytical evaluation of temperature in the plant root zone is based on some assumptions.



The energy balance equation is used to determine the heat conductivity in a spherically symmetrical environment. Suppose that the radius of the plant root medium is r, the thin spherical soil thickness surrounding the plant root medium is δr and the heat flow distribution at the molecular level is symmetrical. In this case, the total radial heat flux from the outer and inner surfaces of the thin spherical soil area surrounding the plant root zone are

$$4\pi(r+\delta r)^2 q_r(r+\delta r) \qquad (1)$$

and

$$4\pi r^2 q_r(r) \qquad (2)$$

respectively.

Figure 1. Heat flow in the plant root zone and in the soil surrounding the plant root zone

Heat flux retained in the thin spherical soil area surrounding the plant root zone is

$$4\pi(r+\delta r)^2 q_r(r+\delta r) - 4\pi r^2 q_r(r) = 4\pi\left[(r+\delta r)^2 q_r(r+\delta r) - r^2 q_r(r)\right] \qquad (3)$$

When considering the expression (2) in (3) and ignoring the higher order ($n \geq 2$) δr, the following expression is obtained:

$$4\pi\left[(r+\delta r)^2 q_r(r+\delta r) - r^2 q_r(r)\right] = 4\pi r^2\left(\frac{2}{r}q_r + \frac{dq_r}{dr}\right)\delta r \qquad (4)$$

Theoretically, according to the law of energy conservation, the heat flow leaving from the thin spherical soil area is partially replaced by the heat energy generated by the soil processes and environmental factors.

If the amount of heat separated from the unit volume of soil (ρ) is H, the total heat leaving the soil surrounding the plant root zone is

$$4\pi r^2 \rho H \delta r \qquad (5)$$

The following equations are obtained by using the (4) and (5) expressions,

$$4\pi r^2\left(\frac{2}{r}q_r + \frac{dq_r}{dr}\right)\delta r = 4\pi r^2 \rho H \delta r \qquad \text{or}$$

$$\frac{dq_r}{dr} + \frac{2q_r}{r} = \rho H \qquad (6)$$

If the expression of $q_r = -\lambda \frac{dT}{dr}$ (λ -soil heat conductivity) Fourier's law (Fourier, 1822) is applied in equation (6) of the heat balance equation, the following equation is obtained:

$$\lambda\left(\frac{d^2T}{dr^2} + \frac{2}{r}\frac{dT}{dr}\right) + \rho H = 0 \qquad \text{or}$$

$$\lambda \frac{1}{r^2} \frac{d}{dr}\left(r^2 \frac{dT}{dr} \right) + \rho H = 0 \tag{7}$$

When statement (7) is written as $\lambda \frac{d}{dr}\left(r^2 \frac{dT}{dr} \right) + r^2 \rho H = 0$, and integrating according to r, the following equations are obtained

$$\lambda r^2 \frac{dT}{dr} + \frac{r^3}{3} \rho H + c = 0$$ or

$$\frac{dT}{dr} + \frac{r}{3\lambda} \rho H + \frac{c}{\lambda} \frac{1}{r^2} = 0 \tag{8}$$

If the statement (8) is integrated again according to r, the following equation is obtained

$$T + \frac{r^2}{6\lambda} \rho H + \frac{c}{\lambda}\left(-\frac{1}{r} + C \right) = 0 \tag{9}$$

Temperature function is obtained from the statement (9) as given below:

$$T = -\frac{r^2}{6\lambda} \rho H + \frac{C_1}{r} + C_2 = 0 \tag{10}$$

The integral constants C_1 and C_2 are determined depending on the boundary condition of each particular problem. For example, assume a homogeneous distribution of heat generated by soil processes and environmental factors in a global area of radius a. In this case, as the boundary conditions, the temperature is finite at the center of the spherical field and T_0 at the surface $r = a$. According to these conditions, $C_2 = T_0 + \frac{a^2}{6\lambda} \rho H$ is obtained from the statement (10) and $C_1 = 0$.

Substituting the integral constants in (10), the distribution of temperature in the spherical area surrounding the plant root zone is expressed by the following function:

$$T = T_0 + \frac{\rho H}{6\lambda}\left(a^2 - r^2 \right) \tag{11}$$

In this case, according to the Fourier's law q_y heat flow at surface of $r = a$ is expressed as

$$q_y = -\lambda \frac{d}{dr}\left[T_0 + \frac{\rho H}{6\lambda}\left(a^2 - r^2 \right) \right],$$

$$q_y = \frac{\rho H a}{3\lambda} \tag{12}$$

The expression (12) is an expression of the energy conservation law and is applied within the global field, regardless of the type of heat convection.

The optimum soil temperature for optimum root development of various plants varies, usually between 15°C and 35°C. At the same time, it was emphasized that in soils including well soil properties, most of the plant roots go to a depth of 90-150 cm and a small part to a depth of 180-240 cm (Çeçen and Çakmak, 1996; Kacar et al., 2020).

In some studies, the thermal conductivity of clay soil is 1.476 Watt · m^{-1} · $°C^{-1}$; bulk density is 1120 kg · m^{-3}; and average surface temperature is 24.8°C; It has been shown that the heat flow (H) leaving the surface is 0.0021 Watt·kg^{-1} (Gülser et al., 2019; Ekberli and Gülser, 2020). Based on the literature information above, the soil temperature surrounding the plant-root zone was calculated according to the expression (11) and given in Table 1.

Table 1. Theoretical temperature values calculated according to the expression (11) in the plant root zone.

r, m	0.75			0.65			0.55			0.45		
a, m	0.75	0.50	0.20	0.65	0.50	0.20	0.55	0.40	0.20	0.45	0.30	0.10
T, °C	24.80	23.97	23.41	24.80	24.34	23.78	24.80	24.42	24.10	24.80	24.50	24.29

Soil temperature decreases slightly when r>a, and approaches the average temperature of the soil surrounding the root zone when r=a (Table 1). It has a significant effect on the temperature change in the root zone, along with the soil properties, on the thermal properties (heat conduction, average temperature, etc.).

Conclusion

It has been examined that it is possible to evaluate the temperature according to the theoretical expression depending on the average surface temperature of the spherical soil environment surrounding the plant root zone, the heat flux and the heat release in the environment. It has been theoretically determined that the soil temperature decreases at a low rate in case of an increase in the r/a ratio. It seems that the change in temperature in the root zone is significantly dependent on the thermal properties together with the soil properties. For the further development of this theoretical research, it is thought that it would be useful to evaluate the parameters experimentally in detail with considering the time factor, other thermal properties (heat capacity, thermal diffusivity coefficient, etc.) and some other soil properties.

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How soil property can be altered with the use of different biodegradable geotextiles? A review

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Abstract

Geotextiles are thermophilic polymer that is produced from synthetic fibres or biodegradable materials. Geotextiles have been used in different sectors including agriculture and civil engineering. However, in most cases, non-degradable polymers such as polyesters were used for geotextile production. The application of such material can bring soil pollution along with the accumulation of microplastic. Since they are imposing an enormous threat to the environment, the search for green, biodegradable, renewable polymers is of growing interest. Biodegradable geotextile covers a large scope of application in the fields of agriculture and environmental engineering. The geotextile produced from natural fibres can be derived from different sources-Plants, animals, and minerals. Depending on their types, geotextiles have significant effects on the physical and chemical properties of soil. Natural geotextile can be used as an alternative to traditional material in many applications such as crop and livestock protection, erosion control, reinforcement systems on embankments, and so on. Previously they have been used mostly for filtration, separation, permeability, drainage, and stabilization purposes. Not much work has been done to enlighten the application of natural biodegradable geotextiles in soil protection and improve crop productivity. Soil covered with biodegradable textiles is protected from direct exposure to sunlight, wind and raindrop. This paper aims to review the previous studies which investigated the effects of different natural geotextiles on the characteristics of the soil. Additionally, different sources, types, applications, and prospects of geotextile are discussed based on recent data.

Keywords: Artificial and natural non-woven fabrics, agriculture, erosion, soil nutrients.

Introduction

The word geotextile derived from Geo and textiles. Geo means 'ground' or 'land', connected to soil. The word "Textile" refers to a general term used by a manufacturer from fibres, filaments, by flexibility and by fitness and by ratio of length to thickness (Reddy & Pal, 2021). Geotextiles appear very durable and soft. It is very helpful in environmental science as it is designed to be suitable to the environment. For the production of geotextile, degradable and non degradable materials are used. The product from non degradable materials, such as synthetic polymers can be found in four different forms - non woven, woven, knitted and composite geotextiles. Textile fibres can be classified into two main groups, man made fibre and natural fibre. Natural geotextiles are produced as woven fabrics and non- woven matting structures or as a combination of both woven and non- woven structures (Desai & Kant, 2016). Synthetic geotextiles are mainly produced from non degradable polymers like polyolefin, polyester and polyamide family. The widespread use of such products increase the amount of plastic production which in turn consumes a large amount of fossil fuel. Plastics produced from non-degradable sources and causes green house gas emission as their combustion takes place. In order to minimize the combustion from non renewable sources and to reduce environmental pollution, the possible solution is to replace petrochemical plastics with naturally degradable products. At present, only 2% geotextiles are produced from natural sources. It is estimated that, about 50% of synthetic materials in all applications can be replaced by natural fibres and biopolymers (Prambauer et al., 2019). Geotextiles produced from natural fibre ensures instant protection and provides organic materials and nutrients to the soil that create an ideal condition for plant growth. After degradation, they When they also enhance soil microbial activity, encourage soil fertility and aggregate stability. Moreover, they do not have an adverse effect on the environment (Broda et al., 2016; Prambauer et al., 2019; Shavandi et al., 2017). However, currently the world market is dominated by synthetic fibre because of their ability for long time use, where natural geotextiles are more useful for short time applications. The present research will focus into the agricultural aspects of natural geotextile application with an aim to determine the effect of biodegradable geotextiles on soil properties.

Historical Development of Using Geotextile

The first use of natural fibre for constructional purposes possibly dated back to the fifth or fourth millennium BC according to Bible (exodus chapter 5, verse 6-9). Two of the remaining role models of materials reinforced by the natural fibres are the Ziggurat in the city named Dur- Kurigatzu (now known as Agar- Quf) and the great wall of China (Pritchard, M., 1999; Rawal et al., 2010) In 1926, woven cotton fabrics were used for the first time as an ancient form geotextile on the construction of roads by the South Carolina Highway Department, the fabric was more likely to be used as geomembrane than geotextile as it was covered with hot asphalt during production. The synthetic-fibre based geotextile started being used in aircraft engineering in the early 1950s, the two earliest usages reported in 1956 in Florida and Netherlands as permeable woven fabric for erosion control, where Dutch engineers started trials for geotextile produced from handwoven Nylon strips for 'Delta works scheme'' (Rawal et al., 2010) which took place immediately after the destructive flood in 1953. One of first professional geotextile organization was the Netherland Geotextile that assemble all the people in designing, testing and manufacturing along with governmental agencies (Ogink, 1975; van Santvoort, 1995 cited in Koerner et al., 2016). Giroud (1986) reported that the use of needle punched non-woven fabrics started in 1960s in France by Rhone- Poulenc. The application of non-woven geotextile for road stabilization and segregation begun in 1968. In Belgium Gyssels (1982) reported the use of woven geotextiles as undersea mattresses tied with willow fascines to collect large stones dropped from boats for the North sea. In US, the use of geotextiles began in 1950s as a shield behind precast solid seawalls. Raymond, G. (1982) reported that in Canada, non-woven geotextiles gained popularity as filters and separators in rail road since early 1970s. In Brazil and South Africa, needle punched non-woven were being produced from continuous filaments in 1971. In Australia, Lowson and Ingles (1975) mentioned that bitumen-sealed geotextiles has been used to encapsulate water sensitive and brittle soil for unpaved roads.

1. Major Geotextile Applications

Now-a-days geotextiles made of both natural and synthetic fibre (Rawal et al., 2010) are being used. A list of such applications are given in the diagram below (Figure 1).

Composition of Geotextile

Manufacturing Geotextile From Synthetic Fibre

The raw material for geotextile selection must be adequate to the cause of production. At present, the most widely used base material for geotextile production is Polypropylene (PP), Polyethylene terephthalate (PET) and Polyethylene (PE) come next in the list (Prambauer, et al., 2019; Wu et al., 2020). Polypropylene (PP) is the most commonly used base fibre for geotextile due to its cost-effectiveness, chemical insensitivity and Flexible properties. The low density of the fibre adds an extra benefit to its feature, as it results in an incredibly low cost per volume. However, one of its major disadvantages includes its low sensitivity to UV. Additionally, its performance declined in high temperatures and shows poor creep characteristics (Stepanovic, et al., 2016; Wu et al., 2020). Another widely used fibre for geotextile is PET. It has considerable tensile properties and high creep resistance. Geotextile made from the Polyester fibre is capable to be used at high temperatures. The only drawback of such fibre is that it easily gets hydrolysed and degraded with the soil which has a PH value of more than 10 (Pelyk, et al., 2019). Polyethylene fibre is a barely used source of geotextile due to its low supply rate, although it's used to produce geomembranes. Additionally, Polyamide is also a less used fibre in geotextile production because of its weak comprehensive performance (Rawal, et al., 2016).

Manufacturing Geotextile From Natural Fibre

Some distinctive properties of natural fibres are i.e., high strength, elasticity, moisture uptake capacity and low elongation. There are three types of natural fibre available- Plant fibre, animal fibre and mineral fibre. Vegetable fibres have better potential for geotextiles due to its higher engineering properties. For example this fibre posses higher strength and modulus compared to animal fibre. On the contrary, Mineral fibre have less strength and flexibility and its expensive. The criteria for a geotextile for reinforcement is that it should possess a higher tensile strength. Choosing those fibres which have higher molecular orientation are best options to fulfil this criteria. Vegetable fibres naturally retain this quality. Therefore, the nature provides appropriate fibres to be used as geotextiles. Some of the most widely used vegetable fibres are- jute, coir, flax, sisal, kenaf, hemp etc. (Pritchard et al., n.d.). The physical property of the fibre is determined by two basic components, those are- Cellulose and hemicellulose. Where cellulose is the strongest organic component of the fibre, hemicellulose has an open structure with an of hydroxyl and acetyl group. It is partially water soluble and it has hygroscopicity. Lignin is fragranced, phenylpropane unit polymer. The service life of natural geotextile depends on the amount of cellulose and lignin content of the fibre. When the content is higher, the durability also goes high (Wu et al., 2020)

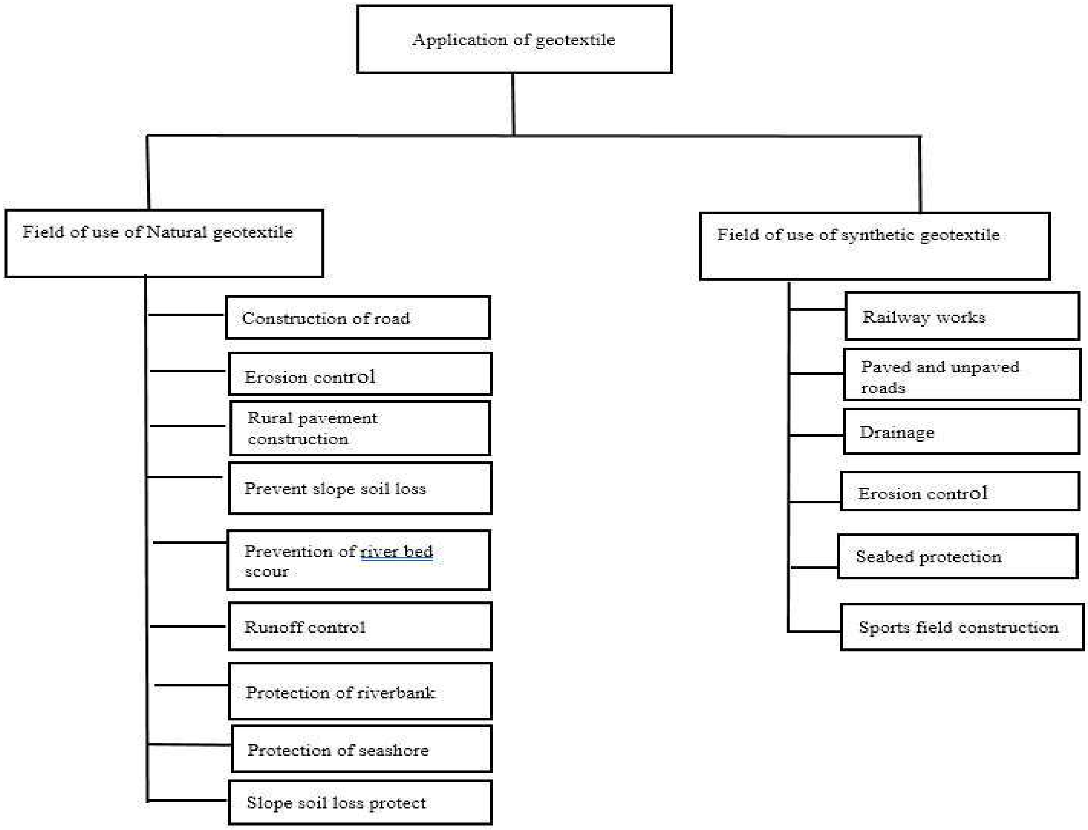

Figure 1. Application of natural and synthetic geotextiles (Rawal et al., 2010)

Functions of Geotextile

Both synthetic and natural geotextiles exhibit a variety of functions in different sectors of agriculture, mechanical and civil engineering. Some of the most distinctive functions are discussed below.

Geotextile Used As Separator and Filer

With an excellent porous structure, geotextile can act as a barrier that controls the transportation of particles from one layer to another. Also, due to its positive permeability, geotextiles can be used as a filter that allows fluids to flow through the surface of the fabric but prevents soil particles from transmitting liquid through the fabric. Thus it checks the loss of soil particles, delicate sand, and small stones upstream. The filtration function is mostly utilized in geotechnical engineering (Desai and Kant, 2016).

Geotextile Used in Drainage

The nature of water conductivity in geotextiles makes it favorable to be used as a drainage channel. The water in the soil structure can be reserved and slowly released along with the geotextiles. Therefore, nowadays geotextiles are used for different drainage purposes such as underground drainage, subgrade drainage, conserving call drainage, and other drainage Works (Wu et al., 2020).

Geotextile Used As An Erosion Control Product

Geotextiles with natural fibre are considered to be protective against erosion and provide stabilization to the soil surface. Geotextiles can serve as an erosion control material that protects soil from the surface flow with water. The mechanism of erosion control is to minimize the destructive force of overland flow by up-taking and storing the least amount of water and by reducing soil particle movement (Desai and Kant, 2016).

Geotextile Used Reinforcement

Compacted soil tends to have a better comprehensive modulus but less tensile modulus. Therefore when subjected to high tensile pressure, the aggregates of such soil can be easily segregated. The fibres in some geotextiles have a considerable tensile module that can be efficiently used as a reinforcing tension element when incorporated between consolidated soils and aggregates. The feature of reinforcement in geotextile is the most widely used in geotechnical engineering. Some examples of such sectors are- runways, unpaved roads and railways, landfills, berms, and reinforcing soft soils infrastructures (Desai and Kant, 2016).

Effect of Natural Geotextile on Soil

Soil Structure and Aggregate Formation

Adhikary and Sankar (2020) proposed that soil aggregate is a very crucial factor in the soil management system. Soil aggregate is consedered to a parameter in measuring soil structure which coordinate many essential physical, chemical and biological processes in soil. In an experiment conducted during 2008-2010 at regional research station at Gayeshpur New alluvial zone of Nadia district in West Bengal, the effect of four natural geotextiles treatments (jute, coco coir, vetiver root geotextile) were examined on groundnut crop. The author mentioned that there are many indicators that are applied to evaluate the condition of soil structure. Such indicators are- mean weight diameter, geonatric mean diameter, water stability aggtegates and percent aggregate stability. In the mentioned publications authors concluded that application of mentioned geotextiles improved soil properties and yield and out of all, jute geotextile was found to be more effective (Adhikary and Sankar, 2020).

Effect on Soil Erosion

Broda et al., (2018) reported that geotextiles installed in the ditch can provide immediate protection of the bank. The experiment was conducted by using wool fibres. Geotextile was produced from scoured polish mountain sheep wool geotextiles were placed on the top of a drainage ditch which was exposed to extreme surface erosion. The author did not observe erosive damage and land sliding of the bank was seen during the growing season. Moreover, the plant growth was very intense in the wool-covered area. The color of the plants was deeper compared to the plants of other parts of the bank. Therefore, it was evident that the plants were in good condition.

Effect on Plant Growth and Yield

A Field experiment was conducted by Pal et al., (2020) in 2015-2016 at Gotka village near Barudia North 24 Parganas, West Bengal. Four different types of geotextiles i. e. Non-woven jute geotextile, dry grasses geotextile, coco-coir geotextile, banana leaf fibre geotextiles were tested and showed satisfactory results in improving soil condition that helps to increase the yield of capsicum crops. Amon them, the jute fibre geotextile recorded for maximum growth and yield. Sarkar et al., (2019) demonstrated an experiment at the central research farm, Gayespur, BCKV on 12 years old lichi orchard. The soil was Gangetic alluvial with sandy clay loam texture, moderately fertile, with good water holding capacity and PH 6. Three non-woven jute geotextiles (T1, T2, T3) of varying thickness and composition were used. The result shows that maximum fruit diameter and fruit length was seen with the first variant (T1) of non-woven jute geotextile. The author suggested that the growth might be caused by conservation of soil moisture, temperature regulation, and suppression of weed growth.

Effect on Organic Carbon

A recent study by Sumi et al (2021) investigated the stability of a new type of coir geotextile with an eco-friendly surface coating called Cashew nut shell liquid and its effect on environment. The soil media was prepared by a mixture of sand, garden soil and cow dung at 2:1:1 ration. The result shows that after 360 day there was a significant increase in microbial activity compared to the control. Additionally, concentration of organic carbon increased after the application of geotextile (Sumi et al., 2021). A positive effect of the use of geotextiles on the content of organic carbon was also noted by Pal et al. 2020, which showed an increase in carbon content by the application of natural fibre geotextile. The increase of organic carbon showed the following order- i.e. Jute geotextile (1.37%)>Dry grasses geotextile (1.27%) >coco coir geotextile (1.24%) > banana leaves geotextile (1.13%) > control (1.02%). The amount of organic carbon found highest in the plot under jute geotextile (1.37%) over the control (Pal et al., 2020)

Effect on Soil Nutrients

Onuegbu (2021) conducted an experiment with three natural geotextiles which include coir, plantain pseudo stem and palm fruit bunch. Geotextiles were prepared from these fibres by decortication process and twisted into yarn and applied on the clear farm over the seeds of groundnut, waterleaf and Green (*Amaranthus*). After three months the effects of woven and non-woven geotextiles on the amount of soil nutrients which were Na, Ca, Mg, and phosphorus was recorded. All of them showed positive outcome in terms of soil nutrient uptake rate. Author explains that the increase of Na and Mg content was caused due to the high content of Na and Mg in the woven coconut fibre derived from the lignin fibre. In case of Ca, the content raised almost twice compared to primary content in soil. The author suggested the reason for increase in the amount of Ca content is the increased rate of degradation of plantain fibre. The use of non-woven palm in the studies presented by Onuegbu (2021) resulted in a two-fold increase in the phosphorus content in the soil. Overall, it can be said that the woven geotextiles showed better results compared to non-woven geotextile (Onuegbu, 2021).

Conclusion

In past few decades, the application of natural geotextiles showed a growing trend and its demand is rising. The reason is its ability to reduce environmental pollution due to its renewable, biodegradable nature. It have been widely used in mechanical engineering and other engineering sectors. The application of natural geotextile in terms of agriculture is still less discussed. In this paper, the author tried to identify the relevant researches that investigated the application of geotextiles that contributed to soil structure and stabilization, anti erosion property, plant growth, plant nutrition uptake etc. Based on the literature review, jute geotextiles contribute to improve soil structure and condition which helps to increase yield, where wool geotextiles protects soil from erosive damage. Soil covered with woven coir fibre showed high amount of Na and Mg content. Similarly, Ca content was higher in geotextiles containing woven plantain fibre. Non oven palm bunch only found to increase phosphorus level in soil due to its high ash content. Overall, woven geotextiles has reported to be more effective than non-woven geotextiles.

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Functional evaluation of available up to date pedotransfer functions for estimation of saturated hydraulic conductivity of selected localities in the Czech Republic

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Abstract

Saturated hydraulic conductivity (Ks), as a fundamental soil property, determines the ease with which pores transmit water within saturated soil profile. It is considered as one of the key parameters in many hydrological simulation models representing the rate of infiltration and surface runoff occurrence. Nowadays, pedotransfer functions (PTF's) are routinely used for its estimation. Large databases of basic soil properties, together with different approaches including high-performance computing are involved to obtain reasonable Ks estimates. The aim of this study was to test the applicability of recently published PTF's based on machine learning approach (Araya and Ghezzehei, 2019) and compare their performance with well-known hierarchical PTF's (ROSETTA by Schaap et al., 2001) for two localities in the Czech Republic (Ruzyně and Strašov), where the predictors and Ks values were measured. Percentage content of clay, silt and sand particles, together with or without information about dry bulk density and organic matter content were used as predictors in both, machine learning approach employing Boosted Regression Trees (BRT) and ROSETTA estimates. The quality of the estimates was determined on the basis of root mean squared error (RMSE) and the correspondence between estimated and measured Ks data was evaluated by the coefficient of determination (R^2). Based on RMSE values, the five tested models of PTF's were ranked. The results reflected high Ks variability measured within the study areas; 1–964 cm/day in Strašov and 10– 1261 cm/day in Ruzyně. Relatively high range of RMSE values was observed, especially for high Ks cases caused by the preferential flow which the predictors could not fully comprehend. The best ranking was identified for models using dry bulk density data in addition to the particle size distribution data (BRT for Ruzyně, ROSETTA for Strašov).

Keywords: Machine learning approach, pedotransfer functions, ROSETTA, saturated hydraulic conductivity, suitability ranking

Introduction

Saturated hydraulic conductivity of soil (Ks) is considered as one of the most important and widely used soil parameters, commonly used in a number of different geotechnical, environmental, and water management applications and models [1-4]. Ks determines the fate of water coming to the ground; determines the infiltration rate, runoff generation, groundwater recharge and deep drainage. Amount of plant available water and water and solute transport processes are regulated by Ks. Different methods were developed to determine the Ks in the field and in the laboratory [5]. However, the direct measurements are often labour intensive, time-consuming and thus costly. Moreover, for larger areas or heterogeneous areas, an unreasonably high number of the replicates should be carried out to account the spatial variability of Ks. That is why a lot of effort has been invested into indirect estimation methods over the last 30 years. Bouma introduced the term pedotransfer function (PTF) as "translating data we have into what we need" in 1989[6]. This concept was based on easily measured and easily available soil properties such as soil texture and dry bulk density used as predictors to estimate desirable hydraulic properties (e.g. Ks). Since then, numerous PTF's have been proposed for a variety of purposes. Reviews discussing already published PTF's can be found in works of Wösten et al. (2001)[7], Pachepsky and Rawls (2004)[8] or Verecken et al. (2010)[9]. These works were aimed mainly on prediction of soil water retention parameters, while the review of Zhang and Shaap (2019)[10] was focused specifically on the predictions of Ks providing an insight into the history, required predictors and statistical techniques for development of PTF's for Ks prediction. In addition to that, accuracy and reliability of existing PTF's were also evaluated in their paper.

Generally, the first types of PTF's were based on tabular values based on the soil texture class (e.g. Wösten et al., 1995[11]) and linear/nonlinear regression equations (e.g. Wösten et al., 1995[11], Minasny et al., 1999[12]). More recent approach utilises neural network analysis (NN) which does not follow any prescribed concept, and the desired output is obtained by an iterative procedure which links the predictors (basic soil properties) to the estimand (Ks). This approach has been implemented into a user-friendly computer program ROSETTA, where the models published by Shaap and Leij (1998 and 2000)[13, 14] are implemented. The current technical progress in high-performance computing and hydraulic data collection in large databases are enabling development of data-driven methods such as machine learning technique (ML). Araya and Ghezzehei (2019)[4] presented ML-based PTF's for Ks prediction using four types ML-algorithms (K-Nearest Neighbours, Support Vector Regression, Random Forest and Boosted Regression Trees) and made them publicly available.

Thanks to their availability and large background soil databases, the program ROSETTA[15] and the ML-based PTF's[4] were used in this study to test the hypothesis, that these PTF's are robust enough to predict Ks of soils from different origin (Czech Republic) with acceptable accuracy.

Material and Methods

Experimental Sites Description

For this study a total number of 45 measurements of Ks together with the information about soil texture, dry bulk density and organic matter content was utilised. The data originated from two research localities in the Czech Republic, Ruzyně and Strašov. Experimental site Ruzyně is located in the area of Crop Research Institute in Prague (50°05' N, 14°20' E, altitude 345 m a.s.l.) with mean annual precipitation 473 mm and mean annual temperature 7.9°C). The agricultural field has been established in 1994 and the soil was classified as Orthic Luvisol (WRB, 2014)[16]. Ks values were measured in situ by Pressure ring infiltrometer[17] and Hood infiltrometer (METER Group, Inc.). Experimental site Strašov (50°05' N, 15°31' E) is an agricultural field with a functional controlled drainage system. It is a relatively flat area in a very small slope (inclined to south-west) which is located in the altitude of 240 m a.s.l. with mean annual temperature of 8-9°C and mean annual precipitation range between 550 and 650 mm. Predominant soils in Strašov are sandy soils classified as Arenosols (WRB, 2014)[16]. Undisturbed soil samples (250 cm^3) from the depth of 5-15 cm were taken and Ks was measured in the laboratory using the K_{SAT} device (METER Group, Inc.).

The different methods for Ks measurement might be leading to different results even in the relatively homogeneous material. Since there is no reference method for Ks, this issue needs to be considered when evaluating and discussing the results and accuracy of the Ks predictions. For soils from both localities, the basic soil characteristics for the surface layer, namely particle size distribution by Hydrometer method[18], particle density (Water pycnometer method), dry bulk density and organic matter content (total organic carbon content by the modified Walkley–Black procedure[19]) were determined in the laboratory (Tab. 1).

Table 1. Overview of basic soil characteristics determined for experimental sites Strašov and Ruzyně

	Clay (%)	Silt (%)	Sand (%)	Dry bulk density (g/cm³)	Particle density (g/cm³)	Organic carbon (%)	Ks (cm/day)
Experimental site Strašov							
Average	22.0	9.8	68.2	1.46	2.59	2.27	156.6
Max	42.0	19.0	90.0	1.74	2.63	3,31	964.0
Min	7.0	2.0	40.0	1.22	2.49	0.48	0.998
St.dev.	10.3	4.3	13.7	0.12	0.03	0.82	231.6
Experimental site Ruzyně							
Average	27.13	60.0	12.9	1.26	2.62	1.42	415.6
Max	32.5	65.5	19	1.36	2.64	1.87	1261.2
Min	22.0	55.0	8.0	1.13	2.60	1.05	10.2
St.dev.	2.85	3.42	3.94	0.06	0.02	0.29	386.3

Applied PTF's

ROSETTA[15] is a computer program available at the web page of US Salinity Laboratory or as a part of free software HYDRUS-1D[20], a public domain Windows-based modelling environment for water and solute transport within a variably saturated media. In total, 1306 soil samples with measured Ks value are incorporated within the database of ROSETTA. It offers 5 hierarchical PTF's models for Ks prediction. The first model is based on a lookup table providing class average Ks value for each USDA soil textural class, while the other four models are based on NN and can utilise more input data variables. NN can be described as a highly interconnected network consisting of many simple processing units that are called neurons (analogical to the biological neurons in the human brain). Neurons that have similar characteristics are in the NN arranged in groups that are called layers. The neurons in one layer are not connected among each other, but are connected to those in the adjacent layer. The connection strength of the neurons in the adjacent layers is represented by a parameter called connection strength or weight. The NN consists normally of three layers: input layer, hidden layer and output layer [21, 22]. Based on the available measured data, the following ROSETTA models were applied in this study: SSC model utilising percentages of sand, silt and clay and SSC, BD model utilising percentages of sand, silt and clay together with the dry bulk density (Tab. 2).

Table 2. Overview of eight applied models of PTF's and their predictors

PTF model	Predictors	Reference
Araya BRT 3-0	% sand, % silt, % clay	Araya and Ghezzehei (2019)[4]
Araya BRT 3-1	% sand, % silt, % clay, dry bulk density	Araya and Ghezzehei (2019)[4]
Araya BRT 3-2	% sand, % silt, % clay, dry bulk density, organic carbon	Araya and Ghezzehei (2019)[4]
Araya RF 3-0	% sand, % silt, % clay	Araya and Ghezzehei (2019)[4]
Araya RF 3-1	% sand, % silt, % clay, dry bulk density	Araya and Ghezzehei (2019)[4]
Araya RF 3-2	% sand, % silt, % clay, dry bulk density, organic carbon	Araya and Ghezzehei (2019)[4]
ROSETTA-SSC	% sand, % silt, % clay	Schaap et al., 2001[15]
ROSETTA-SSC, BD	% sand, % silt, % clay, dry bulk density	Schaap et al., 2001[15]

Araya and Ghezzehei (2019)[4] developed ML-based PTF's on over 18 000 soils based on four types of ML-algorithms; the RF and BRT models were selected for testing in this study (Tab. 2). RF method combines (averages) the decisions of the large number of individual decision trees that are "grown" individually by searching for a predictor that ensures the best split that results in the smallest model error. RF method is reported to be relatively robust to errors and outliers[23]. BRT provides a form of a decision tree model ensemble with enhancing procedure by gradient boosting algorithm that creates additive regression models by sequentially fitting the decision trees (or any different type of "simply based learner") to current pseudo-residuals at each iteration[24]. The BRT methods thanks to their operating principle are attractive in works where the training data originates from different measurement methods (Ks measurement in the field/laboratory with different methods)[4].

Statistical Evaluation

The performance of the tested PTF's was measured in terms of root mean squared error (RMSE), mean error (ME) and coefficient of determination (R^2) as follows:

$$ME = \frac{1}{n}\sum_{i=1}^{n}(x_i - y_i) \quad (1)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - y_i)^2} \quad (2)$$

$$R^2 = \left\{\frac{n\sum_{i=1}^{n}x_iy_i - \sum_{i=1}^{n}x_i\ \sum_{i=1}^{n}y_i}{\sqrt{\left[n\sum_{i=1}^{n}x_i{}^2 - \left(\sum_{i=1}^{n}x_i\right)^2\right]\left[n\sum_{i=1}^{n}y_i{}^2 - \left(\sum_{i=1}^{n}y_i\right)^2\right]}}\right\}^2 \quad (3)$$

where x_i means measured Ks data, y_i predicted Ks data, and n is a number of the $x_i\,y_i$ data pairs.

The RMSE indicates the average deviation of predicted Ks values from the measured Ks. The smaller the RMSE value is, the better performance of the PTF's prediction is obtained. The best ranking value (1) was attributed to the applied PTF with the smallest RMSE value. The ME becomes negative, if the prediction underestimates the Ks value and positive, it the PTF overestimates the measured Ks. Since the Ks data are log-normally distributed, the statistical evaluation is based on log-transformed Ks values and the resulting ME and RMSE becomes dimensionless. The correspondence between the measured and predicted data is indicated by the R^2; the higher the R^2, the better the correspondence. For better imagination, view and comparison to other published studies, the Ks was expressed in cm/day and then they were log-transformed and used in all statistical data analyses.

Results and Discussion

Ks values for two experimental localities were predicted by 8 different models of PTF's based on NN or ML approaches that are utilising large soil databases containing measured Ks data and thus could be considered for general prediction of Ks values for soils in other parts of the world. Generally, quite high natural variability within the experimental sites was observed, especially on the agricultural field in Ruzyně, where the presence of preferential pathways enhancing the water infiltration was observed. The distribution of the data through their quartiles is graphically displayed in Box and Whisker Plot (Fig. 1) for both experimental sites. The high range of measured Ks values within the same experimental site having similar particle size distribution data and not very different dry bulk density data has led to similar predictions of Ks values for this locality (Fig. 1, Fig. 2), but the real measured values were ranging within two orders of magnitude.

Although the ML approaches are showing promising results in many studies, they did not provide the best estimates for the testing localities (Tab.3). The NN based ROSETTA estimates based on known % content of clay, silt and sand particles, together with the information of dry bulk density (SSC-BD model) outperformed all other models for both localities (Tab. 3). Graphical comparison showing quality of each individual point of estimate is presented in Fig. 2, where the measured and estimated Ks values in cm/day are plotted against each other (the axes of the graphs have logarithmic scale). The RMSE values for ML-approaches reported by their authors were reaching 0.34-0.44 for BRT models and 0.37-0.44 for RF models (with increasing number of predictors, the RMSE was decreasing).

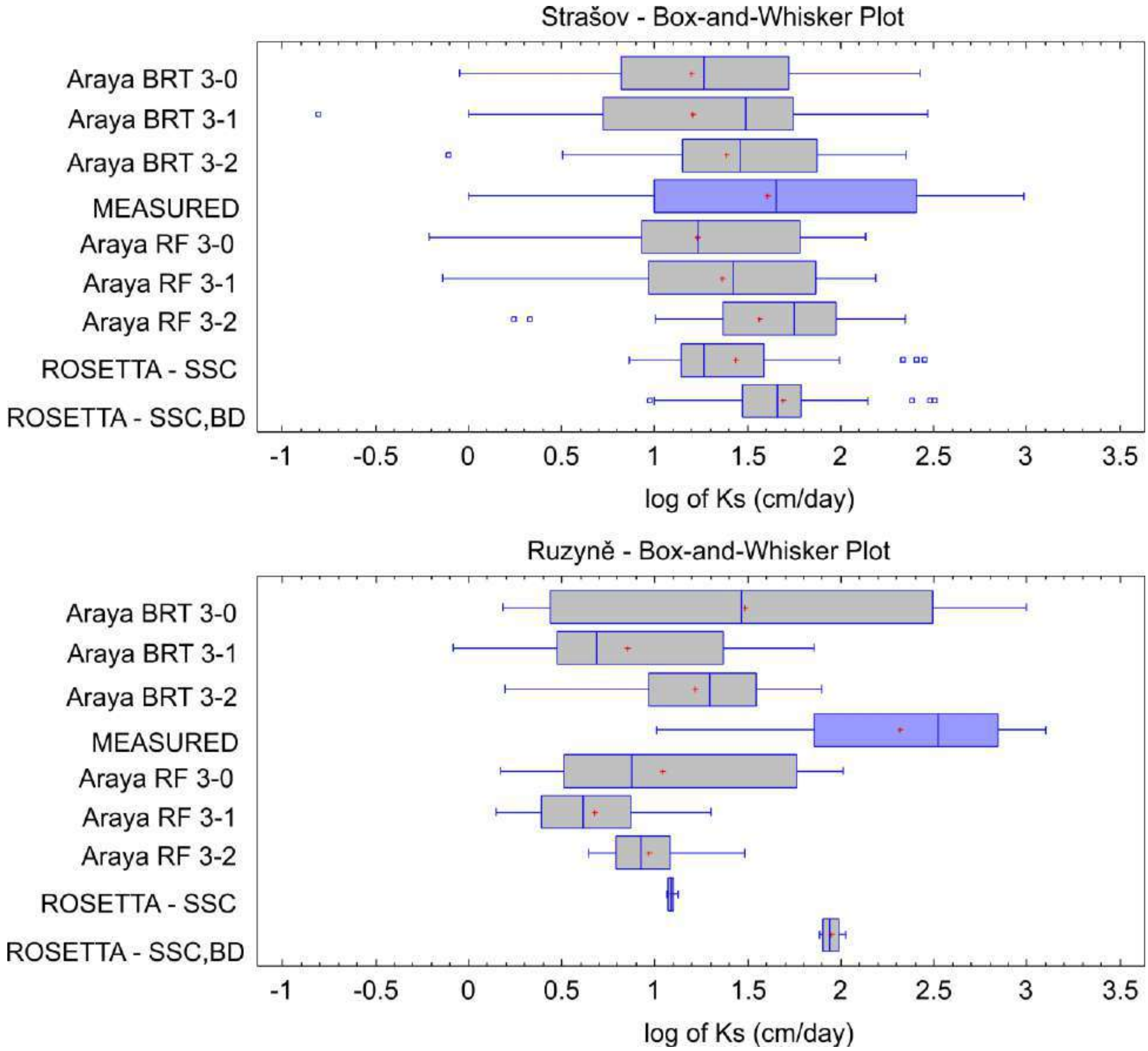

Figure 1. Ks data distribution by Box and Whisker Plots for both experimental localities, the measured Ks are highlighted in blue (Ks before log transformation in cm/day)

Table 3. Basic statistical measures to compare performance of the applied PTF's, the model with the lowest RMSE has the best ranking

Locality	Statistics	BRT 3-0	BRT 3-1	BRT 3-2	RF 3-0	RF 3-1	RF 3-2	ROSETTA (SSC)	**ROSETTA (SSC+BD)**
Strašov	Ranking	8	7	6	5	4	3	2	**1**
	ME (-)	0.405	0.403	0.221	0.378	0.241	0.041	0.174	**-0.086**
	RMSD (-)	0.978	0.961	0.872	0.803	0.720	0.665	0.662	0.595
	R^2 (%)	10.1	19.6	13.2	31.1	37.5	37.3	42.7	57.4
Ruzyně	Ranking	4	7	2	6	8	5	3	**1**
	ME (-)	0.833	1.466	1.099	1.274	1.642	1.350	1.229	0.371
	RMSD (-)	1.484	1.693	1.356	1.545	1.779	1.488	1.367	0.700
	R^2 (%)	0.02	0.06	1.46	0.02	0.27	0.68	6.13	4.66

Note: Values of Ks were log transformed for the statistical evaluation and that is why the ME and RMSE values are dimensionless

The lowest RMSE value for ML-approach was found for Strašov locality model RF 3-2 reaching the value of 0.662, the maximum RMSE was determined for model BRT 3-0 with the value of 0.978. Significantly higher RMSE were found for Ks estimates for locality Ruzyně, the highest RMSE was found for models RF 3-1 and BRT 3-1. Conversely, the estimates based on ROSETTA were showing similar performance as reported by the authors, range of RMSE values of 0.717 for SSC model and 0.666 for SSC-BD. On the other hand, only a very small range of Ks values was predicted due to small variability of predictors not covering the present microporous flow in the agricultural field in Ruzyně.

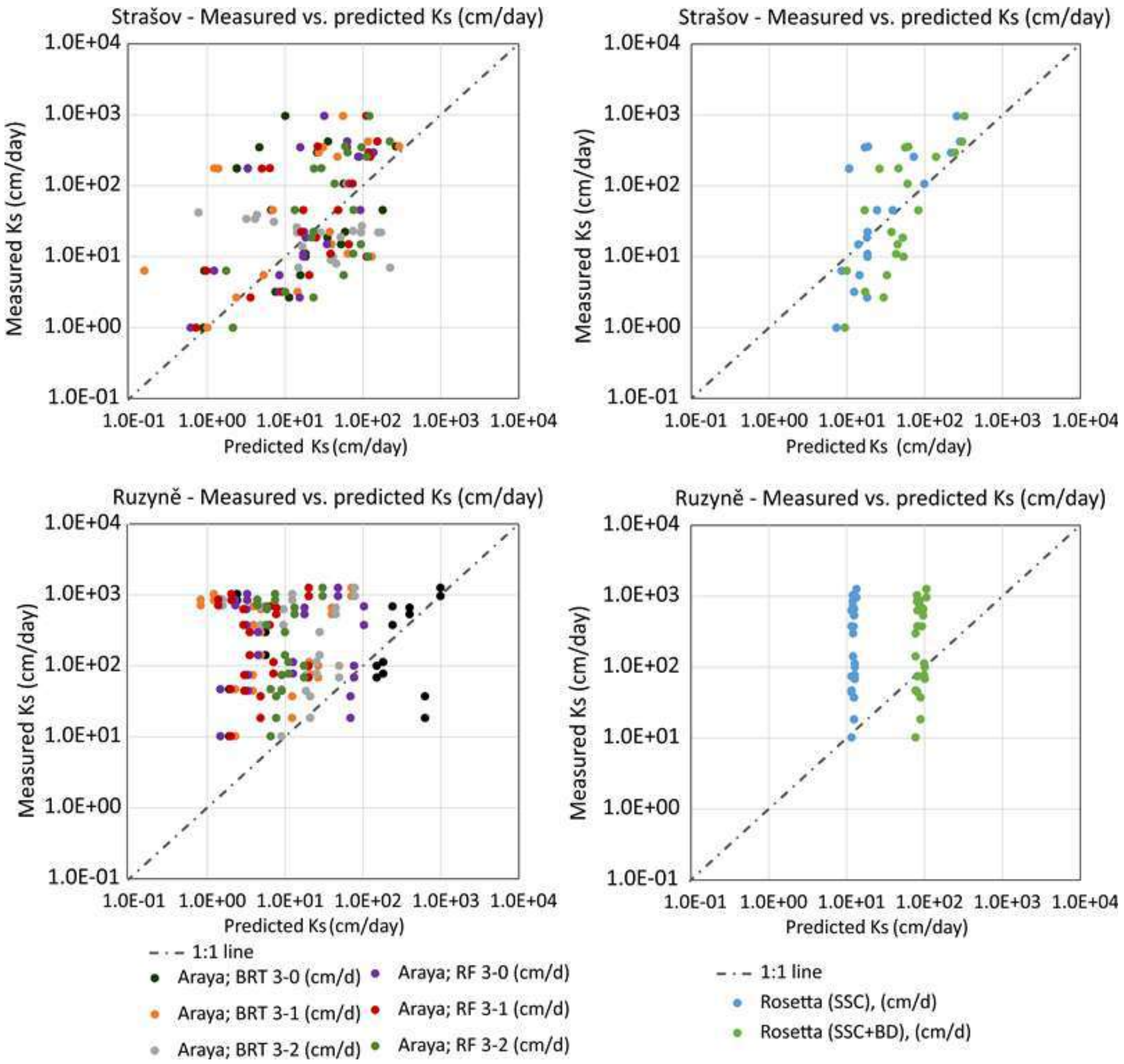

Figure 2. Performance of the tested PTF's for Ks prediction in relation to the measured data

Conclusion

Although a great progress documented by many published models of PTF, the accurate prediction of Ks in agricultural soils remains a challenge. Large national and international soil databases could provide a base for robust models of PTF. However, the Ks depend not only on soil texture which does not change much within the season, but also on the soil structure which is prone to substantial natural alteration in relatively short time (e.g. burrowing by roots or soil fauna, wetting/drying cycles). For agricultural soils, it is the tillage operations which cause an enormous change to soil structure and also Ks. That is why it is difficult to base the predictions only on a few parameters. If more parameters are included within the predictor hierarchy, the better performance of the PTF's could be obtained. Inclusion of water contents at field capacity and/or wilting point (and other θ(h) data points) is nowadays being used in combination with organic matter content. Another parameter affecting water infiltration through the soil surface which can be assumed as predictor, is the stability of the aggregates of the surface layer. But not all the information is often available and their determination might take almost as much time as the Ks measurement itself (e.g. in the laboratory on the collected soil core samples).

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An analysis of the responses of different sub-basins with various soil profile in the central rift valley basin in Ethiopia to the impacts of climate change with their water balances, using the SWAT model. localities in the Czech Republic

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Abstract

The Central Rift Valley Basin (CRVB) in Ethiopia is a closed basin, where continuous pressure on land and water resources has resulted in over-exploitation of the resources. Climate change together with the impacts of population growth represent a critical challenge which needs to be addressed. This study explores responses of different sub-basins with various soil profile to the impacts of climate change on the components of the water balance such as runoff (Q), water yield (WY) and evapotranspiration (ET) on the basis of eight different scenarios taking into account a 10% reduction and increase in precipitation, an increase in temperature by 1.5°C and 3.0°C, and their combinations, calculated from the baseline (averaged simulation values from 1984 to 2014). CRVB was divided into three representative sub-basins (Ketar, Meki and Shalla) and the Arc SWAT model was utilized to perform the simulations. The model was calibrated and validated by the SWATCUP-SUFI-2 algorithm using monthly observed flow data from each of the sub-basins. Although the results of the simulated scenarios show some attributes common to the three sub-basins, the responses to the individual climate scenarios differ. Responses to an increase in temperature showed reductions in Q and WY, while the ET values increased. The highest increase in ET was found to be +8.24% for the scenario combining a 10% increase in precipitation with 3.0°C increase in temperature in Meki. The increase (reductions) in precipitation showed increases (reductions) in Q and WY with only a small effect on ET (± 2.5% difference). The highest increase in Q (+ 29%) was identified in Shalla for the scenario simulating an increase in precipitation by 10%, and the biggest reduction in WY (-23.5%) was found in Meki for a 10% reduction in precipitation and 3.0°C increase in temperature. These variabilities are highly associated with soil hydrology profile to generate lateral flow, favor hydraulic conductivity, and to enhance runoff. Based on the results, water management interventions that reflect these water balance sensitivities are proposed.

Keywords: Climate change, water balance sensitivity, arc swat, soil hydrology profile, climate scenario

Introduction

Sub-Saharan Africa is a region that is very sensitive to, and is highly affected by, re-current droughts, flooding and untimely weather conditions. In addition, the region is characterized by its soil fertility loss, high erosion, and damages to soil structure. The floods and droughts have affected water supplies and have set a challenge for water management. At the same time, agricultural water management practices in these developing regions are not adequate for dealing with the challenges of significant climate changes and those environmental deteriorations [1-4]. Increasing pressure on land, soil, and water resources due to population growth and human activities have also resulted in the degradation of vulnerable ecosystems and biodiversity

[4–6]. This degradation of eco-systems hinders the potential use of ecosystem services [7]. Ecosystem degradation affects land uses and the soil profile. It also poses pressure on natural resource management such as water resource management [5,8]. Climate change alters the hydrological cycle resulting in large-scale impacts on water availability [9]. The climate impacts on water availability could be permanent or it temporarily affects the water balance. The responses of a basin with different soil profiles in their sub-basins to the impacts of changes in climate with their water balance needs to be evaluated. Different soil has different hydrologic characteristic in storing, infiltrating and in generating runoff [10].

Water balance is highly affected by the state of the environment [9]. Climate change significantly affects the water balance conditions, both spatially and temporally at local or regional scale. For example, Africa is vulnerable to inter-annual climate variations due to the El-Nino southern oscillations [11]. In addition, the hydrology of a basin is greatly influenced by changes in land use which, in turn, have a direct correlation with changes in the water cycle [12,13]. Soil erosion and damage to its physical properties will also affect the conditions of water balance in the sub surface together with climate change [14]. Variations in Soil hydrologic characteristics have differences in resisting the impacts of climate change [14]. The purpose in this study is to see the responses of different sub-basins lying within a single hydrologically closed basin with various soil characteristics to the impacts of climate change in terms of their water balances. Without in-depth understanding of seasonal and regional water balances in each area based on climate variability, it is hard to identify optimal management and use options to deal with the impacts [1,5,14–16].

Various studies have been carried out on analyzing the water resources of the Central Rift Valley Basin (CRVB) and have attempted to evaluate and describe the extent and the impact of climate change on existing water resources [17,20–24]. However, few of these studies have been carried out to analyze the impacts of various climate data simulations in different scenarios to evaluate the conditions of components of the water balances in the sub-basin with different soil profile, land use and ecological characteristics. This study is therefore aimed at analyzing the impacts of climate change on the water balance of CRVB in Ethiopia. It is based on different climate scenario (CSc) simulations to find feasible water management practices to optimize the use of scarce water resources for the sub-basins according to their soil hydrology profile. Incorporation of the plausible climate change variable values in the simulation process can be considered as a suitable approach to analyze the response of each sub-basin [12,16–20].

According to Arnold et al., 1998, watershed models can indicate watershed management and planning options by helping to prioritize practices, by targeting critical areas for potential action, and by indicating timely applications. The Soil and Water Assessment Tool (SWAT) is a widely used model for analyzing the water balances of a basin using long term weather and spatial data of the area [21]. Regional climate data simulation based on bias corrected Global Circulation Model (GCM) average values of rainfall and temperature change in the region for near and long terms were adopted [17,22–24]. The work presented here mainly aims to show the responses of each sub-basin to the selected components of the basin water balances for different plausible climate change scenarios.

Material and Methods

A Description of the Study Location

The Central Rift Valley Basin (CRVB) is in Ethiopia between 38°15′ E and 39°30′ E longitude and 7°10′ N and 8°30′ N latitude, Figure 1. The study basin covers an area of approximately 9,112.5 km^2. Locally, the CRVB is situated in two adjoining regions: namely, the administrative regions of Oromiya and the Southern Nations Nationalities and Peoples Region (SNNPR). The mean annual rainfall of the study area varies between 600 mm near the lakes and 1200 mm - 1600mm in the highlands and in mountainous areas. The average minimum temperature is 10.5°C, while the average maximum temperature is 24.3°C [25]. The elevation of the CRVB ranges from 1500 to 4200 meters above sea level. The CRVB has diverse soil types, Figure1, with different infiltration and associated runoff potential. Coarse-textured soils (Leptosols) with high infiltration rates are dominant in the eastern and western highlands and in the valley floor around the lakes. Medium-textured soils (Euvertisols) with moderate infiltration rates dominate the eastern and western mid altitudes of the CRVB, whereas the bottom parts of the western highlands and some places in the central part of the eastern CRVB are dominated by fine-textured black soils (Vertisols) with lower infiltration capacity [5]. The climate of the CRVB is tropical, with spatial and temporal variations [16,20]. The CRVB has four major sub-basins namely Ketar, Meki, Shalla and Langano. The study analysis was done for three of the sub-basins (Ketar,Meki , & Shalla) according to their major soil type. Ketar has mainly Leptosols, Meki has both Lepto and EU-Vertisols and majority of Shalla has LT-Leptosols as indicated in Figure 1.

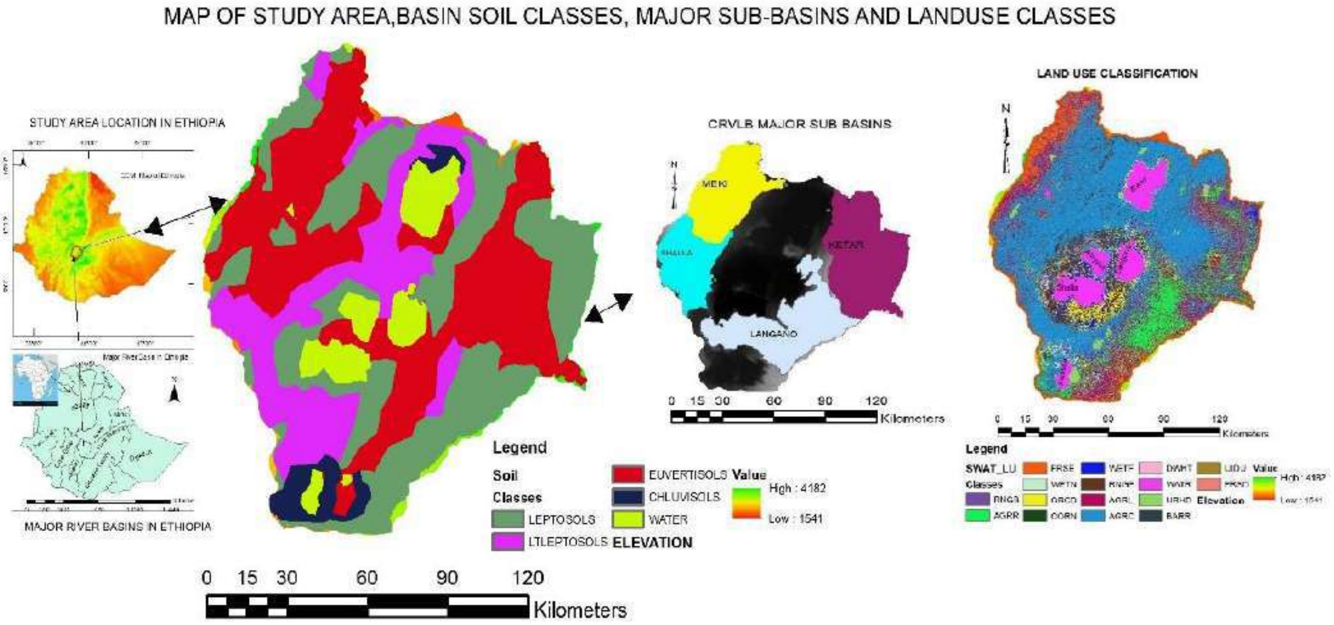

Figure 1. Location of study area, soil map of study basin, major sub-basins, and land uses.

Arc SWAT Application

Arc SWAT is an Arc GIS extension program used for watershed modelling. The SWAT model is a physically based, deterministic, continuous, watershed-scale simulation model developed by the U.S. Department of Agriculture (USDA) - Agricultural Research Service [26]. The model was setup with digitized geographical information (DEM), land cover, land uses, soil profile and hydro climatic data of CRVB. It was set and calibrated with discharge data of monthly records from the year 1990 to 2001 and validated with monthly data from 2004 to 2010. The baseline data record supplied from 1984 to 2014. The model was then calibrated and validated using the monthly monitored water flows from the Ketar, Meki and Jidu (Shalla) river gauging stations with SWAT-CUP software in the SUFI-2 algorithm [26[21]. The model performances were evaluated statistically against the Coefficient of Determination (R^2), the Nash-Sutcliffe Efficiency (NSE), and the Percentage of Bias (PBIAS)[27]. In the model application, the Penman-Monteith method for evapotranspiration and the Soil Conservation Service (SCS) method for surface runoff determination were selected to analyze the water balance.

The discharge simulated by Arc-SWAT is based on a water balance equation defined as:

$$SWti = SW_0 + \sum_{i}^{t} [\![(Rday]\!]_i - Qsurf_i - Ea_i - Wseep_i - Qgw_i) \qquad (1)$$

where:

SW_{ti} = soil water content (mm) at time t, SW_0= initial soil water content (mm), t = simulation period (days), R_{dayi} = amount of precipitation on the i th day (mm), Q_{surfi} = amount of surface runoff on the i^{th} day (mm), E_{ai} = amount of evapotranspiration on the i th day (mm), W_{seepi} = amount of water entering the vadose zone from the soil profile on the i th day (mm), and Q_{gwi} = amount of base flow on the i^{th} day (mm) [23].

Climate Data

Daily data on Minimum and Maximum Temperature, Hours of Sunshine, Relative Humidity, Wind Speed and Precipitation from five meteorological stations located in and near the sub-basins, were introduced into the model to simulate the water balances for the base period from 1984 to 2014 using Arc-SWAT 2012 with ArcGIS. The five meteorological stations are: Arsi-Negelle (located at 7.35 °N and 38.68°E, with an average elevation of 1800 m), Asella (7.97°N, 39.08°E & 2413 m), Awassa (7.06°N, 38.48°E & 1694 m), Shashemane (7.2°N, 38.61°E & 1927 m) and Ziway (7.93°N, 38.7°E & 1640 m). Based on the data collected from the stations, the amounts of missed data are less than 10% of the total data and thus a simple arithmetic mean methods was used to fill the missed data gaps. The data qualities such as outliers, errors were accessed, and the data statistics were processed by the SWAT-WGN weather data base generator software.

Spatial Data (Land Cover and Land Use)

The spatial data used for the study were as follows: DEM data of 30 m resolution obtained from the Oromiya Bureau of Agriculture and Natural Resources, a digitized land-use map of the country obtained from the Ethiopian Geospatial Information Institute, and a digitized soil profile data layer obtained from the Ethiopian Ministry of Agriculture and Natural Re-sources. In the first phase of modelling, the study area was divided into sub-basins based on the topography and the river systems in the basin. Each sub-basin was then divided into several hydrological response units (HRUs) according to the land-use features, the soil profile, and the slope.

Climate Scenarios (CSc).

Eight climate scenarios were simulated to assess the probable impacts of climate change on major water balance components such as Q, WY and ET in the sub-basins. To obtain the realistic outputs, the forecasted climate change average values for rainfall and for temperature based on regional circulation models in Intergovernmental Panel for Climate Change (IPCC) reports, were adopted in the climate scenarios [28,29]. To be specific, the data originate in the regionalized report for Northeast Africa published by Almazroui et.al, 2020. The data in these reports are the most up to date, bias corrected and regionalized to specific region via different approaches and models from coupled model intercomparison project 6 (CMIP6). In this study, regional temperature incremental methods and rainfall incremental and reduction methods were used. Based on IPCC a 1.5°C regional forecast average values for near term (2030 to 2060) and a 3°C for long term (2070 to 2100) together with 10% increase and reduction in rainfall for both terms have been adopted to assess the probable impacts of climate change on the major water balance components of the basin. Their combinations were also analyzed. The Scenarios were presented in Table 1.

Table 1. Applied Climate Change Scenarios for analyzing the impact of climate change on the components of the water balance in CRVB

Individual climate scenario			Combined climate scenario		
Item No	**Code**	**Description**	**Item No**	**Code**	**Description**
1	CSc 1	10% reduction in Precipitation	5	CSc 5	10% reduction in Precipitation and 1.5°C increase in Temperature
2	CSc 2	10% increase in Precipitation	6	CSc 6	10% increase in Precipitation and 1.5°C increase in Temperature
3	CSc 3	1.5°C increase in Temperature	7	CSc 7	10% reduction in Precipitation and 3°C increase in Temperature
4	CSc 4	3°C increase in Temperature	8	CSc 8	10% increase in Precipitation and 3°C increase in Temperature

Results of the Calibration and Validation of the Model

The model was calibrated and validated for the Ketar, Meki and Shalla sub-basins in CRVB, to reduce the uncertainties in the outputs of the model. The calibration results showed a good agreement between the simulated and observed monthly discharges in the sub-basins. From the general statistics, the values are in a good agreement if $R^2 > 0.6$, NSE > 0.5 and PBIAS <= $\pm$25. The calibration and validation results of each basin were presented in Table 2. The calibration and validation help the model performance improvement in each location by adjusting the sensitive hydrological, soil and land use parameters.

Table 2. Calibration and validation statistics for the Ketar, Meki and Shalla sub-basins

Sub-basin	Calibration statistics			Validation statistics		
	R^2	NSE	PBIAs	R^2	NSE	PBIAs
Ketar	0.64	0.54	-22.50	0.85	0.84	-2.60
Meki	0.67	0.63	-4.81	0.72	0.64	-32.17
Shalla	0.67	0.66	0.20	0.77	0.74	1.34

Climate Scenario Analysis Results and Discussion.

The impacts of climate change on the components of water balance in the sub-basins have differences in the near and long terms of the hydrology periods, see Table 3. The mean of monthly water balance distribution for all scenario simulation in each sub-basin is indicated in Figure 2. Though the sub-basins share some common attributes common to all sub-basins, the individual responses of each sub-basin to the possible climate change scenarios are unique. For example, the ranges of variation in evapotranspiration (ET) in the sub-basins is relatively small compared to the other components for all the scenarios in each sub-basin. This indicates that the basin is more sensitive to rainfall variabilities than to changes in temperature within the plausible range of changes adopted for the study. All the sub-basins also generate relatively good runoff, and water yield for incremental scenarios but the capacity of their generation varies significantly from a sub-basin to the other. These variabilities indicate that the response of each sub-basin to the impacts of climate change is different. The main difference in generating runoff, water yield and the variability in ET is mainly associated with: - 1) catchment physical properties and 2) the soil hydrology profile to store, transport or release the water balance components which are highly related to the soil hydraulic properties such as hydraulic conductivity, permeability, infiltration capacity, soil matrix potential, water holding capacity etc.

The mean annual changes, in percentage, for each water balance component in each climate scenario (CSc) from the annual mean of the base year simulation is varying in each sub-basin as indicated in Table 3. The difference is visible, and this shows that the soil hydrology profile has got its own input in improving resilience capacity of the sub-basins to the impacts of changes in climate with regards to its water balances. The land uses are almost similar in the sub-basins as can be observed from Figure 1 and therefore, soil hydrological properties are the major factor for the variations of each sub-basin in response to the impacts of climate change. Water balance sensitivity of the basin due to climate change thus not only depends on whether variabilities but also on soil hydrology profiles.

Table 3. The simulated annual mean value changes, in a percentage, from the annual mean values of the base simulation data in the sub-basins.

Sub-basin	Ketar			Meki			Shalla		
Scenarios	*% of Δ in Q	% of Δ in WY	% of Δ in ET	% of Δ in Q	% of Δ in WY	% of Δ in ET	% of Δ in Q	% of Δ in WY	% of Δ in ET
CSc1	-24.60	-15.55	-2.39	-23.23	-18.55	-2.57	-25.63	-17.30	-2.43
CSc2	27.37	16.47	1.91	25.63	19.78	2.07	28.99	18.30	1.95
CSc3	-1.88	-1.80	2.28	-2.24	-2.98	2.74	0.23	-2.35	2.44
CSc4	-3.38	-3.28	4.80	-4.42	-5.67	5.76	-3.92	-4.32	5.30
CSc5	-26.41	-17.05	-0.29	-25.15	-21.10	-0.09	-27.40	-19.22	-0.18
CSc6	25.23	14.31	4.33	23.18	16.44	4.95	26.69	15.66	4.51
CSc7	-27.73	-18.38	1.98	-27.08	-23.50	2.66	-29.12	-20.96	2.46
CSc8	23.59	12.35	7.05	20.62	13.22	8.24	24.67	13.25	7.56

*% of Δ = Percentage of change

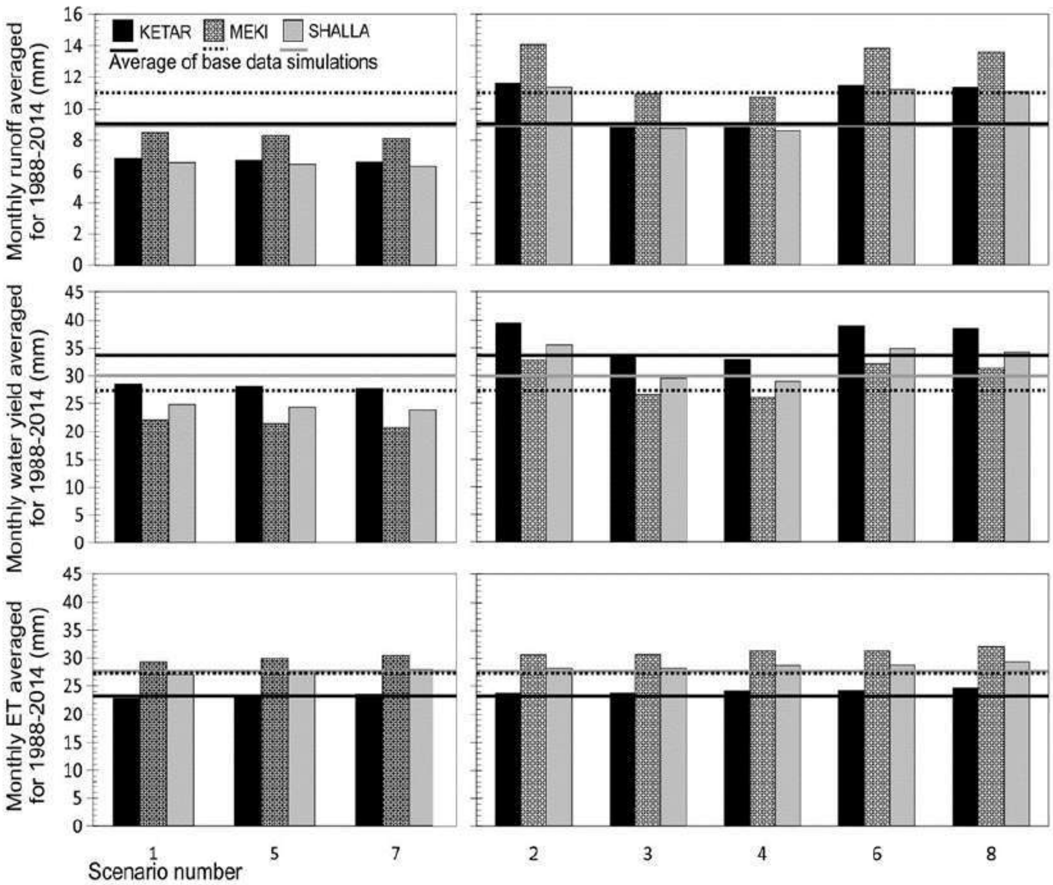

Figure 2. Averaged monthly values of major water balance components in the Ketar, Meki and Shalla sub-basins for different climate scenarios (scenarios with reductions are on the left, while scenarios with increments are on the right) based on data from 1987-2014.

Conclusion

The CRVB sub-basins are heterogeneous and show variabilities among themselves in terms of their responses to the impacts of climate change on their water balance components, although they lie within a single hydrologically closed region. The existing situation and possible changes in the water balance due to changes in climate, as shown in the scenario analysis, indicate that each sub-basin has a unique water balance environment. Thus, management interventions in the sub-basins need to take these variabilities into consideration. Some of the sub-basins are very sensitive to evapotranspiration interaction, while others are good at generating water for use. For example, the high impacts of evapotranspiration in the Meki and Shalla sub-basins make these basins more water-scarce than the Ketar sub-basin. The high-rate runoff in Meki sub-basin may cause flooding during the peak rainfall seasons. Considering the soil hydrologic profile while introducing mitigation and adaptation strategies makes it more feasible.

Water harvesting, efficient water use (particularly more efficient use of irrigation water), minimum tillage (to reduce soil evaporation), scheduling farm operations (to avoid peak evaporation periods), and the selection of ET-resistant crop varieties are recommended for the Meki sub-basin. Enhancing groundwater augmentation from runoff can also help Shalla sub-basin to resist the impacts of climate change and the low recharge ability of the basin. The total annual water yield is higher in the Ketar sub-basin than in the other sub-basins, and the impact of ET is lower. Afforestation to enhance the water storage capacity will therefore improve the capacity to use the excess water for inter-basin transfer to adapt to the impact of climate change on the whole closed lakes region.

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Organic fertilizers as a source of microelements and potentially toxic elements

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Abstract

The paper outlines concentrations and input of microelements and PTEs to the soil by manure, compost, digestate, industrial organic waste and sewage sludge, in Serbia and other countries. In order to get overview of these materials and assess the potential risk, their concentrations and average annual input by use of 30 t/ha of these materials is shown. The quality of organic fertilizers is very different and depends on the type of material, its characteristics and the way of its management. Generally, the highest concentrations of PTEs are in sewage sludge and in pig manure. It is noticed that digestate contains less Cu than other organic fertilizers. The positive effect of the application of organic fertilizers on the availability of essential elements and improvement of physical, chemical and biological soil properties is well known. However, consequences of improper use of organic materials could be accumulation of PTEs in soil, plants and underground water. In order to avoid environmental contamination by PTEs, the control of organic fertilizer quality is important, as a preventive measure in order to establish sustainable agriculture production.

Keywords: Organic fertilizers, soil pollution, potentially toxic elements, PTEs, trace elements, heavy metals.

Introduction

Fertilizers, including those from mineral, synthetic and organic sources, are important and widely used inputs in agriculture helping contribute to global food security, farmer livelihoods and essential human nutrition [1]. Input of organic fertilizers to soil is essential agricultural practices due to maintaining and improving the physical, chemical and biological soil properties; and it is source of the essential elements, including microelements, for plant, animal and human nutrition. Microelements are essential for different biochemical and physiological processes in plants; while potentially toxic elements, PTEs (heavy metals and non-metals) represent trace elements, a group of elements which have toxicity effect on soil microbes, plants and animals especially when they are available in higher concentrations. Agricultural production can increase the concentration of PTEs in the surface layers of the soil, which can lead to increase their accumulation in the plant, entering the food chain and effect on human health and the environment. Agrotechnical measures that contribute to the accumulation of metals in the soil are the application of organic and mineral fertilizers, pesticides use, irrigation [2].

Material and Methods

The paper outlines the concentrations and input of microelements and PTEs to the soil by manure, compost, digestate, industrial organic waste and sewage sludge, in Serbia and other countries. In order to get overview of these materials and assess the potential risk, the relevant data have been collected from different studies in Serbia and several countries. In the tables are shown minimum / maximum values and calculated average values of microelements and PTEs from different studies. Also, the input of these elements (minimum, maximum and average) was calculated for the use of 30 t/ha of different organic fertilizers and expressed as g/ha/year.

Results and Discussion

In order to prevent accumulation of PTEs, reducing their input to the soil is a strategic goal of soil protection policy in the Republic of Serbia[3], and other countries, e.g. Great Britain, EU members[4,5]. For that reason, before application in agriculture, it is necessary to analyze the composition of fertilizers and respect the maximum permissible concentrations of heavy metals in fertilizers regulating their inputs to soils (Table 1).

Table 1. Maximum permissible concentrations of heavy metals in fertilizers, supplementary for soil and supplementary for plants (mg kg^{-1}) and inputs regulation to soils[3]

Heavy metal	Maximum content in mg/kg by dry weight of plant nutrition products and soil improvers			Maximum content in mg/kg P_2O_5	Regulating inputs of heavy metals to soils
	Fertilizers*, soil improvers, other fertilizers and special products	Inorganic fertilizers with more than 5% P_2O_5	Substrates	Inorganic fertilizers with more than 5% P_2O_5	g/ha in a period of two years
Lead (Pb)	100	100	50	-	600
Cadmium (Cd)	3	-	1	75 mg kg^{-1} P_2O_5	10
Chrome (Cr)	100	500	70	-	600
Nickel (Ni)	100	100	70	-	400
Mercury (Hg)	1	1	0.5	-	10
Copper** (Cu)	-	-	-	-	700
Zinc** (Zn)	-	-	-	-	3000

*Except for inorganic fertilizers with more than 5% P_2O_5; **Except for inorganic fertilizers with declared content of microelements

Manure

Manure is one of the oldest fertilizers used in agricultural production. It is a mixture of feces and urine, contains complex organic compounds originating from undigested food and simple organic and inorganic compounds that are produced in the digestive tract of the animal. In addition, it contains various materials used as a mat (e.g. straw), water (used for drinking and washing floors) and spilled food[6].

Its importance of manure for agricultural production is high, because in addition to nutrients, it enriches the soil with organic matter, improves the physical and chemical properties of soil, microbiological activity, water and air, increases the content of $CaCO_3$ in the soil and more[7]. However, manure can contribute to the accumulation of heavy metals in the soil. The composition of manure depends on the system of its management, care and storage, type of animals as well as the nutrition, meals composition. Manure with a water content of over 90% is defined as liquid, while with a water content of less than 90% as solid[8].

Table 2 shows the content of PTEs in different types of manure and their average annual input into the soil. Generally, the highest concentrations of PTEs are found in pig manure; therefore, with long-term application of this manure, overload of PTEs (e.g. Zn, Cu, Cd, As) to soil can be expected.

Copper is added to the diet of pigs for their faster development because it acts as an anti-bacterial agent in the gut[9]. Both Zn and Cu are necessary in poultry nutrition as enzymatic co-factors[10]. As has been used as a dietary supplement to increase the weight of pigs and poultry and to prevent the spread of disease [11]. Although As as a supplement is banned in Europe, it is still in use in some countries such as the United States and China[11]. In addition, the concentration of Cd in manure from China is significantly higher than in manure in England and Wales[12], which is probably due to the use of additives containing P or Zn. The lowest concentrations of Cu and Zn were measured in sheep manure. Solid and liquid manure may contain high concentrations of potentially toxic elements, especially Zn and Cu due to the use of mineral supplements in food and veterinary products.

Table 2. The content of heavy metals in manures

Type of manure	Country	n*	Fe	Zn	Cu	Mn	Mo	Co	Se	Ni	Pb	Cd	Cr	As	Hg
			(mg kg^{-1} DM**)												
Feces (Cows)[13]	Serbia	25	1359	696	118	150	/	/	/	21	3.04	0.38	8.82	/	/
Feces (Sheep)[13]	Serbia	25	600	482	68	135	/	/	/	68	2.20	0.34	2.60	/	/
Farmyard manure[14]	Serbia	1	986	36	5.54	126	/	/	/	/	/	/	/	/	/
Manure[15]	Serbia	7	/	/	/	/	/	/	/	13.3	6.9	1.12	17.6	/	/
Farmyard manure[A]	Serbia	1	1051	123	37	176	/	/	/	/	/	/	19	/	/
Dairy cattle FYM[12]	England and Wales	6	/	153	35.7	/	/	/	/	3.7	3.61	0.38	5.32	1.63	/
Dairy cattle slurry[12]	England and Wales	20	/	209	62.3	/	/	/	/	5.4	5.87	0.33	5.64	1.44	/
Beef cattle FYM[12]	England and Wales	12	/	81	16.4	/	/	/	/	2.0	1.94	0.13	1.41	0.79	/
Beef cattle slurry[12]	England and Wales	8	/	133	33.2	/	/	/	/	6.4	7.07	0.26	4.69	2.60	/
Pig FYM[12]	England and Wales	7	/	431	374	/	/	/	/	7.5	2.94	1.98	1.98	0.86	/
Pig slurry[12]	England and Wales	12	/	575	351	/	/	/	/	10.4	2.48	0.30	2.82	1.68	/
Turkey litter[12]	England and Wales	12	/	378	96.8	/	/	/	/	5.4	3.62	0.42	17.2	9.01	/
Chicken manure[16]	China	70	/	308	102	/	/	/	/	15.9	20.6	3.4	46	3.8	0.13
Pig manure[16]	China	61	/	843	472.6	/	/	/	/	12.5	10.1	4.8	46.6	12.8	0.12
Cow manure[16]	China	42	/	152	46.5	/	/	/	/	14.1	15.7	3.4	15.2	2	0.10
Sheep manure[16]	China	15	/	123	28.7	/	/	/	/	12.4	12.4	1.3	8	1.5	0.19
Beef cattle FYM[17]	Denmark, France, Germany and Great Britain	/	/	119	45	/	/	/	/	7.5	2.85	0.5	1.5	/	/
Pig FYM[17]	Denmark, France, Germany and Great Britain	/	/	387	346	/	/	/	/	5	2.8	0.7	1.9	/	/
Beef cattle slurry[17]	Denmark, France, Germany and Great Britain	/	/	441	51	/	/	/	/	8.65	5.05	0.4	8.8	/	/
Pig slurry[17]	Denmark, France, Germany and Great Britain	/	/	661	377	/	/	/	/	10.1	6.5	0.35	10.2	/	/
Poultry manure[17]	Denmark, France, Germany and Great Britain	/	/	480	80	/	/	/	/	11	3.1	0.59	14.05	/	/
Beef cattle FYM[18]	Austria	/	/	164	51	180	3.5	2.1	0.59	/	/	/	/	/	/
Pig FYM[18]	Austria	/	/	1156	282	358	5.3	4.0	3.37	/	/	/	/	/	/
Pig Feces[18]	Austria	/	/	399	84	317	2.1	2.3	1.35	/	/	/	/	/	/
Poultry manure[18]	Austria	/	/	314	66	339	3.3	1.7	1.40	/	/	/	/	/	/
Min Max			600-1359	36-1156	5.54-473	126-358	2.1-5.3	1.7-4	0.59-3.37	2-68	1.9-21	0.13-4.8	1.4-47	0.8-13	0.1-0.19
Average			999	369	135	223	3.6	2.5	1.7	13	6.2	1.15	12	3.46	0.14
Min-max input g/ha/year* **			4500-10193	270-8670	42-3545	945-2685	16-40	13-30	4.4-25	15-510	15-155	0.98-36	10.6-350	5.9-96	0.75-1.425
Average input g/ha/year* **			7493	2764	1009	1670	27	19	13	96	47	8.6	90	26	1.01

*Number of samples; **Dry matter; ***Minimum, maximum and average input in g/ha/year into the soil using 30 t/ha of manure, with an average moisture content of 75%; [A]Manojlović et al., non published

Compost

Compost is a mature product of composting, a controlled process of biooxidation of a solid heterogeneous organic substrate that includes a thermophilic phase[19]. The quality of compost and the time of composting depend on the applied technology but also on the composition of the initial compost mass. There are six basic types of source materials[20]: 1. food waste (fruits, vegetables, cereals, meat); 2. manure and agricultural by-products.; 3. residues from forestry and wood industry; 4. biowaste or waste sludge; 5. garden waste; 6. organic municipal waste. Compost can be source of microelements necessary for the development of plants (Cu, Zn, Mn, Cr, B). However, compost can be used in agriculture only under the condition that all sanitary rules are observed and if the compost is controlled in terms of the presence harmful chemicals. Waste compost contains PTEs, therefore is question the usability of compost on agricultural soil. The use of compost as a fertilizer containing increased concentrations of heavy metals leads to the risk of their accumulation in animals / humans by entering the food chain[21]. Some countries have a two-class system for the permissible concentrations of heavy metals in composts. Table 3 shows the concentrations of heavy metals in different composts and their average annual input into the soil. Municipal solid waste and composted manure contain the highest concentrations of PTEs (e.g. Zn, Mn, Cu, Cd, Pb, As).

Table 3. The concentrations of heavy metals in different composts

Type of compost	Country	Fe	Zn	Mn	Cu	Mo	Ni	Cr	Cd	Pb	Co	B	As
		(mg kg^{-1} DM*)											
Vermicompost[14]	Serbia	1054	45.2	171	8.9	/	/	/	/	/	/	/	/
MC[14]		1342	23	230	26.8	/	/	/	/	/	/	/	/
MSW[22]		/	249	921	47	6	122	61	2.2	55	13	62	17
MSW[22]		/	309	944	306	5	115	50	2.2	64	13	43	17
Green waste[22]		/	89	484	20	4	127	54	1.7	42	13	34	11
Green waste[22]		/	90	496	19	4	126	48	1.7	40	13	37	11
MSW[23]		11380	117	375	27.8	/	32	24.8	0.5	31	/	/	4.1
CM[24]	Croatia	9818	329	544	71	5	22.6	45	0.88	10.6	2.6	/	/
PDC[18]	Austria	2190	267	447	100	1.3	25.7	38.3	0.43	43.4	7.5	/	/
CW[25]	U. K.	/	75	/	25	/	10	50	0.7	65	/	/	/
GWC[26]	Portugal	/	35	/	14	/	16	13	1.4	34	/	/	/
Min Max		1054-11380	23-329	171-944	8.9-306	1.3-6	10-127	13-61	0.43-2.2	10.6-65	2.6-13	34-62	4.1-17
Average		5157	148	512	61	4	66	43	1	43	10	44	12
Min-max input g/ha/year**		12648-136560	276-3948	2052-11328	107-3672	15.6-72	120-1524	156-732	5.2-26	127-780	31-15	408-744	49-20
Average input g/ha/year**		61882	1776	6149	726	51	795	512	16	513	12	528	14
Limit Agr. use[28]	Belgium	/	1000	/	100	/	50	150	5	600	10	/	/
Limit Park use[28]		/	1500	/	500	/	100	200	5	1000	20	/	/

*Dry matter; MC, mushroom compost; MSW, municipal solid waste; CM, Composted manures; PDC, Plant derived composts; CW, composted waste; GWC, Garden waste compost**Minimum, maximum and average input in g/ha/year into the soil using 30 t/ha of compost, with an average moisture content of 60%; [28]Agr – Agricultural use; Park – Horticultural use (mg kg^{-1} DM)

Digestates (residues from biogas production)

Anaerobic digestion (AD) is a biological process by which, organic matter is transformed into biogas, and can be used to produce energy. The use of AD biomass also results in the production of digestate[27, 29], which can be used as an organic fertilizer. As a raw material for AD provess different materials can be used as soild and liquid manure, straw, and industrial organic waste, and municipal waste, etc. Therefore, the composition of digestat can be quite different and can contain PTEs. Table 4 shows the concentrations of PTEs in the digestate and their average annual input into the soil.

Table 4. The concentration of microelements and heavy metals in digestates

Type of digestate	Country	Co	Cu	Mn	Mo	Se	Zn	As	Cd	Cr	Hg	Ni	Pb
							(mg kg^{-1} DM*)						
Solid digestate[A]	Serbia	/	136	109	/	/	139	/	/	16.8	/	/	3.62
Liquid digestate[A]		/	36	25	/	/	39	/	/	11.7	/	/	8.1
Solid digestate[18]	Austria	2.4	94	289	4.9	0.8	349	/	0.56	22.3	/	14.1	7.7
Solid digestate[30]	Germany	/	39	/	/	/	215	0.73	0.22	17.6	0.055	/	2.59
Solid digestate[31]	Italy	/	21	/	/	/	122	/	<0,5	2.7	0.7	2.47	7.03
Liquid digestate[32]	Sweeden	/	69	190	/	/	387	/	0.75	15.5	<0.1	20.3	2.35
Min Max		2.4	21-136	25-289	4.9	0.8	39-387	0.73	0.22-0.75	2.7-22	0.055-0.7	2.5-20	2.35-8.10
Average		2.4	66	153	4.9	0.8	209	0.73	0.51	14	0.29	12	5.23
Min-max input g/ha/year**		7	62-408	75-867	15	2.4	117-1161	2.2	0.66-2.25	8-67	0.17-2.1	7-61	7.05-24.3
Average input g/ha/year**		7	197	460	15	2.4	626	2.2	1.5	43	0.86	37	15.7

*Dry matter; **Minimum, maximum and average input in g/ha/year into the soil using 30 t/ha of digestate with an average moisture content of 90%; [A]Manojlović et al., non published.

Sewage sludge

Solid organic matter in sewage sludge, primarily generated in the process of wastewater treatment can be efficiently recycled[33]. It is estimated that more than half (about 5.6 million tons) of dry sewage sludge produced annually in the United States is used on agricultural soils. In the European Union, over 30% of sewage sludge is used as fertilizer in agriculture[34]. In Serbia, in most of the towns there are no sewage sludge tretments. Also, according to current legislation its use in agriculture is not permited due to high risk to human healh and the environment. Heavy metals are present in waste sludge due to industrial wastewater[4] and they are susceptible to leaching through the soil profile and can contaminate groundwater[35]. Studies on some New Zealand soils treated with waste sludge have shown increased concentrations of Cd, Ni, and Zn in drainage waters[36, 37]. Table 5 shows the concentrations of PTEs in sewage sludge as well as limit (permitted) values of PTEs prescribes by the EC directive[5] for the concentration of heavy metals in sewage sludge for agriculture. The use of sewage sludge in agriculture can led to Zn accumulation in soil due to higher content than permited values.

Table 5. The content and permitted values of microelements and heavy metals in sewage sludge for use in agriculture

References	Co	Cu	Mn	Mo	Se	Zn	Cd	Cr	Hg	Ni	Pb
						(mg kg^{-1} DM*)					
[38]		140		0	5	25800	1	54	0.1	660	370
		200		28	0.1	27700	0.1	251	0.1	260	604
		33		0.1	0.1	11660	0.1	49	0.1	149	0.1
[39]		500				1000	3		3	40	200
[18]	12.8	166	265	1.3	2.08	683	0.82	30.6	0.58	25.6	38.3
[40]	2-260	50-3300	60-3900	1-40	2-10	700-49000	2-1500	20-40600	0.1-55	16-5300	50-3000
Limit values[5]	/	1000-1750	/	/	/	2500-4000	20-40	/	16-25	300-400	750-1200

Conclusion

The quantities of microelements and PTEs introduced into the soil depend on the type and amount of organic material used, raw materials used, methods of preparation, animal feed, processing, etc. The consequence of continuous use of organic waste as fertilizers can be increased load of PTEs to soil resulting in their accumulation and increased a risk to enter food chain and affect human health. Therefore, maximum concentrations of PTEs in organic fertilizers are prescribed in most countries as well as their inputs to soil. Also, regular assessment of the quality of organic waste for agricultural use is needed as well as continuous soil monitoring in order to avoid negative impact to biota and the environment.

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Coping up metal stress (ZnO NPs) in plants by application of various forms of biochar amendments (A review)

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Abstract

In this project, the use of plants is proposed in order to recover the characteristics of soils that have been exposed to contamination by ZnO in nanoparticle form (NPs). In adittion, a review of the effects of different doses of biochar in order to treat the stress caused by the nano-form of metal pollution in the plants was investigated. This study approached the effects of how plants response to stress caused by bioaccumulation of heavy metals.

It has been reported in several studies that counteracting toxicity due to heavy metals requires complex mechanisms at the molecular, biochemical, physiological, cellular, tissue and plant-wide levels, which could be manifested in terms of improved crop production. Moreover, as plants have developed strategies to adapt to the accumulation of metals, *Hordeum vulgare* was studied as an alternative for bioaccumulation. The changes in plant physiology on both cellular and sub-cellular were analyzed to provide a full mechanism for the impact of biochar application and biochar bioremediation of heavy metals contaminated soils. In addition, the effects caused by the treatment can be consistently traced at all levels of plant organization. The reflection of this treatment process on the plant's physiological parameters especially oxidative enzymes activity, the morphometric characteristics of the plant, photosynthesis parameters along with the ultrastructural changes will be measured to evaluate whether the separate application of biochar into the soil and special amendment with biochar had a positive and negative impact on plant growth and development.

Keywords: Bioremediation, heavy metals, biochar, barley, soil.

Introduction

Soil is a natural, three-dimensional and dynamic body that covers the surface of the Earth. It is an open, complex, structural and above all multi-functional system. It is one of the most important natural resources, since it performs several functions, among which food production stands out. In addition, it is a fundamental piece in the food chain and the basis of life, thus it plays an important role within the environment. Soil composition is varied and has a range of naturally occurring compounds. These compounds include metals, non-metals, inorganic ions and salts i.e phosphates, carbonates, sulfates and nitrates, as well as other organic compounds such as lipids. This set of compounds is generated mainly through a series of processes derived from the microbial activity of the soil and the decomposition of organisms (mainly plants and animals). When the amounts of some of these potentially polluting substances in the soil exceed natural levels, then we speak of soil contamination. On the other hand, if various compounds from various sources, such as fuel burning, spills, agricultural activities, etc., additionally enter the soil in large quantities, then we speak of anthropogenic contamination (Jimenez, 2017).

Soil pollution is one of the degradation processes that affects many territories, worldwide. For this reason, in recent decades there has been an increased interest in knowing the types and sources of pollution, as well as the processes and possible solutions that can be adopted to prevent, mitigate or remedy these pollution processes (FAO, 2021). In general, this field has been approached from different fields and perspectives, so its study and solutions require a multidisciplinary approach.

When substances like heavy metals are accumulated at levels in which an effect is generated that affects the behavior of the soil, we refer to degradation, in such a way that heavy metals, at those concentration levels, represent a toxic level for the organisms present in the soil. At the same time, there is a partial or total loss of soil productivity in the soil (Jimenez, 2017). As it is shown in the table below, it is important to find more technologies to restore the abilities and the qualities that the soil loses when there is contamination, not just because of the properties of the soil that are affected but because of all the functions that soil has.

Functions of the soil (FAO, 2021)
Producer of biomass and source of food for living organisms, since it provides the nutrients, water and physical support necessary for plant growth.
As an essential component of the hydrological cycle, distributing surface waters and contributing to the recharge of groundwater.
Due to its ability to filter, store, degrade, neutralize and immobilize toxic substances, preventing them from reaching groundwater and air or from entering the food chain.
As a natural biological habitat for many organisms of all kinds.
As a source of raw materials.
As a support for the development of numerous human activities (socio-economic structure, landscape and cultural heritage).

Nowadays, plants are used to counteract the levels of contamination in the soil or even to immobilize the absorption of metals and thus, in some way, minimize the impact of contamination by heavy metals in soils.

Plants can adopt different strategies against the presence of metals in their environment (Baker, 1978). Many species tolerate high concentrations of metals in the soil because they restrict their absorption and / or translocation to the leaves (exclusion strategy). However, others actively absorb and accumulate them in their aerial biomass (accumulator strategy), which requires a highly specialized physiology (Baker, 1981). As plants show several response patterns to the presence of potentially toxic concentrations of heavy metal ions. Most are sensitive even to very low concentrations, others have developed resistance and a reduced number behave as hyperaccumulators of toxic metals. This particular capacity to accumulate and tolerate large metal concentrations has opened up the possibility to use phytoextraction for remediation of polluted soils and waters (Barceló & Poschenrieder, 1992). Plant species, including some crops, have the ability to accumulate metals in their tissues. Plants capable of absorbing and accumulating metals above what is established as normal for other species in the same soils are called hyperaccumulators and are mainly found in soils that are rich in metals due to natural geochemical conditions or anthropogenic contamination. Hyperaccumulating plants generally have little biomass because they use more energy in the mechanisms necessary to adapt to the high concentrations of metal in their tissues (Kabata-Pendias, 2000). Plants have developed highly specific mechanisms to absorb, translocate and accumulate nutrients (Yan, 2020). However, some non-essential metals and metalloids for plants are absorbed, translocated and accumulated in the plant due to the fact that they present an electrochemical behavior similar to the required nutritional elements.

Heavy metal accumulation in edible crops is an issue of global concern due to its relation with human health (Onakpa et al., 2018). Previous studies indicate that the heavy metals also affected plant growth by changing root morphology, root/shoot lengths, ultrastructure of cellular and subcellular structures and changes in physiological state of plants (Gorovtsov et al., 2019).

Another approach is the immobilization of HMs in soil by addition of various sorbents that prevent the translocation of metals from the soil solution to plants and their leaching into the underlying soil horizons. One of the most promising types of sorbents applicable in remediation is carbonaceous sorbents and specifically biochar (Anae et al., 2021). Biochar is a carbon-rich material that helps to stabilize the mobility and bioavailability of the metal in the soil (Palansooriya et al., 2020). The porous structure of biochar contributes to its large surface and sorption efficiency. Furthermore, the application of biochar could change the soil physicochemical properties and enhance the activities of soil microorganisms that influence soil quality and plant growth (Palansooriya et al., 2020). The studies of remediation process are important for better understanding the interactions of biochar with soil, as well as with plants.

Several microorganisms, especially bacterial species, are successfully used for bioremediation of HMs due to their significant role in biodegradation of pollutants. Also, microbes are involved in many beneficial soil functions, such as nutrient recycling, organic matter decomposition, soil-structure formation, secretion of plant growth promoters and degradation of organic contaminants (Rajput et al., 2021).

In this review, the plant that has been object of study is the spring barley, in the territory of south Russia. Specifically the Rostov Region it is the largest producer of spring barley (*Hordeum vulgare L.*), one of the food grain crops highly important for industrial uses. The study indicated that the H. vulgare L. is an efficient HMs accumulator and could accumulate HMs equal to Indian mustard (Brassica juncea), also an hyper accumulator plant.

According to (Ghori et al., 2019) heavy metals such as Zn accumulate for a long time in soils through industrial waste and sewage disposal. Although, sometimes, when the level of contamination exceeds the normal levels of heavy metals in the soil, stress is generated in the plants. Plants have different mechanisms to combat stress and are responsible for maintaining the homeostasis of essential metals that plants require. These mechanisms also focus on preventing exposure of plants to heavy metals present in the soil or providing tolerance to the plant by detoxifying the metals. Other mechanisms are specific and are initiated when the respective stress is encountered. The first line of defense provided by a plant is to reduce metal uptake when stimulated by heavy metal toxicity and includes the support offered by cellular and root exudates that restrict the entry of metals into the cell. Many plants have unique mechanisms for individual metal ions and participate in the sequestration of these ions in compartments avoiding their exposure to sensitive components of cells. As a second line of defense, other mechanisms of detoxification of these metals are introduced that chelate, transport, sequester and detoxify these metallic ions in the vacuole of the plant. During the time of metal toxicity, oxidative stress is pronounced in cells and the production of stress-related proteins and hormones, antioxidants, signaling molecules including the synthesis of heat shock proteins begins.

The intensity of stresses and associated adverse impacts are increasing substantially in the era of climate change that again triggers to produce abnormalities in the crops. To overcome the effects of abiotic stresses, a number of strategies have been investigated, such as developing and cultivate stress-tolerant varieties, use of organic fertilizers, and the application of high yielding varieties (Ghori et al., 2019; Yan et al., 2020).

There are numerous known uses for these biofuels today. Its porous structure and its chemical characteristics make it an attractive material with which to work when trying to solve some environmental problems such as: the treatment of waste or contaminated water, by using biochar as a filter and retaining heavy metals or chemical pollutants (Ali et al., 2021).

Application of biochar to mitigate the impacts of major abiotic stresses especially drought, salinity, and heavy metal has been found very effective. Amendment of biochar in stress affected agroecosystems improves the soil physicochemical and biological features and thereby enhances the productivity of crops (*Inicio Decenio Internacional para la Acción "El agua, fuente de vida" 2005-2015*, n.d.) Finally, incorporation of organic amendments is one of the most ecofriendly and economic strategies for the restorat ion of contaminated soils through diminishing mobility and bioavailability of heavy metals in the soil.

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Exploring the potential of metal-organic frameworks (MOFs) decorated biochar for the remediation of heavy metal-contaminated media

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Abstract

Contamination by potentially toxic elements (PTEs) has led to adverse environmental impacts in water and soil. To address this problem, the use of metal-organic frameworks (MOFs) as an emerging class of organic-inorganic hybrid crystalline porous materials has brought a new dimension for remediation purposes. In this context, a general overview of MOFs was presented, along with a deep discussion over the potentials of the MOFs and MOFs-based composites for removing heavy metal ions. Contrary to the well-established usage of the MOFs in the water, there was no report concerning their use in the soil. Therefore, modifying the MOFs with other materials, especially the biochar, was highlighted as a practical solution to facilitate the usage of the MOFs in soil practices. Based on the capacity of biochar as the commonly established soil additive, the corresponding bio-based composite would offer the following advantages: 1) Presenting excellent capacity for immobilizing/adsorbing resulting from a synergistic effect between MOFs and biochar; 2) Preventing the aggregation of MOFs in the soil matrix; 3) Increasing long-term stability; 4) Turning the spent additives to bio-fertilizer; 5) Adding the selectivity towards specific types of heavy metal ions, and 6) reducing the overall cost of composite by using the low-cost biochar. Finally, this overview summarized the future directions regarding the fate of the MOFs in the soil-plant system. Overall, the potential advantages provided by the biochar-MOFs will open a new direction for research in heavy metal remediation processes.

Keywords: Biochar, heavy metal ions, metal-organic frameworks, remediation.

Introduction

Potentially toxic elements (PTEs) such as heavy metal ions (HMs) have led to adverse environmental impacts in soil and water. The existence of HMs in the soil above the permissible limits is widespread. The excessive of HMs are reported to be toxic to humans and other living things due to their carcinogenic, mutagenic, teratogenic, and non-biodegradable nature. The inability of HMs to undergo microbial or chemical degradation compared to organic contaminants necessitates the remediation HMs contaminated soils (Li et al., 2021).

The current methods for treatment (membrane separation, chemical precipitation, ion exchange, electro flotation, coagulation, and solvent extraction) are expensive and detrimental to the environment due to the large quantity of toxic chemicals expended. Hence, the implementation of innovative and greener solutions to remediate HM-contaminated media in a cost-effective, environmentally friendly, and sustainable must be harnessed. Nevertheless, adsorption remains an effective method due to ease of operation and environmental compatibility (Zhang et al., 2021).

Emerging technologies such as nanotechnology bring novel aspects to each of the processes mentioned above by taking advantage of nanosized materials. In recent decades, the metal-organic frameworks (MOFs) nano-enabled remediation technologies have gained much attention in some applications (sensing, gas storage, drug delivery, remediation, etc.) and processes (adsorption, photocatalysis, Fenton-like, radical sulfate oxidation, etc.) (Figure 1). MOFs are an emerging class of organic-inorganic hybrid crystalline porous materials formed by clusters of organic ligands and metal ions via strong covalent/coordination bonds (Liu et al., 2020). From Figure 1, the adsorption process is mirrored for further discussion in the last section of this review due to its simplicity and relatively low cost compared to other techniques mentioned herein.

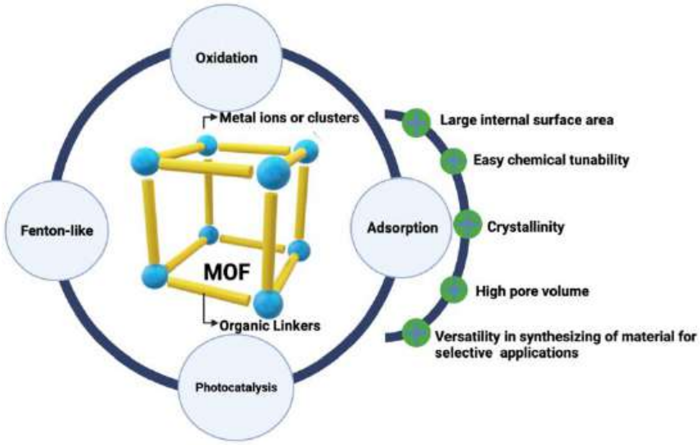

Figure 1. MOFs applications/processes based on nano-enabled remediation technologies.

In the present study, a systematic selection of literature was made to cover the main topic of discussion and uncover the applicability of MOFs in the remediation of HMs. This review creatively summarized the state of the art in emerging remediation technologies, particularly the MOFs-based nano-enabled materials and their broad applicability in HMs-contaminated media. Relying on the versed evidence of MOFs application in water media, the limitations for MOFs application in the soil media were pinpointed. Finally, a strategy for improving MOFs for potential applications in heavy metal was proposed, followed by cautionary conclusions and prospects. This article will open a new direction for researchers in designing optimized synthesis strategies to develop advanced MOFs composites for remediation of HMs-contaminated media.

Application of Metal-Organic Frameworks in Remediation of Heavy metal-contaminated media

The metal-organic frameworks (MOFs) possess high pore volume, adjustable pore topology, large specific surface area, structural tunability, and crystallinity. These unique properties of MOFs allow endless possibilities for modification and high selectivity towards specific HMs in contaminated media (Liu et al., 2020). Several MOFs, such as Materials of Institute Lavoisier (MIL), zeolitic imidazolate frameworks (ZIFs), University of Oslo (UiO), zinc(II) based MOFs (TMU-5), etc. are constructed from carboxylate-based ligands or azolate-based ligands (Fateeva et al., 2015). MOFs such as ZIF-8, UiO-66, TUM-5, etc., have been widely applied in remediation in aqueous systems with reported excellent adsorptive capacities. However, the stability of MOFs depends on some internal (metal ions, organic ligand, hydrophobicity, crystallinity, porosity, etc.) and external (pH, temperature, humidity, etc.) factors. Therefore, an adequate understanding of the interactions between water molecules and MOFs is essential (Li et al., 2021). Much research has been done with different MOFs, and various capacities have been reported, as presented in Figure 2.

Zhang et al. unveiled the adsorption of ZIF-8 for the potential removal of Cu^{2+} in an aqueous solution. An unexpectedly high adsorption capacity of 800 mg/g of Cu^{2+} was achieved without functionalization or pretreatment. At high and low concentrations of Cu^{2+}, ion exchange and coordination were responsible for high removal efficiency (Zhang et al., 2016). On the other hand, Tahmasebi et al. found lower adsorption capacities for TMU-5 (Cd^{2+}:43mg/g, Cu^{2+}:5 mg/g and Pb^{2+}:251mg/g) compared to ZIF-8, which was mentioned earlier (Tahmasebi et al., 2015). Recently, Lou et al. explored UiO-66 in 2021 to remove EDTA-complexed heavy metals. The findings showed that Lewis-acid/-base interactions and possible anion-π interaction with strong binding energies exhibited high adsorption (57.56 mg/g:Cu-EDTA; 120.6 mg/g:Pb-EDTA; and Ni-EDTA:54.27 mg/g) inside Zirconium based UiO-66 (UiO-66(Zr)). The study further revealed that size-matching EDTA-metal complexes within the UiO-66(Zr) framework would promote fast adsorption kinetics and better selectivity for different M-EDTA complexes (Lou et al., 2021).

The results presented above are so interesting for MOFs. Nevertheless, in some cases, other materials such as biochar show a higher capacity, especially for Pb^{2+}. There is no agreement between which material should be used for any remediation. However, adsorptive capacity largely depends on the concentration of sorbents and pollutants, among other factors. For example, in 2018, Son et al. utilized marine algal biomass to produce biochar to remove HMs from aqueous solutions. As a result, the maximum adsorptive capacities of 69.37 mg/g and 23.16 mg/g were reported for Cu^{2+} and Cd^{2+}, respectively (Son et al., 2018). In another study, Wang et al. employed a modified corn straw-derived biochar targeting Pb^{2+} and Hg^{2+} with maximum adsorption capacity reaching approximately 150 mg/g. Therefore, MOFs are as effective as other materials and show better adsorptive capacities in some cases in the remediation of HMs-contaminated media. In the next section, the discussion of the MOFs composites and the advantages are well covered.

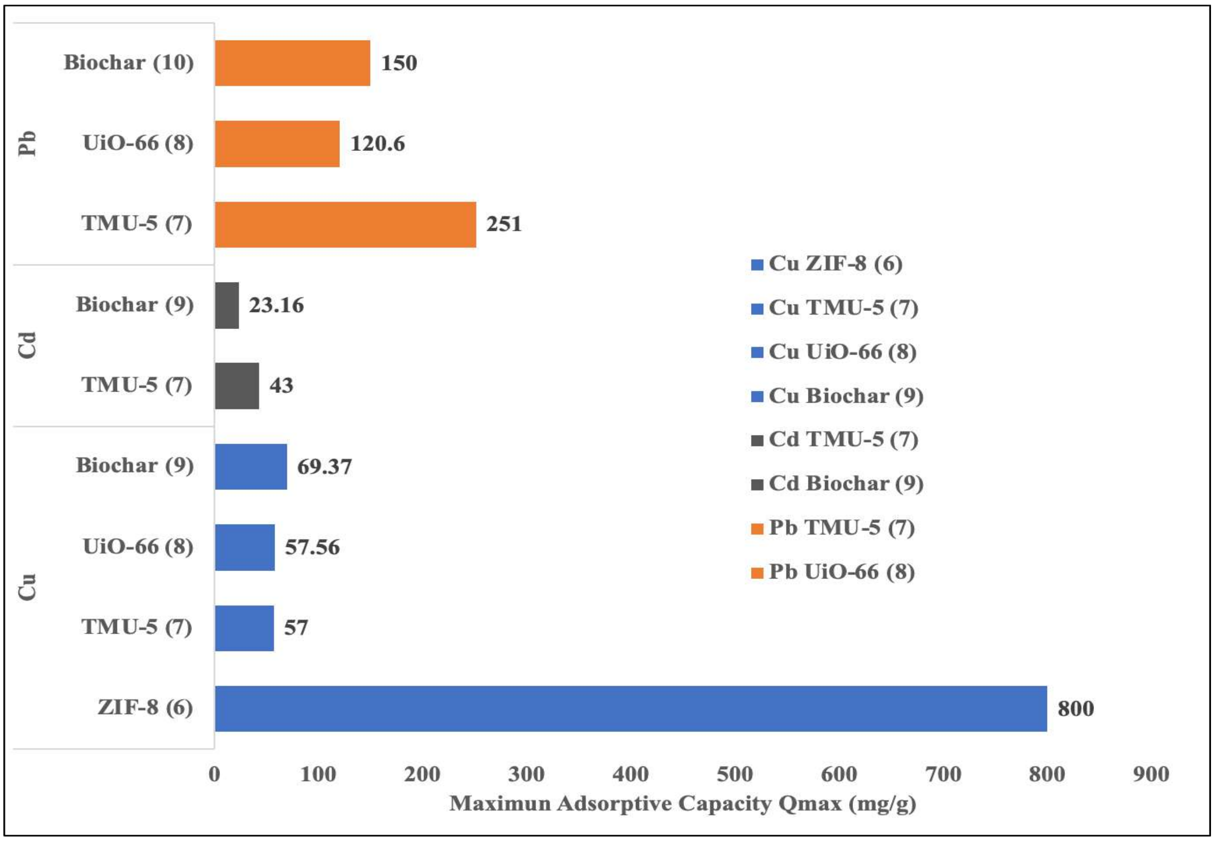

Figure 2. Summary of heavy metal adsorption capacities reported for MOFs and other materials. The annotations 6, 7, 8, 9, and 10 correspond to the references (Zhang et al., 2016), (Tahmasebi et al., 2015), (Lou et al., 2021), (Son et al., 2018), and (Wang et al., 2018), respectively.

Application of Metal-organic Frameworks-based Composites in Remediation of Heavy metal-contaminated media

MOFs-based composites have proven to show a great difference compared to pristine MOFs. For example, a composite of MOF and graphene oxide (GO) will allow the ionic groups and the aromatic sp^2 domains to react through bonding interactions, thereby functioning as structural nodes to bridge with organic groups on MOFs and enrich the reactant concentration during application in advanced oxidation processes (Huang et al., 2021). Also, the versatility of the MOFs makes it possible to make complexes with other substrates of nitrogen and carbon sources. In this context, recent studies that employed MOFs for remediation of HMs-contaminated media and the summary of this section are presented in Table 3.

As summarized in Table 3, in 2016, Moradi et al. formed a magnetic nano sorbent (Fe_3O_4@MOF-235(Fe)–OSO_3H) by sulfonated water-stable MOF-235(Fe) loaded on Fe_3O_4. Cd^{2+} was easily extracted from water by the magnetic solid-phase extraction method (Moradi et al., 2016). A functionalized water-stable MOF, MIL-100(Fe) complexed with polydopamine (PDA) to form a composite (Fe-BTC(MIL-100(Fe))/PDA), exhibited not only rapid, selective removal of Pb^{2+} and Hg^{2+} but also cleared the effect of competing metal ions despite very high concentrations of Na^{+} (Sun et al., 2018). Wei et al. conducted a study in 2019 for adsorption of Cu^{2+} using GO, ZIF-8, and 3-aminopropyl-triethoxysilane (APTES) by amine functionalization. The composite (ZIF-8@GO) showed high removal efficiency for Cu^{2+} up to 1872.24 mg/g with high reusability (Wei et al., 2019).

Table 3. The application of MOF-based composites in different processes for removal of heavy metals-contaminated media

MOF composite	Pollutants	Advantages	References
Fe_3O_4@MOF-235(Fe)–OSO_3H	Cd^{2+}	• The magnetic nano sorbent had high stability, low toxicity and offered high reusability (up to 10 times) of the MOF. • The adsorption was mainly due to the electrostatic attraction between the negative sites of the nano sorbent and the positive charge of Cd^{2+}.	(Moradi et al., 2016)
Fe-BTC(MIL-100(Fe))/ Polydopamine (PDA)	Pb^{2+}/Hg^{2+}	• Compared to MIL-100(Fe) alone, the composite gained extrinsic porosity, open metal coordination sites, and a BET surface area of 2324 m^2/g. • A high adsorption capacity of 1634 and 394 mg/g was reported for Hg^{2+} and Pb^{2+}, respectively. • Excellent affinity towards Pb^{2+} was observed despite the high concentration of Na^+ up 14000 times that of Pb^{2+}.	(Sun et al., 2018)
ZIF-8@Graphene oxide (GO)	Cu^{2+}	• The GO increased the reusability of the composite as compared to ZIF-8. • The composite had a higher surface area (748.42 m^2/g) compared to pristine ZIF-8. The result was excellent, and up to 1872.24 mg/g of Cu^{2+} was removed from the water.	(Wei et al., 2019)
ZIF-8@Calcium alginate (CA) microparticles	Pb^{2+}	• ZIF-8 loaded with sodium alginate enlarged its structure by about 10 times than the pristine ZIF-8. • The adsorptive capacity of the resulting composite was 1321.21 mg/g at a pH of 5 after 120 min of Pb^{2+}. Adsorptive capacity was maintained at 80% even after five cycles.	(Song et al., 2019)
Zirconium based MOF-mercaptosuccinic acid (MA)	Pb^{2+}/Hg^{2}	• The composite showed high selectivity for Hg^{2+} and Pb^{2+} with a maximum adsorption capacity of 1080 and 510 mg/g, respectively.	(Wang et al., 2020)

Apart from the addition of magnetic MOFs, there are some changes to improve the material's capacity by adding some hosts or materials like GO, polydopamine, and calcium alginate. As summarized in Table 3, the results excellently increased for MOFs composites compared to pristine MOF. Hence, the MOFs composites are likely to be more promising for the remediation of HMs-contaminated media. In the next section, we attempt to discuss the drawbacks associated with the potential application of MOFs for remediation and the likely alternatives to consider for futuristic research.

Conclusion and Future Prospects

This review has described the applications of MOFs and MOFs composites in HMs-contaminated media as well as their advantages and corresponding adsorptive capacities. Although the design and optimization of MOFs have reached the advanced stage, some associated drawbacks are still yet to be addressed. It was shown that the composition of MOFs with different materials presents different opportunities, as shown in Figure 3, to address many shortcomings associated with pristine MOFs.

Iron-based metal-organic frameworks (Fe-MOFs) have high redox-related tendencies. However, the Fe^{2+} and Fe^{3+} forms can easily be accessed and exploited in MOFs structures. This advantage, coupled with their low toxicity, leads to more excellent structural stability, environmentally friendly than other MOFs for remediation purposes. Also, magnetic composites could potentially aid the separation of the MOFs in the soil matrix, and this method has never been documented. Therefore, modifying the MOFs with other materials such as biochar complexed with Fe-MOFs may likely present a practical solution for the soil practices. Based on the capacity of biochar as the commonly established soil additive, the corresponding bio-based composite would offer the following advantages: 1) Presenting excellent capacity for immobilizing/adsorbing resulting from a synergistic effect between Fe-MOFs and biochar; 2) Preventing the aggregation of Fe-MOFs in the soil matrix; 3) Increasing long-term stability; 4) Turning the spent additives to bio-fertilizer; 5) Adding the selectivity towards specific types of HM ions, and 6) reducing the overall cost of composite by using the low-cost biochar.

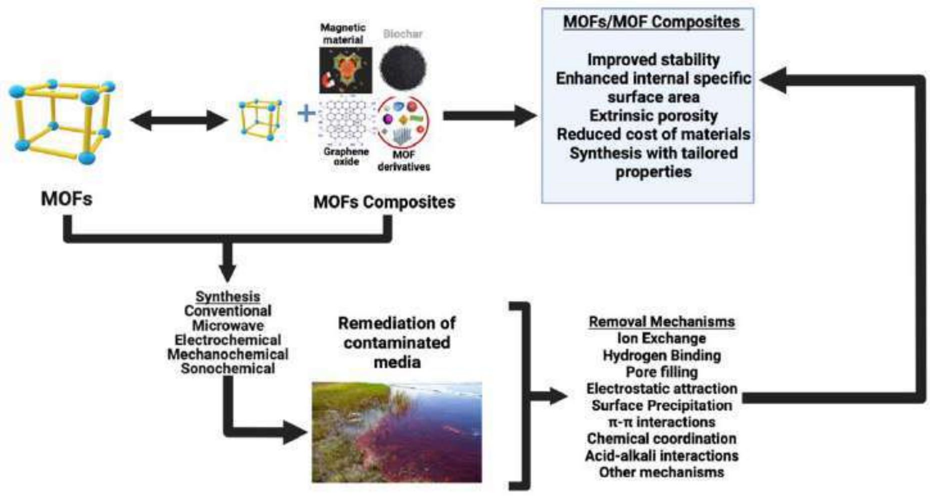

Figure 3. Summary of the conclusion and future directions for MOFs and MOFs-based composites used for remediation of heavy-metal contaminated media.

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Investigation of agricultural use potential of liquid fermented products from biogas plants

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Abstract

Although the disposal of organic wastes that threaten environmental health has been achieved as a result of biogas production, especially liquid fermentation waste (LFW), which is formed as a result of the process, emerges as a new problem that should be solved. In this study, a 2-month greenhouse experiment was conducted to demonstrate the usability of biogas power plant LFWs in agricultural areas, and wheat plant was used as a test plant. In the greenhouse experiment, LFW samples were taken from 16 biogas power plants in operation in Turkey and soil samples representing the region where these power plants are located and pathogen tests and content analyzes were carried out before and after pasteurization (70°C). In the greenhouse experiment, LFWs were applied after pasteurization at different doses (0, 1, 2, 5 ton/da), in addition to the control groups with chemical fertilizer and without any LFW or fertilizer. Most of the liquid wastes (LWs) included in the experiment increased the EC values of the experiment soils compared to the control soils but did not change the salt class. The effect of LFW applications on the infiltration rate was variable. All biogas LFWs increased the organic matter content of the soil and the macro and micro element (Fe, Cu, Zn, Mn) contents of the soil and wheat plant, depending on the increasing application dose. Each liquid waste has a different effect in terms of heavy metal concentration, but in general, their amounts in the soil and plant increase with increasing application dose. The effects of LFW applications on total biological activity (CO_2 output), potential microbial activity (Microbial biomass-SIR (substrate induced respiration)) and catalase enzyme activity of the soil differed. All LFW applications increased the Fe, Cu, Zn, and Mn content of plants depending on the increasing application dose, and there was no statistically significant effect on the heavy metal contents. Applications of 16 LFWs at 2 and 5 ton/ha increased the fresh and dry weights of wheat plants compared to the control ($P<0.05$), while the increase in 1 ton/ha applications was not statistically significant. Considering the results of the greenhouse experiment and the relationship of all parameters with each other, it is deemed appropriate to initiate field experiments for the 16 biogas enterprises included in the study and to allow a 1 ton/da/year temporary application dose until these studies are concluded.

Keywords: Biogas, liquid fermented waste, soil, wheat

Introduction

During anaerobic digestion in biogas power plants, depending on the composition of the raw material, 20% to 95% of the organic matter is decomposed. The waste product remaining in this process is called biogas waste (solid and liquid fermented waste). These wastes can be applied directly to the soil or be subjected to various post-treatment (solid-liquid separation, drying, dilution, filtration, etc.) (Möller and Müller 2012). In Turkey, as a result of the use of organic wastes in biogas plants in biomethanization, a daily average of 250 tons MWh^{-1} of new waste is generated. This renders biogas facilities inoperable, even though they produce sustainable and affordable energy sources, and thus, are important part of strategies to slow down and reverse the effects of climate change. Currently, there is no Biogas Action Plan and/or Biogas Roadmap in our country, and how the "Biogas Strategy" should be is not clear either. There are also big gaps in the technical and economic evaluation of typical biogas plants in Turkey and the ecological impacts that may result from biogas applications (for example, reduction in greenhouse gas emissions, environmental changes in soil and water, raw material supply security, modern stable systems, etc.).

The characteristic of fermentation wastes or their contents are largely determined by the substances used for anaerobic fermentation and the fermentation process itself. Liquid and solid manure from cattle and poultry are mainly used in agricultural biogas plants. There are important steps to ensure effective post-process pathogen reduction, such as absolute pasteurization of liquid waste, periodic sampling of liquid waste, content analysis and declaration, compliance with "good agricultural practices" rules for application to agricultural lands, post-implementation monitoring and considering economic reasons i.e. increased fuel prices and transportation cost. As the carbon components of the materials are changed due to fermentation, the nutrients in them are completely preserved and they are in a form that can be taken by the plants more easily thanks to the anaerobic degradation process (Döhler, 1999). The solid and liquid forms of the waste from the biogas power plant have different nutrient contents. The nutrient content of the waste depends on the original raw material, the digester type and the anaerobic process. The composition of liquid waste from biogas power plants generally includes 93-99% water and 1-7% dry matter (DM), most of which is organic and some inorganic matter. Liquid waste contains N, P, K, Ca, Mg, Fe, Cu, Zn, Mn and different amino acids (Stinner et al., 2008; Fouda et al., 2013; Wentzel and Joergensen, 2016). Depending on the degree of decomposition, the C/N ratio in the fermentation waste decreases as a result of methane fermentation. This has a positive effect on fertilization because the amount of ammonium available to plants increases.

In Turkey, biogas wastes are the least studied wastes among organic wastes. From an environmental point of view, these wastes have been determined to have strong fertilizer properties in many studies conducted in various parts of the world, and the results of these studies have become promising for using biogas wastes for agricultural purposes. On the other hand, while the use of LWs that cannot be pre-treated directly in the fields increases the yield at the beginning, there are studies indicating that they cause various problems in later stages. The easiest way to valorize fermentation wastes (in solid and liquid form), both in Turkey and in the rest of the world, is thought to be transferring them to agricultural areas for fertilization. Considering international practices, the nutrient value, compliance with hygiene legislation criteria, application time, application method, effects on climate change, and economic value are taken into consideration in the use of fermentation wastes from biogas power plants. The disposal of daily wastes from biogas power plants and their use as fertilizer by recycling is required by regulations as well as the demands of the mentioned enterprises. In this study, to reveal the usability of LFWs of 16 biogas power plants that are currently in operation in agricultural production, their effects on several important properties of the soil and on the wheat plant were investigated with a 2-month greenhouse experiment.

Material and Methods

Wheat plant growth of LFWs subjected to pasteurization and some physical (infiltration rate), chemical (total N, available P, extractable K, OM, EC, pH, B, Cd, Cu, Ni, Pb, Zn, Hg, Cr, Sn, Zn, Fe, Cu, Mn) and biological (biomass carbon, respiration, biological index, catalase enzyme activity) properties of the soil were measured in a 2-month greenhouse experiment. Liquid fermented waste from 16 biogas power plants was used as material, and wheat plant (Bezostaja variety) was used as test plant. Greenhouse experiment treatments: Control, chemical fertilizer control, 1 ton da^{-1} LFW, 2 tons da^{-1} LFW and 5 tons da^{-1} LFW. LFW was applied at doses of 1, 2 and 5 kg da^{-1} to each plastic pot containing 3 kg of soil. For chemical control purposes, the application of 100 mg kg^{-1} N (NH_4NO_3), 50 mg kg^{-1} P and K (KH_2PO_4) and control pots in which no application was made were also included in the experiment. In the experiment, which was established as three replications, firstly, 15 wheat seeds were planted at a depth of 6 cm in each pot, and LFWs were added to the relevant pots, starting with a small dose. First water was given to the pots together with liquid biogas waste, enough for the plant to germinate. After planting and the application of liquid waste, the pots were covered with air to prevent sudden drying, and when the plants started to germinate, the covers of the pots were completely removed. The greenhouse conditions and the moisture content of the pots were checked every day to ensure that the potted soil remained at the field capacity. Pots were monitored one by one starting from germination and 10 plants were left in each pot. The plants were weighed each time and the amount of water was added to the amount that was reduced from the pot and phenological observations were made during the experiment. The plants were harvested by cutting from the above-ground parts at the end of a 9-week development period, washed with tap water, dilute acid (0.2 N HCl) and distilled water, then dried and ground in a drying cabinet at 65±1 °C for 48 hours.

After the remaining plant roots were removed from the soil, the soil in each pot was air-dried and sieved through a 2 mm sieve, and the total N was measured by the Kjeldahl method (Bremner 1965), available P spectrophotometrically (Olsen et al., 1954), extractable K by US Salinity Lab. Staff (1954), OM by Walkley Black Method (Jackson 1969), EC and pH in 1:2.5 soil-water mixture (Jackson, 1969), infiltration rate by US Salinity Staff (1954), B, Cd, Cu, Ni, Pb, Zn, Hg , Cr, Sn, Zn, Fe, Cu, Mn by wet combustion in ICP-OES, biomass carbon by SIR method (Isermayer, 1952), respiration by titration method according to Isermayer (1952), and catalase enzyme activity according to Beck (1971). The amount of oxygen released as a result of the separation of hydrogen peroxide was determined gasometrically and the amount of *E. coli*, *E. coli* O157:H7, *Salmonella*, *Entorobacteria* was determined according to Mooijman et al. (2019) and Zadik et al. (1993). In plant samples, however, the nitrogen was measured by Total Kjeldahl method (Kacar and İnal, 2008), P, K, Pb, Cd, Ni, Cr, Zn, Fe, Cu, Mn analyzes were also determined by wet digestion (Kalra, 1997) in the ICP-OES (Kacar and İnal, 2008).

Results and Discussion

Content analyzes of 16 LFWs included in this study were performed after sanitation. Dry matter amounts of LFWs varied between 0.53 and 9.71% (Namli et al., 2021). The organic matter contents of the LWs varied similarly, and the LWs contained organic matter between 0.53 and 7.76%. The nitrogen content of LWs was around 0.10-0.74%; phosphorus contents were around 0.035-0.50% and potassium contents were around 0.14-0.56%. The pH of LFWs ranged between 7.87 and 8.93 and had medium and strong alkaline properties. In direct EC readings of LFWs without any dilution in the raw sample, the EC values of LWs coded as G1, G3, G5, G6, G7, G8, G13, G14, G15, and G16 were above 20 dS m^{-1} and higher values could not be read on the device. It is thought that the salinity class does not change due to the short duration of the greenhouse experiment, and the effect will be pronounced more if they are applied to the land for a long term.

The results obtained from the study, in which the effects of 16 LFWs on soil and plants were revealed by the greenhouse experiment, were evaluated collectively. The textures of the soils used in the experiment were clay loam and clayey.

Most of the LWs included in the experiment increased the pH and EC values of the experiment soils compared to the control soils but did not cause a change in pH and salt class. In the greenhouse experiment, the effect of liquid waste applications has varying effect on the infiltration rate. While the infiltration rate decreased in soils treated with G6 and G14 liquid waste, it increased in soils with G15 and G16 liquid waste. The effect of other liquid waste applications on the infiltration rate was not statistically significant (Table 1). Infiltration, the measure of the amount of water entering the soil surface, is an important process that determines how much water will reach the plant roots and how much runoff will occur. Information on cumulative infiltration is important for efficient soil and water management (Githinji, 2014). The infiltration rate is an important measure in determining how much of the water given by the LFW can leak into the soil and how much can be lost by surface flow, also, the infiltration rate should not decrease. Liquid phase wastes evaluated within the scope of the study generally have low dry matter content (0.53-9.71% by weight), and thus, contain a lot of water. When this type of liquid waste is applied to the soil for fertilizer purposes, it increases the elution of the subsoil in permeable soils with excess water. In impermeable soils and less permeable soils, the imbalance between water and air in the soil can result in a decrease in the number of soil microorganisms, aerobiosis restriction, denitrification and loss of nitrogen to the atmosphere in the form of N_2 or N-oxides, etc. In other words, it may lead to negative consequences (Koláj et al., 2011). Liquid fermented wastes with high homogeneity and flow properties quickly penetrate the soil. However, the application of liquid waste as fertilizer involves the risks of nitrogen loss due to ammonia emissions and nitrate leaching. To minimize these risks, some simple rules of good agricultural practice must be followed (Al Seadi, 2001).

All biogas LFW applications increased the organic matter content of the soil with increasing application dose. In the greenhouse experiment, 6 LFW applications decreased the total biological activity (CO_2 output) of the soil, 8 plant wastes increased the CO_2 output, and 2 plant wastes did not have any effect on the CO_2 output of the soil. Potential microbial activity of soils (Microbial biomass-SIR) decreased in 5 biogas plant waste applications, while 8 plant wastes increased microbial biomass. Regarding the effect of LWs on catalase enzyme activity, 8 biogas power plant wastes increased catalase enzyme activity, while 5 plant wastes decreased, and 3 LFWs did not have any effect on the enzyme (Table 1). The intracellular catalase enzyme is an oxidoreductase group enzyme, and it plays an important role in the soil being a protective environment for living organisms by breaking down hydrogen peroxide, which is a strong toxic compound that occurs as a result of the reaction in the soil, into water and molecular oxygen. Catalase enzyme, which is very common in nature, is not encountered in anaerobic environments and living things. Determination of the catalase enzyme activity in the soil is the biological parameter used in the evaluation of the aerobic microflora present in the environment (Nicholls et al., 2000). Yıldırım (2010), in his study, observed that the activity of catalase enzyme in the soil decreased considerably under salt stress, but it never stopped completely and continued partly.

Table 1. Increasing and decreasing effects of liquid waste applications on EC, pH, infiltration rate, CO_2, SIR and catalase enzyme activity in soil

LFW Code	**EC**	**pH**	**Infiltration rate**	**CO_2**	**SIR**	**Catalase**
G1	+				+	
G2	+	+		-	+ (5 ton da^{-1} dose reduction	+
G3		+		-	-	+
G4	+	+		+	+	-
G5	+	+				-
G6	+	+	-	-		+
G7	+			-		
G8	+	+		+	-	+
G9	+	+		+	+	+
G10	+	+		+	-	
G11	+			+	+	-
G12	+			-	-	-
G13	+			+	+	
G14			-	-	-	-
G15		+	+	+	+	+
G16			+	+	+	+

The increasing effect of the liquid waste application is shown with "+" sign, and the reducing effect is shown with "–" sign. In those for whom no effects were detected, there were no signs.

In the greenhouse experiment, LFW applications of all biogas power plants in the experiment increased the nitrogen content of the soil. The issues, such as whether the LWs from the biogas power plant can be used in agricultural production, what the effective dose(s) should be in case of use, which methods should be applied, etc. are still a matter of debate today. When the international studies on the subject are examined, it is clear that many factors are taken into consideration in practice. Calculation with the equivalent of mineral fertilizers is a common method used to calculate the nitrogen available in the fermentation waste in the application year of the wastes from the biogas power plant. In addition, as per the Nitrate Directive, the use of total organic waste of animal origin should not exceed the application dose of 17 $kg^{-1}N^{-1}da^{-1}year^{-1}$ for organic plant production. A long-term application of fermentation waste (10-15 years later) can be based on a mineral fertilizer equivalent of 60-70% (Döhler, 1996). The amounts of pure nitrogen given to the soil with the dose application of 1, 2 and 5 tons da^{-1} applied in the greenhouse experiment are given in Table 2. According to the table, with the application of 5 tons da^{-1} of G2, G4, G6, G9, G12, G14, G15 and G16 LWs, the 17 kg da^{-1} N amount given in the Nitrate Directive is exceeded. If these biogas power plants use animal waste in production, liquid waste applications of 5 tons per decare will be inconvenient due to the high nitrogen they contain. To obtain optimum benefit from the nitrogen in the liquid waste, their application to the soil should apply the same criteria as for the use of other animal manures. These criteria are to have sufficient storage capacity (minimum 6 months), limited application season as fertilizer (during vegetation), amount applied per hectare (according to the fertilizer plan), and application technique (minimum nutrient loss with rapid application). In total, the effectiveness of nitrogen in fermentation wastes is mainly determined by the type and time of application, weather conditions, soil type and the type of plant grown. Determining the application dose according to the characteristics of the waste and the soil to be applied is the most accurate approach. However, giving the amount of nitrogen required by plant as liquid may cause excessive irrigation of the crop and the soil. Excessive irrigation can lead to complete destruction of irrigated areas and an almost complete loss of potential soil fertility (Stehlík, 1988). When liquid biogas wastes reach water resources they can cause eutrophication problems as they contain high amounts of nitrogen and phosphorus.

Table 2. Amount of N in 1, 2 and 5 tons of liquid waste applied in greenhouse experiment

LFW Code	N kg da^{-1} in 1 ton of liquid waste	N kg da^{-1} in 2 ton of liquid waste	N kg da^{-1} in 5 ton of liquid waste
G1	2.40	4.80	12.00
G2	4.32	8.65	21.62
G3	1.38	2.76	6.89
G4	7.44	14.88	37.20
G5	2.86	5.72	14.29
G6	3.62	7.24	18.11
G7	2.52	5.04	12.60
G8	1.00	2.00	5.00
G9 / G12	6.17	12.34	30.84
G10	1.20	2.39	5.98
G11	1.10	2.20	5.50
G13	1.00	2.00	5.00
G14	4.80	9.60	24.00
G15	4.00	8.00	20.00
G16	4.80	9.60	24.00

When the effects of LFW applications on metal concentration are examined; it has been determined that each liquid waste has a different effect, but the amounts in the soil and plant increase depending on the application dose in general. In all liquid waste applications, the highest heavy metal was determined at 5 tons da^{-1}. Chemical fertilizer applications were found to be close to control values under liquid waste applications, except for a few examples. The heavy metals that show a statistically significant increase in soil and plant due to each LFW application are given in Table 3. Since LWs are given in large amounts, the amount of heavy metals in the soil and plant has increased. Due to the fact that the amount applied to the soil in chemical fertilizer applications was not as high as LWs, it did not have an increasing effect on the metal content of the soil and plant as much as LWs. This should not mean that chemical fertilizers will not cause pollution in terms of heavy metals. There are many studies that show that chemical fertilizers cause heavy metal increase in soil and plant in long-term use (Pezzarossa, 1993; Tu et al., 2000; Ju et al., 2007). In the greenhouse experiment, an increase in the amount of heavy metals due to liquid waste applications was determined, but, this increase was not at the level of point source pollution. It would be beneficial to include General Directorate of Plant Production's farmer registration system analysis support in order to follow heavy metals in areas where LWs will be used for a long time.

Table 3. Heavy metals increasing in soil and plant due to liquid fermented waste applications

LFW Code	Metals increasing in soil	Metals increasing in plant
G1	Pb, Cr, Ni	Cd, B, Pb
G2	Pb, Cr, Ni, B	B, Cr, Pb
G3	Pb, Cr, B	B, Cr
G4	Cr, Ni	Cr, Ni
G5	Pb, Cr, Ni	B, Cd, Ni
G6	Cr	B, Ni, Pb
G7	Cr, Ni	B, Cr, Ni, Pb
G8	Pb, Cr, Ni, B	B, Cd, Cr, Ni, Pb
G9	Pb, Cr, Ni	B, Cr, Ni, Pb
G10	Pb, Cr, Ni	B, Ni, Pb
G11	Pb, Cr, Ni, B	B, Ni, Pb
G12	Cr, Ni	B, Ni
G13	Cr, Ni	B, Cd, Cr, Ni, Pb
G14	Pb, Cr, Ni	B, Ni
G15	Cr, B	B, Ni, Pb
G16	Pb, Cr, Ni, B	B, Cd, Ni, Cr, Pb

Conclusion

The issue of the application of LWs to agricultural lands in our country is not clear. The increase in the amount of liquid waste from biogas power plants has led to the need for the problem to grow and be solved. In this study, which was initiated based on this need, the effects of each LFW on some physical, chemical and biological properties of the soil were different. It should be remembered that the data obtained is the result of a short-term greenhouse experiment. Considering the results of the greenhouse experiment and the relationship of all parameters with each other, it seems appropriate to conduct field experiment with the wastes included in the study and to allow a temporary application dose of 1 ton^{-1}da^{-1}year^{-1} by the Ministry of Agriculture and Forestry until these studies are concluded. In the greenhouse experiment, the evaluations made on parameters such as heavy metal, B, EC, N, infiltration were made by staying on the safe side in terms of soil, plant and environmental health at the recommended dose of 1 ton da^{-1}. In order to determine the appropriate doses based on LFW the biogas power plant, field experiments (in different types of land use such as irrigated/dry farming, pasture, forest, etc.; in different plant types as well as field crops) should established for at least two consecutive years, and the residual effects of LWs and application doses should be specified. It is important to perform heavy metal, N, B, pH, EC analyzes once a year after liquid waste is applied to the soil. In addition, in the fields where LFWs are applied, recording the applied amounts on the basis of parcels will be useful in resolving the disputes that may arise later.

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The effects of biochar on soil biological properties: A review

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Abstract
To improve the quality and production of crops, biochar application has been suggested, which is produced by pyrolysis of biomass derived from various sources impacting the physicochemical properties of biochar. It is instituted that biochar affects soil microbial diversity and abundance by improving soil attributes such as water holding capacity, porosity, pH, nutrient cycle etc. Despite the importance of biochar in soil nutrient cycling, little is known about how soil microorganisms respond to biochar inputs. When biochar is added to the soil, it can have many effects on soil: processes, fertility, and the abundance of microbes. However, in contrast to studies suggesting benefits to soil biota many pieces of research highlight biochar's adverse effects as well. This review summarizes the properties of biochar and its interaction with soil microflora both positively and negatively.
Keywords: Biochar, soil microflora, pyrolysis, nutrient, fertility.

Introduction

Crop growth and productivity are strongly influenced by various biotic and abiotic stresses such as pests, weeds, drought, high salinity, extreme temperature, etc. and soil quality (Rawat et al., 2019). The widespread usage of artificial fertilizers has wreaked havoc on the ecosystem, generating a slew of issues. It not only reduces the nutrient content of crops but also diminishes soil fertility over time. Increased fertilizer and pesticide inputs have a detrimental effect on the soil microflora, impairing soil health and significantly reducing total bacterial and fungal biomass. The application of biochar to soil has been recommended as one of the novels means of increasing agricultural productivity and improving soil quality both physically and biologically, in a sustainable manner. However, according to Alkharabsheh et al., (2021) some potential negative effects of biochar on microbial biomass and activity have been reported. There is also evidence that biochar addition can sorb and retain pesticides for long periods, which may result in a high weed infestation and control cost.

The goal of this review is to gather information from various sources on how biochar can affect soil biological characteristics directly or indirectly.

Biochar and its production technology

Biochar is charcoal; black, porous, light, fine-grained, and has a huge surface area, which is prepared by heating biomass (such as wood, manure, or leaves) in the absence of oxygen, either completely or partially. Carbon makes up over 70% of its composition. The rest is made up of elements like nitrogen, hydrogen, and oxygen(*What Is Biochar? - Regeneration International*, n.d.)

The physiochemical properties and nutrient content of biochar are determined by feedstock qualities and production parameters. Pyrolysis is the most prevalent method for producing biochar, and it can also be found in the early phases of combustion and gasification. Compared to pyrolysis biochar (450-650°C), Gasification biochar (GB) is produced at higher temperatures around 700–1100 °C, using low amounts of oxygen (Hansen et al., 2015). Slower heating rates produce larger biochar particles as compared to higher production temperatures (Jahromi et al., n.d.). Gasification produces more energy than pyrolysis does and leaves biochar with less but more stable carbon than pyrolysis biochar. Bio-char soil management systems can deliver tradable C emissions reduction, and C sequestered is easily accountable, and verifiable (Lehmann et al., 2006)

What is soil biological properties

Soil biological properties refer to the living organisms found in the soil, which can include micro-and macroplants as well as animals. Where, Micro plants group include bacteria, fungi, and actinomycetes, Macroplants refers to roots of higher plants, Micro animals present in the soil consists of nematodes and protozoa while, macro animals include earthworms, rodents, arthropods etc.

Microorganisms and their activities are critical to the soil's normal and long-term health (Milošević & Milošević, 2019). Soil microbial activity reflects microbiological processes of soil microorganisms and is the potential indicator of soil quality, as plants rely on soil microorganisms to mineralize organic nutrients for growth and development (Chen et al., 2003)

Biochar as a soil biota amendment

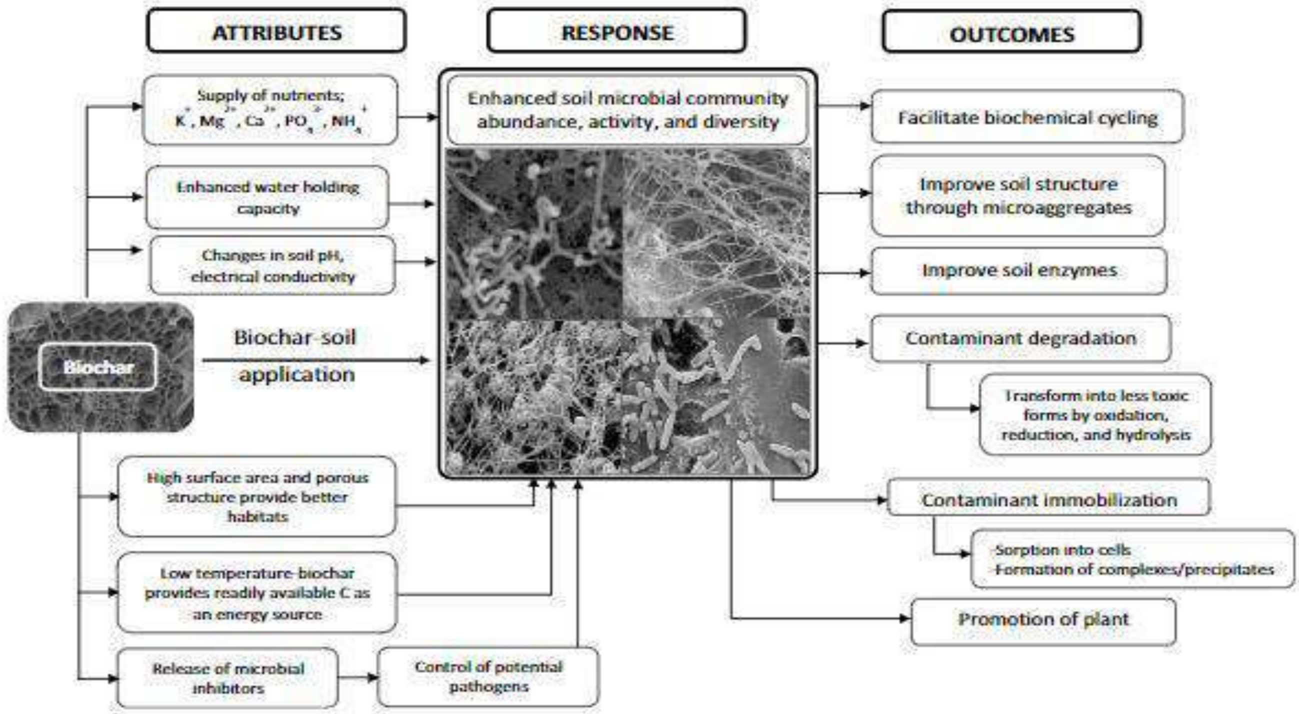

Fig. 1. Schematic diagram showing the effects of biochar on soil microorganisms and microbial responses following biochar application (Niroshika Palansooriya et al., 2019)

Biochar is an organic amendment that improves soil attributes, with a potentially significant effect on soil chemical fertility and quality (Khadem et al., 2021). It helps to improve soil quality by raising the pH, moisture-holding capacity, cation-exchange capacity, and microbial flora of the soil (Mensah & Frimpong, 2018). Ding et al., 2016 explain how biochar may affect soil microorganisms through the following mechanisms:

1. changes in nutrient availability
2. changes in other microbial communities
3. alterations in plant-microbe signalling
4. habitat formation and refuge from hyphal grazers

Microorganism abundance concerning biochar use

Zhang et al., (2014) explain that biochar addition can increase soil microbial biomass, and may also affect the soil biological community composition, which in turn will affect nutrient cycling, plant growth, and greenhouse gas emission, as well as soil organic carbon mineralization.

The addition of biochar to soil has been shown to boost the number of microorganisms in a variety of ways, according to numerous researches conducted over the past few years. For instance, Khadem et al., (2021) reported high application rates of low-temperature biochar stimulated the overall microbial activity more in soils with clayey textures with high organic matter content. The obvious reason for increased microbial activity after biochar amendment is the increased soil porosity, which allows nutrients to be more easily accessed. Similarly, Ahmad et al.,(2022) reported Sewage Sludge biochar improved the bacterial community composition and soil nutrient cycle, furthermore, it was conveyed; Proteobacteria, Actinobacteria, Acidobacteria, Bacteriodetes, and Firmicutes were among the dominant phyla that were prevalent in the amended soil.

Numerous microbiological and chemical processes in soil are negatively impacted by fungicide use, in one of the studies biochar amendment (1%) increased microbial abundance (culturable fungi, bacteria, actinomycetes), enzyme activities (urease, invertase, and dehydrogenase), and the formation of soil macroaggregates (>0.25 mm) under pyraclostrobin (fungicide) stress by removing toxic effects (Q. Zhang et al., 2021).

The pH of soils may change, after biochar additions, because of the acidity or basicity of biochar. Different living conditions will be formed for microorganisms with different pH of biochar (Ding et al., 2016). For instance, one of the researchers found out that with the increase of pH up to values around 7, bacterial populations were possible to increase, whereas, no change in fungi abundance was observed (Rousk et al., 2010).

Furthermore, humidity may play a role in microbial abundance. Dry soil stresses microorganisms, causing dormancy or death, Because of its huge surface area, biochar can hold a lot of water, which could help microorganisms proliferate (Schimel et al., 2007).

This study reveals that different microbial communities respond differently to the addition of biochar to soil.

Biochar's potentially negative effects on soil biota

Biochar has attracted much interest because of its versatility in agricultural and environmental applications. Despite its numerous advantages, there are concerns about the long-term safety and implications of its use. Organic contaminants such as polycyclic aromatic hydrocarbons (PAHs), volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PTEs), and dioxins may be found in biochar. These substances are either naturally present in the biomass used to make biochar or are produced during pyrolysis, including incorrect or incomplete pyrolysis (Hilber et al., 2017). Biochar affects soil microbial communities by altering various properties of the soil, including the organic matter content, water holding capacity, acidity, nutrient availability, or potentially toxic substances content. Such modifications may lead to shifts in microbial abundance among various groups/classes and result in a distinct microbiome. Subsequently, altered microorganism activity can lead to changes in nutrient cycles, crop productivity, and SOM content (Brtnicky et al., 2021). The potential for harmful impacts of biochar application on the soil microbial community and its subgroups are limited by the different types of charred material, soil types, and dosage, as well as the resulting influence on the soil's physical and chemical properties (Brtnicky et al., 2021; Niroshika Palansooriya et al., 2019).

Conclusion

The incorporation of biochar into soils has the potential to improve soil fertility by improving soil microflora and promoting plant growth. In soils supplemented with biochar, the number of beneficial bacteria such as *Trichoderma* is increased. These microorganisms contribute to a phenomenon known as systemic-induced resistance (SIR). Biochar's soil stability makes it a potential ally in combating CO_2 increases and reversing heat-trapping gases.

There is a wide variety of biochar accessible and a lack of standardization among those now available, which contributes to the diverse results. As a result, a thorough definition and standardization of what constitutes good biochar are required. Given the variety of effects that biochar can have on soil, future biochar use guidelines should take a structured and holistic approach, taking into account both the positive and negative consequences of biochar. The majority of research have been conducted in a laboratory and over a short period of time (less than two years). Consequently, long-term field experiments of biochar applications must be carried out in the field.

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The impact of slope aspect on soil temperature and water content

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Abstract

Soil is seen as a natural body whose characteristics are defined by the materials from which it was created and the environment in which it has been exposed. Soils are formed through the interaction of five major factors, topography is well known as one of these factors, it has a great impact on microclimatic and meteorological characteristics, which affect soil hydrology and temperature regimes. Soil temperature and moisture play a decisive role in plant communities. Soil temperature depends on the amount of radiation from the sun which reaches the soil surface (insolation). The radiation amount is directly proportional to the soil temperature. yet the general statement can be made that, insolation has more importance than the air temperature. The temperature of the soil is influenced by a number of factors, including meteorological conditions (air temperature and insolation), topography (slope aspect and gradient), and soil water content. Soil moisture is an important component of the earth system, it affects atmospheric, geomorphic, hydrologic, and biologic processes. Soil moisture is also an essential variable in regional and microclimatic assessments, landscape denudation, runoff generation, and partitioning, mass wasting, and sediment movement due to its dispersive and cohesive properties. The slope aspect is one of the quantitative topographic characteristic factors responsible for the redistribution of water in the landscape, it also has an effect on the pattern and trend of vegetation in mountainous regions. In the northern hemisphere, north-facing slopes receive less direct sunlight (insolation) than south-facing slopes. Sloping lands towards the equator receive a greater amount of solar energy over a longer period of time. Thus, the soil temperature is usually higher on south-facing slopes than on north-facing slopes, and as the temperature of the soil increases the water content decrease so the soil on the north-facing slopes was generally moister than the soil on the south-facing slopes.

Keywords: Slope aspect, soil moisture, soil temperature, topography.

Introduction

Soil is arguably the Earth's most valuable nonrenewable resource and undoubtedly the most biologically diverse part of the biosphere (Barrett, and Petropoulos, 2013). Drainage, organic activity, slope of the land surface, climatic forces, and both vegetative and animals are the environmental factors that influences soil development (Norton and Smith, 1930). Aandahl (1949) postulated that topography (slope aspect and gradient) is one of the factors affecting soil formation. It influences runoff, temperature, transpiration and evaporation. Topography affects soil hydrological and temperature regimes by influencing microclimatic and meteorological properties. It controls the spatial distribution of physical, chemical, and biological soil properties either directly or indirectly (Florinsky, 2016). Thus, plants within a relatively small area has many different climatic conditions due to the effect of topography on climate (Aandahl, 1949).

Aspect is the direction a slope is facing (Ferraz et al. 2009). Microclimatic variations due to differences in slope aspect result from changes in incoming solar radiation, which induces a change in soil temperature, moisture, humidity, and evaporation, thus affecting vegetation dynamics and soil characteristics (Eisenlohr et al. 2013).

The following formula, described by Duffie and Beckman (1974), was used to determine the angle of beam solar radiation on a particular slope and aspect at a specific time and date (eq. 1):

$$CosB = SinD\ SinL\ CosS - SinD\ CosL\ SinS\ CosA + CosD\ CosL\ CosS\ CosH + SinD\ SinL\ SinS\ CosA\ CosH + CosD\ SinS\ SinA \quad \text{[eq. 1]}$$

where B is angle of incidence of beam solar; D is solar declination; L is latitude; S is slope; A is surface azimuth (0 is due south, east is positive, west is negative); and H is hour (Lieffers, 1987). In southern Mexico, Méndez-Toribio et al (2016) studied the effect of slope aspect and topographic position on soil properties. He found that evapotranspiration rate, mean annual temperature, and insolation varied with slope aspect (Méndez-Toribio et al. 2016). In temperate regions, the slope aspect is thought to be the most influential driver of environmental variables in the forest ecosystem. In the northern hemisphere, north-facing slopes receive less direct radiation than south-facing slopes. Sloping land that faces the equator receives a higher amount of solar energy over a longer period. This disparity in solar radiation between two different slope aspects is reported to be 50% higher in south-facing slopes in the northern hemisphere than in north-facing slopes, this is mainly responsible for the primary-aspect related variations in vegetation and associated abiotic factors In comparison to north-facing slopes, south-facing slopes showed higher soil temperatures and deeper active layers (Singh, 2018).

Insolation differences appear to have also distinguished the two different slope aspects in terms of vegetation density, soil carbon content, and soil depth, all of which are higher on the north aspect slope. In north-facing slopes, low insolation may result in higher moisture content, boosting vegetation development (Geroy et al. 2011). On S-facing slopes, the soil moisture content is generally below field capacity due to the higher incidence of solar radiation, resulting in higher transpiration rates and reduced plant growth (Méndez-Toribio et al. 2016). Studies on east and west slopes have shown that solar radiation is skewed to the west at the afternoon peak, therefore a west-facing slope is substantially warmer than a shaded east-facing slope (Singh, 2018) (Fig.1). Slope aspect of the land surface is a key element in distinguishing soil types in the field and it can be used in mapping (Norton and Smith, 1930).

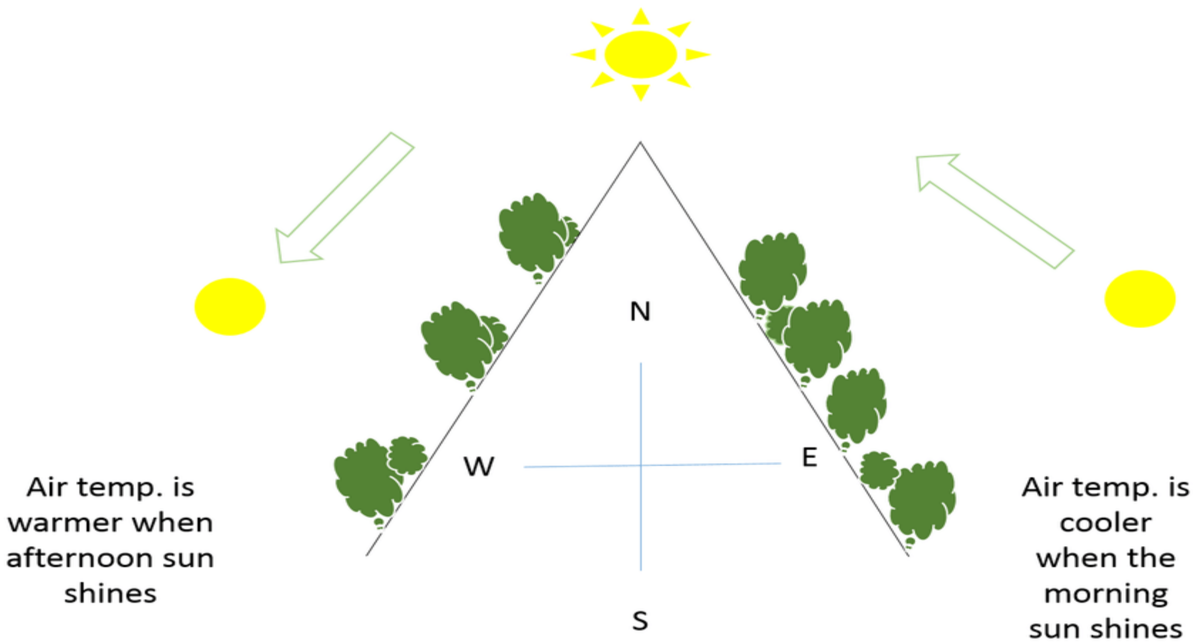

Fig. 1. Aspect induced change in vegetation between east-facing slope and south-facing slope (Singh, 2018)

On sunny and shady slope aspects, differences in soil moisture, temperature, and microclimate can lead to different plant communities, which in turn can affect the soil microbial community (Xue et al. 2018). Difference in vegetation between two different slope aspect is due to the differences in insolation and soil temperature on both slopes (Shreve, 1924). In general, it has been found that south facing slopes may differ from north-facing slopes in soil and air temperature, soil and atmospheric moisture, light intensity and wind velocity (Cantlon, 1953).

Soil Temperature and Moisture as Affected by Slope Aspect

One of the simplest yet most elegant approaches to detect spatial interrelationships between soils and topography is to study soils along a slope (Lambert, 2007). Historically, the study of temperature and moisture conditions affecting plant growth has been ascribed to the science of climatology or meteorology (Buol, 1977).

Soil temperature

Soil temperature is a significant factor, especially in agriculture, since the soil temperature affects the growth of biological systems (Yolcubal et al. 2004). The main source of soil temperature is solar radiation (Onwuka and Mang, 2018). Daily and annual fluctuation of soil temperature affects both biological and chemical processes in the soil, such as decomposition rate and mineralization of soil organic matter as well as CO_2 emission (Paul et al. 2004). Soil temperature plays an important role in seed germination, root growth, and absorption rate. It also affects the soil evaporation rate (Shreve, 1924). Temperature variations caused by slope differences are likely to have an impact on the development of various soil properties (Norton and Smith, 1930). In fact, soil temperature has a significant impact on nearly every process in the soil, from primary mineral weathering through plant nutrition and organic carbon storage (Pregitzer and King, 2005). Meteorological conditions (i.e. solar radiation and air temperature), site topography (i.e. slope aspect and gradient), soil water content and texture, and the area of surface covered by litter and plant canopies all impact soil temperature (Paul et al. 2004).

Soil temperature is determined by the balance between energy input and output. The main determinant of soil thermal regimes is the total amount of radiation reaching the earth's surface (insolation) which is a function of latitude, time of year and cloud cover (Pregitzer and King, 2005; Hillel, 2003). Slope aspect significantly affects insolation. Tajchman and Minton (1986), on their study on a forested Appalachian watershed, they reported greater mean soil temperature on south and west-facing slopes relative to north-facing slopes. Burnett et al. (2008) in his study on southern Colorado Plateau, north eastern Arizona, reported a strong contrast in insolation related to aspect and seasonal changes. Insolation higher on south-facing slopes, resulting in generally warmer and drier conditions (Fig. 2). South-facing slopes annual air temperature were 1.4-2.1 °C warmer than north-facing slopes, and this difference in winter were 2-3 °C warmer.

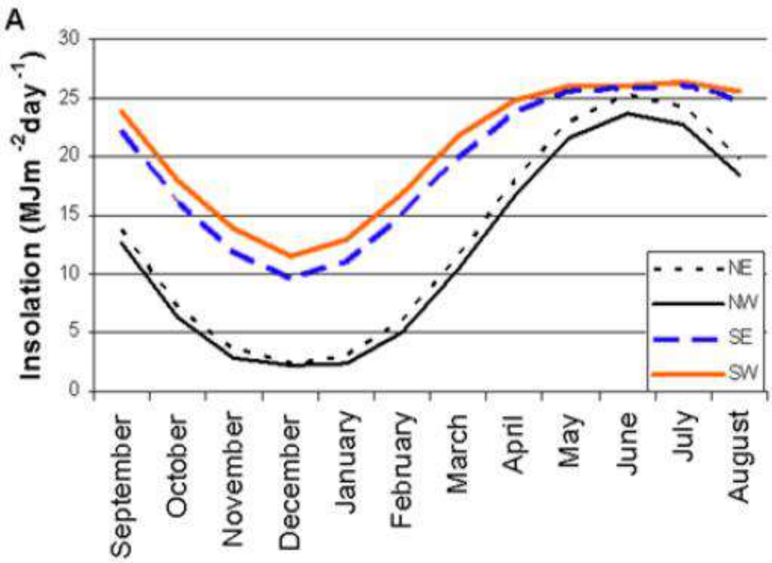

Fig. 2. Daily insulation for each month calculated for different slope aspects (Burnett et al. 2008).

Forrest Shreve (1922) started a series of soil temperature records at depth 3-inches on north-facing and south-facing slopes at different elevations of 7000, 8000, and 9000 feet in the Santa Catalina Mountains area. Six Friez soil thermographs have been used and installed under natural conditions of the altitude and slope. The thermographs were installed at the end of the first week of May and removed at the end of the first week of September, with a total covering 18 weeks. The climatic and vegetation characteristic of this area has been described before by Shreve (1915). The maximum temperatures indicate that the difference in temperature between north-facing and south-facing slope increases as the altitude increase from 7000 to 9000 feet, this is can be seen clearly from the warmest section of the summer. the south-facing slopes always show higher temperature than north-facing slopes 1000 feet below (Table 1). He concluded that, the air temperature is not as important as insolation to determine the soil temperature.

Table 1. Averages of 18 weeks of reading of soil temperature at 3-inches (in degree F), (Shreve, 1924).

Elevation (Feet) and Slope	Maximum (°F)	Minimum (°F)	Range (°F)	Mean (°F)
9000 N	59.3	53.1	6.2	56.2
9000 S	77.7	61.6	16.1	69.6
8000 N	62.4	56.5	5.9	59.4
8000 S	82.6	60.9	21.7	71.8
7000 N	78.9	50.6	28.3	64.7
7000 S	91.9	61.3	30.6	76.6

South-facing slopes receive more direct sunlight than north-facing slopes. This is called insolation receipt. As a result, soil and atmospheric temperatures tend to be higher on south-facing slopes. And soils in south-facing slopes tend to be drier. The coolest and most mesic slopes face north or northeast while the warmer, drier slopes face south and southwest (Lambert, 2007). In compared to north-facing slopes, south-facing slopes has higher soil temperatures and deeper active layers (Singh, 2018). Macyk et al. (1978) in their study on a particular area 50 km west of Edmonton, Alberta, found that the soil temperature was higher on south-facing slopes than north-facing slopes, and air temperature is usually higher than soil temperature at 10-cm depth. From the data obtained, he postulated that the driest site was the upper slope position of the south-facing aspect. The difference in soil temperature between the two aspects was smallest during the months of July and August and largest during May, June, September and October. Cantlon (1953) studied the mean annual soil and air temperature of north- and south-facing slopes of 36% under light shade conditions in a deciduous forest in New Jersey, he found that air and soil temperature were found to be higher on the south than on the north-facing aspects. This difference in temperature should result in both increased transpiration and evaporation in the south-facing slope. over the year, the soil at a depth of 4 cm on the south-facing slope was 4.8°F warmer than that of the north-facing slope. Franzmeier et al. (1969) reported that the direct beam component is responsible for radiation and temperature differences between north and south-facing slopes. The difference in soil temperature due to aspect is greater in winter than in summer.

Soil moisture

Soil moisture refers to the amount of water in soil's pores and generally refers to the water contained in the unsaturated soil zone (Barrett and Petropoulos, 2013). Soil moisture is a critical component of the earth system and plays a decisive role among the various subfields of physical geography. It affects atmospheric, geomorphic, hydrologic, and biologic processes. (Florinsky, 2016). It also influences weather, plant growth, and groundwater storage (Pandey et al. 2021). Theoretically, the rate of soil water depletion will vary with steepness and direction of slope because of their effect on the radiation balance (Sartz, 1972). The influence of slope on the moisture condition of the profile is perhaps the most important effect of slope, yet the general statement can be made that the moisture amount entering the soil at any given region decrease as the slope increase (Norton and Smith, 1930). The slope aspect influences the soil water content because the aspect in association with gradient affects evapotranspiration and insolation (Florinsky, 2016). Macyk et al. (1978) in their study on a particular area 50 km west of Edmonton, Alberta, recorded higher moisture content at the sites on the north-facing slope as compared to sites on the south-facing slope.

Sharma et al. (2010b) reported a reduction in moisture content and water holding capacity in the south-facing slope in Garhwal region of Indian Himalaya. He found an increasing in soil moisture content (40.8%), water holding capacity (48.9%) values for north-facing aspect. Increased rates and depth of evaporation with increasing soil temperature, especially in conditions when the water supply is limited, is the most obvious influence of soil temperature on soil water. The viscosity of water is affected by soil temperature. At low temperatures the water viscosity increases and the rate of water uptake by roots decreases, this, in turn, reduces nutrient transport to the roots in mass flow (Pregitzer and King, 2005). As air and soil temperature are higher on south-facing aspects than north-facing aspects, evaporation rate was also suggested to be higher in south-facing aspects (Singh, 2018). Low temperature minimizes evaporation and transpiration (Burnett et al. 2008).

Burnett et al. (2008) studied the effect of different aspects on soil moisture content southern Colorado Plateau, north eastern Arizona. Soil moisture potential sensors have been installed on slope of NW, NE, SW, and SE aspects, with depth 10 and 30 cm. he found that south-facing aspects (SE, SW) were too dry during most of the year, whereas north-facing aspects (NE, NW) were moist all year. Differences between north and south aspects in soil moisture content are greatest during the early summer and fall (Fig. 3).

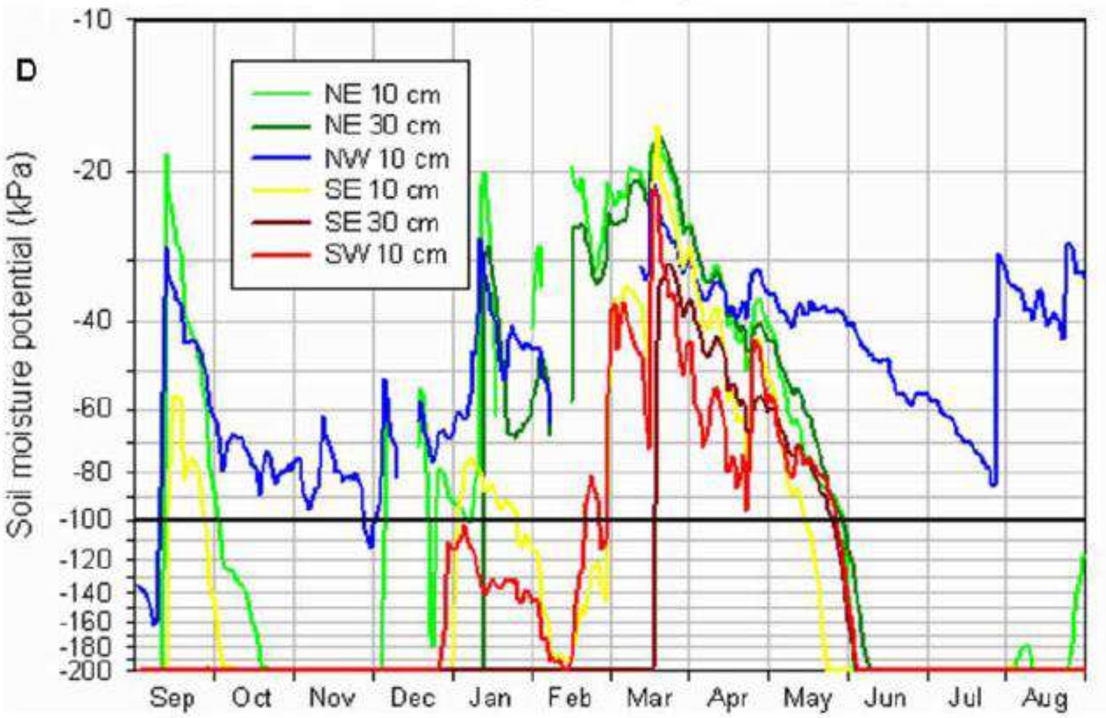

Fig. 3. Soil moisture recorded from September 2002 through August 2003 (Burnett et al. 2008).

Geroy et al. (2011) study the effect of slope aspect on soil moisture in Dry Creek Experimental Watershed, located north of Boise Idaho, USA. During the spring and summer of 2009, soil moisture was measured on 27 days for the south aspect slope and 25 days for the north aspect slope (Fig. 4). Volumetric soil moisture contents are approximately 0.16 and 0.21 on south aspect and north aspect slopes. The north aspect has consistently greater mean soil moisture. S-facing slopes in the northern hemisphere receive more solar radiation than N-facing slopes, making the latter more humid and colder. On S-facing slopes, soil moisture content is often below field capacity due to the increased incidence of solar radiation, resulting in higher transpiration rates and reduced plant growth (Méndez-Toribio et al. 2016).

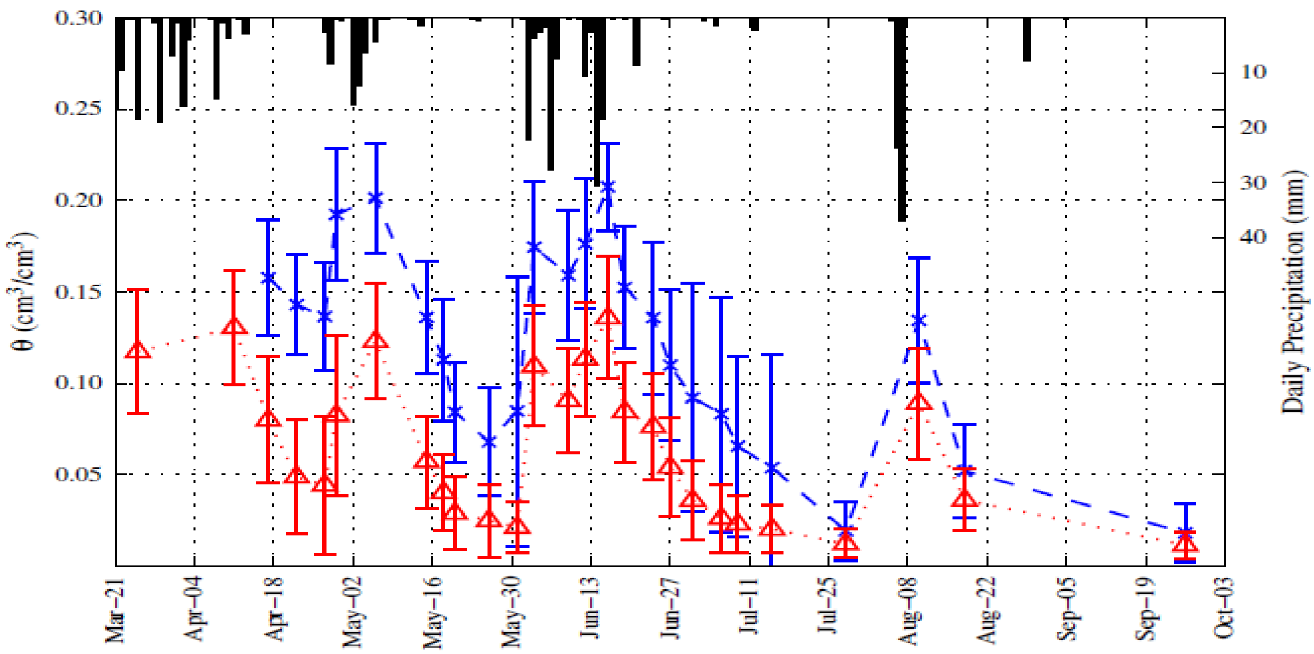

Fig. 4. Average soil moisture conditions on the north (blue) and south (red) aspect slopes (Geroy et al. 2011).

In 1999, Kutiel and Lavee studied the differences in soil and vegetation properties in north and south- facing slopes along a climatic transect which included four different climatic zones: mediterranean, semiarid, arid, and extreme-arid. They found that the moisture content of the soil in all four zones is always higher in north-facing slopes compared to south-facing slopes (Table. 2).

Table. 2. Maximum, minimum, and average soil moisture content (% of dry weight) for the period 23/03/1994 to 01/09/1994, and soil depth (0-2 and 10-15 cm) (Kutiel and Lavee, 1999).

Site	Min				Max				Average			
	SFS		NFS		SFS		NFS		SFS		NFS	
	0-2	10-15	0-2	10-15	0-2	10-15	0-2	10-15	0-2	10-15	0-2	10-15
Mediterranean	4.00	6.61	4.56	8.20	12.55	23.35	17.73	28.29	8.42	15.91	10.54	19.78
Semi-arid	1.93	3.84	2.49	3.99	4.22	9.74	12.90	18.76	2.44	6.54	7.25	11.10
Arid	1.10	2.36	2.01	2.61	3.16	12.19	6.89	14.14	2.13	6.42	3.81	7.40
Extreme-arid	0.26	0.84	0.63	1.10	2.76	7.66	2.03	8.45	0.93	2.91	1.35	3.73

Conclusion

In sum, slope aspect is a dynamic factor which impacts soils on a number of levels, all of which revolve around microclimate. Insolation receipt and wind impacts other processes and characteristics such as snow accumulation, soil moisture and soil temperature. In the northern hemisphere, the soil on the south-facing aspect tend to be warmer then the soil on the north-facing aspect. Moisture content is always higher in the north-facing aspects.

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Molecular characterization of *Beet virus q* isolates in sugar beet production areas of turkey based on coat protein gene

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Abstract

Sugar beet (*Beta vulgaris* L.) is widely grown in Turkey as a raw material for the sugar industry. The beet plant is infected by some soil-borne viruses, belonging to the genus *Pomovirus* within the family *Virgaviridae*, which are transmitted by the plasmodiophorid vector *Polymyxa betae*. Among members of the genus *Pomovirus*, *Beet soil-borne virus* (BSBV) and *Beet virus Q* (BVQ) can only infect sugar beet. In Turkey, BVQ was the first reported of these viruses in 2017 and it was very common (88.4%) in the sugar beet fields sampled in our previous study. In the current study, 15 BVQ-infested soil samples were randomly selected according to their geographic origin and the isolates derived from the soil samples were molecularly analyzed based on the coat protein (CP) gene. RT-PCR analysis with BVQ-CP specific primers, PCR products of the expected size (501 bp) were obtained for all tested samples and sequenced. The CP regions in all Turkish BVQ isolates consisted of 501 nucleotides and 166 amino acid (aa) residues. Interestingly, 14 BVQ isolates obtained from different locations were same at the nucleotide and aa level when those isolates were compared. However, the isolate KNY-419Q had differences only at the 429, 441, 443 and 461 nucleotide positions of the CP region comparing with other Turkish isolates. These mutations caused to changes at aa positions 148 [Histidine (H) →Arginine (R)] and 154 [Lysine (K) →Threonine (T)]. Phylogenetic analysis of 32 BVQ isolates (15 from this study and 17 retrieved from GenBank) showed that all isolates were clustered in two main groups, I and II. Turkish isolates belonged to group II alongside the isolates from Poland (EU785968, EU785969 and EU785979) and Germany (AJ810290). To our knowledge, this is the first molecular characterization of BVQ isolates in Turkey.

Keywords: Soil-borne virus, sugar beet, RT-PCR, sequencing

Introduction

Sugar beet (*Beta vulgaris* L.) is a main source of sugar in Turkey and grown extensively in the country over the areas of 322.000 ha (Anonymous, 2020a). Turkey is the world's fifth largest sugar beet producer, with a production of 19.8 million tons, ranking behind France, Germany, the United States, and Russia (Anonymous, 2020b). Beet plant is affected by soil-borne viruses transmitted by *Polymyxa betae* Keskin such as *Beet necrotic yellow vein virus* and *Beet soil-borne mosaic virus* (BSBMV) in the genus *Benyvirus*, *Beet soil-borne virus* (BSBV) and *Beet virus Q* (BVQ) in the genus *Pomovirus*, in growing areas across the world. Sugar beet is also a host for *Beet black scorch virus* (BBSV) in the genus *Necrovirus* which is transmitted by *Olpidium brassicae* (Wor.) Dang (King et al., 2012).

BVQ was first reported as one of the two BSBV serotypes (Ahlum and Wierthe) (Lesemann et al., 1989; Barbarossa et al., 1992) and then described as a distict member of the genus *Pomovirus* within the family *Virgaviridae*. This virus has a tripartite (RNA 1-3), single-stranded, positive-sense (+) RNA genome that are encapsidated into rod-shaped particles. RNA-1 and RNA-2 encode the replication proteins and the capsid protein (CP) and CP-readthrough (CP-RT), respectively. Also, RNA-3 encodes the triple gene blocks proteins (TGB1-3) that are required for efficient cell-to-cell movements (Koenig et al., 1998).

BVQ was first recorded in the UK, then the virus was detected in nearly all sugar beet production areas of Europe (Stas et., 2001; Meunier et al., 2003; Ratti et al., 2005; Rubies Autonell et al., 2006; Rysanek et al., 2006; Borodynko et al., 2006; Pavli et al., 2010). In addition, it has been reported in Iran (Farzadfar et al., 2005), Turkey (Erkan and Kutluk Yilmaz, 2017) and more recently in Japan (Nakagami et al., 2021).

This virus has a limited host range. BVQ naturally infects sugar beet and it is mechanically transmissible only to *Chenopodium quinoa* (Savenkov, 2021).

Up to now, BNYVV, BSBV and BVQ have been widely recorded in sugar beet growing areas in Turkey (Kutluk Yilmaz et al., 2016; Erkan and Kutluk Yilmaz, 2017). It has been reported that these viruses often occur together in the same field (Meunier et al., 2003; Farfadzar et al., 2007; Mehrvar, 2009; Nakagami et al., 2021; Moradi and Mehrvar, 2021). Similarly, in our previous study, BVQ was detected in 82 soil samples out of 72 tested samples (about 88%) with co-infested with BNYVV and/or BSBV (Erkan and Kutluk Yilmaz, 2017). To date, limited number of sequence information is available in GenBank database for especially European and Iranian BVQ isolates, but there is a lack of data for isolates from Turkey. Therefore, the aim of this study was to characterize BVQ isolates obtained from major sugar beet cultivation areas of Turkey according to coat protein (CP) region.

Material and Methods

Soil samples and bait plant experiment

Fourteen soil samples belonging to 13 provinces maintained since the study of Erkan and Kutluk Yilmaz (2017) and known to be infested with BVQ were selected for further analysis based on geographic origin in order to represent most of the sugar beet growing provinces of Turkey (Figure 1).

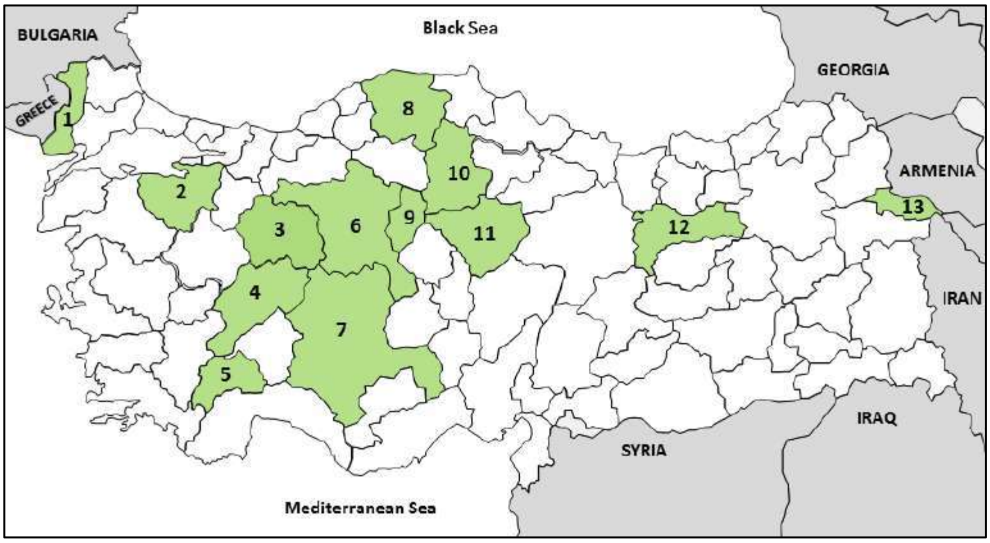

Figure 1. The map of Turkey showing the location provinces where soil samples were collected. The green shaded areas and following numbers show provinces investigated. 1. Edirne, 2. Bursa, 3. Eskisehir, 4. Afyonkarahisar, 5. Burdur, 6. Ankara, 7. Konya, 8. Kastamonu, 9. Kirikkale, 10. Corum, 11. Yozgat, 12. Erzincan, 13. Igdir.

In bait plant experiment, the seeds of a commercial sugar beet variety, BNYVV-susceptible (*rz1*), were used. A representative sub-sample from each of the 15 collected soil samples was mixed in a 1:1 ratio (by volume) with sterilized sand and added to eight 300 ml plastic pots. Then, ten seeds were sown per pot. The plants were grown under controlled conditions at 20°C (night) and 25°C (day) with a 12 h photoperiod. All plants were watered as needed and treated equally with Hoagland's solution each week. After six weeks of growth, the plants were harvested and their roots were stored at -80°C until analysis. Also, uninfected seedlings were grown under the same conditions in sand/soil mixture as a negative control (Meunier et al., 2003).

Total RNA isolation and reverse transcription-polymerase chain reaction (RT-PCR)

Total nucleic acids were extracted from the rootlets of BNYVV-susceptible sugar beet bait plants using RNeasy Plant Mini Kit (Qiagen) according to the manufacturer's instructions. For the molecular characterization of the CP region of the BVQ isolates, two-step RT-PCR was used. Initially, the first strand cDNA was synthesized using the Omniscript reverse-transcriptase kit (Qiagen), according to manufacturer's recommendations. PCR was performed using Phusion High-Fidelity DNA polymerase (ThermoFisher

Scientific). The PCR conditions with primer sets (BVQ/F: 5'-TCTGTTGTGTCTAGAAGTATG-3' and BVQ/R: 5'-TCCCAGGACAATTGATTGCTA-3') (Lennefors et al., 2005) consisted of an initial denaturation at 98°C for 30 s, followed by 25 cycles of denaturing at 98°C for 30 s, annealing at 54°C for 30 s, and extending at 72°C for 30 s and final extension at 72°C for 5 min using a thermocycler (Bio-Rad). The PCR products were analysed on 1% agarose gel and visualised by using Gel Doc 2000 systems (Bio-Rad).

Phylogenetic analysis

PCR products were directly sequenced by a commercial company (Genoks, Turkey) for sequencing with Sanger method. The sequenced data was edited with the CLC Main Workbench program (Version 7.0.2, Qiagen). All the obtained sequences were deposited in NCBI (Table 1). Multiple nucleotide and amino acid (aa) sequence alignments of the CP coding region of 15 Turkish BVQ isolates with 17 isolates from other countries were analysed by the Clustal W method in the MEGA7 (Kumar et al., 2016). Then, the Turkish BVQ isolates compared with each other and the other BNYVV isolates from different geographical regions of the world by using BLASTn and BLASTp which is available online. The maximum-likelihood (ML) phylogenetic analysis was performed (Tamura and Nei, 1993) using MEGA7 (Kumar et al., 2016). *Potato mop-top virus* (isolate P1: GQ503252) was used as an outgroup. Tree branches were bootstrapped with 1.000 replications (Felsenstein, 1985).

Results and Discussion

The presences of BVQ in the soil samples used in this study were previously determined (Erkan and Kutluk Yilmaz, 2017). In this study, RT-PCR analysis with BVQ-CP specific primers produced band of the expected size (501 bp) were obtained for all tested samples and sequenced. The entire CP nucleotide sequence of 15 BVQ isolates from different geographic origin was determined and deposited into the GenBank under accession numbers OL870466 to OL870480 (Table 1). The CP regions in all Turkish BVQ isolates consisted of 501 nucleotides and 166 aa residues as reported previously (Lennefors et al., 2005; Borodynko et al., 2009). Interestingly, 14 BVQ isolates obtained from different locations were same at the nucleotide and aa level when each isolate was compared. However, the isolate KNY-419Q obtained from Konya province had differences at the 429, 441, 443 and 461 nucleotide positions of CP region comparing to other Turkish isolates. There were only two amino acids different. These mutations caused to changes at aa positions 148 [Histidine (H) →Arginine (R)] and 154 [Lysine (K) →Threonine (T)]. Moreover, the isolate KNY-419Q differs from the previously described all BVQ isolates in terms of aa mutations described above (Data not shown). As a result, the CP sequences of various BVQ isolates from Turkey seems to be stable. Similarly, no significant variation was detected in the CP sequences of BVQ isolates from Iran (Moradi and Mehrvar, 2021).

Sequence comparisons of the CP region of the 14 Turkish isolates showed that they were most closely related to the France FP71 isolate (99.40% nucleotide identity; 100% aa identity, respectively) while the other isolate KNY-419Q was most closely related to the French FP71 isolate (98.60% nucleotide identity; 98.80% aa identity, respectively) and the German GT16 isolate (98.60% nucleotide identity).

Additionally, ML tree was constructed using the nucleotide sequences of BVQ CP gene obtained this study and 17 isolates from other countries obtained from GenBank database (Table 1). The CP tree was calculated with sequences obtained from 32 isolates (Figure 2) and clustered into two main groups, I and II. The group I consisted of 11 Iranian isolates (MW798253-MW798263), a German (AJ223597) and a France (AJ810289) isolates. However, the group II were divided into two major clades, subgroup 1 and 2. Three Polish isolates (EU785970, EU785969 and EU785968) and the other German isolate (AJ810290) were included subgroup 1 while all Turkish isolates were clustered in subgroup 2 (Figure 2).

Conclusion

The CP sequences are commonly used for phylogenetic relationship of viruses. In this study, the nucleotide sequences of the CP gene of 15 BVQ isolates were presented for the first time in Turkey. The very low level of genetic diversity among the Turkish BVQ isolates investigated in this study may be due to their limited host range.

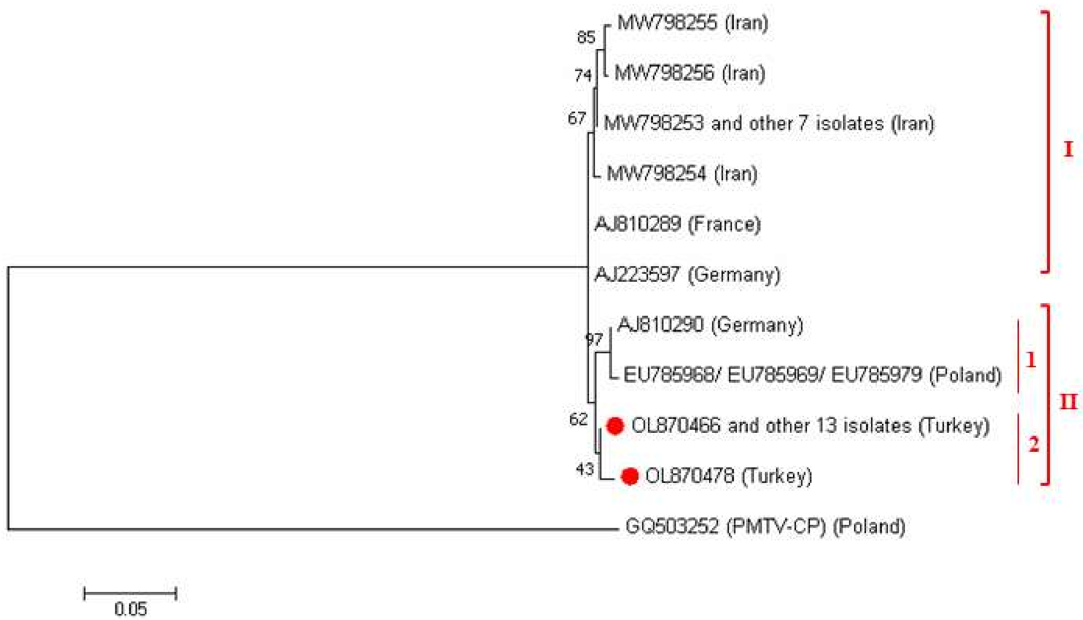

Figure 2. Phylogenetic tree based on nucleotide sequences of the coat protein gene of *Beet virus Q* (BVQ) isolates and all BVQ isolates registered in the GenBank (NCBI) database. Maximum Likelihood method and Tamura-Nei model were used in phylogenetic analysis. Tree branches were bootstrapped with 1.000 replications. The scale shows the amount of base change for the same position (0.05). *Potato mop-top virus* (PMTV), a member of the genus *Pomovirus*, was used as an outgroup in the creation of the phylogenetic tree. Information on reference isolates are included in Table 1.

Table 1. *Beet virus Q* isolates used in this study

Country	Location	Isolate	Accession number	Reference
Turkey	Karakoyunlu, Igdir	IGR-9Q	OL870466	This study
Turkey	Central district, Erzincan	ERC-52Q	OL870467	This study
Turkey	Lacin, Corum	CRM-64Q	OL870468	This study
Turkey	Bosma, Edirne	EDR-125Q	OL870469	This study
Turkey	Uzunkopru, Edirne	EDR-128Q	OL870470	This study
Turkey	Yenisehir, Bursa	BRS-148Q	OL870471	This study
Turkey	Golhisar, Burdur	BDR-164Q	OL870472	This study
Turkey	Alpu, Eskisehir	ESK-215Q	OL870473	This study
Turkey	Cobanlar, Afyonkarahisar	AFY-268Q	OL870474	This study
Turkey	Taskopru, Kastamonu	KAS-281Q	OL870475	This study
Turkey	Akdag Madeni, Yozgat	YZT-313Q	OL870476	This study
Turkey	Karapinar, Konya	KNY-389Q	OL870477	This study
Turkey	Cumra, Konya	KNY-419Q	OL870478	This study
Turkey	Central district, Kirikkale	KRK-594Q	OL870479	This study
Turkey	Sereflikochisar, Ankara	ANK-625Q	OL870480	This study
France	Pithiviers	FP71	AJ810289	Lennefors et al. (2005)
Germany	Thurnhof	GT16	AJ810290	Lennefors et al. (2005)
Poland	unkown	ZQcp	EU785970	Borodynko et al. (2009)
Poland	unkown	JQcp	EU785969	Borodynko et al. (2009)
Poland	unkown	WQcp	EU785968	Borodynko et al. (2009)
Germany	Braunschweig	unkown	AJ223597	Koenig et al. (1998)
Iran	West Azerbaijan	Ir-115	MW798253	Moradi and Mehrvar (2021)
Iran	Ardabil	Ir-136	MW798254	Moradi and Mehrvar (2021)
Iran	Kermanshah	Ir-141	MW798255	Moradi and Mehrvar (2021)
Iran	Kermanshah	Ir-145	MW798256	Moradi and Mehrvar (2021)
Iran	Kermanshah	Ir-150	MW798257	Moradi and Mehrvar (2021)
Iran	East Azerbaijan	Ir-159	MW798258	Moradi and Mehrvar (2021)
Iran	Qazvin	Ir-168	MW798259	Moradi and Mehrvar (2021)
Iran	Qazvin	Ir-169	MW798260	Moradi and Mehrvar (2021)
Iran	Ravazi Khorasan	Ir-189	MW798261	Moradi and Mehrvar (2021)
Iran	Ravazi Khorasan	Ir-192	MW798262	Moradi and Mehrvar (2021)
Iran	Ravazi Khorasan	Ir-203	MW798263	Moradi and Mehrvar (2021)

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Combination of Fuzzy-AHP and Neutrosophic-Set and their applications for the Multiple-Criteria Decision Analyses

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Abstract
Many decisions in real life practices needs taken dissimilar criteria into consideration at the same time. Multi-Criteria Decision Analysis (MCDA) are applied to find a way for the undecided conditions. Further, it's difficult to decide in vague and uncertain conditions with the use of crisp rationality. Therefore, integrated with fuzzy logic, MCDA approaches are mostly used methods. Of late years, new hybrid fuzzy sets have been advanced. Assessing land and soil quality studies, traditional methods are extremely hard owing to necessities such as time, cost and too much workload. Today, with the present techniques like MCDA methods to making rational analysis and assessments can be overcame. MCDA method can be mostly suited to evaluate geographical variations that consist of on a local scale together in the production of erosion risk maps. In this paper, "Neutrosophic Fuzzy Analytical Hierarchy Process" (NF-AHP) which is one of the new hybrid approaches of MCDA methods is presented. NF-AHP is the integration of fuzzy set and neutrosophic set together. Neutrosophic set is better choice comparing the fuzzy sets where indeterminacy conditions are existed
Keywords: Fuzzy Analytical Hierarchy Process, land assessment, Multi-Criteria Decision Analysis, Neutrosophic set, soil quality.

Introduction

Generally, indexes techniques are widely used in the solution of applications needed complex analyse (Rahmanipour et al., 2014), such as associating soil qualifications with multiple units, models have been developing such as multiple-criteria approaches and Geographical Information Systems (GISs) integrated that can measure land quality (Ying et al., 2007; Veisi et al., 2016). For this purpose, the Analytic Hierarchy Process (AHP) (Saaty, 1980) which is one of the methods of Multiple-Criteria Decision Analysis (MCDA) is preferred to assess multiple-heterogeneous factors (Dengiz and Sarıoğlu, 2013; Malczewski, 2006; Mandere et al., 2010).

In land assessment, traditional methods are extremely hard owing to necessities such as time, cost and too much workload. Today, with the present techniques like Remote Sensing and GIS approaches, by applying MCDA methods, efficient analysis and assessments can be made successfully. In AHP, which is one of the MCDA methods and advanced by Saaty (1980), experts must give a number from the scale of 1-9 in pairwise comparison. But, in real life, decision makers may be coming across with the uncertainty conditions and may not give an exact number (Özkan et al., 2020). In the uncertainty condition, accepted approaches are not adequate to operate uncertainties. Consequently, fuzzy logic has been advanced by Zadeh (1965), in addition to this, Buckley (1985) integrated with AHP and fuzzy sets for uncertainty intention. In fuzzy sets, approx. values which are changing from 0-1 are used instead of definite values. 0 represents the elements which are completely apart from the sets, 1 is the element which is totally in the set. There are lots of studies about F-AHP that can be found in literature (Turan et al., 2020; Keshavarzi et al., 2020; Tashayo 2020). With contributions from Zadeh, different types of sets have started to be advanced. One of them is a new method called the Neutrosophic Fuzzy Analytical Hierarchy Process (NF-AHP) which is the combination of F-AHP and neutrosophic sets.

The main purpose of this current paper is to indicate the integration of the Fuzzy-AHP and neutrosophic set which are methods that are used in Multiple-Criteria Decision Analysis.

Logic of the Neutrosophic Approach

Apart from the other fuzzy sets, a neutrosophic set contains 3 different parameters (T, I, F). (T) is defined as the degree of truthiness, (I) is defined as the degree of indeterminacy and (F) is defined as the degree of falseness. Having a more general concept, neutrosophic set includes within the classic and fuzzy set, intuitionistic fuzzy set, and interval-valued intuitionistic set notions. Word of "Neutrosophy" is created by the words of "neuter" in Latin and "sophia" in Greek alphabet. "Neuter" means neutral and "sophia" means ability/wisdom. Neutrosophic logic is acquired with the generalization of fuzzy logic (Smarandache, 1998) (Figure 1). Neutrosophy is a branch of philosophy which combines philosophy, logic, set theory and probability/statistical information. Neutrosophic set includes the other sets. Classical set works according to the 1-0 logic. So, something is true or not, exist or not. There are no interval values. Because of there are no interval values in classical set, fuzzy logic has been developed. In fuzzy logic, there are some uncertain conditions. To overcome this condition, neutrosophic approach has been advanced and <NeutA> notion has been brought to represent uncertainty in neutrosophy.

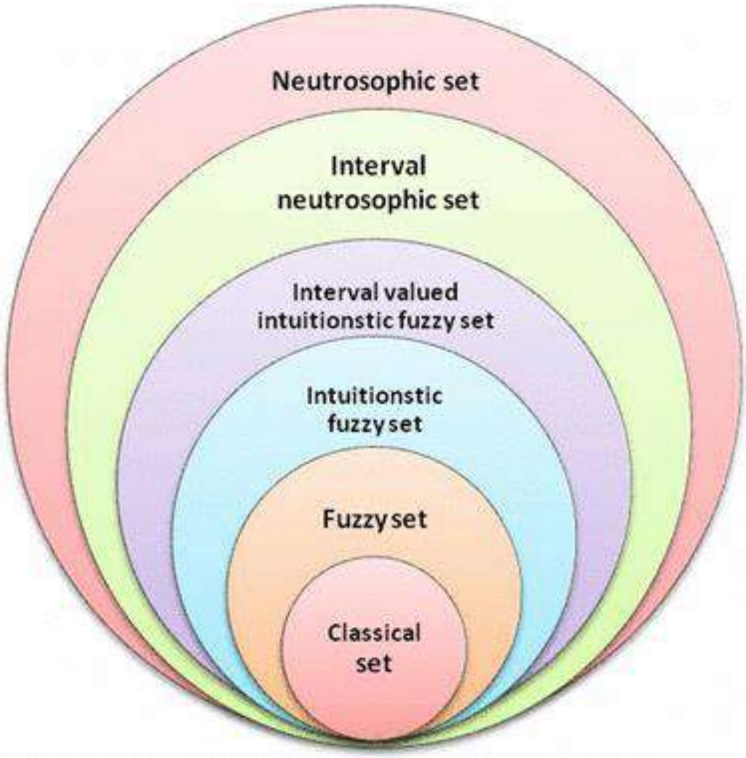

Figure 1. Relationship between the Neutrosophic set and the other sets

Methodological Approach of NF-AHP

When an excellent consistent neutrosophic preference and (T'xk, I'xk, F'xk) are constructed, the steps to calculate each main criterias' weights described in the given below section:

Step 1. Problem is detected and the criteria, sub-criteria and alternatives of the decision-making problem are described properly. After that, problems can be arranged hierarchically.

Step 2. With the use of the scale created by Radwan et al, (2016), experts compared the parameters in each pairwise matrix according to each level (Table 1).

Table 1. Linguistic variables and importance weight based on neutrosophic values

Linguistic Term	Neutrosophic Set	Linguistic Term	Reciprocal Neutrosophic Set
Extremely Highly Preferred	(0.90, 0.10, 0.10)	Mildly Lowly Preferred	(0.10, 0.90, 0.90)
Extremely Preferred	(0.85, 0.20, 0.15)	Mildly Preferred	(0.15, 0.80, 0.85)
Very Strongly to Extremely Preferred	(0.80, 0.25, 0.20)	Mildly preferred to Very Lowly Preferred	(0.20, 0.75, 0.80)
Very Strongly Preferred	(0.75, 0.25, 0.25)	Very Lowly Preferred	(0.25, 0.75, 0.75)
Strongly Preferred	(0.70, 0.30, 0.30)	Lowly Preferred	(0.30, 0.70, 0.70)
Moderately Highly to Strongly Preferred	(0.65, 0.30, 0.35)	Moderately Lowly Preferred to Lowly Preferred	(0.35, 0.70, 0.65)
Moderately Highly Preferred	(0.60, 0.35, 0.40)	Moderately Lowly Preferred	(0.40, 0.65, 0.60)
Equally to Moderately Preferred	(0.55, 0.40, 0.45)	Moderately to Equally Preferred	(0.45, 0.60, 0.55)
Equally Preferred	(0.50, 0.50, 0.50)	Equally Preferred	(0.50, 0.50, 0.50)

Step 3. Experts' assessment is received in Step 2. After that, neutrosophic weighted arithmetic average aggregation operator (Ye, 2014) is applied creating a single decision maker in neutrosophic evaluation:

$$F_w(A_1, A_2, \dots, A_n) = \begin{matrix} 1 - \prod_{k=1}^{n}\left(1 - T_{Aj}(x)\right)^{w_j}, \\ 1 - \prod_{k=1}^{n}\left(1 - I_{Aj}(x)\right)^{w_j}, \\ 1 - \prod_{k=1}^{n}\left(1 - F_{Aj}(x)\right)^{w_j}. \end{matrix}$$

Where $W = (w_1, w_2, \dots, w_n)$ is the weight vector of A_j $(j = 1,2,\dots,n)$, $w_j \in [0,1]$ and $\sum_{j=1}^{n} w_j = 1$.

Step 4. Consistency Ratio (CR) which is advanced by Xu et al., (2014) is applied to calculate consistent preference relations. To get knowledge about how to calculate CR can be seen in the below section:

1. For $k > x+1$, let $N_{xk} = (T'_{xk}, I'_{xk}, F'_{xk})$, where $y = x+1$

$$T'_{xk} = \frac{\sqrt[k-x-1]{T_{xy} * T_{yk} * T_{xk-1} * T_{k-1k}}}{\sqrt[k-x-1]{T_{xy} * T_{yk} * T_{xk-1} * T_{k-1k}} + \sqrt[k-x-1]{(1-T_{xy}) * (1-T_{yk}) * (1-T_{xk-1}) * (1-T_{k-1k})}} \quad (1)$$

$$I'_{xk} = \frac{\sqrt[k-x-1]{I_{xy} * I_{yk} * I_{xk-1} * I_{k-1k}}}{\sqrt[k-x-1]{I_{xy} * I_{yk} * I_{xk-1} * I_{k-1k}} + \sqrt[k-x-1]{(1-I_{xy}) * (1-I_{yk}) * (1-I_{xk-1}) * (1-I_{k-1k})}} \quad (2)$$

$$F'_{xk} = \frac{\sqrt[k-x-1]{F_{xy} * F_{yk} * F_{xk-1} * F_{k-1k}}}{\sqrt[k-x-1]{F_{xy} * F_{yk} * F_{xk-1} * F_{k-1k}} + \sqrt[k-x-1]{(1-F_{xy}) * (1-F_{yk}) * (1-F_{xk-1}) * (1-F_{k-1k})}} \quad (3)$$

2. For $k = x + 1$, let $N_{xk} = (T_{xk}, I_{xk}, F_{xk})$, where $y = x+1$
3. For $k < x$, let $N_{xk} = (F'_{xk}, 1 - I'_{xk}, T'_{xk})$, where $y = x+1$

$$CR = \frac{1}{2(n-1)(n-2)} \sum_{x=1}^{n} \sum_{k=1}^{n} \left(|T'xk - Txk| + |I'xk - Ixk| + |F'xk - Fxk|\right) \quad (4)$$

CR must be less than 0.1.

Step 5. Normalization process which was advanced by Saaty (1977) is implemented to detect each criteria's weights.

Step 6. To get criteria's neutrosophic weights, sums of the rows from the normalized matrix are calculated and divided by the number of criteria.

Step 7. Neutrosophic weights of criteria are defuzzified using Eq. (5):

$$S(N_1) = (3 + t_1 - 2i_1 - f_1)/4 \quad (5)$$

Where N_1 is a single valued neutrosophic number, the score function is convert N_1 into the single crisp output as $S(N_1)$.

Step 8. Lastly, the weights of deneutrospohied weights are normalized and their sum must equal to 1.

Radwan et al., (2016) both advanced and applied this hybrid NF-AHP approach and aimed to handle indeterminacy of information in the decision-making process within the using NF-AHP method. In this study using with the NF-AHP method applied ranking Learning Management System (LMS). They checked the pairwise comparison matrix (Table 2) consistency with the use of Eq. (4) as in the given below section:

Table 2. Neutrosophic comparison matrix by experts

	Cost 1	Evaluative Tools 2	Compatibility 3	Support 4	Sustainability 5
Cost 1	(0.50,0.50,0.50)	(0.25,0.75,0.75)	(0.40,0.65,0.60)	(0.40,0.65,0.60)	(0.50,0.50,0.50)
Evaluative Tools 2	(0.75,0.25,0.25)	(0.50,0.50,0.50)	(0.60,0.35,0.40)	(0.60,0.35,0.40)	(0.60,0.35,0.40)
Compatibility 3	(0.60,0.35,0.40)	(0.40,0.65,0.60)	(0.50,0.50,0.50)	(0.60,0.35,0.40)	(0.60,0.35,0.40)
Support 4	(0.60,0.35,0.40)	(0.40,0.65,0.60)	(0.40,0.65,0.60)	(0.50,0.50,0.50)	(0.50,0.50,0.50)
Sustainability 5	(0.50,0.50,0.50)	(0.40,0.65,0.60)	(0.40,0.65,0.60)	(0.50,0.50,0.50)	(0.50,0.50,0.50)

$$CR = \frac{1}{2(5-1)(5-2)} \sum_{x=1}^{n} \sum_{k=1}^{n} (|12.5 - 12.5|.5 - 12.5| + |12.5 - 12.5|) = 0$$ which is less than 0.1.

As a result, they found out Moodle is the best LMS from alternatives that fulfils defined area (Table 3).

Table 3. The Overall Score of Different Alternatives

Alternatives	Neutrosophic Set	Deneutrosophied Number	Ranking
Moodle	(0.8838, 0.0949, 0.1162)	0.8945	1
Atutor	(0.8709, 0.1120, 0.1291)	0.8795	2
Dokeos	(0.8315, 0.1655, 0.1685)	0.8330	3
Sakai	(0.8147, 0.1895, 0.1853)	0.8126	4
ILIAS	(0.8020, 0.2096, 0.1980)	0.7962	5

In another study, Aydın et al., (2018) also applied the NF-AHP approach ranking four main criteria and 21 sub-criteria and observed personal security is the most crucial criterion of city safety (Table 4).

Table 4. The Overall Score of Different Criteria

Criteria	Neutrosophic Set	Deneutrosophied Number	Ranking
Personal Security	(0.80, 0.21, 0.20)	0.79	1
Health Security	(0.64, 0.34, 0.34)	0.65	2
Infrastructure	(0.54, 0.42, 0.41)	0.57	3
Digital Security	(0.42, 0.54, 0.53)	0.44	4

Conclusion

The indexes that are advanced for potential land assessment and soil quality studies are valid under the limited scale, obvious aims, and environmental conditions. It's not possible in practice to represent all ecological changes and socio-cultural habits, and it's not economically recommended in terms of time, workload, and cost (Doran and Parkin, 1996). For this reason, potential land studies under the different management systems and ecological conditions must be done in the life of expert opinion. MCDA method is a strong application to overcome complex decisions in real life problems. Thanks to this technique, there are several problems that can be fixed that exist in different study areas criteria like biophysical, socio-cultural, political, and environmental. This privilege is one of the most crucial advantages of the MCDA method. In this direction, an extra realistic decision-making and planning process can be achieved. NF-AHP offers trustworthy results that remarkably contributed to the disposal of uncertainty situations in expert ideas. CR checking in pairwise comparison makes NF-AHP more reliable as a decision-making method for people even not experienced at all to decide. Accordingly, it has been foreseen that this new hybrid NF-AHP approach can be developed by adding several biophysical indicators and socio-economic factors in the life of expert opinion apart from leading further studies.

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The role of activated bentonite in the removed of iron toxicity from paddy plant grown in sand culture medium

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Abstract

In this study, the effect of activated bentonite (AB) on the removed of excess iron (Fe) from paddy plants grown in the sand culture media was investigated by the dry weight and uptake of Fe, Mn, Zn and Cu of paddy plants. For this purpose, increasing doses of AB (0, 1, 2.5, 5, 7.5, 10 and 15%) were applied to the quartz sand medium with a dose of 250 ppm Fe (in the form of $FeSO_4.7H_2O$) and rice plant (*Oryza sativa* L. cv. Kızılırmak) were grown in the greenhouse conditions. The experiment was carry out one-waay ANOVA by randomized completed block design with three replicates. According to the variance analysis results, increasing activated bentonite (AB) doses was increased significantly the dry weight and Cu uptake ($p<0.01$) of paddy plants, and also increased the Zn uptake ($p<0.05$), but it significantly ($p<0.01$) decreased Fe and Mn uptake. While the highest rice dry weight (1.70 g/pot) and Zn (0.070 mg/pot) and Cu (0.051 mg/pot) uptakes were obtained at the AB10 dose, the highest Fe (7.06 mg/pot) and Mn (1.33 mg/pot) uptakes were obtained at the control dose. At the end of the study, it was found that the application of activated bentonite to the toxic Fe level in the sand culture significantly decreased the Fe and Mn uptake of the rice plant at a dose of AB7.5, and increased the dry weight of rice plant at a dose of AB5. Moreover, it was found that Zn uptake significantly increased at the dose of AB2.5 and Cu uptake at the dose of AB5. As a result, it was suggested that both to prevent the Fe toxicity and to protect the Mn uptake, and to increase the DW and Zn and Cu uptake of paddy plants was % 5 dose of AB.

Keywords: Rice, Sand culture, Iron toxicity, Activated bentonite.

Introduction

Rice (*Oryza sativa* L.) is one of the most essential foods as it is the main food source for more than half of the world, being. One of the most consumed cereals after wheat. It provides 25% of global human per capita energy (Sürek, 2002) and if this rate is maintained together with the worldwide population growth, it will be difficult to meet the demand in 2030. As in the worldwide population should also be increased in our country by 50% (FAO, 2002). Rice is an ancient cultivated plant classfied under the Oryza tribe of the Paideia subfamily of the Gramineae family. It is the only cereal species that can germinate in water (Kara and Gürel, 2013). Rice grows in soils with low permeability, deep loam and rich in plant nutrients. Therefore, marsch alluvial soil and bottom soils are also suitable areas for paddy cultivation. Rooting depth of rice plant is 50 cm. Paddy, is not sensitive to salt as it grows in water, and thus can adapt to soils with acidity and alkalinity with in the pH ranges of 3-to8 (Anonymous, 2010).

Iron is found in the soil as Fe^{+2} and Fe^{+3}, and however the Fe^{+3} form is insouble and its uptake is difficult. When the soil is ventilated and achieves an alkaline pH value, iron is oxidized to insoluble form (Fe^{+3}). However, under anaerobic conditions, pH decreases in flooded soils, and the Fe^{+3} form is reduced to the Fe^{+2} form (Palmer and Guerinot, 2009). Ferrous ion (Fe^{+2}) is saturated soils. Increased uptake of this ion in roots causes toxicity in the rice plant. The highest Fe^{+2} concentrations are found at 2-15 cm depth, while. It decreases in the deep layers of soil and in soils poor in organic matter processed with plows (Revsbeck, et al., 1980). Soil aeration (aerobic / dry soil), pH effect of organic matter, amounts of other elements in the soil, redox potential, and microbial activities affect the benefits of iron (Sezer, 1991). Iron is absorbed by plant roots in the form of Fe^{+2} and chelates. The uptake of ıron in the soil by plants varies in plant varieties depending on the reduction in plant roots to Fe^{+3} and Fe^{+2} (Brown et al., 1961; Ambler et al., 1970).

Typical symptoms associated with iron toxicity are leaf discoloration (tanning and reddish spots (Ponnamperuma et al., 1955). Tanning symtoms begin on older leaves with the formation of small brown spots spreading from the leaf tip to the base and orange and yellow discoloration of the leaf tips appears in the advanced stage. Drying occurs in patches, while the entire leaf turns from orange to rusty brown or purplishe brown in case of extreme toxicity (Fairhurst and Witt, 2002). Yield losses related to iron toxicity usually range from %15 to %30 and in case of severe Fe toxicity in the young crop damage occurs (Audebert and Sahrawat, 2000). The excess of iron causes yield loss because of antagonistic effect with other nutrients in rice. For example, since Fe toxicity causes Mn deficiency, it has antagonistic effect. Similarly, increasing Fe concentration also results in a decreased uptakes of P, K, Ca, Mg nutrients (Turan and Horuz, 2012). Mendelson et al (1995) reported that an iron plaque (high Fe accumulation) is formed in the roots of paddy plants through an exclusion mechanism and therefore, the absorption of some minerals in the plants may be limited. The present study to investigate the effect of activated bentonite applied to rice grown under iron (Fe) toxicity conditions in sand culture medium on the uptakes of Fe, Mn, Zn and Cu of rice plant.

Material and Methods

The pure quartz sand (bentonite) used as the plant growing medium as per TS EN 196-1 was obtained from the Limak Trakya Cement Factory. The bentonite used in the greenhouse experimet was activated with 5% sodium carbonate. Activeted bentonite (AB) was supplied from Tokat Reşadiye Mining. It has 12.5% moisture content, pH 9.55, EC of 10 (µS/cm) and CEC of 96.8 me/100g. Activated bentonite was weighed as 750 g in 1 kg post on an oven dry weight basis (105°C) and 250 mg Fe kg^{-1} ($FeSO_4.7H_2O$) were applied to the each pot, and then AB was applied at the rate of 0.0% (control), 1%, 2.5%, 5%, 7.5%, 10% and 15%. The seeds of *Oryza sativa* L. cv. (Kızılırmak genotype) soaked in 5% (v/v) sodium hypochlorite (NaClO) solution for 15-20 minutes for sterilization and then washed with water and germinated in moist cloth bags. The germinated seeds were planted 15 seeds per pot to the pots filled with activated bentonite. After the plant emergence, the number of seedlings per pot was decreased to 8 plants. The study was carried out one-way ANOVA test in a completely randomized block design with 3 replication for 70 days. The nutrient solution reported by Zhang et al. (1998) was used for all pots, including the control: 500 µM NH_4NO_3; 60 µM $NH_4H_2PO_4$; 230 µM K_2SO_4; 210 µM $CaCl_2$; 160 µM $MgSO_4.7H_2O$; 2.5 µM $MnCl_2$; 0.75 µM $(NH_4)_6Mo_7O_{24}$; 3.2 µM H_3BO_3; 0.1 µM $CuSO_4$; 2.0 µM $ZnSO_4.7H_2O$. At the end of the experiment, the paddy plants were harvested when they are at 1cm above the growing medium during the spike formation stage. The harvested plant materials were washed with purified water, placed in a paper bag in an oven at 65°C and dried until a constant weight. The dried plants were weighed to determine dry weight (DW) and then ground for nutrienet element analysis (Kacar, 1972). The ground paddy plant materials were digested with HNO_3: $HCLO_4$ (4:1) and, then determined the total Fe, Mn, Zn, Cu concentrations by the atomic adsorption spectrophotometer (AA 2280 PERKIN ELMER).

Nutrient uptake was calculated as follows:

$$\text{Nutrient uptake, mg/pot} = \frac{(\text{Concentration of nutrient x Dry weight})}{1000} \quad (1)$$

$$\text{Percentage change, \%} = \frac{\text{Uptake with AB} - \text{Uptake without AB}}{\text{Uptake without AB}} \text{ x } 100 \quad (2)$$

Statistical Analysis

In order to determine the responses of activated bentonite to the paddy plants to the Fe toxicity medium, one-way ANOVA test in a completely randomized block desing with three replications was applied with SPSS 18.0 statistical package program. The averages of the treatments were compared with the Duncan test at the $p<0.05$ significance level.

Results and Discussion

The results on the effect of activated bentonite on paddy dry weight and microelement uptake in the removal of iron toxicity from sand culture medium is presented in Table 1. The effect of activated bentonite on paddy dry weight in the removed of iron toxicity (Fe^{+2}) is shown in Figure 1, which shows that activated bentonite applications decreased the effect of toxic iron on paddy grown in sand culture medium and increased statistically significantly the dry stem + root weight of rice ($p<0.001$). While the highest dry paddy weight was 1.70 in AB10(10% bentonite) application, the lowest dry paddy weight was as 0.70 g in AB1 application (1%).

Table 1. Effect of activated bentonite on the toxic iron (Fe^{+2}) uptake of paddy plants in sand culture medium

Activated bentonite ratio, %	Dry weight of paddy plant, g	Fe	Mn	Zn	Cu
		mg/pot			
AB0	0.96de[+]	6.992a	1.330a	0.055abc	0.015d
AB1	0.70e	4.328b	0.797bc	0.042c	0.012d
AB2.5	1.10cd	4.784b	0.974b	0.061ab	0.028c
AB5	1.42ab	2.224c	0.886bc	0.068ab	0.034bc
AB7.5	1.51ab	1.972cd	0.651cd	0.066ab	0.039abc
AB10	1.70a	1.246cd	0.645cd	0.070a	0.051a
AB15	1.34bc	0.580d	0.397d	0.051bc	0.045ab

[+] The different letters in the same column indicate significant differences at $p<0.05$
AB: Activated bentonite

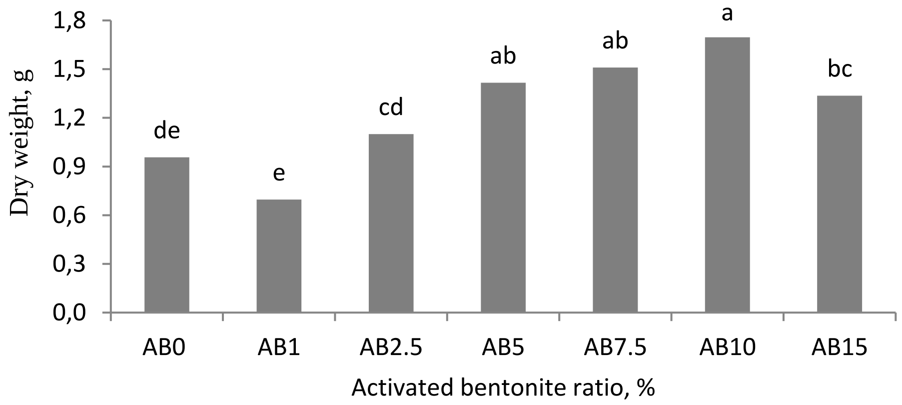

Figure 1. The effect of AB on dry weight of paddy plants in the removed of Fe toxicity

The effect of AB on iron uptake by paddy in eliminating iron toxicity is shown in Figure 2. A statistically significant ($p<0.01$) decrease is observed in the effect of iron in the paddy grown in sand culture medium with activated bentonite. The highest Fe uptake was 6.99 mg/pot in AB0 (control) application, and the lowest Fe uptake was 0.58 mg/pot in AB15 (15% bentonite) application. The decrease in the Fe content in sand may result from the increased ability of the clays in the activated bentonite to hold cations. As reported by Ravichandran and Sivasankar (1997) the acid activation of clays increases the surface areaand pore size of the clays and their absorption capability, as a proton donor or electron acceptor, leading to increased retention of cations on clays.

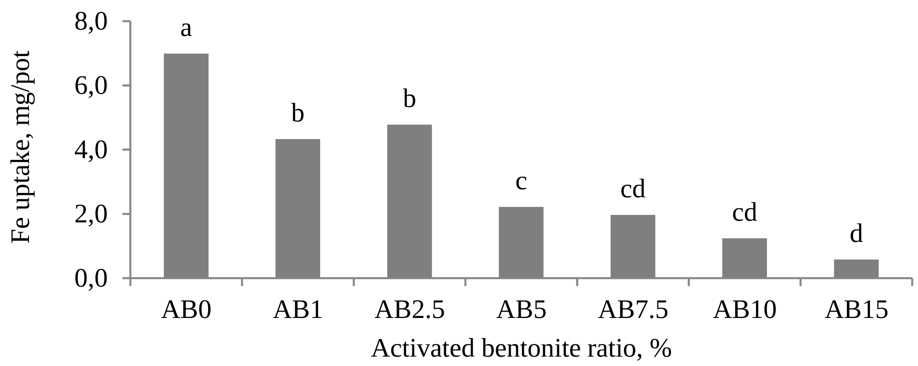

Figure 2. The effect of AB on the Fe uptake of paddy plants in the removed of Fe toxicity

The effect of AB on the Mn uptake of paddy in the removed of iron toxicity is shown in Figure 3. The toxic iron uptake of paddy grown in sand culture medium with activated bentonite results in a statistically significant ($p<0.01$) decrease in its Mn uptake. The highest Mn uptake was 1.33 mg/pot in AB0 application and the lowest Mn uptake was 0.40 mg/pot in AB15 application. In study conductect by Şit (2019), a decrease in the amount of Mn was observed from 22.05 mg/kg to 10.77 mg/kg in the soil with activated bentonite in which iron sulfate was applied under incubation conditions, compared to the control (AB0). As the oxidative power of the root increases, more Fe^{+2} and Mn^{+2} are oxidized from the soil solution and precipitate on the root surfaces, resulting in a decrease in absorption (Okuda and Takahashi, 1964).

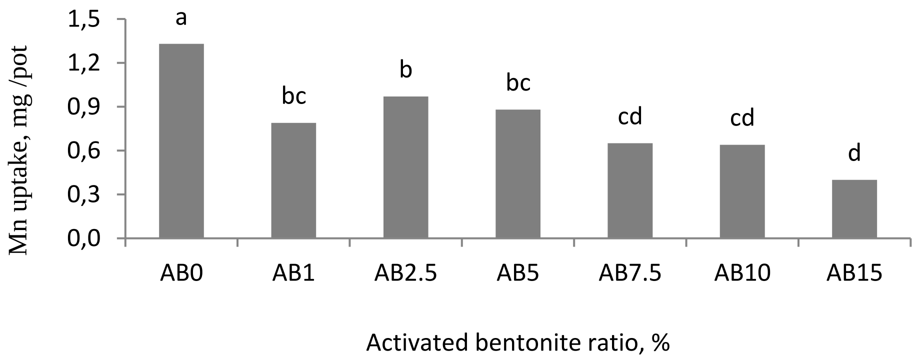

Figure 3. The effect of AB on the Mn uptake of paddy plants in removed Fe toxicity

The effect AB on the Zn uptake of paddy in eliminating iron toxicity is shown in Figure 4. The toxic iron uptake of paddy grown in sand culture medium with activated bentonite results in a statistically significant ($p<0.05$) increase in its Zn uptake. The highest Zn uptake was 0.070 mg/pot in AB10 (10% bentonite) application, and the lowest Zn uptake was 0.042 mg/pot in AB1 (1% bentonite). Iron oxides are known to contribute to strong zinc binding capacity. When the soil is flooded, Zn becomes beneficial in the iron oxide reduction process (Mandal et al., 1992).

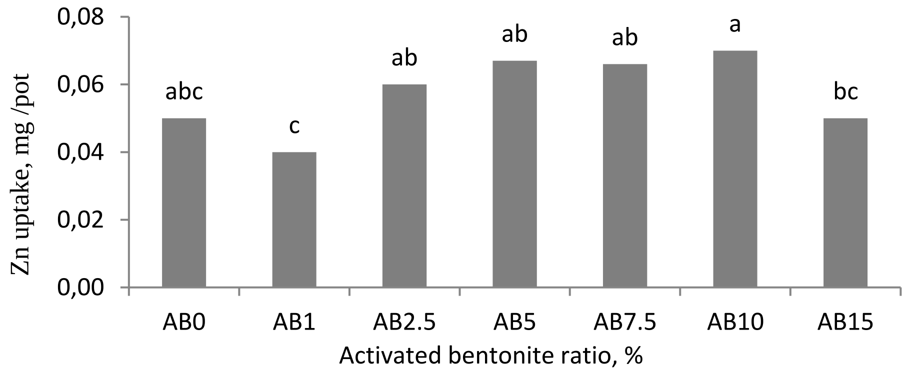

Figure 4. The effect of AB on the Zn uptake of paddy plants in the removed of Fe toxicity

The effect of AB on the Cu uptake of paddy in eliminating iron toxicity is shown in Figure 5. The toxic iron uptake of paddy grown in sand culture medium with activated bentonite results in a statistically significant ($p<0.01$) increase in its Cu uptake. The highest Cu uptake was 0.051 mg/pot in AB10 (10 % bentonite) application, and the lowest Cu uptakes were 0.015 mg/pot and 0.012 mg /pot in AB0 and AB1 applications, respectively. In the study of Silveria et al (2007) lower Cu concentration was observed in the roots of two varieties of *Oryza sativa* L. under Fe toxicity and the Fe plaque was demonstrated to act as a Cu reservoir by increasing the absorption of Cu depending on the amounts of Fe and Cu available (Ye et al., 2001).

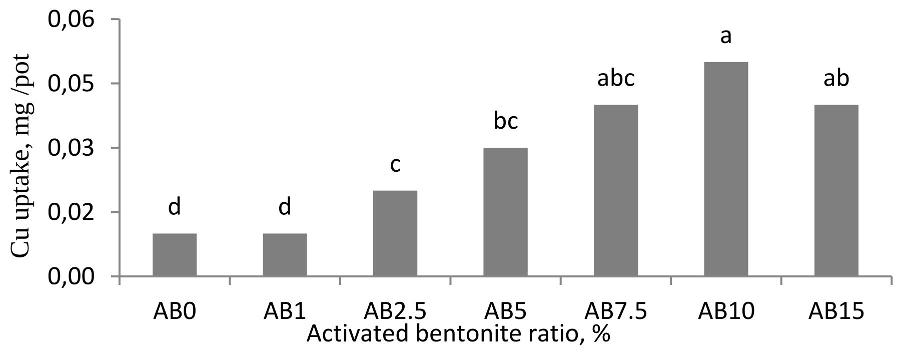

Figure 5. The effect of AB on the Cu uptake of paddy plants in the removed of Fe toxicity

Conclusion

The study showed that the application of activated bentonite to the sand culture with toxic level of Fe significantly decreased the Fe and Mn uptakes of the rice at the AB7.5 dose, and increased the paddy dry weight at the AB5 dose. It was found that Zn uptake increased statistically significantly at AB2.5 and Cu uptake at AB5 dose. In conclusion, AB5 dose was suggested as it increases dry weight of paddy by removing Fe^{+2} toxicity in water-saturated reducing soil conditions.

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Soil microbial activities under different management practices in mountain meadows: A Review

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Abstract

Despite the wide range of aesthetic, economic and ecosystem services and functions of meadows. Semi-natural meadows in the Carpathians were not given much attention compared to other ecosystems. However, because of climate change, land use changes particularly agricultural intensification, abandonment, and urbanization has been reported to be the major drivers of declines and degradation of meadows in Europe. Novel management/conservation technologies are required to curtail and further restore threatens and degraded meadows more especially its biodiversity. In recent years there have been increasing attempts to assess soil biodiversity under different management options. We reviewed studies conducted in the past two decades in European meadows with emphasis on Carpathians meadow of central and Eastern Europe. We identified the main factors leading to the declines or degradation of meadows in Europe and Carpathians. We also consider the restoration and protection policies at national and international level. We identify most widely used management or conservation options, its impact on biodiversity and the challenges of conservation in Carpathian meadows. In the phase of urgent transition to more sustainable management for the climate change adaptation and mitigation suggestions for future research are outlined.

Keywords: Biodiversity, Carpathians, grassland, sustainable management.

Introduction

Meadows are important component of the Grassland biome of the world and play pivotal roles in delivering the ecosystem services of provisioning, supporting and regulation of the key services to humanity, environment and other living components. The three key functions of meadows are support carbon storage and sequestration, biodiversity conservation of fauna and flora above and below ground, and the aesthetic values of beautiful ornamental grasses and tourisms; these were outline in some studies (Boch et., 2021; Tokarczyk , 2018 ; Zarzycki & Korzeniak 2013)

Meadows has greatly contributed to the large extent of global carbon stocks and the sequestration of carbon due to its diversity and richness in abundance grasses beside the benefit of regulating microclimate that harbors diversity community of above and below ground organism that are essential component of the ecosystem dynamics. Grassland alone contributed to between 119-121 Pg of the global carbon stocks with average sequestration rate of 0.5 Pg per year (IPBES 2018; Richard et al.,2021), these serve as basics that grassland including both natural and semi natural were integral part of ecosystem dynamics of regulating, supporting and provisioning as key ecosystem services that involves water-energy balance, gaseous exchange and emission modulation, nutrient cycling and productivity.

Meadows are declining and degrading due to the land use changes more especially due to climate change, agricultural intensification, abandonment, and rapid urbanization in Table 1 and depicted in Figure 1. This was further affirmed by the reports of MacDonald et al., (2000);Richard et al., (2021); Ridding et al., (2015) that most of grassland of the world degraded to a large extent. In this paper, we aim to reviewed state of knowledge about meadows of Europe with more emphasis on central and Eastern Europe Carpathian meadows, in the context of overview, factors and extent of declines and degradation, restoration and protection policy, sustainable management and conservation and the challenges. In the phase of urgent transition to more sustainable management for the climate change adaptation and mitigation suggestions for future research are outlined.

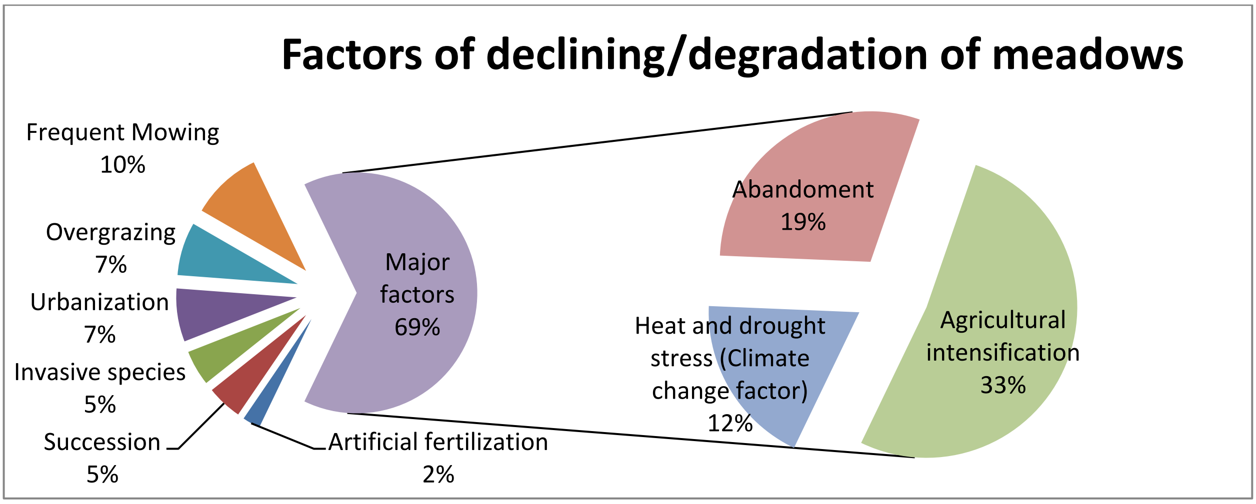

Figure 1: Factors causing the decline and degradation of Europe meadows (draft from various references from Table 1)

Table 1: Factors that causes declines/degradation of Meadows adapted from literatures

Factors causing declines of meadows	Citation	Number of Articles
Abandonment of meadows	Boch et.,2021* Humber et al.,2021* IPBES 2018* Kun et al.,2021* MacDonald et al.,2000* Roth et al.,2013* Swacha et al.,2018* Zarzycki & Korzeniak 2013 *	8
intensification of agriculture	Appleton et al.,2014* Tokarczyk, 2018* Humber et al.,2021* IPBES 2018 * Boch et.,2021* Kun et al.,2021* MacDonald et al.,2000 * Swacha et al.,2018 * Zarzycki & Korzeniak 2013* Roth et al.,2013* Culda et al.,2019* Ridding et al.,2015* Schills et al.,2020* Richard et al.,2021	14
artificial fertilizers	Dahlström et al., 2013	1
Over grazing(1990s practice)s	Dahlström et al., 2013* Tokarczyk, 2018* Zarzycki & Korzeniak 2013	3
Urbanization	Appleton et al.,2014*Tokarczyk , 2018 * Boch et.,2021*IPBES 2018	4
Invasive species	Dahlström et al., 2013 * Tokarczyk , 2018	2
Succession	Tokarczyk , 2018 * Sokołowska et al., 2020	2
Mowing frequency	Kun et al.,2021 * Humber et al.,2021 * Roth et al.,2013, * Tokarczyk, 2018	4
Heat and drought stress	Boch et.,2021* Richard et al.,2021 * Schills et al.,2020* Sokołowska et al., 2020* Tokarczyk , 2018 *	5

Meadows of Europe and Carpathians, Restoration and Protection Policy:

European grasslands, on the other hand, have seen significant decreases in habitat area and quality over the last few decades as a result of land-use and environmental changes. Indeed, meadows are one of the most highly dented habitats in Europe, in just past three decades there was decline in the European meadows by about half between 1990 from 15.34% to 7.85% in 2019 highlighted in Figure 2 (FAOSTAT, 2021).

The Carpathians meadows are Europe's large semi-natural grassland area, stretching across seven countries stretching from the far eastern Czech Republic (3%) and Austria (1%) in the northwest to Slovakia (17%), Poland (10%), Hungary (4%), Ukraine (10%), Romania (50%) and Serbia (5%) in the south.Covered a total area of about 200,000 square kilometers (Appleton et a.,2014). The most common types of meadows in Carpathians are ; Alphine and sub-aphine meadows (Occurs in high mountain Carpathians),Dry meadows (occur in planar to high mountain of Carpathians), Mesic grassland/meadows (dominated by mesophilous species), Nardus Grassland/meadows (characterized by short grasses and form on poor soils), Saline grassland/Meadows (Salt meadows with halophytes as dominant species most found in Romanian Carpathians and Slovakian Carpathians), and Wet grassland/meadows (occur in mineralized fen soils which can be alkaline to acidic) (Appleton et al., 2014). The flora is well represented, over 900 plant species in

Carpathians meadows. Of the dominant species in this Carpathians meadow: *Campanula persicifolia, Corydalis cava, Geranium robertianum, Agrostis tenuis, Festuca rubra, Fagus sylvatica, Picea abies, Sphagnum sp. and Polytrichum sp. , Circsietum rivularis, Valeriano-Carisetum flavae, Aegopodio-Petasit.l;.etum hybridi, Nardus stricta, Festuca rubra* (Appleton et al., 2014; Culda et al., 2019; Tokarczyk , 2018)
Semi-natural meadows have been a low priority in European nature protection for a long time (Tokarczyk 2018) Such meadows are an important part of the Carpathian Mountains' landscape, and they are protected as part of the Natura 2000 network of the European Union (Appleton et al., 2014; Józefowska et al., 2019) Natura 2000, common agricultural policy (CAP), new green deals, BioREGIO Carpathians project, European Landscape Convention 2004, these are considered the important efforts and policies to protection and restoration of meadows both at national and European Union howerver, most of the grant for restoration intervention projects was from EU (Appleton et al.,2014;Tokarczyk , 2018)

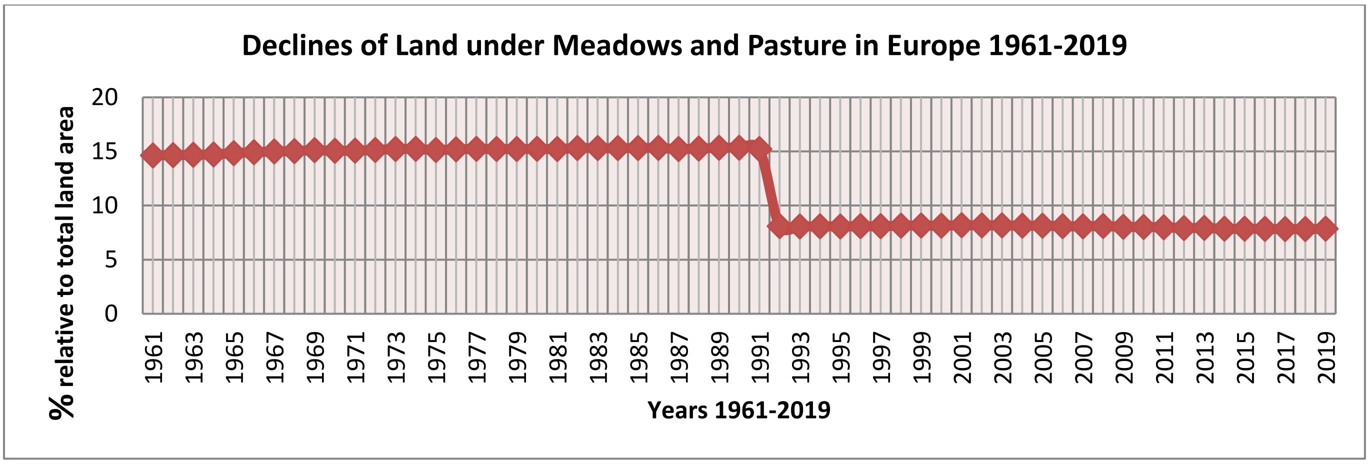

Figure 2: Trend in % changes of European land under meadows and pasture 1961 to 2019(FAO STAT 2021)

Management/Conservation Practices and its Impact on Biodiversity and the Challenges of Conservation in Carpathian Meadows:

The main goal of the management or conservation practices are to restoring the state of the meadow's soils, plant communities and landscape form through some sustainable approaches that would further maintains its functionality and productivity for human-environment-energy continuum. These management or conservation practices govern directly or indirectly the soil environment condition that mediates the activity of microorganism through inputs of nutrients, optimal moisture, suitable temperature and micro-environment which in turn improve their capability in magnitude and frequency to grow and carried out their biological processes.

Management or conservation practices influence the biological processes in the meadows by providing more nutrients medium or substrate for soil biota through composting or organic amendments, through mulching conserve moisture for that enhance microbes growth and activities, mowing grass and removing hay is a crucial activity to maintain semi-natural grassland. Mowing improve physical condition and reduce the suppression of soil organism by favoring more light, air, and enhance species composition and avert invasive species and succession hence improves above and below ground biodiversity (Józefowska et al., 2018;Schlaghamersky et al., 2007). The most widely adopted management or conservation practices in Carpathians meadows and their frequency percentage drafted from the various literatures in Table 2 and highlighted in Figure 3 are mowing, organic fertilization or amendments, mulching, control grazing, removal of invasive species, fallow, irrigation techniques(in dry meadows). Mowing is the predominant management practice in meadows with adoption of 29.1%. Studies by Józefowska et al., (2019); Kummli et al., (2021); Richard et al., (2021) finds out that mowing stimulate the regeneration of plant communities and enhance the richness and their composition, as well controlling the succession of invasive species similarly it's found to enhance phosphorous bacterial activity, increased in communities of vegetative bacterial forms, ammonifying bacteria in mown site than no mowing site (Józefowska et al., 2019)

The conservation practices of Carpathian meadows faced many challenges, most of which were similar to those found in other mountain meadows of the world (Tokarczyk , 2018;Zarzycki & Korzeniak 2013). The nature of the terrain (steepness) was recognized as major setback to the management or conservation practices in Carpathian meadows this challenge rendered it more labor intensive to carry out some conservation operations. Other challenges that are more of human factors most of which are related to Governance and few societal these includes land ownership issues, financing, planning and implementation problems, limited policy, social aspect and lack of communication and knowledge transfer (Appleton et al., 2014; Richard et al., 2021 ;Tokarczyk , 2018).

Table 2: Management/Conservation Practices in Meadows

Conservation/Management practices in meadows	Citation	Number of Authors
Mowing	Appleton et al.,2014* Bonari et al.,2017* Józefowska et al.,2018* Józefowska et al.,2019* Kummli et al.,2021* Kazmierczakowa et al.,2004* Kotas et al 2017* Llumiquinga et al., 2021* Roth et al.,2013* Schlaghamersky et al.,2007* Swacha et al.,2018* Tokarczyk, 2018 *Zarzycki & Korzeniak 2013	13
Controlled grazing	Balogh et al.,2021* Bonari et al.,2017 * Kummli et al.,2021* Roth et al.,2013* Schlaghamersky et al.,2007* Zarzycki & Korzeniak 2013	6
Organic fertilization/Amendments	Appleton et al.,2014*Bonari et al.,2017*Culda et al.,2019* Dahlström et al., 2013 *Humber et al.,2021* Józefowska et al.,2019* Kotas et al 2017* Kun et al.,2021 * Llumiquinga et al., 2021* Richard et al.,2001* Richard et al.,2021* Swacha et al.,2018 *Tokarczyk , 2018*	12
Mulching	Humber et al.,2021*Józefowska et al.,2019* Kotas et al 2017* Kummli et al.,2021* Roth et al.,2013* Tokarczyk , 2018*	6
Enriching the species composition	Balogh et al.,2021*Llumiquinga et al., 2021* Richard et al.,2001* Zarzycki & Korzeniak 2013	4
Removal of invasive species	Kotas et al 2017*Kummli et al.,2021* Roth et al.,2013 Zarzycki & Joanna 2013	4
Fallow	Bonari et al.,2017* Richard et al.,2021* Sokołowska et al., 2020	3
Irrigation Techniques(dry meadows)	Schills et al.,2020	1

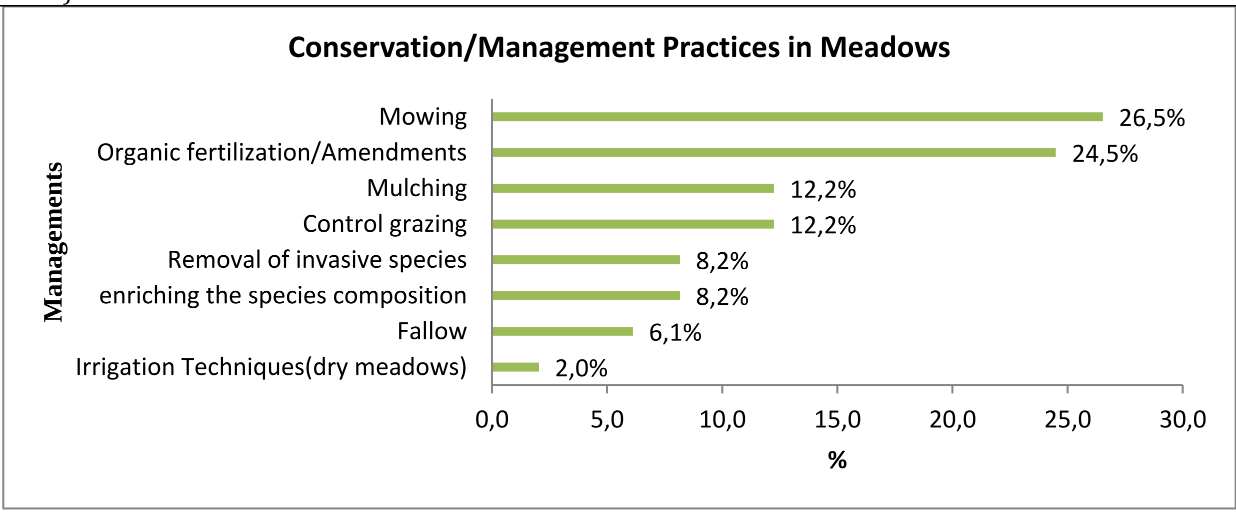

Figure 3: Management Practices in meadows (drafted from Table 2 references)

Conclusion

This paper outlined the current assessment of microbial activities under different conservation management options in Europe with emphasis on Carpathians regions. In meadows, there was great synergy between the soils system with plant species compositions and microbial activities which is complimented by management practices. The most promising and predominant conservation options in meadows as outlined in previous studies were; mowing, organic fertilization or amendments, mulching, enhance species composition, control grazing, removal of invasive species and moisture conservation in dry meadows. These conservation options were found by many researchers to enhance biodiversity in meadows under short and long term. Mowing was the most important management options in meadows as it halt the succession, maintain species composition and soil energy balance that improves soil condition.

Agricultural intensification, climate change and abandonment were identified as the major factors responsible for the decline and degradation of meadows. However, some conservation policies like Natura 2000, European land scape convention and European new green deals have proved to be a pacesetter but some policies need to be reviewed and reshuffle to meet the current needs and more problems specific instead of generalization. Site and problem specific policies need to be implemented. Climate change adaptation and mitigation measures and studies need to be implemented in meadows more especially related to heat stress, fire and drought more especially practices that maintain optimum soil moisture, prevent succession by mowing and rogueing of invasive species. Frequent mowing should be avoided to prevent compaction. Generally activities that undermine both above and below ground biodiversity should be avoided in meadows more especially use of chemicals that affect pollinators, suppress microbial diversity or harm environment.

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Compost and commercial biochar applications may have contrary influences on the low-cost FDR moisture sensor measurements of top-soils: A laboratory experiment

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Abstract

Soil water content is a fundamental factor in geoecological and agricultural research with many related fields, as it is a key state variable in the soil. Several automated techniques exist for continuous point-scale measurements of soil volumetric water content (θ_v), including the use of Time Domain Reflectometry (TDR) and relatively low-cost Frequency Domain Reflectometry (FDR) sensors. These electromagnetic techniques take advantage of the large difference between the relative dielectric permittivity (ε) of solid soil particles, air, and water to estimate the θ_v. However, not enough attention has been paid to the fact that traditional compost applications and increasing applications of commercial or industrial biochars can lead to changes in the dielectric properties of the liquid phase in the porous system of the top-soil. The influence of different sources of soil organic carbon (SOC) on the performance of selected FDR sensors *EC-5* and *5TE* (*METER Group, Inc.*), was investigated in three conceptual scenarios using different reading devices: in long-term organically amended arable soil as the control (2% SOC), in compost amended soils (4% and 8% SOC), and biochar amended soils (4% and 8% SOC). The electrical conductivity and dry bulk density (ρ_d) of soils along with textural properties were also investigated, to distinguish the effect of added organic carbon and its type on the measurements from the possible influences of physicochemical factors. An increase in SOC by the compost application was found to cause underestimation of θ_v, while biochar applications induced overestimation. The most significant influences of organic materials were observed in 8% SOC level, while the different levels of θ_v took a role as an important determinative factor for the mentioned contrasting influences. Furthermore, the *EM50* datalogger was found to be less susceptible to applications than the *ProCheck* and *ECH₂O Check* handheld readers.

Keywords: Biochar, compost, frequency domain reflectometry, soil volumetric water content

Introduction

The gravimetric determination of soil volumetric water content (θ_v) offers the most reliable data, but it requires considerable labor, time and related financial costs compared to the sensor usage. Besides, real-time monitoring of θ_v becomes only applicable by the non-destructive soil water content determination [1, 2]. Time Domain Reflectometry (TDR) and Frequency Domain Reflectometry (FDR) techniques present some major advantages in this case, by their relatively cost-effective budget requirement and the ability to produce a large number of measurements that can store the total pattern of soil moisture in a given soil profile. These sensors were associated with several soil characteristics based on their effect on sensor performance. Some sources of error in soil water content measurements were investigated well; it is clear that the changes in the soil relative permittivity would be especially induced by varying temperature, soil dry bulk density (ρ_d), texture, and salinity, as recently reviewed by Yu et al. (2021) [3]. The low-cost FDR sensors aroused great interest [4] and are also highlighted by their susceptibility to the mentioned environmental effects in soil [5]. There is broad agreement concerning the benefit of increasing soil moisture network density/optimization using cheaper sensors at the cost of accuracy, in order to better represent large-scale satellite footprints and model grid cells [6, 7, 8, 9]. In the meantime, many studies concluded that calibrations specific to organic-rich soils and humus horizons are crucial [10, 11, 12, 13, 14, 15]. However, the effect of organic material amendments on sensor performance got a relatively recent interest in itself: Fares et al. (2016) [16] conducted an artificial packing experiment to examine the effect of changing soil organic matter (SOM) contents (from 0 to 18%) on sensor performance. The researchers used quartz sand as the experimental soil material and sawdust as the organic amendment. As a result, they found a significant underestimation of θ_v by the sensors, with increasing SOM content. The implication of the researchers from this phenomenon was on changing water-holding abilities by the organic material addition, and the emerging competition in the sensor area between the mineral and organic particles. In this context, it is known that water molecules near solid surfaces are subjected to interfacial forces that change their rotation [17]. Consequently, their ability to align with the applied electric field is reduced [18]. In arable lands, the changes in dielectric properties of soils can be observed after the traditional compost application, which is still one of the most common treatment in agricultural practices, mainly for their favorable effects on soil and water relationships [19]. Recently, the application of commercial or industrial biochar to the arable lands found itself a practical popularity. These materials (biochar, gasification residues, charcoal, etc.) gained a stable ground in the scientific community and in commercial farming practices due to their stable carbon structure [20, 21]. However, this trending organic amendment method was found to cause some undesirable alterations due to its hydrophobicity and inert characteristics, especially when used without activation or aging process [22, 23]. Soil water content monitoring in crop and irrigation system management practices may require further calibration due to recent applications of these common materials to soils, while the top-soil θ_v measurements are expected to be the most susceptible to the misinterpretation of sensor readings due to their relatively more increased soil organic carbon (SOC) contents after these applications.

In this study, the influence of SOC content and type on the selected FDR sensor performances was investigated in laboratory under three conceptual scenarios; the sensor performance (i) in the arable soil under long-term organic farming practices as control, (ii) in compost amended soils, and (iii) in the biochar amended soils.

Experimental Soil and Organic Materials

The soil used in the artificial packing experiment was taken from the Malonty locality in Český Krumlov District of the Czech Republic. The area was chosen due to its sandy loam texture and non-saline composition with an inclusive SOC content (2.07%) with regards to the soils of the region. The experimental cambisol soil was taken from a field under organic agricultural practices. Compost material was produced by *Bemagro Inc*. (Český Krumlov District) and commercial biochar 'Agro-Protect-Soil' was obtained from *Ekogrill Ltd.* Organic carbon (OC) content of the experimental soil, biochar and compost material was determined by the modified Walkley-Black method [24]. OC contents of compost and biochar were found to be 22.8% and 47.1%, respectively. All experimental materials were air-dried under the laboratory conditions, and sieved under 2 mm mesh before the experimental setup. The particle size distribution (PSD) of the experimental soil was achieved by wet sieving after the hydrometer method [25], and organic materials were dry-sieved through a set of sieves. There were no significant differences between the PSD of biochar and compost materials concerning their effect on the performance of the sensors.

Sensors and Reading Devices

5TE and *EC-5* sensors with the reading devices *ECH$_2$O Check*, *ProCheck*, and *EM50*

The *5TE* sensor and the *EC-5* sensors (*METER Group, Inc.*) use an electromagnetic field to measure the relative permittivity of the soil, and determine the soil water content (θ_v) by measuring the relative permittivity of the media using frequency domain technology. They supply a 70 MHz oscillating wave to the sensor probe that charges according to the dielectric of the material. They are widely known and used capacitance-type sensors [26].

The *ECH$_2$O Check* is designed for use with *Decagon*'s *ECH$_2$O* soil moisture sensors. It does not store any data and can be used for instant measurements. The *ProCheck* is a handheld read-out/storage device for use with all soil moisture sensors and environmental monitoring sensors made or sold by *Decagon Devices Inc.* (now *METER Group, Inc.*); it can be used to spot-check the θ_v, temperature, and/or salinity. The *EM50* data logger, on the other hand, has five sensor ports and one communication port. The logged data into the *EM50* can be managed by using *ECH$_2$O Utility* software providing a chance to name and select the type of sensor on each port, and specify the measurement interval.

Experimental Setup and Statistical Analyses

In the first stage, the experiment was carried out using experimental soil without the addition of organic materials. The target ρ_d of this soil was chosen according to the field conditions measured at 1.38 g/cm^3. The core rings (100 cm^3) were used to determine the ρ_d of the field [27]. The experimented moisture levels were 0, 5, 10, 15, 20, 25, 30% θ_v (moisture level 0% means air-dry soil). The soil was packed with a plastic tamper into 5l, using calibration container with the dimensions of 28 × 19 × 14 cm (length x width x height). The water pycnometer method [28] was used to determine the particle density of soil samples. The higher limit of adjustment of the water content was assessed according to the calculated porosity. Soil admixtures were created by adding compost or biochar materials to obtain soils that contain OC in two different types/stabilities. The experimental soil without any admixture was used as the control (K) and two separate series of soils with increasing SOC content were prepared to have 4% SOC by compost carbon (4C), 8% SOC by compost carbon (8C); 4% SOC by biochar carbon (4B) and 8% SOC by biochar carbon (8B). Five pieces of *5TE* moisture sensors, and three pieces of *ECH$_2$O EC-5* moisture sensors were used for each moisture level. First, *5TE* sensors were connected one by one to the *ProCheck* reading device, and the readings were recorded after stabilization of the measurement for at least 8 seconds. These *5TE* sensors are then connected to the *EM50* data logger and read-out by using the *ECH$_2$O Utility* software in 1-minute intervals for 5 minutes. After the *5TE* measurements, the *EC-5* sensors were inserted into the soil in positions as can be seen in the scheme presented in Fig. 1, and then connected one by one to the *ECH$_2$O Check* for the measurements.

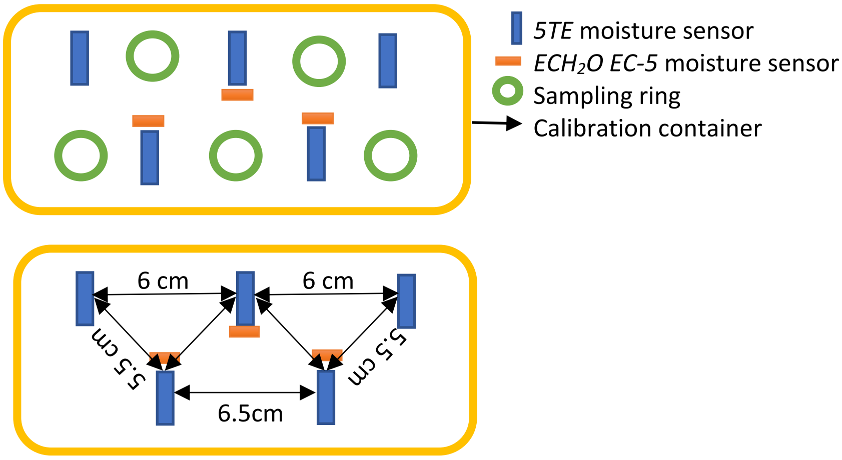

Figure 1. Experimental design of the θ_v measurements

After measurements, undisturbed soil samples were taken using the Kopecky rings with a volume of 15.7 cm^3 from the sections between measurement points. The same soil was used for each moisture level after air-drying, to prevent gravitational loss and degradation of organic matter. The soils were sieved again to prevent aggregation due to the wetting and drying cycles. The EC and pH values of the treated and untreated soils were measured in 1:2.5 (soil:distilled H_2O) solutions [29].

Sensor response to treatments was analyzed by one-way analysis of variance test (ANOVA, *Duncan's*), performed using the *STATISTICA 13* software package. The root mean square deviation (RMSD) was calculated to test the differences between the values determined using the gravimetric method and the values obtained from the sensor reading. Pearson's correlation coefficient (r) and r-squared values (R^2) were used to estimate strength of the relationship between the θ_v determined by gravimetric methods and the sensor output values, and the relationship between measured θ_v (M-θ_v) and SOC.

Results and Discussion

Adjusted θ_v and ρ_d Values with Changes in Soil EC and pH

The average actual-θ_v (A-θ_v) and ρ_d values of the five samples from each container in each measurement round are presented with their coefficients of variation (Table 1). The variation was found to be very low; thus, the mean values were considered to be representative to use in comparison with sensor outputs.

A higher variation was obtained for the moisture level of 0%, where only the determination of the mass water content was possible. There were no significant differences between compost and biochar amended soils of the same SOC content, in terms of the possible influence of different ρ_d values on sensor performance, according to the previous studies [30, 31].

Table 1. Adjusted θ_v and ρ_d values with changes observed in soil EC and pH

		Target θ_v (%)	0	5	10	15	20	25	30
K	pH:5.54 e	A-θ_v	0.018	0.052	0.097	0.147	0.194	0.250	0.309
		CV	8.8	2.9	1.6	0.7	1.7	1.0	1.4
	EC: 221 E	ρ_d	1.36	1.34	1.16	1.26	1.28	1.31	1.42
		CV	na	2.5	4.6	0.9	1.6	1.7	0.8
B4	pH:6.67 b	A-θ_v	0.022	0.056	0.106	0.140	0.192	0.250	0.306
		CV	9.8	1.1	1.8	2.1	1.7	2.9	1.2
	EC:276 D	ρ_d	1.32	1.26	1.25	1.27	1.23	1.25	1.33
		CV	na	1.4	1.5	1.7	1.3	2.1	1.3
C4	pH: 5.77 d	A-θ_v	0.023	0.068	0.107	0.141	0.208	0.247	0.306
		CV	7.2	1.2	4.0	6.3	2.0	3.0	0.8
	EC: 693 B	ρ_d	1.32	1.28	1.25	1.25	1.19	1.24	1.33
		CV	na	1.6	1.4	2.8	1.5	2.9	2.8
B8	pH: 7.54 a	A-θ_v	0.025	0.059	0.095	0.132	0.186	0.272	0.286
		CV	1.9	1.5	5.4	1.0	0.9	1.6	1.8
	EC: 400 C	ρ_d	1.27	1.12	1.04	1.04	1.09	1.15	1.17
		CV	na	1.8	2.8	2.0	1.9	1.3	1.8
C8	pH: 6.03 c	A-θ_v	0.024	0.062	0.097	0.135	0.176	0.240	0.300
		CV	2.4	1.7	1.0	2.1	1.4	2.3	1.2
	EC: 1073 A	ρ_d	1.28	1.08	1.02	1.03	0.98	1.04	1.05
		CV	na	2.0	2.4	2.8	1.3	2.0	1.9

EC: electrical conductivity in µS/cm; lower-case and upper-case letters show the statistical differences between pH and EC values, respectively (P<0.001). A-θ_v: actual volumetric water content of soil in cm^3/cm^3; ρ_d: dry bulk density in g/cm^3; *CV*: coefficient of variation (%).

The EC of the soil increased linearly by the addition of both materials in a dose-dependent manner; it was also statistically significant (P<0.001, Table 1); the highest value was found as 1073 µS/cm for 8C treatment, which is still drastically lower than the value that could cause salinity interference: Scudiero et al. (2012) [30] tested the efficiency of *5TE* sensors under different salinity conditions by assessing the initial experimental salinity level as 5000 µS/cm. Similarly, the salinity conditions were created by much higher salt addition in the study of Matula et al. (2016) [31]. The pH values were found to differ significantly and created a variety of soil reactions between treatments, from 5.54 to 7.54, thus not reaching the extreme ends.

Organic Carbon Source and Sensor Readings

The *5TE* sensor measurements registered with the *ProCheck* and *EM50* devices revealed several significant differences between the mV values of the treatments based on SOC%, mostly dependent on target θ_v (T-θ_v). Biochar amended soils had higher mV values measured, compared to the control and compost soils, except the 30% level of θ_v (Table 2a, 2b). The 8B and 8C soils were differentiated from the K soils by revealing increased and decreased raw values, respectively. In particular, the *ProCheck* measurements presented significantly different values for these high SOC soils (Table 2a) but the significance was lower in the *EM50* measurements (Table 2b), while the results followed the same pattern for both readers. *EC-5* sensor measurements also confirmed the opposite influence of compost and biochar applications on mV readings (Table 2c). The correlations between the SOC of the biochar treated soils and the M-θ_v were significantly positive for the 0% (r=0.934, r^2=0.87; P<0.001), 5% (r=0.651, r^2=0.42; P=0.022), 15% (r=0.661, r^2=0.44; P=0.019) and 25% (r=0.773, r^2=0.50; P=0.003) of θ_v levels; however, the compost-treated soils showed significantly negative correlations between the SOC and the M-θ_v for 20% (r=-0.707, r^2=0.50; P=0.01) and 30% (r=0.635, r^2=0.40; P=0.027) of T-θ_v level. The contrary influence of organic materials was clearly observed especially in soils with 8% SOC for both treatments. The *EM50* registered M-θ_v values of the *5TE* sensors revealed a less differentiated data set; only the SOC of compost treated soils showed a significant correlation with the M-θ_v for the 20% (r=-0.934, r^2=0.44; P=0.019) of T-θ_v. However, the trend of the measurements based on the applications was persistent. On the other hand, the M-θ_v values achieved by *EC-5* for the compost and biochar treated soils differentiated more at relatively lower T-θ_v levels; the influence of compost treatment on sensor performance was more significant, and the achieved correlations led to an underestimation of the M-θ_v values compared to the K soils. This was again the opposite for biochar treated soils, particularly in drier conditions.

Table 2. Mean mV values measured by the sensors and reading devices with statistical differences

Treatment	*a. mV values measured by 5TE and ProCheck*					
4B	137^{b}	196^{ab}	241.8	282.8^{b}	382.4	456.4^{b}	611.8
8B	155^{a}	207.8^{a}	240.4	324.2^{a}	401.4	543.6^{a}	613
4C	132.8^{b}	200^{ab}	241.8	303.2^{ab}	387	436.4^{b}	606.2
8C	122.6^{b}	181.8^{b}	229	282.4^{b}	349.8	442.4^{b}	506.4
K	128.4^{b}	180.8^{b}	219.6	296^{b}	376	439.4^{b}	611.6
	b. mV values measured by 5TE and EM50						
4B	146.6^{b}	191.4	259.2	307.8	381.8	525.5^{a}	595.8
8B	169.6^{a}	214.6	264.2	337	410.4	537.4^{a}	602.4
4C	135.2^{bc}	208.8	230	318.8	394	429.2^{b}	584.4
8C	119^{c}	179.2	240.2	296.8	349.8	463.2^{ab}	539.8
K	117^{c}	188.4	252.2	313.4	383.8	487.2^{b}	614.2
	c. mV values measured by EC-5 and ECH2O Check						
4B	313.7^{b}	361.7^{a}	379.3^{b}	426.7^{a}	470^{ab}	502.3	539.3^{ab}
8B	326.3^{a}	362^{a}	385^{ab}	427^{a}	475.3^{a}	504	527.7^{b}
4C	309.7^{bc}	347.7^{b}	384.3^{ab}	417.3^{ab}	464.3^{ab}	500	556.7^{a}
8C	281.3^{d}	340.7^{b}	378.7^{b}	407.7^{b}	442.7^{c}	495	523.3^{b}
K	302.3c	345^{b}	390^{a}	417.3^{ab}	454^{bc}	492.7	539.3^{ab}

The lower-case letters in the vertical direction show the significant differences between treatments (*P<0.05*)

Soil Organic Carbon Type and Content Specific Calibrations for *5TE* Sensor

The results-based organic carbon type and level-specific calibration equations were generated to improve the accuracy of the sensors; the new calibration for both treatments at the 4% and 8% SOC levels showed an average regression of around 99% in most cases (R^2 = 0.99), except for that of `C 5TE EM50` in soils with 4% SOC, which is around 97% (Fig. 2). The accuracy of the new calibrations was estimated to be around 0.8% to 2.23% (by RMSD). A similar method was applied in the study of Fares et al. (2016), by lowering the RMSD to in between 1.3% to 1.9%, while the default calibration had given RMSD values between 5.3% to 7.2%. In case of the current study, the accuracy of the factory calibration of the more commonly used *5TE* sensor was in the range of 3.13% to 5.29%.

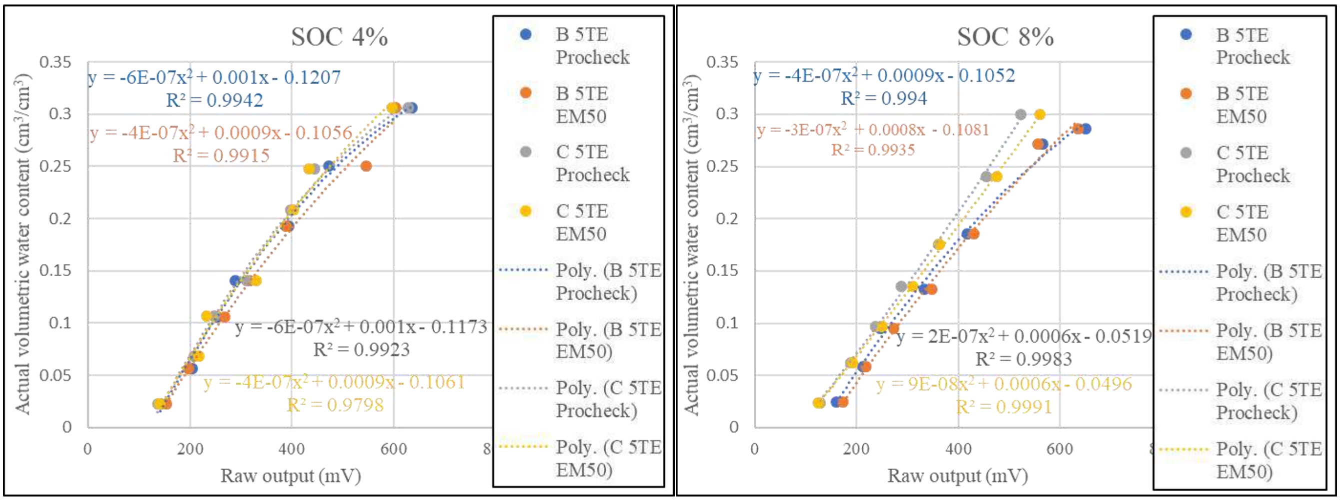

Figure 2. Equations of own calibration for the compost and biochar-amended soils. (SOC: soil organic carbon; B: biochar amended soil; C: compost amended soil. 5TE Procheck: measured θ_v by *5TE* and *ProCheck*; 5TE EM50: measured θ_v by *5TE* and *EM50*)

Conclusion

The improved calibration equations for the sandy loam soil can be either utilized to the agricultural practices when similar doses and types of organic amendments were realized or they could serve as a manipulation factor for the studies conducting their measurements by using low-cost FDR sensors. The speculation from the results may be that the compost applications led to an increase in bonded water fraction in soil as in the mentioned previous reports for organic horizons/amendments, whilst the commercial biochar acted more inert, concerning the bulk exhaustion of the water by the porous system of the organic material. In this manner, the non-activated, or non-aged, biochar treated soil has led to a more pressurized (since the same volume is occupied in the calibration container with the compost treated soils) and more electromagnetically aligned soil-water fraction in the sensor measurement area, leading to increased mV read-outs. This phenomenon was more significant at the 8% SOC level for both treatments, while continuous measurements with the *EM50* datalogger were found to provide less diverted measurements in all included experimental designs, compared to handheld readers.

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Effects of olive pomace application on some soil properties

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Abstract

In the studies carried out, olive pomace and pulp were applied directly to the soil in different doses in order to determine the effects of olive oil factory wastes on soil properties. The effects of the applied pomace and pulp on some physical and chemical properties of the soil and the content of plant nutrients were investigated. It has been determined that olive pomace, which is olive oil factory waste, is applied to soils with low organic matter content and has positive healing effects on some physical and chemical properties of soils. The structural aggregate stability values of the soil increased with pomace application. It has been reported that there are increases in the electrical conductivity, organic matter, total nitrogen, available phosphorus and potassium values of the soils, while decreases in pH values. In parallel with the dose increase in olive pomace application, significant increases occur in the field capacity and available moisture content of the soil.

Keywords: Prina, organic waste, soil physical and chemical properties.

Introduction

Recently, the use of organic conditioners in agriculture has increased in order to preserving the degradation of soils which are generally poor in organic matter content. The number of studies related to reuse of agricultural-based industrial wastes has been increased due to limited organic matter sources affecting soil physical, chemical and biological properties positively (İç and Gülser, 2008; Candemir and Gülser, 2010; Gülser et al., 2015; Özdemir et al. 2018; Gülser, 2021; Demir and Gülser 2021). It has been ensured that olive pomace, which is one of the olive oil wastes, which adversely affects life and causes pollution because it consumes the oxygen of the environment when thrown into the environment, but which has positive contributions to the soil when used for fertilization, can be used as an organic amendment in the soil by composting (Walker and Bernal, 2008; Omer and Mohamed, 2012). Pomace which is the pulp of the olive consisting of fruit flesh and seeds remain after the olives are squeezed, does not lose its richness in terms of oil, and can be used as fertilizer or animal feed (Martin et al. 1991; Brozzoli et al., 2010; Nunes et al, 2018; Muscolo 2019). In a studdy by Garcia-Ruiz et al., (2012), comparision of soil properties after long-term application of olive mill pomace with the control treatment showed that the addition of composted olive mill pomace improved soil quality. In this paper, effects of olive pomace applications on some soil properties were reviewed and discussed.

Results and Discussion

Olive wastes in different researches showed highly variable characteristics, and some chemical properties of different olive waste are given in the Table 1. Galic and Bugonovic (2018) reported that despite the high variability of properties, among the organic waste materials produced by agricultural and industrial activities, olive mill wastes derived from the olive oil extraction process may represent a suitable soil amendment, because contains a large amount of organic matter.

Table 1. Some chemical properties of different olive wastes (Galic and Bugonovic, 2018)

pH	EC (dS/m)	OM (%)	P (%)	K (%)
8.40	1.40	72.7	4.70	19.00
4.69	1.19	–	–	2.10
4.90	0.91	18.5	0.05	0.08
5.38	4.64	90.8	0.08	1.04
5.60	3.80	32.6	–	–

Effects of olive pomace on soil physical properties

In many studies, it is stated that the application of olive pomace to soils has a positive effects on soil physical properties. Abu-Zreig et al. (2002) reported that application of oil pomace contains 94% organic matter, increased the water holding capacity and the saturated hydraulic conductivity, while decreasing the capillarity and unsaturated hydraulic conductivity in all soil samples. Abu-Rumman (2016) determined that water holding capacity, root depth and accumulated infiltration in a clay soil increased as organic waste application rates increased. In a study by Killi (2008), dry bulk densities of loamy sand and sandy loam soils decreased by increasing the application doses of olive pomace and composted olive pomace (Figure 1). In the same study, it is reported that while the hydraulic conductivity values of the soils increased by the higher dose applications, total porosity, field capacity and plant available water contents increased with all application doses (Figure 2).

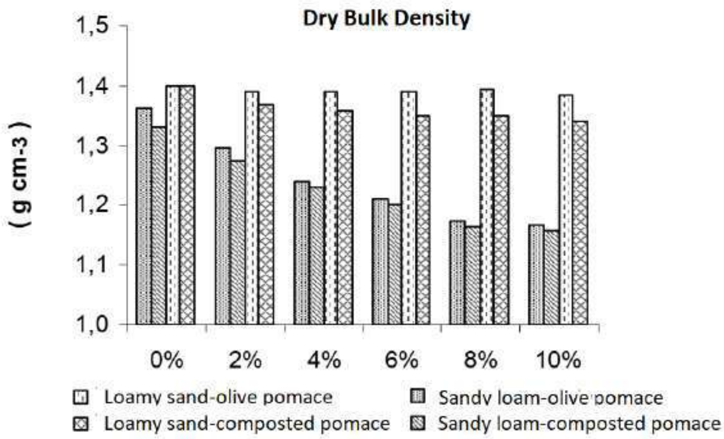

Figure 1. Effects of olive pomace and composted olive pomace applications on soil bulk density (Killi, 2008).

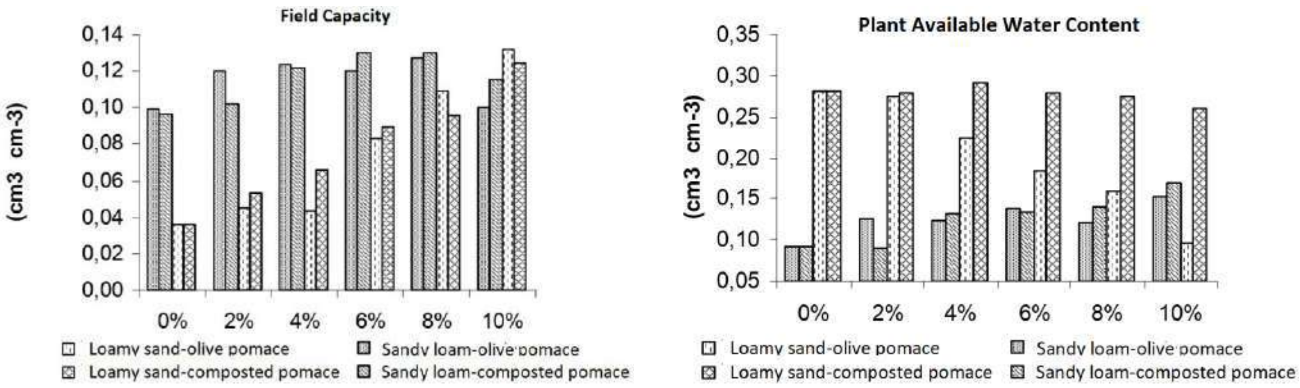

Figure 2. Effects of olive pomace and composted olive pomace applications on field capacity and plant available water content (Killi, 2008).

Moreno et al. (2016) used composted olive waste and concluded that increased soil organic matter content by the compost application resulted in decreased bulk density, and also in increased porosity and available water in the soil. Olive pomace also improves soil structural stability. López-Piñeiro et al. (2008) found that application of olive mill pomace increased soil stable aggregates from 64% to73 % after five years. Kavdir and Killi (2008) also determined that application of olive solid waste significantly increased aggregate stability values of loamy sand and sandy loam soils by the increasing of the application doses (Figure 3).

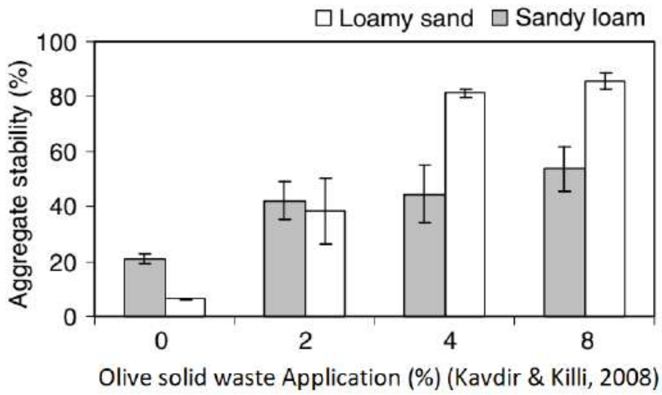

Figure 3. Effect of olive solid waste application on soil aggregate stability.

Effects of olive pomace on soil chemical properties

Tejeda and Gonzales (2004) reported that waste product of olive oil mill process has a great soil amendment potential due to its organic matter and nutrient content. Gómez-Muñoz et al. (2011) described the properties of different composted olive mill pomaces, and found that olive compost was very rich in organic matter content. Moreno et al. (2016) indicated that application of composted olive waste increased soil organic matter content, which is consistent with the low degradation rate of the compost in soil and confirms its usefulness as a source of organic C for soil. They found that the compost material was very effective in increasing soil organic matter content greater than 3% over 5 years and total N content most of it in organic form. Cucci et al. (2008) found that wet olive waste application increased the soil organic matter content from 1.9 to 3.5% over the control treatment (Figure 4). In another study, Cucci et al. (2013) compared the different dose applications (15, 30,45 and 60 ton/ha) of composted olive pomace with mineral fertilization (30 ton N/ha) and concluded that 60 ton/ha of composted olive pomace application increased organic matter content 100% (Figure 4), total N by 1.29 g/kg, available P by 11.5 g/kg exch. K 251 mg/kg over the control treatment. Moreno et al. (2016) reported that composted olive husk increased soil organic matter content in greenhouse, which is consistent with the low degradation rate of the compost in soil and confirms its usefulness as a source of organic carbon for soil.

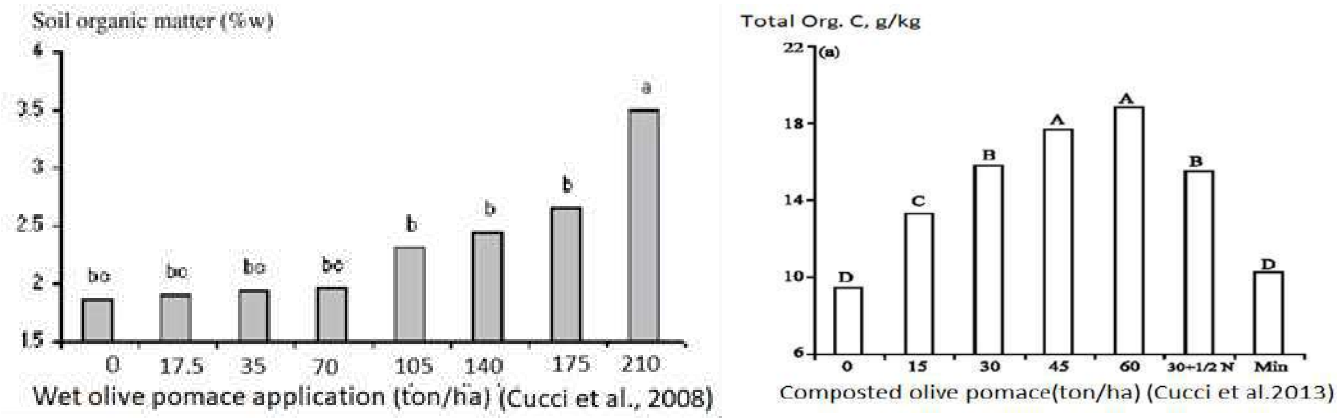

Figure 4. Effect of olive solid waste application on soil organic matter content.

In the studies by Cucci et al. (2008) and Kavdir and Killi (2008), similar results showed that while soil pH values decreased with increasing the application doses of olive solid waste (Figure 5), electrical conductivity (EC) and total N values of sandy loam and loamy sand soils increased (Figure 6 and 7).

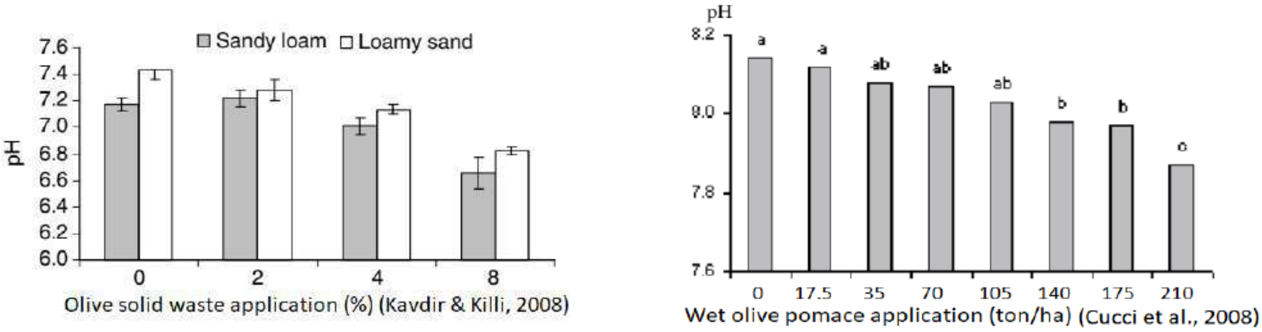

Figure 5. Effect of olive solid waste application on soil reaction (pH).

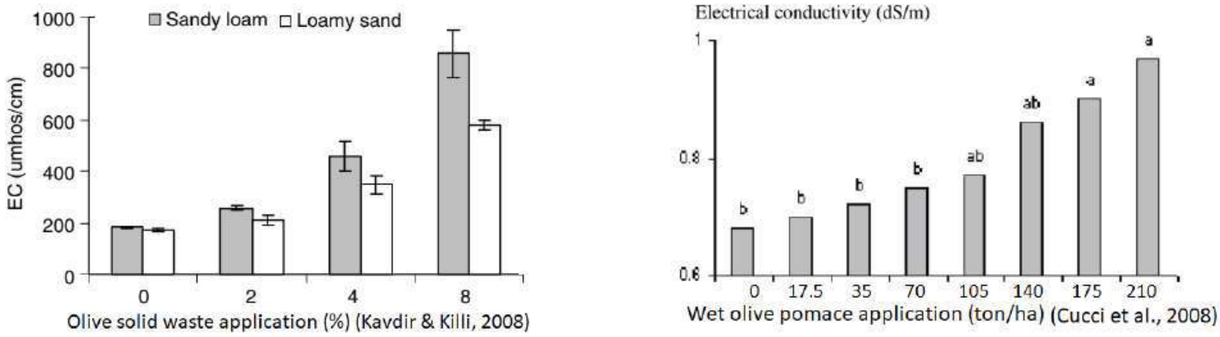

Figure 6. Effect of olive solid waste application on electrical conductivity (EC).

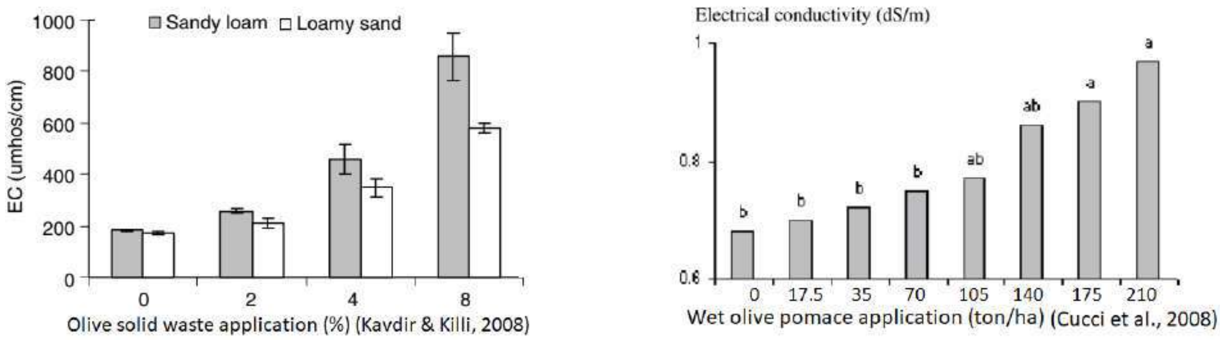

Figure 6. Effect of olive solid waste application on electrical conductivity (EC).

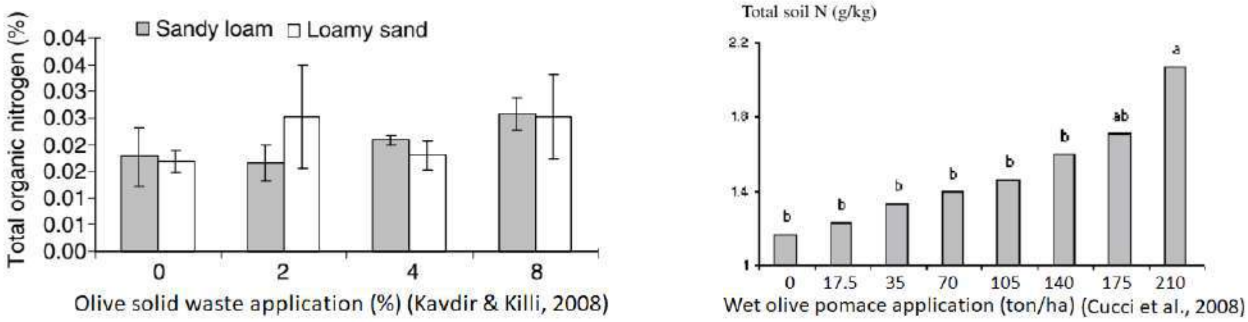

Figure 7. Effect of olive solid waste application on total N content.

Alburquerque et al. (2006) reported that the application of a composted olive waste to soil increased concentrations of phosphorus and potassium and decreased the contents of calcium and magnesium. Cucci et al. (2013) similarly determined that 60 ton/ha application dose of composted olive waste increased available P from 17.8 mg/kg to 29.32 mg/kg and exch. K from 194 mg/kg to 444 mg/kg over the control treatment. In another study Cucci et al. (2008) found that the soil conditioned by the highest wet olive pomace (210 ton/ha), available P increased from 33.6 to 113 mg/kg and exch. K increased from 273 to 353 mg/kg (Figure 8). Tejada and Gonzales (2004) concluded that the application of olive mill waste product to the soil resulted in an increase in soil microbial activity, structural stability, porosity, cation exchange capacity, exchangeable cations (Ca, Mg, Na, and K) and mineralized total nitrate N content. Moreno et al. (2016) reported that composted olive husk was an effective source of nutrients, particularly N, P, K and Ca.

On the other hand Moreno et al. (2016) stated that there was metal enrichment in the soil surface with increased soil organic matter content after application of composted olive husk. They suggested that metals may have remained bound to organic matter or oxides present in the compost or immobilized by adsorption and precipitation in the soil.

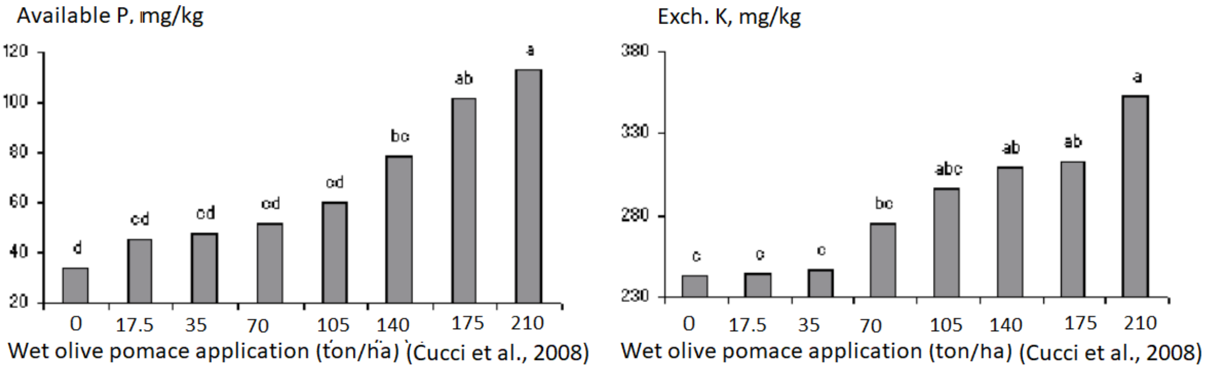

Figure 8. Effect of wet olive pomace application on available P and exch. K contents.

Conclusion

The use of pomace as a fertilizer has shown improvement in the physical and chemical properties of the soil. Many studies showed that crude and composted olive pomace improves water retention, structural stability, cation retention, total N, available P content with increasing the organic carbon content of soils. Overall it generally helps increasing soil quality parameters. More researches should be done and added to the economy to evaluate olive pomace as a soil conditioner that improves soil properties, as well as preventing environmental pollution and being a source of organic matter for soils having low organic matter content.

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The effect of iron enriched acidified and non-acidified biochars on DTPA extractable iron content of a calcareous soil

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Abstract

This study was carried out to determine the effects of three different biochar applications (B: original biochar, BFe: iron-enriched biochar and ABFe: acidified+iron-enriched biochar) on some chemical properties of a calcareous soil. The five different application rates (0%, 1%, 2%, 4% and 6% w:w) of biochars were mixed into the soil and incubated for 30 days under laboratory conditions around room temperature (20-24^{0}C). Soil pH increased with increasing the doses of B and BFe treatments and decreased with ABFe treatment. All biochar treatments had significant increments in the soil organic carbon (OC) content. The highest increment in soil OC content was obtained with 6% of B treatment which increased soil OC by 54% over the control. The iron content in soil significantly increased by the all biochar treatments compared to the control. While BFe treatment was more effective at 1% and 2% doses of DTPA extractable iron content in soil, ABFe treatment was more effective at 4% and 6% doses. The highest increments in iron content in soil over the control treatment was determined as 50% by the 4% of ABFe application.

Keywords: Calcareous soil, iron content, biochar, modification, soil pH, organic carbon

Introduction

With the rapid increase in the world population, it is a necessity to increase the productivity in agricultural soil worldwide. For this purpose, increasing, protecting and maintaining soil fertility is one of the most important management practices for the sustainability of agricultural production. Calcareous soil tends to be low in organic matter and available nitrogen in semi-arid or arid regions. As a result of the high pH and calcium content of these soils, phosphorus is insoluble, potassium and magnesium may be antagonistically affected. Also, zinc and iron deficiency are important limiting factors in these areas where cereals production is intense (Alloway, 2008). Nowadays most of farmers in the world have customarily used different kind of inorganic fertilizer to hold on or enhance the productivity and fertility of agricultural soils. However, this process is not economically sustainable and causes problems such as environmental and groundwater pollution as a result of improper fertilization. Also, excessive use of fertilizers resulted in accumulation of toxic heavy metals in soils. Thus, there is a need to find an appropriate soil management strategy that could reduce inorganic fertilization and enhance soil fertility. The amendment of biochar in the soil has received increased attention over the past two decades for sustainable agriculture by increasing efficiency, productivity along with numerous benefits such as waste management and climate change mitigation (Peiris et al. 2019; Awad et al. 2018). Biochar is a carbon-rich porous material obtained by thermal decomposition of biomass in an oxygen-free environment. There are many studies stating that biochar improves the chemical, physical and biological properties of soils. The productivity of the soils to which biochar is added has increased, the water use efficiency of the plants has improved, and the uptake of nutrients has become easier (Glaser et al. 2002; Ahmad et al. 2014; El Naggar et al. 2015). However, there are studies in which biochar is not effective or has negative effects. The factors that are important in the effectiveness of biochar are soil properties and characteristics of biochar (Purakayastha et al., 2019; Singh et al., 2020). One of the obstacles to the application of biochar to calcareous soils is that biochar has an alkaline pH. Acid or base application is frequently used to activate biochar. After acidification, the negative charges on the biochar surface increase and it can play a regulatory role in calcareous soils. Biochar enrichment process or biochar fertilizers have attracted attention recently. Biochar fertilizers contain plant nutrients that increase soil fertility for better plant growth (Chan & Xu, 2012; Ippolito et al., 2015).

The aim of this study is to determine effect of acidified and non-acidified iron-enriched biochars on soil pH, organic carbon and DTPA extractable iron content in a calcareous soil.

Material and Methods

In this incubation study used a sandy loam calcareous soil and gasification biochar from hardwood waste. Basic chemical and physical properties of soil and biochar are given in Table 1. Soil has a sandy loam texture, neutral pH, non-saline, moderate lime, very low organic carbon and low iron content (Hazelton & Murphy, 2006).

Table 1. Basic chemical and physical properties of soil and biochar

	units	Biochar	Soil
Texture	-	-	Sandy loam
pH	-	9,43	7,62
EC	dS/m	0,36	0,32
CaCO3	%	-	12,95
Organic carbon	%	4,88	0,90
Fe	mg kg^{-1}	77,50	5,87

For the iron enrichment of biochar sample 0.834g of ferrous sulphate (FeSO4.7H2O) was dissolved in 100 ml of distilled water and added to 100g of biochar sample. In order to acidification + iron enrichment the biochar sample 0.834 g FeSO4.7H2O was dissolved in 1.6 N H2SO4 solution and 100 ml solution was added to 100 g biochar sample. All samples were left to dry under laboratory conditions and then dried in an oven at 60^{o}C for 48 hours.

The laboratory incubation experiment involving 3 different biochar (B; original biochar, BFe; iron-enriched biochar and ABFe; acidified+iron-enriched biochar). The five different application rates (0%, 1%, 2%, 4% and 6% w:w) of biochars were mixed into the soil and incubated for 30 days under laboratory conditions around room temperature (20-24^{0}C). The samples were kept moist to 60% of the field capacity during the incubation period. Soil samples were spoiled after a month and pH, organic carbon and DTPA extractable Fe analyses were made on these samples. Soil and biochar pH was measured with a glass electrode using a (soil-to-water ratio of 1:1). Organic carbon content determined with the Walkley Black method (Nelson and Sommers 1982), DTPA extractable iron was analysed using DTPA method with (Lindsay and Norvell, 1978).

Results and Discussion

After the modification process, some chemical properties of biochar samples are given in Table 2. The acidification and enrichment processes reduced the pH, did not affect organic carbon content, and increased iron content enormously. Acidified iron-enrichment with was more effective than iron enrichment alone for iron content of biochar. These increments in iron content were sixfold in iron-enriched biochar and sevenfold in acidified iron-enriched biochar than original biochar.

Table 2. Some chemical properties of biochar samples after modification

	units	Biochar	Iron enriched biochar	Acidified + iron enriched biochar
pH	-	9,43	9,02	6,10
Organic C	%	4,88	4,75	4,92
DTPA exc. Fe	mg kg^{-1}	77,50	441,35	557,56

Biochar treatment and treatment rates had a significant effect on all parameters. Treatment and dose interaction have affected on soil pH and iron content but has not affected soil organic carbon content.

Table 3. The effect of treatment, treatment dose and their interactions on some chemical properties

	pH		Fe		OC	
	F-value	Prob. > F	F-value	Prob. > F	F-value	Prob. > F
Treatment	167,7	**<,0001**	4,98	**0,0135**	5,69	**0,008**
Dose	9,57	**<,0001**	14,52	**<,0001**	23,56	**<,0001**
T*D	14,98	**<,0001**	2,93	**0,0150**	1,52	0,1889

*Bold texts indicate significance level at %5.

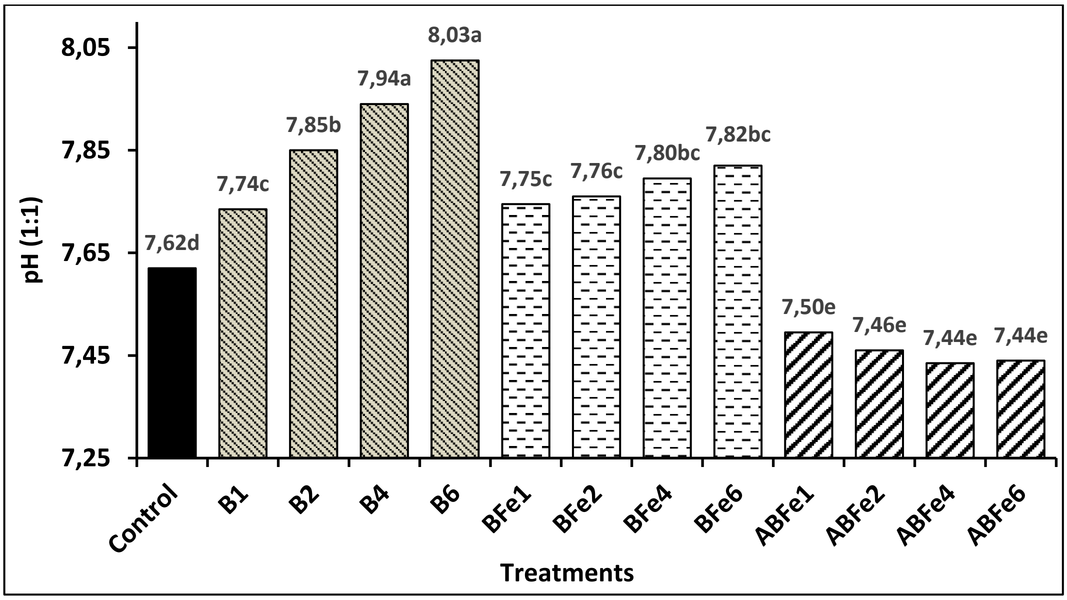

Figure 1. The effect of different treatments on the soil pH

The solubility of heavy metals increases at low pH and decreases at high pH. In calcareous soils with high pH, the solubility of heavy metals is generally low. Therefore, lowering the soil pH by adding acidified biochar is important to increase heavy metal availability. The B and BFe treatments increased the soil pH with increment doses while ABFe treatment decreased the soil pH. However, iron enriched biochar application increased soil pH less than the original biochar.

Maximum pH value (8,03) was obtained from 6% dose of B treatment while minimum pH value (7,44) was obtained from 4% and 6% doses of ABFe treatment. The low decrease in pH after the application of ABFe can be explained by the buffering capacity of the soil or acidified biochar may have increased the solubility of lime and exchangeable cations in the soil and therefore could not influence on soil pH.

There are many studies in which biochar application increases soil pH (Pandit et al, 2017; Asap et al, 2018; Jaafar et al, 2015).

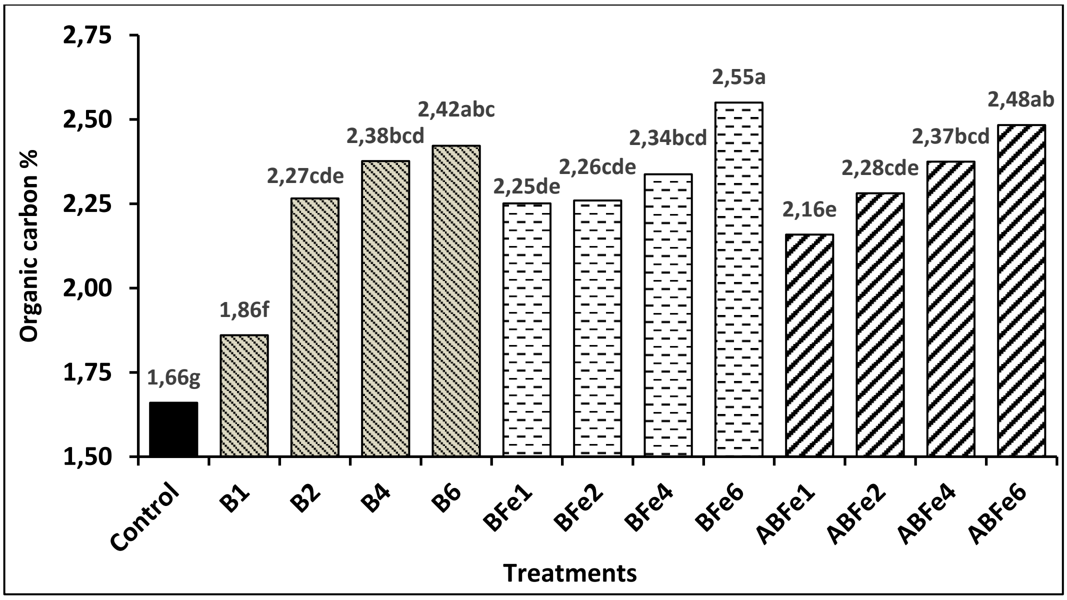

Figure 2. The effect of different treatmens on the soil organic carbon content

Soils in arid and semi-arid regions generally require the addition of organic material due to their low organic carbon content. With the addition of organic material, the physicochemical and biological properties of these soils improve and their productivity increases (Pascual et al, 1997; Gülser et al., 2015; 2017). All biochar treatments have significantly increased the soil organic carbon. The maximum organic carbon content (2,54%) was observed from 6% dose of BFe treatment while the minimum organic carbon content (1,66%) was obtained from control. Many studies have shown that biochar application increases soil organic carbon content. In the study by (Akça and Namlı, 2015), they applied increasing doses of poultry litter biochar to clay loam soil and grew three different (tomato, pepper and lettuce) plants. They showed that biochar material applied at high doses significantly increased soil organic matter.

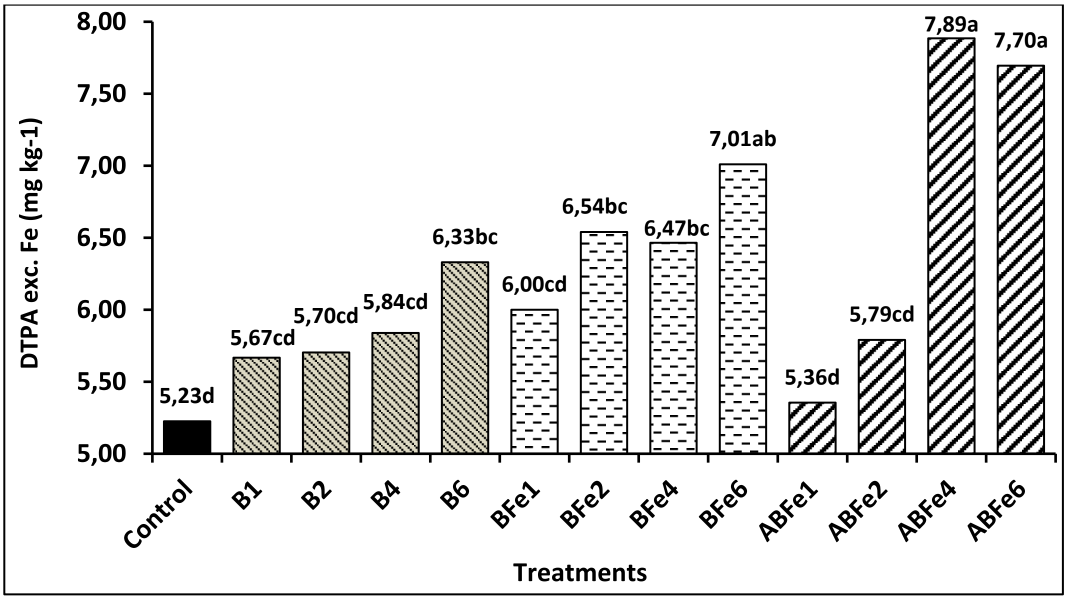

Figure 3. The effect of different treatments on the DTPA extractable iron content

All treatments have positively effect on DPTA extractable iron content in soil. In all treatments, the general trend is to increment the iron content in the soil with increasing application dose. Maximum DTPA extractable iron content was obtained from 4% dose of ABFe treatment (7.89 ppm) while minimum content was obtained from control soil (5.23 ppm). The highest increments in iron content in soil over the control treatment was determined as 50% by the 4% dose of ABFe treatment.

The effects of biochar application on soil microelement content are controversial. A similar result was reported by Akanji et al (2021). They applied the biochar obtained from poultry manure to the calcareous sandy soil in an acidified and non-acidified form. At the end of the incubation period (30 days), the highest increment of the iron content was observed from acidified biochar treatment.

On the other hand, there are studies showing that the usefulness of microelements in the soil decreases after the addition of biochar. In the study by (El-Naggar et al, 2015), three different organic wastes were applied to the calcareous sandy loam soil (conocarpus waste, conocarpus biochar and poultry manure). They found that the application of biochar significantly reduced the iron, zinc and manganese content in soil.

The feedstock of biochar, pyrolysis process (time or temperature), particle size of biochar and soil properties may be affect usefulness of micronutrients in the soil. Therefore, it is necessary to be careful when applying biochar to soils with low microelement content.

Conclusion

According to the results of this study biochar application in a calcareous soil can be helpful for productivity and maintenance. Soil pH increased with increasing the doses of non-acidified (original and iron-enriched) biochar treatments and decreased with acidified biochar treatment. All biochar treatments had significant increments in the soil organic carbon content. The general observation was that soil organic carbon content enhance linearly with increasing biochar application dose. The iron content in soil was significantly increased by the all biochar treatments compared to the control. The application of iron-enriched biochar at low doses was more effective than the acidified iron-enriched biochar. However, the highest increases in the iron content of the soils were observed at high doses of acidified biochar application. Acidified biochar can be useful to lower the pH of soils and provide organic carbon and micronutrients for the calcareous low fertility soil.

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Phyto extraction of nickel using nickel hyperaccumulator in serpentine soils of Bulgaria

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Abstract
Ultramafic (serpentine) soils, developed upon ultramafic rocks, are widely distributed in different parts of the world. These soils contain high concentrations of Mg and Fe, and also relatively high amounts of Ni, Cr and Co. Serpentine soils, which contain relatively high concentrations of nickel and some other metals, are the preferred substrate for some plants, especially those that accumulate Ni in their tissues. Hyperaccumulation is a mechanism that is believed to allow plant to servive on serpentine soils. The Ni hyperaccumulator Alyssum murale is widely present in ultramafic region and can accumulate upto 1-3% Ni in biomass. Phytoextraction employs metal hyperaccumulator plant species to transport high quantities metal from soil into the harvestable parts of roots and aboveground shoots. Suitable plant species for phytoextraction must meet the following criteria: (1) High biomass yield and (2) High Ni (>1%) in aboveground biomass. The need to manage the Ni polluted soils necessitates the study of the behaviour of hyperaccumulator plant in pot and field conditions. Effective phytoextraction requires both plant genetic ability and the development of optimal agronomic management practices. It has been well documented that modifying soil fertility may affect the efficiency of phytoextraction of heavy metals such as Ni, Zn, Co, Cd with a single crop. In case of phytoextraction, the use of native flora (including local populations of hyperaccumulators) with limited agronomic practices (extensive phytoextraction) could be an alternative to intensively managed crops provided that Ni bio-availability in soils is high and that hyperaccumulator cover is reasonably efficient. However, there is an evident need for amendment and phytoextraction yield improvement to achieve sufficient Ni extraction. Such extensive practices of phytoextraction could be more easily implemented in country such as Bulgaria (small area, limited investment capacity of farmers).
Keywords: Alyssum murale, Hyperaccumulator, Nickel, Phytoextraction, Serpentine soils.

Introduction
In Bulgaria, the largest serpentine bodies are located in the Eastern and Central Rhodopes, Vlahina, Ograzhden, Belasitsa and Rila Mts. Serpentine soils are widespread over the Balkans. Biodiversity in the area is high with a great number of local and regional endemics (Pavlova, 2010). Ultramafic (serpentine) soils have provided the greatest number of hyperaccumulators to-date, due to part to the inherent specificity of the associated ultramafic flora (Anderson, Brooks, Simcock, & Robinson, 1999). Serpentine soils, which contain relatively high concentrations of nickel and some other metals, are the preferred substrate for some plants, especially those that accumulate Ni in their tissues (Brooks & Radford, 1978). The species of Alyssum murale are endemic to serpentine (ultramafic derived) soils throughout Mediterranean Europe, but unlike many serpentine-endemic species, they grow rapidly and prolifically, even in non-native environments (Reeves,

Baker, & Ensley, 2000). Further, A. murale can also hyper-accumulate Ni in nonserpentine soil types, such as limestone and organic soils (Broadhurst, Maugel, & Sparks, 2008).

Hyperaccumulation is a mechanism that is believed to allow plants to survive on serpentine soils. Hyperaccumulators are defined as plants that contain in their tissue more than 1,000 mg per kg dry weight of Ni, Co, Cu, Cr, Pb, or more than 10,000 mg per kg dry weight of Zn, or Mn. Aside from metal tolerance, hyperaccumulation is thought to benefitt the plant by means of allelopathy, defence against herbivores, or general pathogen resistance. There are at least 400 known Ni hyperaccumulators. The Ni hyperaccumulator, Alyssum murale is widely present on ultramamafic regions and industrial areas (Bani, Echevarria, Sulce, Morel, & Mullai, 2007).

The Ni-hyperaccumulating plant Alyssum murale has received the most attention because of its extraordinary ability to extract and accumulate Ni from soils. As a result of this ability to remove considerable quantities of metals from soils, these hyperaccumulators are attracting interest from scientists interested in phytoremediation (also more generally called phytoextraction), a cost-effective, 'green' technique for decontamination of polluted environments (Abou-Shanab, et al., 2003).

The discovery of hyperaccumulators of Ni has led to an upsurge of interest in these plants because of the interesting questions that arise when a normally phytotoxic element is accumulated by plants to such an extraordinary degree. Phytochemical studies have also been encouraged because it is now possible to isolate milligram quantities of metal complexes for further study instead of the microgram quantities to be expected with non-accumulating species (Homer, Morrison, Brooks , Clemens, & Reeves, 1991). Nickel (Ni) phytomining involves growing selected Ni hyperaccumulator plants ('metal crops') on sub-economic ore bodies or mineralised (ultramafic) soils, or anthropogenic metal-rich materials (such as contaminated soils, mine wastes, industrial sludges), and processing the biomass after harvesting to recover valuable products such as Ni metal or Ni salts (Nkrumah, Echevarria, & Erskine, 2019).

Soil amendment with manures, municipal biosolids, and other organic wastes has been found to improve the physical and chemical properties of soil. Beneficial effects of organic soil amendments include decreased soil bulk density and increased water holding capacity, aggregate stability, saturated hydraulic conductivity, water infiltration rate, and biochemical activity (Zebarth, Neilsen, Hogue , & Neilsen, 2015).

The objective of the research was to evaluate the effect of organic amendment on Ni uptake and growth characteristics of the hyper-accumulator Alyssum murale grown on serpentine soil. The objective will be achieved by solving the following specific tasks:

1. Characterization of serpentine soils from the area of village of Kazak in Bulgaria.
2. To determine distribution of Ni, macro and trace element in the vegetative organs of Alyssum murale.
3. Investigate the effect of organic amendments application on Ni uptake potential of Alyssum murale in pot experiments.

Methods and Material

Pot experiments were carried out in serpentine soils. The serpentine soils were collected from the surface soil horizon (0-20 cm) from the Kazak region (Eastern Rhodopes). After sieving the soils through a 2 cm2 mesh sieve, organic soil meliorants (compost, biochar, leonardite and humic acids) were added at 2.5% and 5% respectively, (recalculated based on dry soil weight) and gently mixed with the soil by hand. All treatments were performed in three repetitions. Additionally, three test containers were prepared for the control samples (no additives).

To determine the effect of the organic amendments, the soil samples were collected 1 month after addition of organic amendments. The soil characteristics (pH, EC, organic content and humus fractions) were determined.

Total content of Ni in soil samples will be prepared for analysis by treatment with aqua regia (HCl:HNO3 -3:1) (ISO 11466). To determine the mobile forms of nickel, 0.005 M DTPA (diethylene triamino pentaacetic acid) will be used as an extractant (ISO 14870).

The nickel, macro and trace element contents of the plant samples (roots, stems, leaves) will be determined by the microwave mineralization method.

In the determination of nickel, macro and trace elements in soil and plant samples, an atomic emission spectrometer (ICP) of the company Jobin Yvon Emission model JY 38 S will be used. The calibration lines for the elements will be constructed by five aqueous standard solutions obtained by dilution of a starting multi-element standard solution (Merck) with a concentration of 100 mg/L. The concentrations of the calibration standard solutions are 0; 0.2; 0.5; 2.0 and 5.0 mg/L. The acidity of the standard solutions will be aligned with that of the samples.

Statistical analysis: Descriptive Analysis (mean, range, standard deviation, root mean square error, coefficient of variation) will be carried out in MS excel and while other deep analysis and interpretation will be carried out by SPSS and R-stat.

Result and Discussion

The obtained results will enrich the knowledge regarding the possibilities of practical application of phytoextraction as a "green technology". The results of this research are practical. For the first time, results will be reported on the impact of organic meliorants on optimizing yield and improving phytoextraction of Ni from A. murale grown on serpentine soils in Bulgaria.

New information will also be obtained on the effect of organic amendments application on distribution of Ni, macro and microelement in vegetative organs, biomass yield and Ni phytoextraction of the hyperaccumulator A. Murale.

New information will be obtained on (i) the optimization of extensive phytoextraction methods adapted to the soil-climatic conditions in Bulgaria and (ii) the establishment of the relationship among the application of organic additives, soil characteristics, the amount of Ni uptake and the plant response (yield of A. Murale).

New knowledge will be gained on the factors affecting plant growth and Ni uptake by hyperaccumulator plants.

The main results of the research will be published in specialized scientific journals and presented as paper at scientific forum of Bulgaria.

Conclusion

Ni phytoextraction is a promising technology for Ni recovery from ultramafic soils. Ultramafic soils are usually marginal in macronutrients (nitrogen (N), phosphorus (P), potassium (K), and calcium (Ca)) for the growth of plants. Commercial nickel phytoextraction is dependent on attaining high yield and high Ni concentration in harvestable biomass of Ni hyperaccumulator species. However, many of these plants produce low biomass, which makes the use of agronomic techniques for improving their growth necessary. Metal-hyperaccumulators are good candidates for phytoextraction due to their extraordinary capacity for Ni accumulation. Alyssum murale is a native plant to Mediterranean serpentine soils. In this review study, was evaluated the phytoextraction efficiency of Ni hyperaccumulator Alyssum murale from Ni-rich serpentine soils. Effects of soil inorganic fertilization (NPK) and soil organic amendment addition (compost and biochar) on plant growth, biomass production, and Ni accumulation were evaluated. All soil treatments greatly improved plant growth, but the highest biomass production was generally found after the addition of 2.5 or 5% compost (w/w). Total Ni phytoextracted from soils was significantly improved using both soil treatments (inorganic and organic), despite the decrease observed in soil Ni availability and shoot Ni concentrations in compost amended soils. The most promising results were found using an intermediate amount of compost, indicating that these types of organic amendments can be incorporated into phytomining systems.

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Conclusion

Salinity inhibits germination and seedling growth in maize. Seed priming is an effective method to increase salinity tolerance in maize fields. The better performance of primed seeds in this experiment illustrates the necessity of priming seeds before sowing in the saline soils. Seed priming induces germination and helps in the overall growth and development of the plant. Salt sensitive nature of maize variety Arun-2 makes it unsuitable to grow in saline soil without seed priming. Although our research found the usefulness of seed priming in the early growth stages of maize, additional research on late growth and reproductive stages would be beneficial. Advanced research on priming induced alteration of physiological and biochemical attributes in maize will be the goal of our future research.

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Relationship between chemical & organic fertilization practices and global warming

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Abstract
Fertilization is one of the main elements of agriculture. More than 90% of fertilization practices in all over the world consist of nitrogen fertilization. In addition, soils always need the addition of nitrogen, which is a macro plant nutrient, from the outside. The need for nitrogen in agricultural areas is continuous, because of the element that plants remove the most from the soil is nitrogen and the mobility of nitrogen in the soil. However, nitrate leaching, and denitrification are constantly present in the nitrogen cycle in nature. Therefore, unconscious fertilization and accompanying unconscious tillage, nitrogen is washed away and progresses as a pollutant to the underground waters and the oceans in a chain manner, in addition, the nitrogen that is denitrified from soils in unfavorable conditions under reducing conditions is mixed into the atmosphere as nitrous oxides (nitrogen protoxide). Although natural fertilization is quite innocent compared to chemical fertilization, unconscious composting processes also contribute negatively to nitrate accumulation and nitrate leaching in the soil. Of course, nitrogenous gases emitted from chemical fertilizer factories, which are the dominant element of this fertilization, should not be ignored. Although the emission of nitrous oxides in greenhouse gases is proportionally less than CO_2, its effect is 298 times higher. The unitary increases of nitrous oxides contribute 10% to the total greenhouse effect caused by CO_2. Global warming has turned into a cycle that affects agricultural practices, and agricultural practices affect global warming. With a holistic approach, considering global warming, new fertilization programs should be made, which includes a conscious chemical fertilization and a correct organic fertilization that can reduce the percentage of chemical fertilization, and alternative organic fertilizers. In this article, recent studies on the relationship between chemical and organic fertilization and global warming are included and the results are evaluated.

Keywords: Fertilization, global warming, nitrous oxide, plant nutrition, soil health.

Introduction
Global warming ranks first among the important environmental problems that threaten the future of the world. Global warming is not a spontaneous environmental problem, but an inevitable result of other environmental pollution problems caused by the unconscious activities of human. Global warming has occurred due to the extraordinary increase in the natural greenhouse effect existing in the atmosphere with the increase in the amount of greenhouse gases released into the atmosphere. The Paris Agreement includes limiting warming to less than 2°C; but ideally it aims not to rise above 1.5 °C. Among the greenhouse gases that increase the greenhouse effect, primarily CO2 and methane are mentioned, but the reactive nitrous oxide form of nitrogen is a greenhouse gas that can stay in the atmosphere for more than 100 years and is 298 times more effective than CO2. In this article, recent studies on the relationships between chemical and organic fertilization and global warming are included and the results are evaluated.

Nitrogen in the Atmosphere

Although nitrogen makes up the majority of the atmosphere's content, less than 2% of it is in the form of reactive nitrogen. Most of the reactive nitrogen is produced by biological nitrogen fixation in annual amounts of 90-130 TgN. The amount of approximately 150 Tg N $year^{-1}$ occurs with anthropogenic activities such as agricultural production, fertilizer and energy production. 1% of the production takes place during natural events such as lightning (Wetzel, 2001). NO and NO_2 gases, which are mostly formed as a result of combustion, are absorbed in raindrops, fog and water in clouds and react with ammonia carried in airborne dust to form acid droplets. Aerosols are formed by the combination of dust and vapor in the air and usually contain NH_4NO_3. NO and NO_2 gases cause ozone formation in the troposphere and have toxic effects on plants. In addition, N_2O gas damages the ozone layer in the stratosphere (Stumm and Morgan, 1995; Crutzen ve Ehhalt, 1977; Ravishankara ve ark., 2009).

Fertilization and Nitrogen

Nitrogen, which plants remove in the highest amount from the soil, is the element at the top of the macronutrients of plants. Considering the mobility of nitrogen in the soil and the needs of plants, more than 90% of chemical fertilization and fertilizer production all over the world is nitrogen fertilization. In addition, chemical fertilizers are produced and used from the forms of nitrogen that can be used by plants (NH_4^+ and NO_3). Imprecise chemical fertilization causes a high nitrate leaching. The use of high amounts of nitrogen fertilizer in crop production is one of the important causes of groundwater pollution. Pollutant sources are very diverse, primarily human activities and excessive fertilization. Water mixed with streams and rivers causes nutrient excess and thus eutrophication (UNEP and WHRC, 2007). Increasing nitrate concentration in ground waters poses a global risk with increasing denitrification levels.

In organic fertilization, the aim is not only to provide plant nutrients. However, plant and animal residues and wastes go through a maturation (traditional thermophilic composting) process, even if they are used only for fertilization purposes. During the maturation process, nitrogen in the pile undergoes intense nitrification or denitrification depending on inner conditions. There is a high nitrate leaching in compost piles. The imprecise composting technique, which is mostly carried out in rural areas and in areas where agricultural facilities are clustered, causes nitrate pollution of the surrounding wells, underground waters, lakes, streams and sea. Nitrous oxide released from fertilizer production plants is another pollutant in terms of nitrogen. However, this is the subject of another study.

Global Warming and Nitrogen

Nitrous oxide (N_2O) is one of the major greenhouse gases and contributes significantly to global warming (Case et al., 2015; Tao et al., 2018; Shi et al., 2019). Agricultural activities such as the widespread application of chemical fertilizers, especially those containing synthetic nitrogen (N) (Sun et al., 2016) are responsible for approximately 60-80% of anthropogenic N_2O emissions (Wang et al., 2017; UNEP, 2019). Vegetable farming accounts for 9% of total anthropogenic NO emissions (Rezaei et al., 2015; Bouwman et al., 2002; Mosier and Kroeze, 2000; Reay et al., 2012; Tian et al., 2020).

Most of the N_2O production in soil is due to microbial nitrification and denitrification processes (Firestone and Davidson, 1989; Butterbach Bahl et al., 2013). N_2O emissions from agricultural soil are mostly driven by chemical N management practices (Mosier et al., 1998). Atmospheric N_2O concentrations today are about 20% higher than pre-agro-industrial levels (Ciais et al., 2013). The Intergovernmental Panel on Climate Change (IPCC) has prepared protocols to develop national inventories for the measurement of greenhouse gas emissions and direct and indirect N_2O emissions from cultivation areas.

Anthropogenic sources of N_2O gas are chemical and organic fertilizers and fossil fuels especially used in agricultural areas and pastures, symbiotic nitrogen-fixing products, industrial processes, wastewater treatment. In the nitrification process, the oxygen in the water is rapidly consumed and the resulting nitrate ion is reduced to nitrogen gas by denitrification. During this process, N_2O and NO gases with low solubility in water are released to the atmosphere as a by-product. With nitrogen fixation, free nitrogen in the atmosphere is reduced to ammonia. This process, which takes place slowly in nature, accelerated with the emergence of the Haber-Bosch Process at the beginning of the 20th century. Thus, the NH_3 molecule has accelerated to reach receiving environments such as soil and lakes. According to the EPA, N_2O molecule, like CH_4, is a long-lasting greenhouse gas, and the potential of N_2O molecule to affect global warming is 298 times that of a single CO_2 molecule. The NO molecule causes the formation of acid rain with the accumulation of NOx gases in the atmosphere. Gaseous ammonia, on the other hand, combines with neutralizing compounds such as H_2SO_4 to form atmospheric aerosols, which are important acid rain droplets (Öğün, 2012). Nitrous oxide is a reactive nitrogen form whose negative effects on global climate change are known with certainty.

While the effect of 1 kg of carbon dioxide gas on global warming is accepted as 1, the same amount is accepted as 23 for methane, 296 for nitrous oxide, 7300 for chlorofluorocarbon, 17000 for nitrogen trifluoride, 22200 for sulfur hexafluoride (DEFRA, 2005). The increased use of nitrogen fertilizers can cause the release of ammonia and nitrogen oxide gases, which adversely affect the air. In addition, nitrous oxide and nitrous oxide gases reaching the stratosphere cause the decomposition of ozone in the stratosphere, and this is due to the excessive use of nitrogen fertilizers (Sönmez et al., 2008).

Although, the sulfur emissions were reduced in atmosphere, the ammonia emissions could not be reduced that much. This means that ammonia in the atmosphere reacts with other substances. For example, NO_2 in the atmosphere turns into nitric acid, and this nitric acid reacts with ammonia to form ammonium nitrate. Ammonium nitrate is very volatile. Ammonium nitrate is a particle or droplet at higher altitudes. However, ammonium nitrate decomposes into nitric acid and ammonia on hot days and near the soil surface, then sink rapidly below the soil surface.

Fertilization and Global Warming

Nitric acid provides additional nitrogen to the earth and acts effectively as a fertilizer for our plants. In this way, the atmosphere fertilizes the natural environment just as the farmers fertilize the cultivated land. The additional nitrogen that fertilizes natural land creates acids in the atmosphere, leading to increased emissions of nitrous oxide. Although this situation causes pollution, it is an advantage in terms of fertilization. The most important effect of nitrogen accumulating in nature is to provide additional nutrients to natural ecosystems. All plant species need nitrogen during their growth period. As some species consume high amounts of nitrogen during the growth period, more specialized species adapted to growth in a low-nitrogen climate are lost and vegetative biodiversity is reduced.

It has been successfully struggled with sulfur compounds that cause air pollution among atmospheric gases. The level of awareness about the ozone layer has been increased and the fight against CO_2 emission continues intensely. However, although it is the main component of the atmosphere, the biggest pollutant is nitrogen, and the increase in the rate of nitrogenous compounds in the atmosphere is largely caused by agricultural activities. Therefore, long-term and elaborative studies are required with a determined will to reduce the release of nitrogenous compounds without reducing plant productivity.

Ogun et al. (2014) reported that there is a high amount of N_2O release from the bottom of Eymir Lake and it reaches the photic zone by being transported between the phases, the H+ ion concentration in the photic zone decreases with increasing alkalinity as a result of photosynthesis, and as a result of denitrification, ammonium ion is released into the atmosphere in the form of NO and N_2O without being reduced to N_2 gas. Due to the low solubility of these gases in water accelerates the denitrification process. It has been reported that approximately 230.5 g $L^{-1}h^{-1}$ N_2O is released per hour from the entire lake surface, which indicates that the annual amount can be expressed in terms of Tg (1 million tons). According to the EPA, this measurement is equivalent to 71500 g $L^{-1}h^{-1}$ CO_2 emissions.

N2O is produced in microbial nitrification and denitrification processes, which depend on temperature and moisture levels in soils and determine the mineralization, oxidation or reduction rates of soil N (Khalil et al., 2004; Kool et al., 2011). To reduce N losses and maximize plant yield, it is necessary to optimize the fertilization rate, for which an appropriate N management approach is imperative (Sun et al, 2020). Oenema et al. (2015) increased the effective nitrogen use (NUE) by using 32% of the standard fertilizer input, while providing a 5% increase in grain yield by using field-specific nutrient management (SSNM).

Certain studies report that postponing basic fertilizer application can increase crop yield while reducing the N application rate and reduce environmental pollution from production (Nishikawa et al., 2015; Guo et al., 2017; Maaz et al., 2021; Yang et al., 2021). A significant amount of N_2O emission occurs from paddy fields, especially during the dry-wet cycle in rice cultivation (Zhong et al., 2016). Irrigated paddy fields in China account for about 11% of annual cultivated land's N_2O emissions. Therefore, water management is also very important in terms of NO emissions in rice cultivation (Zhang et al., 2020).

Huang et al. (2020) reported that although cattle manure application increases vegetable yield, it also greatly increases yield-scale N_2O emissions, in the results of their study that aimed to determine the effects of organic fertilizer substitution on soil N_2O emissions, and which environmental factors play the key roles in N_2O emissions. The increase in the population of denitrifiers and the predominant presence of denitrification in soil play a key role in NH_4^+ and NO_3^- N_2O emissions. In addition to chemical fertilization, in organic fertilizer supplements, the process can partially contribute to N_2O emissions by reduction of nitrate to ammonium and decomposition of the organic fertilizer itself.

Gurung et al. (2021), in a study focusing on NO emissions from agricultural soils and their reduction, aimed to develop a dynamic modeling approach for the use of slow-release N fertilizers and the use of nitrification inhibitors, incorporating other important factors, including soil properties, weather patterns and irrigation management. In conclusion, the adoption of effective nitrogen fertilizers as an alternative to conventional fertilizers can reduce N_2O emissions, but their reduction potential depends on climatic conditions, edaphic characteristics, and management practices.

Glenn et al. (2021) investigated the effect of N application at different rates on seasonal and annual N2O emissions in canola cultivation. As a result, they determined that high-dose N applications increased soil N2O emissions in uncultivated canola cultivated land. Agrometeorological conditions (the difference between cumulative growing season precipitation and evapotranspiration) and soil environment (temperature and moisture content) increase daily N_2O emissions the most, soil N and moisture presence increase cumulative seasonal emissions the most. Measurements of daily soil NO emissions must be made with a large number of observations and simultaneous forecast variables.

Geng et al. (2021) aimed to determine the potential role of the use of bio-organic fertilizers containing Trichoderma guizhouense in cucumber cultivation in reducing N_2O emissions. As a result, they determined that organic and bio-organic (containing T. guizhouense) fertilizers significantly reduced N_2O emissions in greenhouse cucumber cultivation compared to conventional chemical fertilization.

Zhang et al. (2022) investigated the effects of the use of vegetable organic fertilizers on N_2O emissions and productivity in rice cultivation in a field study. According to the results of the study, it was reported that N_2O emissions during mid-season drainage constitute 70-85% of the total N_2O emissions from rice. However, when the organic fertilizer application rate was between 30% and 60%, the nitrogen use efficiency increased by 7-10% and the grain yield increased by about 8.9%. It was also found that basic fertilization significantly increased N_2O emissions. The optimization of the organic fertilizer ratio increased soil fertility and increased grain yield by 20% also reported. As a result, with an optimized organic fertilization, N_2O emissions can be reduced, nitrogen utilization can be improved, and grain yields can be increased.

In a recent study, Liu et al. (2022) aimed to determine the relationships between N stabilizer chemicals and the reduction of N_2O emissions in the surface soil and the role of microbial differences in this mechanism. As a result, they determined that the application of N-(n-butyl) thiophosphoric triamide (NBPT) and 3,4-dimethylpyrazole phosphate (DMPP), separately or together, significantly reduced N_2O emissions. While NBPT increased the presence of nitrifying bacteria, decreased N_2O production by decreasing denitrifying bacteria, DMPP application decreased both nitrifying and denitrifying bacteria.

Inorganic nitrogen fertilizers, which provide yield increase in plant production together with their positive contributions to food safety, constitute 60-80% of the total human-sourced reactive nitrogen. The most important technique to minimize the negative effects of reactive nitrogen on the environment and increase profitability in plant production is to increase the efficiency of nitrogen intake (Battilani et al., 2008). In order to reduce nitrogen leaching, it is necessary to plan fertilizer applications and application timings, frequencies and doses in advance depending on the plant development periods and the hydraulic properties of the soil (Unlu et al., 1999).

Conclusion

Agricultural activities are one of the main sources of nitrous oxide gases, which contribute 10% to the effect of greenhouse gases that cause global warming and are more effective than CO_2 in global warming. The biggest share in the mentioned agricultural activities belongs to especially nitrogenous chemical fertilization and organic fertilization that will increase nitrification and denitrification. Fertilization is, of course, an indispensable element of agriculture. However, soil, water and atmosphere are polluted due to unconscious chemical fertilization and nitrate washing in compost piles. Although organic fertilization is innocent when compared with chemical fertilizer, the contribution of nitrogen in the atmosphere to global warming should be taken into account as well as focusing on the importance of soil organic matter. Because global warming first affects and disrupts agricultural systems. Therefore, in the light of the studies, effective nitrogen use practices should be increased. It is necessary to increase the knowledge by making studies on the use of slow-release nitrogen fertilizers without decreasing soil fertility and plant yield. The use of chemical and organic fertilizers should be optimized, and an appropriate N management approach is mandatory for this purpose. Global warming is unfortunately felt all over the world, not regionally like soil or air pollution. Global warming, its causes, consequences, and solutions are under the responsibility of human.

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The selection of rice genotypes (*Oryza Sativa* L.) resistant to zinc deficiency in the sand culture medium

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Abstract

The aim of the study was to determine the paddy genotypes (*Oryza sativa* L.) resistant to Zn deficiency with principal component analysis (PCA). In the study was used eleven characteristics that was the stalk dry weight (SDW), stalk relative dry weight (SRDW), stalk Zn content (SZn), stalk relative Zn (SRZn), stalk removed Zn (SRmZn) and stalk relative removed Zn (SRRmZN), leaf chlorophyll value (SPAD) and leaf relative chlorophyll values (RSPAD), and NPK contents of rice genotyopes. The experiment was carried out in pure sand culture medium nutrient solution under greenhouse conditions in randomized factorial plots design with three replications by applying 2 Zn doses (0 and 5 ppm) to 6 paddy genotypes that are Terme incisi (G1), Rekor (G2), Efe (G3), Kızılırmak (G4), Karadeniz (G5) and Romeo (G6). In the study, it was determined that G5 genotype was good cultivars in terms of biological indexes (SDW, SZn, SRZn and SRmZn) under Zn deficiency conditions, while cultivar no 3 was determined to be good cultivars in terms of SRDW and SRRmZn. Similarly, it was determined that cultivar no 1 in terms of SPAD value and G2, G4 and G6 genotypes in terms of RSPAD value were good cultivars. It was determined that G5 and G2 genotypes were better in terms of P and K contents, and G6 genotype in terms of N content. On the other hand, it was determined that G5 genotype was the best cultivar in terms of SDW, SZn, SRmZn leaf chlorophyll SPAD value under the zinc sufficient medium condition. As a result, it was determined that Romeo G5 genotype was the most resistant to Zn deficiency in terms of biological indexes, followed by G3 genotype while the most sensitive cultivars were G1, G2, G4 and G6 genotypes outside the group.

Keywords: Paddy genotype, dry weight, zinc content, zinc deficiency tolerance, PCA.

Introduction

Paddy is a herbaceous plant species that is most cultivated after corn and wheat from the Poaceae family. It is of great importance in nutrition for more than half of the world's population. It is estimated that by 2050, to feed 9.1 billion people with this food, the current yield should be increased by another 100 million tons (Jaggard et al., 2010). Rice is mostly grown in monsoon Asia under tropical and subtropical climatic conditions. It grows very commonly in south or southeast Asia and Africa, more often.

Rice plant is faced with multiple biotic and abiotic stresses in all ecosystalks where it is grown (Horuz et al., 2017). In addition to different abiotic stresses such as drought, salinity and acidic soils, nutrient deficiencies and toxicities in the soil also cause significant losses in grain yield (Mahender et al., 2019). In another study, field mapping of QTL (tolerance-associated quantitative trait loci) with a population derived from a cross of Jalmagna (tolerant to zinc deficiency) and IR74 (sensitive to zinc deficiency) largely confirmed that both were under independent genetic control (Wissuwa et al, 2006).

Forno et al. (1975) reported that the IR8 variety resistant to Zn deficiency did not show a significant difference from the sensitive IR184-67 variety in terms of Zn uptake ability under hydroponic solution culture conditions. They reported that the IR8 variant was slightly lower in critical Zn uptake (0.23 and 0.27 ppm, respectively) than IR184-67, but that IR8 was significantly more resistant to HCO3 concentrations. The researchers stated that the performance of the two cultivars in Zn uptake under field conditions was largely due to the reuse of zinc for the plant. On the other hand, under Zn deficiency conditions, the Zn content of the first three leaves and leaf sheaths of the rice genotypes CSR10, CSR23, CSR-89IR1, 89H1-931098 and IR47538-3B-9-3B-1 decreased 33 days after planting, but CSR-88IR15, which is in the same group, It was put there that CSR-89IR14 has higher Zn concentration compared to IR4630-22-2-5-1-2 and Trichi rice genotypes (Quadar, 2007).

In this study, it was aimed to select the paddy genotypes with the best performance, which has an important place in human nutrition, whose commercial importance is increasing, and which will increase the yield by reducing the yield loss in rice (Oryza sativa L.). For this purpose, stalk dry weight (SDW), stalk Zn content (SZn), removed Zn (SRmZn) amount, leaf chlorophyll SPAD value and stalk NPK contents of paddy genotypes in sand culture medium were evaluated by principal component analysis (PCA) and the genotypes tolerant to Zn deficiency were revealed.

Material and Methods

Material

The medium material in which paddy genotypes are grown was obtained from CEN Standard Sand TS EN 196-1 LİMAK company. In the study, 6 paddy genotypes such as Terme pearl (G1), Rekor (G2), Efe (G3), Kızılırmak (G4), Romeo (G5) and Black Sea (G6) were used. Genotypes were obtained from Samsun Black Sea Agricultural Research Institute. The experiment was conducted in Ondokuz Mayıs University Faculty of Agriculture trial greenhouses for 83 days between 22 July and 15 October 2020. In the experiment, 850 grams of CEN Standard Sand was placed in pots with a diameter of 20 cm, a height of 17 cm and a base diameter of 12 cm.

Method

The study was carried out in 6 paddy genotypes with 2 Zn doses (0, 0.25 ppm) in completely random blocks according to the factorial trial design with 3 replications (6×2×3). In the study, the macronutrient solution reported by Zhang (1992) was given to rice genotypes grown in sand culture medium as control (Zn0) and 5 ppm zinc (Zn5).

Before planting, rice seeds were kept in 5% (v/v) sodium hypochlorite solution for 15 minutes, and the seeds were sterilized. Then, after the rice seeds were washed with deionized water and germinated in moist cloth bags, the germinated seeds were transferred to 40×25×5 cm white plastic tubs containing perlite and they were transformed into rice seedlings within 10 days. Rice seedlings were planted in plastic pots filled with 850 g quartz sand, with 7 plants in the pot. Then, plant nutrient solution in the form of ZnSO4.7H2O at doses of 0 (-Zn) and 5 ppm Zn (+Zn) was given to the pots (Zhang et al., 1998): 500 µM NH_4NO_3; 60 µM $NH_4H_2PO_4$; 230 µM K_2SO_4; 210 µM $CaCl_2$; 160 µM $MgSO_4$.7H2O; 2.5 µM MnCl2; 0.75 µM $(NH_4)_6Mo_7O_{24}$; 3.2 µM H_3BO_3; 0.1 µM $CuSO_4$.

Stalk total K, Ca, Mg, Fe, Mn, Zn, Cu and B: were determined by ICP-OES (Avio 560 Max) in the samples burned according to the wet burning method (4:1 HNO_3:$HClO_4$) (Temminghoff and Houba, 2004). The basis of this method; The intensity of the light emitted as a result of the excitation of atoms and ions formed by the transition to the gas phase and the dissensation of the solutions containing K, Ca, Mg, Fe, Mn, Zn, Cu and B sprayed on the argon plasma, respectively, is 766,491nm; 317,933 nm; 280,270 nm; 259.94 nm; 257,610 nm; 206,200 nm; 327,395 nm; It was determined in ICP-OES tuned to a wavelength of 249,678 nm (Kacar, 2014).

Principal Component Analysis (PCA)

The effect of activated bentonite (AB) on the removed Fe toxicity from the paddy plants in the sand ulture medium was evalueted with principal component analysis (PCA) in the CAP 4.1.3 program (Seaby and Henderson 2007). Eigen Value (EV) and cumulative total EV in the Zn deficiency medium were 6.59 and 9.12, respectively, and they were 3.75 and 5.47 in the Zn deficiency medium. Total variance and cumulative total variance in the Zn deficiency medium were 59.91 and 82.94%, respectively and they were 53.47 and 78.15 in the Zn sufficient medium. The Axis l and aix II values of the stalkDW, stalk relative dry weight (stalkRDW), stalk Zn content (stalkZn) and stalk relative Zn content (stalkRZn), stalk removed Zn (stlakRmZn), stalk relative removed Zn (stalkRRmZn), SPAD value, relative SPAD values (RSPAD) and NPK contents of rice genotypes in Zn deficient and sufficient conditions were given in Table 1.

Table 1. Axis I and axis II values in zinc deficient and sufficient mediums in PCA

Characteristics	Zn deficient		Zn sufficient	
	Axis 1	Axis 2	Axis 1	Axis 2
StalkDW	-0,34	-0,3	-0,49	-0,03
StalkRDW	-0,05	-0,61	-	-
StalkZn	-0,38	-0,05	-0,33	-0,46
StalkRZn	-0,37	0,03	-	-
StalkRmZn	-0,38	-0,1	-0,48	-0,18
StalkRRmZn	-0,34	-0,29	-	-
SPAD	0,34	-0,16	-0,16	-0,58
NSPAD	0,35	-0,03	-	-
N, %	-0,13	0,27	0,29	-0,34
P, %	-0,22	0,47	-0,31	0,51
K, %	-0,19	0,36	-0,47	0,20

Results and Discussion

Grouping Genotypes According to Best Traits in The Zinc Deficient Medium

The growth characteristics of the 6 rice genotypes grown in sand culture under zinc (Zn) deficient conditions are given in Table 2. When Table 2 is examined, the tolerance index values for Zn deficiency, that is, the highest stalk dry weight (SDW), stalk Zn content (SZn), stalk relative Zn content (SRZn), stalk removed Zn (SRmZn) according to Zn sufficient plants (5 ppm Zn) under zinc deficiency conditions.) and stalk relative removed Zn (SRRmZn) were found in cultivar 5 (2.12 g/pot, 41.67ppm, 30.34%, 0.089ppm and 36.71%, respectively). The highest stalkNDW and SPAD values were in cultivar 3 (134.74% and 21.10%, respectively), the highest NSPAD value in cultivar 4 (119.38%), the highest N in cultivar 6 (1.52%), the highest P and K (0.21%, respectively). and 1.77%) were found in variety 2. The lowest stalkDW, stalkNDW and stalkNKZn were found in cultivar 2 (1.09g/pot, 69.22% and 13.69mg/pot, respectively). The lowest stalkZn, stalkNZn and stalkKZn values were found in cultivar 1 (15.33 ppm, 13.65% and 0.018 mg/pot, respectively) and the lowest SPAD and NSPAD values were found in cultivar 5 (14.03 and 64.37%, respectively). Accordingly, it was found that cultivar no 5 was the most suitable cultivar under the conditions of Zn deficiency in terms of the investigated properties.

Zinc active rice genotypes are genotypes that have the ability to grow despite the Zn concentration, which is generally thought to be insufficient in the soil. Therefore, it is of great practical importance for producers to determine the effective genotypes in zinc care. According to Dirasamy et al. (1988), researchers who applied 0, 10, 20 mg Zn kg-1 to the rice plant in sodium soil in a greenhouse experiment they conducted, determined that the Zn uptake in the stalk of the rice plant increased due to the increase in zinc application. Cayton et al., (1985) reported that rice genotypes that are tolerant of zinc deficiency in the soil may have lower Zn requirements or may translocate relatively more zinc from plant roots to shoots. Hoffland et al. (2006) reported that higher organic acid excretion rates were detected from the roots of genotypes tolerant to Zn deficiency (Hoffland et al., 2006). It has been reported that more Zn is transported from leaves to shoots as the physiological activity of Zn increases in many grains, including wheat, rye, barley, triticale, and oats (Çakmak et al., 1998). Nitrogen, phosphorus and zinc deficiency are the most common and economically important nutritional factors limiting rice growth and production (Neue and Lantin, 1994). Zinc deficiency is generally seen in sodic, calcareous and organic soils in rice-growing regions (Turan and Horuz, 2012).

Table 2. Biological index value and NPK content of paddy genotypes under the zinc deficiency conditions

Genotypes	SDW*	SRDW	SZn	SRZn	SRmZn	SRRmZn	SPAD	RSPAD	N	P	K
	g	%	ppm	%	mg/ pot	%	value	value	%	%	%
G1	1.17	103.39	15.33	13.65	0.018	14.11	18.30	97.34	0.69	0.06	1.49
G2	1.09	69.22	23.00	19.77	0.025	13.69	17.03	93.08	0.89	0.21	1.77
G3	1.35	134.74	18.00	14.63	0.024	19.72	21.10	107.84	0.37	0.05	1.16
G4	1.24	94.29	21.33	17.93	0.026	16.90	18.07	119.38	0.75	0.07	1.27
G5	2.12	120.98	41.67	30.34	0.089	36.71	14.03	64.37	0.97	0.15	1.61
G6	1.15	92.28	24.33	22.32	0.028	20.60	19.83	99.83	1.52	0.11	1.08

*SDW: Stalk dry weight:, SRDW: Stalk relative dry weight:, SZn: StalkZn:, SRZn: Stalk relative Zn, SRmZn: Stalk removed Zn, SRRmZn: Stalk relative removed Zn

Paddy genotypes in zinc deficient medium in terms of SDW 5 > 3 > 4 > 1 > 6 > 2, SRDW 3>5>1>4>6>2, SZn and SRZn 5>6>2>4>3>1, SRmZn 5> 6>4>2>3>1, SRRmZn followed a sequence as 5>6>3>4>1>2. In terms of leaf SPAD value, 3 > 6 > 1 > 4 > 2 > 5, NSPAD value 4>3>6>1>2>5 followed a sequence. The cultivars followed a sequence as 6>5>2>4>1>3, in terms of leaf N content, 2>5>6>4>1>3 in terms of P content, and 2>5>1>4>3>6 in terms of K content. . In the zinc deficient medium, the best variety was determined as the 5th variety. This was followed by the 3rd variety. .

8 biological index values and 3 nutrient content (11 features in total) of rice cultivars grown in sand culture under zinc (Zn) deficient conditions are grouped according to cultivars and the variation of the cultivars according to the investigated characteristics is given in Figure 1. When the table is examined, the characteristics and the distribution of the cultivars differed according to the cultivars. While SDW, SRDW, SZn, SRZn, SRmZn and SRRmZn, among 11 characteristics of paddy genotypes examined under zinc deficiency conditions, are in the same group; Stalk NPK contents were in a separate group and leaf chlorophyll SPAD and NSPAD values were in another group. Thomas et al. (2015) Bario reported that the K content of the brown rice variety was higher (197.41 mg/100g) in the grain of brown and white rice genotypes.

It was determined that cultivar no 5 was good cultivars in terms of SDW, SRmZn, SZn, SRZn under the conditions of zinc deficiency, while cultivar no. 3 was determined to be good cultivars in terms of SRDW, SRRmZn characteristics. Similarly, it was determined that the leaf chlorophyll NSPAD value of the cultivar no. 1 and the cultivar no 4 were better in terms of SPAD value, but the cultivars no. 1, 4 and 6 were found to be good cultivars in terms of both NSPAD and SPAD values. It has been determined that the 2nd variety is bad in terms of all characteristics. Accordingly, it was determined that cultivar 5 was the most suitable cultivar, followed by cultivar 3, and cultivars 1, 4, 2, and 6 were the most sensitive cultivars in terms of the investigated characteristics.

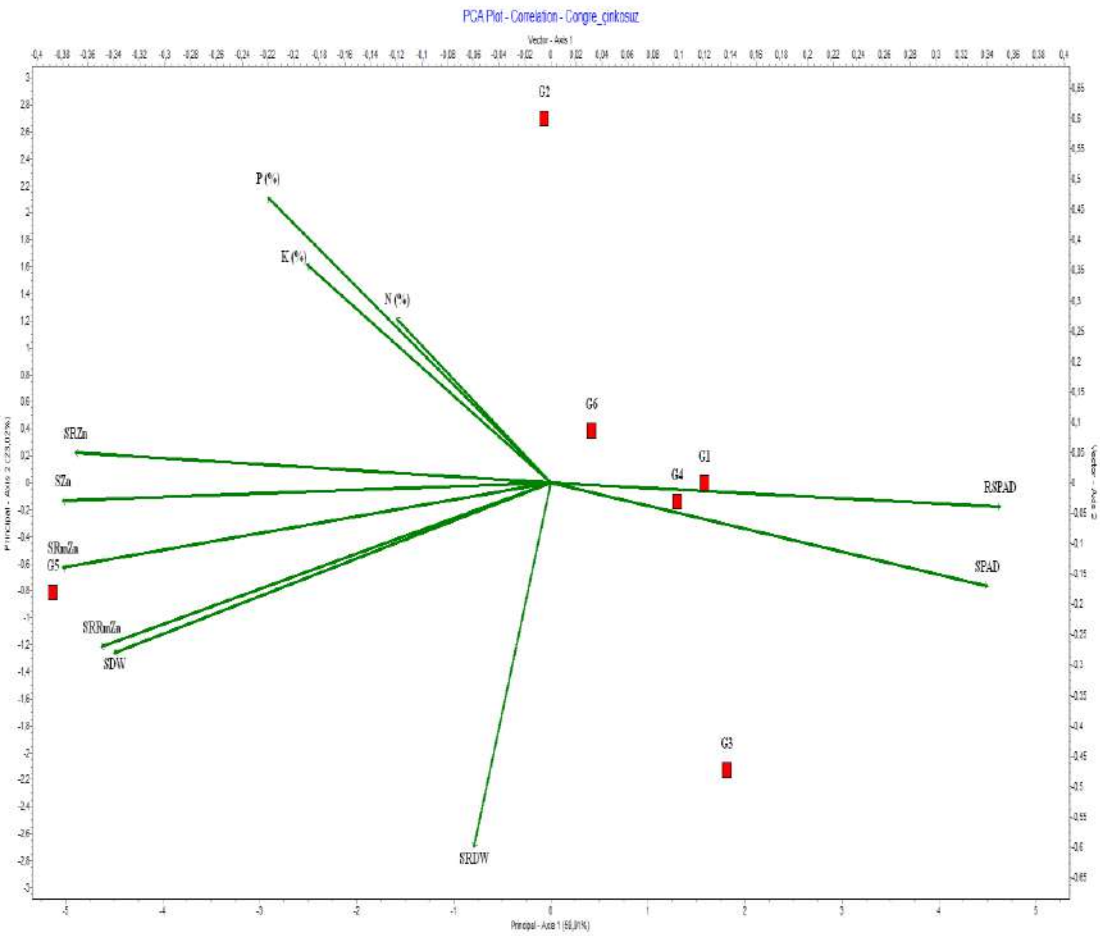

Figure 1. Biological characteristics of rice genotypes under zinc deficient conditions, stalk dry weight (SDW), stalk relative dry weight (SRDW), stalk Zn content (SZn), stalk relative Zn (SRZn), stalk removed Zn (SRmZn), stalk relative removed Zn (SRRmZn) leaf chlorophyll SPAD and NSTALKD values and their effects on NPK were determined (axis I: 60.18 and axis II: 22.68).

Grouping Genotypes According to Best Traits in The Zinc Sufficient Medium

Paddy genotypes grown in sand culture zinc (Zn) sufficient medium were grouped according to their best characteristics into the examining their 7 characteristics, including 4 biological index values and 3 nutrient content. The biological index values and nutrient content of these properties are given in Table 3.

Table 3. Biological index values of rice genotypes under the zinc sufficient conditions

Genotypes	SDW*	SZn	SRmZn	SPAD value	N	P	K
	g	ppm	ppm		%	%	%
G1	1.13	112.33	0.127	18.80	0.77	0.12	1.41
G2	1.58	116.33	0.184	18.30	0.27	0.14	1.67
G3	1.00	123.00	0.123	19.57	0.71	0.03	1.19
G4	1.31	119.00	0.156	15.13	0.85	0.12	1.23
G5	1.76	137.33	0.241	21.80	0.77	0.11	1.56
G6	1.25	109.00	0.136	19.87	1.13	0.09	1.13

* SDW: Stalk dry weight:, SZn: Stalk Zn, SRmZn:Stalk removed Zn

When Table 3 is examined, the highest plant SDW, SZn content, SRZn and leaf chlorophyll SPAD values are in cultivar 5 (1.76 g/pot, 137.33 ppm, 0.241 mg/pot and 21.80, respectively), and the highest N content is in cultivar 6 under Zn sufficient ambient conditions. (1.13%), the highest P and K contents were found in cultivar 2 (0.14% and 1.14%). The lowest stalkDW is in cultivar 3 (1.00 g/pot), stalkZn content in cultivar 6 (109.00 ppm), stalkKZn content in cultivar no. 3 (0.123 mg/pot), SPAD value in variety no. 4 (15.13), stalk N content in variety no.2 (50.27), stalk P content was found in cultivar 3 (0.03%) and stalk K content in cultivar 6 (1.13%). In zinc sufficient conditions, cultivars 5 > 2 > 4 > 6 > 1 > 3, SZn content 5>3>4>2>1>6, SRmZn 5>2>4>6>3>1, SPAD value 5>6 >3>1>2>4, N content 6>4>5=1>3>2, P content 2>4=1>5>6>3 and K content 2>5>1>4>3>6 followed a sequence. It was determined that variety 5 showed the best performance in all biological indices. Therefore, the best variety was determined as the 5th variety under sufficient conditions for Zn. It was determined that variety no. 6 was better in nitrogen content, variety no. 2 in P and K content. Hirasawa et al. (2010) stated that Aikoku, Asonihikari and Takanari rice cultivars, Takanari cultivars, have higher K content than the others in terms of NPK content in zinc sufficient conditions. Researchers also reported that the stomatal conductivity of the Takanari rice cultivar increased significantly with the increase in the stalk nitrogen content. Nitrogen in particular significantly affects crop production by affecting photosynthetic efficiency in rice (Yang et al., 2016). In a study conducted in Japan in a zinc sufficient medium, it was found that rice genotypes had higher N, P and K contents compared to zinc deficient conditions (Tsunada et al., 1953).

The classification of the cultivars according to the characteristics and the changes in the cultivars according to the examined characteristics are given in Figure 2. When Table 2 is examined, the characteristics and the distribution of the cultivars differed according to the cultivars. While stalkDW, StalkZn, stalkKZn and leaf chlorophyll SPAD values, which are among the 7 characteristics examined, belong to the same group under zinc sufficient mediumal conditions; The stalk K and P content were in a separate group and the stalk K content was in a separate group. While it was determined that cultivar no 5 was the best cultivar in terms of stalkDW, StalkZn, stalkKZn and leaf chlorophyll SPAD values under zinc sufficient medium conditions; It was determined that cultivar no. 2 was the best variety in terms of stalk P and K content, and cultivar no. 3 and 6 in terms of N content. Rana and Kashif (2014) reported that different zinc sources ($ZnSO_4.7H_2O$, ZnO and Zn-EDTA) applied to the soil increased SPAD values in fresh leaves of rice plants compared to those grown in control application (Zn:0). It has been determined that cultivar 5 is the most suitable cultivar under Zn sufficient medium conditions in terms of the investigated properties, followed by cultivars 3 and 2. It has been determined that the most sensitive cultivars under the conditions of zinc deficiency are the cultivars 1, 4 and 6.

Conclusion

It was determined that G5 variety showed the best performance in terms of dry weight and Zn uptake, G3 genotypes had medium performance, and G1, G2, G4 and G6 genotypes were sensitive to Zn in terms of dry weight and Zn uptake. . It has been suggested that similar studies are repeated with different plants in the soil medium, and that genotypes resistant to Zn deficiency are determined for each plant genotype and added to the production and food chain.

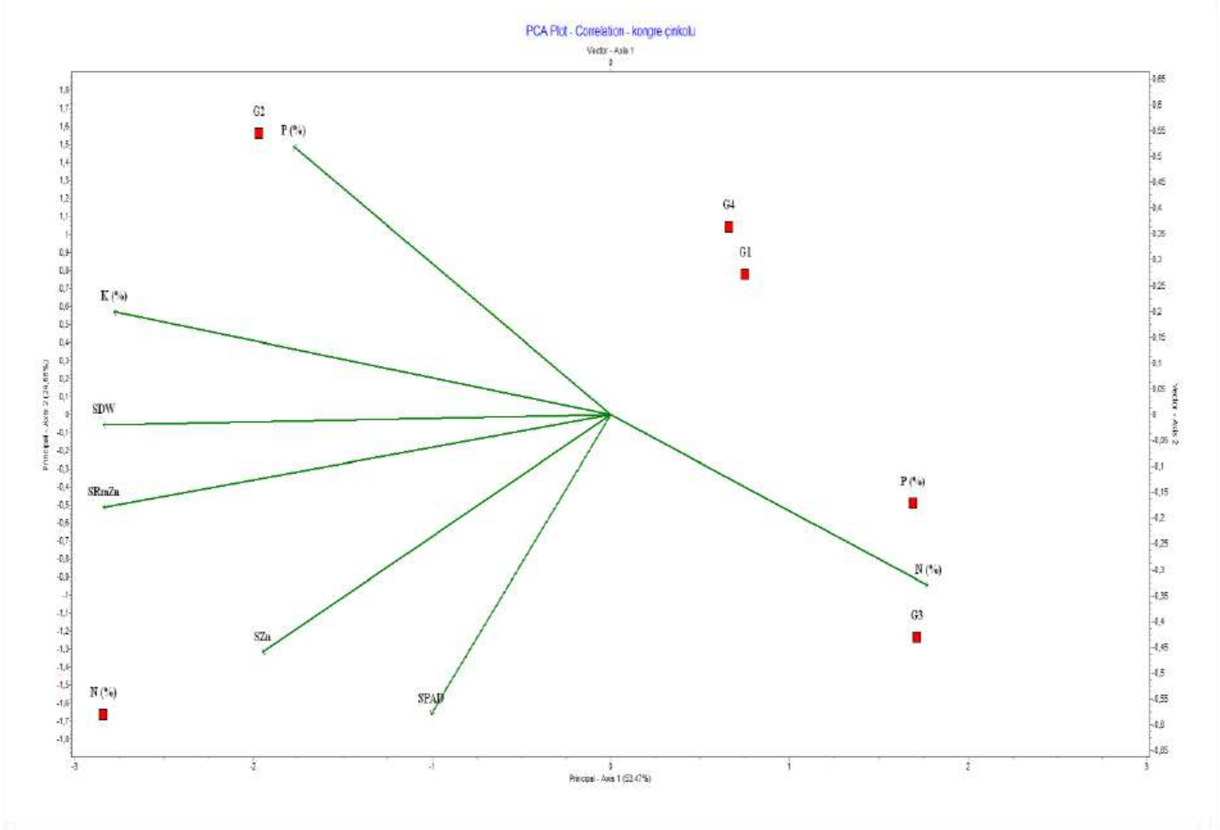

Figure 2. The relationships between the biological characteristics of rice genotypes and under the zinc sufficient medium. Stalk dry weight (SDW), stalk Zn content (SZn), stalk removed Zn (SRmZn) and leaf chlorophyll SPAD and NPK values (axis I: 53.06 and axis II: 24.63)

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Overview of heavy metal contamination in urban soil and impact on human health

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Abstract

This paper examines heavy metals contamination research, as well as the relationship between urban soil and human health. The results demonstrate that heavy metals (Ni, Cu, Cr, Zn, Pb and Cd) concentrations are higher than their geochemical background. The level of contamination varies due to pollutants from traffic and industrial regions, as well as unplanned land use schemes. Heavy metal use by ingestion, inhalation, and skin contacts causes both carcinogenic and noncarcinogenic disorders in humans. As a result, adequate urban soil management should be implemented for eco-friendly and sustainable development and consumption.

Keywords: Health risk, heavy metals, policy and management, urban soils

Introduction

Accumulation of heavy metals in urban soils have been a major source of concern, owing to their non-biodegradability and extended biological half-lives for removal from the body (Odewande & Abimbola, 2008). It is a peculiar phenomenon that urban soils are first a recipient of pollution and then become a source of pollution (Kumar K., Hundal L., 2016). Metal-polluted soils can endanger human health, the soil microbial biomass, aquatic ecosystems (surface and ground), quality of food, and biodiversity (Chabukdhara & Nema, 2013).

According to (Li et al., 2018), several research has found heavy metal contamination in urban soils, which has been linked mostly to industrial enterprises, traffic, and mining operations in urban areas. When compared to naturally developed or weakly anthropogenic impacted soils, urban soils can vary considerably over short ranges. The majority of urban soils are quite young, the result of soil exchange and combination caused by construction operations. Because urban landscapes are complex in character and include various sources of heavy metals, it is a challenge in determining the quantity and degree of metal pollution.

The main objective of this paper is to assess the concentration of heavy metal in urban soil and the health risk associated with urban soil contamination.

Urban Soils

Urban soils known sometimes as anthropogenic soils is considered where the human influence is greater and natural characteristics have frequently receded. In varied environments, such as parks, gardens, roadsides, and turf areas, urban soils sustain a diverse variety of recreational plants. Though it is referred that urbanization has many benefits (healthcare, sanitation, and transportation), this process converts the natural landscape posing a great threat to ecosystem and human health. The most visible difference in urban and natural soil is the structural change caused by urban soil usage resulting soil hardening which limits to reduce pollution, hydrological cycling, energy balance and increase in organic (polychlorinated dibenzo-p-dioxine (PCDD), polychlorinated biphenyl's (PCBs), Polycyclic aromatic hydrocarbons (PAHs), Dichloro-dipphenyl-tricholoroethane (DDT) and inorganic pollutants (Cd, Cr, Ni, Pb, Cu, Zn). In addition to this, it reduce the available soil moisture content in soil, waterlogging caused of poor soil infiltration, and impact on soil microbial diversity (De Kimpe, Christian R.; Morel, 2000; Fabietti et al., 2010; J. Saha et al., 2017).

Pollution Sources of Heavy Metals

According to Li et al. (2018), levels of heavy metals were high in industrial and urbanized cities, where metals were deposited by traffic exhaust, power stations, and industrial operations. Collected available data of different cities around the world from different studies shows higher content of Cu, Zn, Ni, Pb and Cd than As, Hg and Cr.

Soil accumulates Cd, Cu, Pb, Zn and Ni due to the exhaust emission, wear of tires and brake abrasion. They can enter into soil via wet and dry deposition. From coal burning sites As, Cr, Hg, Ni, Pb and Zn can enter into soil. In steel industrial site contamination of Cd, Pb, Cu and Zn are most. In China, Nigeria and UK concentration of Cu found highest. In New York and in Kuala Lumpur, Seoul Pb found highest whereas in Athens Zn is large (Table 1). In Bangladesh, Cr is the largest compound found in Dhaka city (Hanfi & Yarmoshenko, 2020; Islam et al., 2020; Li et al., 2018).

Krakow, is one of Poland's largest cities, with a population of almost one million people. The typical urban landscapes of central and eastern Europe are characterized by rapidly increasing car traffic and industrial expansion (Jasek et al., 2013). According to (Gąsiorek et al., 2017), industrial and economic waste, vehicle exhaust, industrial pollution are the causes of Cd, Cu, Pb and Zn pollution found in the Planty Park; a historic green park surrounding the historic centre of Krakow.

Table 1: Concentration of heavy metal (mg kg^{-1}) in urban soils in different cities around the world (Hanfi & Yarmoshenko, 2020).

City	Country	Cu	Pb	Zn	Ni	Cd
New York	USA	356	2583	1811	NC	8
Athens	Greece	NC	121	125	128.5	2.4
Kuala Lumpur	Malaysia	NC	2466	344	NC	3
Seoul	Korea	101	2582.5	1811	NC	3
Various Sites	Nigeria	12	111	31	1.9	0.7
Istanbul	Turkey	152	184	477	30.4	2.1
Oslo	Norway	123	182	412	41	1.4

*NC – Not considered

Human Helath Risks of Pollutants in Urban Soils

As it is not possible to be unexposed to urban soil so it is very important to find out the possible hazard to human health. Heavy metals can be exposed to human body via two ways: soil-human and soil-plant-human pathway. The intake of heavy metals could be done in three ways: inhalation, ingestion and dermal contact and the result could be carcinogenic or non-carcinogenic disease. Due to increasing environmental pollution and accumulation of heavy metals in agricultural lands human are exposed to heavy metals via ingesting and inhaling heavy metals (Chabukdhara & Nema, 2013; Li et al., 2018). Negative effects of heavy metal toxicity are presented in Table 2.

Table 2: Health hazards of heavy metal exposure

Metal	Toxicity	References
Cr	Kidney and liver damage, skin rash, stomach ulcer, lung cancer, alternation of genetic materials	(Parvin, Rashida & Sultana, Afroza & Zahid, 2014)
Cd	Nausea, vomiting, abdominal cramps, muscular weakness, pulmonary and renal effects. Itai-Itai disease in Japan caught the attention worldwide about the danger of Cd toxicity.	(Singh & Kalamdhad, 2011)
Hg	Miscarriage in pregnant women, reduce kidney function, male infertility	(Nigam et al., 2016)
Pb	Neurobehavioral problems, impulsivity, impaired hemoglobin synthesis, renal function problem, blindness	(Simul Bhuyan, 2017)
As	Skin lesion, diabetes mellitus, skin cancer, high blood pressure	(Smith et al., 2000)
Cu, Zn, Ni	Anemia, liver and kidney damage, intestinal irritation, birth defects, cancer	(Wuana & Okieimen, 2011)

Urban Soil Management and Policy

In order to maintain an eco-friendly urban ecosystem, effective management of urban soils is crucial. As urbanization has many negative impacts on environment a proper legislation regarding land use land use planning management is required. For example, establishing industrial areas far from the city or allocating agricultural lands, in less polluted areas could be a solution. China and Germany published urban soil management strategy for monitoring, risk assessment and remediation of contaminated urban area; application of nanotechnology, phytoremediation, biochar etc. Unfortunately, remediation of soil is expensive. Thus, precise soil management and land use planning might provide economical strategies to reduce the risk of soil pollution and human health hazards.

Another method of preserving soil quality and preventing degradation is to develop a soil policy. Work must be done to build a soil policy framework directed to urban soils having distinct features and environmental services (Li et al., 2018; Saha et al., 2014)

Conclusion

Rapid urbanization causes heavy metal contamination in urban soil and possess a great threat to human health. Intensity of pollution varies from country to country, from city to city in individual countries depending on population, industries, and transportation management. So, it is the high time to focus on developing urban soil management guidelines with an urban land use management policy to provide a sustainable and less polluted environment to future generation.

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Effect of organic waste and polymer applications on some mechanical parameters of soils

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Abstract

This study was carried out to determine the effects of wheat straw (WS), hazelnut husk (HH), humic acid (HA) and polyacrylamide (PAM) treatments on some mechanical soil parameters (shrinkage limit (SL) and COLE-clod) in two soils with sandy loam and clayey loam in texture. Soil samples used in the study were taken from two different areas of land (0-20 cm) from Samsun province's Bafra district. WS (0, 2%, 4%), HH (0, 2%, 4%), HA (0, 200 and 1000 ppm) and PAM (0, 30 and 90 ppm) were used in this study that was conducted in a split plots experimental design with three replications. After a five-month incubation period, wheat plants were grown in pots. After the harvest of the wheat plant, analyzes and evaluations were made on some mechanical soil parameters in the soils. According to our evaluation results; organic regulator and polymer applications to the soils mostly increased the shrinkage limit values and of the soils and decreased the COLE-cloud values. The effectiveness of the applications varied according to the soil properties and application doses.

Keywords: COLE-clod, hazelnut slag, humic acid, PAM, shrinkage limit , wheat straw

Introduction

Changes in soil moisture can alter soil mechanical behaviors through cracking, swelling-shrinking, crust formation and jamming, which are critical for soil management. Evaporation of the water in the soil pores and cracks in the profile depth during the swelling shrinkage process cause damage to the plant roots, deteriorate the water and air balance of the soil, increase moisture loss, decrease efficiency of irrigation water and deteriorate the soil structure (Sönmez and Öztaş, 1988; Dengiz and Gursoy, 2019).

To reveal effect or contribution degrees of factors such as clay mineralogy, soil water's chemistry, soil structure, soil permeability, soil consistency, dry unit weight, initial moisture condition and moisture changes, which are effective on swelling and shrinkage potential in the soil, creation of a suitable plant development environment, very important in terms of reducing water losses and controlling erosion's (Nelson and Miller, 1992). Soil organic matter and synthetic polymers can have significant effects or contribution in this direction (Yakupoğlu, 2010; Özdemir et al., 2016).

Organic matter is a source of nutrients for soil micro-organisms, significantly affects the physical and biological properties and fertility of the soil, and increases the water holding capacity of the soil. Organic matter, which affects the better aeration and warming of the soil, also shapes the soil structure. Soil organic matter is a good store of most plant nutrients and is closely related to the activity of soil microorganisms (Ergene, 1982; Andiç, 1993). Due to the difficulty of maintaining the continuity of organic materials in the soil and the long decomposition period in the soil, organic-based synthetic soil conditioners are an alternative in this direction (Özdemir et al., 2016).

On the other hand, Malongweni et al. (2019) investigated the healing effects of agricultural residues on cracking and swelling shrinkage properties in soils with expanding clays. Researchers used non-carbonated rice husk, rice husk biochar, unprocessed sugarcane meal and sugarcane meal biochar. Results indicated that the applications improved the physico-mechanical properties of the soil; they reported that the applications reduced the COLE-clod, crack size and crack area density. Civelek and Özdemir (2021), in a study they conducted in a similar direction, found that organic waste and polymer applications reduce the swelling and shrinkage potential of the soil and their regulatory effectiveness is more pronounced in fine textured soils.

Abdi et al. (2008) investigated the effect of polypropylene fiber added to soils consisting of 75% kaolinite and 25% montmorillonite on mechanical soil properties. Result indicated that the swelling, shrinkage and consolidation of the samples decreased based on the application dose of fiber reinforcement, and the hydraulic conductivity value and the shrinkage limit increased as the fiber amount and length increased.

In this study, the effects of organic waste and synthetic conditioner applications on soils on COLE-clod and shrinkage limit values were investigated.

Material and Methods

Material

This study was carried out on soil samples taken from the Bafra application area of Samsun Ondokuz Mayıs University and the Black Sea Agricultural Research Institute's Bafra experimental field and its surface (0-20 cm). In the study, wheat straw (WS) and hazelnut husk (HH) were used as organic waste, while humic acid (HA) and polyacrylamide (PAM) were used as synthetic conditioners. Organic wastes were used by passing through a 2 diameter sieve. These wastes and conditioners were obtained from different institutions and organizations. Some chemical properties of organic wastes used in the study are given in Table 1. The wheat straw used in the study has 53.46% organic C and 0.65% total N content, and its C/N value is 82.25. The pH and P contents of wheat straw were determined as 5.69 and 2055.00 ppm, respectively. Hazelnut husk has 46.93% organic C, 1.86% total N content, and its C/N ratio is 25.23. The pH and P contents of the hazelnut husk are 6.16 and 6291.52 ppm, respectively. The applied PAM is of technical quality, and HA is a commercially available material containing 15% active substance.

In the study carried out under greenhouse conditions as a pot experiment and in a split plots experimental design, organic residues (0, 2% and 4%); humic acid (0, 200 and 1000 ppm) as a synthetic conditioner; and PAM (0, 30 and 90 ppm) were used with three replications. During the experiment, the air temperature was kept between 25-30 0C with the air conditioner and irrigation was done when fifty percent of the available moisture in the pots was exhausted. Soil samples were incubated for five months and wheat plants were grown in pots after the incubation period. After the wheat plant was harvested (3 months), the relevant analyses were made on the soil samples.

Table 1. Some chemical properties of organic wastes used in the study

Organic waste	pH (1:10)	EC (1:10) dS m^{-1}	O.C (%)	TOTAL N (%)	C/N	Ash (%)	P (%)
WS	5.69	2.848	53.46	0.65	82.25	7.84	0.205
HH	6.16	2.058	46.93	1.86	25.23	19.09	0.629

WS: wheat straw, HH: hazelnut husk, OC: organic carbon

Methods

The particle size distributions of soils were determined by the Bouyoucos hydrometer method (Gee et al., 1986); the soil reaction (pH) in a 1:2.5 soil-water suspension with a pH meter (Rowell, 1996); the electrical conductivity in soil water suspension with a glass-electrode electrical conductivity meter (Bayraklı, 1987); the lime content of soils by measuring the volume of CO2 gas released due to hydrochloric acid treated with CaCO3 using Scheibler calcimeter (Kacar, 1994); and the organic matter contents were determined by the Walkley-Black method (Nelson and Sommers, 1983) based on the oxidation of organic carbon.

COLE-clod

This value was determined by the assumption that dimensional changes that will occur along the three axes will be equal to each other and with the help of the equation below (Grossman, et al., 1968).

$$\text{COLE-clod} = [(Vm/Vd)^{1/3}] - 1$$

Here;

Vm: volume of moist soil clod,

Vd: volume of soil clod dried under atmospheric conditions,

Shrinkage limits (SL)

Shrinkage limits (SL) value was calculated using the dry weight values determined by placing the soil paste containing moisture close to the degree of saturation in an evaporation container so that no air bubbles, smoothing the surface and drying it under atmospheric conditions, taking its measurements and drying it in an oven and with the help of the equation below (ASTM, 1974).

SL= [w-((V-V0) / W0)]*100

Here;

SL: Shrinkage limits; %

w: Moisture content of wet soil, %

V: Volume of wet soil mold, cm3

V0: Volume of soil mold dried under atmospheric conditions, cm3

W0: Mass of kiln dry soil mold, gr

The statistical evaluation of the data obtained as a result of the research was performed using the Minitab computer package program. The Duncan test was used in multiple comparisons (Minitab, 2013).

Results and Discussion

Soil Properties

Some physical and chemical properties of the soils studied are given in Table 2. As can be seen from the examination of this chart, the research soils have clayey loam and sandy loam texture. The lime content of clayey loam soil is 7.24%, organic matter content is 2.09%; the lime content of soil with sandy loam texture was determined as 17.92% and organic matter content as 1.06%. COLE-clod, shrinkage limit are measured as 96.10, 26.76% for clayey loam soil and as 23.50, 22.68% for sandy loam soil, respectively.

Table 2. Some characteristics of the soils used in the research

	Soils	
	OMU	BSARI
Sand%	59.42	23.86
Silt%	29.88	42.30
Clay%	10.70	33.82
Texture Class	SL	CL
pH (1:2.5)	7.96	7.59
EC dS m^{-1} (1:2.5)	0.418	0.425
$CaCO_3$, %	17.92	7.24
OM, %	1.06	2.09
COLE-clod	23.50	96.10
Shrinkage limit, %	22.68	26.76

$CaCO_3$: lime content, OM: organic matter content, EC: electrical conductivity, OMU: Ondokuz Mayıs University's Bafra Experimental Field, BSARI: Black Sea Agricultural Research Institute's Bafra Experimental Field

Swelling-shrinkage Parameters

COLE-clod

In the study carried out under greenhouse conditions, the changes in the COLE-clod values were determined after harvest in soils that were mixed and incubated with the different doses of conditioners (WS, HH, HA and PAM) and where wheat plants were grown are shown in Figure 1. As can be seen from this Figure, the applied conditioners provided significant decreases in COLE-clod values. These decreases were higher in the samples from Black Sea Agricultural Research Institute's Bafra Experimental Field with high clay (33.82%) and organic matter content (2.09%) and low lime content (7.24%). COLE-clod values ranged between 16.20-96.10, with the lowest COLE-clod value recorded in the soil with sandy loam texture and in the third dose application of the wheat straw conditioner, and the highest COLE-clod value recorded in the control soils (D1 doses) and in the soil with clayey loam texture. Moreover as can be seen in Figure 1, organic residues were more effective in reducing the COLE value in both soil textures than the synthetic regulators.

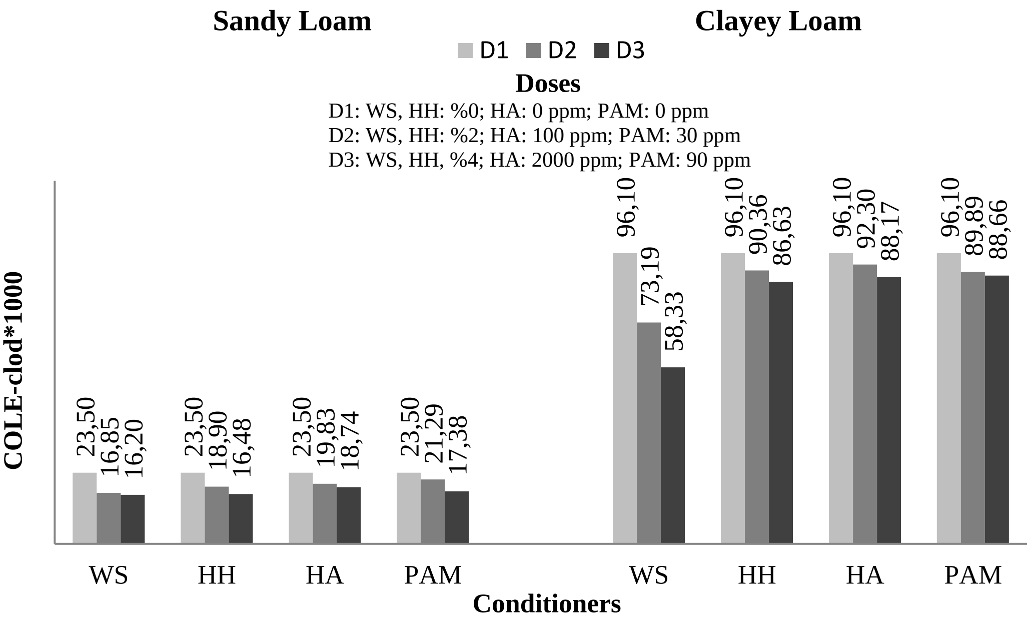

Figure 1. Changes in the COLE-clod values due to applications compared to control

(WS: wheat straw, HH: hazelnut husk, HA: humic acid, PAM: polyacrylamide)

According to the results of variance analysis, the effect of the mean squares of soils, conditioner types and application doses on the change in the COLE-clod values of the study soils ($p<0.01$) was found to be significant. The Duncan multiple comparison test results, which were conducted to examine the conditioner types and the effectiveness of the applied doses, are given in Table 3. As can be understood from the examination of these data, the effectiveness of wheat straw on the COLE-clod value of the soils is the highest, and the effectiveness of the humic acid conditioner is the least; and it was determined that the COLE-clod values decreased with the higher dose levels.

Significantly negative correlations were detected at the level of 1% between COLE-clod values and lime content (-0.944**), pH (-0.558**) and organic matter content (-0.552**) values of soils. According to a study, Moustakas (2012) determined that positive relationships between the COLE-clod value and the clay content and cation exchange capacity in Vertisol soils.

Table 3. Duncan test results on the effects of soils mixed with different doses of conditioners on COLE-clod values

Conditioners	WS	HH	HA	PAM
COLE-clod	47,3606^{a}	55,3283^{b}	56,4406^{c}	56,1383^{c}
Doses	D1	D2	D3	
COLE-clod	59,8017^{a}	52,8258^{b}	48,8233^{c}	

(Averages denoted by individual letters differ according to Duncan multiple comparison test)

Shrinkage Limit

In the study carried out under greenhouse conditions, the changes in the shrinkage limit values were determined after harvest in soils that were mixed and incubated with the different doses of conditioners (WS, HH, HA and PAM) and where wheat plants were grown are shown in Figure 2. As can be seen from this Figure, except for PAM applications in sandy loam textured soil, the applied conditioners provided significant improvements in shrinkage limit values. These increases were higher in the samples from Ondokuz Mayıs University's Bafra Experimental Field with high sand (59.42%) and lime content (17.92%) and low organic matter content (1.06%). SL values ranged between 22.38-29.57%, with the lowest SL value recorded in the soil with sandy loam texture and in the third dose application of the PAM conditioner, and the highest SL value recorded in the third dose application of PAM in the soil with clayey loam texture. As can be seen in Figure 2, while organic residues were more effective in increasing the shrinkage limit values in sandy loam soil, synthetic regulators were more effective in clayey loam soils.

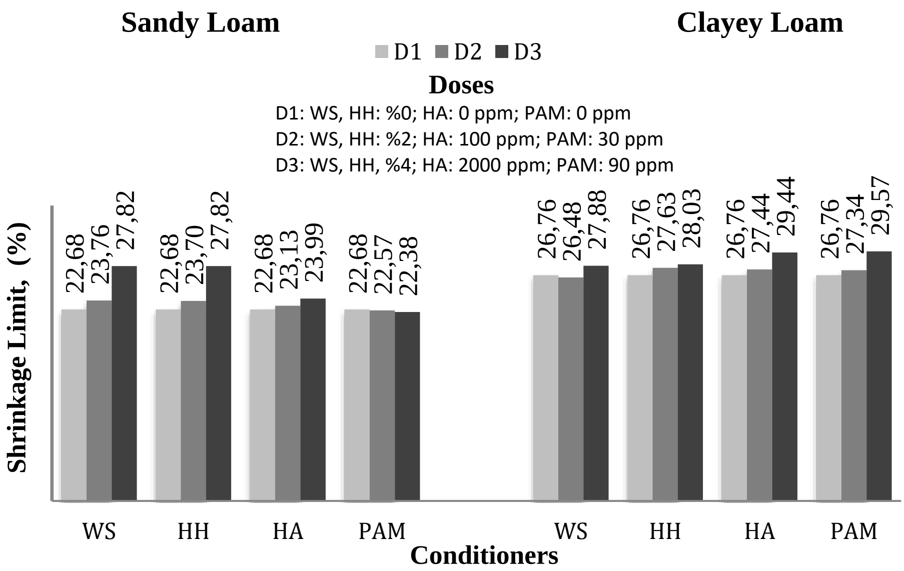

Figure 2. Changes in the shrinkage limit values due to applications compared to control

(WS: wheat straw, HH: hazelnut husk, HA: humic acid, PAM: polyacrylamide)

According to the results of variance analysis, the effect of the mean squares of soils, conditioner types and application doses on the change in the shrinkage limit values of the study soils ($p<0.01$) was found to be significant. The Duncan multiple comparison test results, which were conducted to examine the conditioner types and the effectiveness of the applied doses, are given in Table 4. As can be understood from the examination of these data, the effectiveness of hazelnut husk on the shrinkage limit value of the soils is the highest, and the effectiveness of the PAM conditioner is the least; and it was determined that the shrinkage limit values increased with the higher dose levels.

Significantly negative correlations were detected at the level of 1% between SL values and lime content (-0.805**) and pH (-0.564**) values of soils, while significantly positive correlations were found at the level of 1% between SL values and the organic matter content (0.738**). Considering relevant studies, Zong et al. (2014) wheat straw, wood chips and rice husk biochar, Tiwari et al. (2016) polypropylene, Hemmat et al. (2010) determined that the shrinkage limit values of the soils increased as a result of the addition of solid waste compost, sewage sludge, farm manure and inorganic fertilizer to the soils.

Table 4. Duncan test results on the effects of soils mixed with different doses of conditioners on shrinkage limit values

Conditioners	WS	HH	HA	PAM
Shrinkage limit, SL	25,8956^{bc}	26,1033^{c}	25,5733^{ab}	25,2561^{a}
Doses	D1	D2	D3	
Shrinkage limit, SL	24,7200^{a}	5,2567^{b}	7,1446^{c}	

(Averages denoted by individual letters differ according to Duncan multiple comparison test).

Conclusion

In this study, in which changes in the shrinkage parameters were examined with the addition of WS, HH, HA and PAM in clayey loam and sandy loam textured soil samples; it has been observed that the aforementioned conditioners added to the soils cause mostly increases in the SL values and decreases in the COLE-clod values. It has been found that mostly organic residues are more effective than synthetic regulators on swelling parameters. The effectiveness of conditioners depends on their own characteristics, and the texture, lime and organic matter content of soils, as well as on the application dose.

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Effect of water stress related with soil properties on plant growth

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Abstract

Stress is an environmental factor that negatively affects the growth and development of plants. The plant takes various plant nutrients from the soil with its roots during the growth and development period, but if there is not enough water in the environment, it becomes difficult for the plant to take the nutrients. Water stress in plants occurs when the amount of water in the soil is low and transpiration is high, and it causes the plant to not be able to fulfill its normal vital functions and to loss of crops. The decrease in water resources due to climate change and the resulting lack of irrigation water negatively affect the development and yield of the plant. However, this may change depending on the type of plant grown and soil characteristics. Soil quality should be increased in order to reduce the negative effects on plant growth due to water stress. Increasing the organic matter content of the soil is one of the most frequently applied methods in improving soil quality. Soil organic matter not only improves the physical and chemical properties of the soil, but also helps to keep the useful water required for the plant in the soil by keeping the water in the soil. In this article, information is given about the effects of organic matter applied to plants grown under water stress conditions on soil quality and yield.

Keywords: Water stress, soil quality, organic amendments, yield.

Introduction

Plants require optimum conditions in every aspect during their growth and development period. When any of environmental factors such as; temperature, salinity, water, pH, porosity etc. is not at an optimum level for the plant, it causes a negative condition for plants and this negatively affects the growth, development and yield of plants (Calanca, 2017; Yadav et al. 2020). Recently there is a reduction in precipitation due to climate change; in this case water deficiency becomes more important for plants. Water is very important for plant growth and yield. The opening and closing of stomata, photosynthesis depends on the presence of water. When there is no water in the environment, none of these will happen, and the plant cannot take the necessary plant nutrients from the soil. Soils are characterised by poor structure, low organic matter content, and low levels of microbial activity which makes them susceptible to external stresses associated with climate change and management practices such as tillage (Hoyle and Murphy 2006; Fisk et al. 2015). Mickan et al (2019) studied how soil disturbance and soil water deficit alter colonisation of roots by naturally occurring arbuscular mycorrhizal fungi and rhizosphere bacteria. They found that mycorrhizal colonisation and plant growth were reduced by disturbance under water stress but not for wellwatered soil cores.

Plants absorb various plant nutrients from the soil through their roots in order to grow and develop. But in order to do this, the presence of water is required in the environment. If there is not enough water in the environment where the plant grows, it becomes difficult for the plant to take the nutrients from the soil. Water stress in plants occurs when the amount of water in the soil is low and transpiration is high. In order for the plant not to experience water deficiency, the amount of water in the soil must be kept within the soil. Power (1983) reported that water use efficiency generally improves as the availability of plant nutrients increases, as long as enough water is available to provide reasonable growth rates and water use efficiency increases with level of fertility, but often the greatest increases come from fertilizer rates below optimum for maximum yield. In this paper effect of water stress on plant growth related with some soil properties are reviewed.

Results and Discussion

Stress and Water Stress in Plants

Stress is an environmental factor that negatively affects the growth and development of plants. Stress factors may appear in different periods in plant life and give different results depending on the plant species. Stress is an adverse change in environmental conditions that can reduce or reverse plant growth or development. Levitt (1980) defined the ability of a plant to survive against unfavorable environmental conditions as "stress endurance" or "stress resistance". Stress factors faced by the plant can lead to loss of yield and quality in the products produced by the plant, and can also cause the death of the plant if the necessary precautions are not taken.

Plants may face various stress factors throughout their lives. These stressors are divided into two groups as abiotic and biotic.

I) Abiotic stress factors can be classified as physically or chemically;

Physically ; drought, salinity, high or low temperature, radiation, plant nutrients, light, flooding, wind, snow etc.

Chemically; air pollution, plant nutrients, pesticides, toxins, salts, soil pH, etc.

II) Biotic stress factors are pathogens, wild plants, insects, microorganisms, animals, etc.

Water stress in plants is a situation where the amount of water in the soil is low and transpiration is high. Water stress significantly reduces the growth and division of plant cells (Farah, 1981). As a result, it causes the plant's above-ground organs to shrink proportionally (Neuman et al., 1988; Sakurai and Kuraishi, 1988).

When the plant is under water stress;

- Yellowing and later shedding of the leaves are seen.
- The stomata close.
- The formation of photosynthesis slows down,
- The root of the plant begins to extend into the depths to reach the water,
- Wax accumulation on the leaf surface increases.

Water stress induces a decrease in leaf water potential and in stomatal opening. Water stress directly affects rates of photosynthesis due to the decreased CO_2 availability resulted from stomatal closure (Flexas et al., 2006; Chaves et al., 2009). Osakabe et al. (2014) reported that there are several molecular mechanisms involved in the plant responses to water stress. Managing these mechanisms including stomatal responses, ion transport, activation of stress signaling pathways, and responses to protect photosynthesis from injury may help to improve plant productivity during water stress.

Under water stress condition, leaf growth is more affected than photosynthesis and transport of assimilates. For this reason, plants such as pasture crops, silage crops, tobacco and vegetable crops, are more sensitive to water deficiency than plants that use their generative organs (Begg and Turner, 1976). The water stress seen in the vegetative development period of these plants, whose leaves are used, significantly reduces the yield. Drought stress in the generative period affects the yield more than the vegetative period in plants whose generative organs are used. For example, water stress seen during the flowering period of determinate annual plants such as corn and wheat reduces the yield significantly (Begg and Turner, 1976; Robertson and Giunta, 1994).

Soil properties and plant growth under water stress

Plant growth under water stress conditions are greatly influenced by the soil physical and chemical properties. Continuous soil water deficiency decreases nutrient mobility, alters soil structure by reducing water-filled pore space, and consequently increases the volume of air-filled soil pores and nutrient concentrations in the residual water (Schimel et al. 2007; Fuchslueger et al. 2014; Moyano et al. 2013). Gülser and Kızılkaya (2020) studied the relationships between water use efficiency and yield parameters of wheat grown at 25%, 50% and 100% of available water capacity (Table 1). They found that while the amount of total irrigation water reduced from 378 mm (100% AWC) to 286 mm (50% AWC) and 249 mm (25%AWC), the plant parameter values decreased as 14,5% and 23.0% in plant height, 37,3% and 56,1% in total biomass, 31,5% and 53,3% in grain yield, respectively. They concluded that soil moisture level is an important factor for plant growth, and also water use efficiency, plant growth and yield values decrease with reducing photosynthesis rate due to decreasing soil moisture level.

Table 1. Effects of different irrigation levels at plant available water contents on wheat growth parameters (Gülser & Kızılkaya, 2020).

Irrigation levels	Plant height, cm	Spike height, cm	Total biological yield, g/pot	Seed yield, g/pot	1000 seed weight, g	Harvest Index %
25 %	47,64 c	7,68 b	6,29 c	3,01 c	28,83 b	45,04 b
50 %	52,95 b	8,62 a	8,98 b	4,42 b	31,06 ab	49,19 a
100 %	61,91 a**	8,84 a**	14,32 a**	6,45 a**	33,59 a**	47,89 a*

**P<0,01 *P<0,05

In a study by Nielsen and Halvorson (1991), canopy temperatures of wheat plant were used to estimate for the crop water stress index (CWSI). They found that when CWSI <0.38, increasing N fertilizer rate decreased water stress because a slight increase in rooting volume resulted. However when CWSI >0.38, increasing N fertilization rate increased water stress because the excessive transpirational demand of the resulting larger leaf area and vegetative mass was not fully compensated by the increased rooting volume.

In another study by Baghbani-Arani et al. (2020), under different irrigation levels including irrigation after depleting 40%, 60% and 80% of available soil water, effects of zeolite application with the combinations of organic and mineral fertilizations on sunflower water use efficiency, soil fertility and yield of sunflower in a sandy soil were investigated. They found that the application of zeolite increased water use efficiency and biological yield of sunflower in water deficit conditions (60% and 80% depletion) higher than the yield in well watered condition (40% depletion) (Figure 1). They concluded that zeolite might be regarded a suitable soil amendment due to its properties that increase the retention capacity of water and nutrients in root zone and also replacing chemical nitrogen source with manure farmyard as organic source in both normal and water deficit conditions caused significant increase in sunflower's productivity and water use efficiency.

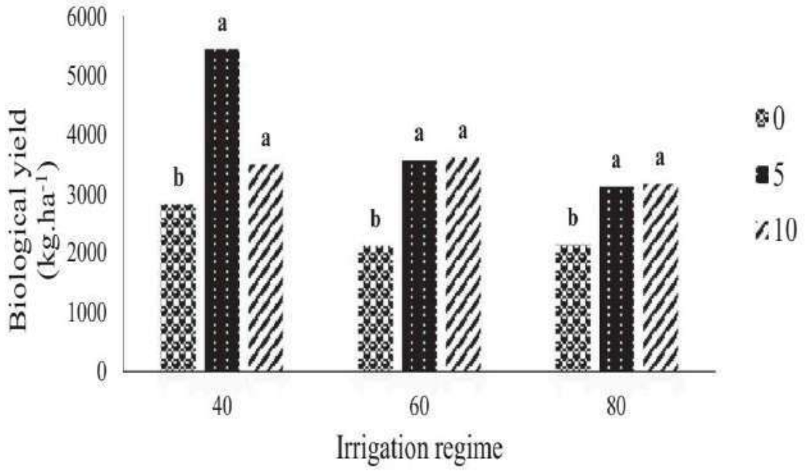

Figure 1. Irrigation regime Zeolite interaction effect on biological yield (Baghbani-Arani et al. 2020)

Many studies showed that application of compost or agricultural waste increased water holding capacity of soils (Gülser et al. 2015; Gülser and Candemir, 2015; Candemir ang Gülser, 2015; Mamedov et al. 2016; Gülser 2021). Demir and Gülser (2021) determined that rice husk compost application generally improved the soil quality parameters according to the control treatment during the experiment carried out with growing tomato plant in the field and greenhouse conditions with increasing soil organic matter content, electrical conductivity, field capacity and permanent wilting point, available water content and reducing soil pH and bulk density values over the control treatment. They concluded that rice husk compost treatments reduced evapotranspiration values, and to improve the soil quality parameters, water use efficiency and tomato yield (Figure 2).

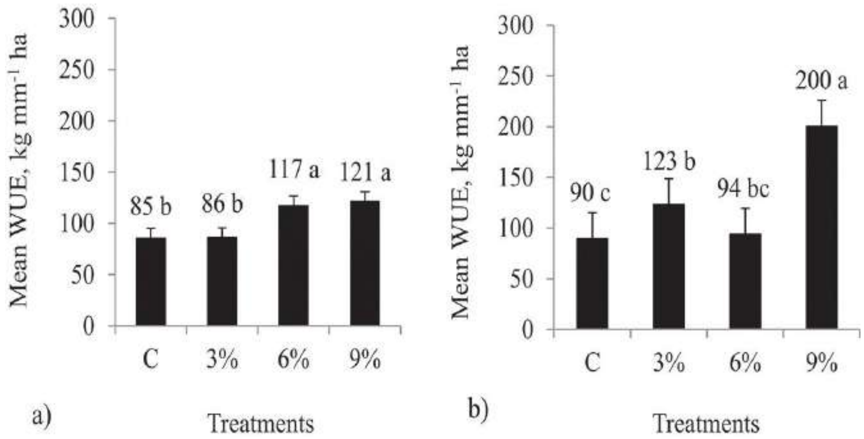

Figure 2. Effects of RHC treatments on WUE in the field (a) and greenhouse (b) conditions (Demir & Gülser, 2021).

Yoo et al. (2020) found that when comparing with the control treatment, plant growth and the optimum water condition in water stress condition was higher in biochar application due to higher maintenance of plant available water in soil. Abdallah (2019) reported that the use of fine grained hydrogels as a soil amendment increases water holding capacity, plant available water content, plant growth and survival of seedlings. Tahiri et al. (2021) determined that compost application alone or in combination with plant growth–promoting rhizobacteria or arbuscular mycorrhizal fungi alleviated the negative effect of water stress and, thus, a significant increase in tomato plant growth, development with increasing soil macro and micro nutrient contents.

Conclusion

Soil moisture content should be an optimum level for optimum growth and development of plants. In the water stress condition, plant growth and development regress, as well as a decrease in yield and quality. Many studies showed that some soil managements should be taken in consideration to prevent the plants from being affected by water stress such as; increasing soil organic matter and nutrient contents by mineral or organic fertilization, improving soil physical, chemical and biological quality parameters by using mineral or organic soil conditioners. Therefore, it is highly important to increase the soil quality by increasing the amount of organic matter in the soil and ensuring that the existing water stays in the soil for a longer time.

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Research and mapping of the liberated soils of Azerbaijan

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Abstract

The article describes comparative situation of the soils liberated from occupation. General quality indicators of Karabakh lands were noted. Agroecological features of Karabakh lands and proposals for future use are given. Agro-ecological zoning and ecological assessment were carried out on the basis of geographic information systems. Elevation model, soil maps, assessment and environmental assessment of the Lesser Caucasus have also been developed. In addition to general maps, these maps are compiled for each area.

Keywords: bonitet balls, agroecological features, agroecological zoning, ecological assestment, Geographical information, GIS, height model

Introduction

The liberated lands of Karabakh belong to Mil-Garabagh, Arazboyu, Lachin-Gubadli, Nagorno-Karabakh valuable (cadastral) regions in the price cadastral zoning of Azerbaijan and the total area is 1 million 212 thousand square kilometers (Table 1). The Karabakh region of our country covers most of the Lesser Caucasus region (81.5%), which is one of the 5 physical-geographical regions. The Lesser Caucasus physical-geographical region, in turn, is divided into 4 agro-ecological regions.

Lesser Caucasus Physical-Geographical Province (150134 ha)

1. Ganja mountains agroecological region - borders with Armenia (595580 ha);
2. Upper Karabakh agro-ecological region - borders with Armenia (621375 ha).
3. Karabakh volcanic agroecological region - borders with Armenia (139683 ha).
4. Hakari agro-ecological region - borders with Armenia and Iran (213496 ha).

In all times and in all countries, land is the first blessing. The whole existence of mankind has been established on earth. Issues of land protection, conservation and fertility are one of the most important tasks in low-land countries such as Azerbaijan [3].

Large-scale soil surveys were conducted in the Lesser Caucasus, as well as in the territories of our liberated regions from the 1940s to the 1990s, and soil types, subtypes, genera, species and species diversity were identified. Land maps and land quality maps have been compiled for each farm and district. In conducting soil researches M.E.Salayev (1966), M.E.Salayev, A.K.Zeynalov E.F.Sharifov (1965), M.P.Babayev (1967), Sh.G. Hasanov (1965, 1978), E.F.Sharifov (1984), A.O. Suleymanov (1986) and G.Sh.Mammadov (2002, 2003) services are great (Table 1) [7,8].

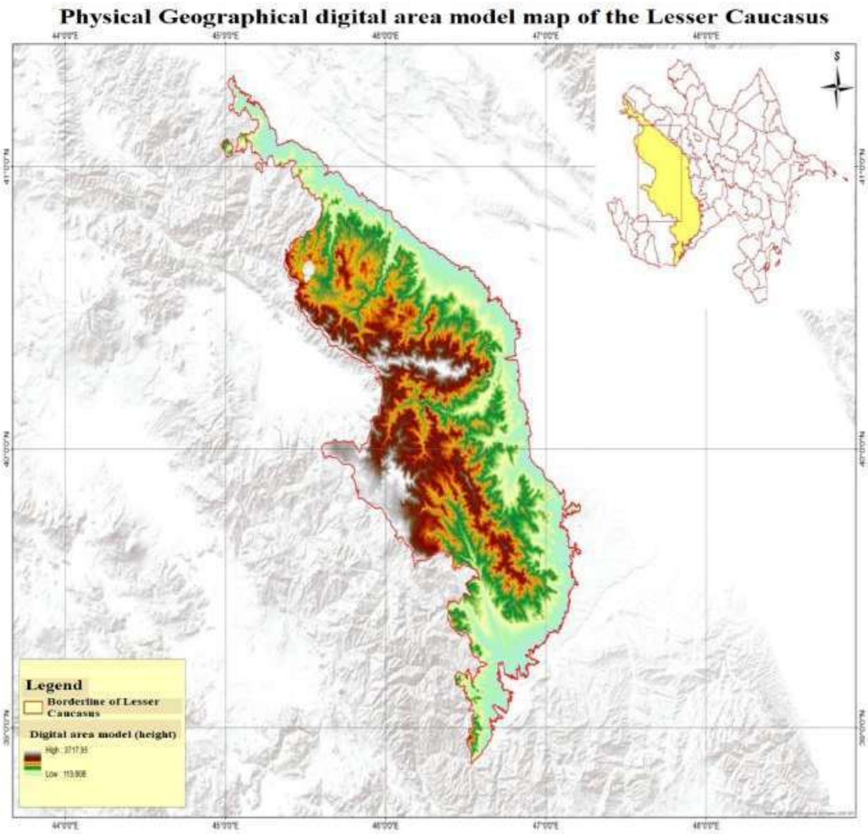
It should be noted that the process of demining these areas will be completed in 5-10 years, and field research is impossible. For this reason, these areas are surveyed using space and aerial photography, the number of violations of the legal regime and purpose of lands is determined, and research is conducted on the basis of GIS technology and earth plasticity. Once conditions are created for conducting research in the areas, large-scale field research will begin to compile land, valuation and agro-ecological price maps. [1]

Distribution of liberated lands by natural and economic areas before occupation . Table 1.

Number	Regions	Area ,ha	Also					
			Plantings	Perennial plantings	Hay field	Pasture	Yard soils	Other soils
1	Aghdam	66631	17199	9547	-	18384	1669	19832
2	Jabrail	104497	20501	7243	24	23154	789	52786
3	Fizuli	67649	23428	10376	444	25541	1059	6801
4	Kalbajar	198972	6327	10	7571	75600	753	108711
5	Qubadli	78812	14956	850	631	17192	454	44729
6	Lachin	182603	14167	245	4682	69319	720	93470
7	Zangilan	72550	7801	2667	607	22873	412	38190
8	Upper Karabakh	440372	80601	15138	4177	82013	3042	225401
Total:		**1212086**	**184980**	**46076**	**18136**	**334076**	**8898**	**619920**

It will also allow us to identify changes in soil structure, morphological structure, fertility rates and reserves over 30 years. Employees of the Department of agroecology and soil valuation at the Institute of Soil Science and Agrochemistry of the Azerbaijan National Academy of Sciences (Figure 1), "Methodical instructions on compiling interactive electronic lands and ecological price maps of lands on the basis of geographic information systems" (G.Sh.Mammadov, A.T.Aliyev, L.C.Gasimov, N.S. Ismayilov, Z.R.Mammadov, A.S.Agbabali and others, 2018), "Methodical instructions on preparation of interactive electronic lands and ecological price maps of lands on the scale of 1:

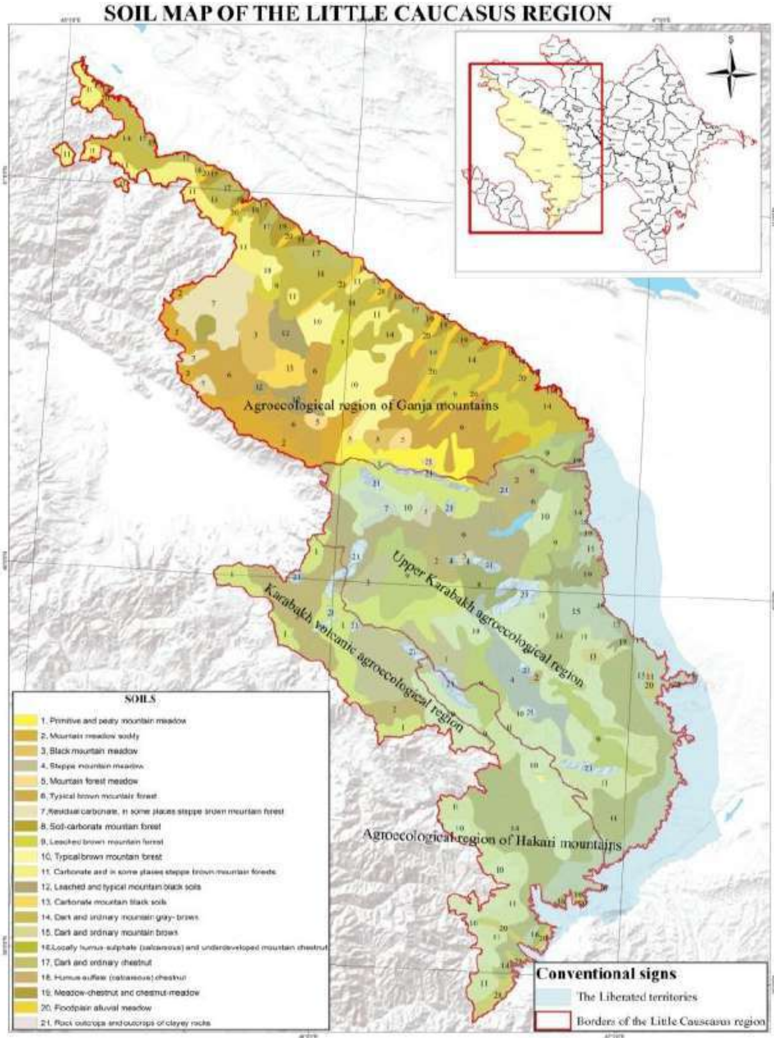
100000"(G.Sh.Mammadov,S.Z.Mammadova,M.G.Mustafayev,R.M.Heydarova,Z.R.Mammadov, G.Sh. Yagubov, S.A.Osmanova and others, 2021) developed land, valuation, and environmental price maps using GIS technology. In addition to general maps, these maps have been compiled for each district [4].



Relief (earth's plasticity) played an important role in the formation of lands in the liberated territories. Under the influence of the basins of the Bargushad, Hakari, Tartar, Araz and other rivers, and the mountain ranges of the Lesser Caucasus, various mosaic soils have been formed in these areas. Soils are distributed in vertical zoning from dry subtropics to alpine and subalpine zones (0-4000).

As a result of large-scale soil surveys in the mountainous part of the Lesser Caucasus, primary mountain-meadow, grassy mountain-meadow, mountain-forest-meadow, dark mountain-meadow, black-grass mountain-meadow, black-soil mountain-meadow, typical brown mountain-forest, carbonate mountain-forest, typical brown mountain-forest, less brown brown mountain-forest, mountain-meadow-steppe, civilized brown mountain-forest, dark mountain gray-brown, washed brown mountain-forest, steppe brown mountain-forest, dark mountain-forest , in the foothills and plains, common chestnut, ancient irrigated chestnut, meadow-chestnut, gray, dark gray, typical gray, irrigated gray, meadow-gray, subasar-meadow (alluvial-meadow), dark chestnut soil types and subtypes were found [6].

SOIL MAP OF THE LITTLE CAUCASUS REGION



The area of land categories that existed in these areas before the occupation was as follows:

I. Agricultural soils - 592166 ha. The latest information on these lands (1992) is given in the table. Armenians committed extreme violations in these lands and used all of them under the cultivation of cereals, and in many cases under the cultivation of narcotics.

II. During the occupation, the main drug trafficking occurred in the territory of Karabakh. It is these lands that cover 30% of the grain needs of the Republic of Armenia [5].


Pre-occupation landscape of arable soils ***View of arable lands during the occupation***

Soon, the preparation of large-scale land use plans for the area, the boundaries of natural and economic areas should be clarified.

III. **Lands of settlements -** only 5592 ha, of which 1709 ha are residential houses of citizens, and 3668 ha are lands under public construction. All housing stock was destroyed in cities, towns and villages. All houses, schools, hospitals, factories were demolished and useful construction materials were transported to Armenia.

During the reconstruction period, it plans to restore all these settlements and provide the population with comfortable housing, along with the restoration of old infrastructure and the construction of new infrastructure. For the first time, smart cities and smart villages will be created in these areas of Azerbaijan. Projects of settlements to be reconstructed, road-transport, communication and telecommunication lines to be established there must be taken into account in the category of lands of settlements.

IV. **Land, industrial, transport, communications,** defense and other categories of land were not used, and the land was used for cultivation. The whole transport and communication system has been destroyed. The total area of these lands is 301311 ha [5].

Villages before occupation

Villages now

V. **The lands of specially protected areas** are 43947 hectares. Garagol State Nature Reserve (240.0 ha) established in the territory of Lachin region functioned in the direction of protection of rare species of fauna. Brown bears, wolves, roe deer, wild boars, jackals, badgers and mountain goats, which are rare species of animals, were protected here. State nature reserve and Basitchay (107.0 ha) state nature reserve, Lachin (21400.0 ha), Gubadli (20000.0 ha) and Arazboyu (2200.0 ha) state nature reserves organized in the territory of Zangilan region are rare plants of flora. plane trees, hornbeams, lindens, oaks, maples, hawthorns, hips, junipers, gum trees, oriental plane trees, white poplars, and trees and shrubs whose names are listed in the Red Book. In these areas, plane trees with a diameter of one meter, 30 m in height and over 300 years of age and protection of rare vegetation of Tugay forests have been organized.

VI. **As a result of the deforestation** of about 25-30% (60,000 ha) of forests and their transportation to Armenia The of parquet. As a result, the lands became deserted and in some places deserted. It will take forest fund amounted to 246,187 hectares. Forests have also been subjected to Armenian vandalism. On the other hand, forests have been cut down for fuel and large open fields have been formed. These fields were mainly used for planting narcotic plants.

as construction materials, strong water and wind erosion processes took place in the forest lands. Especially relict rare tree species were cut down for the production decades to plant and grow forest trees in these areas.

As a result of the deforestation of about 25-30% (54,000 ha) of forests and their transportation to Armenia as construction materials, strong water and wind erosion processes took place in the forest lands. Especially relict rare tree species were cut down for the production of parquet. As a result, the lands became deserted and in some places deserted. It will take decades to plant and grow forest trees in these areas.

VII. **The total area of the water fund lands** was 19,800 hectares. The Sarsang and Sugovushan reservoirs and hydroelectric power stations, built by the Azerbaijani government, are of great importance. The water fund also includes part of the Bargushak, Hakari, Tartar, Araz rivers, as well as other small rivers and lakes. For a long time, the Armenian occupiers did not allow the use of these reservoirs, and therefore there was a constant shortage of water in the surrounding areas.

VIII. Previously, the area of reserve fund lands was 3,083 ha, which includes lands withdrawn from cultivation, conserved and unsuitable for agricultural production. However, the area of these lands has increased significantly due to various defense facilities, fortifications, trenches and trenches built by Armenians on suitable lands during the occupation. Reclamation studies should be carried out on these lands to determine their area, and then measures should be taken to return these lands to agricultural use. In parallel, large-scale soil surveys should be conducted on the reserve fund lands, and the fertility of the area should be assessed. First and foremost, the legal regime of lands must be restored and the areas and boundaries of land categories must be clarified. In this process, the new infrastructure to be reconstructed must be taken into account in the master plans to be developed for the rehabilitation of urban and rural settlements [5].

Lands out of agricultural turnover

Large-scale land use plans should be developed for each administrative district and municipality (former farms for land reform). In order to ensure the implementation of all these works, field surveying should be started immediately. The area of land categories, purpose (ugodias) should be determined and land management field works should be carried out in order to clarify the boundaries.

Changes in the soils of the region with the involvement of the region's lands in large-scale soil research, changes caused by anthropogenic impacts (wind and water erosion, man-made disturbances, desertification) should be studied scientifically. The reasons for the decline in fertility should be scientifically investigated and suggestions and recommendations made to restore it. New land maps and quality maps of administrative-territorial districts and municipalities on a scale of 1: 10000 (1: 25000 in mountainous areas) should be prepared.

Soil quality assessment studies the soil's nutrient supply, structure, granulometric composition, and intensity of erosion processes, and these indicators are used as a basis for calculating quality grades. In the agro-ecological assessment, agro-ecological maps will be prepared by studying more than 50 elements of soil, climate and relief.

The staff of the Institute of Soil Science and Agrochemistry of ANAS has a great responsibility in the implementation of this work. The institute has already started work in this direction. For this purpose, a special laboratory should be established to conduct large-scale soil and agro-ecological research. Modern GIS technologies are used in all research and mapping. It would be expedient to use the Karabakh Scientific Research Base of the Institute of Genetic Resources of ANAS in order to organize the implementation of works on the spot and to observe the processes taking place in the soil. One of the important issues is to conduct reclamation research on these lands and then implement scientific and practical measures to return the lands to cultivation. This deplorable landscape is present throughout the liberated lands from occupation.

As a result of large-scale soil research conducted by the Institute of Soil Science and Agrochemistry in the pre-occupation years, quantitative assessment of soil fertility was carried out for all regions of the region, land maps and quality cartograms were compiled, and agro-industrial grouping of lands was carried out.

Most of the lands in the region belong to quality groups I, II and III. Fertility was estimated at 54-100 points.

30-40 years have passed since the assessment of these lands, and as a result of Armenians engaged in wild farming and destruction of flora and fauna in many places, due to strong soil degradation processes (washing, salinization, salinization, desertification, wind, water and war erosion). , has undergone profound and negative changes in its structure and the amount of nutrients it contains [2].

Agro-ecological features of the liberated territories are given in Table 1. There are all kinds of favorable conditions for the cultivation of various trees and shrubs, the development of agriculture and animal husbandry. Average annual temperature of the area, amount of precipitation, effective temperature, relative humidity and other climatic elements, soil plasticity, rehabilitation of irrigation systems Grain and legumes planting wheat, rye, millet, peas, lentils, beans, etc.), orchards (apples, pears, quinces, pomegranates, dates, pulses, cherries, blueberries, plums), planting vineyards, mulberry seedlings for the development of cocoons There are all the soil and agroecological conditions for planting. In addition, cotton, corn, sunflower, soybeans, etc. are grown as technical crops in the foothills and plains. There are also fertile soil and agro-ecological conditions for cultivation. Annual effective air temperature (above 10C), high bioclimatic potential, high soil and air temperature in this area, the amount of precipitation meets the needs of these plants, the normal amount of frosty and snowy days determine the development and high yield of agricultural crops. . Even kiwi, a subtropical plant, can be grown in these areas and give high yields. In addition, the use of water from the Araz, Hakari and Bargushad rivers, Sarsang and Sugovushan reservoirs will ensure high yields.

There are good conditions for orchards and potato planting in the high and middle mountainous parts of Lachin, Kalbajar, Shusha and Gubadli regions. The lands in the lower parts of these regions can be used for agriculture.

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The effect of two iron fertilizers on DTPA extractable micronutrient contents of a calcareous soil

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Abstract

This study was carried out to determine the effects of two iron fertilizers that contain 6% of Fe (F1: all Fe chelated with EDDHA and F2: 4.8% rate of Fe chelated with EDDHA) on the micronutrients content of a sandy loam calcareous soil. The fertilizers were applied as 15 ppm doses to each pot with three replicates and incubated for 20 and 40 days under the laboratory conditions around room temperature (20-25^{0}C). After each incubation period, fertilization increased the DTPA extractable micronutrient contents of the soil samples over the control treatment. While DTPA extractable Fe, Cu, Mn and Zn contents increased as 54%, 15%, 32% and 11% by F1 application at 20 days, they increased as 44%, 4%, 14% and 6% at 40 days, respectively. Similarly, while DTPA extractable Fe, Cu, Mn and Zn contents increased as 51%, 13%, 28% and 10% by F2 application at 20 days, they increased as 43%, 2%, 14% and 2% at 40 days, respectively. The effects of both fertilizers on soil micronutrient contents were found to be higher at 20 days than 40 days. Generally, F1 application was more effective to increase DTPA extractable micronutrient contents of the soil. According to results, application of Fe chelated fertilizers into a calcareous soil generally increased micronutrient levels in the following order Fe>Mn>Cu>Zn.

Keywords: Calcareous soil, EDDHA chelate, iron fertilizer, micronutrients

Introduction

There are many studies that have shown that the availability of soil micronutrients is largely influenced by the soil microenvironment as well as soil properties, such as pH, CaCO3, organic matter, and available P. (Christensen et al., 1951, Jenne, 1968, Lutz et al., 1972, Olomu et al., 1973, Yuan, 1983, Shuman, 1988a, Shuman, 1988b). Cropping systems and fertilization practices also influence micronutrient availability Liu et al. (2002).

Fertilization with iron (Fe), manganese (Mn), and zinc (Zn) is common in calcareous soils with high pH as these micronutrients are not available for plants (Aye, 2011). Micronutrient fertilizers are applied directly to soils, in nutrient solutions through fertigation systems or as foliar sprays. However, the interactions between soil and fertilizer may reduce element availability following soil applications of fertilizer.

Micronutrient fertilization is traditionally done using inorganic compounds or recalcitrant chelates such as EDTA, DTPA, or EDDHA (Laurie et al., 1991). A chelate describes a kind of organic chemical complex in which the metal part of molecule is held so tightly that it cannot be taking by contact with other substances, which could convert it to an insoluble form. Chelating agents are organic molecules that can trap or encapsulate certain metal ions like Fe, Co, Cu, Zn and Mn, then release these metal ions slowly so that they become available for plants to taking (Sekhon, 2003). The three main micronutrient sources are inorganic, synthetic chelates and organic complexes. Inorganic sources such as sulphates of Fe, Cu, Mn and Zn are the most common salts and chelating agents used for the production of such as synthetic micronutrient chelates are EDTA, EDTA-OH and DTPA (Sekhon, 2003). Ethylenediamine-*N*,N'-bis (2-hydroxyphenyl)acetic acid (EDDHA) is the most efficient to prevent and remedy iron chlorosis under neutral and alkaline soil conditions due to its high stability in a wide range of pH (3–10). Currently, 80% of fertilizers used in agriculture are synthetic iron chelates with 56–79% of EDDHA (Nahim-Granados et al., 2019).

The effectiveness of chelates in alkaline soils is related to their stability at various pH values of soil. For example, because above pH 6.8 reacts with Ca, DTPA chelates are ineffective in soils with high pH. However, EDDHA chelated fertilizers are not affected by this situation due to the stable structure of it chelate. It prevents micronutrient from precipitating even when soil pH rises above 9 (Sekhon, 2003; Forner-Giner and Ancillo, 2011).

This study was carried out to determine the effects of two iron fertilizers that contain 6% of Fe (F1: 4.8% rate of EDDHA-Fe chelated and F2: all EDDHA-Fe chelated) on the micronutrients content of a sandy loam calcareous soil.

Material and Methods

Soil and Analyses

The soil was taken from Ondokuz Mayıs University Agricultural Study Area, Bafra, Samsun. Soil was air-dried and passed through a 2-mm sieve for analyses. Soil pH and electrical conductivity were determined in a 1:1 soil-water suspension using pH-EC meter. Soil texture was determined by hydrometer method (Gee and Or, 2002), organic C by the Walkley-Black method as described by Jackson (1958); and CaCO3 by acid neutralization (Allison and Moodie, 1965). Available cations were extracted using 1 M ammonium acetate method (Jackson 1958). The DTPA procedure of Lindsay and Norvell (1978) was used to extract Fe, Zn, Cu, and Mn, followed by determination with atomic absorption spectrophotometry. Some properties of these soils are presented in Table 1.

Table 1. Some physical and chemical properties of the soil

Texture	OM	$CaCO_3$	pH	EC	Total N	P	Ca	Mg	Na	K	Fe	Cu	Mn	Zn
	%			µS/cm	%	ppm	me/100g				ppm			
Sandy loam	0,90	14,53	7,80	212,75	0,07	12,2	20,30	5,00	0,28	0,25	8,00	0,26	0,50	0,27

Incubation Study

The incubation study was carried out in laboratory of Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Ondokuz Mayıs University, Samsun. The incubation study was planned according to a two-factorial trial design. After sieving, 200g of soil sample was weighed in plastic pots. Two fertilizers with the same water-soluble iron content (6%) and different EDDHA chelated iron rates (6% and 4.8%) were used in the experiment. The study treatments are control application (C) without ferrous fertilizer application, 6% EDDHA chelated iron (F1) fertilizer application, and 4.8% EDDHA chelated iron (F2) fertilizer application. The fertilizers were applied as 15 ppm doses to each pot with three replicates and incubated for 20 and 40 days under the laboratory conditions around room temperature (20-25^{0}C). During the study, the pots were weighed daily and kept at field capacity. The data were analyzed using two-way ANOVA in RStudio software. Mean comparisons were made using least-square means (LSD) tests and significance were detected when the p-values were less than 0.05.

Results and Discussion

The effects of fertilizer applications, incubation periods and their interaction on the micronutrients content of soil are given in the Table 2. Accordingly, fertilizer application effected on micronutrients contents of soil. Incubation period affected on micronutrients contents of the soil except for Cu content. Interaction between fertilizer application and incubation period affected on soil micronutrients content except for Zn.

Table 2. The effects of treatments and incubation period on micronutrients content

F value	Fe	Cu	Mn	Zn
Treatment	*	*	*	*
Period	*	ns	*	*
Treatment x Period	*	*	*	ns

*: P<0.05, ns: nonsignificance

According to the variance analysis results, the highest increase in the micronutrient content of the soil occurred in the F1 fertilizer and at the end of the 20th day. It only increased the Zn content equally in both fertilizers and incubation period.

After each incubation period, fertilizer increased the DTPA extractable Fe and Mn contents of the soil sample over the control treatment. While DTPA extractable Fe and Mn content increased as 54% and %15 by F1 application at 20 days, they increased as 44% and %14 at 40 days, respectively. Similarly, while DTPA extractable Fe and Mn contents increased as 51% and %28 by F2 application at 20 days, they increased as 43% and %14 at 40 days, respectively. Depending on the amount of chelated Fe in the fertilizers, the Fe and Mn content of the soil also increased. At the same time, the Fe and Mn content decreased with the prolonged in the incubation period. This decrease is thought to be due to the alkaline character and high lime content of the soil. It has been reported that in soils incubated with chelated Fe, reductions in soluble Fe content occur due to fixation and displacement of chelated Fe by Ca (Boxma,1981).

Table 3. The variance analysis results of the effect of fertilization and incubation times on the micronutrients content of the soil.

Period	Treatments	Fe	Cu	Mn	Zn
20 days	C	5,38f	2,01d	8,79d	0,66bc
	F1	11,79a	2,39a	13,08a	0,75a
	F2	11,02b	2,33ab	12,23b	0,74a
40 days	C	5,93e	2,18c	8,35e	0,64c
	F1	10,59c	2,23b	9,77c	0,68b
	F2	10,45d	2,24c	9,73c	0,65bc

Values followed by the same letter are not significantly different at the 5% level according to least significative difference Fisher's test.

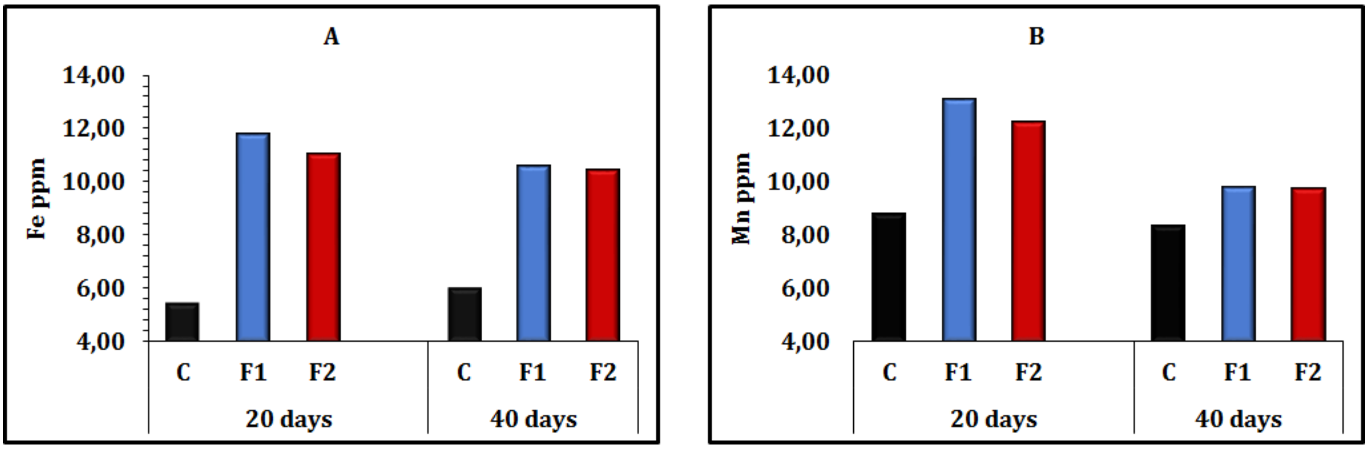

Figure 1. DTPA extractable Fe (A) and Mn (B) contents of soil both incubation period.

At the end of the 20 days, while DTPA extractable Cu and Zn content of soil increased as 15% and %11 by F1 fertilizer, they increased as 13% and %10 by F2 fertilizer, respectively. Similarly, at the end of the 40 days, while DTPA extractable Cu and Zn content of soil increased as 4% and %6 by F1 fertilizer, they increased as 2% and %2 by F2 fertilizer, respectively. The highest increase occurred by F1 fertilizer at 20 days. With the increase in the amount of chelate, the DTPA extractable Cu and Zn content of the soil increased, while they decreased with the increase in incubation period. Gil-Ortiz and Bautista-Carrascosa (2004) were reported that due to chelating effect chelated Fe fertilization to soil were increased the other micronutrient. Similarly, they reported that as incubation period prolonged chelating effect was decreased.

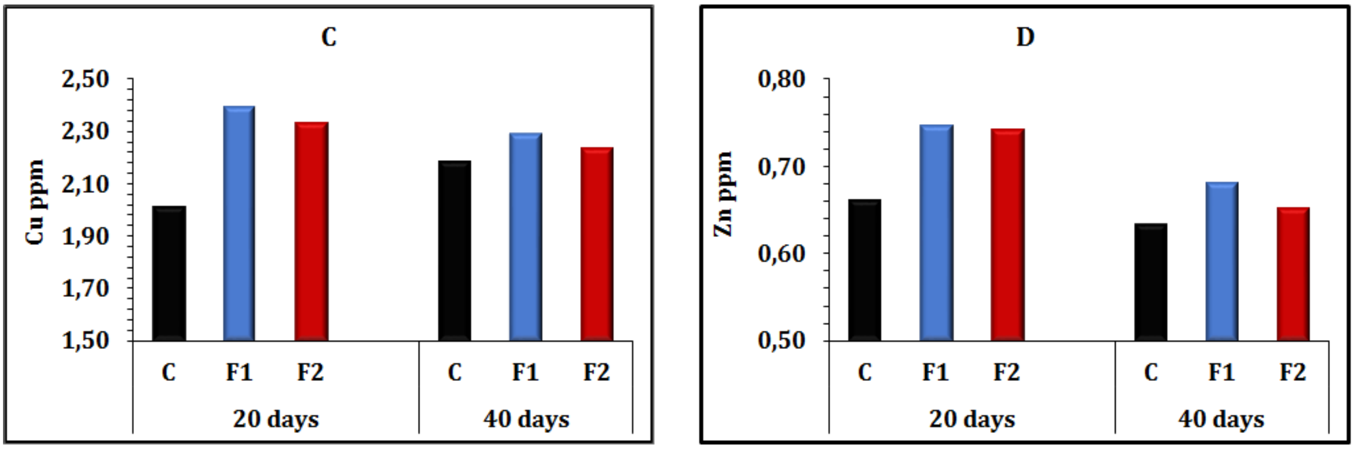

Figure 2. DTPA extractable Cu (C) and Zn (D) contents of soil both incubation period.

At the end of the 20 days and 40 days correlation analysis results between DTPA extractable micronutrients content of soil are given in Table 4. According to Table 3, except for the correlation between Fe and Zn, the relations between the other elements were found to be significant at the rate of 1%. Durgun et al., (2017) reported that there were positive relationships between soil micronutrients except for Fe-Cu and Fe-Zn.

Table 4. Correlation analysis results between DTPA extractable micronutrients content of the soil.

	Fe	Cu	Mn	Zn
Fe	1	0,895**	0,807**	0,682*
Cu		1	0,797**	0,711**
Mn			1	0,930**
Zn				1

Significance level*: P<0.05, **: P<0.01

Conclusion

As a result, in the incubation study, the application of chelated iron fertilizers with EDDHA to the calcareous soil increased the DTPA extractable micronutrients contents of the soil, due to the chelating effect. F1 fertilizer was more effective in both incubation periods, because of contained more chelate. As the incubation period increased, the contents of microelements in the soil decreased. This decrease is thought to be due to the alkaline character and high lime content of the soil.

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Soil quality index calculated including the evaluated soil ecological units in Central Bohemia Region in the Czech Republic

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Abstract

This paper deals with soil quality assessment from the point of view of sustainable soil fertility and ability to fulfil ecosystem services. Five districts from Central Bohemia region were selected as a study area (4290 km^2). In total 278 sampling points from a countrywide database called „Systematic Soil Survey" that was conducted in years 1961-1970 were included, as well as information about the Evaluated Soil Ecological Units (ESEU). Soil quality index (SQI) was determined in topsoil by evaluating totally 15 parameters; climatic region, hydrologic soil class, combined class of slope and aspect, percentage of clay, silt and sand, field capacity, wilting point, combined class of stoniness and soil depth, organic matter content, base saturation, cation exchange capacity, pH, P_2O_5 and K_2O contents. The parameters were divided into three categories: geographic, physical and chemical soil properties. Standard scoring functions like "More is better, Less is better and Optimum range" were used in data preparation. Analytical hierarchical process was used for assigning weights to parameters by filling the pairwise comparison matrix and finally, linear combination method was used for SQI calculation. Geographic parameters were already classified by ESEU system, thus the standardization process was applied to the available classes.

For physical and chemical parameters were used their real values, however, field capacity and wilting point were estimated from soil texture and organic matter content by employing the k-nearest neighbor method from a verified database NearriCZ. SQI was calculated and maps were produced in ArcGIS environment using interpolation of point-based data (RBF-CRS method). Results were compared with currently used system of soil protection classes and high similarity was found; 28 % of the total area was classified as high and very high quality soils. The proposed method can serve as an alternative to the traditionally used methods for soil evaluation in the Czech Republic.

Keywords: Analytical hierarchical process, Evaluated Soil Ecological Unit, field capacity and wilting point, soil protection classes, soil quality index.

Introduction

Soil quality indices can be defined as a minimum set of parameters that, in relation to each other, provide numerical data on the ability of soil to provide one or more functions. Soil quality indicators can be divided into physical such as dry bulk density, texture, structure, aggregate stability, porosity, available water capacity (AWC), hydraulic conductivity and infiltration capacity; chemical such as organic matter and total nitrogen contents, content of available nutrients (P, K), pH, electrical conductivity, cation exchange capacity (CEC) and carbonate content; and biological such as microbial biomass, microbial respiration, composition of microbial microflora, enzymatic activity of microorganisms, number of earthworms and nematodes, which are available only locally [1]–[3].

In the Czech Republic (CR) exist two main sources of soil data. Systematic Soil Survey of Agricultural Soils in Czechoslovakia conducted between years 1961 – 1970 was the first detailed systematic collection of soil data during which about 500 000 soil profiles were sampled just in the CR [4]. Digitized data are available in interactive online application [5] and recently have been used in several practical studies with combination of digital soil mapping approaches such as PuGIS database [6]. Second source, however based on the Systematic soil survey as well, is a system of Evaluated Soil Ecological Units [7], [8] used to evaluate the absolute and relative production capacity of agricultural land and the conditions of their most efficient use. ESEU is characterized by a five-digit code explained in Table 1. An online catalogue of ESEU is available [9].

Table 1. Description of ESEU units.

ESEU code	Definition and range of the code	Description
X.xx.x.x	code of climatic region (0–9)	The first digit of the code is a climatic region classified from 0 to 9, climatic regions were allocated exclusively for the purpose of bonitation of agricultural land resources and cover areas with similar climatic conditions for the growth and development of agricultural crops.
x.XX.x.x	code of main soil unit (01–78)	The main soil unit (the second and third digit) is defined as a synthetic agronomized unit characterized by a purposeful (agronomic) grouping of genetic soil types, subtypes, soil-forming substrates, texture, soil depth, type and degree of hydromorphism and land relief.
x.xx.X.x	associated code of slope and aspect (0–9)	The fourth digit consists of a combination of habitat factors slope and exposure of land to the world sides.
x.xx.x.X	associated code of stoniness and soil depth (0–9)	The fifth digit indicates the combination of the depth of the soil profile and its stoniness.

Soil water retention data belong to the not routinely measured data and for regional studies their estimation using pedotransfer functions, decision trees or other machine learning algorithms can be justifiable and successful [10]–[12]. K-nearest neighbor method is one of the rather reliable methods for estimation of soil water retention points from soil texture data, in addition with dry bulk density and/or soil organic matter content [13]. In the Czech Republic, FC and WP were estimated by employing the k-Nearest code [14] and with careful calculation of uncertainty [10]. The source database serving as reference dataset for estimation was increased recently [15], [16] with newly measured data, and enables to estimate the water content at both -10 and -33 kPa matric potentials most commonly associated with FC.

Aim of the study was to i) assess sustainable soil fertility and the ability of soil to provide ecosystem services by determination of soil quality index (SQI) obtained by evaluation of selected available and estimated parameters, and ii) compare the results with the generally used soil protection classes based on Evaluated Soil Ecological Units (ESEU).

Material and Methods

Study Area

Central Bohemia is the most populated region in the Czech Republic due to its vicinity to Prague. Northern part consists of lowland belonging to alluvium of the Elbe River, southern part is hilly. The region is very heterogeneous including areas with intensive agriculture as well as forests and cities with developed industry. Study area was selected as five adjacent districts in the eastern part of the Central Bohemia covering area of 4290 km^2 (Fig. 1).

The districts are Praha-východ, Mladá Boleslav, Nymburk, Kolín and Kutná Hora. Altitude of the study area is between 200 and 500 m a.s.l. Climatic regions in the study area vary from warm, mildly dry to mildly dry, moist. Longterm annual precipitation in Central Bohemia is 587 mm with maximum 82 mm in July and minimum 30 mm in February. Longterm annual temperature is 8.6°C with maximum 18.5°C in July and minimum -1.2°C in January. The longterm precipitation in the region is lower and longterm temperature is higher than average of CR (686 mm, 7.9°C, respectively). Various soil types can be found in the study area with prevailing Luvisols, Chernosols and Cambisols, however Arenosols can be found especially in Mladá Boleslav district and Vertisols especially in Nymburk district. Soil data from Systematic Soil Survey were obtained from PuGIS database [6].

Fig. 1. Study area in the Czech Republic.

Soil quality index determination

SQI was determined in the following steps: a) selection of parameters and their overview via spatial distribution maps, b) unifying the parameters employing the SSF, c) assigning weights to parameters employing the AHP, and finally d) calculation of SQI using the linear combination equation and mapping its spatial distribution. Within the step a) were estimated the parameters field capacity (FC) and wilting point (WP) according to method described in Duffková et al. (2020) [15] and using the NearriCZ database [16]. In the present study, contents of clay, silt and sand and OM were used as predictors.

From the available data in total 15 parameters were selected and divided into 3 categories: geographic, physical and chemical. They are listed in Tab. 2. Geographic parameters were already classified [7], [17]. Their interactive maps are available online [18]. ESEU system is available as polygons for agricultural land. In the present study, point-based interpolation of the whole study area was used and ESEU of each sampling point was included.

Standard scoring functions [19] were used for standardization of data measured or estimated in different units. All parameters including the classified geographic parameters were expressed as unitless number in the range between 0.1 and 1.0, see equations 1-3.

"Less is better" (LB)
$$f(x) = 1 - 0.9 \times \frac{x-L}{U-L} \qquad L \le x \le U \qquad (1)$$

"More is better" (MB)
$$f(x) = 0.9 \times \frac{x-L}{U-L} + 0.1 \qquad L \le x \le U \qquad (2)$$

"Optimum range" (OR)
$$\left. \begin{array}{ll} f(x) = 0.9 \times \frac{x-L1}{L2-L1} + 0.1 & L1 \le x \le L2 \\ f(x) = 1 - 0.9 \times \frac{x-U1}{U2-U1} & U1 \le x \le U2 \\ f(x) = 1 & L2 \le x \le U1 \end{array} \right\} \qquad (3)$$

Where *x* is the value of the parameter, *f(x)* is the score of parameters ranged between 0.1 and 1, and *L* and *U* are the lower and the upper threshold value, respectively. Type of SSF is indicated in Tab. 2.

LB type of function was used for combined codes of ESEU system, because the lowest values are assigned for deep, flat soils without skeleton, and opposite, the highest values are for shallow soils located on slopy areas, with nothern aspect and high amount of skeleton. The same system is generally used for climatic region code, so that the most valuable soils are located in very warm, dry climatic region (code 0) and descending to cold, humid climatic region (code 9). Thus the LB SSF could be used, but recent dry seasons showed, that the warmest regions of the Czech Republic are in drought risk, thus OR SSF was used and warm regions with lower risk of soil moisture deficit were given higher score. Hydrologic soil class B was given the highest score in OR[17].

Soil texture fractions scoring: OR for clay was 5-30 %, silt 10-65 % and sand 15-75 %.

Field capacity (FC) scoring: MB function was employed. Water content at -10 kPa was used for samples belonging to coarse textured soils (sand, loamy sand, sandy loam classes) while for other soils the water content at -33 kPa was used.

Wilting point (WP) scoring: OR was found as water content 0.1-0.2 cm^3/cm^3 (at -1500 kPa) as follows: from the database NearriCZ were collected samples belonging to the optimum range soil texture fractions and mean of their water content plus minus one standard deviation was calculated.

Active pH between 6.5 and 7.0 was considered as OR.

Phosphorus and potassium content were scored by MB function. Heavy soils (silty clay loam, clay loam, sandy clay loam, silty clay, sandy clay and clay classes) were evaluated separately from medium and coarse soils, both according to the favourable content in soil [20].

Table 2. Evaluated parameters

GEOGRAPHIC (B1 category)	Type of data	Type of SSF
climatic region	code ESEU 0-9	OR
hydrologic soil class	classes A, B, C, D	OR
slope+aspect	code ESEU 0-9	LB
stoniness+soil depth	code ESEU 0-9	LB
PHYSICAL (B2 category)		
clay (%)	real value	OR
silt (%)	real value	OR
sand (%)	real value	OR
FC (cm^3/cm^3)	estimated value	MB
WP (cm^3/cm^3)	estimated value	OR
CHEMICAL (B3 category)		
OM (%)	real value	MB
sat. of sorption complex (%)	real value	MB
CEC (mmol/100 g)	real value	MB
pH	real value	OR
P_2O_5 (mg/kg)	real value	MB
K_2O (mg/kg)	real value	MB

Abbreviations: FC (field capacity), WP (wilting point), OM (organic matter), CEC (cation exchange capacity).

Analytical hierarchical process (AHP) was used for assigning weights to parameters by filling the pairwise comparison matrix (PCM) [21]. PCM was filled for each category of parameters separately, due to consistency of calculations. Finally a superior PCM (A category) was calculated and final weights were resulting from multiplication of partial weight values A*B, see Tab. 3. Consistency ratio was calculated for each category. All consistency ratios were below 10%, which means stable PCM [22].

Table 3. Weights of parameters

Category		B1	B2	B3	A	Final weight
B1 geographic	climatic region	0.387			0.490	0.190
	hydrologic soil class	0.275			0.490	0.135
	slope+aspect	0.198			0.490	0.097
	stoniness+soil depth	0.140			0.490	0.069
B2 physical	clay		0.277		0.312	0.086
	silt		0.277		0.312	0.086
	sand		0.238		0.312	0.074
	FC		0.119		0.312	0.037
	WP		0.090		0.312	0.028
B3 chemical	OM			0.421	0.198	0.083
	base saturation			0.211	0.198	0.042
	CEC			0.198	0.198	0.039
	pH			0.091	0.198	0.018
	P_2O_5			0.040	0.198	0.008
	K_2O			0.039	0.198	0.008
Sum		1.000	1.000	1.000		1.000
Consistency ratio (%)		4.5	1.9	8.8	4.6	

Abbreviations: FC (field capacity), WP (wilting point), OM (organic matter), CEC (cation Exchange capacity), CR (consistency ratio).

As a final step, SQI was calculated using the linear combination method according to equation (4):

$$SQI = \sum_{i=1}^{n}(W_i \, . X_i) \quad (4)$$

Where *SQI* is the soil quality index, W_i is the weight of the parameter, X_i is the standardized unitless value of the parameter.

Interpolation methods

Deterministic models such as Inverse Distance Weighting (IDW) with power 1, 2, 3 and Radial Basis Function (RBF) with Completely Regularized Spline and Thin Plate Spline semivariogram models, and scholastic models such as Ordinary, Simple and Universal Kriging with spherical, exponential, and gaussian semivariogram models were tested for each soil parameter and the root mean squared error (RMSE) was calculated for each model. The model with the lowest RMSE was then selected for mapping, employing the ArcGIS 10.6.1 software.

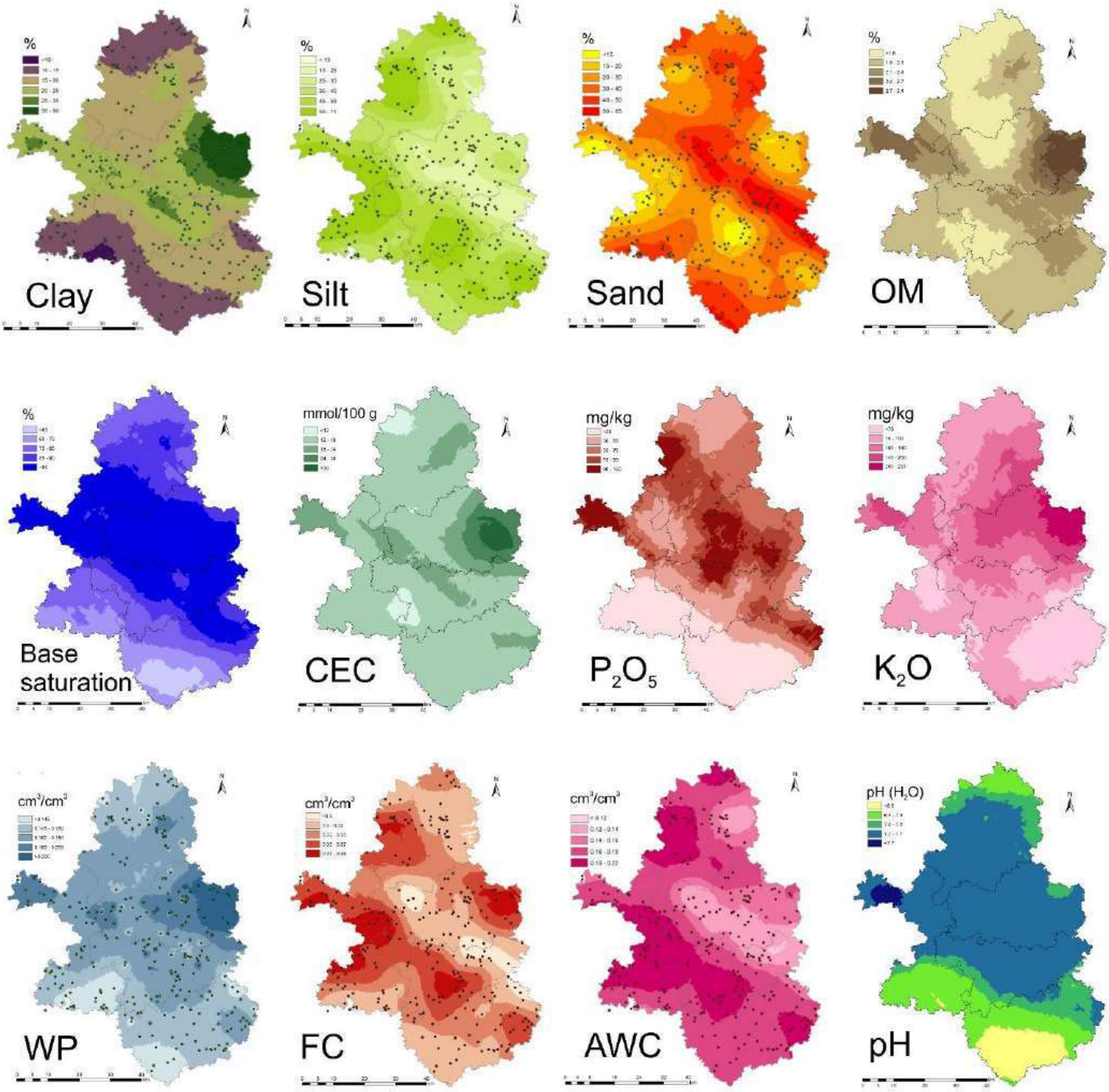

Fig. 2. Distribution maps of physical and chemical parameters (OM – organic matter, CEC – cation exchange capacity, WP – wilting point, FC – field capacity, AWC – available water capacity).

Results and Discussion

In order to get detailed insight into the study area, interpolation maps of physical and chemical parameters were prepared (Fig. 2). Model IDW-1 was used for WP, Ordinary Kriging - Gaussian model for FC and AWC and Simple Kriging - Spherical model for all chemical parameters, based on their lowest RMSE. In the Fig. 2 are presented also the estimated parameters FC, WP and map of available water capacity (AWC) as a difference of FC and WP. Arithmetic mean of estimated FC was 0.339 cm^3/cm^3 ranging from 0.21 to 0.411 cm^3/cm^3 (minimum and maximum, respectively) with standard deviation (SD) 0.044 cm^3/cm^3, and for WP mean was 0.167 cm^3/cm^3, min. 0.102 and max. 0.258 cm^3/cm^3 and SD 0.032 cm^3/cm^3. To verify the estimation reliability, the map of FC was compared with a map of soil water retention capacity [18] (Fig. 3). That map was created on the base of ESEU polygons and the soil moisture constant was obtained by using a filter paper method. However the value can be associated with FC and although both maps use different system, their pattern is similar. Detailed comparison will be subject of further investigation.

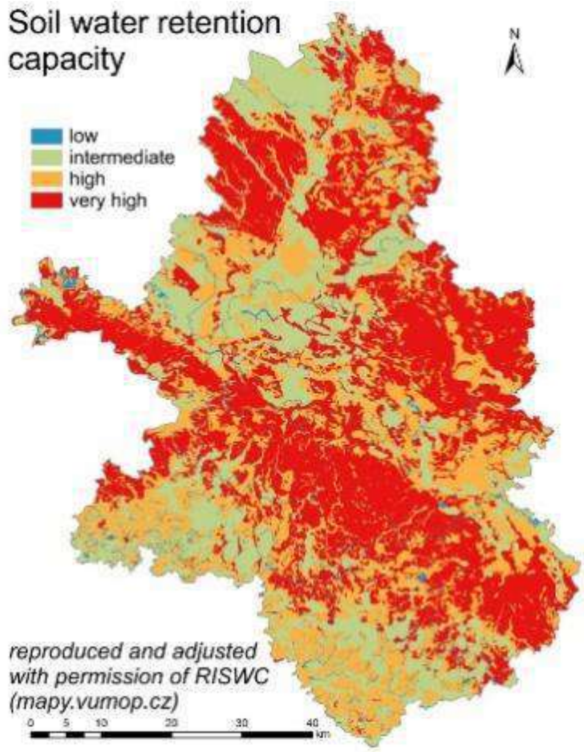

Fig. 3. Distribution map of the soil water retention capacity.

Interpolation model RBF - Completely Regularized Spline was used for SQI map (Fig. 4).
Map of final SQI was compared with a map of soil protection classes, which are defined in the Law on soil protection (No. 334/1992 Coll.) [23]. The classes are based on ESEU system and classification is related to their productivity, regardless the need of irrigation. Thus soils, which would be much less productive in rainfed agriculture, have high classification and protection, while the SQI does not consider the effect of irrigation and thus soils in dry climatic regions have lower value of SQI. This is particular e.g. in Mladá Boleslav district (north of the study area).

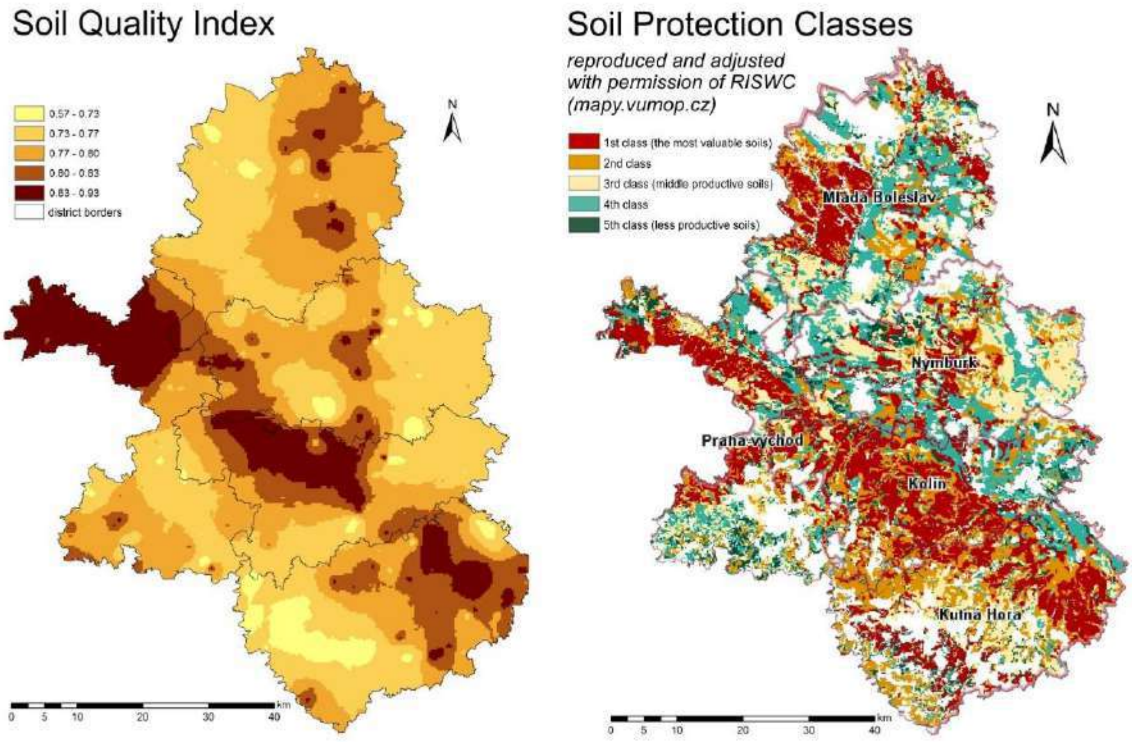

Fig. 4. Soil quality index distribution and soil protection classes.

Conclusion

Resulting map of SQI shows similar pattern as the map of soil protection classes, although the purpose and way of their construction and classification is different. Thus the present method can be used as an alternative to the present way of soil quality evaluation in the Czech Republic. However, for future studies an update of current dataset and more detailed data analysis should be considered.

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Influence of slope and management practices on top-soils fertility status of compound farms in Nsukka Campus

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Abstract

The study was carried out to assess the influence of slope and management practices on top-soils fertility status of compound farms in the University of Nigeria Nsukka (UNN) campus, Enugu state Nigeria. Top soil samples (0-20 cm depth) were collected from twenty compound farms, ten each from the upper slopes compound farms (USCFs) in Ikejiani and Ezenwaeze streets and lower slopes compound farms (LSCFs) at Mbanefo street. The elevation of the USCFs ranged from 458 to 447 m while LSCFs ranged from 415 to 423 m above the mean sea level (amsl). The soil samples were analyzed in the UNN Department of Soil Science Laboratory. The results showed that slopes and management practices influenced top-soils fertility status of compound farms. Slopes affected soil fertility parameters such as organic matter content, total nitrogen, exchangeable calcium, cation exchange capacity, and effective cation exchange capacity. The upper slope compound farms were more fertile relative to the lower slopes compound farms. The combined application of organic and inorganic manures had a greater effect on soil fertility status compared to a single application of organic or inorganic fertilizer. The combined application of organic and inorganic fertilizers should be adopted to enhance soil fertility status of compound farms in both slopes.

Keywords: Compound farms, management practices, slopes, soil fertility

Introduction

Soil fertility is the status of the soil with respect to its capacity to supply nutrients to plants in adequate and suitable amounts. Nigerian soils are generally low in fertility as a result of their origin. Poor management practices employed by farmers further depreciates soil fertility through harvesting, leaching and soil erosion. In order to maintain soil fertility, farmers have to take note of the characteristics and constraints of their soils and use sustainable management practices to conserve and improve fertility. Slope is one of such characteristics of farmland that farmers have to take into consideration. Though slope is an inherent geographic condition of lands that is beyond the control of farmers. However, through management practices, farmers can manage their farmlands for greater crop productivity. Management practices refer to techniques and methods employed by farmers to maintain and improve the overall soil fertility. Farmers deliberately incorporate household refuse, crop residues, animal manures and inorganic fertilizer into compound farm soils with the sole purpose of improving soil fertility so as to enhance crop productivity. Compound farm can be defined as a gardening system of cultivating crops and rearing livestock on fragmented lands within the confines of homesteads whereby wastes from the house, residues from crops, and droppings from animals reared are added back to the soil to enhance fertility. These additions buffer the effect of nutrients lost through harvesting, leaching and runoff as a result of slope positions. Slope positions influence the movement of nutrients and water within the soil thereby affecting soil fertility status at any given time. Mulugeta *et al.* (2012) noted that slope accelerates soil disturbance through erosion and affects soil properties by shaping the patterns of crop production, litter production, and decomposition, with resultant effects on carbon and nitrogen contents of the soils. Slopes therefore have marked influence on soil properties (Amuyou and

Kotingo, 2015), such that fertility and physical properties of soils differ across slope gradients (Awdenegest and Nicholas, 2008). The influence of slope on soil properties has been widely discussed by Noma *et al*. (2005); Essoka and Jaieyeoba (2008); Ogunwale *et al*. (2002); Babalola *et al*. (2007); Farmanullah *et al*. (2013) and Amuyou and Kotingo (2015). The relationship between soil fertility and slope positions varies depending on inherent soil properties, vegetation cover, weathering, leaching, erosion, among others. Generally, organic materials and nutrients tend to be transported from upper slopes and deposited at lower slopes.

Therefore, slope not only influences soil properties but also determines farmers' choice of management practices for effective maintenance of the fertility of soils. Since the removed nutrients from the soil have to be adequately replaced, sustainable management practices are employed to minimize nutrient losses, improve the overall soil fertility and increase crop yield. However, not much is known of the influences of slope and management practices on the fertility status of compound farms in Nsukka. Thus, this research assesses the influence of slope and management practices on top-soils fertility status of compound farms in the University of Nigeria Nsukka (UNN) campus.

Material and Methods

Study Location

The study was carried out at the University of Nigeria Nsukka campus, situated approximately by latitude 6°54'N and longitude 7°24'E within the derived savanna zone of eastern Nigeria with an altitude of 447.26 m above sea level (Oko-Ibom and Asiegbu, 2006). The area is characterized by a humid tropical climate with wet (April- October) and dry (November –March) seasons, and a mean annual rainfall of 1750 mm bimodally distributed with peaks in July and September; mean annual maximum (day) and minimum (night) temperatures of 31°C and 21°C respectively (UNN Meteorological Station, 2010). Relative humidity ranges between 70 to 80% (Oko-Ibom and Asiegbu, 2006) and falls below 60% during the period of Harmattan- a short period of about three weeks of hazy and very dry weather usually from December through January (Asadu et al., 2001).

The altitude of the compound farms sampled ranged from 415 to 458 m above mean sea level (amsl) and was divided into two topographic positions; upper slopes compound farms (USCFs) and lower slopes compound farms (LSCFs). Upper slopes ranged from 458 to 447 m while LSCFs ranged from 415 to 423 m amsl. The road that cuts across UNN's main gate through St Peter's Catholic Church to Medical Centre bordering school premises and staff quarters demarcated the upper slopes from the lower slopes. A handheld Global Positioning System (GPS receiver) was used to identify the geographical locations of the compound farms sampled in both slope positions as shown in Table 1. Topsoil samples (0-20 cm depth) were collected from representative upper slope compounds at Ikejiani street and Ezenwaeze street; and lower slope at Mbanefo street of UNN during February 2019 (Table 1). The random method based on the variability of the land was used to collect soil samples from the selected compound farms using soil auger. Twenty soil samples were collected in all, ten from the upper and ten from the lower slopes. A structured questionnaire was used to obtain information on management practices adopted by the compound farmers across the slopes. Farmers provided information on the farming practices such as organic manure and inorganic fertilizer applications, supplemental irrigation and cropping systems (Table 1).

Laboratory Analysis

All the sampled soils were bagged in fresh clean polythene bags and were prepared for analyses in the laboratory by air drying and sieving using a 2 mm sieve. The samples were analyzed for particle size distribution, soil pH, organic carbon, total nitrogen, available phosphorus, exchangeable acidity, and exchangeable calcium, magnesium, potassium, and sodium. Laboratory analyses were conducted at the Department of Soil Science University of Nigeria, Nsukka using the following standard methods. Soil particle size distribution was determined by the Bouycuous hydrometer method (Gee and Or, 2002). Soil pH was measured in both water and 0.1 N KCl at the soil-liquid ratio of 1:2.5. Soil organic carbon was determined by the Walkley and Black wet digestion method (Nelson and Sommers, 1982). Total nitrogen was determined by the micro Kjedahl digestion method (Bremner and Mulvaney, 1982). Available phosphorus was determined by the Bray II method (Olsen and Sommers, 1982). Exchangeable calcium and magnesium were determined by ETDA titration while exchangeable potassium and sodium were determined by flame photometry (Jackson, 1962). Exchangeable acidity was determined by the titration method (Mclean, 1982). Effective Cation

Exchange Capacity (ECEC) was obtained by the summation of all exchangeable cations. Base saturation was calculated as a percentage of the value of the summation of exchangeable bases over cation exchange capacity.

$PBS = \sum EB/CEC \times 100$

Where $\sum EB$ = Summation of the exchangeable bases.

Table 1: Sampling locations and site characteristics

Compound Farm	Altitude (m amsl)	Latitude (N)	Longitude (E)	Management Practices
Upper Slopes Compound Farms				
4 Ezenwaeze street	451	N6°51.493′	E7°24.472′	Organic, Not irrigated
7 Ezenwaeze street	453	N6°51.493′	E7°24.534′	Organic, irrigated
11 Ezenwaeze street	453	N6°51.475′	E7°24.529′	BIO, Not irrigated
236 Ikejiani street	449	N6°51.490′	E7°24.403′	BIO, irrigated
238 Ikejiani street	447	N6°51.523′	E7°24.465′	Organic, Not irrigated
239 Ikejiani street	447	N6°51.527′	E7°24.438′	Organic, irrigated
241 Ikejiani street	447	N6°51.536′	E7°24.450′	BIO, Not irrigated
243 Ikejiani street	449	N6°51.518′	E7°24.530′	BIO, irrigated
248 Ikejiani street	455	N6°51.487′	E7°24.607′	Organic, Not irrigate
250 Ikejiani street	458	N6°51.469′	E7°24.617′	Organic, irrigated
Lower Slopes Compound Farms				
4 Mbanefo street	415	N6°52.236′	E7°24.748′	BIO, Not irrigated
7 Mbanefo street	417	N6°52.217′	E7°24.786′	BIO, irrigated
8 Mbanefo street	418	N6°52.243′	E7°24.800′	Organic, Not irrigated
10 Mbanefo street	417	N6°52.258′	E7°24.835′	Organic, irrigated
12 Mbanefo street	419	N6°52.256′	E7°24.853′	BIO, Not irrigated
15 Mbanefo street	420	N6°52.200′	E7°24.888′	BIO, irrigated
16 Mbanefo street	419	N6°52.245′	E7°24.887′	Organic, irrigated
17 Mbanefo street	423	N6°52.201′	E7°24.930′	Organic, Not irrigated
19 Mbanefo street	421	N6°52.232′	E7°24.939′	BIO, Not irrigated
20 Mbanefo street	423	N6°52.257′	E7°24.944′	BIO, Irrigated

BIO: both organic and inorganic fertilizer

Statistical Analysis

The data generated from the laboratory analysis were subjected to two-way analysis of variation (ANOVA) using GenStat Discovery Edition 2. Slope (location) positions and management practices were considered as main factors. The mean comparison was done using fisher's least significant difference (LSD) test at $P < 0.05$ significant level.

Results and Discussion

Effects of Slope and Management Practices on Soil Particle Size Distribution

The result showed that the effect of slope on particle size distribution in both slopes was significant whereas the effect on management practices was not significant (Table 2). However, the interaction of slope and management practices significantly influenced particle size distribution (Table 3). The values of sand, silt, and clay varied from 818.00 - 902.00 g kg^{-1}; 40.00 – 72.00 g kg^{-1} and 62.00 – 110.00 g kg^{-1} respectively in both the LSCFs and USCFs. Comparison at slope level revealed that sand fraction was significantly greater in the LSCFs relative to the USCFs at ($p \leq 0.05$). The quartz-rich parent material upon which the soils are formed could be responsible for the high values in the lower slope. The removal, transport, and re-deposition of sand particles by erosion could have also influenced the higher sand fraction at the lower slope relative to the upper slope. The silt and clay contents of the USCFs were higher than that of LSCFs due to their low mobility down the slope. Low silt content is an indication of highly weathered soils (Ahn, 1993) implying that the lower slope soils are at an advanced stage of weathering compare to upper slope soils.

Table 2: Effects of Slope on Soil Particle Size Distribution

Slope	% Clay	% Silt	% Total Sand
Lower slope	6.20	4.00	90.2
Upper slope	11.0	7.20	81.8
F-LSD$_{(0.05)}$	2.78	2.53	4.75

F-LSD $_{(0.05)}$: Fisher's Least Significant Difference at 5% probability, NS: Not significant

Table 3: Interaction Effects of Slope and Management Practices on Soil Particle Size Distribution

Management practice	Slope	% Clay	% Silt	% Total Sand
Fertilization	**Lower**			
	Organic and inorganic	7.00	5.00	88.0
	Organic	5.40	3.00	92.4
	Upper			
	Organic and inorganic	9.80	6.60	83.6
	Organic	12.20	7.80	80.0
F-LSD$_{(0.05)}$		3.93	3.57	6.71
Irrigation	**Lower**			
	Irrigated	6.87	4.00	89.2
	Non irrigated	5.53	4.00	91.2
	Upper			
	Irrigated	10.83	7.95	81.2
	Not Irrigated	11.17	6.45	82.4
F-LSD$_{(0.05)}$		3.67	3.61	6.78

F-LSD $_{(0.05)}$: Fisher's Least Significant Difference at 5% probability, NS: Not significant

Effects of Slope Positions and Management Practices on Soil Fertility Properties

The interaction of slope and management practices significantly influenced soil fertility status of the compound farm soils. Management practices alone had no significant effect on soil fertility properties. However, slope significantly influenced OM, TN, Ca, CEC, ECEC and BS. Whereas pH, Mg, K, Na, EA and Av. P were not affected. The pH values in H_20 ranged from 6.74 to 6.32 in the USCFs and LSCFs respectively and were rated neutral to slightly acid by Enwezor *et al.* (1989). The higher value of USCFs pH (6.74 for pH in H_2O) compared with the LSCFs (6.32) can be attributed to higher vegetation cover as well as a lower rate of mineralization of organic material at the upper slope, hence the accumulation of more organic matter content which enhances soil pH. Similarly, Amuyou and Kotingo (2015) reported that soil pH value was relatively high in the upper slope segment compared to other segments of the catena attributed to grasses which covered the upper slope. Ogunwale *et al.* (2002) and Babalola *et al.* (2007) also reported a decrease in pH down the slope. Contrariwise, Hendershot et al. (1992) reported a slightly higher pH at the downslope positions. However, the main effect of slope and the interaction effect of slope and management practices on soil pH (H_2O) were not significant across the compound farms.

The value of organic matter was found to be higher at the USCFs (30.2 g kg^{-1}) against 13.9 g kg^{-1} at the LSCFs. Generally, the OM content was rated moderate to high according to Enwezor et al. (1989). The higher value of organic matter at the upper slope (30.2 g kg^{-1}) relative to the lower slope (13.9 g kg^{-1}) could be due to higher vegetation density leading to higher accumulation of organic materials in the upper slopes compound farms. Contrariwise, Farmanullah *et al.* (2013) reported that organic matter was higher at lower slopes relative to upper slopes.

Total nitrogen varied from (0.9 g kg^{-1}) at the LSCFs to 1.6 g kg^{-1} at the USCFs and rated low to high respectively according to Enwezor *et al.* (1989). Nitrogen influences the decomposition of organic matter in the soil which ultimately leads to enhanced fertility (Essiet, 1990). This explains the higher value of total nitrogen and organic matter content at the upper slope relative to the lower slope. Noma et al. (2005) reported that total N followed a similar trend as soil organic matter since organic nitrogen constitutes the bulk of total N in tropical soils. However, this contrasting result may be due to higher fertilization with nitrogen fertilizers at the lower slopes. Ezeaku and Iwuanyanwu (2013) reported that the cultivation of soil exposes the soil organic matter to a greater rate of decay and oxidation resulting in a low amount of total nitrogen content of the soil.

Available phosphorus varied from 50.9 - 52.5 mg kg^{-1} in the USCFs relative to LSCFs. These values were rated high by Enwezor *et al.* (1989). High level of available phosphorus in both slopes may be attributed to intensive P fertilization. However, slightly lower values of P at the USCFs can be attributed to the high weatherability of the soils, higher clay content, leaching by high-intensity rainfall (Bubba et al., 2003). Similarly, Farmanullah *et al.* (2013) reported that phosphorus was higher at lower slopes than top slopes. Mengel and Kirkby (1987) reported that the availability of nitrogen improved the availability of phosphorus and vice versa, thus TN and available P were both higher at lower slope relative to the upper slope. Poor soil management practices and the nature of tropical soils account for heavy nutrient losses through soil erosion and nutrient leaching (Hossner and Juo, 1999). Moreover, with the intensification of cropping system, organic matter and N in the soils are readily depleted, while phosphorus and other nutrient reserves are slowly but steadily mined (Tanimu *et al.*, 2013).

Exchangeable acidity (EA) was significantly affected ($p \leq 0.05$) by the interaction of slope and management practices. The EA varied from 1.76 cmol kg^{-1} in the LSCFs to 1.48 cmol kg^{-1} in the USCFs with no significant difference between the means. These values of EA were rated low by Enwezor *et al.* (1989). This can be attributed to the pH values which were neutral to slightly acid. However, continuous cultivation leads to the acidification of soils (Aguilera *et al.*, 2013). The EA values in these locations were made up of only hydrogen ions with trace amounts of aluminum ions. The higher EA value in the LSCFs was a result of the lower organic matter content of the soils resulting in lower exchangeable bases.

Exchangeable calcium varied significantly at ($p \leq 0.05$) from 3.44 cmol kg^{-1} in the USCFs to 1.78 cmol kg^{-1} in the LSCFs. These values of Ca^{2+} were rated low to moderate by Enwezor *et al.* (1989). Low values of Ca^{2+} at the LSCFs could be attributed to leaching losses by the high tropical rainfall as well as low content in the parent rock from which the soils were formed. Higher Ca^{2+} levels in the upper slopes could be due to the denser vegetation that hinders the impact of raindrops on soil surface thus decelerating runoff and leaching of nutrient elements down the slope. According to Essiet, (2001) for any soil, its fertility would be determined by two compounds, clay, and organic matter. The low clay, silt and organic matter content of the LSCFs as well as unfavorable management practices might be responsible for the low values of Ca^{2+}. Exchangeable magnesium was higher in the USCFs (1.31 cmol kg^{-1}) compare to the LSCFs (1.14 cmol kg^{-1}) with no significant difference between the means. These values of Mg were rated high by Enwezor *et al.* (1989). The exchangeable Na varied from 0.17 cmol kg^{-1} in the USCFs to 0.18 cmol kg^{-1} in the LSCFs with no significant difference between the means. These values of exchangeable Na were rated moderate by Enwezor *et al.* (1989). Similarly, Garcia *et al.* (1990) reported highest Na^{+} concentration at bottom slope position in eroded sites relative to top sites. The exchangeable K varied from 0.49 cmol kg^{-1} in the USCFs to 0.46 cmol kg^{-1} in the LSCFs with no significant difference between the means. These values of K were rated high by Enwezor *et al.* (1989). Farmanullah *et al.* (2013) reported higher values of K at lower slopes relative to top slopes. The higher values of exchangeable K in the USCFs compared to the LSCFs could be a result of combined fertilization with organic and inorganic fertilizers.

Slope had a significant effect on CEC of soils in the study area. Cation exchange capacity (CEC) is an overall assessment of the potential fertility of the soil and the values depend critically on soil pH (Kodiya, 1988). The CEC varied from 7.80 cmol kg^{-1} in the LSCFs to 13.88 cmol kg^{-1} at the USCFs. This value of CEC was rated low to moderate by Enwezor *et al.* (1989). According to Landon (1991), the higher the CEC, the more the soil fertility and the more productive the soil is. Low values of CEC may be attributed to low clay and humus contents as well as low pH values (Asadu *et al.*, 1997). It has been reported that low to medium CEC value of tropical soils is due to the dominance of kaolinitic clays in the fine-earth fractions (Ojanuga and Awojuola, 1981). Most researchers have observed that the CEC of tropical soils is related to their organic matter content (Aluko and Oguntala, 1997, Noma *et al.*, 2005). Ludwig *et al.* (2001) noted that soils with low CEC might have been subjected to leaching of nutrients like nitrogen, potassium and magnesium and hence lower yield potentials than those with higher CECs (Asadu *et al.*, 1997). However, lower CEC levels at the LSCFs was due to low organic matter contents as well as the influence of soil texture and the type of clay minerals. Clayey soils were reported to have higher CEC than Sandy soils mainly due to charges resulting from isormorphous substitution (Rhoades, 1982).

Effective cation exchange capacity (ECEC) and % base saturation (BS) were significantly affected by slope positions. The ECEC was greater at the USCFs (6.88 cmol kg^{-1}) relative to the LSCFs (5.34 cmol kg^{-1}*)* and rated low to moderate respectively by Enwezor *et al*. (1989). Whereas the % BS was rated high by Enwezor *et al*. (1989) and was greater at the USCFs (77.40 %) relative to the LSCFs (68.80 %*)*.

Table 4: Effects of Slope on Selected Soil Fertility Properties

Slope	p H	OC	OM	TN	Ca	Mg	K	Na	EA	Av. P	CEC	ECEC	BS
	H_20		%		Exchangeable bases cmol kg^{-1}				cmol kg^{-1}	mg kg^{-1}	cmol kg^{-1}		%
Lower	6.32	0.92	1.39	0.90	1.78	1.14	0.46	0.18	1.76	52.50	7.80	5.34	68.80
Upper	6.74	1.75	3.02	0.16	3.44	1.31	0.49	0.17	1.48	50.90	13.88	6.88	77.40
F-LSD$_{(0.05)}$	NS	0.24	0.42	0.05	0.69	NS	NS	NS	NS	NS	1.76	0.70	4.86

OC: organic carbon, OM: organic matter, TN: total nitrogen, Ca: calcium, Mg: magnesium, K: potassium, Na: sodium, EA: exchangeable acidity, Av. P: available Phosphorus, CEC: Cation exchange capacity, ECEC: effective cation exchange capacity, BS: percentage base saturation, F-LSD $_{(0.05)}$: Fisher's Least Significant Difference at 5% probability, NS: Non-significant.

Table 5: Interaction Effects of Slope and Management Practices on Soil Chemical Properties

Management Practice	Slope	pH H_2O	OC	OM %	T N	Ca	Mg	K	Na	EA cmol kg^{-1}	AV. P mgkg^{-1}	CEC cmol kg^{-1}	ECEC cmol kg^{-1}	BS %
						Exchangeable Bases cmol kg^{-1}								
Fertilization	Lower													
	BIO	6.32	1.04	1.79	0.08	2	1.22	0.47	0.17	1.64	57.5	7.6	5.54	70.2
	Organic	6.32	0.8	1.39	0.09	1.56	1.06	0.45	0.2	1.88	47.6	8	5.14	63.4
	Upper													
	BIO	6.58	1.75	3	0.18	3.1	1.3	0.49	0.16	1.48	61.7	13.28	6.53	76
	Organic	6.9	1.76	3.03	0.13	3.78	1.32	0.48	0.17	1.48	40.1	14.48	7.23	78.8
F-LSD $_{(0.05)}$		NS	0.34	0.59	0.07	0.98	NS	NS	NS	NS	NS	2.49	0.99	6.88
Irrigation	Lower													
	IRR	6.28	0.88	1.52	0.09	1.92	1.08	0.42	0.19	1.91	57.4	7.55	5.57	65.3
	NIR	6.36	0.97	1.66	0.08	1.64	1.2	0.5	0.17	1.61	47.6	8.05	5.11	68.3
	Upper													
	IRR	6.98	1.72	2.95	0.17	3.53	1.39	0.48	0.17	1.48	55.9	12.63	7.05	78.5
	NIR	6.5	1.79	3.08	0.14	3.35	1.24	0.49	0.17	1.48	46	15.13	6.71	76.3
F-LSD$_{(0.05)}$		0.62	0.35	0.6	0.07	0.99	NS	NS	NS	NS	NS	NS	1.01	6.95

BIO: organic and inorganic fertilizer, IRR: Irrigated, NIR: Non-irrigated, NS: non-significant, OC: organic carbon, OM: organic matter, TN: Total Nitrogen, Ca: Calcium, Mg: Magnesium, K: Potassium, Na: Sodium, EA: Exchangeable Acidity, Av. P: Available Phosphorus, CEC: Cation exchange capacity, ECEC: effective cation exchange capacity, BS: percentage base saturation, F-LSD $_{(0.05)}$: Fisher's Least Significant Difference at 5% probability

Conclusion

The study was carried out to assess the influence of slope and management practices on top-soils fertility status of compound farms in the University of Nigeria Nsukka (UNN) campus, Enugu state Nigeria. From the findings, slopes affect soil fertility parameters such as organic matter content, total nitrogen, exchangeable calcium, cation exchange capacity, and effective cation exchange capacity. Soils vary widely from slope to slope and the fertility status is determined by many factors according to the location such as vegetation and soil inherent properties. The upper slope compound farms had higher organic matter content, CEC, and exchangeable Ca^{2+} than the LSCFs. The interaction of slope and management practices better influenced soil fertility properties than any single component. Proper management practices should therefore be adopted to improve soil fertility status of compound farms.

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The spacio-temporal dynamics of soil moisture and temperature: A review

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Abstract
Moisture and temperature influence most of the processes that take place in the soil and also have a great influence on ecosystem functions. Soil moisture content has a direct impact on the hydrogeological cycle, gas exchange with the atmosphere, regulation of the energy available for evaporation and transpiration processes, recharge of subway aquifers, control of surface runoff, availability of water for plants, and distribution of nutrients and pollutants. On the other hand, soil temperature regulates chemical and biological reactions and is directly related to plant nutrition, growth, and development, especially during the germination process. Both moisture and temperature of soil are dynamic parameters in time and space, and their variation is influenced by various factors such as soil and climatic conditions, parent material, land use, relief and pedogenetic processes. Therefore, the characterization and analysis of these parameters on a local/global scale provides the basis for understanding biogeochemical and flow processes, both at the surface and within the soil profile necessary for environmental, and commercial applications in sustainable water resource management and conservation of areas vulnerable to erosion. In consequence, the objective of this review is to provide a theoretical basis for understanding the physical phenomena that mediate soil moisture and temperature dynamics and their role in the provision of ecosystem services.
Keywords: Ecosystem services, Hydro-physical properties, Soil water balance, Soil water regime

Introduction

Moisture and temperature influence most of the energy relationships and processes that take place in the soil. Both are dynamic parameters in time and space, and their variation is influenced by various factors such as soil and climatic conditions, parent material, land use, relief and pedogenetic processes (Crave, 1997, Lal et al., 2004).

In Jenny defined soil as the result of interactions between climate, vegetation, parent material, topography and time, these formative factors determine the variation and distribution of soils at local and global scales. In this model, climate is often the most relevant factor in the temporal variation and distribution of soils, especially through the impact of precipitation and temperature that control processes such as weathering. Factors such as relief and parent material play a significant role in spatial variation and distribution. If, for example, it was necessary to monitor inter-annual variations of soils, then factors such as climate and weather could be used, because of their high dependence on the specific conditions of the regions that give rise to the soils (Lal, 2006).

In the case of small-scale variations, it is the geomorphological processes and soil properties that play a key role. Properties such as texture, or hydraulic conductivity have spatial variations that can be measured over a relatively small range along the soil profile or over a short time period respectively (Western et al., 2004) and can give an idea of the role of soil in the hydrological cycle with a special focus on transient water storage, however, these dynamics can be modelled and brought to larger spatial and temporal scales to understand also the annual hydrological trends for example (Lal, 2006).

Water movement in soil is mainly determined by hydraulic forces and soil pore spaces, which is why among the properties with the greatest impact on these dynamics is texture and structure, which largely establishes the pore space of the soil and in turn modifies secondary properties such as bulk density, total porosity, and pore size distribution. This determines the water holding capacity, water movement and water availability and modifies the hydraulic conductivity of the soil. Similarly, mineralogy and a specially amount of clay minerals, gives rise to secondary properties such as aggregation, potential fertility, water holding capacity and infiltration within the profile and also plays a role as natural barriers limiting the movement of water, nutrients, and soil contaminants (Palm et al., 2007).

For the importance of these dynamics, this review aims to provide a theoretical basis for understanding the physical phenomena that mediate soil moisture and temperature dynamics and their role in the provision of ecosystem services.

Soil moisture and temperature and ecosystem services

The importance of the soil system lies mainly in the ecosystem services it provides for the development and survival of species, which in turn establish the parameters for characterizing soil quality and health based on its properties and functions. To properly provide these services, the dynamics of water movement and temperature in the soil play a fundamental role as they are directly associated with functions such as buffering and moderation of the hydrogeological cycle, soil-plant-atmosphere gas exchange, climate regulation, nutrient cycling, and soil formation (Palm et al., 2007, Hincapié et al., 2012; Petropoulos et al., 2017). Most ecosystem services are difficult to quantify and the fulfilment of one function may provide co-benefits to other services or require trade-offs (FAO, 2015).

Moisture and temperature are also related to soil-atmosphere gas exchange, these services are now well quantified, and their importance is given by the exchange of greenhouse gases. (Palm et al., 2007). On the other hand, soil temperature regulates chemical and biological reactions and is directly related to plant nutrition, growth, and development, especially during the germination process (Bhatti et al., 2000; González-Rouco et al., 2003; Zhang et al., 2005; Qian et al., 2011; Houle et al., 2012; Sun et al., 2012; Aalto et al., 2018).

Soil moisture and temperature and evapotranspiration

One of the most important climatic factors in determining soil moisture and temperature is evapotranspiration. The importance of this process lies in the exchange of energy between various surfaces and the atmosphere, thus being a coupling factor between energy and moisture (Henn et al., 2018). Evapotranspiration includes in its parameters plant transpiration, soil and surface water evaporation and sublimation (Miralles et al., 2011) and for its calculation, the standard method (Penman-Monteith) is generally used where meteorological conditions such as precipitation, temperature, wind, and radiation are considered (Allen et al., 1998; Wang et al., 2021).

In relation to the soil, evapotranspiration acts as an external force that extracts water from the surface horizons normally located in the first 30 cm of depth or rooting systems depth, however, in deeper horizons the movement of water is mediated by capillarity and therefore the movement of water is slower, as well as the heat fluxes and as a consequence they are presented as more stable processes in the soil (Buckman et al., 1968, Lal 2004, Wang et al., 2021).

Soil moisture and temperature and the spatio-temporal variation

Relief, parent material and climate are parameters with great influence on the spatial variation of soil moisture and temperature dynamics. Relief directly influences the direction and flow of water both at the surface and through the soil profile. After precipitation events, areas with slopes have a higher runoff, while flat or basin areas have a higher infiltration and percolation rate and therefore a higher water availability for plants. These dynamics are important because they determine soil degradation mainly through erosion, and can modify aquifer recharge processes (Lal, 2006; Li et al., 2021).

For its part, the parent material conditions the movement of water either in its internal flow through the soil pores or the external flow through the land surface area (Bukman et al., 1968). Stratified soils, for example, become barriers that limit movement within the soil profile due to abrupt textural changes or an increased number of clays in the soil (Lal, 2004). The dynamics of moisture and temperature within the soil profile have been well described by several authors, The environmental drivers that regulate soil water dynamics are mainly precipitation, and evapotranspiration. Precipitation has a greater impact on the top 10-20 cm of soil, while the impact of evapotranspiration reaches 30-40 cm depth, (Yan et al., 2018; Sun et al., 2019; Han et al., 2020) indicated that hydrological processes close to the land surface are more sensitive to changes in vegetation and respond quickly to meteorological anomalies (Xu et al., 2021; Du et al., 2021).

Studies by Wang et al., (2021) analyzed the fluctuation of moisture in grassland soils in relation to evaporation and concluded that the horizons closest to the surface, between 0-20 cm, are the main zone of activity of organisms and plants, and also of greatest influence of evapotranspiration, which will first extract the water located within 10 cm, this evapotranspiration phenomenon acts as an upward force in water movement, being one of the main factors of available water in the surface horizon (Lal et al., 2004). Wang et al. (2021) also showed that although the 20-40 cm horizons are still considered as a near-surface layer, at this depth water movement is slower than in the 0-10 cm layer. At this depth there are still changes in soil moisture after a first precipitation event.

A different dynamic is shown in deeper horizons, the zone with lower moisture occurs between 40-60 cm, because at these depths it takes longer to increase the water level after precipitation events, there are changes in water content after a second or third precipitation event, compared to the upper layer, and there is a lower water retention capacity due to the presence of both evapotranspiration, due to the presence of perennial plant roots, and infiltration. At the same depth, several authors have found that in arid regions, these conditions can lead to dry soil layers that limit percolation. In contrast, relatively deep layers between 60-100 cm soil moisture fluctuations are lower, this relative short-term stability tends to respond to precipitation changes over longer periods (Wang et al., 2021; Xu et al., 2021).

Similar studies by Zaleski et al. (2003, 2005, 2009, 2012) showed a similar pattern of water movement and water content. During this study, the fluctuation of moisture and temperature in Retisols with loess deposits in southern Poland was evaluated, and the study concluded that these soils have two zones that differ in the type of water regime: an upper zone comprising humic and eluvial horizons, and a lower zone consisting of illuvial and parent material horizons. The boundary between these zones was generally around 50 cm deep. The soil profile was characterized by an upper zone with a lower moisture content, lower plant-available water retention and relatively wider fluctuations in moisture compared to the lower zone, which in turn showed a more stable moisture content during all years, with moisture values close to the field capacity.

Like moisture, the variation of temperature within the soil profile is mediated by climatic factors, mainly by solar radiation, which is quantified as net radiation and distributed into three main components sensible heat, latent heat, and soil heat (Hu et al., 2003, Holmes et al., 2008). In addition to this energy flux, vegetation cover and the heat generated by the decomposition of organic matter by soil microorganisms are the main factors why higher temperature fluctuations occur in the uppermost horizons. In soils with vegetation cover, the daily and annual mean soil and air temperatures values are usually the same. The heat flow within the profile depends on the composition and ratio of the liquid, gas and solid phases of the soil which determine the thermal conductivity. As properties such as soil porosity, water content and organic matter increase, thermal conductivity decreases. (Zhang et al., 2022)

Conclusion

The spatio-temporal dynamics of soil moisture and temperature are complex relationships involving multiple factors that can only be understood from the systemic approach of different important scientific disciplines, such as climate science, hydrology, geomorphology, and soil science. Furthermore, their study and modelling on a global scale is still limited by the complexity of in situ characterization of these properties and their high cost for large-scale projects.

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