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SOIL SCIENCE & PLANT NUTRITION

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Samsun, Türkiye

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Dr.Coşkun GÜLSER
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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 2022). 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 I

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 7th 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 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.
This year we will discuss the importance of Soil Science and Plant Nutrition. 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. The symposium will provide a great opportunity to learn and discuss recent advances in the soil science in general and to establish contacts and collaborations with participants from many different parts of the word. The symposium will focus on multidisciplinary approach to soil science, with special interest on basic research, latest and technological developments for soil science and plant nutrition. The scientific sessions will also emphasize basic concepts of soil. The symposium will also provide multiple opportunities for interaction among scientists from public and private institutions.
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

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 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 four Universities: Ondokuz Mayıs University (OMU-Türkiye), University of Agriculture in Krakow (UAK-Poland), Agricultural University Plovdiv (AU-Bulgaria) 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, there are 50 international emiSS programme 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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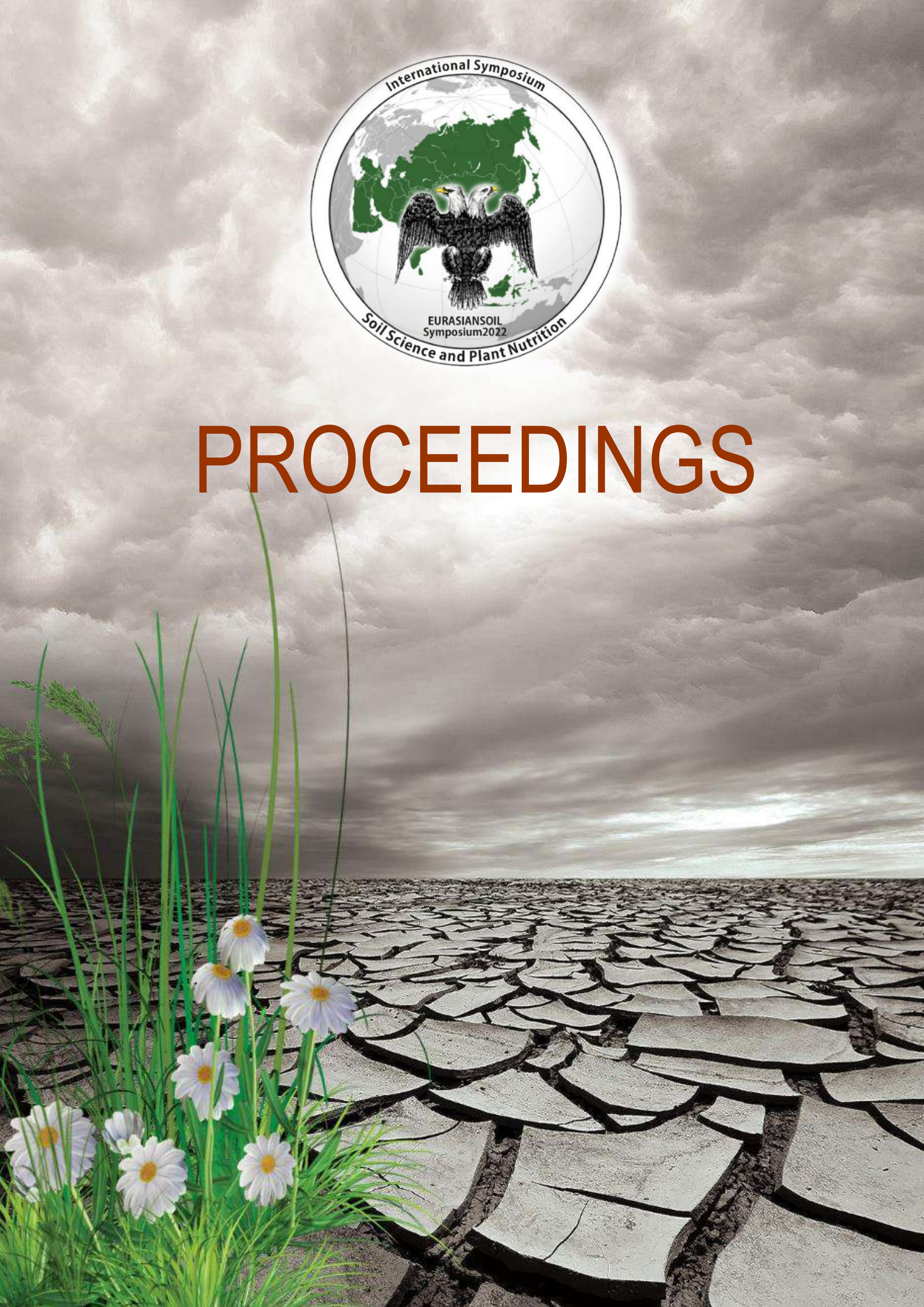

Estimation of soil aggregate stability by different regression methods

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Abstract

In this study; the estimation of aggregate stability, which is one of the erosion susceptibility parameters, was investigated by using some basic soil properties (sand, clay, silt, organic matter). Different regression methods (Linear, Ridge, Lasso, and Elastic Net), one of the machine learning algorithms, were compared as models. When the accuracy of the models was evaluated, the root means squarer error (RMSE) values obtained by linear regression in the estimation of aggregate stability were 3.76, while the others (Ridge, Lasso, Elastik Net) were 3.73, 3.74, and 3.65%, respectively. In the evaluation made according to the minimum and maximum accuracy method, the highest accuracy of 95.1% was obtained in the Elastic Net method. While all parameters were found to be important for the model in the Ridge regression method, the sand content of the soils was not included in the model in the Lasso regression. In the Elastic Net regression, the most important parameter in the estimation of aggregate stability was determined as clay. As a result of this study; The estimation accuracy of the regression methods examined was determined close to each other. However, with the determination of appropriate lambda and alpha values, the most successful estimation of aggregate stability was obtained with Elastic Net regression.

Keywords: Lasso, Ridge, Elastic Net Regression, Structure, Soil Properties

Introduction

Today, artificial intelligence applications such as computers performing human tasks, computer systems that can perform tasks that normally require human intelligence such as visual perception, speech, recognition, decision-making and translation between languages, and chatbots have become widely used. Machine learning is considered among the popular artificial intelligence techniques. Machine learning techniques are techniques based on learning from data. Their outputs constitute algorithms that provide classification or clustering. Supervised learning, one of the machine learning techniques, is based on the method of predicting the output value based on a set of input values (Hastie et al., 2008). Classification is defined as classification when each input vector is assigned to one of the different categories, and regression method if the predicted values are continuous values (Bishop, 2007).

Modeling studies have become a frequently studied subject in soil science as in many other fields. Pedotransfer functions (PTFs) are often defined as mathematical models created to predict soil properties measured by laborious, time-consuming and expensive methods from easily measured soil properties (McBratney et al., 2002; Pachepsky and Van Genuchten, 2011). Some statistical methods used in the construction of models include multiple linear regression to measure the relationship between multiple independent variables (Yılmaz et al., 2005; Shalmani et al., 2010; Igwe and Agbatah, 2008) and other machine learning algorithms (Yang and You, 2013; Yakupoğlu et al., 2015; Mohanty et al., 2015; Usta et al., 2018). Multivariate linear regression has been widely used for many years. However, there are different regression methods (Lasso, Elastic Net, Ridge) that can minimize the error rate and selectively eliminate variables.

Erosion is an event that causes the irreversible loss of the function that the soil has gained in the terrestrial ecosystem for centuries (Saygın et al., 2019). For this reason, the productivity capacity of the soil, which plays a leading role in agricultural production, decreases, and cannot fulfill its other duties in the ecosystem. Soil erosion has a negative impact on the environment as it reduces soil fertility, damages agricultural areas and land topography (Rodrigo-Comino, 2018). Identifying this hazard in advance will reduce degradation in the future. In addition, analyzing some soil properties from the easy parameters obtained will be an important step for these measures. The aggregate stability of soils used in the evaluation of erosion susceptibility is also examined and erosion decreases due to the increase in aggregate stability (Alaboz et al., 2021).

The aim of this study was to evaluate the prediction accuracy of aggregate stability of soils using different regression methods. While general linear regression is used in many studies, the unique aspect of this study is the comparison of ridge, lasso, elastic net regression types with linear regression in soil aggregation.

Material and Methods

The study was carried out on soil samples taken from 80 sampling points around Eğirdir district in Isparta province. The province, which is located in the transition zone between the Lakes region, continental climate and Mediterranean temperate climate, is dominated by semi-arid climate type. According to the meteorological data of the region for many years, the average annual temperature is 12.5ºC, the average total precipitation is 466.8 mm and evapotranspiration is 724.58 mm (TSMS, 2022). Artificial regions constitute 0.97% of the district's surface area, agricultural areas constitute 17.34%, forests and semi-arid areas constitute 63.77%, wetlands constitute 0.12% and water bodies constitute 17.81% (Corine, 2018). Apple cultivation is widely practiced in the region. The some soil properties of the study area are given in Table 1.

Table 1. Some soil properties

Variable	Mean	StDev	CoefVar	Minimum	Maximum	Skewness	Kurtosis
Organic matter %	1.25	0.29	23.54	0.70	1.93	0.04	-0.82
Sand %	40.05	14.42	36.00	17.74	72.40	0.26	-1.18
Silt %	23.088	4.61	19.97	13.22	33.68	0.22	-0.69
Clay %	36.86	12.62	34.23	11.82	61.53	0.28	-1.00
Aggregate stability %	57.388	3.79	6.62	50.35	65.28	0.35	-0.52

Disturbed surface soil samples were taken at 80 randomly selected locations within the study area at 0- 25 cm depth. The disturbed soil samples were subjected to standard pretreatments for some physical and chemical analyses. The sand, silt and clay contents of the soils were measured by bouyoucos hydrometer method (Bouyoucous, 1951), electrical conductivity (EC) and pH values were measured in 1:1 soil-water suspension (Soil Survey Staff, 2014; Kacar, 2016). $CaCO_3$ % content was determined by volumetric calcimeter and organic matter content by modified Walkley-Black method (Soil Survey Staff, 2014). For wet aggregate stability analysis, the wet sieving method proposed by Kemper and Rosenau (Kemper and Rosenau, 1986) (with a single sieve diameter) was applied. Correlations between soil properties were obtained in R core package program Multiple linear regression, Ridge, Lasso and Elastic Net regression algorithms were used in model estimation. Models were obtained using the R package program. R package program (glmnet) was used to create the models. To evaluate the accuracy of the models, R^2, mean absolute error (MAE), root mean square error (RMSE) and Min-Max Accuracy parameters, which indicate the accuracy of the model, were analyzed.

In multiple linear regression, a model is created that predicts the dependent variable with more than one independent variable. Least squares try to find coefficients that minimize the residual sum of squares (Equation 1)

$$\mathrm{RSS} = \sum_{i=1}^{n}\left(y_i - \beta_0 - \sum_{j=1}^{p}\beta_j x_{ij}\right)^2$$

Equation 1

In linear regression, values deviating from linearity in the test phase are strengthened by reducing the slope in other regression methods. Lasso, Ridge and Elastic net regression are used for this purpose. Ridge regression is a type of regression using L2 regularization. With this method, the slope decreases compared to the general regression. The rate at which beta parameters are corrected is determined (Equation 2). If the variance between the data set and the test set is too high, the curve is redrawn and the β coefficient is changed. The variance is reduced. In addition to the RSS in Ridge, additions are made by squaring the beta coefficients.

λ (alpha) takes the value 0. In Lasso, the slope does not decrease as much as in Ridge. It forms a curve between OLS and Ridge (Equation 3). In this method (as in Ridge regression), the coefficients are forced towards zero by using a penalty term (L1 type penalty). The value of this penalty term determines the amount of shrinkage applied to the regression coefficients. In Ridges, the coefficients of insignificant variables are forced closer to 0, while in Lasso the coefficient is given as 0. λ (alpha) takes the value 1.

$$L_{ridge}(\hat{\beta}) = \sum_{i=1}^{n}(y_i - x_i'\hat{\beta})^2 + \lambda \sum_{j=1}^{m} \hat{\beta}_j^2$$

Equation 2

$$L_{lasso}(\hat{\beta}) = \sum_{i=1}^{n}(y_i - x_i'\hat{\beta})^2 + \lambda \sum_{j=1}^{m} |\hat{\beta}_j|.$$

Equation 3

Elastic net is a method in which Lasso and Ridge regression are evaluated together. While the aim is to find the appropriate lambda value in Ridge and lasso, in Elastic Net regression; the alpha and lambda value that gives the lowest error are found. Alpha value varies between 0-1.

Results And Discussion

The correlation matrices between soil properties are shown in Figure 1. Statistically significant negative correlations were found between aggregate stability properties of soils and sand and positive correlations were found with clay (p<0.01).

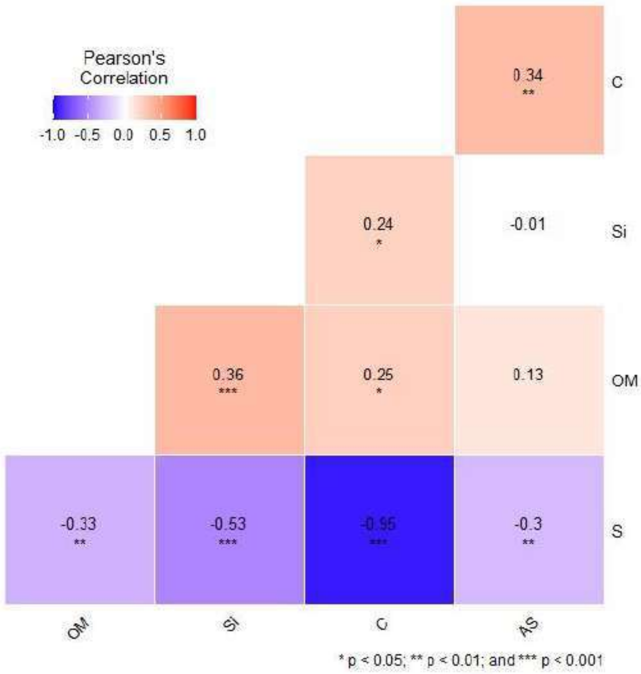

Figure 1. Correlation matrix of soil properties

C: clay, S: Sand, Si: Silt, AS: Aggregate stability, OM: organic matter

There was a positive correlation between aggregate stability and organic matter at a very low level, but it was not statistically significant. Aggregate formation and aggregate stability are important factors for the sustainability of air and water balance suitable for plant growth in soil (Karaman et al., 2007). In general, clay minerals, colloidal substances of organic origin, iron, aluminum, manganese oxides and calcium carbonate are among the effective parameters in aggregate formation in soil. In addition, enzymes secreted by soil organisms are an indicator of biological activity and it is known that enzymes formed by microorganisms during the breakdown of organic material are effective in aggregation (Helgason et al., 2010).

The equations obtained with different regression models are shown in Table 2. In linear and ridge regression, all properties are included in the model, whereas in ridge regression the coefficients of the properties are differentiated as the angle of the slope changes to minimize the error. When changing the angle of the slope in the Lasso regression, the coefficient of the sand property of the soils was set to zero to obtain the minimum error. In the elastic net regression, the beta coefficients of all properties except clay content were reset to zero and not included in the model.

Table 2. Estimation models with different regression methods

Model	Equation	λ	Lambda
Lineer	AS= 57.6043+ 0.413OM-0.1433S-1.369Si + 0.09C	-	-
Ridge	AS=57.605+0.218OM-0.326S-0.544Si+0.577C	0	2.04
Lasso	AS= 57.603+0.356OM-0.8379Si+ 1.208C	1	0.04
Elastic Net	AS= 57.612+0.3012C	1	0.8

C: clay, S: Sand, Si: Silt, AS: Aggregate stability, OM: organic matter

R^2, MAE, RMSE and Min-Max accuracy parameters showing the predictive accuracy of the models are given in Table 3. The lowest R^2 value was obtained in linear regression and the highest in elastic net regression. MAE and RMSE values are very close to each other in all models. According to the Min - Max accuracy parameter, the model predicted with the lowest accuracy (94%) was linear and ridge, while the highest prediction accuracy was determined as elastic net regression with 95.1%.

Table 3. predictive accuracy of the models

Model	R^2	MAE	RMSE	Min-Max. accuracy
Lineer	0.072	2.80	3.76	0.940
Ridge	0.117	2.75	3.73	0.940
Lasso	0.076	2.79	3.74	0.942
Elastic Net	0.246	2.85	3.65	0.951

Conclusion

In this study, the prediction of aggregate stability was determined by different regression methods. A high correlation was determined between soil aggregate stability and clay content. Its relationship with organic matter was found at low levels. Variations in the predictive accuracy of the models were determined due to the differences in the methods. As a result of the study, the best prediction was obtained with elastic net regression by determining the appropriate alpha and lambda values.

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Land evaluation for sustainable land management with multi-criteria decision making and linear combination technique; A case study in Samsun-Kavak District

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Abstract

The aim of this study is to identify the potentially suitable agricultural areas for cultivated agricultural production using two widely used multi-criteria decision-making approaches such as Fuzzy Analytical Hierarchal Process (FAHP) and Linear Combination Technique (LCT) together in order to make use of the soil effectively and sustainably. In order for this a previously prepared soil map on a scale of 1/25000 was used. Physical properties such as soil depth, slope, erosion, stonyness, and soil texture using drainage, pH, EC, Organic Material, and polygene parameters were used from a 397.3 ha study area which consists of Seyitali, Kaya, İdrisali, Muhsinli, Beyköy and Çayırlı neighbourhoods of Kavak district of Samsun province. According to the study results, no S1 level area was found in the approximately 397 ha area. Only 11.81 % of the area was found to be suitable at S2 level. 3.4 % of the area was found to be at class N, and the remaining approximately 84.79 % of area was found to be at S3 level.

Keywords: B-AHS, Linear Combination, Soil evaluation, Samsun.

Introduction

The bright blue colour of the Earth is gradually turning into a pale brown colour. Unbalanced and excessive water consumption, unconscious agricultural practices, inappropriate management techniques can have irreversible consequences in some cases by degrading the natural environment. While there is ecological degradation on the one hand, on the other hand, it is no longer possible to keep up with the increasing food demand of the rapidly growing population. Soil, the existence of which cannot be increased, needs to be protected much more in order to grow plants on it, both to meet today's needs and to leave a sustainable geography to future generations.

Sustainable agriculture is the creation of an agricultural structure that uses agricultural technologies that do not harm the environment as well as the protection of natural resources in the long term (Turhan, 2005). Rapid change in agriculture based on intensive input use has enabled agricultural production to be carried out with less labour, but has also led to significant environmental costs arising from conventional agriculture (Eryılmaz and Kılıç, 2018). Although different definitions have been made, the Burtland report published in 1987 has accepted the definition as the process of meeting today's needs without compromising the needs of future generations. The definition expresses the understanding of development that takes into account the balance between development and natural resources, ensures that future generations benefit from the benefits of development as well as today, and that the environment and development complement each other (Tıraş, 2012).

The concept of land stands out as the basic element in terms of agricultural production. Agricultural production depends on the land, soil and other physical, chemical and biological factors affecting the soil and production capacity to a great extent (Shukla et al., 2006). In particular, the accumulation of different soils in different areas can give the soils very different properties within short distances (Dengiz and Gülser, 2014). The definition of soil quality defined as the capacity of soil function to be effective today and in the future for an efficient and sustainable agricultural production (Doran and Parkin, 1994) In recent years, it has become important in terms of measuring the changes caused by different management practices in the territories (Karlen et al., 1994). It has become imperative that the most appropriate of these management practices be selected and implemented according to the results of land assessment or land use planning studies prepared with detailed data, especially soil data (FAO, 1976). It is seen that the valuation processes, which have become more complex today, have developed methodologically with the effect of the development of computational systems and artificial intelligence application processes. Geographical Information Systems based (GIS) and multi-criteria decision making (MCDM) methods are used together because of the problems of spatial decision making methods, the most appropriate and unique one can be selected from the applicable alternatives depending on some multiple and independent valuation criteria, and it provides equal facilities (Malczewski, 2006). These processes are used for the estimation of potential land for urban or national planning of very large areas and for the determination of alternative land suitability (Chen et al., 2008).

The aim of this study is to determine the suitability classes for agricultural use (TKUS) of the soils formed on the slope lands and alluvial deposited lands in Kavak district of Samsun province with the help of detailed basic soil maps and data by using the linear combination technique (DCT) and to determine the weight values of some selected soil parameters by using the Fuzzy Analytical Hierarchical Process technique and to create a suitability map for agricultural use.

Material and Methods

General Characteristics of the Study Area

The study area was carried out on 1523 parcels with a total cadastral area of 377.83 ha in İdrisli, Muhsinli, Çayırlı, Beyköy, Seyitali and Kaya neighbourhoods within the borders of Kavak district of Samsun province. The net area covered by the study area is 397,28 hectares including non-agricultural areas. The majority of the study area has 76.1% mild and moderately steep slopes and only around 2% of the area is flat and nearly flat. In addition, 23.6% of the area consists of steep and very steep slopes. The average annual precipitation is 512,5 mm and the average temperature is 10,2^{o} C. According to the data of the meteorological station of Havza district; soil temperature regime is Mesic, soil moisture regime is Xeric and subgroup moisture regime is Typic Xeric (Thornthwaite, 1948).

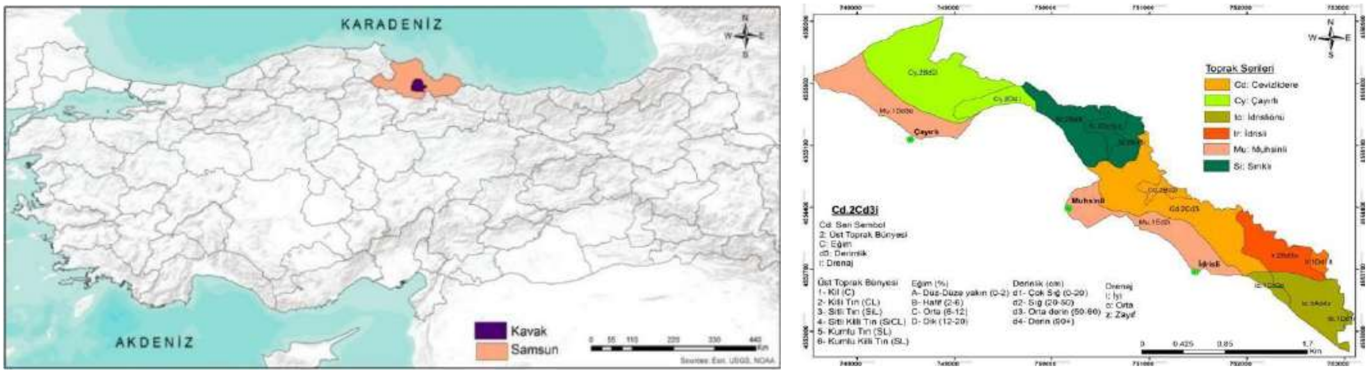

Figure 1. Location and basic soil map of the study area

In the study area, 14 different soil series were found. Some surface and subsurface diagnostic horizons formed after the formation process of the soils were identified and these were placed in Entisols, Inceptisols and Vertisols. Among these orders, Entisols cover the most area with 67.5%, followed by Inceptisols with 21.8% and Vertisols with 10.6% (Soil taxonomy, 1999).

Method

Evaluation Criteria

According to the soil survey study by Dengiz, (2002), it was revealed through detailed soil survey mapping studies that there are 10 parameters that can be determinative in terms of agricultural suitability of lands. These parameters are divided into physical (slope, depth, erosion, texture, stoniness and drainage) and chemical (EC, pH, $CaCO_3$ content, organic matter). In addition, these criteria were divided into sub-factors and weight values between 0 and 4 were given. If the sub-factor makes agricultural use of the land impossible, it takes the value of 0, and if it provides optimum opportunities for the cultivation of cultivated plants and in-field technology applications and traffic, it takes the value of 4. The values between 0-4 vary according to the degree to which soil characteristics limit plant growth or mechanisation.

Table 1. Agricultural land suitability classification model parameters and weight scores of sub-factors

A-Land parameters

Sub Factor	Weight Score	Sub Factor	Weight Score	Sub Factor	Weight Score	Sub Factor	Weight Score	Sub Factor	Weight Score
Slope (%)		Erosion		Drainage		Soil Depth (cm)		Stoniness (%)	
Flat: 0-2	4	Light	4	Good	4	0-20	1	0-5	4
Light: 2-6	3	Medium	3	Medium	3	20-50	2	5-15	3
Medium:6-12	2	Severe	2	Inadequate	2	50-90	3	15-50	2
Steep:12-20	1	Extreme	1	Extreme	1	90+	4	50-90	1
Very steep:20+	0							>90	0
B-Soil parameters									
Composition		pH		EC (dS/m)		$CaCO_3$ (%)		OM (%)	
Sub Factor	Weight Score	Sub Factor	Weight Score	Sub Factor	Weight Score	Sub Factor	Weight Score	Sub Factor	Weight Score
Very fine: (C->%45)	2	>8.3-<5.5	1	0-2	4	0-5	2	0-1	1
Medium fine: (C-<%45, CL, SiL, SCL)	3	5.5-6.5	2	2-4	3	5-15	4	1-2	2
Medium: (L, Si, SiL, fSL)	4	6.5-7.5	4	4-8	1	15-25	3	2-3	3
Rough: (S, SL, LS)	0	7.5-8.2	3	8-10	0	> 25	1	> 3	4

Weighting with FAHP Method

Fuzzy Analytical Hierarchical Process (FAHP) is one of the most frequently used methods in the literature within the Multi-Criteria Decision Making approaches. AHP is a mathematical method that takes into account the priorities of decision makers in the evaluation processes and evaluates the parameter variables of the evaluation together (Saaty, 1980). The biggest handicap of the AHP method is its inability to handle uncertainty and indecision situations (Deng, 1999) Although it is used effectively in many fields, it is the fact that it reveals clear situations such as black and white and ignores the shades of grey in between (Dağdeviren, 2007). For this reason, it is criticised for the use of precise values and the absence of human influence, in other words, for not reflecting the variability of human logic and expert opinion (Kahraman et al., 2004). For this reason, (Van Laarhoven and Pedrycz, 1983) A new approach (FAHP) was introduced by integrating fuzzy logic and AHP using a method called triangular fuzzy numbers (Chang, 1996). He took this method to a further stage and used the order analysis method for artificial order values of pairwise comparisons of fuzzy triangular numbers. For the first time (Zadeh, 1965) The concept of fuzzy sets, which was put forward by the authors of the study, is stated as a method characterised by a membership function with a membership degree in the range of 0 and 1 based on the continuity of the parameter included in a data set.

In this study, in order to better express the verbal uncertainty encountered in determining the relative importance levels of the criteria to be used in ranking the suitability of potential arable farming areas, the rank analysis method proposed by Chang (1996) was used. In his study, Chang (1996) used triangular fuzzy numbers for pairwise comparisons in FAHP. A triangular fuzzy number is represented as (l | m, m | u) or (l, m, u) (Kahraman, 2004).

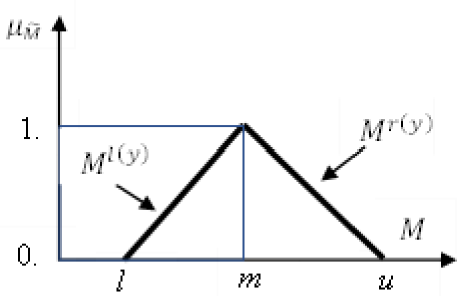

Figure 2. Triangular fuzzy number

Table2. Triangular fuzzy Reciprocal triangular transformation scale

Triangular Fuzzy Transformation Scale Numerical Value	Linguistic Expression	Triangular Fuzzy Number	Reciprocal Triangular Fuzzy Number
1	Equal	(1,1,1)	(1,1,1)
2	Weak Superiority	(1,2,3)	(1/3,1/2,1)
3	Not Bad	(2,3,4)	(1/4,1/3,1/2)
4	Preferable	(3,4,5)	(1/5,1/4,1/3)
5	Good	(4,5,6)	(1/6,1/5,1/4)
6	Pretty Good	(5,6,7)	(1/7,1/6,1/5)
7	Very Good	(6,7,8)	(1/8,1/7,1/6)
8	Absolute	(7,8,9)	(1/9,1/8,1/7)
9	Perfect	(8,9,10)	(1/10,1/9,1/8)

Determination of Suitable Areas for Agriculture

Agricultural land evaluation is the process of estimating the utilisation potential of land. Land evaluation methods are generally divided into qualitative methods based on expert knowledge and quantitative models based on simulation models. It would be appropriate to approach the analysis of agricultural land suitability classes as an evaluation or a QCDM problem involving more than one criterion (Dengiz et al., 2022). Especially in this system, land suitability classes are determined according to the index values of each of the parameters to be used in soil valuation. This will be done by calculating the ratios of these parameters for each mapping unit determined in the area. Among many different techniques, especially in this study, linear combination technique is used together with FAHP approach as a multi-criteria land suitability classification technique. (Çakır and Dengiz, 2021). In the Linear Combination technique, a weight value is assigned to each of the criteria affecting the agricultural land use pattern. These weight values are determined according to the relative importance of the criteria. Sub-criteria belonging to these criteria are then formed and these sub-criteria are subjected to a separate numerical evaluation and sub-criteria scores are obtained. These sub-criteria scores are then multiplied by the weight value of the criterion to which they belong. As a result, the criteria are put on the same scale and can be summed together, i.e. combined (Kahraman et al., 2004). The mathematical equation (11) for the approach of suitability assessment of land for agricultural purposes in this technique is as follows.

$$S = \sum_{i=1}^{n}(W_i \cdot X_i) \; (1)$$

Where S is the total land suitability score; Wi is the weight value of parameter i; Xi is the sub-criteria score of parameter i; n is the total number of parameters considered. The land suitability map of the area was created by classifying the values calculated by the linear combination technique for each mapping unit according to Table 3.

Table 3. Land suitability classes and values of the classes

Description	Classroom	Value
Very convenient	S1	3.501- 4.000
Suitable	S2	3.001- 3.501
Less suitable	S3	2.001- 3.000
Not suitable	N	0.000- 2.000

Results and Discussion Determination of Criteria Weights with B-AHS

Detailed soil map of the study area was prepared by Aydın and Dengiz (2019). There were 14 mapping units in the study. Pairwise comparisons for the physical and chemical criteria selected for the determination of agricultural suitability of the land belonging to the study area are shown in table 4.

In the next step, analytical hierarchical process evaluation was carried out by following the steps described in equations (1-9) above within the framework of fuzzy logic and weight values were found as shown in table 5.

As a result of the assessment using the FAHP method, no area at S1 level was found in a total area of approximately 397 hectares. Only 11,81% of the area was found suitable at S2 level. Another 3,4% of the area was found in N class and the remaining 84,79% of the area was found in S3 level. It is seen that the areas with N class, especially the areas that are shallow in terms of steep soil, are at this level and the areas at S3 level are not suitable for agricultural use when the soil depth factor is added, even though they are not steep slopes in terms of slope.

Table 4. Pairwise comparison matrix of criteria

Criteria	Slope	Depth	Erosion	Drainage	Stoniness	Composition	OM	pH	EC	Lime
Slope	1,1,1	2,3,4	2,3,4	2,3,4	4,5,6	2,3,4	2,3,4	4,5,6	4,5,6	4,5,6
Depth	1/4,1/3,1/2	1,1,1	2,3,4	2,3,4	4,5,6	2,3,4	2,3,4	4,5,6	4,5,6	4,5,6
Erosion	1/4,1/3,1/2	1/4,1/3,1/2	1,1,1	2,3,4	2,3,4	1/4,1/3,1/2	1/4,1/3,1/2	4,5,6	4,5,6	4,5,6
Drainage	1/4,1/3,1/2	1/4,1/3,1/2	1/4,1/3,1/2	1,1,1	4,5,6	1/4,1/3,1/2	1/4,1/3,1/2	2,3,4	2,3,4	2,3,4
Stoniness	1/6,1/5,1/4	1/6,1/5,1/4	1/4,1/3,1/2	1/6,1/5,1/4	1,1,1	1/6,1/5,1/4	1/6,1/5,1/4	1/4,1/3,1/2	1,2,3	2,3,4
Composition	1/4,1/3,1/2	1/4,1/3,1/2	2,3,4	2,3,4	4,5,6	1,1,1	1/3,1/2,1	2,3,4	2,3,4	4,5,6
OM	1/4,1/3,1/2	1/4,1/3,1/2	2,3,4	2,3,4	4,5,6	1,2,3	1,1,1	4,5,6	2,3,4	2,3,4
pH	1/6,1/5,1/4	1/6,1/5,1/4	1/6,1/5,1/4	1/4,1/3,1/2	2,3,4	1/4,1/3,1/2	1/6,1/5,1/4	1,1,1	2,3,4	2,3,4
EC	1/6,1/5,1/4	1/6,1/5,1/4	1/6,1/5,1/4	1/4,1/3,1/2	1/3,1/2,1	1/4,1/3,1/2	1/4,1/3,1/2	1/4,1/3,1/2	1,1,1	2,3,4
Lime	1/6,1/5,1/4	1/6,1/5,1/4	1/6,1/5,1/4	1/4,1/3,1/2	1/4,1/3,1/2	1/6,1/5,1/4	1/4,1/3,1/2	1/4,1/3,1/2	1/4,1/3,1/2	1,1,1

Table 5. Weights of the criteria used in the evaluation of potential cultivated agricultural areas

Factors	Weighting scores
Slope	0,3000
Depth	0,1960
Erosion	0,1000
Drainage	0,0700
Stoniness	0,0250
Composition	0,1205
OM	0,1400
pH	0,0035
EC	0,0250
Lime	0,0200

Table 6. Distribution of suitability classes at series level and by each mapping unit

Soil Series	Suitability Value	Suitability Class	Map Unit	Area (da)	Ratio (%)
Cevizlidere	3,18	S3	Cd.2Bd2i	67,7	1,7
Cevizlidere	3,06	S3	Cd.2Cd3i	755,42	19,01
Çayırlı	2,57	S3	Cy.2Dd i	139,17	3,5
Çayırlı	3,04	S3	Cy.2Bd2i	817,42	20,57
İdrisli	3,33	S3	Ir.2Bd3o	287,45	7,24
İdrisli	2,93	S3	Ir.1Dd1it	37,2	0,94
İdrisliönü	2,17	N	Io.1Dd1i	10,25	0,26
İdrisliönü	2,93	S3	Io.1Cd3o	59,45	1,5
İdrisliönü	3,52	S2	Io.1Ad4z	352,98	8,88
Muhsinli	2,665	S3	Mu.1Dd3o	458,66	11,54
Muhsinli	2,62	S3	Mu.1Ed2i	443,46	11,16
Sırıklı	3,23	S3	Si.2Bd3i	124,57	3,14
Sırıklı	2,39	N	Si.2Dd1it0	116,9	2,94
Sırıklı	3,565	S2	Si.2Bd3i	302,24	7,61

Conclusion

In the study area, the area with flat and nearly flat lands (0-2%) slopes is only 2.1% of the whole area. The areas with a slope of 2-6% have the highest rate of 38.9%. The areas with 6-12% slope are 37,2%. The remaining 21,8% are areas with 12% and above. In terms of slope, it is seen that the study area is not very suitable for cultivated agriculture. Approximately 40% of the area can be suitable for cultivated agriculture when some arrangements are made. The fact that the area is suitable at S2 level in only 2 mapping units, especially the biggest reason for not having S1 level is the slope. Although pH seems to be alkaline at a localised point in the area, there is no problem in terms of these parameters since EC, stoniness and erosion are homogeneously distributed in the rest of the area. As the slope is variable, it is observed that the soil depth decreases relatively towards the areas where the slope increases, which shows that the S3 level is one of the main reasons why the S3 level is the highest. In the areas with S2 level, the amount of OM is high and there is no drainage problem. When considered together with this determination, it is understood that Çayırlı 2 (weight score 3,04), Cevizlidere series (weight scores 3,18 and 3,06) and İdrisli series (weight scores 3,33 and 2,93), which are the areas with the lowest slope, can be transformed from S3 to S2 with the elimination of the drainage problem and the organisation of the soils by adding organic matter.

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Sandy soils in Poland: Exploring research constituents

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Abstract

More than 900 million hectares are covered by sandy soils on the Earth's surface. Nevertheless, because of their marginal status as often-low fertile soils, they have received limited research attention worldwide. Almost 55% of the soils of Poland are classified as Arenosols (29%) and Podzols (26%) according to WRB. However, the WRB itself has changed some concepts related to Arenosols and Podzols through the last three editions (2006, 2015, and 2022) such as Albic horizon and Claric material. There is a need to explore research constituents and intellectual structure of sandy soils in Poland in the extant literature. In this way, a comprehensive science mapping analysis was conducted using the R-tool bibliometrix with Scopus databases.

During the last five years, China, the United States, and Poland have led as the most productive countries for sandy soils publications based on their corresponding authors. Meanwhile, Germany is the most average cited corresponding author's country followed by China and the United States. Among the keywords in sandy soils research conducted in Poland stand out biochar, soil organic matter, soil organic carbon, and heavy metals. Podzolization as a keyword is ranked in 10th place, which indicates lower interest in sandy soils formation than sandy soils biogeochemistry.

This gap between the biogeochemistry and the pedogenesis of sandy soils has been recognized by the Commission for the Soil Genesis, Classification, and Cartography of the Soil Science Society of Poland which dedicated the year 2021 to Gleba rdzawa (Pol.) – the rusty soils. Finally, the research in sandy soil formation will contribute to the understanding of Polish and Central European soil geography.

Keywords: Arenosols, Bibliometrix, Pedogenesis, Podzols.

Introduction

The texture as a soil constituent is specific and determines the soil system responses to the environment and to soil use (Blum *et al*., 2018). Specifically, the main characteristic of sandy soils is their relative dominant proportions of sands. Huang and Hartemink (2020) defined them as those soils with average sand content grater than 50% and a clay content less than 20% to a depth of 30 cm. In this way, the textures included are sandy, loamy sand, and sandy loam (WRB, 2022). Principally, their main land use are savanna and forest (46%), grass (25%), and crops (12%).

These soils are widely distributed on the Earth. In central-north Europe they geographically dominate thanks to the so-called European Sand Belt, a Holocene inland aeolian sand sediments region which covers almost a half of Poland territory (Kalińska, 2019). In fact, the combined areas of Arenosols, Fluvisols, and Podzols in Poland represent circa 60% of the territory.

According to the WRB (2022), sandy soils generally can comprise Arenosols, Regosols, Leptosols, and Fluvisols. Based on Soil Taxonomy, they are mainly referring to Entisols and Aridisols. The Polish Soil Classification (2019) distinguish them in the first three orders, Order 1 – wakly developed soils, Order 2 – Brown earths, and Order 3 – Podzolic soils (Kabała *et al*., 2019).

It is remarkable the geographical importance of sandy soils in Poland. In this way, a bibliometric analysis was conducted to explore the principal research constituents in recent extant scientific data.

Material and Methods

Data base collection

The data from research articles was obtained from Elsevier's Scopus using the following keywords: sandy, soils, and Poland. The most recent 2,000 articles data from 2017 was exported as a BibTex file.

Bibliometrix: The R tool

Bibliometrix is a package in the R environment as an open-source tool for bibliometrics research, developed by Aria and Cuccurullo (2017). It provides several functions for importing bibliographic data from Scopus and performing bibliometric analysis and building data matrices.

Results and discussions

As rapid radiography, the *trend topics* reflect the principal topics published related to sandy soils in Poland, their main frequency over time and term frequency in the spectrum. After "soil", "heavy metals" is the most popular topic published since 2017. Furthermore, "biochar" constitutes one of the most published topics. The topics influenced by the biochemistry vision are the majority with topics such as microorganisms, soil enzymes, or compost. On the other hand, climate change and soil properties show minor interest in the time and term frequencies (Figure 1).

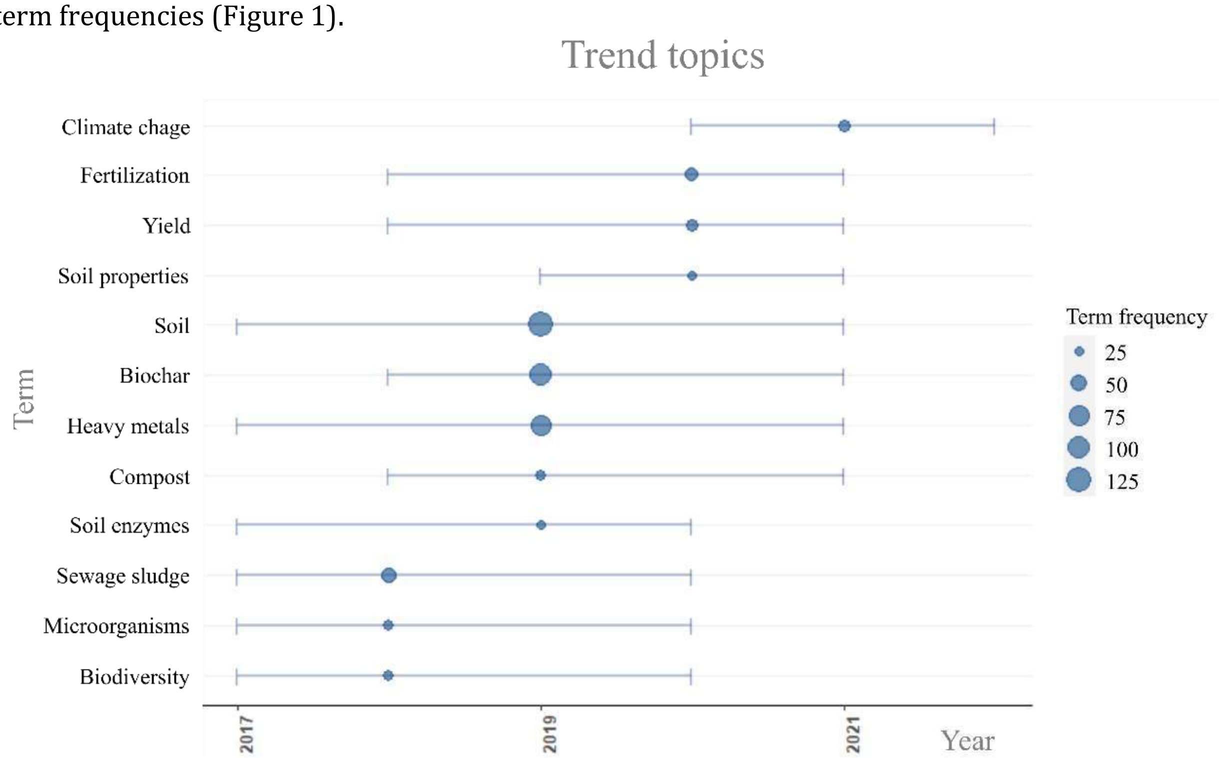

Figure 1. Trend topic analysis for sandy soils in Poland data from 2017, using Bibliometrix.

The taxonomy of sandy soils in Poland published articles since 2017 can be reflected as a dendrogram map (Figure 2). It shows 12 categories in 3 general themes. The climate change, yield, and soil properties categories as one main theme. Another with biodiversity, microorganisms, and soil enzymes combined. The third one is subdivided into two; heavy metals and fertilization on one side, and compost and biochar on the other. This information is useful to generally understand which topics are more related in recent research articles related to sandy soils. It is highlighted that the soil properties category is closely related to the yield category, which indicate more interest in land use research than in soil genesis properly.

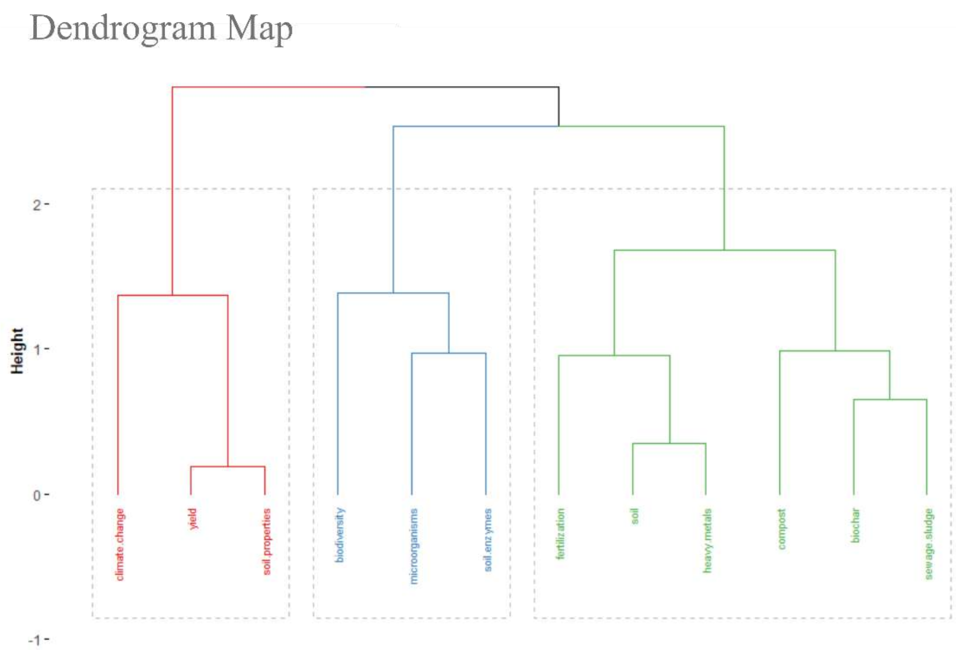

Figure 2. Dendrogram Map for sandy soils in Poland data from 2017, using Bibliometrix.

The information in Figure 2 also can be shown as a conceptual structure map (Figure 3). Particularly, the map is constituted in clusters according to theirs constructed dimensions. In other words, the map reflects closely related topics as clusters and the distances between them. In this way, biodiversity is so far related to compost, in the same way microorganisms and yield.

Finally, the information can be expressed as a density and centrality map (Figure 4) which states three parameters among themes: niche (those very specific), motor (novel), emerging o declining (not very relevant nowadays), and basic. It is that biochar and groundwater are two of the most important motor themes. Furthermore, microbial biomass and soil moisture lead as niche themes. Meanwhile, agriculture, climate change, and soil organic carbon remains as basic themes in Polish sandy soils research constituents. It is noticeable the absence of soil genesis-related themes in general.

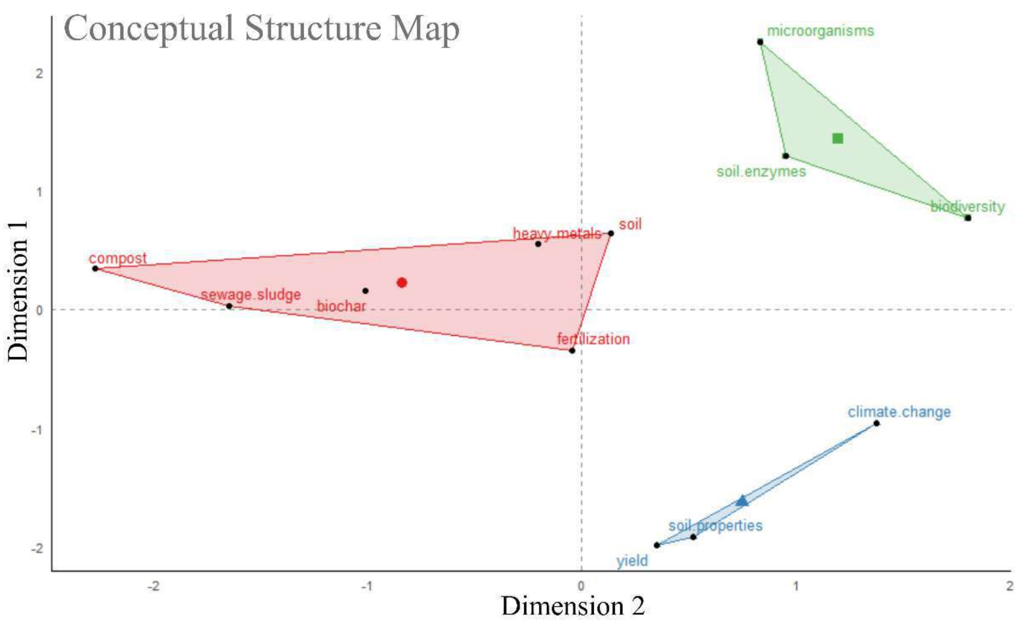

Figure 3. Conceptual Structure Map for sandy soils in Poland data from 2017, using Bibliometrix.

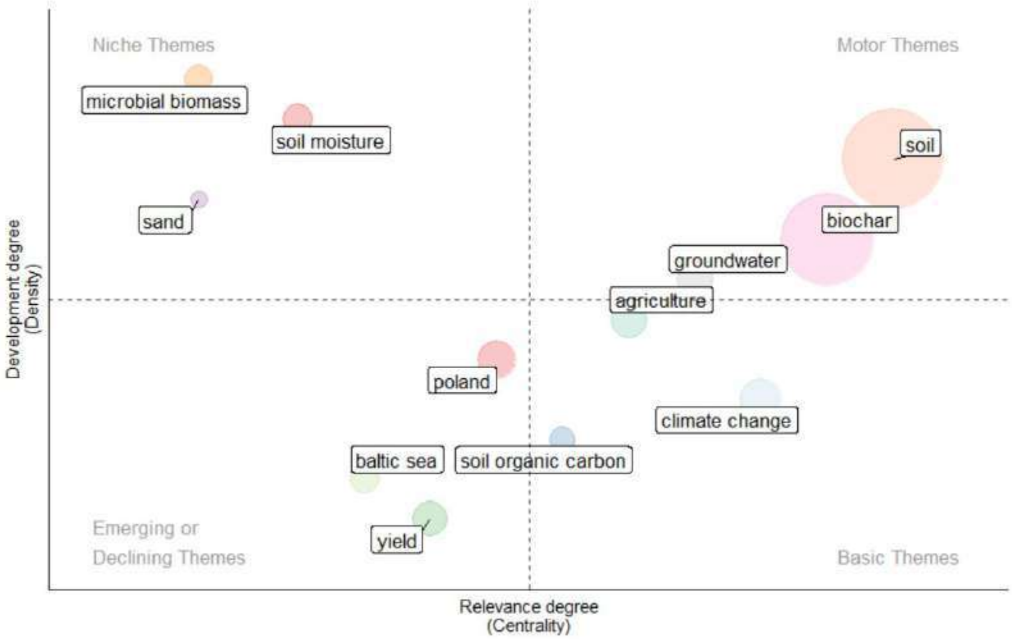

Figure 4. Conceptual Structure Map for sandy soils in Poland data from 2017, using Bibliometrix.

Conclusion

The recent academic interest related to sandy soils in Poland is mainly based on the biochemistry vision, particularly in themes such as biochar. Furthermore, topics like heavy metals have been constantly published since 2017. It is stated the research gap in sandy soils genesis and properties. At present, the research in soil properties is closely related to yield publications. In this way, Bibliometrix was useful to determine spaces to contribute knowledge about sandy soils in Poland and Central Europe.

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Topsoils nutrient dynamics of compound farms in the upper and lower slopes of University of Nigeria, Nsukka

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Abstract

Information on fertility status of compound farms are invaluable for proper management of soils to enhance crop productivity especially in farmlands with different slope gradients. This research aims to assess topsoil's nutrient dynamics of compound farms on upper slopes (CFUS) and lower slopes (CFLS) of the University of Nigeria, Nsukka (UNN). Since the inception of UNN in 1960, there hasn't been much known about how fertile the soils are in CFUS and CFLS, hence this study. A handheld GPS receiver was used to delineate the campus area into CFUS (458 to 447 m above mean sea level (AMSL)) and CFLS (415 to 423 m AMSL). Twenty compound farms were randomly sampled at 0-20 cm soil depths, ten each from CFUS of Ikejiani and Ezenwaeze areas and CFLS of Mbanefo area. Standard methods were used to analyze the soil samples at the UNN Soil Science Undergraduate Laboratory. Higher values of organic matter, CEC, pH, and exchangeable calcium recoded at CFUS showed that soil fertility status of CFUS was generally higher than CFLS. The CFUS had significantly higher clay and silt contents (p 0.05) than the CFLS, while the lower slope had a higher sand fraction. The results did not follow the typical trends of soil nutrients being transported from upper to lower slope, probably due to anthropogenic activities such as buildings and road constructions between the upper and lower slopes of the campus. Therefore, this result will help compound farmers in both CFLS and CFUS achieve higher crop productivity by adopting efficient management techniques to complement the soils' fertility using both organic and inorganic fertilizers.

Keywords: Compound farms, Fertility status, Topsoil, Slopes, Nutrient dynamics.

Introduction

People take advantage of available lands surrounding their homes to cultivate crops, using domestic and livestock wastes to fertilize the soils. These lands surrounding homesteads on which crops are grown, are generally known as compound farms. Compound farms encompass a system involving the incorporation of trees and shrubs into crop and small livestock farming systems within the compounds of peoples' yards (Okafor and Fernandes, 1987). In this system, garbage, leftover crops, and animal waste are used to keep the soil fertile (Onyenweaku *et al.*, 1996). However, soil loss due to crop harvesting result in loss of soil nutrients (Oshunsanya *et al.*, 2018). This is because a lot of soil and soil nutrients are taken from cropped land when root, tuber, bulb, and legume crops like yam, cassava, onion, and groundnut, which are often grown in compound farms, are harvested (Dada *et al.*, 2016). Therefore, to ensure optimum soil productivity and crop performance, nutrients lost through harvesting and other losses must be adequately replaced as fertilizers (Marschner, 1995).

Management practices adopted by farmers are crucial to the overall soil fertility and productivity status of compound farms. Proper soil fertility management helps to improve soil fertility status by enhancing organic matter content, increasing the efficiency of nutrients by using closed nutrient cycles, and minimizing nutrient losses (Conway, 1997).

For example, farmers have to consider the slope positions of their farmlands as a critical approach to manage the fertility of the soils effectively. This is due to the fact that different slope positions often result in different soil fertility attributes (Awdenegest and Nicholas, 2008). Slope positions shape nutrient and water flux, distribution and concentration across toposequence. As pointed out by Mulugeta *et al*. (2012), slope increase soil disturbance and erosion, and equally influence soil parameters by altering plant growth, litter formation, and decomposition patterns, which in turn affect carbon and nitrogen contents of soils. However, there seems to be little or no information available on the fertility status of CFUS and CFLS of UNN even before and after the inception of the University in 1960. Thus, this research aims to assess how fertile the soils of compound farms are in the upper and lower slopes of UNN in order to help compound farmers make more efficient management decisions.

Materials and Methods

Location of the study

The location of this research was at University of Nigeria, Nsukka campus in Southeast Nigeria sited at 6°54'N and 7°24'E latitude and longitude respectively, on an elevation of 447.26 meters above mean sea level (Oko-Ibom and Asiegbu, 2006). The CFUS and CFLS were at Ezenwaeze /Ikejiani and Mbanefo areas in the University, respectively, as shown in Figure 1.

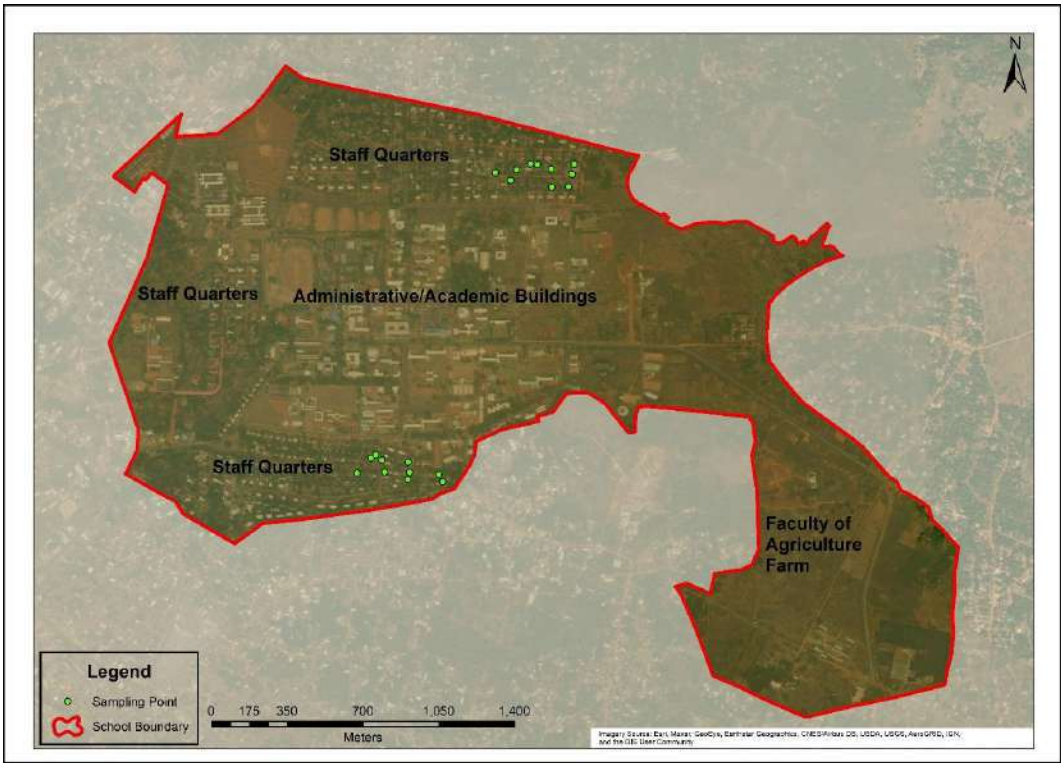

Figure 1: Map of the University of Nigeria, Nsukka Campus showing the sampling points in CFUS and CFLS

Geology and Soils

The soils of Nsukka are a blend of many soil types, including hydromorphic soils in the floodplains and ferrallitic soils (also called red earth or acid sands) on the cuesta and plateau slopes (Ezeaku and Iwuanyanwu, 2013). They are predominantly Ultisols, an order of well-drained ferallitic sandy clay loams. Sand deposits of false bedded sandstone create the dark red to brownish red soil color matrix of the mid and higher slopes (Ezeaku, 2000). Soils on gentler slopes are majorly Alfisols; a reddish brown to brownish black soils (Soil Survey Staff, 1999). However, the soils of this region are inherently low in fertility due to poor nutrient reserves in their parent materials, rapid organic matter decomposition due to high temperatures, and increased nutrient leaching and losses due to rainfall of increased amount and intensity (Asadu et al., 2010).

Climate

The area has a humid tropical climate with wet (April–October) and dry (November–March) seasons. Precipitation averages 1550 mm per year, with the highest totals occurring in July and September. Average highest temperatures during the daytime reach 31 degrees Celsius, while lowest at night dip to 21 degrees

Celsius (Asadu, 2002). The relative humidity varies between 70 and 80 percent (Oko-Ibom and Asiegbu, 2006). This range dips below 60% during the Harmattan; a 3-week period of foggy, dry weather that occurs between December and January (Asadu et al., 2001).

Vegetation

The vegetation of Nsukka is secondary, mainly due to anthropogenic activities such as land clearing, bush burning, and land cultivation (Asadu and Akamigbo, 1987), and hence best described as derived savannah (Savanna-mosaic) agroecology (Ezeaku and Iwuanyanwu, 2013). The following species of shrubs and grasses are native to this area: Elephant grass (*Pennisetum purpureum*), Gamba grass (*Andropogon gayanus*), Guinea grass (*Panicum maximum*), Bahia grass (*Paspalum notatum*), Green couch (*Cynodon dactylon*), Para grass (*Brachiaria mutica*), African star grass (*Cynodon lemfuecens* and C. *plectostachyus*), etc. (Ezeaku and Eze, 2014). The tree species are oil bean tree (*Penteclethra mycrophylla*), oil palm (*Elais guinensis*), cashew (*Anacadium occidentales*), among others.

Agriculture

Rainfall is the primary determinant of agriculture in Nsukka. However, compound farmers irrigate their small farms to supplement rainfall. Generally, farming of crops and livestock at small scale levels is predominant. Ridges and mounds are common seedbeds often prepared with local hoes after clearing the vegetation. Inorganic or mineral fertilizers and organic fertilizers like manure, household waste, and some agricultural residues are the major sources of nutrients that are added to the soil in order to improve its fertility. The principal crops commonly cultivated in the Nsukka area include cocoyam (*Dioscorea* spp), water yam (*Dioscorea alata*), cassava (*Manihot* spp), maize (*Zea mays*), white yam (*Dioscorea rotundata*), and plantain (*Musa paradisiaca*), potatoes (*Ipomea batatas*) as well as a variety of vegetables such as okra (*Abelmoschus esculentus*), pepper (Capsicum spp), fluted pumpkin (*Telfairia occidentalis*), cucumber (*Cucumis sativus*), tomatoes (*Solanum lycopersicum*), garden egg (*Solanum melongena*) and amaranthus (*Amaranthus viridis*).

Characteristics of the sampling locations

Table 1 shows the precise altitudes (elevations), latitudes and longitudes collected using GPS. Above mean sea level, CFUS had an elevation range of 458 to 447 meters, whereas CFLS had an elevation range of 415 to 423 meters. The crops grown by residents range from vegetables, cereals to root and tubers. There was no marked difference in the crops grown due to topographic positions and within the streets. This reflects prevailing similar climatic conditions within UNN and food preferences by the residents.

Table 1: Sampling locations and site characteristics

Street Number and Name	Altitude (m AMSL)	Latitude (N)	Longitude (E)	Crops Grown
Compound farms on the Upper slope (CFUS)				
4 Ezenwaeze	451	N6º51.493′	E7º24.472′	Maize, cassava, Fluted pumpkin
7 Ezenwaeze	453	N6º51.493′	E7º24.534′	Maize, cassava, Fluted pumpkin
11Ezenwaeze	453	N6º51.475′	E7º24.529′	Maize, cassava, Fluted pumpkin, pepper
236 Ikejiani	449	N6º51.490′	E7º24.403′	Maize, cassava, Fluted pumpkin, cocoyam, potatoes, okra
238 Ikejiani	447	N6º51.523′	E7º24.465′	Maize, cassava, vegetables, potatoes
239 Ikejiani	447	N6º51.527′	E7º24.438′	Maize, cassava, okra, curry
241 Ikejiani	447	N6º51.536′	E7º24.450′	Maize, potato
243 Ikejiani	449	N6º51.518′	E7º24.530′	Maize, vegetables, Fluted pumpkin, Amaranthus
248 Ikejiani	455	N6º51.487′	E7º24.607′	Maize
250 Ikejiani	458	N6º51.469′	E7º24.617′	Maize, cassava, cocoyam, potatoes
Compound farms on the Lower slope (CFLS)				
4 Mbanefo	415	N6º52.236′	E7º24.748′	Maize, cassava, vegetable, tomato
7 Mbanefo	417	N6º52.217′	E7º24.786′	Maize, cassava, Fluted pumpkin
8 Mbanefo	418	N6º52.243′	E7º24.800′	Cassava, cocoyam
10 Mbanefo	417	N6º52.258′	E7º24.835′	Maize, water yam, and vegetables
12 Mbanefo	419	N6º52.256′	E7º24.853′	Maize, cassava, yam, Fluted pumpkin
15 Mbanefo	420	N6º52.200′	E7º24.888′	Maize, cassava, yam, Fluted pumpkin
16 Mbanefo	419	N6º52.245′	E7º24.887′	Cocoyam, cassava, Fluted pumpkin, plantain
17 Mbanefo	423	N6º52.201′	E7º24.930′	Yam and plantain
19 Mbanefo	421	N6º52.232′	E7º24.939′	Maize, cassava, plantain, banana
20 Mbanefo	423	N6º52.257′	E7º24.944′	Maize, cassava, groundnut, okra

Soil sampling

The campus was divided into CFUS and CFLS according to their respective elevations (458–447 m and 415–423 m AMSL) using data from the Global Positioning System (a handheld GPS receiver with a 2.2-inch monochrome display). The upper and lower slopes compound farms were separated by the major road that runs from the University of Nigeria, Nsukka entrance gate through St. Peter's Catholic Church and on to the Medical Centre. This road also borders the school buildings and the staff residential houses. The compound farms were identified by traversing the compounds in the upper and lower slope areas (Figure 1). Random sampling method was used to reduce bias during the sample collection. All the compound farms sampled have been cultivated for at least five years and more. Using a soil auger, soil samples were taken at topographical places associated with CFUS (Ikejiani street and Ezenwaeze) and CFLS (Mbanefo) (Table 1) totaling 20 soil samples randomly taken from 0 to 20 cm soil depths.

Laboratory analysis

The collected soil samples were each bagged in a new, polythene before being air dried and passed through a 2 mm sieve in order to be prepared for analysis in the laboratory. Standard procedures were used at the undergraduate laboratory of the Department of Soil Science at the University of Nigeria in Nsukka to conduct analyses of the samples for fertility indices. The Bouycous hydrometer technique was used to determine the particle size distribution of the soil (Gee and Orr, 2002). At a ratio of 1:2.5 of soil to liquid, the pH of the soil was determined in both water and 0.1 N KCl. The Walkley and Black wet digestion method was used to determine the organic carbon content of the soil (Nelson and Sommers, 1982). Micro Kjeldahl digestion was used as the method of analysis to determine total nitrogen (Bremner and Mulvaney, 1982). The Bray II method was utilized to provide an accurate reading of available phosphorus (Olsen and Sommers, 1982). ETDA titration was used to evaluate the amount of exchangeable calcium and magnesium, whereas flame photometry was used to assess the amount of exchangeable potassium and sodium (Jackson, 1962). The titration method was used to determine the exchangeable acidity of the sample (Mclean, 1982). The Effective Cation Exchange Capacity (ECEC) was determined by adding up all of the exchangeable cations in the solution. The percentage of base saturation was determined by taking the value of the sum total of exchangeable bases and dividing it by the amount of cation exchange capacity.

$$PBS = \frac{\sum EB}{CEC} X\ 100 \qquad \text{Equation 1}$$

$\sum$EB = sum of the exchangeable bases.

Statistical analysis

GenStat Discovery Edition 2 was utilized to conduct a simple factor t-test on the data that was produced from the laboratory analysis. The comparison of the means was carried out using the Fisher's least significant difference (LSD) test at a significant level of P 0.05. Enwezor *et al*. (1989) critical limits of interpreting fertility levels of soil fertility indices and distinguishing between insufficiency and sufficiency concentration levels were used to make sense of the result of the statistical analyses.

Results and Discussion

Soil particle size distributions at CFUS and CFLS

The result of particle size distributions (PSD) of all the compound farms sampled at the upper and lower slope is given in Table 2. The particle size distribution results revealed that the trend across the slopes is sand >clay>silt. Both slopes had a range of sand values between 818.00 and 902.00 g kg^{-1}, silt values between 40.00 and 72.00 g kg^{-1}, and clay values between 62.00 and 110.00 g kg^{-1} and were all significantly affected by the slope gradient factor. Lower slope had a significant (p 0.05) higher sand fraction than the upper slope. Ogban (2021) reported that slope position had no significant effect on soil particle-size fractions. Literature is awash with a plethora of evidence that slope affects soil properties by enhancing the eluviation of materials from upper to lower slopes. However, these results did not follow this typical trend, probably due to anthropogenic activities such as buildings and road constructions between the upper and lower slopes on the campus. This explains why the silt and clay contents were higher at CFUS whereas sand fractions were higher at the CFLS. The denser vegetation at CFUS could have contributed to why its higher silt and clay contents relative to CFLS. Asadu *et al*. (1997) reported that vegetation, other crops grown, rocks, minerals, and other geologic components from which a soil originally developed shape the textural properties of such soil. The soil textural classes of the compound farms ranged from sand, sandy loam, and loamy sand such that soils of the upper slopes are made up of loamy sand and sandy loam, majorly with sand texture only in one farm. In comparison, the lower slopes are made up of sandy soils, majorly with sandy loam texture only in one farm.

Table 2: Soil Particle Size Distribution at CFLS and CFUS

Compound farms	Sand %	Silt %	Clay %
CFLS	90.20	4.00	6.20
CFUS	81.80	7.20	11.00
P-Value	0.001	0.014	0.001
T-value	-3.838	2.709	4.00

Selected soil chemical properties at CFLS and CFUS

Tables 3 shows the mean values for pH, organic matter content, exchangeable acidity and bases, CEC, ECEC, BS, and other selected fertility parameters in the topsoil (0-20 cm) of the upper and lower slopes compound farms respectively.

The soil pH (H_2O) was not significantly different across the compound farms. A mean value of 6.32 was recorded at CFLS compared to 6.74 at CFUS. Organic matter content was significantly higher in CFUS (3.02 %) than CFLS (1.39 %). Total nitrogen was significantly higher in CFLS (0.9 %) relative to the CFUS (0.16 %). The exchangeable bases were not significantly different between the upper and lower slopes, with the exception of Ca^{2+}, which was significantly higher in the upper slope (3.44 cmol kg^{-1}) relative to the lower slope. There was no statistically significant difference in the exchangeable acidity (EA) levels of CFLS (1.76 cmol kg^{-1}) and CFUS (1.48 cmol kg^{-1}). Available phosphorus was higher in CFLS (52.5 Mg kg^{-1}) than CFUS (50.90 Mg kg^{-1}) with no significant dfference. CEC and BS were significantly higher in CFUS (13.88 cmol kg^{-1} and 77.4 %) compared to CFLS (7.80 cmol kg^{-1} and 68.8 %), respectively (Table 3).

Table 3. Selected soil chemical properties at CFLS and CFUS

Cpd	p H	OM	TN	Ca	Mg	K	Na	EA	Av. P	CEC	ECEC	BS
Farm	H_20	%	%	(Exchangeable bases and acidity cmol kg^{-1})					mg kg^{-1}	cmol kg^{-1}		%
CFLS	6.32	1.39	0.9	1.78	1.14	0.46	0.18	1.76	52.5	7.8	5.34	68.8
CFUS	6.74	3.02	0.16	3.44	1.31	0.49	0.17	1.48	50.9	13.88	6.88	77.4
P-Value	NS	0.00	0.004	0.001	NS	NS	NS	NS	NS	0.00	0.001	0.005
T-value	1.734	6.277	3.282	3.886	1.515	0.724	-0.87	-1.775	-0.11	6.965	3.74	3.167

Nutrient Dynamics of CFLS and CFUS of the University of Nigeria Nsukka

Table 4 presents a general ranking of the examined soil fertility indicators, for CFUS and CFLS. The soil pH (H_2O) varied from (6.74) neutral to (6.32) slightly acidic, across CFUS and CFLS. There could have been a slower rate of mineralization of organic matter at CFUS and that explains the higher values of soil pH and organic matter content relative to CFLS. Amuyou and Kotingo (2015) found that grasses covering an upper slope segment caused the soil pH to be significantly higher than in other parts of the catena. Both Ogunwale *et al.* (2002) and Babalola *et al.* (2007) found a decrease in pH from to the bottom of the hill. However, Hendershot *et al.* (1992) found that downslope areas had somewhat greater pH. Furthermore, higher pH values slow down the decomposition of organic molecules by inhibiting microbial activity. Slope however, did not significantly influenced pH (H_2O) levels in this study.

CFUS (30.2 g kg^{-1}) had higher organic matter relative CFLS (13.9 g kg^{-1}). These values were rated as "moderate to high" by Enwezor *et al.* (1989). A greater buildup of organic materials in CFUS may account for the higher value of organic matter there compared to CFLS. However, organic matter was found to be more on lower slopes than on upper slopes by Farmanullah *et al.* (2013).

While the CFLS had a total nitrogen content of 0.9 g kg^{-1}, the CFUS had a total nitrogen level of 1.6 g kg^{-1}. Soil fertility can be increased due to nitrogen's role in the breakdown of organic matter (Essiet, 1990). Because of this, the total nitrogen and organic matter content is higher on the upper slope than on the lower slope. In tropical soils, where organic nitrogen makes up most of the total N, Noma *et al.* (2005) found that total N followed the same trend as organic matter. The difference, however, could be due to higher nitrogen fertilization on the lower slopes. Soil cultivation, as reported by Ezeaku and Iwuanyanwu (2013), leads to a low total nitrogen content due to a high rate of decomposition and oxidation of soil organic matter.

Available phosphorus was higher on the CFUS (50.9 mg kg^{-1}) than on the CFLS (52.5 mg kg^{-1}). Both CFUS and CFLS have a high concentration of available phosphorus, which can be traced back to the mineralization of organic matter content. Phosphorus and other nutrients are slowly but continually lost when the cropping system is intensified, whereas organic matter and nitrogen in the soils are rapidly depleted (Tanimu *et al.*, 2013). The higher clay concentration and pH levels in CFUS are responsible, at least in part, for the relatively lower P concentrations on the upper slopes. Farmanullah *et al.* (2013) also found that phosphorus concentrations were higher at lower slopes than at higher slopes, so our findings are in line with theirs.

There was no statistically significant difference ($p > 0.05$) between the means of EA across CFUS (1.48 cmol kg^{-1}) and CFLS (1.76 cmol kg^{-1}). These principles were given a low rating in accordance with the standards established by Enwezor *et al.* (1989). This is due to the fact that the pH levels were rather consistent across the board, falling between 7.0 and 4.5. In addition, as pointed out by Aguilera *et al.* (2013), persistent farming practices might acidify the soils. The EA values in these locations were found to be sensitive to changes in pH because hydrogen ions predominated.

The moderate level of exchangeable calcium found at CFUS was 3.44 cmol kg^{-1} whereas 1.78 cmol kg^{-1} was recorded for CFLS. Ca^{2+} values in this range were deemed "low to moderate" by Enwezor *et al.* (1989). Leaching losses due to intense tropical precipitation and its low concentration in the parent rock from which the soils were produced could explain the low Ca^{2+} measurements. It is also possible that the dense vegetation on CFUS caused higher Ca^{2+} concentrations because it slows runoff and nutrient leaching down the slope by reducing the impact of raindrops on the soil surface.

There was no statistically significant difference between the exchangeable magnesium values at both CFUS (1.31 cmol kg^{-1}) and CFLS (1.14 cmol kg^{-1}). Similarly, the result for exchangeable Na^{-} was not statistically significant across CFUS and CFLS. There was no significant difference in the mean exchangeable K concentration between CFUS and CFLS, with a range of 0.46 - 0.49 cmol kg^{-1}. The higher exchangeable K values seen CFUS relative to CFLS, may be the result of a blend of organic and inorganic fertilization. However, Farmanullah *et al.* (2013) reported higher K values at lower slopes relative to upper slopes.

The CEC values of the soils varied from 7.80 - 13.88 cmol kg^{-1} across CFLS and CFUS respectively. Reasons for low CEC values at CFLS may be due to low pH, clay and humus concentrations at the lower slopes. Thus, the higher values of pH, clay and organic matter at CFUS resulted to the concomitant higher CEC value too. This is in line with what has been established by a vast majority of researchers especially in the tropics where CEC of soils increases as organic matter content increases. The loss of nitrogen, potassium, and magnesium in the soil through any means results to low CEC and a corresponding low crop yield. Soil CEC in the study area was highly affected by slope. Soil texture and clay mineral type may also have a role in the low CEC levels seen on the lower slopes. Enwezor *et al*. showed that the ECEC was low on the higher slope (6.88 cmol kg^{-1}) but moderate on the lower slope (5.34 cmol kg^{-1}) (1989). The slope's major effects had sizeable impacts on cation exchange capacity (ECEC) and % base saturation (BS).

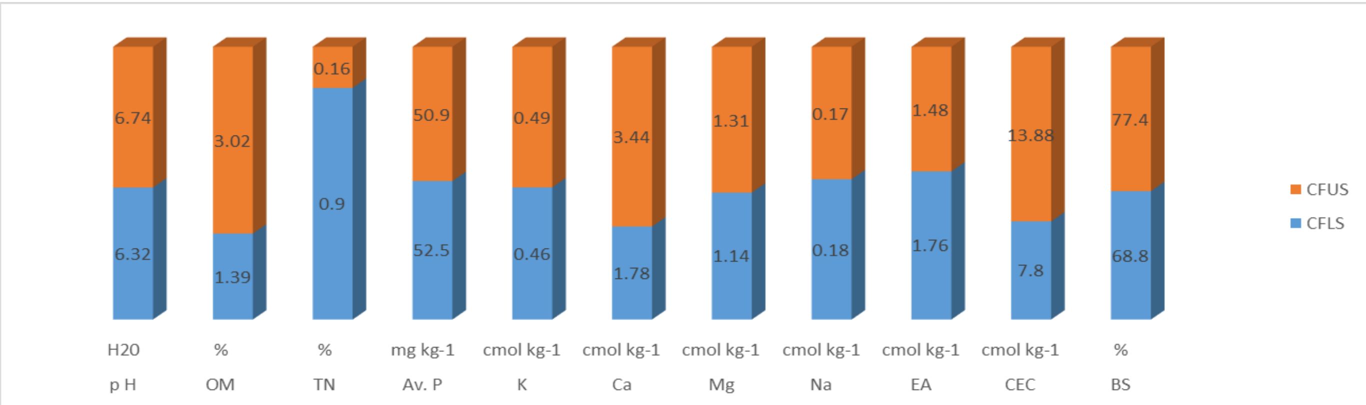

Figure 1: Nutrient Dynamics of CFLS and CFUS

Table 4: Rating of Nutrient Dynamics of CFLS and CFUS using Enwezor *et al*. (1989) critical limits

S/N	Fertility Parameters	Upper Slope	Lower Slope
1	pH	Neutral	Slightly Acid
2	OM	High	Low
3	TN	High	Very High
4	Ca^{2+}	Moderate	Low
5	Mg^{2+}	High	High
6	K^{+}	High	High
7	Na^{+}	Moderate	Moderate
8	CEC	Moderate	Low
9	ECEC	Moderate	Low
10	BS	High	High
11	AV. P	High	High
12	EA	Low	Low

Conclusion

The purpose of this study was to assess topsoil's nutrient dynamics of compound farms in upper (CFUS) and lower slopes (CFLS) of the University of Nigeria, Nsukka (UNN). From the findings, the CFUS had higher pH, organic matter content, CEC, and exchangeable Ca than the lower slope. However, the results did not follow the typical trends of soil nutrients being washed from upper to lower slopes, probably due to anthropogenic activities such as buildings and road constructions between the upper and lower slopes of the campus. Therefore, this result will guide compound farmers in adoption of efficient nutrient management practices in CFUS and CFLS. Compound farmers can improve soil fertility status by adding leguminous crops such as cowpea, groundnut, etc. in rotation with vegetables like fluted pumpkin, amaranthus, etc., and tuber crops, like yam, cassava, etc., so as to enrich the compound farms soils with nutrients. Systematic assessment of the fertility status of in both the CFUS and CFLS from time to time should guide the combined application of organic and inorganic nutrients to enhance the overall soil fertility and ensure higher crop productivity.

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Global research on the relationship of soil iron to nutrient cycling: A bibliometric analysis

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Abstract
This paper aims to study the development of research trends on the relationship of soil iron to nutrient cycling published by international journals. Research publications of 1587 between 2000-2022, were analyzed using R-Package Bibliometrix, aided with Biblioshiny. Results showed significant increase on this research topic from the year 2011, and was able to identify the relevant journals, trends and patterns that may help interested future researchers gain insights of the potential direction of the selected theme.

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

Introduction
Iron is the fourth most abundant element in soil relative to other major elements (Rout & Sahoo, 2015) comprising around 5% of the lithosphere as ferrous and ferric ions (Gabriel, et al., 2021). Soil iron has been recognized as an important player of other biogeochemical cycles like carbon because of its interaction with plants, carbon decomposition, etc. (Calabrese & Porporato, 2019). Conversely, soil iron is also affected by different environmental conditions. For example, (Hall & Silver, 2013) cited that redox fluctuations are closely linked to rainfall dynamics in tropical forests and so, changes in the frequency and intensity of precipitation in the humid tropics could have an impact on redox cycling and soil C dynamics (Hall & Silver, 2013). Through the years, researches to understand the relationship of soil iron to other nutrient dynamics have gained popularity and the number of publications continues to expand. Thus, collection of publications becomes more complicated (Aria & Cuccurullo, 2017), and a more reliable method is needed to structure a large body of information.

To introduce a systematic, transparent, and objective review process, this paper aims to identify the trend and patterns on the specified topic – relationship of soil iron to nutrient cycling – using Bibliometrix analysis methods, which is an open-source tool for a comprehensive science literature mapping analysis (Aria & Cuccurullo, 2017).

Material and Methods
Data were collected from Scopus database, where subject area was limited to Environmental Science, Earth and Planetary Sciences, and Agricultural and Biological Sciences. Documents were searched using keywords Environment AND Soils AND Iron AND Redox AND Clay AND Minerals AND Nutrient AND Cycle, and then exported in a "BibTex" format. The exported file was analysed using R package *Bibliometrix* (Aria & Cuccurullo, 2017), other analyses were done using Biblioshiny, a web interface for bibliometrix (Zupic & Čater, 2015) which can also perform science mapping analysis.

Results and Discussion
Descriptive Analysis
Table 1 presents the main information of the bibliographic data. The collection contains 1587 published documents spanned over 544 scientific sources between the years 2000 to 2022, covering 6079 authors. Publication on this topic started only from 15 in 2000, to 248 in 2022 (Figure 1). It gained a significant increase in 2011 following an annual growth rate of 13.6%.

Table 1. Main information about bibliographic data collection

Description	Results
Timespan	2000-2022
Documents	1587
Sources (Journals, Books, etc.)	544
Authors	6079
Single-aouthored document	141
Co-authors per document	5,37
Annul Growth Rate	13,6%
Average citations per doc	62,08

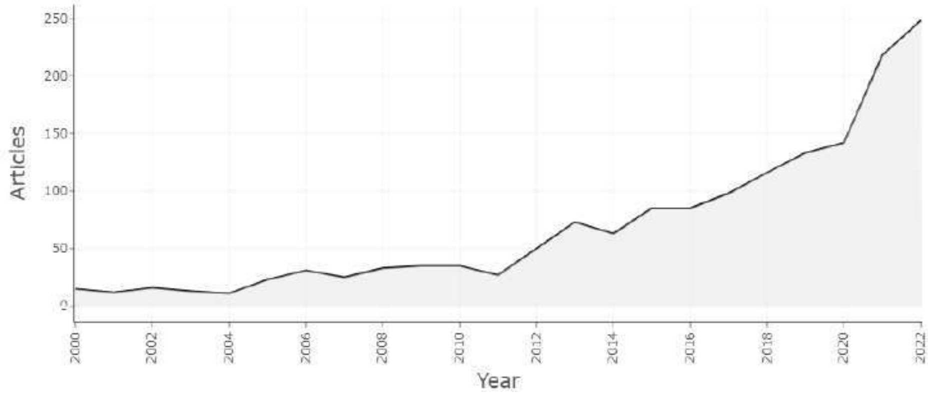

Figure 1. Distribution of annual scientific publication

Most Influential Journals

The study employed the use of Bradford's Law of Scattering that quantifies the relationship between journals and papers published (Viju, 2013). Based on Bradford's Law the major cluster consists of top 15 journals (Figure 2). This list of journals below attracts the large number of publications relevant to the research theme covering 33.5% in the bibliographic collection.

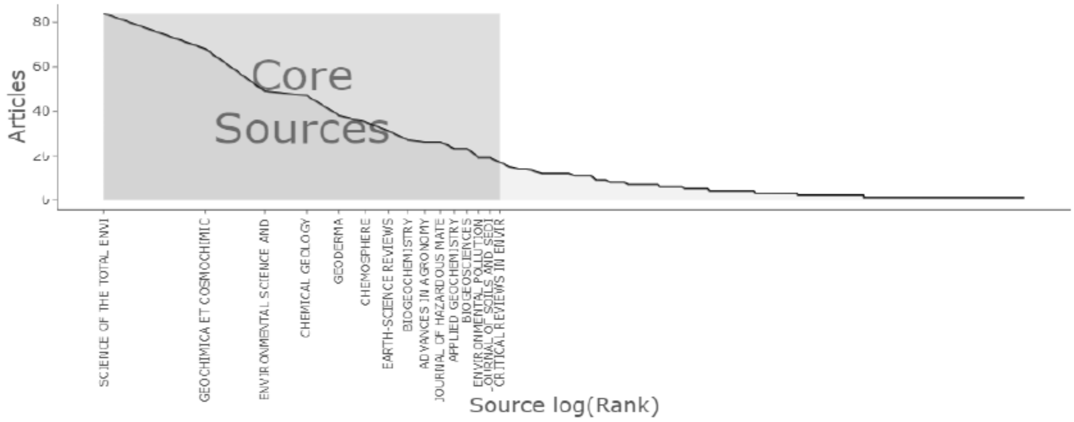

Figure 2. Source clustering through Bradford's Law

Conceptual Structure Map

The study also describes a conceptual structure map of the word that frequently appears in research papers by clustering it based on mapping the relationship between one word and another through area mapping. Each word is situated based on the values of Dim 1 and Dim 2, whose value are almost similar to each other. The red area and blue area, contain words that are related to each other. Red area comprises more various words related to it, showing that there are many research papers are connected to the words listed to this area.

Thematic Map

Figure 4 shows the thematic map. Themes that appear in the upper-right quadrant are called motor themes with high relevance degree (centrality) and development degree (density), and are therefore considered as well-researched and important. Themes that appear in the lower-left quadrant like *Iron*, *Biogeochemistry*, and *Organic Carbon* are declining or emerging themes with low degree of centrality and density. These research themes are considered not-well developed and minimal importance.

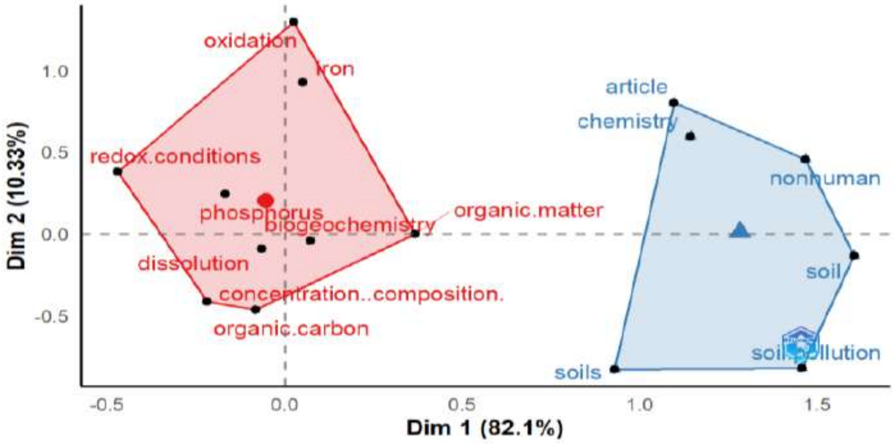

Figure 3. Conceptual structure map – method multiple correspondence analysis

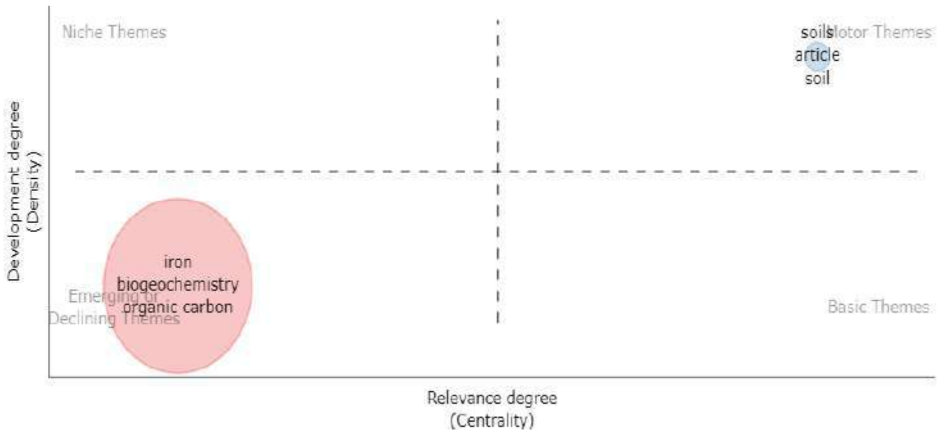

Figure 4. Thematic map

Conclusion

The Bibliometric analysis on soil iron relationship to nutrient cycling examined the publication trends and pattern to capture the importance and level of productivity on this research theme. The analysis was able to define the annual growth rate of publication, the most influential journals, the concept map, and thematic map which provides insights and overview for future researchers interested on this topic. Other analysis can also be run using Bibliometric methods such as Topic Dendogram, and Factorial Map of Most Cited Documents in order to extract useful knowledge quickly and easily as compared to other systematic review analysis.

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Effect of different salt contents in irrigation water on some growth parameters of sorghum plant

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Abstract

Sorghum is a well-adapted plant to semi-arid and arid conditions due to its tolerance to abiotic stress factors such as; drought and salinity. In this study, effects of two different salt contents (NaCl and $CaCl_2$+$MgCl_2$) of irrigation water on some growth parameters of sorghum plant were investigated under a greenhouse condition. Sorghum seeds were sown in the pots including 3 kg sandy clay loam soil in each one. During the experiment, the pots were weighed 2 days interval and irrigated around field capacity with water including three different salt contents which were NaCl (W_{Na}:10 dS/m), $CaCl_2$+$MgCl_2$ (W_{CaMg}:10 dS/m) and rainwater (W_R:0.045 dS/m) as a control treatment. At the end of the 45 days, the plants were harvested. The highest plant biomass was obtained in the control treatment pots irrigated with W_R. When the plants were irrigated with W_{Na} and W_{CaMg}, the biomass values decreased as 26% and 13% over the control, respectively. The highest main stem diameter was obtained in W_{CaMg} irrigation, and it was 15% higher than the control. However, the main stem diameter decreased 6% with W_{Na} irrigation compared to the control. While the highest plant height was found in the control treatment (W_R), the plant heights in W_{Na} and W_{CaMg} treatments decreased by 23% and 8% compared to the control, respectively. As a result, increasing salt concentration and content (W_{Na}, W_{CaMg}) in irrigation water reduces plant growth parameters. The worst plant growth was obtained in W_{Na} treatment compared to the control (W_R).

Keywords: Salt Stress, Irrigation Water Quality, Sorghum, Plant Growth.

Introduction

Salinity level in soil and water is one of the most important abiotic stress factors that negatively affect plant growth and productivity. Among all the development stages of plants, germination and seedling stages are the most sensitive period to stress (Almansouri et al., 2001; Çulha and Çakırlar, 2011; Lauchli and Epstein, 1990).

Under abiotic stress conditions such as; drought, low and high temperature, salinity and excessive precipitation, plants generally respond with physiological and metabolic changes to reduce stress effects on their growth and development (Kalefetoğlu and Ekmekçi, 2005).

Despite many years of work to develop tolerant or resistant cultivars, the resistance mechanisms of plants to abiotic stress factors have not been fully determined (Öz and Ekinci, 2015). Salinity level in soil and water is one of the most important abiotic stress factors that negatively affect plant growth and productivity. Among all the development stages of plants, germination and seedling stages are the most sensitive period to stress (Almansouri et al., 2001; Çulha and Çakırlar, 2011; Lauchli and Epstein, 1990).

The germination of the seed starts with the appropriate protection water intake (Şehirali, 1997). However, there are many factors such as uptake of water in the soil by the seed, salinity, low temperature, and drought. The negative effect of salinity on germination occurs in two ways.

Firstly, salts increase the osmotic potential of water, causing the decrease of water uptake by seeds or plants. Secondly, germination is prohibited by the toxic effects of ions in soil solution such as; Na^+, Ca^{+2}, Cl^- and SO_4^{-2}

(Murillo-Amador et al., 2002; Okçu et al., 2005; Kaya, 2009). Salinity significantly affects all characteristics associated with germination and early seedling growth, and the stress effect of salinity depends on variety used, level of salinity, and irrigation water quality (Mbinda and Kimtai, 2019).

Sorghum [*Sorghum bicolor* (L.) Moench] is the 5th most important cereal in the world (Ighbal, 2015). It is well adapted to semi-arid and arid regions due to its tolerance to abiotic stresses such as drought and salinity (Igartua et al, 1994; Marsalis et al, 2010). Although sorghum is highly resistant to abiotic stress factors, exposure to salt stress during germination restricts seedling growth and reduces final yield (Keshavarizi et al, 2012; Munns 2002).

In this study, effects of two different salt contents (NaCl and $CaCl_2$+$MgCl_2$) of irrigation water on some growth parameters of sorghum plant were investigated under a greenhouse condition.

Material and Methods

This study was carried out in the greenhouse of Soil Science and Plant Nutrition Department of Agricultural Faculty in Ondokuz Mayis University between 20/05/2022 and 05/07/2022. Some chemical and physical properties of the soil used in the experiment are given below.

Table 1. Some chemical and physical properties of the soil

Texture	pH	EC	Organic Matter	Ca	Mg	Na	K
-	(1:1)	dS/m	%	cmol/kg	cmol/kg	cmol/kg	cmol/kg
Sandy clay loam	7.73	0.65	3.72	50.50	29.73	0.62	1.13

The experiment was conducted in a randomized plot design with four replicates. Sorghum seeds were sown in the pots including 3 kg sandy clay loam soil in each one. During the experiment, the pots were weighed 2 days interval and irrigated around field capacity with water including three different salt contents which were NaCl (W_{Na}:10 dS/m), $CaCl_2$+$MgCl_2$ (W_{CaMg}:10 dS/m) and rainwater (W_R:0.045 dS/m) as a control treatment.

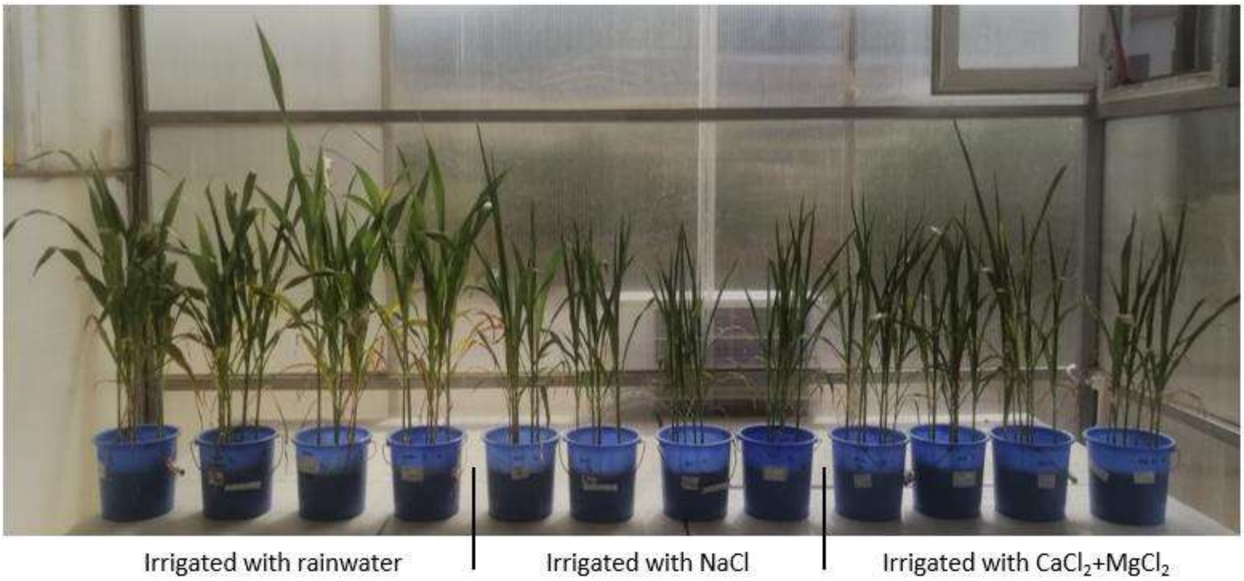

Figure 1. Effects of different irrigation water quality on sorghum plant growth in greenhouse conditions

After the harvesting plants at the end of the 45 days, the growth parametrs of plant (dry plant biomass, plant height and stem diameter) were measured.

Statistical difference between treatments was evaluated according to One-Way ANOVA test using SPSS 17 programme.

Results and Discussion

Plant Height of Sorghum Plant

The values of two different salt content of irrigation water (W_{Na} and W_{CaMg}) and rain water (W_R) application in sorghum plant height are given in Figure 2.

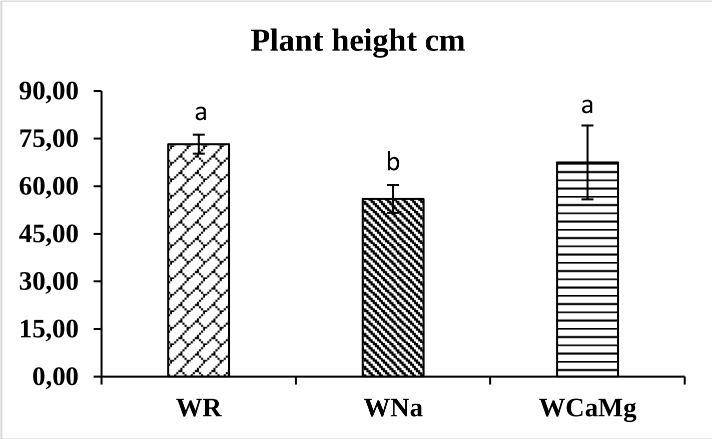

Figure 2. The effects of treatments on plant height

The highest plant height was determined as 73.6 cm in W_R treatment, the lowest plant height was determined as 56 cm in W_{Na} treatment (Figure 2). The plant height in W_{CaMg} treatment was determined as 67.5 cm, it was statistically in the same group with the control treatment (W_R). The plant heights in W_{Na} and W_{CaMg} treatments decreased by 23% and 8% compared to the control, respectively.

Akay et al., (2019) investigated the effect of irrigation water including 6 different salinity levels (0, 2, 4, 6, 8, 10 dS/m with NaCl) on germination and early seedling development on three different sugar maize (*Zea mays L. sacharata sturt)* type. They determined that the highest plant height was found in the control treatment and the plant height decreased in all three types depending on the increasing salt content. The highest decrease (54%) compared to the control was determined in the maximum salt containing (10 dS/m) treatment.

Parlak and Özaslan Parlak (2005) investigated the effects of irrigation waters including five different salt levels (0,29, 3, 6, 9, 12 dS/m with NaCl, $MgSO_4$ and $CaCl_2$) on two different (Sorghum bicolor (L.) Moench., cvs Northrup King 265 ve Asgrow Double TX) sorghum types. In the study, the maximum plant height was obtained in the control treatment (109.63 cm), while the minimum plant height (91.67 cm) was taken from the irrigation water treatment including highest salt content (12 dS/m). They showed that with the increase of the salt level of the irrigation water, the plant height was decrease. The decrement in plant height due to the increment in the salinity level of the irrigation water has been determined by various researchers (Aydınşakir et al, 2012; Bilgili et al, 2018).

Stem Diameter of Sorghum Plant

The values of two different salt content of irrigation water (W_{Na} and W_{CaMg}) and rainwater (W_R) treatment irrigation in the sorghum plant's main stem diameter are given in Figure 3.

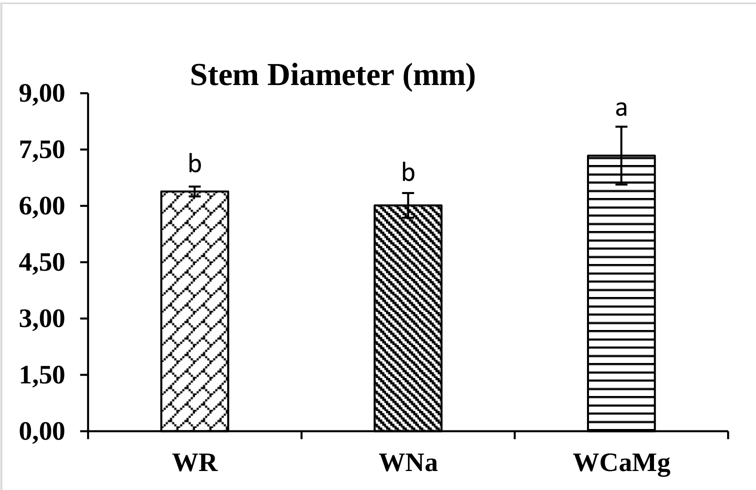

Figure 3. The effects of treatments on main stem diameter

The highest main stem diameter was determined as 7.33 mm in W_{CaMg} treatment, the lowest stem diameter was determined as 6.01 mm in W_{Na} treatment (Figure 3). The stem diameter in W_R treatment was determined as 6.38 mm, it was statistically in the same group with the W_{Na} treatment. The highest main stem diameter was obtained in W_{CaMg} irrigation, and it was 15% higher than the control. However, the main stem diameter decreased 6% with W_{Na} irrigation compared to the control.

They stated that the growth and development parameters of sorghum plant were adversely affected under saline conditions, and that there was a 50% decrease in growth and development parameters in plants grown at salinity levels higher than 10 dS m-1 (Tabatabaei and Anagholi 2012).

Total Dry Biomass of Sorghum Plant

The values of two different salt content of irrigation water (W_{Na} and W_{CaMg}) and rainwater (W_R) treatment irrigation in the sorghum plant's total dry biomass are given in Figure 4.

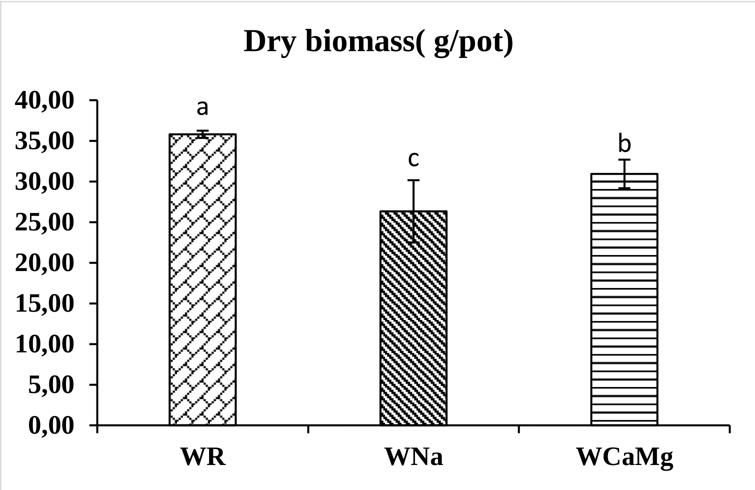

Figure 4. The effects of treatments on dry biomass

When Figure 4 is examined, while the highest total dry biomass was determined as 35.8 g/pot in the control (W_R) treatment, the lowest total dry biomass was determined as 26.32 g/pot in W_{Na} treatment. The total dry biomass of W_{CaMg} treatment was determined as 30.92 g/pot. The highest plant biomass was obtained in the control treatment pots irrigated with W_R. When the plants were irrigated with W_{Na} and W_{CaMg} the biomass values decreased as 26% and 13% over the control, respectively. In a study, it was determined that increasing doses of different salt and alkaline stress sources decreased the total dry biomass of the sorghum plant (Sun et al, 2019).

Conclusion

As a result, the stress response of sorghum plants to salt content in irrigation water was not only depend on the salt amount but also depend on the salt type. Increasing salt amount in irrigation water reduced plant growth parameters. According to the salt type, the worst plant growth was obtained in W_{Na} treatment compared to the control (W_R) and W_{CaMg} treatments. Therefore, knowing the salt content and type in irrigation waters is important for sustainable crop production.

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Determination of desertification risk for pasture areas under semi-arid ecological conditions using DIS4ME model and estimation with artificial neural network

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Abstract

The purpose of this study, which was prepared using the Desertification Indicator System for Mediterranean Europe (DIS4ME) model developed for Mediterranean countries, was to calculate the desertification risk of the basin with semi-arid ecological features within the borders of Çorum province and to estimate the results obtained by ANN. The desertification risk potential of the pastures spread in the micro basin was estimated 5.83 index value as high level based on the results of 40 soil samples collected from the research area. However, the model's outcomes were also predicted by ANN and R^2 values, with the best validation being 0.2040 in the fourth epoch; 90% for training, 91% for validation, 95% for testing, and 85% for all data. As a result, distribution maps of DIS4ME model and ANN showed parallel patterns. In addition, the approach aimed at reducing the area's risk of desertification revealed that developing soil protection policies in the model and implementing protective measures such as controlled grazing in the area would result in significant reductions in the risk of desertification in the study area.

Keywords: Desertification, Desertification Risk, Artificial neural network, DIS4ME

Introduction

Soils formation takes hundreds of years, are among the most important natural resources that cannot be produced or re-created by human influence. With the effect of the increasing world population day by day, it has become essential to provide maximum efficiency from minimum areas. This situation leads to the emergence of a global food security problem. The intensive use of agricultural lands by many developing countries for the purpose of economic development has led to serious restrictions on the sustainability of the lands and has caused great losses in agricultural lands. The last stage of land degradation is accepted as desertification and defined as a process in which biological and economic losses become continuous. In this case Desertification, especially in arid, semi-arid and semi-humid areas and regions where semi-arid subtropical Mediterranean climate is dominant regardless of the drought class, climatic-ecological changes and physical, biological, political, social, cultural, and economic factors and the relationships between these factors are complicated interactions. It is the process of land degradation or decreased productivity the results from (UNCCD, 1995). Especially in many countries in the world, researchers have conducted studies to examine regional desertification status and desertification indicators (Uzuner and Dengiz, 2019). One of the prominent studies is DIS4ME (Desertification Indicator System for Mediterranean Europe), which has been developed in connection with the MEDALUS project, in which Desertification Indicators for European Countries in the Mediterranean are determined. The DIS4ME model, which was developed to determine the desertification situation in Mediterranean countries, works according to the context between approximately 150 desertification indicators.

The Artificial Neural Network (ANN) approach, which has been used in various fields by many researchers in the past, is a non-linear method adapted based on data.. Artifical Neural Networks have significantly helped to achieve successful results in solving problems belonging to different fields that are difficult and complex to solve today. Ann primarily defines the elements of certain nonlinear sets (Pacci et al., 2022). Within the scope of this study, the desertification risk of pasture lands in the micro-catchment with semi-arid ecological characteristics within the provincial borders of Çorum was calculated using the Desertification Indicator System for Mediterranean Europe (DIS4ME), which was developed for the countries of the Mediterranean region, and the results obtained were analyzed with Artificial Neural Networks (ANN) has been predicted.

Material and Methods

Description of the study area

The current research was performed at the micro catchment in the Çorum province located in the north of Turkey and in the central part of the Black Sea region. This micro catchment is located between 660000–685000 E and 4444000 – 4460000 N (WGS84, Zone36N, Universal Transverse Mercator-UTMm). The total study area is about 20287.4 ha. The lowest and the highest elevations of the stud area are 894 m and 1292 m (a.s.m.l). In mountainous areas in the northeast sides, the elevation rises above 1400 meters with steep slope (>30%) whereas southwest part of the study area has low and gently slopes. In addition, most of the study area has southeast and southwest aspects whereas some of the southern regions have north and northwest aspects.

Soil sampling and analysis

To determine the physical and chemical properties of the soils, 40 degraded soil samples were taken from a depth of 0-30 cm from each point determined within the soil sampling micro-catchment. After the soil samples taken were air-dried in the laboratory they were beaten with a wooden mallet and passed through a 2 mm sieve and made ready for analysis. Soil samples were Texture, bulk denstity, organic matter soil pH analysis and electrical conductivity (EC) made with glass electrode.

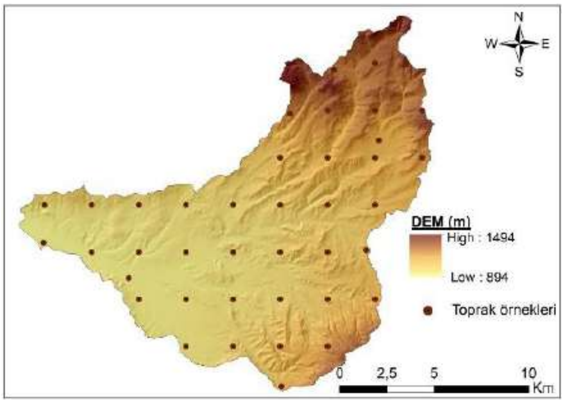

Figure 1. soil sampling pattern

Within the scope of the study, the DIS4ME model was used to determine the classes according to desertification risk values at each point where soil sampling was made. The DIS4ME model was developed in 2004 as part of the Desertlinks research Project, under the editorships of Jane Brandt, to provide users, including scientists, politicians and farmers with wide range of information on the Mediterranean's Desertification Indicators for European Countries (Desertlinks, 2004). Within the scope of the DIS4ME system which is used to determine the classes according to the desertification risk value at each soil sampling point in the study area; The indicators in the algorithm determined for Pasture Areas were used and the desertification parameters in Table 1 were used for each point. In this context, selected indicators related to the main components (climate, soil and management characteristics) used by DIS4ME and the subcomponents used in the desertification survey from (e.g. Precipitation for the main component of climate characteristics) were determined using the field.

Table 1. Desertification parameters for pasture areas

Climate Factors	Rainfall	<280mm / 280-650mm / >650
Soil Factors	Parent Material	Limestone, Marble / Shale, Schist / Sandstone / Marl, Clay, Conglomarete / Basic Igneous / Acid Igneous / Alluvium, Colluvium
	Rock Fragments	< 15 % / 15 - 40 % / > 40 %
Topographic Factors	Slope Gradient	< 6 % / 6 - 18 % / 18 - 35 % / > 35 %
	Slope Aspect	NW, NE / SW, SE / Plain
Management Factors	Previous Land Use	Agriculture / Pasture / Shrubland / Forest / Mining / Recreation
	Period of existing land use type	< 1 Year / 1 - 5 Years / 5 - 10 Years / 10 - 20 Years / 20 - 50 Years / > 50 Years
	Soil Erosion Control Measures	Adequate / Moderate / Low / None
	Grazing Control	Sustainable Number of Animals / Fencing / Avoiding of Soil Compaction / Fire Protection / None
	Farm Ownership	Private / Rented / State / Specific Regulations
	Policy Enforcement	Adaquate (> 75 % of area covered) / Moderate (25 - 75 % of the are covered) Low (< 25 % of the area covered) / None

DIS4ME uses the multiple regression model in Equation 1 to calculate the desertification risk of rangelands.

DR = (9.33) - (0.55 * farm ownership) + (0.71 * previous land use) - (0.54 * period of existing land use) + (0.31 * slope gradient) + (0.17 * parent material) - (0.38 * rock fragments) - (0.48 * rainfall) + (0.41 * slope exposure) - (0.44 * controlled grazing) - (0.23 * erosion control measures) + (0.10 * policy enforcement) (1)

Desertification risk (DR) is classified as follows, taking into account the calculated values.

•No Risk: DR < 1.49, •Low Risk: 1.50 < DR < 2.49, •Medium Risk: 2.50 < DR < 5.49, •High Risk: DR > 5.50. After calculating the desertification risk for pasture areas in micro-catchment using the DIS4ME system, the spatial change of the desertification risk was analyzed with the help of the Inverse Distance Weighing- (IDW) interpolation model and a desertification risk map was created ArcGIS 10.5v program was used to create the distribution maps of the calculated desertification risk values.

Preparation of datasets and ANN

Soil samples taken from each point of the study area are classified between 1 and 4 depending on the parent material, the rock fragment of the point, the slope of the point and the aspect of the point, depending on the increase and decrease in the risk of desertification (Table 2). Points with a value of 1 are classified as having a very low effect on desertification risk, while points with a value of 4 are classified as having a high effect on desertification risk. These values, which are assigned between 1 and 4, are determined depending on whether the effect of the parameter under investigation on the risk of desertification is in the direction of increasing or decreasing. Many studies have been helped to determine these class ranges.

Table 2. Parameters and weight scores affecting desertification risk

Rock Fragments			Slope Aspect		
Class	Range	Definition	Class	Range	Definition
4	> %40	High	1	NW,NE	Very Low
2	15 – 40	Low	4	SW,SE	High
1	≤ 15	Very Low	1	Plain	Very Low
Parent Material			Slope Gradient		
Class	Range	Definition	Class	Range	Definition
1	Alluvium, Colluvium	Very Low	1	< 6 %	Very Low
2	Basic and Acid Igneous	Low	2	6 - 18 %	Low
3	Conglomerate	Medium	3	18 - 35 %	Medium
4	Limestone, Sandstone	High	4	> 35 %	High

The data set created from these values divided into classes was used as input data for the artificial neural network. The values of desertification risk obtained by calculating with the DIS4ME Model for each point of soil sampling were used as the target. Artificial Neural Networks, designed by taking the working principle of biological neural networks as an example, have a feature that is much more convenient than statistical techniques in terms of estimation, especially in nonlinear systems (Pacci et al., 2022). With this feature, Artificial Neural Networks have become a very important method in solving complex and non-linear problems (Odabaş et al., 2016). In this study, Matlab® R2012a (7.14.0.739) 32-bit (win32) The ANN applied with the program was carried out with the Levenberg-Marquardt (LM) algorithm to train the network.

Results and Discussion

Nine different soil properties were examined in 40 soil samples taken from the study area and descriptive statistical calculations of the properties were made (Table 3). Most of soils are clay textured, their contents vary between clay 23.88% - 62.82%, sand 17.13% - 56.92% and silt 12.66% - 37.33%. Desertification in arid areas causes soil erosion by causing displacement of the surface soil due to water and wind (Mutlu et al., 2013). Therefore, soil erosion is one of the indicators of desertification. The most important soil feature affecting one of the factors affecting desertification and/or soil erosion is soil organic matter. The organic matter content of the soils of the micro-catchment ranges from 0.74% to 6.32%, with an average of 2.45%. With the effect of high temperature and low precipitation, the low organic matter content in the soil, and because of cultivated agricultural activities, disrupt the soil aggregation and cause the soil grains to become dispersed and the soil structure to deteriorate. On the other hand, low organic matter (OM) also increases the formation of crust in the soil, and soils in this state have very low resistance to erosion due to surface runoff. The bulk density (BD) values of the soils vary between 1.11 gr cm-3 and 1.57 gr cm-3 depending on the organic matter content and especially the amount of sand and clay. According to the results obtained, the clay, BD and pH values are left skewed (-) when compared to the normal and values show a right skewed (+) distribution, while other features. The feature with the highest skewness coefficient and the farthest distribution from the normal was determined as EC. The data show that the curves of all soil properties have a steeper (+) distribution than the normal distribution. Dengiz (2020) stated that CV is a necessary element in defining the instability of soil properties in the region. Coefficient of variation; classified as low (< 15%), medium (15-35%) and high (> 35%). Accordingly, the BD and pH variation coefficients from the soil properties of the study area are low; clay, sand and silt have medium variation. On the other hand, OM, CaCO3, EC and carbon are soil properties with high variation.

Table 3. Descriptive statistics of some properties of soil sample.

Parameters	Mean	SD	CV	Variance	Min.	Max.	Skewness	Kurtosis
OM	2.45	1.18	48.16	1.4	0.74	6.32	1.11	1.78
Clay	44.66	8.61	19.27	74.14	23.88	62.82	-0.42	0.31
Sand	33.73	8.22	24.36	67.64	17.13	56.92	0.64	0.76
Silt	21.59	5.48	25.38	30.06	12.66	37.33	0.98	1.46
BD	1.36	0.08	5.88	0.007	1.11	1.57	-0.55	2.40
pH	8.13	0.27	3.32	0.07	7.01	8.45	-2.19	6.72
CaCO3	12.56	6.16	49.04	37.95	2.58	28.41	0.63	0.11
EC	0.32	0.26	81.25	0.06	0.11	1.70	4.12	20.090
Carbon	57.47	28.12	48.92	791.08	17.38	148.46	1.07	1.70

OM: Organic Matter, BD: Bulk Density, SD: Standard Deviation, CV: Coefficient of Variation, Min: Minimum, Max: Maximum.

Estimation of desertification risk with ANN

In general, Artificial Neural Networks try to imitate the biological neural structures of the human brain or the working principles of the central nervous systems. They can be defined as computer programs that use previously learned or classified datasets with the support of neural sensors and that enable to create new information in line with this information. While it is desired that the data set be large and comprehensive enough for artificial neural networks to process the data, they are so small that they can generalize, providing healthier results. Basically, the expected task of an artificial neural network is to produce an output in return for the data specified as input. In doing so, the network needs to be trained with specific examples. One of the problems that may occur during the training of the network may be the result of memorizing the data set. This situation is considered as an undesirable situation. Considering these situations, our expectation from the network is that it will be able to generalize and be at a level to decide. In the next stage, it is expected to present us the outputs together with this acquired ability. Artificial Neural Networks (ANN) uses data from real-life problems and their results in learning and prediction processes. While the variable factors related to the real-life problem space constitute the input data of the ANN, the real-life results obtained from these variables constitute the series of outputs that the ANN aims to achieve (Pacci et al., 2022). Drought and desertification, together with human-induced climate change, is one of the most important global and regional environmental issues facing humanity today in terms of its consequences and should be taken seriously. In the model, Levenberg-Marquardt combination was used to estimate desertification risk values by using 4 input parameters: parent material content of soil samples from 40 points, stony status of the point, slope of the point and aspect status. The model using 4 epochs in the estimation process showed the best validation data performance at the 4th epoch with 0.20401. (Figure 2). In the figure, the test and training data show a sudden decrease until the first iteration, while the validation data show a slight decrease until the second iteration, while the model shows the best validation data performance at the fourth epoch.

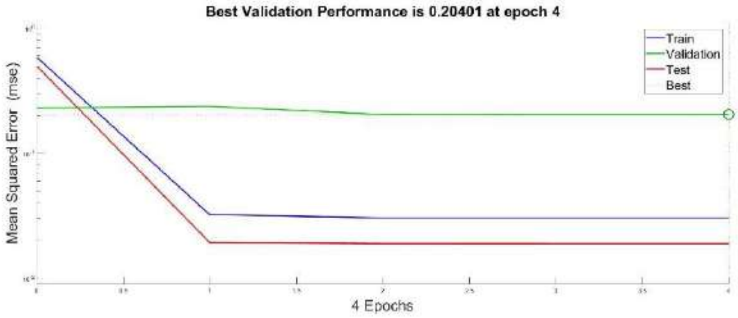

Figure 2. Graph of Levenberg-Marquardt combination performance.

The coefficient of determination (R^2) used to explore the proposed prediction performance of the neural network is an important indicator. In determining the risk of desertification obtained, training was 90%, validation was 91%, tes was 95%, and all data were predictable with an accuracy of 85% (Figure 3).

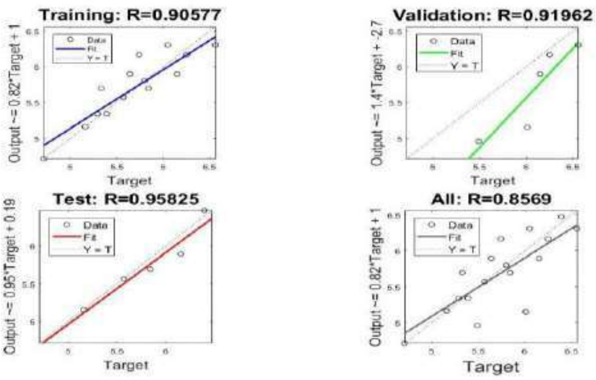

Figure 3. Results of regression between output data and targets for the Levenberg-Marquardt approach.

To investigate the negative effects of desertification observed in Mediterranean countries and to prevent them, the Environment Program was established in 1999, which was formed by 31 different groups from 10 different countries. Among these programs, MEDALUS (Mediterranean Desertification and Land Use) is the largest project. Within the scope of MEDALUS Europe, the ESA Index (Environmental Sensitive Areas) has been developed to identify the endangered areas because of the impact of climate and land use. This index; includes parameters such as soil quality, climatic conditions, vegetation, and land management. Geographic Information Systems (GIS) and Remote Sensing (RS) techniques are used in bringing these parameters together and determining their changes over time. The MEDALUS (Mediterranean Land Use and Desertification) project, which they developed to determine how sensitive the land features and uses make the environment to desertification, forms the basis of the DIS4ME model.

Desertification is one of the most dangerous environmental problems on a global scale. Land degradation due to climate change and human impact, especially in arid and semi-arid areas, and the reduction of vegetation increase the importance of desertification. Selection of desertification indicators according to the topographic structure of the area, soil, climate, and plant characteristics; It provides a clear determination of the risk situation and therefore the tendency to desertification. Thus, it will be more effective in determining the conditions and reliability of the measures that can be taken according to the risk situation for the area. The desertification risk distribution map of the micro-catchment, which is located within the provincial borders of Çorum and is being used as pasture, produced from the data obtained because of the study, is shown in Figure 4. In the study, it is observed that the risk distribution map obtained from the DIS4ME model, and the risk distribution map obtained from the ANN reveal parallel patternsIn addition, when the data obtained are evaluated according to the desertification class, it is observed that the whole basin is at risk of desertification. It is observed that the risk distribution generally increases towards the southeast.

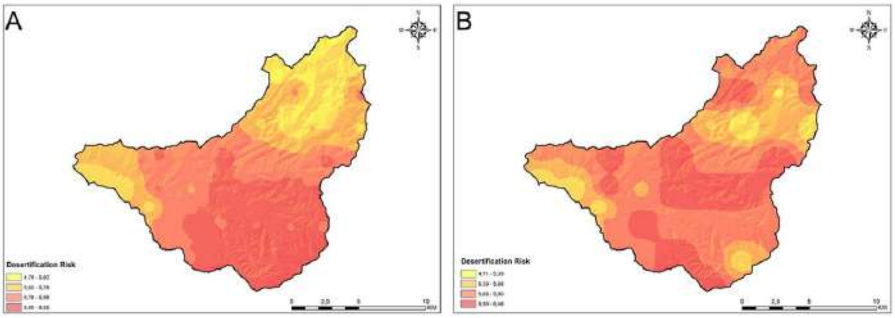

Figure 4. Desertification risk maps (A: DIS4ME, B: Estimated with ANN).

However, the change that may occur in the desertification risk of the region, if "development of the implemented policies, ensuring grazing control and erosion control practices", which is an important parameter in the model, is included in the scope of this study, is shown in Figure 5. With the result obtained from the decrease in the risk situation on the maps, it is thought that desertification can be prevented if the policies implemented in the region are changed and if measures are taken to prevent this situation in the regions under the risk of desertification.

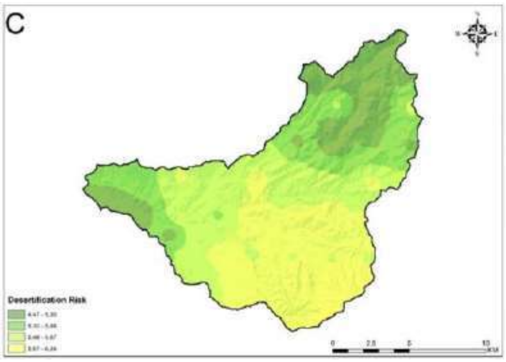

Figure 5. Risk map of the study area after additional parameter

Conclusion

In this study, the desertification risk situation was determined with the DIS4ME desertification model for the areas where intensive pasture activities are carried out in the micro-basin within the provincial borders of Çorum and it was estimated with ANN. According to the results obtained, it was determined that the pasture areas distributed within the micro-catchment are under a very high risk. In addition, the results obtained with the model were found to be quite high with ANN, and the distribution maps showed parallelism with each other. The approach aimed at reducing the desertification risk of the area, on the other hand, revealed that the development of policies for the rangelands applied in the model, the expansion of grazing controls and erosion control practices, can be observed to reduce the risk of desertification. It is thought that the findings obtained in the current study will provide important scientific contributions to desertification studies.

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Effects of polymer applications on soil stability

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Abstract

This study was conducted under greenhouse conditions in order to determine the effects of polyvinyl alcohol (PVA), polyacrylamide (PAM) and humic acid (HA) applications on the soil stability (instability index). Surface soil samples with three different textures (clay, loam and sandy loam) were used in the study. In the greenhouse, PVA, PAM and HA were applied to soil samples at doses of 500, 100 and 500 ppm, respectively, and incubated in four different periods (0, 15, 30 and 45 days). During the incubation, irrigation was performed when 50% of the available moisture in the soil samples was decreases. As a result of the analysis and evaluation made on the soil samples after the incubation, it was determined that PVA, PAM and HA applications increased resistance to stability all three soil groups and that the conditioners were more effective in the soil in sandy loam texture category. It was observed that the conditioners were ranked as PVA>PAM>HA in terms of the said effectiveness. It was observed that PVA's first period applications were more effective on instability index value.

Keywords: Polymer, Soil Texture, Instability index, Soil erodibility.

Introduction

Soils, as dynamic natural resource, form the basis of life. The demands created by the increasing population and developing economies and the widespread use of inappropriate production techniques in agricultural systems cause degradation of soil quality, the emergence of certain environmental problems and a decrease in the crop production (Verhulst et al., 2010; Martinez-Blanco et al., 2011; Kassım and Özdemir , 2022). In addition to the use of naturally-derived organic materials, the application of polymers that can give results in a short time provides significant benefits in order to reduce the effect of degrading processes in the soil, improve the structural stability of the soil and increase the degree of aggregation (Harris et al., 1966). For this purpose, various soil stabilizers such as polyvinyl alcohol, Polyacrylamide and humic acid have been emphasized in recent years. Studies show that synthetic organic polymers have positive effects on stability and soil structural properties when applied even at very low concentrations (Sojka and Lentz, 1994; Nadler et al., 1996; Imbufe et al., 2005; Yönter and Houndonougbo, 2022).

Synthetic polymers are effective in decreasing susceptibility to erosion (Wood and Oster, 1985), and porosity and hydraulic conductivity, increasing water-holding capacity (Shanmuganathan and Oades, 1982). In the studies conducted in this respect, polymers such as polyvinyl alcohol and polyacrylamide (Graber et.al. 2006; Yönter, 2010; Yılmaz and Uysal, 2010) are focused on. Cochrane et al. (2005) found that phosphogypsum (PG), polyacrylamide (PAM) and (PG + PAM) applications under simulated precipitation conditions significantly reduced soil losses in splash erosion, while Sinkpehoun and Yönter (2018) found that liquefied humic substance applications did the same thing. Piccolo et al. (1997) reported that the application of humic acid to the soil reduced soil loss by 36% and increased aggregate stability and water-holding capacity.

The determination of the degrees of contribution or effect of the components affecting the soil stability or the susceptibility to erosion in the soil is very important in terms of creating an ideal plant development medium, reducing water losses, controlling erosion, and planning an appropriate land management. This study was conducted to determine the effects of polyvinyl alcohol (PVA), polyacrylamide (PAM) and humic acid (HA) applications on the soil stability parameters for soils with clay ©, loam (L) and sandy loam (SL) texture.

Materials and Methods

The research was carried out on surface (0-20 cm) soil samples taken from Ondokuz Mayıs University Faculty of Agriculture, trial area (41°36'-36°18') and Ondokuz Mayıs University, Bafra application field (41°55'-35°86'; 41°50'-35°82'). In the greenhouse trial, humic acid, polyvinyl alcohol and polyacrylamide conditioners were used. As humic acid, commercially-available material containing 15% humic matter was used. Fluka-labeled material, which is insoluble in organic solvents and especially soluble in hot water, is used as polyvinylalcohol. As polyacrylamide, water-soluble PAM obtained from the company ACROS was used.

Surface soil samples taken from the land were dried in the shade and then passed through a 4.75-mm sieve and used in the experiment. Soil samples were weighed on the basis of their oven dried weights and transferred to 1-kg pots. PVA, PAM and HA were applied to the labelled pots at doses of 500, 100 and 500 ppm, respectively (Özdemir, et.al., 2015; Yakupoğlu and Öztaş, 2016; Aksakal and Öztaş, 2010), by mixing PAM and HA with pure water, and by turning PVA into a solution at 80 °C in pure water. The study, which is based on four different periods (0, 15, 30, and 45 days), was set up on 30 September 2020 in the greenhouse of the Department of Soil Science and Plant Nutrition. During the experiment, irrigation was done when 50% of the available moisture in the soil was decreases. After the end of each period, soil samples were dried in the air and crushed by hand and made ready for analysis.

Soil texture was determined by Bouyoucos hydrometer method (Demiralay, 1993); soil reaction (pH) by pH meter in soil-water mixture of 1:2.5 (Kacar, 2016); electrical conductivity value by a glass-electrode electrical conductivity tool in soil-water mixture (Kacar, 2016); lime content of soils by Scheibler calcimeter method (Kacar, 2016); soil organic matter by Walkley-Black method (Kacar, 2016); field capacity (Demiralay, 1993); cation exchange capacity by Bower method (Kacar, 2016).

After laboratory analysis, the soil instability index was calculated. This index was proposed by Comdeau and Monnier (1961). It is based on soil structural characteristics which have been proved useful in predicting erosion risks for a wide range of soils (Cotler, 1998; Emadodin et.al., 2009). This index is obtained from the formula:

$$Is = \frac{\%\text{silt} + \%\text{kil}}{(\%\text{agregates} > 0.2mm\ after\ wet\ \ sieving\ ) - 0.9(\%\text{coarse sand})} \quad (1)$$

Is = Instability index

Statistical evaluation of the data obtained as a result of the research was made using SPSS computer package program. Duncan test was used for multiple comparisons (IBM SPSS statistics 21.0).

Results and Discussion

Soil Properties

Some of the physical and chemical properties of the soil samples used in the study conducted under greenhouse conditions, determined before the trial, are given in Table 1.

Table 1. Some of the physical and chemical properties of the soils used in the research

Soil properties									
Soil number	Sand, %	Silt, %	Clay, %	Texture class	pH (1:2.5)	EC dSm^{-1}	$CaCO_3$, %	OM, %	CEC me/100g
1	31.70	23.14	45.16	C	6.97	0.1497	2.22	1.54	65.48
2	36.18	41.57	22.25	L	7.40	0.4924	8.47	3.02	38.26
3	58.91	29.34	11.75	SL	7.92	0.1173	8.26	0.77	31.66
				Is					
1				1.14					
2				2.32					
3				1.04					

Note: 1, Ondokuz Mayıs University Faculty of Agriculture, trial site; 2, Ondokuz Mayıs University, Bafra Application field; 3, Ondokuz Mayıs University, Bafra Application field; OM, organic matter; CEC, cation exchange capacity; Is, instability index

As can be seen from the examination of this table, the soil sample (sample no. 1) taken from the Ondokuz Mayıs University Faculty of Agriculture experiment area is a soil with clay texture, neutral reaction, low lime and medium organic matter content; the soil sample taken from Ondokuz Mayıs University Bafra Application field (sample no. 2) is a soil with loamy texture, slightly-alkaline reaction, medium lime and high organic matter content; and the other soil sample taken from Ondokuz Mayıs University Bafra Application field (sample no.

3) is a soil with sandy loam texture, moderate alkaline reaction, moderate lime and low organic matter content. The pH values of the soils are below 8.5 and there is no alkalinity problem in the soils (Soil Survey staff, 1993).

The instability index values of the soils vary between 1.04% and 2.32%, and sample 3 in the sandy texture class has the lowest (1.04%) instability index value and sample 2 in the sandy loam texture class has the highest (2.32%) instability index value.

Instability İndex

The results of the variance analysis of the instability index values determined after the soil samples in the experiment were subjected to incubation in four different periods by mixing polyvinyl alcohol, polyacrylamide and humic acid are provided in Table 2, and the average changes in the instability index values (mean of the three values) and the results of the multiple comparison (Duncan) test are provided in Table 3. As can be seen from the examination of the variance analysis results in Table 2, the mean of squares ($p<0.01$) of the instability index values of the tested soils were found to be significant. In other words, the soils differed in terms of their instability index value at the end of the trial.

Table 2. The results of the variance analysis of the instability index values of the soils

Sources	Degrees of freedom	Sum of squares	Mean of squares	F value	Level of significance
Soils (A)	2	46,698	23,349	2939,394	,000
Conditioners (B)	2	7,617	3,809	479,457	,000
Periods ©	3	2,432	,811	102,059	,000
A*B	4	7,501	1,875	236,066	,000
A*C	6	3,750	,625	78,683	,000
B*C	6	5,752	,959	120,696	,000
A*B*C	12	2,895	,241	30,373	,000
Error	72	,572	,008		
General	108	314,091			

Again, from the same table, the mean of squares ($p<0.01$) of the conditioners and the applied periods were found to be significant. This result emphasizes that the effects of the conditioners such as polyvinyl alcohol, polyacrylamide and humic acid used in the experiment and the applied periods, on the instability index value are different. From the results of the variance analysis, it was determined that soil x conditioner, soil x period, conditioner x period and soil x conditioner x period interaction were also significant.

Table 3. The instability index values of the soils (mean) and Duncan multiple comparison test results

Soils	Conditioners	Periods				Soil averages
		1	2	3	4	
1	PVA	0.91	0.87	0.88	0.9	1.0972b
	PAM	1.05	1.13	1.12	1.24	
	HA	1.11	1.24	1.37	1.34	
2	PVA	1.29	1.84	1.84	2.14	2.4064c
	PAM	1.41	2.33	2.83	2.67	
	HA	1.87	2.82	3.18	4.67	
3	PVA	0.72	0.72	0.79	0.83	0.9393a
	PAM	0.89	0.96	1.01	1.03	
	HA	1.1	1.01	0.98	1.24	
Periods averages		1.4297b	1.3636ab	1.3929ab	1.737793c	
Conditioner averages	PVA	1.1483a				
	PAM	1.49636b				
	HA	1.7983c				

(The averages shown in separate letters are different from Duncan multiple comparison)

When the effects of conditioner applications (Table 1, Table 3) are examined, it is seen that all three conditioners provide significant decreases in the instability index values of soils depending on the application periods and soil texture. Given the changes, it was determined that the conditioners used were more effective in the soil number 3 in the Sandy loam texture class.

Upon examination of Duncan's multiple comparison test results (Table 3) applied to the data for the comparison of the tested soils, applied conditioners and application periods according to the mean of instability index value at the end of the trial, it is determined that the soils, the conditioners used in the application, and the application periods are ranked as given in Table 3 in terms of the effect they have on the mean of the instability index values. In this grouping, the differences between soils and periods ($p<0.01$) were found to be significant (Values shown with separate letters are significant at 1% level on the basis of the mentioned test).

The average decreases (%) found in the instability index value according to the controls are presented in Figure 1. In all three soils, the decreases occurred with polyvinyl alcohol were much higher.

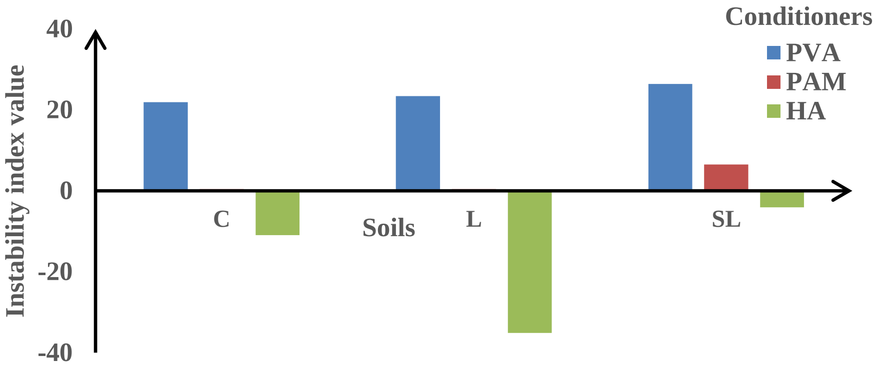

Figure 1. Average decreases (%) determined in the instability index value on the basis of conditioners

The mean decreases (%) caused by the applications of polyvinyl alcohol, polyacrylamide and humic acid in the instability index value of the soils showed significant differences between the said conditioners. The decreases (%) caused by the periods related to these three conditioners in the instability index value of the soils are given in Figure 2. As it can be understood from these data, the efficiency of the conditioners decreases as the period time increases.

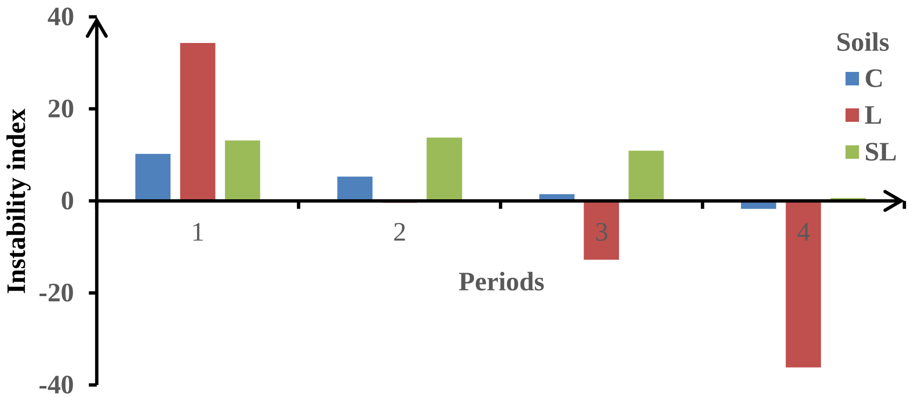

Figure 2. Average decreases determined in the instability index value over the periods on the basis of control (%).

Instability index value is a parameter used to evaluate the resistance of soils to erosion, and this index value varies between 0 and 3, 3 reflects the highest structural instability (Cotler, 1998). When the tested soils are evaluated in this respect, it can be initially considered that sample 3 is too resistant and samples 1 and 2 are susceptible structure. The applied conditioners decreased the index value depending on the application periods and increased the resistance of the soils to erosion. On the other hand, when the test findings are examined accordingly, it can be stated that the İndex values are affected by the type of conditioner used (as PVA>PAM > HA) and the application periods as 1 > 2 > 3>4 (Table 3). In their study, Yılmaz and Uysal (2010) examined the effects of polyvinyl alcohol and polyacrylamide applications on surface flow and soil loss. As a result of the research conducted on 3 soil samples with sandy loam textures with PVA and PAM solution, the researchers found that the mentioned polymers significantly reduced the surface flow and soil loss, but that PVA was more effective than PAM. Tümsavaş (2005), who investigated the effects of different doses of PVA application in agricultural soils, found that PVA application at a dose of 500 mg/L was an effective dose in protecting the soils against erosion.

Conclusion

As a result of this study that was conducted under greenhouse conditions in order to determine the effects of polyvinyl alcohol, polyacrylamide and humic acid applications on the improvement of instability index values (susceptibility to erosion) in the soils.

PVA, PAM and HA applications increased the resistance of soils to erosion by causing significant decreases in the instability index values depending on the application periods and soil texture. It was observed that the applied conditioners were effective as PVA>PAM>HA and the application periods were effective as 1 > 2 > 3>4.

As a result, it was determined that polyvinyl alcohol, polyacrylamide and humic acid applications increased resistance to erosion in the soils. It was also determined that the effectiveness depends on the characteristics of the conditioners, soil texture class, and the period duration. It would be helpful to pay attention to this issue in practice.

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Microelement composition of soils (Basegi Ridge, Middle Urals) and its spatial differentiation

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Abstract

The studies were carried out in the undisturbed part of the Middle Urals (Basegi Ridge). The ridge is confined to a strip of the most ancient rocks resistant to weathering in the territory of the Middle Urals. Soil profiles were studied on different relief elements (m above sea level): mountain tundra (821-940) – crooked forest (715-816) – meadows (600-736) – swamp (492-578 m) – light forest (557-655) – taiga (315-590).We compared the content of trace elements with soil Clarks. Soils have an increased natural background of some microelements. So, at a height of 600-940 m, Br, Pb, Zn, Cu, Ni accumulate, in a dispersed state - Sr, Y, Ga, Rb .; soil-eluvium is enriched in Br, Pb, Zn, Zr, Ga, Ni. Taiga soils accumulate: Pb, Zn, Cu, Ni, Br; in the scattered state are Y, Sr, Ga; soil-eluvium is enriched in Pb, Zn, Cu, Zr.Pair dependences of microelement concentrations showed that at a height of >600 m, a significant high correlation was found in Ni-Cu, Ni-Zn, Zn-Cu, Zn-Rb vapors, which is associated with a large manifestation of physical and frost weathering in severe conditions. Pair relationships of microelement concentrations revealed the main elements that form geochemical conditions in high-altitude zones.With the help of geochemical indices [(Rb+Zr)/Sr, Zr/Rb, Rb/Sr, Zr/TiO2], it was found that the intensity of soil formation is higher in soils formed below 691 m a.s.l., and the intensity of sedimentation processes, on the contrary, it has the opposite trend. In soils in transitional ecotones and geomorphologically transitional zones, according to lithogeochemical indices, the chemical weathering of the substrate is minimally manifested at its maximum physical (frosty) weathering. Evolutionary-genetic features of soils and geochemical heterogeneity have been established. A number of soil types have been determined according to the intensification of chemical change and the degree of weathering.
Keywords: Geochemical indices, Mircoelements, Middle Urals, Soil Formation, Soils, Weathering.

Introduction

The study of the microelement composition of soils and its spatial differentiation is one of the main tasks in landscape geochemical studies. Soil genetic studies use lithochemical indices and geochemical indicators calculated on the basis of data on the total content of macro- and microelements (Bowen, 1979; Nesbitt et al., 1982; Nesbitt et al., 1989; Retallack, 2001; Rodionova, 2012; Samofalova et al., 2014; Samofalova et al., 2016a, 2016b: Maslennikova et al., 2016; Kalinin et al., 2016; Tunçay et al., 2016). Studying the geochemistry of soils using geochemical parameters makes it possible to minimize the influence of heterogeneity and variegation of the soil cover and diagenetic changes (Dyakonova, 2009; Kalinin et al., 2016; Tunçay et al., 2016; Senol et al., 2018). Using the methods of geochemical indication of weathering and elementary processes of soil formation, the evolutionary genetic features of the bulk composition in soils are determined (Kulizhsky, Rodikova, 2009; Nordt et al., 2010; Samofalova, 2014; Samofalova, 2020a, 2020b).

The purpose of the study is to study the microelement composition of the soils of the Middle Urals and its differentiation in space with a change in the height of the area.

Material and Methods

The studies were carried out within the undisturbed part of the Middle Urals - the Basegi Ridge (Fig. 1), which is included in the Basegi State Reserve in a key area on Mount Northern Baseg.

Soils were studied on various relief elements in the most typical biogeocenoses in high-altitude landscapes (m above sea level): mountain tundra (821-940) – crooked forest (715-816) – meadows (600-736) – mountain swamp (492-578) – park light forest (557-655) – mountain taiga (315-590) on the slope of the western exposure (12 soil profiles). Soil diagnostics was carried out based on the presence of a diagnostic horizon (Field Guide, 2008). The survey of the territory was carried out by the method of routes using the comparative geographical method of research and the morphological method.

Figure 1. Study area

Gross analysis of macro- and microelements was carried out in the laboratory of physical chemistry of soils at the Institute of Soil Science named after V.V. Dokuchaev (Moscow) by X-ray fluorescence method on the device Respekt. Molybdenum content was determined by atomic emission spectrometry on an AgilentAES-4100 instrument.

Geochemical coefficients were calculated: (Rb+Zr)/Sr (Kabata-Pendias et al., 1992), Rb/Sr (Gallet et al., 1996; Batista, 2007); Zr/TiO_2 is the homogeneity coefficient (Bushinsky, 1963; Schilman et al., 2001); $(Fe_2O_3 + MnO)/Al_2O_3$ is the oxidation coefficient (Retallack, 2003); MnO/Al_2O_3, $MnO/Fe_2O_3$are biological activity coefficients (Kalinin et al., 2016). The accumulation and dispersion coefficients were calculated as the geometric mean of the ratios of the content of each element in the horizon to the Clarke of the soils of the world (Vinogradov, 1957; Radionova, 2012; Okolelova et al., 2014).

Mountain soils are developed on a thin eluvium of bedrocks and, therefore, fine earth-clastic formations serve as a soil-forming rock and are called “soil-eluvium” (Targulyan, 1971). To assess hypergenesis, the data were processed separately for the humus (upper) soil-eluvium horizons.

Statistical methods were used: descriptive statistics; correlation analysis; cluster analysis. Statistical processing was carried out in the Data Analysis program in Microsoft Excel and the STATISTICA 6.0 program. The significance level of statistical processing is significant at P=0.95.

Natural Conditions. The ridge is confined to the zone of the most ancient rocks resistant to weathering in the territory of the Middle Urals (quartz, micaceous-quartz, feldspar-quartz varieties) (Chronicle of nature..., 1997). Basegi – low mountains of the Middle Urals – elongated meridional: Northern Baseg (951.9 m), Middle Baseg (994.7 m), Southern Baseg (850 m). Temperate climate zone, continental climate, precipitation 800 mm. The climate is typically mountainous. Mountain-forest, subalpine, mountain-tundra zones and three subzones of the subalpine (subalpine) zone (park woodlands, crooked forests, subalpine meadows) are pronounced (Gorchakovsky, 1975; Chronicle…, 1997).

Soil Characteristics. The soil cover is varied. The order of vertical soil zones on the slopes has been established: 1) burozems (315-655 m); 2) gray-humus, (570-760 m); 3) podburs and podzols (745-930 m), petrozems and podburs (930-950 m above sea level) (Samofalova, 2020c; 2021).

Soil types were identified within the key area: burozems, podburs, podzols, gray-humus soils, lithozems, gleyozems (Samofalova, 2015, 2017, 2018; Samofalova et al., 2012). Description of the morphology and characteristics of the physicochemical properties of soils are given in the author's publications (Kondrateva et al., 2015; Samofalova, 2015, 2018, 2021, Sayranova et al., 2018, Samofalova et al., 2012). The bulk composition and geochemical features of the mountainous soils of the Middle Urals are considered in previously published works (Samofalova, 2020a, 2020b; Samofalova et al., 2014). Based on the conditions of formation and physical and chemical properties, for statistical processing of analytical data, the soils are conditionally combined: group 1 (profiles 18, 28, 29, 30, 31, 32) – alpine-subalpine zone (crooked forest, subalpine meadows); group 2 (profiles 15, 17, 19, 24, 26, 27) – mountain-forest zone and park woodlands). The presentation of the results was carried out within the selected groups.

Results and Discussion

The contents of trace elements were compared with their soil Clarks: Ni, Cu, Pb, Sr - according to A.P. Vinogradov. (1962), and the clarks As, Zn, Rb, Y, Ga – according to Ovchinnikov L.N. (1990). In relation to the Clark of soils of the world, 4 groups of elements have been identified (Table 1). The average content of most of the elements is below the Clark or equal to the near-Clark value. Clark exceeds only Zr. Moreover, the composition of elements along the horizons almost does not change for the upper and lower parts of the profile

Table 1 – The group of elements in relation to clarke soils of the world

Soilhorizon	<K	=K	>K	>>>K
Humus	Ni, Cu, Zn, Rb, Sr, Ga, As	Ga, Pb, Y, Nb, Br, Ni	Br, Nb	Zr
Soileluvium	Ni, Cu, Zn, Rb, Sr, As	Ni, Ga, Br, Pb, Y, Nb	Br, Pb, Nb, Y,Cu	Zr

The content of microelements varies widely in soils (Table 2). Clark exceed the maximum values of the content of elements, and only for Sr, Zr there is no excess. The content of elements in the soil corresponds to a normal distribution. Zr, Sr, Rb, Zn, and Ni vary the most in the soils of the alpine-subalpine zone; in the mountain taiga - Sr, Zr, Zn. The smallest variation is noted for Pb and Ga. According to the range of variability, the elements are conditionally divided into 3 groups: 1) variability less than 45 mg/kg (Ga, Pb, Nb); 2) 46-90 mg/kg (Ni, Cu, Zn, Rb, Y); 3) more than 90 mg/kg (Sr, Zr).

The relationship between the content of trace elements and soil acidity has been established. In the alpine-subalpine zone, the effect of pH on the concentration of Ni, Cu, Zn, and Rb increases and weakens for Pb, Sr, Y, Zr, and Nb. In the soils of the mountain taiga, the concentration of elements to a greater extent depends on the acid-base properties of the soil, as well as on the content of humus.

Table 2 - Statistical distribution of the content of elements in soils

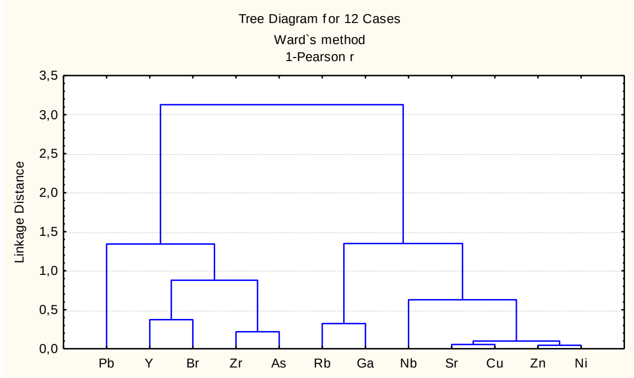
Statisticsindicator	Ni	Cu	Zn	Ga	Pb	Rb	Sr	Y	Zr	Nb
Clark	40	20	84	23	10	95	300	50	400	-
Min	4	8	24	9	10	32	85	18	215	13
Max	63	78	110	26	33	108	241	77	359	43
X	36	24	71	17	17	85	141	26	295	26
Rv	59	70	86	17	23	76	156	59	144	30
Sx	1,92	1,55	3,07	0,53	0,56	2,45	5,99	1,25	5,03	1,47
Me	36	23	71	18	17	88	130	25	301	21
S^2	166	109	423	13	14	271	1619	71	1141	98
S	13	10	21	4	4	16	40	8	33	10
V	36	44	29	20	22	19	29	32	11	38

Note: min - minimum, max - maximum X - sample mean, Sx - sample mean error, Mo - mode, Me - median, S^2 - variance; S - standard deviation; V - coefficient of variation; Rv is the range of variation.

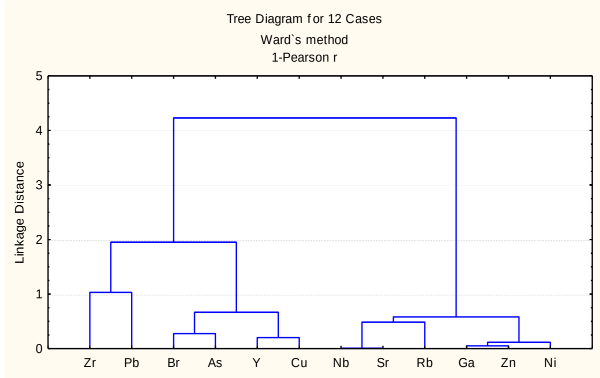
The analysis of the relationship between the content of trace elements in soils was carried out by the method of pair correlation. An average dependence between the concentration of Ni and the elements Zn (r= 0.69), Cu (r= 0.59), Sr (r= 0.54) was revealed. Cu concentration depends on Y concentration (r=0.84). The content of Zn is associated with a direct average relationship with the presence of Rb, Nb and Ga (0.67-0.52-0.50, respectively). The concentrations of Ga and Rb (r=0.54), Br and Rb (r=0.36), Sr and Nb (r=0.67) are interconnected. The concentration of As has an inverse average relationship with the concentration of the elements Nb (r= -0.40), Zn (r= -0.47) and Ga (r= -0.37).

Pair dependences of microelement concentrations were calculated. In the alpine-subalpine zone, a significant high correlation was found in Ni-Cu, Ni-Zn, Zn-Cu, Zn-Rb pairs, which is more pronounced than in mountain taiga soils. Possibly, this is due to the lower thickness of soil profiles and the greater manifestation of physical and frost weathering in severe conditions at an altitude of more than 600 m above sea level (Samofalova, 2021). So, for example, the Zn-Ni-Cu relationship, which manifests itself in soils in the alpine-subalpine zone, is absent in the soils of the mountain taiga, and the Ga-Zn relationship, on the contrary, is somewhat enhanced.

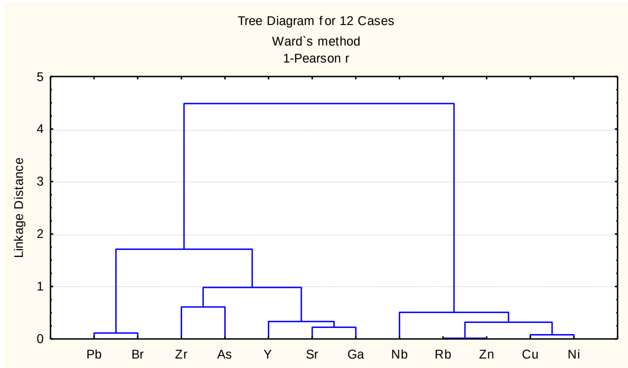
Cluster analysis of the multiple interconnection of elements confirmed the patterns of pair correlation. The geochemical associations Zn–Ni–Sr–Cu and Pb–As are distinguished in the humus horizon of the soils of the alpine-subalpine zone (Fig. 2a). In the humus horizon of the soils of the mountain taiga, clusters of Nb–Sr and Ga–Zn–Ni were identified, which are interconnected and form a single larger cluster. A separate cluster was formed by Cu–Y–Br–As (Fig. 2b).



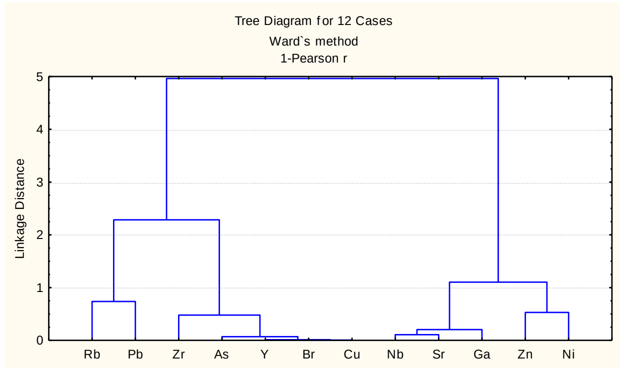
a) Humus horizon



b) Humushorizon



c) Soileluvium



d) Soileluvium

Figure 2. Dendrograms of microelement content in soils

Various associations were found in the soil eluvium (Fig. 2c,d). Thus, the level of the altitudinal zone and vegetation have a complex effect on the geochemical relationships and geochemical associations of elements in soils.

The geochemical series of microelements in relation to the Clark soils of the world for humus horizons and soil eluvium demonstrate the following features. Br, Pb, Zn, Cu, and Ni accumulate in the soils of the alpine-subalpine zone; Sr, Y, Ga, and Rb were found in the scattered state. Strontium is a light element in acidic soils. Y, Ga, Rb are vital and are actively absorbed by gymnosperms, mosses, lichens, which develop to a greater extent in the alpine-subalpine zone. Rocks on which soils are formed at an altitude of 600-940 m above sea level.enriched in Br, Pb, Zn, Zr, Ga, Ni. In the soils of the mountain forest zone, the same elements are accumulated as in the alpine-subalpine belt: Pb, Zn, Cu, Ni, Br; in the scattered state – Y, Sr, Ga; rocks are enriched in Pb, Zn, Cu, Zr.

The geochemical series of microelements are compiled to the regional clarke of soils. The regional background of the Perm Territory for some trace elements is elevated. The territory of the ridge is included in the Usvalithogeochemical anomaly (area anomaly in Ga, Pb, Zn, Cr, Mn, Cd, Ti, Zr). Cu, Ba, P, Ni, V, Sn have a local distribution on the territory of the anomaly. Relative to the regional background, Sr, As, Rb, Nb, Y, Ga, and Ni accumulate in the soils of the ridge, both in the surface horizons and in the soil eluvium in all altitudinal zones. In the alpine-subalpine zone, the accumulation coefficient of As, Nb, Sr, Ga is higher than in the mountain taiga, and the accumulation of Zn is also noticeable. Cu, Pb, Zr are in the dispersed state. Thus, the soils of the ridge have an increased natural background of some microelements.

With the help of geochemical coefficients, the intensity of sedimentation and soil formation processes (weathering, leaching, salinization, plant bioproductivity, etc.) is determined, and to achieve this goal, geochemical indices were used: (Rb + Zr)/Sr, Zr/Rb, Rb/Sr, Zr/TiO_2.

The ratio (Zr+Rb)/Srreflects the balance between silicate and carbonate components. In non-calcareous soils, the indicator reflects changes in the composition of heavy minerals (for example, zircon) of shales. The indicator varies in the range of 1.65-4.09, the minimum values are confined to the soils of meadows and light forests. The ratio Zr/Rb shows that with the increase in the height of the terrain, the dimension of the fractions increases. The maximum (6.4-8.8) is recorded in soils at an altitude of more than 700 m above sea level, the minimum values (2.0-3.0) are recorded in soils below 691 m.

The Rb/Sr ratio has been proposed as the difference in the resistance of various minerals to weathering, namely micas and K-feldspars, with which Rb is associated, and carbonates, with which Sris associated (Gallet, 1996). The Rb/Sr coefficient in soils is in the range of 0.273-1.202. The maximum values are noted for surface horizons.

The homogeneity coefficient of Zr/TiO_2 varies from 0.025 to 0.062. The minimum values are typical for meadow soils (605-650 m), the maximum values are for soils of the tundra zone (more than 930 m). In soils in the alpine-subalpine zone, a gradual change in Zr/TiO_2 along the profile with a decrease towards the rock is noted. In the mountain forest zone, on the contrary, there is a profile variation of Zr/TiO_2, which indicates the introduction of secondary material.

Conclusion

The excess of the content of some microelements in relation to Clark does not mean their technogenic nature of accumulation. The predominant influence of pairs of elements that form geochemical conditions in high-altitude zones is revealed. It has been established that the change in the content of microelements and their ratios in the soils of the Middle Urals is associated with altitudinal and vegetative conditions. The intensity of soil formation is higher in soils formed below 700 m, while the intensity of sedimentation processes, on the contrary, has an opposite trend.

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Soil resistance to vertical penetration and saturated hydraulic conductivity of fine-textured agricultural soil under controlled drainage

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Abstract

Drainage systems are present in almost 25% of agricultural land in the Czech Republic; approximately 1.1 out of 4.2 million hectares. Controlled drainage is a clever, sustainable water management method providing subsurface irrigation by artificial setting of the water level during dry periods of vegetation season. This study, carried out on agricultural field with controlled drainage, compares and relates experimental data of soil resistance to vertical penetration and saturated hydraulic conductivity (Ks) of the soil in areas with and without regulation of the groundwater level in the system. In addition to that, supplementary characteristics such as field volumetric water content, saturated volumetric water content, porosity and dry bulk densities were evaluated. Relatively wide range of the Ks values was measured; from 0.26 to 99.07 cm/day. The Ks values measured on non-regulated part were approximately six times higher than those on the regulated area. This finding is corresponding with lower values of dry bulk density and higher values of porosity which were determined for the non-regulated part. Penetration resistance showed not only an expectable increasing tendency with increasing depth and/or with decreasing soil water content, but also revealed interesting multi-layered profile present at the locality. Significantly higher values of penetration resistance (for significance level α = 0.05) were found on the regulated area, which corresponded with the lower values of measured saturated hydraulic conductivity.

Keywords: Hydraulic conductivity at saturation, Penetration Resistance, Regulation of Groundwater Level, Soil Characteristics Relations

Introduction

The Czech Republic is a landlocked country in the Central Europe that covers an area of 78 871 km^2; 4.2 million hectares is agricultural land from which approximately 1.1 million hectares is equipped with drainage system. History of the moisture regimes regulation of wet soils in the Czech Republic dates from the end of the 19th century to roughly the end of the 1980s of the 20th century (Kulhavý et al., 2007; Prax and Hybler, 2012). The drainage systems were built to enable agricultural use of wet soils due to high groundwater level or due to low rate of natural drainage. The basic principle of drainage is the removal of excessive water from the surface layer of the agricultural field. The excess water in the soil hinders the development of the roots, reduces the microbial activity and affects the soil structure. In the past, the drainage systems ensured the required crop yield in times of excess soil moisture. Nowadays, in time of climate change, the retention of the soil moisture within the landscape became a priority. Adaptation of the regular drainage system into a controlled drainage system provides a solution of great benefits; i) excess water is drained deeper (as in the regular drainage system), ii) by controlling the drainage outflow, significant amounts of water can be stored on site; iii) in times of agricultural droughts, additional water can be brought into the system and serve as subsurface irrigation system. Optimizing soil moisture regimes by means of drainage outflow regulation leads to more efficient use of nutrients by agricultural crops grown within the precision pharming. Naturally, the controlled drainage systems are not suitable for all agricultural fields with drainage systems in the Czech Republic. Relatively flat area, source of irrigation water and good condition of the drainage system are required. Of the total area of registered drainage systems, approx. 150 thousand hectares are suitable for controlled drainage (Fučík et al., 2021). Currently, there are about 30 controlled drainage systems in the Czech Republic and a lot of research is being done; i.e. functional evaluation of existing drainage systems (e.g. Tlapáková, 2017), selection of location and a design of measures on land drainage (e.g. Zajíček et al., 2022), effect of the controlled irrigation on crop yield (e.g. Duffková et al., 2022), and monitoring of the drainage water quality (Fučík et al., 2015).

This study as a part of ongoing research has been carried out on agricultural field in Uherčice, a locality, where existing regular drainage system was adapted to controlled drainage. This controlled drainage system is based solely on the principle of gravity which makes this locality very special. Experimental data of soil resistance to vertical penetration and saturated hydraulic conductivity (Ks) of the soil on part with and without regulation of the groundwater level in the system are related and compared. In addition to that, supplementary characteristics such as field volumetric water content, saturated volumetric water content, porosity, and dry bulk densities are evaluated.

The study area of 46.5 hectares is located in the Czech Republic, on the western side of the village of Uherčice; 48°58'2.904"N, 16°38'23.742"E. This relatively flat area is located at an altitude of 218 m a.s.l. in average. It is characterized by warm and dry weather conditions with average annual temperature of 9-10 °C and average annual precipitation sum of 500-600 mm. The present fine textured soil (Silty clay, Silty clay loam) was classified as Fluvisol (WRB, 2022). The drains are located in 1 m depth, following the scheme on Figure 1 (left), where one part of the regular drainage system has been adapted to controlled drainage (Figure 1 (right). The field experiments and sampling took place on 3rd and 4th November 2021, when the inflow of water from Svratka River was stopped and the whole area was in the drainage phase. The position of the ground water level was detected 1.393 m below the surface in area with regulation and 1.048 m in the area without regulation. The crop (maize) was already harvested, soil preparation and sowing of the main crop was carried out just before our field work. The field work was preceded by rain totaling approx. 5 mm, resulting in relatively high soil moisture contents (allowing the measurements of the penetration resistance).

Soil resistance to vertical penetration by FieldScout SC 900 - Soil Compaction Meter (Spectrum Technologies, Inc.) was measured on 12 soil profiles (6 on area with regulation and 6 on area without regulation). The profiles from surface to the depth of 45.7 cm were measured together, together with the determination of mass water contents for layers 0 – 15 cm, 15 - 30 cm and 30 – 50 cm. The measurements were following the soil sampling scheme indicated on Figure 1 (right). In total, 15 disturbed and 12 undisturbed soil samples (size 250 cm^3) were taken for further laboratory determinations. The measurements were following the soil sampling scheme indicated on Figure 1 (right).

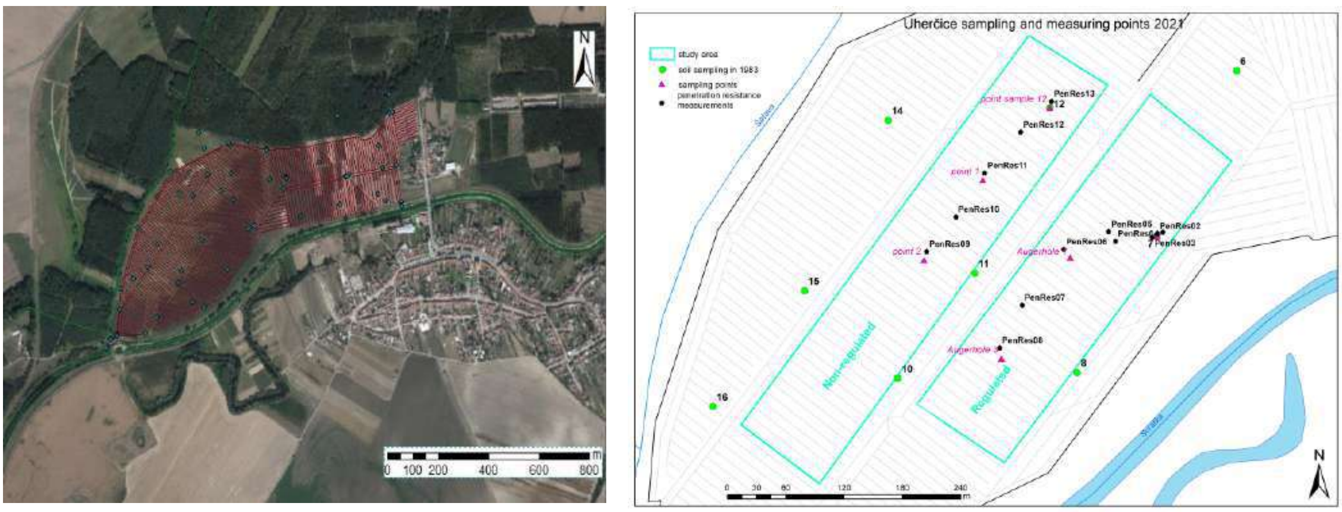


Figure 1. Study area delineation and the drainage pipes layout (left), identification of regulated and non-regulated part, sampling points and measurements of penetration resistance (right).

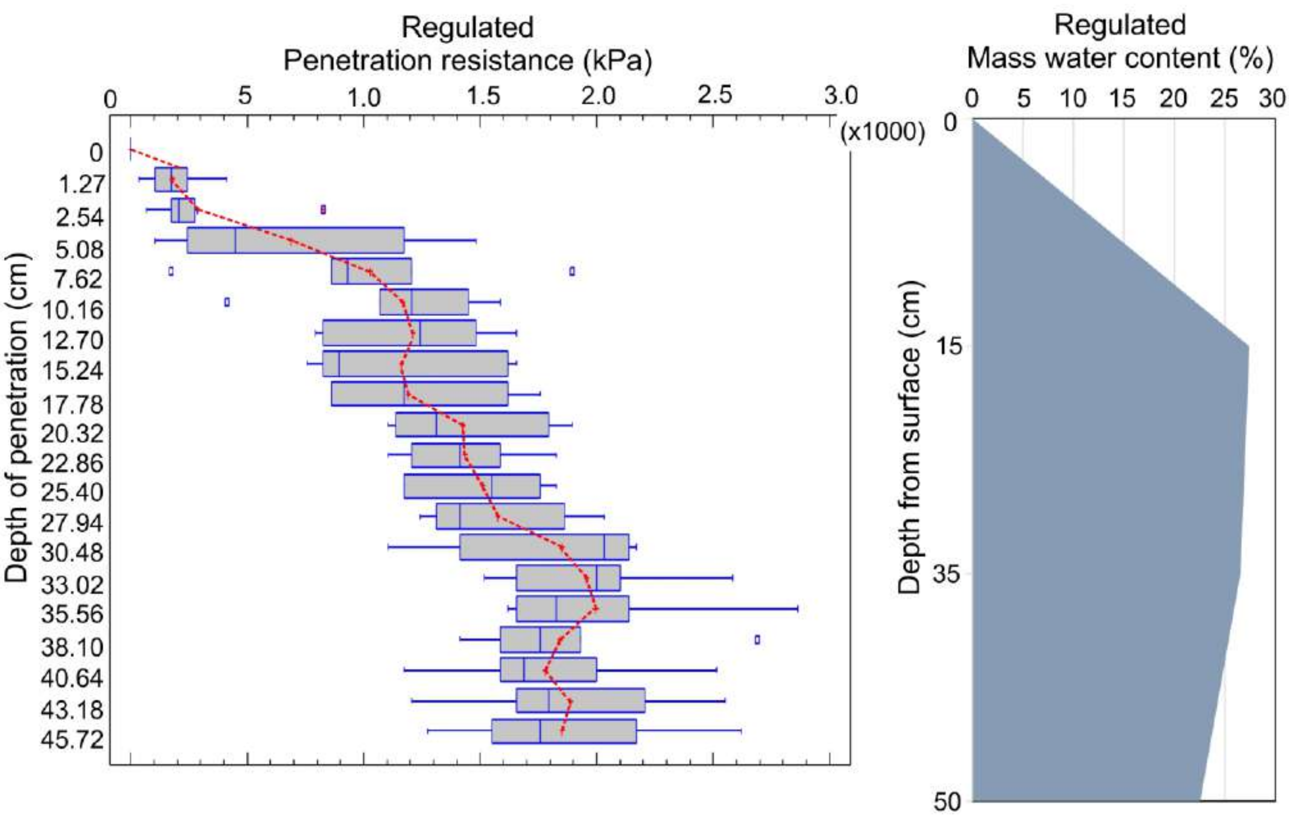
In total, 15 disturbed and 12 undisturbed soil samples (size 250 cm^3) were taken for further laboratory determinations. The disturbed samples were taken on 3 spots on each, regulated and non-regulated part in different depths (from soil surface to the depth of 200 cm and 260 cm respectively). The particle size distribution analysis was performed by Hydrometer Method, and soil moisture content by gravimetric method. The undisturbed soil samples were used to determine Ks in the laboratory (Ksat device, METER Group, Inc.), dry bulk density (by gravimetric method) and volumetric water content (volume of water/volume of the sample).

The measured data was statistically evaluated by means of the STATGRAPHICS Centurion XV Version 15.2.14 program (*StatPoint, Inc.*). The following tests were performed on a significance level ⍰ = 0.05; t- test, F-test, Kruskal-Wallis-H test.

Results and Discussion

The results of the basic statistical evaluation of the penetration resistance data are displayed in box plots (Fig. 2-left). The box plots allow monitoring the range of measured values of penetration resistance in kPa, identify outliers and, display the median of the penetration resistance values (Q50) at given depths (on Fig.2-left, the medians are connected by a red line). Since the penetration resistance of the soil is strongly dependent on soil moisture, the soil moisture values were determined gravimetrically at 3 depths and are graphically displayed right next to the penetration resistance values (Fig. 2-right). Based on the statistical comparison, it can be seen from Fig.2-right that due to the preceding rain, the soil moisture was very similar in both, regulated and non-regulated areas. The soil moisture values ranged between 27.7 and 33.3% by mass on the non-regulated area and 24.4 and 33.9% by mass on the regulated area. With increasing depth, an overall trend of increasing penetration resistance was observed, however, from Fig. 2, a certain stratification of the profile with different properties is evident (dry bulk density and particle size distribution affecting the magnitude of the penetration resistance).

The majority of the soils had over 33% by volume; the F-test or Kruskal Wallis-H test revealed no statistically significant difference between the regulated and non-regulated areas. When the volumetric soil water contents under field conditions were evaluated, a bell curve distribution from 29% to 38% was observed.



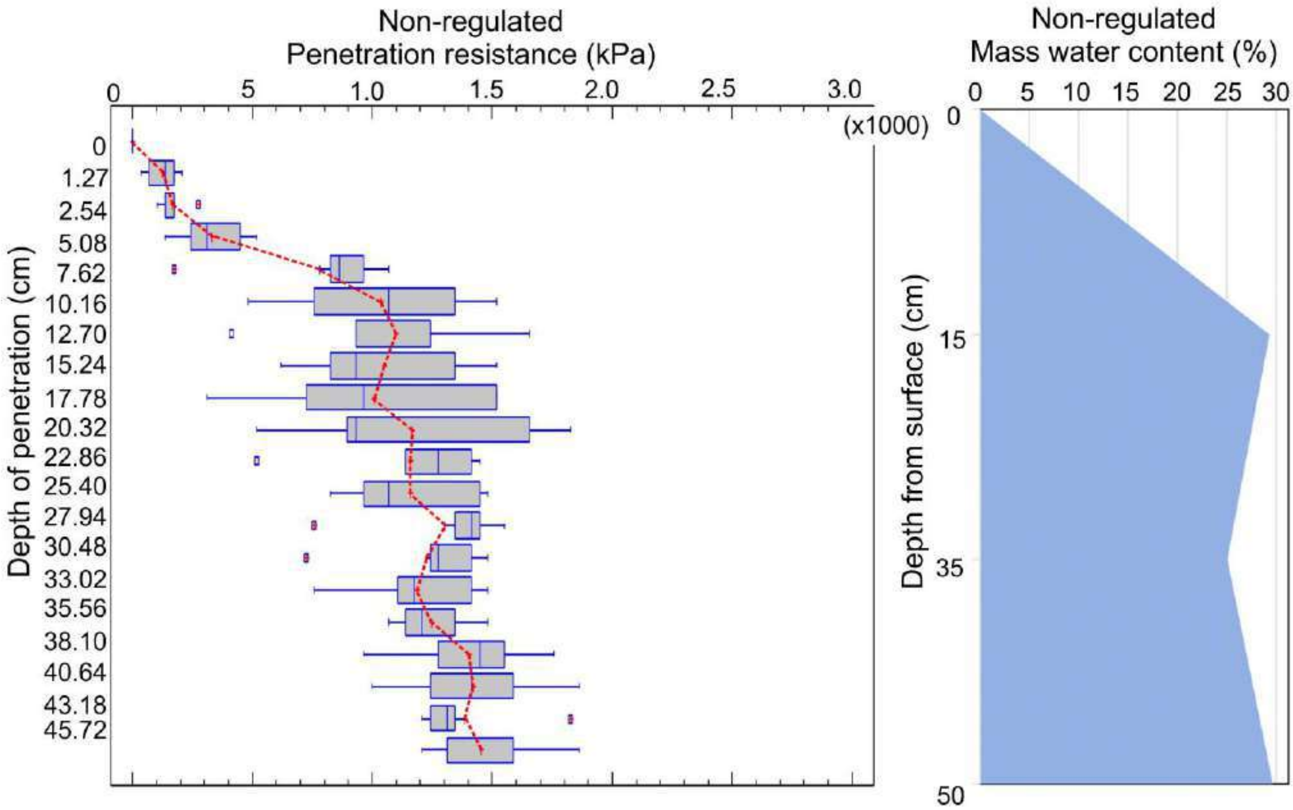
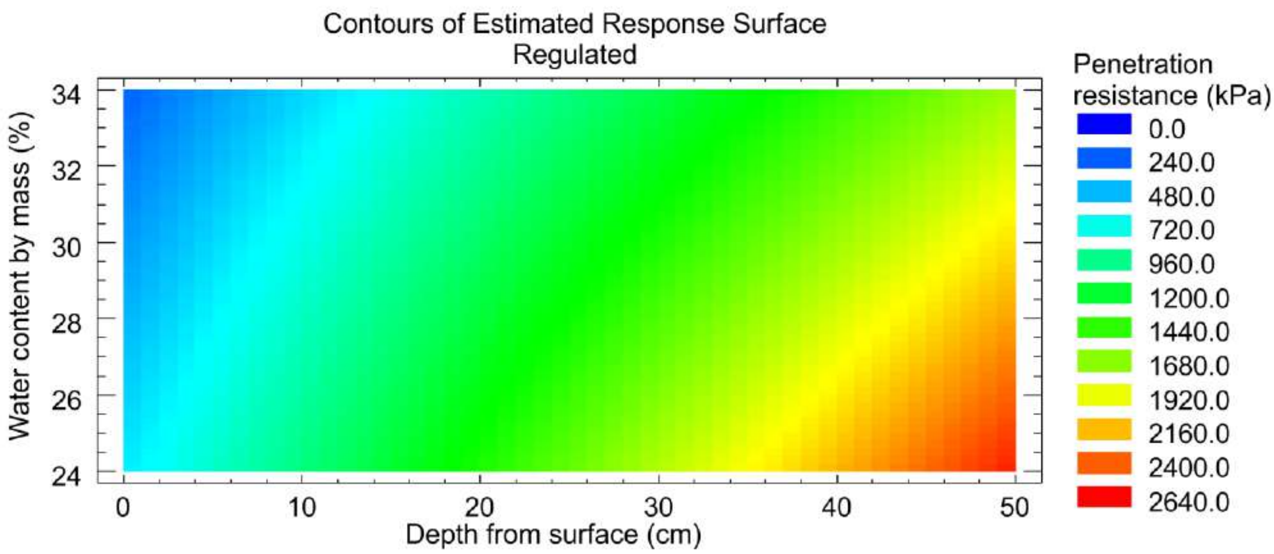


Figure 2. Penetration resistance (left) and mass moisture content (right) within the profile of the upper 50 cm in the soil with regulation (top) and without regulation (bottom) of the experimental site Uherčice.

Supporting the volumetric water content distributions, the dry bulk density values were also distributed in the bell-curve shape. Dry bulk densities were scattered between 1.13 to 1.45 g/cm^3. These structural differences throughout the field were also observed during the field work. The higher saturated moisture contents achieved in the non-regulated area were found to be matched with the lower bulk density values in the same region. However, this difference in bulk densities between the regions was only significant at the level of $p<0.1$. Overall, a statistically significant difference (for the significance level $\alpha = 0.05$) between the penetration resistance found on the regulated and non-regulated parts was found. Statistical comparison of the penetration resistance, moisture content and soil depth is shown in Fig. 3.



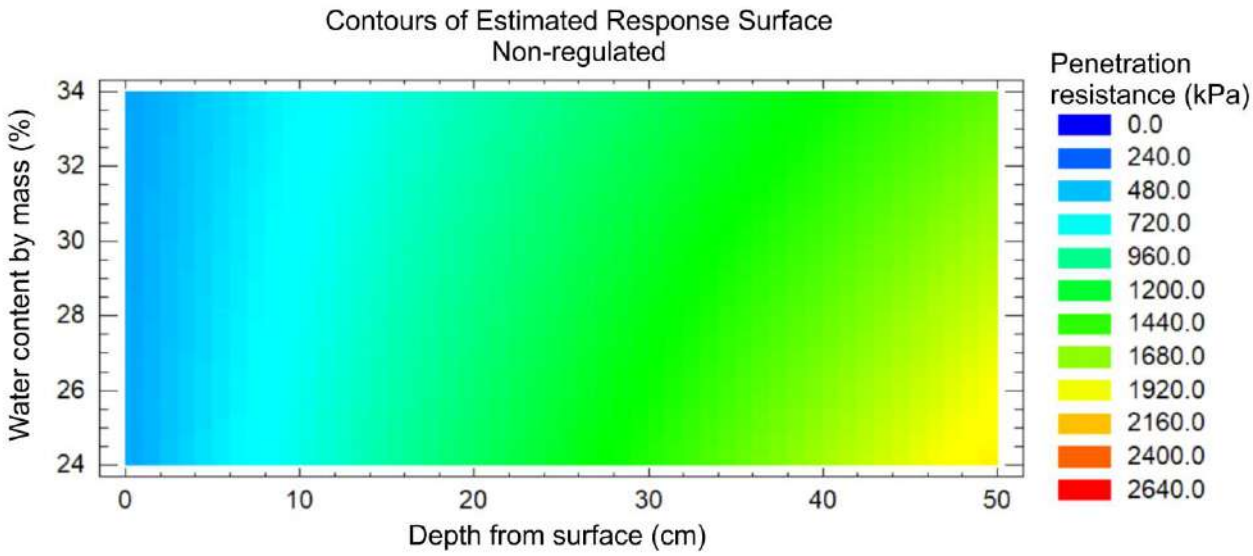


Figure 3. Statistical evaluation of penetration resistance in kPa as a function of depth and soil moisture for the non-regulated part (top) and the regulated part (bottom) of the experimental site Uherčice.

Saturated hydraulic conductivity values revealed the highest coefficient of variance by 11.46% and 64% of the samples showed lower hydraulic conductivities than 10 cm/day. The majority of these lower conductivity soils were in the area with regulation and the mean value for the Ks was nearly six times lower there, comparing to the non-regulated area (Fig. 3).

In overall evaluation of the areas, dry bulk density values were in strong correlation with volumetric water contents under saturated conditions; and both of these parameters were in strong correlation with the Ks values.

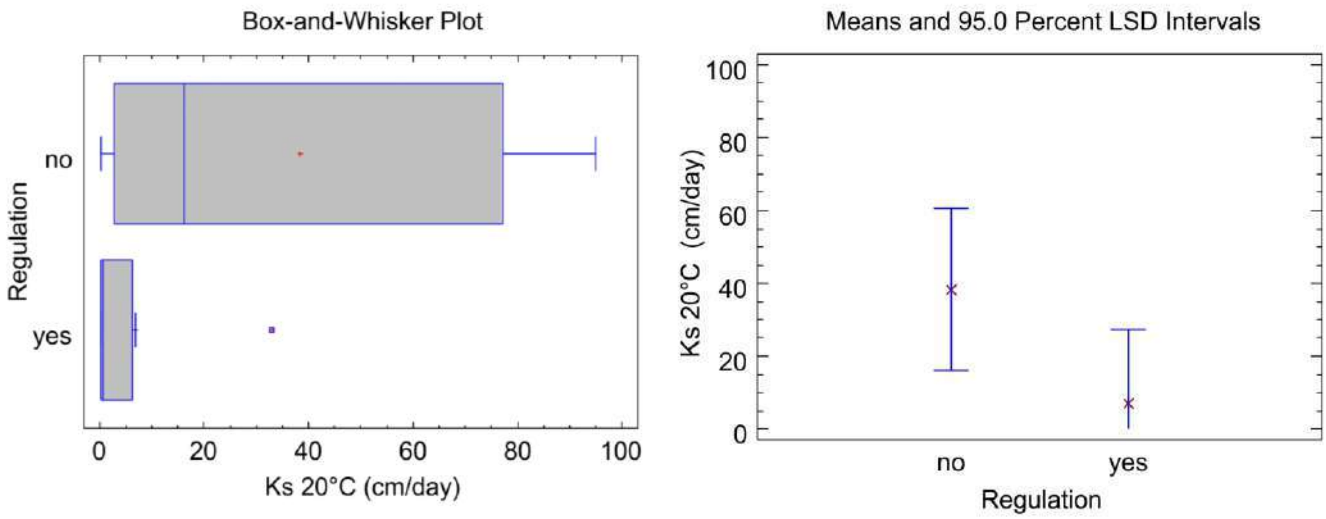


Figure 3. Statistical results for Ks values in cm/day on regulated and non-regulated areas on experimental sites in Uherčice.

Conclusion

Soil resistance to vertical penetration together with the dry bulk density values might serve as good indicators for the saturated hydraulic conductivity prediction. Higher Ks values corresponding with lower dry bulk density values and lower values of penetration resistance were measured on non-regulated area.

Acknowledgement

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How does salt-stress affect on plant growth and yield?

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Abstract

Salt stress is one of the major abiotic problems for arid and semi-arid region. Salt in soil or water retarded growth and yield of plant and reduce overall agricultural production. Salt can change the metabolism which affect the ultimate plant growth and development. Salinity dominated by Na+ and Cl decreases Ca2+ and K+ availability as well as Ca^{2+} and K^{+} transport and mobility to growth regions of the plant. High soil salinity reduces plant net photosynthetic capacity and results in physiological stress, which has a negative impact on agricultural productivity and sustainability. In case of cereals, the number of grain yield per plant, grains per panicles, grain yield, plant height, and relative water content all decline as a result of the elevated salt concentration. The inhibition of the enzyme activity could be caused by salt stress. It may affect a plant's ability to absorb minerals. However, during growth and development, a plant's sensitivity to salt stress also varies. Even mild soil salinity affects the physiological and biochemical pathways in plants. There are several ways to mitigate salt-stress problem. Despite of having other solution, organic amendments are optimistic solution for salt-stress problem. Additionally, biochar amendment has frequently been mentioned as a successful way to improve salt-stressed fields and raise plant resistance. Especially, improved soil cation exchange capacity, water holding capacity, soil nutrient retention, and increased soil enzyme activities and diversity of microbial communities. Moreover, composting salt-affected soils may speed up Na+ leaching, improve cation exchange and water infiltration, boost aggregate stability and water holding capacity, and reduce electrical conductivity and exchangeable sodium content. In conclusion, adding biochar and composting might be a potential strategy to lessen the negative effects of salt stress on plants.

Keywords: Abiotic Stress. Plant Growth, Soil Conditioner, Biochar, Composting

Introduction

One of the most significant barriers to crop growth and output in arid areas is salt stress. 37% of the world's arable land is sodic, while 23% is saline (Khan and Duke, 2001). Widespread losses in agricultural output for a range of crops worldwide are caused by high salt concentrations in soil. Approximately 2% of dryland agricultural land and 20% of irrigated area worldwide have secondary salinization, which affects more than 770,000 km2 of land (FAO, 2000).

The plant's ability to withstand soluble salts in the root medium depends on soil, water, and climatic conditions. During growth and development, a plant's sensitivity to salt stress also varies. According to recent findings, cereal crops are particularly vulnerable to salt stress during the vegetative and early reproductive stages. The effects of salt stress on particular yield components and the growth responses of various crops during critical growth stages are being measured (Maas, 1993). Alternately, the insolubility or competitive absorption of ions may have an impact on the plant's nutritional balance and specific ion impacts can result in direct toxicity (Greenway, 1980). The number of grains per spike, the number of grains per spikelet, the yield, the height of the plant, and the relative water content all decline as a result of the increasing salt concentration, although proline and water-soluble carbohydrates are seen to grow most (Shamsi and Kobraee 2013). All aspects of a plant's physiological and biochemical activity, including respiration, nutritional imbalance, osmotic adjustment, and photosynthesis, are disrupted by too much salt in the soil solution (Ben-Laoane et al., 2020). This paper will describe general plant responses to salt-stress and alleviation of salt-stress by organic amendments.

Effect of Salt Stress in Plants

Maize growth and development are impacted by salt stress, however plant responses vary depending on the level of stress and crop growth stage. Salinity with Na^+ and Cl^- predominance decreases Ca^{2+} and K^+ availability as well as Ca^{2+} and K^+ transport and mobility to the plant's growth regions, which impacts the quality of both the plant's vegetative and reproductive organs (Grattan and Grieve, 1999). The success of crop production on salt-affected soils depends on the seed germination phase of seedling establishment. Salt stress during germination typically retards the beginning, slows down the rate, and increases the dispersion of germination events.

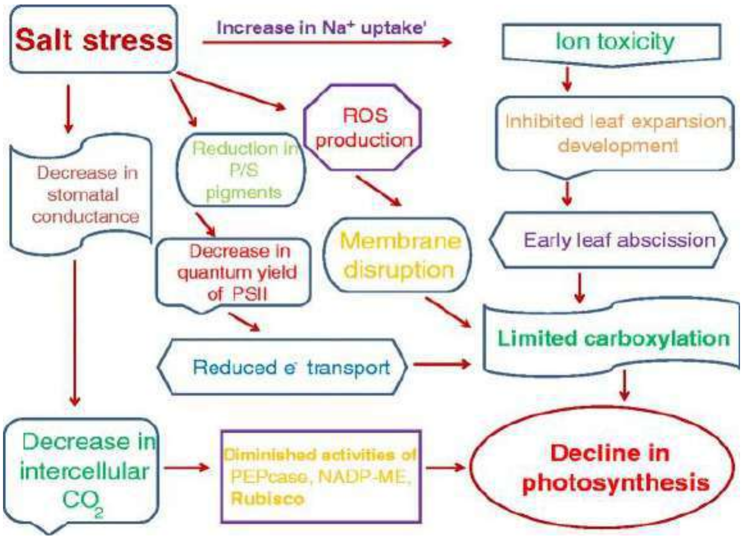

Figure 1. Salt stress in plant ((Farooq et al., 2015)

Although programmed cell death can also happen under extreme salt shock, growth inhibition is the main harm that causes other symptoms. Abscisic acid is produced in response to salt stress and, when delivered to guard cells, it seals stomata. Stomatal closure causes photosynthesis to decrease as well as photoinhibition and oxidative stress. Extra sodium ions at the root surface interfere with the plant's ability to absorb potassium. Due to the sodium and potassium ions' similar chemical make-up, potassium uptake by the root is significantly inhibited by salt. Additionally, calcium may directly inhibit sodium import carried out by nonselective cation channels (Jouyban, n.d., 2012). According to Levy (1992) and Jefferies (1996). Salinity reportedly hindered the germination of seed tuber or real potato seeds. Salinity was found to steadily decrease the size and quantity of marketable tubers per plant. The reduced yield of plants treated with salt can be related to the decrease in the number of marketable tubers per plant and the weight of those tubers (Ghosh and others, 2001).

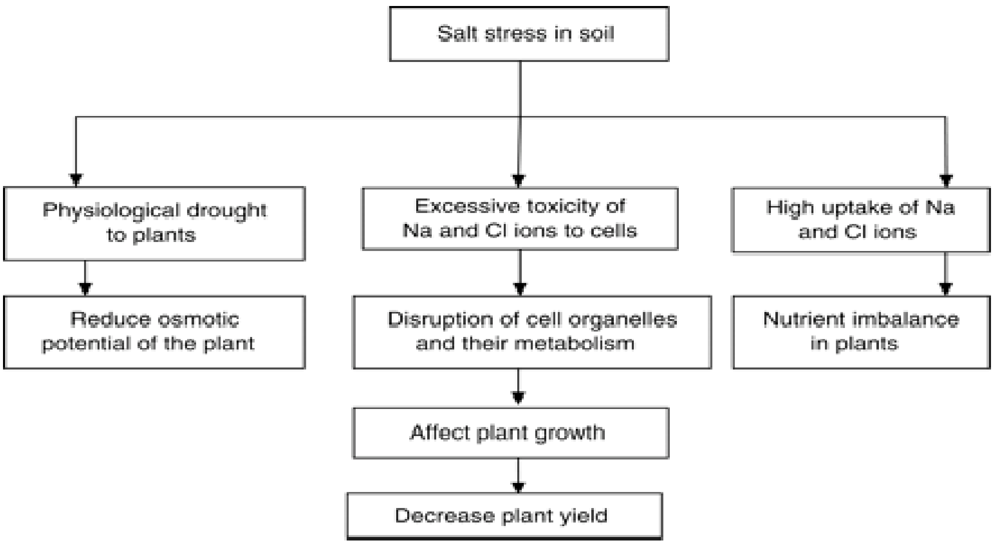

Figure 2. Salt stress in soil (Evelin et al., 2009)

Effect of salt stress on nutrient uptake

The availability, transport, and partitioning of nutrients are all impacted by nutritional disturbances under salinity that decreases plant growth. Anyway, salinity can influence plant's mineral nutrition. Due to Na+ and Cl-'s competition with nutrients including K^+, Ca^{2+}, and NO^{3-}, salinity may result in nutrient imbalances or deficiencies. Reduced plant development occurs in saline environments as a result of specific ion toxicities (such as Na^+ and Cl^-) and ionic imbalances acting on the biophysical and/or metabolic components of plant growth (Grattan and Grieves, 1999). Shoot and grain nitrogen uptake was significantly reduced by a steady rise in salts in irrigation water, with the greatest reduction seen at 6 dS m1 salinity (Gadalla et al., 2007). Under conditions of potassium deficit, the detrimental effects of salt on the uptake of potassium, calcium, and magnesium are exacerbated.

Changes in Metabolism

Salt stress has an impact on a variety of metabolic processes in plants, which has an adverse effect on growth and yields. Excess salt in the soil solution might harm plant growth by osmotic obstruction of water uptake by roots or particular ion effects (Yildirim et al., 2006).

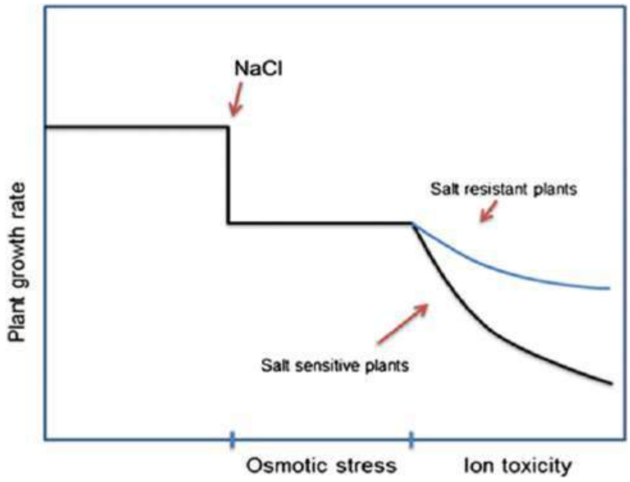

Figure 3. Biphasic model of salinity-induced growth reduction (Farooq et al., 2015)

Osmoregulation And Osmoprotectants

Plants need to keep their internal water potential lower than the soil when under stress in order to sustain turgor and water uptake for growth (Tester and Davenport, 2003). It is necessary to boost osmotica, either by synthesising metabolic solutes or by absorbing soil solutes. Low-molecular-mass substances—known as compatible solutes—accumulate in the cytoplasm to help maintain the ionic equilibrium in the vacuoles because they do not obstruct regularly occurring metabolic processes (Zhifang and Loescher, 2003). Instead, they operate as a substitute for water in these processes. Osmotic balance supporting continuous water influx (or reduced outflow) and protection of structures are recognized roles of osmolytes, with accumulation proportionate to the change in external osmolarity within species-specific limitations (Hasegawa et al., 2000). While some critical elemental ions, such K^+, are compatible osmolytes, the majority are organic solutes (Yokoi et al., 2002). Therefore, the solutes that build up differ depending on the organism and even between different plant species.

Possible mitigation of salt-stress

Studies have been done on a number of strategies to reduce the negative effects of salt stress on plants, including the use of various irrigation techniques, scraping, flushing, and leaching to remove extra salt from the plant's root zone, as well as the development of salt tolerance in plants (Inoue 2012). (Hichri et al., 2017; Shams et al., 2019). However, these methods may be ineffective in resolving the salinization issue because of their high costs and manpower demands. In recent years, organic soil regulators have attracted attention as a more promising and sustainable strategy to improving the fertility of salt-affected soils, which would ultimately boost agricultural productivity.

Biochar

Biochar, an organic fertilizer containing activated carbon, can be used as a soil conditioner in saline soils (Lehmann and Joseph 2009). Biochar is regarded as an organic fertilizer and an activated carbon soil conditioner (Kanwal et al., 2018). According to Thomas et al. (2013), adding biochar to the soil can lessen or even completely remove the detrimental effects of salinity on plant performance. Salinity primarily affects biomass production by lowering carbon inputs, which lowers biomass production. Biochar application boosts carbon inputs since it is a material rich in carbon created by burning biomass, which lessens the negative effects of salt stress on plants (Ali et al., 2017).

Characteristics of biochar

Source: (Kanwal et al., 2018)

Parameters	% Content
content Carbon (%)	64.54
Nitrogen (%)	2.1
Phosphorus (%)	0.98
pH	8.9
EC (micro-Siemens per meter)	36

Usman et al. (2016) found that the application of biochar amendments significantly increased the vegetative parameters of tomato crop grown under saline irrigation water regimes. Similar to this, Hansen et al., (2016) study's findings demonstrated that adding biochar improved plant development. According to Kim et al., (2016), corn planted in salty soil dramatically improved its plant dry weight after receiving a 5% biochar treatment. Additionally, Parkash and Singh (2020) discovered that applying 5% biochar by weight to eggplant plants under salt conditions increased yield and growth characteristics. According to studies by Jeffery et al., (2011) and Liu et al., (2013), applying biochar to plants promotes their development and increases their need for nutrients and water.

Composting

Organic fertilizer application to soil has become a popular practice in places suffering from excess salinity in recent decades, and it is seen as a potential environmental strategy for soil regeneration and fertility restoration, particularly in dry and semi-arid zones (Scotti et al., 2016, Boutasknit et al., 2020). Compost is an organic material that decomposes and enhances the soil's physiochemical qualities (Meena et al., 2016). Many recent research have focused on the use of compost in reducing the detrimental impacts of salinity (Ait-El-mokhtar et al., 2022). Composting salt-affected soils may accelerate Na+ leaching, boost water infiltration, cation-exchange capacity, aggregate stability, and reduce electrical conductivity and the proportion of exchangeable sodium (Wang et al., 2014). Furthermore, the organic input may have an effect on plant development and stress tolerance due to soil enrichment with humic compounds, minerals, and beneficial microorganisms, as well as improved soil enzymatic activity.

Conclusion

Salt-stress induced significant adverse effect on growth, physiological, bio-chemical attributes of plants. Excess salt must be removed from soil to produce optimum agricultural production. Composting and bio-char application might be a good source to alleviate salt-stress in plant.

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Possibility of using vermicompost to improve oil plants productivity

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Abstract

The world now is facing a shortage almost in all kind of plant yields. Research has shown that plant yields influenced by several factors (E.g. Soil fertility, high temperatures, and water deficit); a decline in soil fertility is the primary cause of yield decline, and that the presence of one or more of these factors increases the negative impact on plant yield. This review aims to determine the effect of vermicompost application to soil on oil production in plants. Based on a review for many literatures related to the effect of vermicompost on plants, multiple pot and field experiments to different plants were held. Multiple Measurements were done for the plants (E.g. oil quality, oil yield, seed yield, flower yield, etc.) and determine the respond for multiple vermicompost doses. Analysis of the experiments demonstrated that vermicompost can increase the production of oil content, soil fertility, fresh and dry flower yield and seed yield. Eventually improve plant growth and quality. On this basis, it is recommended that farmers use vermicompost as a key factor in enhancing and maintain their soil fertility and oil productivity. Further research is needed to identify other materials that could strengthen the effectiveness of this organic amendment.

Keywords: Essential Oil. Organic Fertilizer, Vermicompost, Yield

Introduction

Food production and waste management are two increasing issues ensuing from the growing world population. Recycling organic residues into amendment for food production seems to appear as an opportunity to partially solve this double challenge. Vermicomposting is a process whereby earthworms transform organic residues into compost that can be used as a substrate for plant growth (Blouin et al, 2019).

What is vermicompost

Vermicomposting is a bio-oxidative natural decomposition process that occurs under mesophilic conditions further aided by the biochemical action of microorganisms. Various categories of wastes are vermicomposted using different earthworm species. The mutual action of worms and microbes convert waste into fine, homogenized, odor-free, nutrient-rich, and humus-rich manure that is called vermicompost. Earthworms fragment the waste substrate in their intestine and improve its physicochemical characteristics by enhancing organic matter decomposition. Microorganisms present in the guts of earthworm help in biochemical degradation of the waste (Sharma and Grag, 2019). Physically, vermicompost-treated soil has better aeration, porosity, bulk density and water retention. Chemical properties such as pH, electrical conductivity and organic matter content are also improved for better crop yield (Lim et al, 2015).

Vermicompost in agriculture

Vermicompositing appears to be the most promising as high value biofertilizer, which not only increases the plant growth and productivity by nutrient supply but also is cost effective and pollution free. It was found that the vermicompost was rich in nutrients like Potassium, Nitrate, Sodium, Calcium, Magnesium, and Chloride and have the potential for improving plant growth than pit compost and garden soil (control) (Khan, A., and Ishaq, F. , 2011), which plays an important role in enhancing plant growth in specific amounts, as it serves a rich source of plant nutrients. Table 1 shows the chemical composition of vermi-compost (Garg, Gupta, 2009).

Table 1: The chemical composition of vermi-compost (Garg, Gupta, 2009).

Characteristics	Value
Organic carbon %	9.15 to 17.88
Total Nitrogen %	0.5 to 0.9
Phosphorus %	0.1 to 0.26
Potassium %	0.15 to 0.256
Sodium %	0.055 to 0.3
Calcium & magnesium (Meq/100g)	22.67 to 47.6
Copper; mg kg^{-1}	2.0 to 9.5
Iron, mg kg^{-1}	20. to 9.3
Zinc, mg kg^{-1}	5.7 to 9.3
Sulphur, mg kg^{-1}	128.0 to 548.0

Effect of vermicompost on seed yield.

Most investigations have confirmed that Vermicompost could increase seed yield production in some situations. The biological fertilizer "Vermicompost" increases the seed yield of fennel by 20.48% (Mohammadii and Chiyaneh, 2019). And the Application of vermicompost at 3t/ha had a positive effect on dry matter production, grain yield and protein content of chickpea, dry fodder yield of succeeding maize. Table 2 shows an enhancement of grain yield by 28.3 and 28.0% in two years (Y1, Y2) (Jat and Ahlawat, 2006).

Table 2: Effect of vermicompost on dry matter (DM) accumulation, grain yield and protein content of chickpea, dry fodder yield of maize.

Treatment	DM of chickpea (g/plant)		Grain yield of chickpea (t/ha)		Protein content in chickpea seed (%)		Dry fodder yield of maize (t/ha)	
	Y1	Y2	Y1	Y2	Y1	Y2	Y1	Y2
Vermicompost								
No vermicompost	17.44	19.62	1.91	2.05	19.2	19.5	6.66	7.05
Vermicompost 3t/ha	18.60	20.95	2.26	2.44	19.8	20.1	7.43	7.58

Also grain yield of maize (Zaremanesh et al, 2019). Grain weight (g/plant) of barley plants in soil treated by vermicompost (Mahmoud and Ibrahim, 2012). The number of pods and seed weight of soybean (Glycine max L) have increased (Aritonang et al, 2020). On the other hand, some research indicates that vermicompost has a negative effect on lentil pods number per plant in high concentrations (Ceritoğlu and Erman, 2020). Other experiments have a linear relationship between applied vermicompost levels, plant growth and seed yield. Higher doses of vermicompost did not vary significantly from lowest dose (Joshi et al, 2015).

Effect of vermicompost on the floral oil plants growth.

Floral oil is an essential oil, which is extracted from the plant flower. Floral oil quality can be negatively impacted due to many factors like; using chemicals, soil condition, nutrient deficiency, etc. Vermicompost is considered as a rich source of plant nutrients, humic substances and microsites that has an important role in high microbial population and diversity, thus enhance plant growth. Many researchers confirmed that flower head diameter and essential oil percentage were significantly increased by vermicompost treatment. In addition, Vermicompost had positive effects on the fresh and dry flower yield of chamomile. Table 3 shows the effects of vermicompost on chamomile (Matricaria chamomilla L.).

Table 3: the effects of vermicompost on chamomile (Matricaria chamomilla L.).

Treatment	Height (cm)	Flower head diameter (mm)	No. flowers/plant	Fresh flower yield (kg/ha)	Dry flower yield (kg/ha)	Essential oil (%)
Vermicompost						
V1	25.3	18.5	65.42	1800.77	352.98	0.34
V2	31.2	18.6	89.21	2311.23	462.42	0.37
V3	34.1	18.9	95.76	2733.5	535.77	0.38
V4	37.2	19.4	107.5	3172.54	592.63	0.43
V5	41.8	21.5	110.23	3335.7	653.81	0.49

Vermicompost levels: V1, 0 ton/ha (control); V2, 5 ton/ha; V3, 10 ton/ha; V4, 15 ton/ha; V5, 20 ton /ha.

The high flower yield of chamomile under V5 might be due to higher number of flowers per plant and an increased flower head diameter. Flower head diameter was greater ($P \leq 0.05$) after the V5 treatment (Mohammad et al, 2011). Also, researchers found that the largest diameter was recorded in the highest dosage of vermicompost (vermicompost%=20%) treatment applied on French marigold (*Tagetes patula)* and the smallest diameter of plants was recorded in control (vermicompost%=0) (Gupta et al, 2014).

No negative effect on floral oil and plant flower growth have been recorded yet.

Vermicompost effect on essential oil content and oil yield.

(Darzi et al. 2015) observed that essential oil content and oil yield were positively affected by application of vermicompost on Coriander (*Coriandrum sativum*) and dill (*Anethum graveolens*) which is shown in table 4. (Mean comparison of the essential oil and oil yield in dill at various levels of vermicompost) The most significant essential oil content (2.21%) was obtained by applying 4-ton vermicompost per hectare. Among various treatments, the application of 8 ton vermicompost per hectare has indicated maximum increase in essential oil yield (48.6 kg/ha) (Darzi et al, 2012).

Table 4: Mean comparison of the essential oil and oil yield in dill at various levels of vermicompost.

Treatment	Essential oil content in seed (%)	Essential oil yield (kg/ha)
Vermicopmost (ton/ha)		
v1	2.00	26.1
v2	2.21	43.0
v3	2.20	48.6
v4	2.14	46.1

Vermicompost effect on essential oil quality and its chemical composition.

Essential oils are important in many fields in real life i.e. food, perfumes, pesticides and for medical purposes. Regarding oil quality and its chemical composition, researchers have different observations. (Anwar et. al, 2014) analyzed the chemical composition and quality of French Basil oil (i.e., methyl chavicol and linalool).

methyl chavicol (estragole), which plays a role in basil odor and is considered as an active organic compound in medical uses such as muscle pain and stomach cramps, has been affected significantly by vermicompost addition which increased the content of methyl chavicol. Also, linalool which is included in some cleaning agents, in some insecticides and used as a scent in 60%-80% of perfumed hygiene products, got affected significantly by vermicompost addition which increased the percentage of linalool.

Table 5: Influence of inorganic fertilizer (NPK) and organic manure (FYM and Vermicompost) on herb, dry matter, essential oil yield, and quality of French basil (Ocimum basilicum L.) oil.

Treatments	Oil content (%)	Content of principal ingredient in basil oil (%)	
		Methyl chavicol	Linalool
T1	0.65	76.04	17.55
T2	0.66	77.74	18.82
T3	0.75	78.60	18.66
T4	0.69	77.32	18.49
T5	0.71	78.41	18.58
T6	0.72	78.69	19.60

T1, Control (no fertilizer and no manure); T2, farmyard manure (10 t ha21); T3, Vermicompost (10 t ha21); T4, Fertilizer NPK (100:50:50 kg ha21); T5, Farm yard manure (5 t ha21) þ Fertilizer NPK (50:25:25 kg ha21); and T6, Vermicompost (5 t ha21) þ Fertilizer NPK (50:25 25 kg ha21). As a result of the increase of these chemical components concentrations, this research confirmed that vermicompost enhances oil quality (Anwar et al. 2005).

(Singh et al. 2013) confirmed that Content and quality of rosemary (*Rosmarinus officinalis* L.) oil were not influenced by organic and chemical fertilizers.

Conclusion

Vermicomposting appears to be one of many viable ways to utilize the organic wastes. Moreover, it has many impacts on the environment and agriculture. Most studies have confirmed the positive effect of vermicompost application on crop yield, oil quality and quantity, flower head diameter, fresh and dry weight of flower and fertility level of soil. Mostly, high concentration of vermicompost has a negative effect on the mentioned characteristics due to improper increase in soil pH and EC which inhibits seed germination. Many researchers confirmed that applying chemical fertilizers -in specific ratios- in addition to vermicompost enhance plant growth in huge levels, which will decrease the excessive and disproportionate amount of chemicals and reduce its damaging impacts on the environment and humans. Few researchers confirmed that there is no significant effect of vermicompost application on plant growth, oil quantity and quality. In general, vermicompost is one of the best and highly recommended soil amendments in organic farming.

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Agroecological significance of ekofertile™ plant biostimulant on tropical soils and crop improvement

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Abstract

The environmentally degrading effects of synthetic chemical fertilizers have triggered the search for sustainable alternatives to resolve the global food crisis exacerbated by Covid-19. This has led to the development of biostimulants from plants, animals, or organic mineral salts. Biostimulants from these sources enhance plant growth through benefit nutrient uptake, nutrient use efficiency, tolerance to abiotic stress, pest and disease suppression, or crop quality and yield. Scientific research to produce and validate biostimulants from these sources is increasing in scope and number. ekofertile™ plant biostimulant produced from coal is capable of all biostimulant functions defined by the European Union on fertilizers aside from being environmentally friendly. ekofertile™ plant biostimulant from sand is rich in mineral nutrients and beneficial microorganisms. While biostimulants perform their role efficiently, their potential is limited to agroecological locations, edaphic factors, and crop types, as revealed by the literature. Tropical soils, considered one of the oldest soils, have organic matter within a few centimeters of the topsoil, making them variable, highly productive, and poor at the same time, needing inputs mostly from none agroecological-friendly sources like synthetic chemical fertilizers. Understanding the relationship among biostimulants, agroecological locations, edaphic factors, and crop types could be exploited to improve agricultural plant production. Thus, the current study was carried out to examine the agroecological significance of ekofertile™ plant biostimulant on tropical soils and crop improvement.

Keywords: Beneficial microbes, Eco-friendly, Mineral nutrients, Organic acids.

Introduction

With the advent of Covid-19, coupled with climate change and the ever-increasing human population, agriculture is facing a dilemma in sustaining the world food demand with more than 1 billion people without a guarantee for food security (Workie et al., 2020; Ben Hassen & El Bilali, 2022). This situation is the worst in tropical and subtropical locations, constituting 60 % of people without food security (Moroda et al., 2018). This is because the soils are acidic, where phosphorus, potassium, and some trace elements are highly immobile. The soils are also low in cation exchange capacity and experience higher temperatures and heavy rainfall leading to a greater rate of nutrient leaching (Stocking, 2003; Markgraf, 2011). Although tropical soils are very productive, they are variable and destitute in nutrients.

To cut this food crisis in the tropics, food importation and the use of agro-industrial fertilizers and pesticides of synthetic origin have been instrumental (Reveles, 2017; Mabhaudhi et al., 2018). While Covid-19 has compounded the situation, the aftermath of agro-industrial chemicals has left devastating consequences for the environment and human health (Stephens et al., 2020; Agbor et al., 2022a). These are soil degradation, biodiversity loss, climate change enhancement, eutrophication, food poisoning, heavy metals contamination, and cancer (Biswas et al., 2018). This has led to the global motion for holistic, sustainable agricultural inputs (Khadse et al., 2018; Agbor et al., 2022b).

Biostimulants have been at the forefront of this evolution because they are natural, come from plants, microbes, or inorganic salts, and are environmentally friendly (Bhupenchandra et al., 2020; Rouphael et al., 2020). The European Regulation on fertilizers defines biostimulants to have the following functions: benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, or crop quality and yield (Woo & Pepe, 2018; Caradonia et al., 2019; Ricci et al.,2019). Thus, the current study explores the significance of ekofertile™ plant biostimulants on acidic nutrients limiting tropical soils in boosting soil fertility and crop production.

Overview of Tropical Soils

The significant area occupied by tropical soils is in west Africa. Their formation is mainly bioclimatic, while the types and quality depend on the parent material, making them variable, highly productive, and poor at the same time for each climatic type (Lebel et al., 2009; Daniel et al., 2013; Moroda et al., 2018; Hounkpatin et al., 2022).

There are three major tropical soils sub-desert soils, ferralitic soils, and ferruginous tropical soils (Silva et al., 2020). The sub-desert soils lack organic materials, are shallow, and are generally well-provided with nutrients. They consist of sand and peddles that are thin and stony. Ferruginous soils cover a chunk of west Africa, and they are red or yellow. They are heavily weathered and protected from erosion by the dense forest vegetation. The yellow soil is rich in goethite and gibbsite-hydrated minerals, while the red soil consists of less hydrated or dehydrated hematite and kaolinite (Mancini et al., 2019). The soils are deep, old, and impoverished chemically, and the rich organic matter at the topsoil is only a few centimeters thick (Silva et al., 2018). Replenishment of organic matter is depleted rapidly due to the high rate of decomposition by microorganisms (Singh et al., 2020).

Areas with 250–600 mm/year of rainfall are alkaline and slightly acidic when heavily leached and are associated with ferruginous soils, same with dark brown or black vertisols that are easily flooded (Giresse, 2007). The best tropical soils are young, poorly evolved, deep loam soils derived from basalt and other tertiary volcanics and include hydrated minerals. They are well-drained and liable to gullies' erosion.

Generally, tropical soils are formed under hot conditions and experience hefty rainfalls (Ramankutty et al., 2002). They are the world's oldest soils, with little organic matter and nutrients (Martius, 2001). Tropical soils are ultisols that are reddish, clay-rich acidic soils, they are oxisols that are extensively leached, and the clay-size particles are dominated by oxides of iron and aluminum, which are low in natural fertility (Ca^{2+}, Mg^{2+}, $K+$) and high in soil acidity (H^+, Al^{3+}) (Fageria and Baligar, 2008; Shibata et al., 2017).

Overview of the Ekolive

Ekolive is the first and leading provider of an EU/ETV-certified eco-innovative bioleaching method (InnoBioTech®) for processing waste/minerals/soil using bacteria. This allows new raw material resources to be explored or gives various industrial wastes a second life, replacing dangerous mining and processing methods, and environmental hazards to sustainable eliminated.

Ekolive is ecological, innovative, and value-adding; the breadth and contribution of its innovative technology to achieving global sustainability goals are exceptional

In addition to biological soil remediation (cleaning of pollution – including pesticides) with bacteria, ekolive produces highly effective biostimulants that are listed on the input list for organic production (FiBL Netherlands). These complex and therefore unique biostimulants consist of plant growth-promoting bacteria, various effective organic acids and dissolved minerals and are currently produced at five locations in Europe using an EU-certified bioleaching process. They are basically environmentally friendly, ecologically sustainable, and serve in general:

• increasing the efficiency and yield of classic fertilizers by improving nutrient uptake and nutrient utilization by the plants,
• the improvement of all quality characteristics of the plants,
• faster germination, development and acceleration of growth – above all by promoting root growth and thus enlarging the root surface,
• increasing the germination rate and the yield (by 30 – 40 %), thus securing the yield,
• increasing the immunity of plants against pathogens,
• the increase in the nutrient and sugar content of the plants (by up to 150 %),
• increasing the plants´ resistance to abiotic stresses – such as drought, heat and cold.

Chemical, biological and organic acid constituents of ekofertile™ plant biostimulant

Table 1a. Chemical and microbial constituents of ekofertile™ plant biostimulant

Chemical content			Microbial content	
Constituent	Unit	Quantity	Genus	Species
Dry matter	%	0.91	Lactobacillus	Lactobacillus satsumensis
Organic matter	%	0.27		Lactobacillus diolivorans
Ash	%	0.53		Anaeromassilibacillus senegalensis
Total Nitrogen	%	0.04		Lactobacillus bifermentans
NH_4^+	%	0.01		Lactobacillus perolens
NO_3^-	%	< 0.01		Lactobacillus nagelii
Nitrogen	%	0.01	Clostridium_IV	Clostridium tyrobutyricum
Carbamide N	%	< 0.05		Clostridium ljungdahlii
P_2O_5 min. acid sol.	%	< 0.01	Clostridium_sensu_stricto	
K_2O	%	0.08		
Total MgO	%	0.03	Bifidobacterium	Bifidobacterium mongoliense
Total CaO	%	0.09		
Total Sulphur	%	0.03	Leuconostoc	Leuconostoc fallax
Sodium	%	0.09		
Silicon	%	< 0.01	Acetobacter	Acetobacter indonesiensis
Alkaline active comp.	%	0.44	Macellibacteroides	Macellibacteroides fermentans
Boron	mg/kg	< 2.00		
Cobalt	mg/kg	0.12	Bacteroides	Bacteroides luti
Iron	mg/kg	142		
Copper	mg/kg	< 2.00		
Manganese	mg/kg	6.58		
Molybdenum	mg/kg	< 0.10		
Zinc	mg/kg	< 2.00		
pH		4.50		
Salt content	% KCl	0.78		

Table 1b. Organic acid constituent of ekofertile™ plant biostimulant

Sample	Formic acid (mg/l)	Lactic acid (mg/l)	Acetic acid (mg/l)	Propionic acid(mg/l)	Butyric acid (mg/l)	Methanol (mg/l)	Ethanol (mg/l)
Organic acid	<5	9320	1550	19*	900*	8.6**	610

*HS-GC-MS measurement with internal standard calibration (4-methyl valeric acid)

**HS-GC-MS measurement with external standard calibration

Role of beneficial microbes found in ekofertile™ plant biostimulant

Table 2. Role of beneficial microbes found in ekofertile™ plant biostimulant

Genus	Coal Species	Function
Lactobacillus	Lactobacillus satsumensis	catalyzes the hydrolytic depolymerization of polysaccharides in soil. Breakdown of complex polysaccharides, including starch, to a readily available form of glucose, extracellular polymeric substances secretion & Fermentation (Adegboye et al., 2021)
	Lactobacillus diolivorans	Solubilize insoluble inorganic phosphate (Divjot et al., 2021)
	Anaeromassilibacillus Senegalensis Lactobacillus bifermentans Lactobacillus perolens Lactobacillus nagelii	
Clostridium_IV	Clostridium tyrobutyricum	Free Nitrogen fixation release polysaccharides and carboxylic acids like tartaric acid and citric acid to solubilize K, breakdown organic matter releasing citric acid, formic acid, malic acid, and oxalic acid making K available, fermentation (Figueiredo et al., 2020)
	Clostridium ljungdahlii	obligatory anaerobic heterotrophs only capable of fixing N2 in the complete absence of oxygen, isolated from rice fields (Figueiredo et al., 2020)
Clostridium_sensu_stricto		Fermentation (Figueiredo et al., 2020)

Bifidobacterium	Bifidobacterium mongoliense	degradation of non-digestible carbohydrates, protection against pathogens, production of vitamin B, antioxidants, and conjugated linoleic acids, and immune system stimulation (Zhang et al., 2019).
Leuconostoc	Leuconostoc fallax	catalyzes the hydrolytic depolymerization of polysaccharides in soil. Breakdown of complex polysaccharides, including starch, to a readily available form of glucose, fermentation
Macellibacteroides	Macellibacteroides fermentans	Fermentation (Jabari et al., 2012)
Bacteroides	Bacteroides luti	Pathogen-suppressing, contribute prominently to rhizosphere phosphorus mobilization, express constitutive phosphatase activity, and organic matter degradation (Lidbury et al., 2021)

The significance of ekofertile™ plant biostimulant on tropical soils and crop improvement

The significance of ekofertile™ plant biostimulant on tropical soils

- Supply of primary macronutrients (NPK), exchangeable cations (Ca, Mg, K, Na), micronutrients (Co, Fe, Mn), ekofertile™ plant biostimulant is also rich in salt, Sulphur, silicon, and organic matter (Table 1a). This will augment the variable highly productive and poor soils, ensuring continuous productivity and replenishment of the lost organic matter.
- The ekofertile™ plant biostimulant has an acidic pH of 4.5, which when mixed with water becomes neutral coupled with the alkaline active component (Table 1a), will buffer the acidic tropical soil pH to levels that permit an optimum uptake of nutrients, thus preventing the possibility of iron or aluminum toxicity due to acidic pH that permits their excess availability.
- Ekofertile™ plant biostimulant is endowed with beneficial microorganisms (Table 1a and Table 2) involved in free nitrogen fixation, phosphorus and potassium solubilization, organic matter degradation, organic acid production (Table 1b), vitamins, and enzyme activities that enrich the soil, making it fertile, thus nutrient turnover and soil formation.
- Owning to the fact that ekofertile™ plant biostimulant comes from natural sources, there will be no soil and environmental degradation, rather there will be improved the agroecological diversity of soil life.

The significance of ekofertile™ plant biostimulant on crop improvement

- Nutrients from ekofertile™ plant biostimulant and beneficial microorganisms (Table 1a, b, Table 2) provided in the soil will enhance crop growth and development.
- Beneficial microbes from ekofertile™ plant biostimulant exhibit pathogen suppression ability, preventing the plants from being devoured by pests.
- The high mineral content of the ekofertile™ plant biostimulant will boost the nutritional constituent of the crops grown with it, thus providing more nutritional food to the increasing population.

Conclusion.

Ekofertile™ plant biostimulant thus have tremendous agroecological beneficial potentials to tropical soils while ensuring sustainability and carrying out research to ascertain these literature potentials will be perfect.

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Exploring the soil fertility and plant nutrition potential of LAB isolated from palm wine and sha'a

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Abstract

The degrading effects of synthetic agrochemicals on soil health and fertility have provoked a revolution for sustainable pathways to improve soil quality and productivity. Recent advances have proven and postulated soil fertility enhancement using plant growth promoting beneficial microorganisms without deleterious effects on soil health. Such beneficial microbes are lactic acid bacteria. LAB is a group of microorganisms that are non-motile, gram-positive cocci or bacilli, non-spore-forming, and finally produce lactic acid for the fermentation of carbohydrates through heterofermentative or homofermentative. LAB have shown to enhance soil fertility and plant nutrition through phosphorus solubilization, nitrogen fixation, siderophore secretion, and decomposition of organic matter. Due to LAB's role in soil quality augmentation, their isolation from different sources has increased in modern times. They are found to be dominant in fermented products such as compost, yoghurt, palm wine, and sha'a also known as corn beer. Palm wine and sha'a are drinks that is been produced and consumed traditionally in most developing nations. They harbour an array of LAB with the potential to increase crop productivity and enhance soil quality. Nonetheless little is known about the isolation of LAB from palm wine and sha'a and their role in soil fertility and plant nutrition. This review is therefore set out to explore the potential roles of LAB from palm wine and sha'a on soil quality and plant nutrition.

Keywords: Beneficial microbes, soil health, plant and LAB sources.

Introduction

Anthropogenic activities, including excessive use of synthetic agrochemicals, have emanated in soil degradation, nutrient imbalance, salinization, and acidification as soil pH decreases, as well as toxicity on non-target soil-beneficial organisms (Zhou et al., 2013). This has necessitated the use of sustainable alternatives such as beneficial microbes as a promising approach to achieving food security and sustainability (Rurangwa et al., 2018, Agbor et al., 2022a)

Modern approaches in plant-microbe interaction research tilted attention to the value of microbial communities in enhancing plant growth, health, and resilience. Engineering the phytomicrobiome to meliorate plant growth is a promising approach for maintaining crop productivity in a dynamic climate and increasing population. Broadly, plant growth-promoting microorganisms (PGPM) enhance plant growth by improving nutrient uptake, serving as biocontrol agents (BCAs), abating the potential of the plant to withstand abiotic stress, or by producing compounds that directly stimulate plant growth (Lamont et al., 2017). Many PGPMs enhance plant growth via different mechanisms simultaneously (Avis et al., 2008). However, the roles of other groups of potential PGPMs, including lactic acid bacteria (LAB), are largely untapped. LAB has demonstrated the potential to improve soil fertility and the nutrition of many crops. This has resulted in LAB isolation from various sources, including palm wine and sha'a, to stimulate soil fertility.

The sap of the oil palm wine can be obtained from the three palm tree species (*Elaeis guinneesis, Raphia hookeri, and Borassus aethiopumserve)* as a rich substrate for various types of microorganisms to grow primarily lactic acid bacteria (Theodore et al., 2020). The palm sap is obtained from either the immature male inflorescence (inflorescence tapping) or the stem (stem tapping). This is commonly practiced in Nigeria, Benin, and Cote d'Ivoire. However, in Cameroon and Ghana, the tapping process of palm wine entails felling or cutting down the tree (*Elaeis guinnesis*), leaving the tree for about two weeks, followed by tapping palm wine for up to 8 weeks. While for the palm tree species *Raphia hookeri* and *Borassus aethiopumserve*, the palm sap is obtained while the tree is still standing (Ayernor and Mathews, 1971). Palm wine samples collected within three hours of tapping had an alcoholic content of about 15%, with an average population of lactic acid bacteria of 10^5 to 10^9 CFU ml^{-1}. The following lactic acid bacteria are found in fermented palm wine *Lactobacillus plantarum*, *Lactobacillus johnsonii, Lactobacillus helveticus, Leuconostoc mesenteroides, Fructobacillus* and Gluconobacter (Amoa-Aqua et al., 2006, Theodore et al., 2020).

Also, sha'a or corn beer, commonly known in Cameroon by the name, is made from fermented maize. It contains LAB that contributes extensively to nutritional properties, food safety, shelf-life quality, promotion of plant growth, and organoleptic properties through producing organic acids, bacteriocins, and volatile compounds. These LAB present in sha'a include *Lactiplantibacillus plantarum, Limosilactobacillus fermentum*, *Levilactobacillus*, *Lactococcuslactis*, *Leuconostoc* species, and *Pedicoccus* specie, while the others include *Streptococcus* and *Corynebacterium* species. The population of Lactic Acid Bacteria in corn-beer ranges from 1.2×10^7 to 6.7×10^7 CFU/Ml (Bertrand et al., 2018).

The widespread use of LAB in food processing has generated much knowledge about their physiology and the bioactive compounds they produce (Gaisa et al., 2014). This usage has also resulted in the designation of LAB as generally considered safe and would pose no risks for soil fertility and plant nutrition applications. Thereby reducing the time and cost for regulatory approval (Lutz et al., 2012). Moreover, the scientific evidence makes a convincing case for using LAB to improve soil fertility and plant nutrition. This review explores LAB from palm wine and sha'a potential in soil fertility and plant nutrition.

Soil Fertility

It refers to the soil's ability to enhance plant growth by providing plant habitat resulting in sustained and consistently high-quality yields (Sturt et al., 2002). Fertile soil has the following properties:

- The capability to supply water in adequate amounts and proportions and nutrients to plants for their growth and reproduction,
- The absence of toxic chemicals may inhibit plant growth.

Plant Nutrition

Plant nutrition refers to the supply and utilization of nutrients for growth, reproduction, and plant metabolism (Housome et al., 2008). In the absence of one or more nutrients, the plant is unable to complete its life cycle. Seven essential plant nutrients are needed for plant metabolism (Rahimi; 2020). Their nutrients are:

1. Macronutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), sulfur (S), magnesium (Mg), carbon (C), oxygen (O), hydrogen (H)
2. Micronutrients (or trace minerals): iron (Fe), boron (B), chlorine (Cl), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), nickel (Ni)

Plants absorb these nutrients as mineral ions from air and water in the case of hydrogen, oxygen, and carbon or the soil as the rest of the nutrients (Kathpalia and Bhattla, 2018). Most soils around the world are capable of supplying mineral nutrients for their growth and development. However, due to the scarcity of land and the ever-growing population, there is a need to produce twice or thrice more food per unit area, thus needing artificial supplements to modify soil fertility and plant nutrition by adding fertilizers. Nonetheless, these artificial nutrient sources' continuous and unscrupulous use has devastating environmental effects. Thus, the search for holistic, sustainable avenues to remedy the situation while enhancing soil fertility and plant nutrition has been seriously undertaken. One such avenue is the use of natural plant growth-promoting microorganisms in which LAB has been tremendous in ameliorating the damaging effects of nutrients from artificial sources. However, isolation and utilization of LAB from different sources significantly impact LAB functionalities in soil fertility and plant nutrition, with palm wine or sha'a serving as an excellent source for isolating these potentially valuable microorganisms.

Lactic Acid Bacteria (LAB)

Overview of Lactic Acid Bacteria History and Isolation

The term lactic acid bacteria cover a large group of microorganisms. The first pure culture of the lactic acid bacterium was obtained in 1873. The similarity between milk-souring bacteria and other lactic acid-producing bacteria of other habitats was recognized in the early 1900s (Halima et al., 2020). The basis of the systematic classification of LAB was elaborated and published in 1919 by Orla-Jensen. Although revised to a considerable extent, the main characteristics of classification have remained unchanged. Lactic acid bacteria comprise a large and diverse group of non-spore-forming, non-motile, gram-positive cocci or rod shape bacteria capable of producing lactic acid as the primary end-product of the fermentation of carbohydrates (Tongwa et al., 2019). Based on metabolic pathways, LAB is classified as homofermentative or heterofermentative. In homofermentative LAB, they ferment sugars to produce chiefly lactic acid without oxygen. In heterofermentative LAB, sugars are fermented to produce ethanol, CO2, and less lactic acid (Goyeas et al., 2021). Lactic Acid Bacteria (LAB) are ubiquitous members of many plant microbiomes, but little is known about functional interactions between LAB and their hosts. Most strains of LAB grow at pH levels between 4.0 and 4.5, whereas others grow at pH 3.2 and 9.6. LAB uses three main pathways to produce fermented foods and develop their flavor, including the fermentation of sugars (glycolysis) and the breakdown of fat and proteins, lipolysis, and proteolysis (Mashau et al., 2021). LAB can be isolated from various sources like yogurt, fermented meat, compost, palm wine, soil, sha'a, and other fermented products.

Lactic Acid Bacteria from Palm Wine and Sha

Palm Wine

Palm wine is a global name for a group of alcoholic beverages produced from the sap of palm trees by natural fermentation. Various species of the Palmae family (Theodore et al., 2020), such as *raffia palm (Raphia hookeri), oil palm (Elaeis guineensis*), date palm (*Phoenix dactylifera*) coconut palm; Cocos nucifera and ron palm (*Borassus aethiopum*) are used for the production of palm wine in Africa. The most commonly consumed traditional alcoholic beverage in Western Africa is Palm wine (Mbuagbaw et al., 2012), with an estimated more than 10 million people consuming it. Palm wine is a cultural heritage, mainly used in traditional naming and marriage ceremonies, folk medicine, and traditional incantations. Palm wine is rich in vitamins and trace elements, traditionally believed to lactate women's general well-being (Lucky et al., 2017). Two methods are used to produce palm wine: non-destructive and destructive. Recent studies have shown that this product is rich in microorganisms, especially LAB (Eukainure et al., 2019). According to Theodore et al. (2020), the predominant bacterial phyla present in the three types of palm wine were Firmicutes (68.8%) and Proteobacteria (32.6%). The Firmicutes phylum was dominated m by Lactobacillaceae (46.6%) and Leuconostocaceae (15.9%), while the Proteobacteria phylum included Acetobacteraceae (27.8%), Sphingomonadaceae (1.4%) and Enterobacteriaceae (1.4%). The analysis showed that Lactobacilliaceae has the highest abundance in palm wine. At the genus/species level, *Lactobacillus plantarum*, *Lactobacillus johnsonii, Lactobacillus helveticus, Leuconostoc mesenteroides, Fructobacillus* and Gluconobacter are predominantly present in palm wine (Amoa-Aqua et al., 2006, Theodore et al., 2020).

Sha'a

A maize-based fermented beverage called "*Sha'a*" or "corn-beer" in Cameroon and "Ogi" in Nigeria is a traditional drink that is most popular and widely consumed in these countries. "Sha'a" is a sweet or low-alcoholic beverage that is viscous, effervescent, and whitish-grey to brown-colored. Due to its thick consistency, it is also considered food by consumers. In producing the drink, maize is soaked in water for about three days. After three days, it is removed and spread in a dark, cool, dry corner of a room for it to germinate (fermentation process), after which it is ground into flour. Later, the flour is mixed in water and sieved with a fine cloth to remove the chaff. After sieving, the liquid obtained is boiled and allowed to cool. It has been revealed that one of the predominant microorganisms present in the drink is Lactic acid bacteria (Aka et al., 2020). According to Piere et al. (2012), *Lactobacillus plantarum* (72%), *Lactobacillus rhamnosus* (8%), *Lactobacillus fermentum* (67%) and *Lactobacillus coprophilous* (33%) are present in sha'a based on phenotypic characteristics and rep-PCR fingerprinting. Also, other LABs present in sha'a include *Lactiplantibacillus plantarum, Limosilactobacillus fermentum, Levilactobacillus, Lactococcuslactis, Leuconostocand Pediococcus* species. The population of Lactic Acid Bacteria in sha'a or corn beer ranges from 1.2×10^7 to 6.7×10^7 CFU/Ml (Bertrand et al., 2018).

LAB as Bio Fertiliser

Biofertilizers are products containing a substance that contains different microorganisms which can break down organic waste into usable, beneficial soluble substances such as amino acids, sugars, alcohols, and hormones (Nurul et al., 2022). Despite the quick release of nutrients by chemical fertilizers, biofertilizers are more sustainable and enrich the soil, reducing water pollution (Bhardway et al., 2014). Additionally, applying a biofertilizer can help maintain the soil's natural habitat, protect the plant against soil-borne disease, and improve crop yields by up to 30% (Kumar et al., 2017, Brahmaprakas et al., 2013). From recent studies, the biofertilizer properties in LAB have been brought out.

Lactic acid bacteria have been used for decades in the agricultural system to improve soil fertility and plant nutrition. Lactic acid bacteria used as a biofertilizer increases nutrient use efficiency and opens new routes of nutrient acquisition by plants. Thus, microorganisms added to plants can have a dual role of biocontrol agent and biostimulant (Boraste et al., 2001). It has been discovered that the synergistic growth of LAB and photosynthetic bacteria makes it possible to be used as a biofertilizer which helps to promote the growth of photosynthetic bacteria (PB) and used in paddy field (Abdel-Ghany et al., 2013). LAB is very effective in improving air ventilation in soil and promotes the growth of fruit trees and leafy vegetables, which can be through the breaking down of organic matter, thereby making the soil more humus. Lactic acid has a strong bactericidal ability that can effectively inhibit the activity of harmful microorganisms through the production of secondary metabolites such as antibiotics (Halima et al., 2020). LAB has been shown to solubilize phosphate (Shrestha et al., 2014, Giass et al., 2012), likely through the production of organic acids. Moreover, it has been reported that some three-plant growth-promoting strains of Lactobacillus produced siderophores [32]. Compost inoculated with an effective microorganism (predominantly made of lactic acid bacteria) was shown to increase the nutrient uptake of crops and greater yield (John et al., 2017).

In addition, L. *acidophilus* has been found to produce cytokines, and some strains of Lactobacillus produce indole-3-acetic acid (IAA), which are examples of plant hormones that promote plant growth (Shrestha et al., 2014, Giass et al., 2012). It has shown that the applications of an EM product containing at least five Lactobacillus strains changed the morphology of *Lolium perenne* to make it less susceptible to mechanical damage associated with turf grass management (Gaggia et al., 2013). Moreover, Phoboo et al., 2016 investigated the effect of an EM containing *Lactobacillus plantarum* on the growth and development of cucumber. It was found that the microorganism turns to increased cucumber growth, nutrient uptake, and amino acid content.

Lactic Acid Bacteria as Environmental Stress Reducer

The environment has become more stressful for plant growth due to climate change and land degradation. Also, the growing population's increasing food, fiber, and energy demands will force farmers to marginal lands, which is even more stressful on food production globally. It has been proven that stress alleviation with LAB offers a low-input, low-environmental impact way to sustain food production in a more stressful environment.

LAB can improve the ability of plants to withstand stressful environments by protecting plants from abiotic stresses or by altering the stress response of the plant, which may be through the effect of the organic acid, or other secondary metabolites or exopolysaccharide they are producing, thus improving the survival of the entire phytomicrobiome (John et al., 2017). It was found that some clones of the medicinal plant (*Swertia chirayita)* that were inoculated with L. *plantarum* (ATCC 9019) were more resilient to salt (Phoboo et al., 2016). With increasing salt concentrations, treated plants had increased proline concentrations and decreased total phenolic concentrations. In contrast, untreated plants had consistently low proline concentrations and consistently high phenolic concentrations across salt concentrations. Most plants also had decreasing antioxidant activity with increasing salt concentrations except for guaiacol peroxidase, which increased with increased salt concentration. LAB alleviates stress by producing the following molecules: polyamines (putrescene, citrulline, and ornithine), NO, etc. According to (Henry et al 2012), Microbe-associated molecular patterns (MAMPs) are known to change plant response to abiotic and biotic stresses. Therefore, MAMPs associated with LAB is responsible for the increased resilience of plants treated with LAB.

Application

Lactic acid bacterial culture can be used with water in a ratio of 1:1000, mixed with plant substrate solution such as Fermented Plant Juice (Halima et al., 2020) and applied as a foliar specie spray to leaf surfaces or fruit crops and on the root zone of plants. LAB culture can also be used with either nutrient solution to treat the seed before planting, thereby improving seed germination, inoculating the seed with beneficial microbes, and deterring fungal problems, such as damping off (Hanssan et al., 2021) LAB is used with IMO (indigenous microorganisms) in natural farming in making composts for soil preparation before planting Applying LAB culture can accelerate the decomposition of organic amendments in soil and enhance the release of plant nutrients for absorption [16]

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State of art approaches, insights, and challenges for digital mapping of electrical conductivity as a dynamic soil property

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Abstract

Soil electrical conductivity (EC) as a measure of soil salt content is a good indicator of nutrient and water availability or excessiveness in soils, which in return affect the productivity of soils. Therefore, mapping the spatial distribution of EC under intense agricultural management is important for managing soil fertility (e.g., fertilization and soil salinity remediation). However, mapping soil EC with high accuracy and spatial resolution remains to be challenge among digital soil mappers due to being a highly dynamic soil property. In this study, random forest (RF) was applied to map soil EC in an agricultural plain around the lake Manyas in the northwestern Türkiye. Fifty soil samples and a unique set of environmental predictors (aka covariates) were used to build a predictive soil EC model. The covariates were produced from Sentinel-2 optical satellite images-based vegetation and salinity indices as well as produced from Sentinel-1 with different polarizations (i.e., VV and VH), and terrain attributes representing the topography at varying scales were produced. Twelve environmental variables were selected to be relevant to predicting soil EC after using a correlation-based feature selection procedure. Resulting model performance was evaluated by root-mean-square-error (RMSE) of 10-fold cross-validation (CV). RF predicted soil EC with an RMSE of 0.07 dS m^{-1}. Per each soil prediction in the final soil EC map, an uncertainty map was created using a sensitivity-based approach. The uncertainty map revealed the areas that were more difficult to accurately predict. Present study successfully mapped soil EC with acceptable error and can provide useful insights for managing soil fertility. In addition, an uncertainty map of soil EC can facilitate future soil sampling campaigns. For nearly a quarter of a century, while satellite-based remote sensing data has become the first choice for generating and updating soil survey information, in the near future, artificial intelligence techniques (e.g., ML) will be able to accompany soil surveyors in drawing map boundaries, especially in updating soil salinity phases.

Keywords: Digital soil mapping, random forest, soil electrical conductivity, dynamic soil property, uncertainty.

Introduction

Spatial modeling of soil dynamic properties in arable lands is essential for agricultural management and decision-making (Ning et al., 2022). However, digital maps created for dynamic soil properties with the sufficient accuracy and spatial resolution is particularly rare for the areas where there is intensive agriculture (Baltensweiler et al., 2021). On the other hand, rapid increase in the environmental datasets that could represent soil formation factors (Burke et al., 2021) has made it easier to map soil dynamic properties using digital soil mapping (DSM) framework (Flynn et al., 2022). DSM refers to the creation of soil maps based on the relationships between environmental datasets (aka covariates) and mesaured soil data using statistical learning algorithms (e.g., machine learning (ML)) (McBratney et al., 2003). In recent years, machine learning (ML) approach has been rapidly adopted in the prediction of soil properties (Hengl and MacMillan, 2019). Despite the succesful use examples of ML algorithms in mapping soil dynamic properties, large variations of soil EC and its highly dynamic nature at the field scale makes it difficult to predict soil EC accurately. This is typically due to its high dependence on agricultural activities as well as soil formation factors (Jenny, 1941). Current approaches to capture this variation have witnessed field-based studies specific to many different ML algorithms (Tomaz et al., 2020; Hateffard et al., 2022). Since EC is seen as a surrogate of soil salinity in the literature, studies are focused on predicting areas where salinity threats may develop. (Hopmans et al., 2021). This study aimed to digitally map the spatial distribution of soil EC using RF ML algorithm, using the environmental covariates satellite imagery products and digital terrain attributes derived from a digital elevation model (DEM) with varying analyis scales. An associated uncertainty map was also created to improve credibility of resultant soil EC map.

Material and Methods

Study area, sampling, and analyses

The study field was located around the lake Manyas and covered an undulating area of 59 928 ha (N35 Zone UTM, 570000-595000 East, 4440000-4460000 North). The climatic conditions are characterized by an average annual temperature of 15°C and annual precipitation of about 700 mm (TSMS, 2022). The current area is rainfed marginal lands in the north of the study area in Vertisols, and essential and marginal irrigated complex agricultural areas in the south and west, according to field surveys. Fifty soil samples according to the stratified random sampling method at a depth of 30 cm were taken from the research area between June and August of 2019. The soil samples were air-dried at a room temperature of 24°C without a direct exposure to sunlight, ground, and then sieved with a 2 mm sieve. The processed samples were mixed with water to make a soil solution (the ratio of soil to water is 1:5) according to FAO (2021). After the solution was shaken for 1 hour (180 osc./min), EC (1:5 w/v, dS m^{-1}) of soil samples was measured by a conductivity meter (Orion Star A112; Thermo Fisher Scientific). Duplicate analysis was performed on randomly selected 20 % of all samples in a test group. Relative Percent Difference (RPD) was calculated to determine whether the precision of duplicate analyzes was within specification. In many cases, RPDs of replicate pairs were less than 5%. Average RPD for the replicates was 5.66%, which was below the standard rule of 20% determined by FAO (2021).

Environmental covariates

In this study, nineteen environmental variables was used to model soil EC. The variables were from the European Space Agency's (ESA) Sentinel-2A satellites (ESA, 2015) (and corresponding spectral indices), ESA's Sentinel-1 Synthetic Aperture Radar (SAR), and digital terrain attributes (DTAs) created by using the digital elevation model (DEM) from Shuttle Radar Topography Mission (SRTM). DEM and satellite imagery products were downloaded using google earth engine (GEE). These imagery products were useful to represent soil formation factors that could be influential in the spatial distribution of soil EC in our study area (Jenny, 1941). Sentinel-2A imagery represented organisms through providing information about the conditions of vegetation. Sentinel-1 SAR imagery in both VV and VH polarizations was obtained as the average of the relevant month of the year of the sampling date within the boundaries of the study area to indirectly represent climate through providing information about soil moisture (ESA, 2012). Soil EC is especially known to be affected by soil moisture (Taghadosi et al., 2019).

Varying analysis scales (i.e., 130 m to 1010 m) were used to calculate the DTAs based on the pixel values of DEMs using the r.param.scale function in GRASS GIS 7.6.1 (Geographic Resources Analysis Support System, available online: grass.osgeo.org, accessed on 3 July 2022). As land-surface derivatives are dependent on the scale for calculation (Roecker and Thompson, 2010), different analysis scales may result in different outcomes. The use of DTAs with varying analysis scales as potential environmental predictors is useful because different analysis scales may be more appropriate for representing various phenomena (Miller et al., 2015) (Table 1). Since all covariates were obtained from different sources and have the different spatial resolutions, all covariates were aligned to the same grid cell resolution (10 m) and extent before constructing the data matrix. Complete list of environmental covaraites used in this study can be found in Table 1.

Table 1. The specifications of used covariates derived by DEM and remote sensing imageries in this study.

Environmental covariates			
Digital Terrain Attributes		**Produced via program**	
Elevation (m) Slope (%) Aspect (°) Topographic wetness index		SAGA 8.4.0 (Conrad et al., 2015)	
Longitudinal Curvature Cross-sectional curvature		GRASS GIS 7.8.7 (GRASS Development Team, 2022)	
Remote Sensing (RS) (Sentinel-2A) Optical Based (Accessed to three satellite image close to the sampling date in 2019)			
Vegetation-soil based indices	Equations (Brown et al., 2017; Mponela et al., 2020)	Salinity indices	Equations (Avdan et al., 2022)
GRVI	$\frac{(Green-Red)}{(Green+Red)}$ [1]	SI 1	$\sqrt{Blue \times Red}$ [6]
SatInd	$\frac{(Red-Blue)}{(Red+Blue)}$ [2]	SI 2	$\sqrt{Green \times Red}$ [7]
NDVI	$\frac{(Near\ Infrared-Red)}{(Near\ Infrared+Red)}$ [3]	SI 3	$\frac{(Blue-Red)}{(Blue+Red)}$ [8]
CI	$\frac{(Red-Green)}{(Red+Green)}$ [4]	SI 4	$\frac{Green \times Red}{Blue}$ [9]
GNDVI	$\frac{(Near\ Infrared-Green)}{(Near\ Infrared+Green)}$ [5]	SI 5	$\frac{Blue \times Red}{Green}$ [10]
		SI 6	$\frac{Near\ Infrared \times Red}{Green}$ [11]
Remote Sensing (RS) (Sentinel-1 SAR) synthetic aperture RADAR Based			
VV-Vertical transmit, Vertical receive polarisation VH- Vertical transmit, Horizontal receive polarisation			

Abbreviations: GRVI: Green-Red vegetation index, SatInd: Saturation index, NDVI: Normalized difference vegetation index, CI: Coloration Index, GDVI: Green Normalized Difference Vegetation Index, SI: Salinity Index. With GRASS GIS, magnitude of maximum gradient was taken as the calculation basis for slope, aspect, cross-sectional curvature.

A trial-error based feature selection (FS) process was carried out to overcome the multi-collinearity and curse of dimensionality issues (Ferhatoglu and Miller, 2022). Correlated covariates were removed by using Pearson's r of 0.8 while keeping only one of the correlated covariates. The final selection of environmental covariates determined was 12 variables.

Modelling and creation of digital maps

Overall workflow of this study is shown in Figure 1. RF-based regression analysis was used to model and map the spatial distribution of soil EC. The RF algorithm is known to be advantegous because input data to be used in RF algorithm does not make assumption about the normality of the input data (Velázquez et al., 2022). Thus, the original data was directly used in the modeling. In addition, RF algorihtm has been succesfully applied in the prediction of dynamic soil properties (Kaya and Basayigit, 2022).

Using the *randomForest* (Liaw and Wiener, 2002) function in the R Core Environment (R version 3.6.1) (R Core Team 2022) and RStudio IDE (RStudio 2022), the EC of the surface soil in the study area was estimated using a laboratory soil analysis set and environmental covariates. Multiple models were created by the process of 10-fold CV. The average outcomes of these models were used to create the final soil EC map, using the "mean" base function in randomForest function. As error metrics in creation of decision trees by RF algorithm, %IncMSE and IncNodePurity metrics were used. %IncMSE was calculated for each tree with and without the relevant predictors, the mean value of the differences being normalized to the standard deviation of the differences. IncNodePurity represented the average overall trees of the total reduction in node impurity from splitting among a predictor in the tree-building process.

Assessment of model performance and uncertainty measurement

RF algorithm with 10-fold CV was used to create uncertainty map for soil EC, splitting all samples into calibration (75% of all samples) and validation (25% of all samples) sets during each of ten iterations. In each iteration, a model-building and prediction process is carried out in such a way that the distribution of the predicted values at the pixel level represents the uncertainty and the sensitivity of the model to changes in the current dataset (Yigini et al., 2018). Coefficient of determination (R^2), Root mean square error (RMSE) is obtained for each iteration. The standard deviation (sd) of all ten predictions allowed the model sensitivity to be mapped, using the limited available sample set used this study.

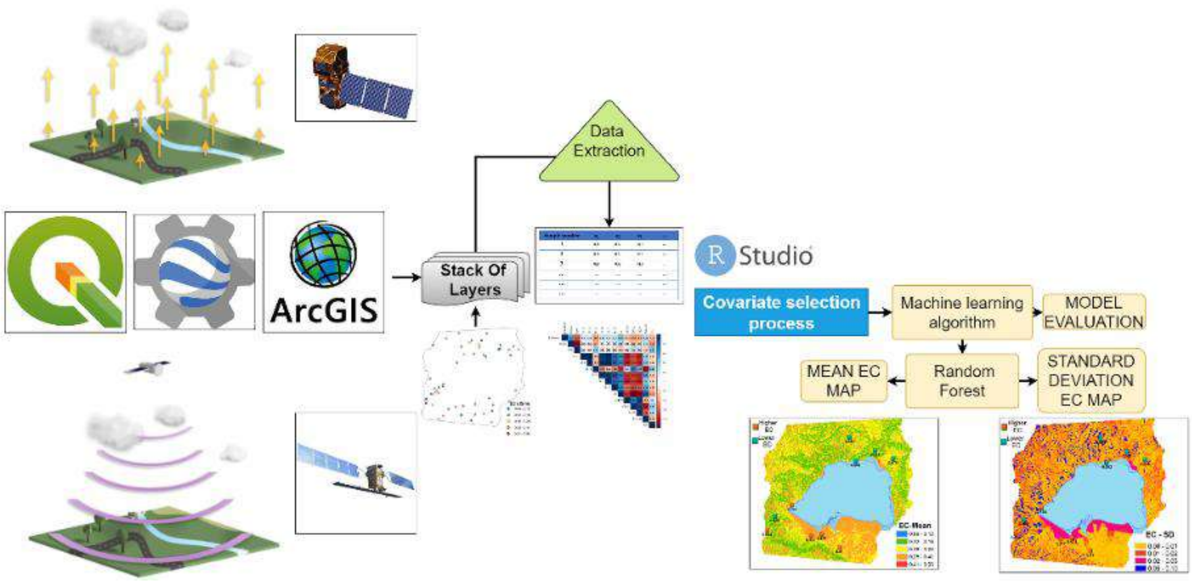

Figure 1. Overall workflow in this study to map soil EC.

Results and Discussion

Descriptive statistics of soil data

Soils of the study area were slightly or non-saline with a mean of 0.2 dS m^{-1} (Table 2) according to the criterion determined in Omuto et al. (2020). Soil EC values of the study area indicate that long-term land use could affect soil EC (Figure 2-c). Exceptionally, high EC values in the study area (Figure 2-b) were found in the soils that in the marginal irrigated lands. These areas were also used for intensive agriculture. Therefore, the surface EC, which is a dynamic soil property, can show high variability over short distances with intensive organic or chemical fertilization in marginal irrigated lands. To quantify the correlations between soil EC and environmental covariates, Spearman's correlation values were calculated (Figure 2-a). While there was a negative correlation between EC and Elevation in our study area ($r = -0.32$, $p<0.05$), EC showed a positive correlation with TWI ($r = 0.43$, $p<0.05$). There was a positive correlation between vegetation-based indices and EC (GNDVI r=0.20, GRVI r=0.39, $p<0.05$). Negative correlations were detected between salinity indices and EC values, ranging from r=-0.21 to r=-0.25 ($p<0.05$). Positive (r=0.27, $p<0.05$) relationships were determined between S1VV and EC in SAR data and these findings are compatible with literature (Triphati and Tiwari 2021) (Figure 2).

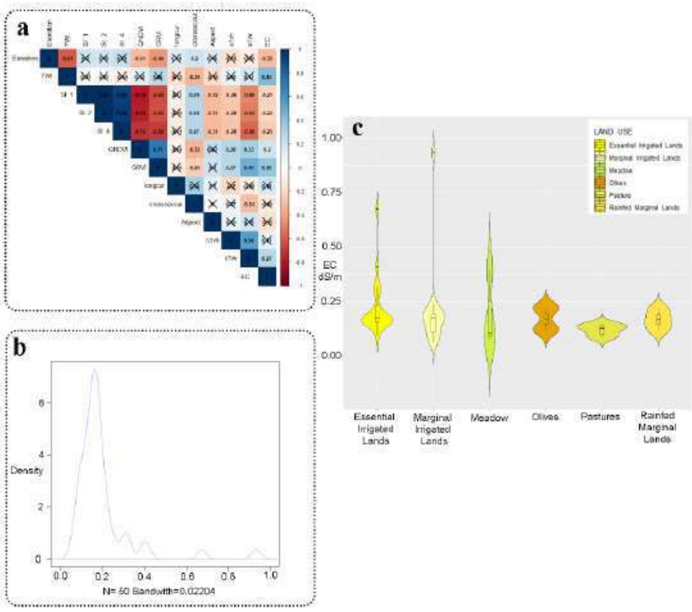

Figure 2. The statistical descriptive statistics of used field observations across the study area. a) correlation graph- Spearman correlation coefficient values of the dependent variable (EC) with predictive environmental variables ($p < 0.05$), b) Density plot of the dependent variable (EC), c) Violin graph- Comparison of EC values of soil samples according to land uses.

Table 2. Descriptive statistics of soil EC based on all samples (50).

	Mean	SD	CV	Minimum	Median	Maximum	Skewness	Kurtosis
Soil EC (dS m^{-1})	0.20	0.15	73.85	0.06	0.17	0.93	3.40	13.94

Abbreviations: SD: Standard deviation, CV: Coefficient of Variation (%).

Performance of spatial predictions and quantified uncertainties

RF algorithm allowed us to identify the relationships between soil EC and selected environmental covariates and leverage these relationships to create a soil EC map. Modeling and mapping were executed using R-studio (version: 2022.07.2). The model performance criteria in the data set used at the end of the modelling process carried out in 10 iterations for this study are presented in Table 3. As a result of the modeling, prediction accuracy of soil EC was determined to be acceptable with an average RMSE of 0.07-0.08 dS m^{-1} CV performance.

Table 3. The performance of the RF model for estimating soil EC across the study area based on R^2 and RMSE of a 10-fold CV. Variation among the performance based on the created models from different folds were presented by minumum, median, mean, and maximum values.

			10-fold Cross-validation results			
			Used random samples of 75%		Used random samples of 25%	
Soil property		Model	R^2	RMSE dS m^{-1}	R^2	RMSE dS m^{-1}
EC	RF	Minimum	0.50	0.03	0.79	0.06
		Median	0.85	0.05	0.88	0.08
		Mean	0.81	0.07	0.88	0.08
		Maximum	0.94	0.11	0.91	0.09

Evaluating with soil surveyor's insight how to evaluate maps beyond point estimation is an important contribution to the advancement of soil mapping as a science.In this regard, some of the important observations in our data were as follows: 1) Across the study area, areas with high soil EC values were very limited (Figure 3-B). To allow the qualitative evaluation of the soil surveyor, spatial maps were presented by zooming in on the points with higher and lower soil EC values using a geographical information system (GIS) (Figure 3-A, C). Land use images at the time of soil samples were also referenced for qualitative assessment (Figure 3-D-E). As a result of zooming in on the point with the highest EC value among all samples, it was observed that the high soil EC values in the surrounding pixels were detected by the RF algorithm (Figure 3-A). Considering the land use image of this area supported the judgement of the areas around this soil sample (with high soil EC) as the areas with intensive agriculture. In the areas with intensive agriculture, to use detailed land use data as input to the models for the prediction of a dynamic soil property is recommended.

An approach specific to the current study is demonstrated to estimate the sensitivity of the model to available data (spatial pattern of environmental variables) and the uncertainty of the ML models (Figure 5-B). Lands with complex soil formation, such as our study area, which was characterized by large plains, are often characterized by strong multifactorial interactions, non-linearity, and non-stationarity in data relationships. This makes it challenging to predict soil dynamic properties easily due to highly dynamic nature of soils in such lands. Despite that, the RF algorithm produced reasonable estimates for the mean soil EC maps (Figure 3-B) within the areas that had relatively low and high soil EC values. However, the uncertainty map (Figure 5-B) usually showed large standard deviation values for such areas. This indicated that current selection of environmental covariates or the quantity of soil samples were insufficient to reliably map the spatial variation of soil EC in those portions of the study area.

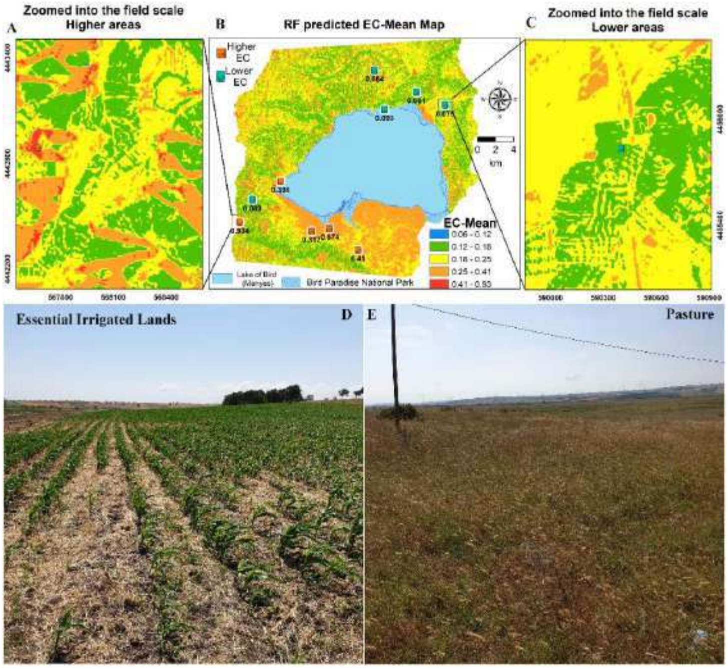

Figure 3. Mean maps of the predicted soil EC (dS m^{-1}) derived from ten times random forest (RF) models (B). (A) Zoomed in on higher areas and (C) zoomed in on lower areas. Fotographs were taken from different areas of the study area in July 2019 (D-E). Photo credit: Fuat KAYA, 2019-July, Manyas, Balıkesir, Türkiye.

To provide information about the reliability of soil EC predictions, it is suggested that the areas with high standard deviation values need to be emphasized. Many other scientists also pointed out the importance of uncertainity maps when mapping soil dynamic properties for local areas with high soil heterogeneity or small sample sizes (Liu et al., 2022). As decision-makers often prefer to define the areas with sharp boundaries (such as the topsoil salinity phase in soil survey), the presentation and use of uncertainty maps are highly needed for improving the decision-making process (Arrouays et al., 2020).

Relative importance of environmental variables

Relative importance of the covariates in modeling was assessed according to RF's %IncMSE and IncNodePurity metrics (Figure 4). Topographic covariates such as elevation and TWI were identified as the most important variables in the estimation of soil EC. The covariate Aspect had the highest level of IncNodePurity value, which meant that Aspect was the least useful predictor in mapping soil EC in our study. Interestingly, the areas with extreme Aspect values in the study area matched the areas with the highest standard deviation or uncertainty (Figure 5-B).

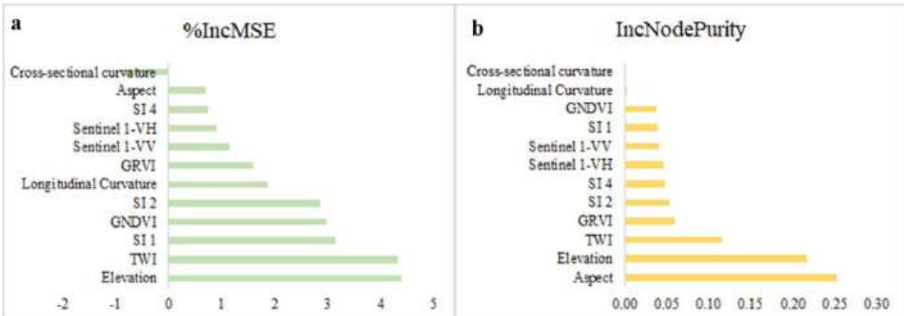

Figure 4. Relative importance by RF algorithm for the covariates to predict soil EC: a) %IncMSE, b) IncNodePurity.

Lower light intensity, evaporation, air and soil temperatures were usually observed on shaded hillsides. The change between soil freezing and thawing was also less frequent on shady hillsides relative to the sunny sides. As a result, soils on shaded hillsides exhibited stronger and deeper water penetration than those on generally more sunny hillsides. However, the dissociation intensity was lower on colder shaded hillsides. Similar results were also found in other studies (Blume et al. 2016). The current study area exhibited an undulating formation. The difference in the numerical values of the "aspect" variable in the" undulating" physiographic structure in our study area may be effective in the natural change of the EC value. However, covariates related to farming history (e.g., tillage, fertilization, cropping system) can be useful to be included in modeling that were not present in our study.

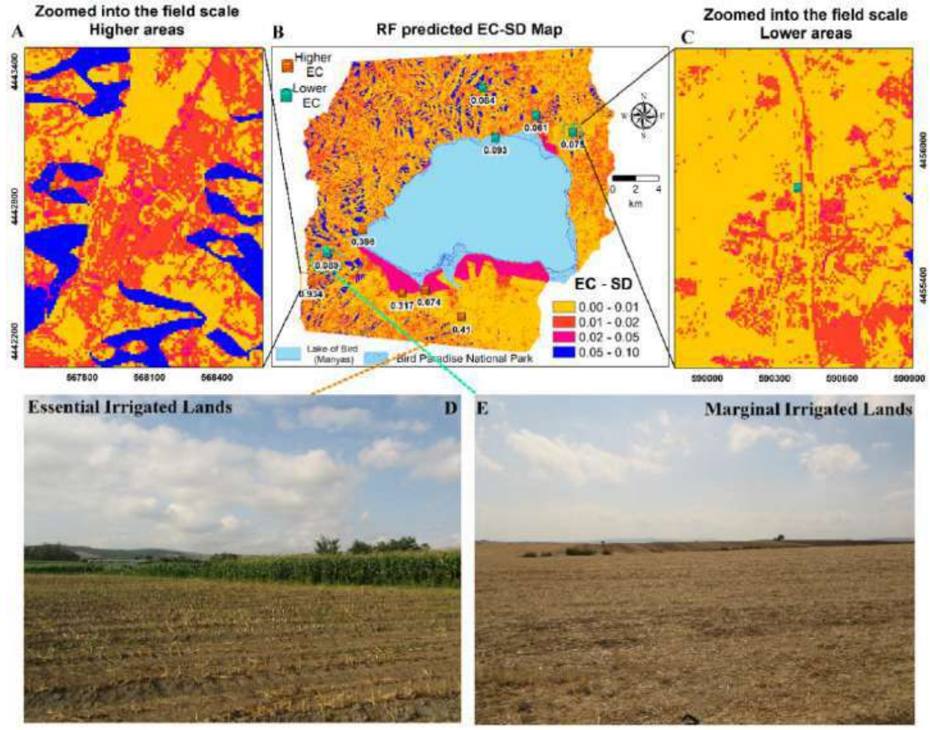

Figure 5. (B) Uncertainty maps by standard deviation of the predicted soil EC (dS m^{-1}) derived from running RF algorithm ten times with CV. (A) Zoomed in on higher areas and (C) zoomed in on lower areas. (D&E) The fotographs were taken from different locations within the study area in July 2019 using a digital camera. Photo credit: Fuat KAYA, 2019-July, Manyas, Balıkesir, Türkiye.

Conclusion

Soil EC is one of the dynamic soil properties. It should always be determined in the most up-to-date form. EC data can be obtained from soil maps that are not up-to-date and be produced with coarse-resolution conventional approaches.In this study, there is the production of a digital soil EC map based on soil analysis with 50 samples.The process was performed by integrating the RF algorithm and a detailed digital surrogate of soil formation factor in a high-performance computational environment with adaptive quantification of the predictive soil mapping paradigm over a large area with complex soil dynamics.In the study, the associated uncertainty map for soil EC predictions was successfully generated.Spatial information about soil EC created in this study can provide remarkable insights into decision-making processes aligning with the increasing need for soil information for sustainable development goals in the future.The approach proposed in the study may be an opportunity for the production of the salinity phase in detailed soil maps. In addition, associated uncertainty fields can show priority points in the selection of soil samples for salinity.

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Soil organic carbon stock in post-mine sites after reclamation with various tree species: A review

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Abstract

Mining is a major cause of damage to surface morphology and soil structure of lands. Indeed, mining activities damage the natural ecosystem in numerous ways, e.g. by distorting the landscapes, discharging massive quantities of hazardous tailings and depositing pollutants in the atmosphere and water bodies. Thus, resulting in considerable detrimental influence on the quality of the air, water and soil, along with the loss of biodiversity. The restoration of vegetation at post-mining areas is an efficient approach of conserving soil, water and environment. Many restoration methods using several vegetation types have been executed to tackle this concern. In the current article, we analyzed numerous research studies concentrating on the influence of mine site reclamation on soil organic carbon (SOC) accumulation. We also analyzed the influence of various tree species such as, common Birch (*Betula pendula Roth*), European Larch (*Larix decidua Mill.*), Black alder (*Alnus glutinosa*) and Scots Pine (*Pinus sylvestris L.*) on SOC in reclaimed mine sites (RMS). Consequently, the SOC in RMS was prominently increased as a result of several restoration techniques. Several factors e.g. the age of restoration, tree species and type of vegetation, and the reclamation type or substrate used, were some of the factors which significantly influenced the SOC in RMS. Furthermore, the Cstock levels proved to be higher in the litter horizons of Pine trees while in mineral horizons, the Cstock levels were high in that of Alder trees. The most efficient reclamation techniques were regarding, NPK fertilization and liming. The amount of SOC accumulation in restored mining sites was observed to be improved from 0.37 - 5.68 Mg/ha/yr. Thus, the suitable reclamation techniques, restoration age, appropriate tree species selection and the type of vegetation are the core components of high SOC accumulation rate in soil.

Keywords: Organic carbon stock, post-mines, reclamation techniques, tree species.

Introduction

Anthropogenic activities like mining have degraded the entire ecosystem as well as disrupted the earth's surface on a huge scale (Johnson et al., 2017; Bell and Donnelly, 2006). Moreover, frequently occurring extreme climatic conditions such as subsequent fire and drought, as a result of climate change, have altered landscapes and entire forest ecosystems (Seidl et al., 2017).

The succession process starts when an ecosystem undergoes significant changes brought on by anthropogenic (such as mining) and natural (such as fire) activities. (Auclerc et al., 2019; Frouz et al., 2007). The re-assembly of biological communities after anthropogenic and natural environmental disturbances is referred to as ecological succession (Chang and Turner, 2019). The primary succession process results in soil formation on freshly exposed substrates of soil at post-mining sites. (Uzarowicz et al., 2020; Macdonald et al., 2015). Extensive wildfires with secondary succession can result in the restoration of soil properties (Weng et al., 2021; Knelman et al., 2015). Both in post-mining and in post-fire situations, the long-term succession process is sped up by human interventions through rehabilitation and afforestation using a variety of tree species (Zhang et al., 2008; Pietrzykowski, 2008).

The appropriate tree species selection aimed at reforestation has an impact on the biodiversity, biological activity, and soil regeneration processes (Šnajdr et al., 2013; Pietrzykowski, 2019). Soil properties are affected mostly by the type of vegetation and tree species. The closures of their canopy govern the quantity of light which reaches the forest floor, hence affecting microclimatic environments (Joly et al., 2017; Barbier et al., 2008). Trees affect carbon, nutrients income and outcome and the pace of nutrients cycling through their litter fall, root activity, and root exudates (Angst et al., 2019).

Leading tree species in Central Europe like European Larch (*Larix decidua* Mill.), Scots Pine (*Pinus sylvestris* L.) and Common Birch (*Betula pendula* Roth) are frequently grown for the reclamation of post-mine and post-fireplaces (Kaczmarek and Bojarski, 2018). They have also emerged to be the first throughout natural secondary succession in forest sites that have experienced fire or any other disturbance (Dzwonko et al., 2015; Ellenberg, 2009). These tree species are well suited to soils with low fertility, have a large ecological amplitude and require a significant amount of light. Moreover, these tree species are fiercely combative with weeds because of their quick growth at their young age (Ellenberg, 2009). Organic carbon accumulation and the availability of other nutrients (particularly N) in soil, are significantly influenced by tree species (Vesterdal et al., 2008; Hobbie et al., 2007). Common Birch and Scots Pine remains the two species which are frequently grown in the afforestation of European degraded lands (Pietrzykowski, 2019) and are preferred because they can withstand nutrient deficient soils (Pietrzykowski et al., 2013; Kuznetsova et al., 2011). These tree species can also be found in the succession phases at both post-mine and post fire sites (Mudr´ak et al., 2016; Pietrzykowski and Krzaklewski, 2007).

Soil Organic Carbon (SOC) in forest is one of the leading dynamic terrestrial C pools. Soils are naturally dynamic, the amount of carbon contained in forest soil and its distribution along depths is greatly influenced by climatic changes and its management (Nave et al., 2019). Numerous sandy soils are being used for agriculture, although their fertility is frequently low and are primarily reliant on the amount of soil organic carbon available. Around 900 million ha of land is composed of sandy soils globally, mostly in arid and semi-arid areas (Jenifer et al., 2019). The ultimate objectives of post-mine site reclamation are; soil reconstruction, topsoil restoration and improvement of nutrient and organic matter content in the soil for the process of revegetation (Ahirwal and Maiti, 2017). Organic supplements like compost and sewage sludge are frequently used to enhance phytoremediation of post mining sites (Grobelak et al., 2017). Consequently, post-mine site reclamation results in the increase of SOC accumulation even more than that in the natural succession process in those regions (Placek et al., 2018). This review article aims to bring together the existing knowledge of organic carbon stock in restored mining sites (RMS) using diverse tree species such as Pine, Birch, Alder and Larch.

Factors Affecting SOC in Reclaimed Mining Sites

The Influence of Age of Restoration on SOC

SOC is frequently accumulated as a result of the restoration of mining sites, but the rate at which it occurs may vary depending on numerous factors, together with the method of reclamation, the age of the restoration, climate, moisture content in the soil and the vegetation (Ahirwal et al., 2017; Bandyopadhyay et al., 2020; Pietrzykowski et al., 2013). Macdonald et al. (2015) and Bandyopadhyay et al. (2020) concluded in their analysis of a reclaimed mine site that the carbon stock level increases with the age of restoration (Table 1), nonetheless which relies on the type of vegetation. For instance, for deciduous vegetation, the growth of SOC with age touches its maximum in the first 10 years, then subsequently increases with a slow pace, meanwhile in case of coniferous vegetation, the accumulation of SOC with age increases gradually up to 40 years (Vindušková and Frouz, 2013). Likewise, Sperow (2006) revealed that over the first 11 years for pastures and the first 13 years for forest, the annual average rate of SOC accumulation increases more rapidly and then reduces in the next 20 years. Certain tree species, shrubs and grasses grow more readily with the increase in age of restoration, as a result; their roots, twigs and litterfall aid in the organic matter content that also acts as a base for soil formation at post-mine sites (Filcheva et al., 2000).

According to Ahirwal and Maiti (2018), the amount of SOC accumulation during afforestation with tree species ranged from 1.2 to 2.8 Mg SOC/ha/year. Similarly, the annual SOC varied from around 0.32 Mg/ha to 5.0 Mg/ha, as specified in table 1 (Frouz et al., 2009; Vindušková and Frouz, 2013; Ahirwal and Maiti, 2017), the computed average annual increase was 1.84 Mg/ha and the variability of the annual increase might be altered by climate, reclamation techniques and the tree species (Ahirwal et al., 2017; Akala and Lal, 2001;

Parajuli and Duffy, 2013). Correspondingly, Pietrzykowski and Krzaklewski (2010) also claimed that the mined soil in Poland had SOC buildup at a rate of around 1.5 Mg C/ha/year.

Tree Species	Plantation age	SOC Stock (Mg ha^{-1})	SOC Accumulation Rate (Mg ha^{-1} $Year^{-1}$)	Reclamation methods	References
Mixed Forest	5	9.11	1.82	Topsoil with mixed forest	(Bandyopadhyay et al., 2020)
	10	19.89	1.99		
	25	41.37	1.65		
Quercus liaotungensis	11	32.59	1.59	Leveling and top soiling	(Yan et al., 2020)
Pinus tabuliformis		16.04	0.37		
Mixed *Acacia auriculiformis, Sennasiamea, Acacia catechu* and *Dalbergia sissoo*	3	1.83	0.61	Regrading of spoil materials and plantation of tree species	(Ahirwal et al., 2018)
	7	3.65	0.52		
	10	5.82	0.58		
	15	7.60	0.51		
Mixed Forest	2	5.4	2.70	Only backfilled dumps	(Ahirwal and Maiti, 2017)
	8	16.4	2.05		
	14	26.4	1.89		
Scots pines and giant miscanthus plants.	n/a	33	n/a	Sewage sludge	(Placek-Lapaja et al., 2019)
		45	n/a	Compost	
Scots pines	25	27.2	1.1	Liming and NPK fertilizers	(Greinert et al., 2018)
		37.4	1.50	NPK fertilizers	
	30	34.4	1.15		
	8	45.4	5.68	Regrading and top soiling	(Ahirwal et al., 2017)

Influence of Tree Species and Vegetation Types on SOC Accumulation

Woś et al. (2022) highlighted a relationship between $C_{stock\ (total)}$ level (Litter, 0-5 cm and litter+0-5 cm) with tree species at the post-mining areas. Their results were in line with those of Hüblov'a and Frouz (2021), who found that at an early stage of development in young soil (such as post-mine areas), the tree species have a stronger influence over the $C_{stock\ (total)}$ than that in matured soil (such as forest and post-agricultural sites). At the post mining sites, the soils under alder and pine showed to have a high amount of $C_{stock\ (total)}$ (9.96 and 14.43 Mg/ha respectively) than that of the birch (6.37 Mg/ha). In the case of Alder tree soil, it was due to the availability of high amount of C_{stock} in the upper horizons of soil (0-5 cm).

According to Ahirwal and Maiti (2018), the increase in soil organic C content was because of the accumulation of litterfall as well as its gradual degradation into humus. *Quercus liaotungensis* was recommended by Yan et al. (2020) for the recovery of damaged mined areas in China due to its much greater organic C sequestration rate (1.59 t/ha/year) compared to *Pinus tabuliformis* and *Rhus typhina*. In the post-mine areas of Czech Republic, Frouz et al. (2009) also found statistically significant differences in SOC accumulation levels for several tree species, ranged from 0.15 – 1.28 t/ha/year.

Vegetation has a great impact on soil respiration as it influences the microclimate and structure of the soil, the amount and quality of detritus added to the soil and thus the total rate of root respiration (Schwenke et al., 2000). In a mixed forest in north India, Tewary et al. (1982) observed that the rates of soil respiration were lower under the coniferous tree species than that of the trees having broad leaves. Pietrzykowski (2019) also emphasized the significance of carefully selecting the tree species in case of afforestation in post-mining sites, in order to speed up the development of high-tech soil substrates. Thus, choosing the proper tree species is of utmost importance for SOC enhancement in RMS because of the adverse mining spoil features, including large rock fragmentation (60-80%), low pH values, high bulk density (BD), low water holding capacity (WHC), low nutrient contents as well as poor microbial activities (Ahirwal and Maiti, 2017; Józefowska et al., 2017). Similarly, the addition of organic matter from various tree species enhanced positively the N, C and P levels, WHC, BD and pH in RMS (Mukhopadhyaya et al., 2014; Adeli, 2018). Izquierdo et al. (2005) observed a decline in bulk density after growing the trees in the degraded mining locations. The soil becomes loosen as a result of soil organic carbon, helping the roots to grow and develop, consequently decreases the bulk density (Akala and Lal, 2001). All of these advances promote the development of a variety of plants, soil and hence enhances carbon stock in reclaimed mining sites.

The Influence of Reclamation Treatments over SOC Accumulation

The recovery of damaged mining sites enhances the easy growth of vegetation, improving the chemical and physical characteristics of the soil substrate and consequently raising the SOC content. Topsoil application, backfilling and regrading are the three types of mining site rehabilitation techniques that are most frequently used (Ahirwal et al., 2018; Bandyopadhyay et al., 2020; Ahirwal and Maiti, 2017). Similarly, topsoil application having the mixture of seeds of annual short survival species (Van Rooyen et al., 2013) levelling of the surface, hydro seeding (Avera et al., 2015), applying mineral fertilizer with NPK, liming and introducing green manure (Pietrzykowski and Krzaklewski, 2010; Pietrzykowski et al., 2017) are some of the other reclamation techniques being followed. In a five-year-old rehabilitated coal mine site, 9.03 Mg C/ha stock was found, which was five times greater than that found in an unreclaimed mining site, this was because the mine site was reclaimed through the topsoil addition and the scattering of a mix of grass seedlings prior to the afforestation of fast-growing trees (Ahirwal and Maiti, 2018). Similar findings were found by Cková et al. (2018), who discovered that restored grassland with topsoil had a high capacity for carbon sequestration (calculated up to 1.6 Mg/ha/year). Topsoil application thus improves the environment for the development of soil organic matter.

Moreover, Pietrzykowski et al. (2017) suggested 1-year cropping of lupine green manure for mined soil reclamation earlier to vegetation because it contributed to around 13.55 Mg/ha SOC in comparison with the 2 years lupine cultivation (9.5 Mg/ha), 1 year fallow and 2 years lupine cultivation (10.23 Mg/ha) and 2 years fallow and lupine cultivation (8.4 Mg/ha). Even though, with the same applied reclamation techniques, the parental material also influences the accumulation of SOC. Therefore, adopting any of the reclamation techniques, improves the colonization of microbes as well as the early development of vegetation, both of which aid in the accumulation of SOC in RMS.

Conclusion

Considering the susceptibility and complication of mining sites, their reclamation requires scientific research on a global scale. Restored mining sites provide significant ecosystem services, with carbon sequestration being considered to be the most significant. These ecological functions are pivotal for aiding in adaptability of the environment to climate change. The physicochemical characteristics of mine soil are drastically altered as a result of issues related to mining, like compaction, removal of topsoil, pollution and organic matter elimination. Scientific studies have concluded that upon mining sites restoration, SOC sequestration consequently increases. After reviewing numerous research articles, we concluded that the amount of soil organic carbon accumulation in restored mining sites is largely influenced by the age of restoration, the kind of tree species and vegetation used in restoration process, the type of reclamation treatment, climate and moisture. Thus, these factors should be given more importance when aiming to reclaim a post-mine site in order to get high SOC accumulation. To do so, it requires detailed interpretation of the substrate type and the climatic factors to be kept in mind for effective accumulation of SOC in post-mining sites.

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Comparison of physical soil quality of surface and subsurface soils affected by long-term cultivation based on SOC stock

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Abstract

The aim of this study is to determine some relationship between surface and subsurface physical soil qualities (soil compaction, crust formation and K-erodibility of subsurface soils) affected by long-term continuous cultivation in terms of soil organic carbon (SOC) content. In this current study, it was investigated six different soils formed under in "mesic" temperature and "xeric" moisture regime soil environmental conditions. The results of the study showed that soil compaction, crust formation, erodibility K are very important ($P < 0.001$) for organic carbon (OC), organic carbon stock, and organic matter (OM). The research also determined that the study area generally has silt texture, neutral pH, high amount of $CaCO_3$, high amount of OC and OM, medium level in the upper layer and the lower layer. No significant differences were detected between soil properties in the surface and subsurface soil layers.

Keywords: Soil Organic Carbon, Compaction, Crusting formation, Erodibility K-value.

Introduction

Soil is the main terrestrial pool of soil organic carbon (SOC) due to its carbon storage potential, which is usually greater than vegetation (Post ve Kwon, 2000). Recently, with increasing CO2 concentrations in the atmosphere and increasing global warming, the importance of soil organic carbon in the carbon cycle has become increasingly recognized (Rumpel et al., 2020). The topic of soils organic carbon is being investigated in the scientific community, not only for its import for global warming, but also for its impact on soil quality and sustainable food production. Soil organic carbon (SOC) is one of the most important natural resources, which is extremely important for ensuring soil quality. In addition, one of the non-renewable natural resources that all living things need is soil (Schoonover & Crim, 2015).

It shows that soil types and land use systems and vegetation have a significant impact on soil organic carbon in soils. In addition, the system of cultivated land to other land use and land cover lower amounts of organic carbon, having to reverse the situation, crop rotation, the addition of organic matter such as ruins that are in need of sustainable product systems and product reveals. Therefore, one of the most important questions for scientists at the moment is to finally find effective ways on how to increase the SOC in the soil and stop the reduction of CO2 emissions into the atmosphere. SOC is also an important factor for soil quality. Compared to water quality and air quality, soil quality is much more complicated (Bünemann et al., 2018). The easiest definition of defining soil quality is "the capacity of the soil to function". It should include three main elements: soil quality, sustainable biological productivity, plant and animal health, and environmental quality. All of these three parts must function decently and be balanced between each other (Karlen et al., 1997).

The main purpose of the current research is to determine the relationship between some soil physical quality characteristics and soil organic carbon. The study area has been cultivated for a long time. Therefore, the motivation in the current research is to find out, understand some soil physical quality characteristics of the soils of the study area, such as compaction, crust formation and soil erodibility-K factor, and check their relationship with the amount of SOC in the soil.

Material and Methods

General Characteristics of the Study area

The study area is located within the borders of Isparta Province, which is located in the Western Mediterranean Region (Figure 1). The study area has the 0-1% sloping and is base lands of the Atabey-Kumacık plain, 15 km north of the city center. The study area varies between 930m and 920m above sea level and was coordinated between 36283500–36294200 East – 4193000–4199000 North (WGS-84, UTM, 36. Zone) (Ormancı, 2007).

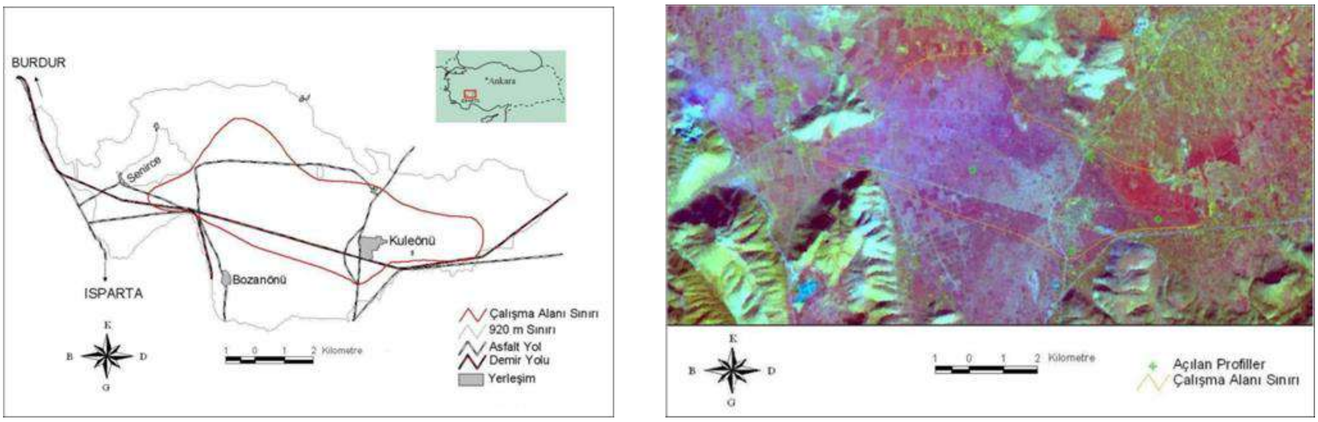

Figure 1. Location and Soil profiles location maps of the study area

The highland type of Mediterranean climate prevails in the region. December August is the month with the most precipitation with 94.3 mm and the least precipitation with 10.4 mm. According to the 62-year average meteorological data in Isparta province, the average rainfall is 597.2 mm and the most precipitation is in December with 94.3 mm during the year. The average annual temperature is 12 oC, the average annual proportional humidity is 61%. the average annual temperature at a soil depth of 50 cm is 14.5 oC. The temperature regime in the region is Mesic, the soil moisture regime is Xeric (Ormancı, 2007)

Soil Sampling and Analysis

Six soil profiles (Figure 1) opened on neighboring units with significant differences in terms of basic properties were identified and 30 disturbed and undisturbed soil samples were taken from genetic surface and subsurface horizons. Texture, bulk density, pH, lime, organic matter, electrical conductivity analyses were performed. These parameters were obtained from the thesis study conducted by (Ormancı, 2007).

Calculations of soil physical properties

Soil organic carbon stock (C_{stock})

The C_{stock} of the surface layers (0–20 cm and 20-40 cm), expressed in kg m^{-2}, was calculated by the following equation (1): (Penman et al., 2003)

$$Cstock = SOC * BD * H * \frac{(100-SK)}{100} \quad (1)$$

SOC - soil organic carbon content (%)

BD - bulk density (g cm^{-3}), SK - skeleton content (% by weight), H - layer depth (2 dm)

Soil compaction susceptibility

For calculating the soil compaction susceptibility was used Vignozzi et al. index. This index is integrating the algorithm of Smith et al. with the equation for estimating the ρ100kPa (Pellegrini et al., 2018). Soil compaction susceptibility index (CI) calculated according to the following equation (2):

$$\rho 100kPa = 1.04231 + \exp(-0.486474 - 0.464448186 * SOC) \quad (2)$$

$$CI = -0.09266 + 0.01576 * (Si+Cl) - 0.00012 * (Si+Cl)^2 + \rho 100kPa$$

SOC - soil organic carbon (%), Si – silt (2–50 μm) (%), Cl - clay (< 2 μm) (%)

Soil crusting susceptibility

For calculating soil crusting susceptibility, the FAO (1979) crusting index (Ic, dimensionless) was used (Pellegrini et al., 2018). The soil crusting susceptibility calculated according to the following equation (3):

$$I_c = \frac{1.5*(Sif)+0.75*(Sic)}{Cl+5.8*SOC} \quad (3)$$

Sif - fine silt (2–20 µm) (%), Sic - coarse silt (20–50 µm) (%), SOC - soil organic carbon (%), Cl - clay (< 2 µm) (%)

Soil erodibility

The soil erodibility K-value based on the basic soil properties analyses results was expressed in calculation by Wischmeier et al. (USDA-NRCS, 2017). The soil erodibility was calculated with formula wish is below (4):

$$Kfactor = \{0.00021 \times M^{1.14} \times (12-OM)+3.25 \times (SSC-2)+2.5 \times (PSHCC-3)\}/100 \quad (4)$$

OM - organic matter (%)

SSC - soil structure code (1, = very fine granular, 2, = fine granular, 3, = med or coarse granular, or 4 = blocky, platy, or massive), PSHCC - profile saturated hydraulic conductivity code (1, 2, 3, 4, 5, or 6)

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

Results and Discussion

Soil Sampling and Analysis

Six soil profiles (Figure 1) opened on neighboring units with significant differences in terms of basic properties were identified and 30 disturbed and undisturbed soil samples were taken from genetic surface and subsurface horizons. Texture, bulk density, pH, lime, organic matter, electrical conductivity analyses were performed. These parameters were obtained from the thesis study conducted by (Ormancı, 2007).

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Results and Discussion

Physical and Chemical Properties of Soil

Descriptive statistical values of soil physical and chemical properties analyzed for surface and subsurface soils in the study area are presented in Table 1. In this study, the soils are in the fine and medium-fine texture group, and the texture classes are determined as C, CL, L, LS, SiC for both surface and subsurface horizons (Ormancı, 2007). The bulk density of the soils was determined to be about 1.3 g cm3 in both layers. The pH values of soil samples on the surface 7,12–7,74 under the surface, 7,10–7,80 varies from the average of both layers, indicating 7,58 is close to neutral soil reaction. The electrical conductivity ranges from 328.00 µS m^{-1} to 787.00 µS m^{-1} on the surface and between 240.00 and 451.00 µS m^{-1} under the surface, with an average of about 400 µS m^{-1} for both layers. The $CaCO_3$ average is just over 3% in both layers. Therefore, the CaCO3 content of the soils of the study area was classified as 'calcareous'. The OC and OM are higher at the surface with an average of 0.86% and 1.55%, respectively, and the OC, 0.61% and OM are 1.00% subsurface. According to Doran & Jones (1996), Kaçar (2016) and Hazelton & Murphy (2016) The OM content ranged from 'low' to 'high'while the soil reaction was classified as 'slightly alkaline' and EC was classified as 'Salty'. In a study conducted by Yılmaz and Dengiz (2021), it was determined that OM, OC, BD and pH showed low variability in surface soil samples in the study area, while other soil properties had high variability. In their study surface soils (0-20 cm) varies 5.02 and 8.75 ph, 38.10 -1874.00 µS cm^{-1}, the rate of clay 4.23 -69.20, sand ratio % 13.04-61.93, silt ratio % 8.66-75.18, rate of OM 0.27-6.24, CaCO3 content, % 0.62-38.16, the BD value of 1.20-1.59 g cm^{-3} and the value of SOC 4.79 -94.10 tons ha^{-1}. While the skewness coefficients in the subsurface soil samples exhibit a normal distribution at BD value, it has been determined that other properties are far from the normal distribution. In addition, clay and pH far from the normal distribution had a negative (left) skew, while other properties that did not show a normal distribution showed a positive (right) skew. According to the coefficient of variability, CaCO3, silt, clay, sand, EC and pH have high variability in the study area, while other soil properties have low variability. In this study, organic carbon stock is 2.80 kg m^{-2} in the upper layer, while the average average is 2.48 kg m^{-2} in the lower layer. The compaction is more under the surface, with an average of 1.44 at the surface and an average December of 1.51 under the surface. The average crust formation is 2.38 on the surface and 1.47 under the surface. In addition, the erodobility-K value is similar in both layers with an average of 0.36 on the surface and an average of 0.34 under the surface. According to Table 1, most often all soil parameters are determined to be unsymmetrical, which is called skew. When the changes in physical and chemical soil properties at both soil depths are examined in terms of the coefficient of variation (CV), it can be noted that the analyzed soil properties usually show moderate to high variations. According to CV Wilding (1985), it can be classified into 3 groups: low (<15%), medium (15% and 35%) and high (>35%). Salem et al. (2015), water content, hydraulic conductivity, bulk density, compaction, and soil parameters such as organic matter compared with dynamic, Mineralogy, soil properties, including soil texture and soil thickness variation has a reduced amount of static. In the present study, soil pH, bulk density and compaction of 'low' CV classified as the top layer in the amount of silt, clay, and erodibility-K middle, the values for other properties 'high' is classified as CV.

Table 1. Descriptive statistics of soil properties

Parameters	P 1	P2	P3	P 4	P 5	P 6	Variance	SD	CV	Variance	Min.	Max.	Skewness	Kurtosis
Surface horizon														
pH	7,74	7,65	7,73	7,70	7,55	7,12	7,58	0,22	2,85	0,05	7,12	7,74	-2,02	4,20
EC (µS/cm)	337,0	412,0	346,0	598,0	787,0	328,0	468,0	170,0	36,3	28907,0	328,0	787,0	1,29	0,47
CaCO3	25,50	7,02	32,50	12,03	5,17	0,44	13,78	11,46	83,2	131,44	0,44	32,50	0,73	-1,16
OM	1,25	1,31	1,83	1,25	1,83	1,83	1,55	0,28	18,1	0,08	1,25	1,83	-0,02	-3,28
Sand	21,30	52,30	30,29	29,56	41,39	25,54	33,40	10,44	31,2	108,94	21,30	52,30	0,99	0,19
Silt	48,40	22,42	43,31	36,56	36,63	41,60	38,15	8,12	21,2	65,98	22,4	48,40	-1,13	1,92
Clay	30,30	25,28	26,40	33,88	21,98	32,86	28,45	4,25	14,9	18,08	21,9	33,88	-0,18	-1,59
BD (g.cm^{-3})	1,43	1,29	1,45	1,31	1,22	1,27	1,33	0,08	6,30	0,01	1,22	1,45	0,51	-1,53
SOC_{stock}	2,078	2,947	3,702	1,904	3,245	2,972	2,8084	0,630	22,4	0,397	1,90	3,702	-0,2939	-1,24
Compaction	1,885	1,860	1,840	1,903	1,836	1,832	1,8596	0,026	1,42	0,000	1,83	1,903	0,7389	-1,31
CF	1,588	2,746	2,625	1,774	3,122	2,457	2,3857	0,539	22,6	0,290	1,58	3,122	-0,3999	-1,31
Ero.-K	0,327	0,394	0,385	0,407	0,407	0,280	0,3672	0,047	12,9	0,002	0,28	0,407	-1,1963	0,05
Sub-Surface horizon														
pH	7,80	7,74	7,66	7,63	7,66	7,10	7,60	0,23	3,03	0,05	7,10	7,80	-2,10	4,81
EC (µS/cm)	357,0	308,0	339,0	448,0	451,0	240,0	357,17	74,76	20,9	5588,47	240,0	451,00	-0,09	-0,96
CaCO3	25,70	12,56	30,73	11,81	6,79	0,96	14,76	10,35	70,1	107,04	0,96	30,73	0,46	-1,17
OM	0,73	1,18	0,67	0,80	1,18	1,44	1,00	0,28	28,2	0,08	0,67	1,44	0,33	-1,82
Sand	28,77	49,02	17,15	29,93	31,37	21,98	29,70	9,95	33,5	99,01	17,15	49,02	1,11	2,06
Silt	36,67	24,67	46,63	35,24	39,04	40,59	37,14	6,64	17,8	44,15	24,67	46,63	-0,81	1,84
Calay	34,56	26,3	36,22	34,83	29,59	37,43	33,16	3,92	11,8	15,34	26,31	37,43	-0,96	-0,48
BD (g.cm^{-3})	1,44	1,25	1,43	1,30	1,34	1,37	1,36	0,07	4,98	0,00	1,25	1,44	-0,21	-1,23
SOC_{stock}	1,89	3,85	1,33	1,81	3,03	2,98	2,486	0,871	35,0	0,7589	1,33	3,859	0,2890	-1,377
Compaction	1,96	1,88	1,94	1,96	1,91	1,86	1,923	0,037	1,96	0,0014	1,86	1,968	-0,3732	-1,701
CF	1,02	2,31	0,808	1,14	1,71	1,84	1,475	0,5260	35,6	0,2766	0,808	2,314	0,3597	-1,363
Ero.-K	0,32	0,41	0,317	0,37	0,37	0,27	0,346	0,045	13,19	0,002	0,27	0,418	0,0440	-0,365

SD: standard deviation, Min: minimum, Max: maximum, CV: coefficient of variation, BD: Bulk Density, OM, Organic matter, SOC: Soil organic carbon, EC: Electrical conductivity, Ero.-K: Erodibility K factor, CF: Crust formation

Relationshiphs between Soil Characteristics and Physical Quality Parameters

The correlations between soil properties and physical soil quality parameters are given in Table 2. it was determined that there was a high level of association ($P<0.001$) between soil organic carbon, soil organic carbon stock, and organic matter with erodability-K. In addition, it was determined that the erodability -K factor has a statistically significant relationship with pH, sand, clay, bulk density ($P<0.001$). Many previous studies on soil erosion have confirmed that erodibility is strongly related to soil organic matter, soil texture and structure (Wang et al., 2013).

The results of Dikinya's (2013) showed that the erodibility factor K is significantly related to the amount of organic matter, the percentage of clay fraction, slope length, bulk density, structural properties and soil porosity. The results of Dikinya's (2013) showed that the erodibility factor K is significantly related to the amount of organic matter, the percentage of clay fraction, slope length, bulk density, structural properties and soil porosity. In addition, it is understood that the decrease in soil organic carbon increases the erodibility (Radziuk and Switoniak, 2021). It was determined that compaction had a statistically high relationship with organic carbon, organic carbon stock, organic matter, clay, volume weight ($P < 0.001$), while it was determined that it had a lower relationship with sand ($P < 0.005$). For example, Kumar (2009) reported that soil compaction is highly correlated with texture. In addition, the studies of many other scientists have confirmed the important relationship between organic matter and soil compaction and have noted that the increase in soil organic matter and compressibility.

Crust formation has a relationship with soil organic carbon, SOC stock, organic matter, silt and clay ($P < 0.001$). Soil crust formation only external factors, but also organic matter content, soil texture, clay Mineralogy, exchangeable cations, seskioksit content, soil factors such as soil water content are well known from previous studies (Pagliai et al., 2004). The study of Maiga-Yaleu et al (2021) pointed out an important relationship between soil crust and SOC. In addition, Negyes' study states that surface crusts differ depending on the soil texture, and silty-loamy soils result in harder and more solid crusts than other textures (Negyesi et al., 2021). As a result, in the current study, soil compaction, crust formation and erodibility-K have a strong relationship between each other ($P < 0.001$). In general, soil quality parameters with minor differences in both soil layers are sensitive to erosion-K and compaction and crusting.

Table 2. Relationshiphs between soil characteristics and physical soil quality parameters

Parameters	SOC_{stock}	Compaction	CF	Ero.-K
Surface				
pH	-0,208	0,568	-0,279	0,682
EC	-0,035	0,033	0,365	0,658
CaCO3	0,066	0,230	-0,365	0,132
OM	0,824	-0,906	0,693	-0,183
Sand	0,363	-0,235	0,693	0,602
Silt	0.060	0,025	-0,476	-0,505
Clay	-0,661	0,528	-0,791	-0,515
BD	-0,035	0,267	-0,511	-0,123
SOC_{stock}	-	-0,900	0,849	0,088
Compaction		-	-0,828	0,235
CF			-	0,291
Ero.-K				-
Sub-Surface				
pH	-0,192	0,669	-0,266	0,660
EC	-0,293	0,621	-0,339	0,471
CaCO3	-0,686	0,719	-0,720	-0,049
OM	0,837	-0,941	0,858	-0,043
Sand	0,739	-0,245	0,716	0,867
Silt	-0,683	0,220	-0,677	-0,774
Clay	-0,719	0,248	-0,669	-0,891
BD	-0,693	0,417	-0,733	-0,767
SOC_{stock}	-	-0,805	0,992	0,446
Compaction		-	-0,843	0,063
CF			-	0,422
Ero.-K				-

BD: Bulk Density, OM, Organic matter, SOC: Soil organic carbon, EC: Electrical conductivity, Ero.-K: Erodobility K factor, CF: Crust formation, **. Correlation is significant at the 0.01 level, *. Correlation is significant at the 0.05 level.

Conclusion

In the study area, it is aimed to investigate the relationship between physical soil quality properties (crust formation, compaction and erodobility-K of surface and surface horizons belonging to 6 different soil profiles and soil organic carbon. The highest values of erodobility-K and compaction in the surface horizons were determined in profile 4, while the soil crust formation was determined in profile 3. In the subsurface horizons, the highest erodobility -K and soil crust formation was determined in profile 2, while the highest compaction value was determined in profile 4. Soil compaction and erodobility-K and crust formation are soil quality parameters that, in general, show minor changes in both layers. Correlation analysis showed that soil compaction, crust formation, erodobility-K are quite important between organic carbon, organic carbon stock, organic matter and each other ($P < 0.001$). Here, no significant differences between soil properties in the upper and lower layers have been determined. This study has demonstrated the importance of soil quality assessment for monitoring soil degradation and establishing policies to improve soil quality.

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Peculiarities of the formation of grain sorghum hybrids biometric indicators with the application of microfertilizers and growth regulators

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Abstract

The selection of elements of grain sorghum cultivation technology should be carried out taking into account its biological features, which are different from C3 crops of the photosynthesis type traditionally grown in the conditions of the forest-steppe of Ukraine. The laboratory similarity of the grain sorghum hybrids studied by us depended exclusively on the quality of the seed material, thats how for the Brigg hybrid it was 95.2%, and for the Yutami hybrid this indicator was 94.7%. The density of crops at the time of harvesting of grain sorghum plants was in the Brigg hybrid, the best indicators were obtained by treating plants foliar with microfertilizers Alpha-Grow-Extra 2 l/ha (1 treatment of 5 leaves, 2 - 9 leaves, 3 - throwing out panicles), or Intermag - Corn, 2 l/ha (1 treatment in the phase of 5 leaves, 2 and 3 - with an interval of 7 days). In the Yutami grain sorghum hybrid, the best level of conservation of crop density, similar to the other researched hybrid, was ensured by the use of foliar fertilization. By the end of the growing season, and in particular at the time of full maturity, the average height of the plants according to the experiment was 117.3 cm, and the use of additional elements of growing technology did not lead to a significant impact on the studied indicator at the later stages of the growing season. Thus, the height of the sorghum plants of the Brigg hybrid was within 118.5-124.1 cm, and in the Yutami hybrid - 111.7-117.2 cm.

Keywords: Grain sorghum, Hybrids, Micro fertilizers, Growth regulator, Laboratory germination, Plant density, Plant height.

Introduction

Grain sorghum, in contrast to traditional agricultural crops common in Ukraine, has a C4 type of photosynthesis, and hence a number of limitations and features of plant growth and development.

First of all, plants are resistant to high air temperatures, rationally use moisture. However, crops require a high level of purity to create conditions for a good supply of solar energy and actually have initial periods of slow growth, which are critical for the accumulation of an undesirable weed component in the agroceonosis (Kurylo and Gerasimenko, 2012; Makarov, 2006; Rozhkov and Sviridova, 2017).

Despite the fact that the culture is quite new, over the past 20 years it has become widespread in Ukraine not only in the conditions of the Steppe, but also in the Forest-Steppe region due to its unpretentiousness to growing conditions, and in particular, its resistance to conditions of water shortage and high air temperatures. After all, such conditions are increasingly common in the forest-steppe of Ukraine (Anon, 1987; Demydenko, 1963; Karazhbey et al., 2017).

Also, in the first half of the growing season, grain sorghum forms a fairly voluminous root system capable of penetrating the deep layers of the soil in search of moisture and nutrients. But before the beginning of flowering, it already absorbs about 70% of all the elements necessary for full-fledged growth and development. That is, if the conditions for a lack of nutrients are created in the first half of the growing season, then their additional application after the flowering of the crop will not be able to correct the situation and improve the yield and quality of sorghum.

Therefore, optimization of nutrition conditions, including foliar application of various types of fertilizers in the first half of the growing season of the crop is a reliable way to provide plants and stimulate better conditions for their formation of a high level of productivity.

Also, when choosing grain sorghum hybrids suitable for cultivation in the conditions of a certain agro-climatic zone, the length of their growing season should be taken into account. After all, mid- and late-ripening hybrids can vegetate until the end of October, which is unacceptable in the conditions of the forest-steppe of Ukraine, since not every year there is good weather for an effective crop harvest.

Thus, the selection of elements of grain sorghum cultivation technology should be carried out taking into account its biological features, which are different from C3 photosynthesis type crops traditionally grown in the conditions of the Forest Steppe of Ukraine (Russo, 1978; Safarov, 1977; Steiner, 1986).

Material and Methods

In 2019-2021 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.

In the years when the research was conducted (2019-2021) the weather conditions differed from long-term indicators. However, generally they were favourable for the growth and development of grain sorghum.

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 grain sorghum yield capacity; a statistical analysis of the research results was made with help of variation, disperse, correlation and regression methods using applied computer software Statistics.

Results and Discussion

Let’s consider the parameters of germination, density and survival of grain sorghum obtained in our experiment (Table 1). Seed germination indicators of grain sorghum and their derivative, the density of crops during the growing season, are a measure of the effective application of the main, basic, elements of growing technology. And also, at the same time it can indicate that during the cultivation of plants, sufficient characteristics of the sowing obtained are necessary for its effective work.

Table1. Similarity, density and survival of grain sorghum, average for 2019-2021

Hybrid	Microfertilizer	Growth regulator	Laboratory germination, %	Field germination, %	Density at the time of full germination	Density at the time of harvesting	Plant survival, %
Brigg	Without microfertilizers	Without regulator	95,2	85,3	162,2	145,2	89,5
		Regoplant	95,2	85,2	162,0	146,6	90,5
		Stimpo	95,2	85,6	162,7	147,6	90,7
	Alpha-Grow-Extra	Without regulator	95,2	85,4	162,4	148,2	91,3
		Regoplant	95,2	85,2	162,0	150,2	92,7
		Stimpo	95,2	85,5	162,5	150,3	92,5
	Intermag	Without regulator	95,2	85,3	162,2	151,0	93,1
		Regoplant	95,2	85,5	162,5	152,8	94,0
		Stimpo	95,2	85,2	162,0	152,0	93,8
Yutami	Without microfertilizers	Without regulator	94,7	84,3	161,3	145,5	90,2
		Regoplant	94,7	84,2	161,1	146,3	90,8
		Stimpo	94,7	84,1	160,9	146,4	91,0
	Alpha-Grow-Extra	Without regulator	94,7	84,7	162,0	151,3	93,4
		Regoplant	94,7	84,3	161,3	152,6	94,6
		Stimpo	94,7	84,6	161,8	152,4	94,2
	Intermag	Without regulator	94,7	84,5	161,6	150,5	93,1
		Regoplant	94,7	84,6	161,8	151,9	93,9
		Stimpo	94,7	84,7	162,0	152,4	94,1
		$SSD_{0,05}$	0,4	0,6	1,2	1,1	0,8

The laboratory similarity of the grain sorghum hybrids we studied depended exclusively on the quality of the seed material and for the Brigg hybrid was 95.2%, and for the Yutami hybrid this indicator was 94.7%.

Accordingly, the field germination of seeds was somewhat lower and was generally initially determined by the basic laboratory germination. However, it also depended on the environmental conditions, since the experiments were laid out in the same way and we did not perform additional elements of agricultural technology in the initial period. Therefore, the field similarity was 85.2-85.6% for the Brigg hybrid, and 84.1-84.7% for the Yutami hybrid.

And therefore, at the time of the formation of full seedlings, the crops had sufficient density for their effective development in the future. Thus, in the Brigg hybrid, the density was 162.0-162.7, and for the Yutami hybrid - 160.9-162.0 thousand pcs./ha.

Accordingly, the basic parameters of the density of crops played a role in the preservation of plants during the growing season, but this indicator is also highly influenced by the factors of crop care, the presence of pests and diseases, and the weather conditions of the growing season.

So, according to the data received by A.O. Rozhkov, L.A. Sviridova 55% of the changes in survival depended on the rate of sowing, while sowing methods and hybrids determined about 15.5% of the changes (Rozhkov and Sviridova, 2017).

If we analyze the density of crops at the time of harvesting grain sorghum plants, then in the Brigg hybrid, the best indicators were obtained when the plants were treated foliarly with microfertilizers Alpha-Grow-Extra 2 l/ha (1 treatment of 5 leaves, 2 - 9 leaves, 3 - throwing out panicles), or Intermag - Corn, 2 l/ha (1 treatment in the phase of 5 leaves, 2 and 3 - with an interval of 7 days). Moreover, it was the application of Intermag - Maize, 2 l/ha (1 treatment in the 5-leaf phase, 2 and 3 - with an interval of 7 days) in combination with the growth regulator Regoplant, 50 ml/ha in the 5-leaf phase, that ensured the density of crops at equal to 152.8 thousand pieces/ha, and the survival of plants during the growing season is 94.0%.

In the Yutami grain sorghum hybrid, the best level of conservation of crop density, similar to the other researched hybrid, was ensured by the use of foliar fertilization. At the same time, by treating plants Alpha-Grow-Extra 2 l/ha (1 treatment of 5 leaves, 2 – 9 leaves, 3 – discarding panicles) in combination with the growth regulator Regoplant, 50 ml/ha in the phase of 5 leaves, the density of crops was preserved at the level of 152.6 thousand units/ha, and the survival of plants during the growing season is 94.6%. And for the application of foliar feeding Intermag - Corn, 2 l/ha (1 treatment in the phase of 5 leaves, 2 and 3 - with an interval of 7 days), the best combination option was a combination with Stimpo, 20 ml/ha in the phase of 5 leaves density of crops remained at the level of 152.4 thousand units/ha, and plant survival during the growing season was 94.1%.

The height of plants depends to a large extent on growing conditions, feeding area and other factors. Thus, Safarov T. shows that the height of sorghum increases by 18 cm due to thickening in a row, and according to the data of Krylov A.V. and Filatova V.I. a high number of plants in a row helps to increase the height of grain sorghum by 8.6 cm (Krylov and Filatov, 2002).

Let's consider the peculiarities of the formation of the height of grain sorghum plants under the influence of experimental factors (Table 2).

In the full seedling phase, the height of the Brigg hybrid sorghum plants was within 4.8-5.2 cm, and in the Yutami hybrid - 5.1-5.6 cm. Similarly, in the tillering phase, plant height differentiation did not depend on the factors of our experiment. yes, the height of the sorghum plants of the Brigg hybrid was within 12.2-13.2 cm, and in the Yutami hybrid - 12.0-13.2 cm.

In the tube emergence phase, the height of sorghum grain hybrids Brigg and Yutami was minimal in the control variants and also in the case of exclusively using growth regulators.

With Alfa-Grow-Extra foliar fertilization of 2 l/ha (1 treatment of 5 leaves, 2 - 9 leaves, 3 - throwing out panicles), the height of the sorghum hybrid Brigg was 61.4 cm, and the hybrid Yutami - 59.8 cm. And for the application as foliar fertilization with microfertilizer Intermag - Corn, 2 l/ha (1 treatment in the phase of 5 leaves, 2 and 3 - with an interval of 7 days), respectively 62.6 and 58.0 cm. Moreover, combined options for applying microfertilizers and regulators growth were better in terms of plant height formation.

In the phase of panicle shedding during foliar feeding of sorghum hybrid Brigg with microfertilizer Alpha-Grow-Extra 2 l/ha (1 treatment of 5 leaves, 2 – 9 leaves, 3 – panicle shedding) in combination with Stimpo growth regulator, 20 ml/ha in phase 5 the leaves of the plant formed a height of 111.3 cm, while in the control it was only 106.9 cm. And with the use of foliar fertilization Intermag - Corn, 2 l/ha (1 treatment in the phase of 5 leaves, 2 and 3 - with an interval of 7 days) in combination with Stimpo growth regulator, 20 ml/ha in the phase of 5 leaves - 111.0 cm.

Table 2. Peculiarities of grain sorghum plant height formation under the influence of experimental factors, average for 2019-2021.

Hybrid	Microfertilizer	Growth regulator	Development phase: Full shoots	Bushing	Exit to the tube	Ejection of the panicle	Flowering	Full ripeness of the grain
Brigg	Without microfertilizers	Without regulator	4,9	12,3	59,1	106,9	112,4	119,0
		Regoplant	5,1	12,6	60,0	111,7	114,6	122,5
		Stimpo	4,8	13,2	58,9	114,5	113,1	120,5
	Alpha-Grow-Extra	Without regulator	5,0	12,5	61,4	107,9	118,2	120,6
		Regoplant	4,9	12,2	62,7	109,2	111,3	119,0
		Stimpo	5,1	13,0	63,4	111,3	115,7	124,8
	Intermag	Without regulator	5,2	12,1	62,6	109,0	116,3	118,8
		Regoplant	4,7	12,4	63,0	109,0	111,1	118,5
		Stimpo	4,8	12,9	62,5	111,0	115,3	124,1
Yutami	Without microfertilizers	Without regulator	5,2	13,2	56,5	102,5	107,2	111,7
		Regoplant	5,3	12,5	57,4	107,1	110,4	115,0
		Stimpo	5,1	13,2	55,4	109,6	112,8	115,9
	Alpha-Grow-Extra	Without regulator	5,4	12,3	59,8	102,6	109,1	111,3
		Regoplant	5,2	12,0	58,1	104,7	107,1	111,6
		Stimpo	5,6	12,7	59,8	106,7	111,5	117,2
	Intermag	Without regulator	5,5	12,8	58,0	103,7	109,2	113,5
		Regoplant	5,2	12,4	57,1	104,5	106,9	111,1
		Stimpo	5,1	12,9	56,9	106,5	111,0	116,6
		$SSD_{0,05}$	0,4	1,0	1,5	2,0	4,3	7,5

In the Yutami hybrid, by treating plants with microfertilizer Alpha-Grow-Extra 2 l/ha (1 treatment of 5 leaves, 2 - 9 leaves, 3 - throwing out panicles) or Intermag - Corn, 2 l/ha (1 treatment in the phase of 5 leaves, 2 and the 3rd - with an interval of 7 days) in combination with the introduction of the growth regulator Stimpo, 20 ml/ha in the phase of 5 leaves, the height of the plants was obtained at the level of 106.7 and 106.5 cm.

In the flowering phase, sorghum plants formed a height of 111.8 cm, and the use of additional elements of the growing technology did not significantly affect the height of the plants. That is, the patterns obtained were of a more tendentious character and the best in terms of plant height in the Brigg hybrid were the options for applying Alpha-Grow-Extra 2 l/ha (1 treatment of 5 leaves, 2 - 9 leaves, 3 - throwing out panicles) - 118.2 cm and Intermag – Corn, 2 l/ha (1 treatment in the phase of 5 leaves, 2 and 3 – with an interval of 7 days) – 116.3 cm. But for the Yutami hybrid, we did not observe patterns associated with the introduction of a complex of microfertilizers or growth regulators in their combination. The best height was on the option of foliar feeding of plants with Stimpo growth regulator, 20 ml/ha in the phase of 5 leaves - 112.8 cm.

By the end of the growing season, and in particular at the time of full maturity, the average height of the plants according to the experiment was 117.3 cm, and the use of additional elements of growing technology did not lead to a significant impact on the studied indicator at the later stages of the growing season. Thus, the height of the sorghum plants of the Brigg hybrid was within 118.5-124.1 cm, and in the Yutami hybrid - 111.7-117.2 cm.

So, as we determined earlier, in the experiment, the average plant height of different grain sorghum hybrids had differences. Therefore, we will analyze the average height of grain sorghum in an interhybrid comparison (Figure 1).

On average, according to the experiment, in the phase of full seedlings, the plants of the Brigg hybrid were 0.3 cm higher than the Yutami hybrid, similarly, this dependence was preserved in the bushing phase. But in the phase of emergence into the tube, we did not observe differences between the studied hybrids.

However, during the period of active growth and development, the situation changed somewhat, and in the panic phase of the Brigg hybrid plant, it was 3.8 cm higher, in the flowering phase by 2.2 cm, and in the phase of full grain maturity, it was 3. cm higher than the Yutami hybrid. Considering the fact that the Yutami hybrid has a 10-day shorter growing season, the lower plant height is justified by its growth and development speed.

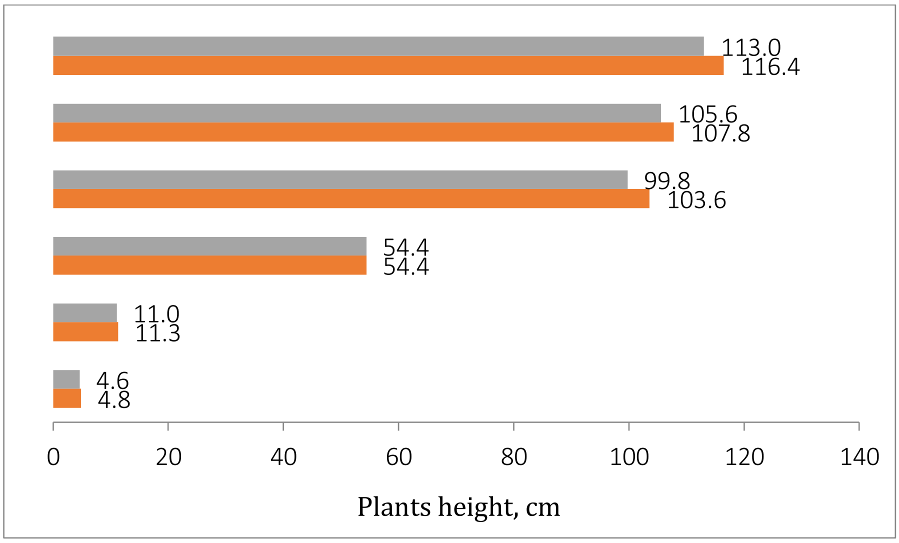

Figure 1. Average height of grain sorghum in an inter-hybrid comparison, 2019-2021.

Conclusion

The density of crops at the time of harvesting in the Brigga sorghum hybrid was better when treated with foliar microfertilizer Intermag - Corn, 2 l/ha in combination with the growth regulator Regoplant - 152.8 thousand pcs./ha, and plant survival during the growing season - 94.0%. In the Yutami hybrid, the best level of preservation of density was provided by the use of foliar feeding Alpha-Grow-Extra 2 l/ha in combination with the growth regulator Regoplant - 152.6 thousand pcs./ha, and plant survival - 94.6%.

It was investigated that the elements of the technology used by us influenced the formation of plant height only in the phase of throwing out panicles and flowering, and by the end of the growing season, and in particular at the time of full maturity, the average height of plants according to the experiment was 117.3 cm, and the use of additional elements of growing technology did not lead to a significant impact on the studied indicator in the late stages of vegetation. Thus, the height of sorghum plants of the Brigga hybrid was in the range of 118.5-124.1 cm, and in the Yutami hybrid - 111.7-117.2 cm.

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Heavy metals in urban soils: A systematic literature review using R studio

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Abstract

Heavy metals in urban soils is a topic which can be investigated from different views. Based on 123 papers collected from the Web of Science and a bibliometric analysis done using R software and the R package Bibliometrix were able to obtain the most cited papers, the most productive authors, the most relevant sources, evolution of keywords, conceptual structure of articles, trending terms and topics. From this information, the following concepts were selected: pollution indices, trace metal, soil distribution, bioavailability and risk assessment; terms defined in this paper. The main aim is to achieve a systematic, specific, and contextualized review which allows a conceptual vision and understanding of the ongoing potential and available research around the concept of heavy metals in urban soils.

Keywords: Bibliometric analysis, Bibliometrix, Heavy metals, Urban soils.

Introduction

Nowdays, more than a half of people live in urban areas, it is equivalent to 4.3 billion of population (Ritchie and Roser, 2018); increasing the effect of anthropogenic activities on cities environment including urban soil. According to Li (2018), the rapid urbanization and industrialization in a relatively short-term and intensive human activities will bring many inorganic pollutants as heavy metals. The soil, atmosphere, and water are all contaminated by the pollutants that are present in urban environments. (Cheng et al., 2014). The importance of heavy metals control is due to they are difficult to degrade and control because of their wide sources, many forms, and complex migration (Singh, 2011, as cited in Li, 2018); The same author mentioned that in recent years, the acceleration of urbanization and the public hazards caused by heavy metals increased interest in this topic. A consequence of this issue is the great number of investigations around this subject therefore a literature review must be detailed and not redundant, distinguishing the most important sources, authors, and topics as information useful for each stated research objective; a tool used for this proposal is bibliometric analysis, a rigorous method for exploring and analyzing large volumes of scientific data; it can summarize historical achievements and development trends comprehensively, systematically, and objectively (Li et al., 2019). The combination of this analysis and literature review in this paper allows identifying the directions of the research field.

Material and Methods

Collection of data base

It was collected using the platform Web of Science which is possible to access multiple databases of academic journalists. Papers were searched filtering according to the following words: heavy metals* anthropogenic activity*pollution*effect and topic soil; the database was exported in a file extension "BibTex".

Bibliometric Analysis

It was done using an R package called Bibliometrix (Aria and Cuccurullo, 2017); from the input database was obtained one descriptive analysis, the most cited authors and sources, trend terms, the most important keywords, thematic map, relevant definitions and conceptual structure by the method multiple correspondence analysis.

Literature Review

Using the previous results obtained was elaborated a new conceptual structure which avoids illogical results and is an interpretation of the different results that includes definitions which explain the most important concepts for current and future research about heavy metals. These terms which are part of the conceptual structure are defined and explained using the most important sources found in the bibliometric analysis.

Results and Discussion

Collection of database

According to the criteria for building the database 123 papers were found, these have been published in 73 sources between 1997 and 2022 by 855 authors; the annual growth rate for this type of article is 13.23%, increasing significantly from 2014.

Bibliometric Analysis

The following results were obtained through the bibliometric analysis.

Descriptive information

Table 1 contains the most relevant sources, papers, key words and countries of publication.

Table 1. Descriptive information of database

Rank	Relevant sources	Relevant papers	Relevant Key words	Country
1	Envıronmental scıence and pollutıon research	10.3390/ijerph17030679	Pollutıon	China
2	Chemosphere	10.1007/s11356-009-0134-4	Phytoremedıatıon	Poland
3	Journal of soıls and sedıments	10.1016/j.scienta.2017.12.039	Bıoremedıatıon	India
4	Scıence of the total envıronment	10.1016/j.scitotenv.2018.04.268	Sedıments	Spain
5	Envıronmental geochemıstry and health	10.1016/j.chemosphere.2005.02.026	Accumulatıon	Italy
6	Ecotoxıcology and envıronmental safety	10.1016/j.scitotenv.2016.12.028	Toxıcıty	Russia
7	Envıronmental earth scıences	10.1007/s10311-016-0587-x	Enrıchment factor	Mexico
8	Envıronmental monıtorıng and assessment	10.1016/S0009-2541(99)00172-2	Soıl pollutıon	Romania
9	Journal of geochemıcal exploratıon	10.1016/j.chemosphere.2017.03.10	Pb	Turkey
10	Water aır and soıl pollutıon	10.1016/j.envint.2019.105117	Cadmıum	France

Trend topics: The top trend topics are pollution, contamination, sediments, accumulation, toxicity, cadmium, trace – elements, zinc, city, agriculture soils, contaminated soils, wastewater, risk – assessment, copper, lead and urban.

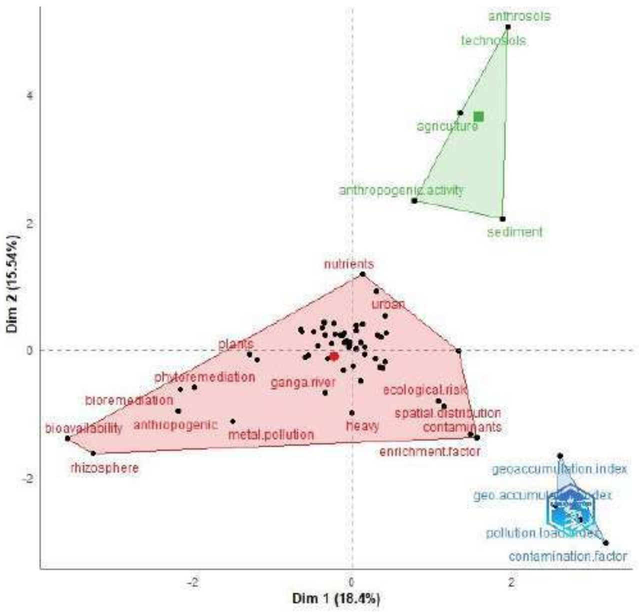
Trend terms: Soil remediation, geoaccumulation index and bioavailability.

Conceptual structure map: Graph 1 shows the conceptual structure map grouped into 3 clusters that explain the medium in which heavy metals are deposited (green cluster), the quantification of these pollutants (blue cluster) and the interaction between factors associated to heavy metals pollution and their consequences (red cluster).

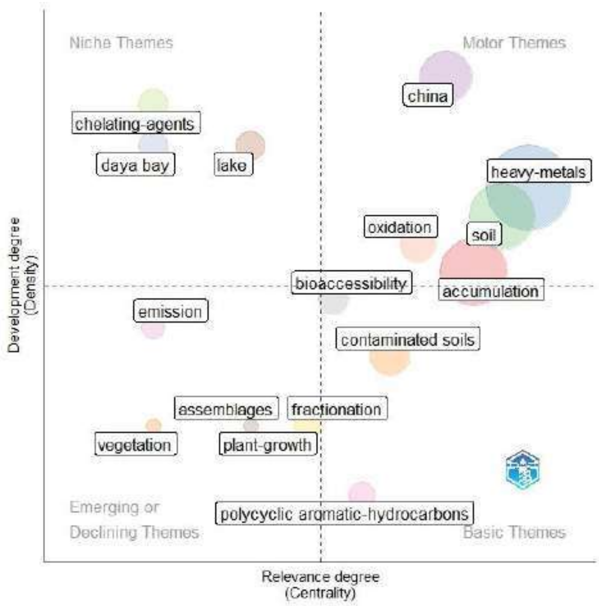
Thematic map: Graph 2 describes the topics which are motor (themes which have been widely investigated currently); the basics topics are those include in the majority of research, based on this is possible to discuss and stablish the investigation. On the other hand, emerging or declining topics are not very important at the moment and niche subjects are those which are very specific and detailed**.**

Literature review

The following Figure 1 is a new conceptual structure that includes concepts which explain the location, the process of measuring and their interaction with the ecosystems. It is a result obtained from the professional analysis of previous results avoiding redundant definitions and considering those necessary for a literature review with updated terms and concepts.



Graph 1. Conceptual structure Map



Graph 2. Thematic map

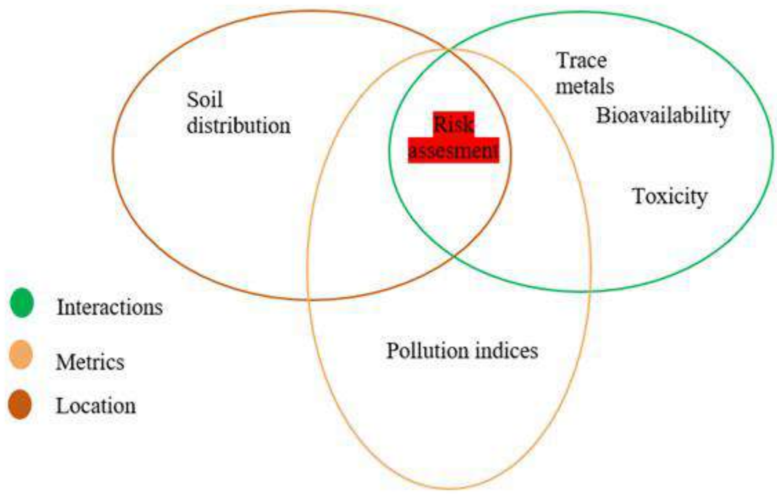


Figure 1. Updated Conceptual Structure

Definition of the conceptual structure

Bioavailability describes the release of a chemical substance as heavy metal from a medium where live receptors like plant roots and microbes, regarding heavy metals bioaccessibility is the fraction accessible to the food chain (Abdu et al., 2017) and is a term relevant in soil remediation and toxicity. The author (Tack et al., 2006) explains the reasons why pH affects the mobility and bioaccessibility of heavy metals. In general, acidic conditions tend to increase the mobility of heavy metals due to proton competition (Horckmans et al., 2007; Abdu et al., 2017); elevated pH precipitates some metals as lead becoming this in insoluble hydroxides (Abdu N., 2010), thus other properties like structure, soil redox state, soil enzymes, organic matter chelants (Abdu et al., 2017) and microorganisms influences this being a heavy metals remediation or increasing the problematic; for instance, according to (Spain and Alm, 2003) microbes can solubilize or immobilize pollutants.

Trace metals: It refers to metal elements with a concentration lower than 100 ppm but produce novice effects. They are classified in essential and not essential, the first group is those which are necessary for the normal function of the organisms but when the concentrarion is higher than required can be toxic; on the other hand, which are part of the group denominated not essential are those which are toxics when the concentration is higher than the tolerance of organisms for this metal. This concept (trace metal) is fundamental and well known, how ever, it allows the study of the interaction between metals and living things useful for the knowledge of the limits of metals and understanding of toxicity definition and risk assessment (Adriano, 2001).

Soil distribution: Generally, the distribution in the soil is done by in situ samplings and extrapolations using data collected in the field. Currently, the application of models developed for soil science is being used for heavy metals a topic which although can be an "old" concept the researchers around it have to be at the forefront because the pollution by these elements in cities has increased during the last years. One answer to this quick urbanization is faster data production and the availability of this information; for this purpose is being used mathematical models and spatial databases of the soil cover; for instance; the author (Ballabio, et al., 2018) used LUCAS (Land Use/Land Cover Area Frame Survey) data for the modelling of copper distribution, Gaussian Process Regression (GPR) and Kriging were used to map copper and Generalized Linear Models for study the factors which influence copper distribution.

The study of soil distribution is a key topic because based on this is known the places where there is a great accumulation and is possible to define a hazard by heavy metals when the accumulation is higher than the permissible limits of one determined country ; these reference limits are defined by the geologic formation and specific environmental conditions of every place (Ramirez and Navarro, 2015). On the other hand, from this distribution is obtained the pollution indices, an objective tool for assessing the real enrichment of soils with trace elements, due to the pollution is defined by the accumulation of trace metals, geological formation and factors related to the specific place (e.g., anthropogenic activities), therefore indices allow to get comparable metrics between places while are one indicator of pollution. Finally, the access and reliability of this geographic information is necessary to support strategic environmental decisions – making and studies about risk assessment.

Pollution indices: Mainly five parameters are used for the assessment of degree of contamination in the environment due to the trace metal accumulation (Gasiorek et al., 2017); these are the following indices:

Contamination Security Index (CSI): CSI provides useful information on the level of heavy metal concentration in the soil. CSI is useful for determining the toxicological threshold and the influence of humans on soil (Gasiorek et al., 2017).

Nemerow Pollution Index (PINemerow): This index is utilized to determine the level of soil pollution (Ogunkunle and Fatoba, 2013; Qing et al., 2015, as cited in Gasiorek et al., 2017).

Enrichment factor (EF): The enrichment factor is the variable used to calculate the level of contamination brought on by trace elements in soil or sediment samples (Salah et al., 2012).

Geo-accumulation index (Igeo): The geo-accumulation index, which Mullar developed, calculates the concentration of metal accumulation in sediment above the baseline concentration. It is a quantitative indicator of the level of pollution in aquatic sediments and is divided into seven classes. The seven groups are classified from unpolluted to extremely polluted groups (Rubio et al., 2000; Praveena et al., 2008).

Potential Ecological Risk (RI): According to Hakanson (1980), the RI indicator is used to evaluate the level of environmental risk brought by a concentration of heavy metals in soil, water, and air.

According with the author (Chen et al., 2005), the spatial distribution of the RI and SCI values is the result of time and type of exposure from human activity, it is well known that the heavy metal pollution of urban soils comes from traffic exhaust, sewage irrigation, improper fertilizer, and pesticide application (Li, 2018). In general, all the above indices quantify the contamination and therefore take place in the risk assessment research.

Risk assesment: The scientific and reasonable environmental health risk assessment and control of environmental pollutants in urban soil have significant strategic, pragmatic, and tactical implications for protecting the health of urban populations. The importance of risk assessment is that soil pollution happens gradually, builds up over time until it causes harm, has irreversible and long–term consequences (Li, 2018).

Although the current soil environmental management system can reduce soil heavy metal pollution, the relationship between the contamination and urban human health had not been considered; for this reason, during the last years organizations like European Union and countries such as the USA, Canada or Japan have created legislations not only for the management of pollution but also for risk assessment which is evaluated through 4 steps hazard identification, dose-response assessment, exposure assessment, and risk characterization. According to (Van Leeuwen and Vermeire, 2007); the first step (hazard identification) aims to understand the characteristics of the substance in the environment; an objective which can be developed by soil scientist.

Conclusion

With a view on the comprehensive display of research in this area, it was possible to summarize the academic output features, interdisciplinarity characteristics, research hotspots, and trends of heavy metals in urban soils using Web of Science and Bibliometrics. This approach offers new researchers an easy way to thoroughly study the body of research in a topic, as well as a tool for summarizing the level of information in a field, locating research hotspots, and identifying trends.

In addition, the descriptive analysis found that the connotation of heavy metals in urban soils continues to expand; it can be investigations about new techniques of sampling; laboratory determination or mixed with others disciplines such as politics and medical science.

There are some terms such as bioavailability, geoindex, soil distribution and trace metals which are denominated "old" but are necessary to be at the forefront of the topic of heavy metals. Based on this, there are developed researches which include soil science and other disciplines and have the aim of decreasing the impact of pollution in the urban population.

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Effects of rhizosphere microbiome on alleviate environmental stress on strawberry crop: A review

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Abstract

Strawberry (*Fragaria x ananassa Duchesne*) is cultivated widely in most regions of the globe, growing outdoors in open fields or controlled environments, such as polytunnels or greenhouses. Strawberry production and quality primarily depend on soil fertility, mineral fertilization, mineral ratio, and climatic conditions. Organic fertilizer inputs are necessary to boost crop output and preserve soil organic matter. Whereas using organic fertilizers is beneficial in increasing plant resistance against nutrient deficiency, which results in regulating different physiological processes such as decreased lipid peroxidation, high antioxidant enzyme activity, and increased osmotic regulation. Strawberry fruit quality is impacted by numerous pre-harvest factors, including picking time, fruit maturity, diseases, and fertilization. Furthermore, fruit quality can vary from season to season due to environmental factors influencing physical, chemical, and sensory properties. Fluctuations in the ecosystem, especially fluctuations in temperature and light, will considerably influence the growth of strawberries. The temperature factor is one crucial objective effect on strawberry growth. Low temperatures (below 7 °C) raise the probability of damaged fruits and changes in color and size. Also, Higher temperatures influence the electron transport chain and photosynthesis process. Moreover, elevated temperatures on the fruit surface can accelerate maturation, and a high rate of ripening could be a factor that decreases the duration of the crop cycle. Thus, high strawberry growth has been maintained at day temperatures of 23–28 °C, and the optimum night temperature is between 5–10 °C. It is well-known that changes in environmental conditions affect the development of strawberry plants, influencing flowering, producing fruit, and the quality of strawberry berries, among other characteristics. On the other hand, high temperatures decrease the plant's photosynthetic ratio by up to 44%, reducing crop yield and causing a decrease in sugars at the fruit level and, consequently, dropping sweetness. In this review, we will discuss a series of studies that have indicated that organic amendments significantly affect microbial communities in agricultural soil and alleviate Environmental Stress on Strawberry crop.

Keywords: Strawberry, Rhizosphere microbiome, organic manure, Environmental stress, Climate factors.

Introduction

Strawberry (*Fragaria* x *ananassa Duchesne*) is cultivated widely in most sections of the globe, growing outdoors in the open field or in controlled environments, such as polytunnels or greenhouses. Strawberry production has increased over the years (Nagamatsu et al., 2021). In 2016, Index Box, a market research company, said that the strawberry market worldwide reached 9.2 million tons, boosted by 5% from the preceding year. Strawberry production depends on human labor, especially picking (Xiong et al., 2019). The fruit is abundant in vitamin C, phosphorus, potassium, calcium, and iron (Das et al., 2015). Strawberry production and quality primarily depend on soil fertility, mineral fertilization, mineral ratio, and climatic conditions (Tohidloo et al., 2018). Strawberry has a large harvest window with intensive nutrient uptake, which decreases soil fertility (Mohamed et al., 2021). Therefore, a high yield of good-quality fruits is related to adequate nutrients for appropriate plant nourishment (Agehara and Nunes, 2021). This nutrient amount could be various fertilization schemes, methods, and technologies (Serri et al., 2021). As a result, organic fertilizer inputs are necessary to boost crop output and preserve soil organic matter. Organic enhancements enhance soil enzyme activity, available nitrates, carbon to overall organic carbon ratio, and metabolic proportions when soil fertility improves (Piotrowska-Długosz et al., 2022). The usage of organic fertilizers is beneficial in increasing plant resistance against nutrient deficiency which results in the regulation of different physiological processes such as decreased lipid peroxidation, high antioxidant enzyme activity, and increased osmotic regulation (Anwar et al., 2018). Among organic fertilizers, farmyard manure and poultry manure are excellent soil amendments that provide nutrients for crop growth and enhance soil quality when applied wisely. Poultry manure helps improve soil structure, such as water holding capacity, aeration, water infiltration, and nutrition holding (Sharma and Negi, 2019). Since farmyard manure and poultry manure have a high content of organic matter, excessive nutrients can be supplied to the plants for high growth (Nand et al., 2018). Vermicomposting is a more environmentally friendly farming process that saves energy by turning waste into absorbable nutrients (Yuvaraj et al., 2021). A range of inorganic and organic fertilizers has been researched on strawberries in Türkiye, and the outcomes proposed that organic fertilizers enhanced strawberry color and antioxidant properties. However, inorganic fertilizers were still required for high yield (Kilic et al., 2021). Moreover, it has also been detected that the effectiveness of organic and inorganic fertilizers differs with the area, cultivars, and climatic conditions (Kilic et al., 2021). Vermicompost proved to be a tremendous economic enterprise for waste management (Baghel et al., 2018). However, little is known about soil amendments' impact on growing habits and fruit quality using organic and inorganic fertilizers before transplanting strawberry plants. The availability of nitrogen is the most crucial factor for its production and fruit quality (Agehara, 2021).

Impact of Climate Factors on Strawberry Plants

Strawberry fruit quality is impacted by numerous pre-harvest factors, including picking time, fruit maturity, diseases, and fertilization (Chandramohan Reddy and Goyal, 2020). Furthermore, fruit quality can vary from season to season due to environmental factors influencing physical, chemical, and sensory properties (Di Vittori et al., 2018). Seasonal variances in strawberry sensory and physicochemical profiles have been definite in various strawberry-producing regions (Cayo et al., 2016). Fluctuations in the ecosystem, especially fluctuations in temperature and light, will considerably influence the growing of strawberries (Sønsteby et al., 2016). The temperature factor significantly affects the strawberry's proper temperature range for growing Sonata strawberries is 18–24 °C (Gonzalez-Fuentes et al., 2016). The temperature factor is one crucial objective effect on strawberry growth. Low temperatures (below 7 °C) raise the probability of damaged fruits and changes in fruit color and size (Ariza et al., 2012). Also, Higher temperatures influence the electron transport chain and photosynthesis process (Sage and Kubien, 2007). Moreover, elevated temperatures on the fruit surface can accelerate maturation, and a high rate of ripening could be a factor that decreases the duration of the crop cycle (Palencia et al., 2013). Thus, high strawberry growth has been maintained at day temperatures of 23–28 °C, and the optimum night temperature is between 5–10 °C (Tekai, 2010). Additionally, Strawberry cultivation in greenhouses is a common practice that inhibits damage from natural disasters and supplies a suitable environment for growth (Khoshnevisan et al., 2013). Many scholars have recently studied strawberry fruit morphology, productivity, and quality. The favorable temperature inside the greenhouse outcomes in the strawberry plants having a high growth rate and also improves the crop quality (such as flesh firmness, skin resistance, skin color, soluble sugar content (SSC), and organic acids) (Atkinson et al., 2005). In winter strawberry production, early-season N fertilization significantly influences fruit earliness and yields, mainly when pre-plant N is not applied (Agehara, 2021). it is well-known that changes in environmental conditions affect the development of strawberry plants, influencing flowering, producing fruit, and the quality of strawberry berries, among other characteristics (Ariza et al., 2012). On the other hand, high temperatures decrease the plant's photosynthetic ratio by up to 44%, reducing crop yield and causing a decrease in sugars at the fruit level and, consequently, dropping sweetness (Kadir et al., 2006).

Soil Microbes and Strawberry

Soil microbes are important in maintaining soil health and environmental function (Huang et al., 2018). Long-term monocropping on the same site may cause considerable problems (Fuentes et al., 2009), which could cause alterations in soil microbial community structure, particularly in pathogenic microbial mass, and a decrease in the abundance of beneficial microbes (Liu et al., 2015). For instance, over the preceding decade, there has been a significant decline in the abundance and variety of bacterial and fungal communities and a significant increase in the communities of *Fusarium* in the continuously growing strawberry fields (Li and LIU, 2019). Corresponding to recent research, the growing problem of monocropping in strawberry production is widespread in all regions (Li et al., 2018). Anaerobic soil disinfection (ASD) is mainly applied as a soil chemical fungicide in plant farming (Benlioğlu et al., 2005). It has been shown to block the spread of soil-borne plant pathogens in field sites, boosting crop yields (Shennan et al., 2018). In 2018 Mazzola and other researchers conducted a field experiment that showed that ASD stimulates changes in soil microbiome formation and strawberry disease-causing pathogens and increases commercial strawberry production (Mazzola et al., 2018). The fact that the pathogen can persist in the soil for years becomes soil fungicide only partially effective (Gilardi et al., 2017). Commonly, beneficial soil microbes can compete with pathogens (Peralta et al., 2018). Moreover, these microbes assist handle nutrients by make-up nutrients available in plants through decomposition, solubilization, iron carrier production, or symbiosis (Chamberlain et al., 2021). A series of studies have indicated that organic amendments generally have the most significant effects on microbial communities in agricultural soils such as manure or compost (Ashworth et al., 2017). However, these conventional techniques have many disadvantages, for instance, high costs and ecological pollution. Subsequently, we have focused more on this problem with more economical and eco-friendly soil amendments. The study of groups of microorganisms rhizosphere and their interactions aims to establish their impact on plant development, yield, and protection (Mikiciuk et al., 2019). These organisms penetrate the roots of the plant and elevate growth and immunological processes, which can help to deactivate or reduction of the impact of stressors such as water deficiency (Yaghoubi Khanghahi et al., 2021), low temperature (Zubair et al., 2019), high temperature (Chatterjee et al., 2020), contaminated soil with heavy metals (Kang et al., 2020) salinity (Azarmi et al., 2016) and biotic factors (pathogens) (Ghazalibiglar et al., 2016). Organic waste application into soils has the most significant effect on organic matter content and nutrient values and also improves the structure, water and air balance, and microbiological activities of soils (Gülser et al., 2015).

Strawberry Production and Rhizosphere Microorganisms

The health of people, plants, and other living things is influenced by the microbiome populations that live in an ecosystem. The rhizosphere is the root zone where the interactions taking place at the plant–microorganism–soil level are stimulated by many biological (bacteria and fungi), chemical (pH, nutrient content, exudates), and physical (temperature, water availability, soil structure) factors (Mimmo et al., 2017). In plants, different microbiomes colonize in various niches: the rhizosphere, endosphere (in the tissues), and phyllosphere (Berendsen et al., 2012)**.** Rhizosphere microbial communities and their relations have been the topic of research for many years, aimed at establishing their effect on plant development (Berg et al., 2014). Many authors exhibited that microorganisms bring many advantages to grown plants, such as resistance to environmental stresses (Pérez-Jaramillo et al., 2016). protection against soil pathogens (Mendes et al., 2013). and nutrient uptake (Berendsen et al., 2012). The rhizosphere is a site of microbiological activity contributed by bacteria, fungi, protozoa, nematodes, algae, and archaea (Lakshmanan et al., 2014). The mechanism that protects a plant against infections (biotic stress) or helps it develop under abiotic stress is indirect. in comparison, the direct mechanism affects the plant growth through the supply of nutrients or the production of plant growth regulators (Goswami et al., 2016).

The Importance of Rhizosphere Microorganisms Mitigating Environmental Stresses

Rhizosphere Microbiome

The rhizosphere is the most complicated of these varied niches because of its massive effect on plant nutrition and, consequently, plant growth (Bandyopadhyay et al., 2017). The plant below the soil consists of the primary root system and the lateral roots and hair of its root. Roots interacting within an ecological niche with numerous microbial communities may impact plant growth and stress resistance in a considerable way (Bandyopadhyay et al., 2017). and jointly form the root plant microbiome (Rich et al., 2017). Given the massive variety of species, staggering interactions, and complicated community structure within the rhizosphere, an understanding of the biological character of the root system and its microbiota is still in its early stages (Hacquard, 2016). We first recap the position of root exudates as potential motors, attracting micro-organisms from the bulk soil to desired rhizosphere niche. Combining microbes with plants may differ from mandatory (endo) symbionts to temporary partners. During the rhizosphere, the various plant-microbial interactions have been given growing attention in abundance, diversity, and complexity as the microbial component's genetic composition often advantages phytopathogens. These micro-organisms may be part of a plant's secondary genome and significantly affect the plant and soil health (Bandyopadhyay et al., 2017). Decoding the multi-functional diversity and enclosed species is required to elucidate the processes behind the recruitment of rhizospheric micro-organisms. Although remarkable steps have been achieved, it is still an enormous challenge because only 1% of all soil micro-organisms are cultivable (Barea, 2015). Scholars have gained insight into rhizospheric microbiota by creating omics and culturally-independent technologies (De-la-Peña and Loyola-Vargas, 2014). High-performance techniques have generated estimates of up to 1011 microbial cells per gram of root, including at least 30,000 prokaryotes based on plant species, genotypes, and age (De-la-Peña and Loyola-Vargas, 2014). The recruitment of rhizospheric microbiota received considerable attention because it impacts plant productivity and soil health. In natural environments, plants have been the guiding factor for the rhizosphere microbiota consisting of several fungi, bacteria, nematodes, and actinomycetes associated with complex habitats such as endosphere rhizosphere and rhizoplane. Crop plant emissions are likely 10–20 percent as exudates, including low molecular weight metabolites such as amino acids, sugar, organic, and dead boundary cells as mucilage (Kaiser et al., 2015). Such exudates change the physical and chemical properties of soil and microbial spread niche (Miransari et al., 2014). The most common transmission of rhizospheric microbiota is from a soil ecosystem that includes mainly varied microbiota from the families, i.e., Proteobacteria Verrucomicrobia, Acidobacteria, Actinobacteria, Planctomycetes, and Bacteroidetes (Compant et al., 2019).

Rhizosphere Microbiome Alleviating Environmental Stresses

Stress factors impact the development and growth of plants in horticultural and agricultural production. Minerals, water, and Light regulate their development, growth, and reproduction (Lata et al., 2018). However, when access to them is disrupted, plants suffer morphological and physiological alterations to adapt to sudden changes (Shukla et al., 2012). Abiotic stresses that affect the plant's effectiveness include drought, salinity, light, and hot and cold stress. When indicating the factors negatively impacting production, one cannot ignore the existence of plant pathogens, the lack of nutrient availability in the soil, and the content of heavy metals (Lata and Gond, 2019). microorganisms improve plant development by regulating the hormonal and nutritional balance, production of plant growth regulators, and induction (Spence and Bais, 2015). Intensive agricultural and animal husbandry practices throughout the globe can meet the demands of an exponentially increased population. Typical use of chemicals and non-biodegradable materials in these practices has caused unwanted environmental changes, especially in agricultural soil (Hossain et al., 2021). There is an alarming requirement to use organic materials and techniques in farming and agriculture. On the other hand, these agro-farming practices generate vast quantities of organic refuse (Geethakarthi, 2021). Vermicasts work as 'micro-dams' and gravitational water and store hygroscopic. A rise in the water-holding capacity of soils improves productivity. The burrowing action of the earthworm also plays a significant role in altering the water-holding ability of soil and soil porosity. During feeding, earthworms fragment the organic substrate, enhancing the microbial number and activity (Edwards et al., 2010). oxidize and decompose the substrate; add humification effect with their mucus to stabilize the organic matter; and pass as a rich product—vermicompost from the gut (Ravindran et al., 2015). Vermicompost is better than other fertilizers due to its nutrient availability (Kumar and Gupta, 2018).

The Decontamination of Heavy Metals in The Soil

Pollution of natural resources is one of the main concerns these days, impacting human health and the other biota close to the polluted sites (Kumar et al., 2019). This also causes ecosystem imbalance by putting pressure on specific varieties of health. The main components of pollutants have been anthropogenic sources. However, various pollutants can naturally occur within the soil as mineral components and tend to be toxic at high levels. Soil contamination may not be measured or seen, but it is usually a mysterious challenge. Due to modern-day society's agrochemical and industrial growth, pollutants are regularly developing. Thus, the complicated nature and their different rate of disintegration make the soil surveys challenging and expensive to discover the enormity of the pollutant impacts. The impacts of soil pollution also depend on soil characteristics because of the field's multi-layered research that regulates contaminants mobility, bioavailability, and length (Rome, 2015). Accumulating heavy metals is an environmental challenge that negatively impacts human health, plants, and soil (Singh et al., 2019). These components do not degrade and are toxic at low levels (Ma et al., 2016). The interactions of heavy metals with bacteria boost their bioavailability, which can result in their detoxification or elimination from the soil (Mishra et al., 2017). The use of Plant Growth Promoting Rhizobacteria (PGPR) is a practical, environmentally friendly, and at the same time, economical approach to alleviating the stress linked to the high concentration of heavy metals in soil (Ahemad, 2015). The heavy metals are classified into three categories like (i) precious metals (Pd, Pt, Ag, Ru, etc.), (ii) toxic metals (e.g., Hg, Cr, Pb, Zn, Cu, Ni, Cd, and Co) and (iii) radionuclides (U, Th, Ra, Am, etc.). The elements like metals and metalloids that occur naturally are heavy metals, referred to as chalcophiles (ore-loving) or lithophiles (rock-loving). These atoms have a large mass of more than 20 and a particular specific gravity of more than 5, which is approximately 5 percent in the crust on earth (Gupta et al., 2019). Through enhanced heavy metal contamination, the viability of microbial declines. For instance, (Smejkalova et al., 2003) observed a decrease in the total heavy metal concentration of the CFUs of bacteria and the micromycetes. The indirect association of microbial viability has been indicated for prolonged Pb exposure by (Fernández San Juan et al., 2018). (Nayak et al., 2015) recorded a 40% and 100% rise in concentrations in agricultural land of Zn, Fe, Cu, Mn, Cd, and Cr, which also impacts microbial population dynamics. They also indicated that the response of microorganisms to the pace of ash amendments was different. Microorganisms are essential to soil fertility as they contribute to the rundown of organic matter and the circulation of nutrients. However, these can be adversely impacted when exposed to fret variables such as chemical emissions, salinity, pH, and high temperature (Nayak et al., 2015). Topics may be polluted by heavy metals from different anthropogenic practices such as mining, industry, and agriculture. Heavy metals in sewage sludge, mine waste, pesticides, and inorganic fertilizers, for instance, can penetrate the soil system and influence microbes (Sharma et al., 2017).

Alleviating The Drought Stress

Water scarcity in the soil is presently one of the highly severe stressors changing the quality and size of plants due to noted global warming. Drought impacts one-third of the world's soils. (Golldack et al., 2014). The drought-induced stress is one of the most threatening world challenges, reducing crop production. Almost 30% of the Earth's soils are exposed to this stress (Calvo-Polanco et al., 2016). Water scarcity causes several adverse changes in plants, such as inhibition of photosynthesis, disorders of the photosynthetic system, decrease of chlorophyll concentration and transpiration, decrease in relative water content, and boost in ethylene production (Naveed et al., 2014). Soil water lack can reduce assimilation storage and movement and photosynthetic efficiency by limiting stomatal function (Zhou et al., 2007). The rhizosphere microorganisms promote the growth of plants during drought stress by stimulating various mechanisms such as the production of bacterial exopolysaccharides (EPS), synthesis of 1-aminocyclopropane-1-carboxylic acid (ACC) deaminase, and production of plant growth regulators (IAA, cytokinins, and ABA) (Porcel et al., 2014). Plant Growth Promoting Rhizobacteria (PGPR) can produce phytohormones that promote plant growth and cell division under water scarcity conditions (Kumar and Verma, 2018). IAA regulates the differentiation of vascular tissues and promotes cell division and root and shoot growth under stress (Goswami et al., 2015). Abscisic acid (ABA) alleviates the stress caused by water insufficiency through transcription and regulation of xylem transport to the aerial parts of plants (Wang and Song, 2014). New techniques are being pursued to lessen the water shortage's effect on crops to manage water most logically, both environmentally and economically. Inoculating crops with beneficial microorganisms isolated from the rhizosphere of the plant species to which they are to be applied is one innovative approach to generating resistance and protecting plants against stresses.

Alleviating Salinity Stress

Extreme soil salinity is a complicated phenomenon, harmful to plants because it influences osmotic and ionic homeostasis disorders. It leads to decreased development and growth and premature senescence of plants (Enebe and Babalola, 2018). Salinity is mainly caused by Na^+, K^+, NO_3^- and Cl^- and Ca^{+2} (Shrivastava and Kumar, 2015). It decreases the microbiological activity of the soil, which is set off by osmotic stress and ion toxicity, which impact the decline in the growth of plants. Rhizosphere bacteria decrease the impacts of extreme soil salinity by producing the so-called biofilm (biological membrane) on the roots (Kasim et al., 2016). Both Arbuscular Mycorrhizal Fungi (AMF) and Plant Growth Promoting Rhizobacteria (PGPR) help plants adapt to salinity, improving water uptake, increasing the availability of nutrients, phytohormones (auxins, cytokinins, ethylene, gibberellins) and increasing the efficiency of CO_2 assimilation, and the synthesis of osmoregulatory (Porcel et al., 2015). Vermicompost was proven to be effective amelioration material for the reclamation of Na salt-effected soils (Demir, 2020).

Alleviating Temperature Stress (Heat Stress, Cold Stress)

The continually changing climate raises the risk of temperature stress, a significant threat to crop yield worldwide (Kumar and Verma, 2018). heat stress meaningfully affects the physiological and biochemical characteristics of plants, development, growth, and yielding (causing loss of vigor and inhibition of seed germination, wilting and leaf senescence, lesser plant mass, discoloration and fruit damage, as well as cell apoptosis and increased oxidative stress) (Zandalinas et al., 2018). the stress related to low temperature impacts many biological processes, such as a change in the photosynthetic system and starch metabolism in plant cells and damage to cell membranes (Zhuang et al., 2019). The rhizosphere microorganisms stimulate the processes by which plants can impede or reduce the impacts of cold stress. These processes include: increased nitrogen fixation processes for the plants exposed to frost, production of ACC deaminase to minimize the synthesis of ethylene caused by low temperature, synthesis of plant growth regulators (ABA, GA, IAA), activation of antioxidant enzymes, the release of iron chelators (siderophores), and growing the nutrients uptake (Kushwaha et al., 2020) and indicated in their reports that inoculation with AMF boost plant resistance to cold.

Increasing the Availability of Nutrients in the Soil

Nutrient deficiency, even at an asymptomatic level, is important in decreasing the plant's crop (Etesami and Adl, 2020). The processes by which rhizosphere microorganisms directly accelerate the uptake of nutrients or boost their availability involve: the solubilization of sparingly soluble phosphorus and potassium, atmospheric nitrogen fixation, and synthesis of siderophores (Di Salvo et al., 2018). Atmospheric nitrogen fixation is a process proceeding both symbiotic and non-symbiotic interactions between plants and microorganisms (Shridhar, 2012). The nitrogen-fixing microorganisms help to boost the absorption capability of plants. Roots release exudates, which are processed by bacteria, which then supply plants with assimilable nitrogen to synthesize amino acids (Lata et al., 2018). The rhizosphere microorganisms secrete some organic acids (apple acid, citric acid, succinic acid), which solubilize the phosphorus forms unavailable to plants and convert them into an assimilable inorganic form (Waghunde et al., 2017).

Rhizosphere Microbiome Engineering Innovative Techniques to Induce Beneficial Microbial Establishment and Agro-Ecosystem Restoration a Significant Problem for Long-Term Precision

The ability to defeat a variety of stressors makes beneficial rhizospheric microbiomes valuable resources for the intensification of sustainable agricultural production. Strategically, understanding the host microbial compatibility in micro-organisms will permit the transport of these insights to crops and the identification of their genetics. Probiotic competence may become a priority for plant breeders when genetic determinants are established in legumes, cereals, and vegetable crops. Using probiotic mixes in the experiments on the ground may counteract abiotically (drought and salinity) and biotic stress conditions that threaten agricultural productivity. Contemplating the importance of the microbial interactions between plants system, biology may play a relevant role in understanding these complicated processes of inter-organisms (Kumawat et al., 2021). Although the rhizospheric plant microbiome is a broad concept, an active research area is the beneficial microbial group associated with the host plant. The leading cause is the exponential growth in publications over the last year on this topic, research on the niche of specific plants, and how interactions occur between particular microbial communities (Naylor and Coleman-Derr, 2018). Various recent research approaches are currently being explored to determine whether the rhizosphere can be engineered to promote beneficial organisms while preventing the presence of phytopathogens. It is important to note that affecting the rhizosphere via plant engineering can be a very multifaceted process due to degradation or deactivation of the engineered compound in the soil, inadequate rate of exudation to stimulate the rhizosphere, partial knowledge about root exudates composition, and changes in exudate releasing time and level with plant development and external stimuli (Dries et al., 2021). Bioengineering synthetic microbial communities for disease resistance, plant growth promotion, and stress tolerance or regulation presents a unique opportunity (Ahkami et al., 2017). Rhizospheric microbiome engineering is the next step towards developing crop varieties/cultivars that integrates knowledge of rhizospheric microbial communities to identify target plant growth promotion (PGP) characteristics for beneficial plant microbial interactions (French et al., 2021). Although several recent researchers have identified natural differences for the recruitment of beneficial indigenous microbes to roots, few sites related to the rhizospheric microbiome that correlate to PGP traits have been isolated (French et al., 2021). By integrating signal recognition with containment approaches, these systems might alleviate microbial bio-inoculants' persistence limits and concerns about the confinement of genetically modified rhizospheric microbiomes. Obtaining a good rhizosphere undoubtedly opens new avenues for future agricultural technologies centered on utilizing potentially beneficial microbial services to reduce inorganic fertilizer and pesticide inputs, hence attaining long-term environmental and economic goals.

Conclusion

Stress factors impact the development and growth of plants in horticultural and agricultural production. Minerals, water, and Light regulate their development, growth, and reproduction wherefore the use of organic fertilizer is beneficial in enhancing plant resistance against nutrient insufficiency, resulting in the regulation of different physiological activities, such as declined lipid peroxidation, improved osmotic regulation, and high antioxidant enzyme activity. Organic additions increase available nitrates, soil enzyme activity, metabolic amounts, and the ratio of carbon to total organic carbon, subsequently in improved soil fertility. Organic fertilizer inputs are essential to maintain soil organic matter and boost crop productivity. Among the organic fertilizers, poultry manure, cow manure, compost, and vermicompost serve as superb soil amendments which provide nutrients for crop growth and enhance soil quality when applied wisely also vermicompost is better than other fertilizers due to its nutrient availability Poultry manure improves soil structure, for instance, aeration, water holding capacity, nutrition retention, and water infiltration. Sheep manure has a good texture and contains more organic compounds than other animal manure. It is a neutral fertilizer suitable for sandy soil and clay. Farm manure has been used in agricultural production for a long time as a plant nutrition material rich in the macronutrients nitrogen, phosphorus, potassium, calcium, and magnesium. Vermicompost, with its porous structure, supports aeration of the soil, raises the water holding capacity, is high in plant nutrients, has a low carbon level, and enhances the microbial activity on the soil surface by providing a slow release of nutrients to the plants, enabling them to be taken up more effectively by the plants. Organic fertilizers, which enrich the soil in terms of the amount of organic matter, improve the soil pH and facilitate plants' uptake of macro and micronutrients.

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Vermicompost: A gateway to sustainable agriculture production

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Abstract

There is a crucial problem of disposing bio-waste in a safer way. These wastes can be converted into valuable composts which have long been recognized in agriculture as beneficial for plant growth and yield and the maintenance of soil fertility rather than when they are directly applied. Thus, the aim of this review is to emphasize the use and importance of vermicompost as a gateway to sustainable agriculture production. After that, the efforts have been made to products amount of nutrient rich high-quality food in practical way to ensure bio-safety towards sustainable agriculture. Sustainable agriculture is an alternative farming to agrochemicals, which means meeting society's present food and textile needs, without compromising the ability of future generations to meet their needs. Use of Vermicompost is an eco-friendly approach that not only ensures the safety of food but also adds to the soil biodiversity and improve tolerance of plant against plant stresses. Vermicompost play crucial role in maintaining long term soil fertility and sustainability also it is an essential component of organic farming and would be a viable alternate for farmers to upturn the productivity per unit area in organic farming for an era of clean environment and prosperity.

Keywords: Sustainable agriculture production, Vermicompost, Eco Friendly, Organic Farming, Biotic and abiotic stress.

Introduction

Since the time of Charles Darwin, earthworms' significance in soil fertility has been understood. Being a natural bio-reactor, earthworms speed up the decomposition of organic waste through activities that increase the surface area and aeration of a substrate (Dominguez *et al*., 1997). In the decomposition system, earthworms act as aerators, crushers, mixers, chemical degraders, and biological stimulators (Edwards, 1995). They, along with microorganisms, are important for breaking down organic waste and preserving the system's nutritional flux. Early 1980s research initiatives focused on the use of earthworms to break down organic waste. Wastes from rural and urban areas, including plant residues and dung, are fragmented and mixed as they pass through the worms' gut.

Vermicompost is a conditioner of soil and food for plant that is made by earthworm species like the red worm (Eisenia foetida) by modifying the physical and chemical composition of organic plant matter and animal waste. Due to the extensive use of agrochemicals the natural resource security has come under scrutiny, which endangers both human health and environmental safety, degrades soil quality, and boosts pathogen resistance. Scientists have developed sustainable agricultural production techniques as a result of all of this, focusing on the use of efficient organic products as pesticides and biological fertilizers. Products like vermicompost and aerobic compost, which improve soil quality in all ways, have become very important in this field (Demir *et al*., 2010).

Vermicompost has been promoted as a beneficial organic manure for use in field crops' integrated management practices. Organic farming pioneers advise using vermicompost as a biofertilizer and an alternative to chemical fertilizers (Shroff and Devesthali, 1994). Vermicompost would improve the soil and crop production sustainably by increasing soil organic carbon status, soil water holding capacity, soil flocculation, and nutrient availability (Rajkhowa *et al*., 2000). Vasanthi and Kumaraswamy (1996) have reported on the contribution of vermicompost to the increase of soluble nutrients in soil. Because it transports nutrients and stabilized, fine, peat-like organic manure with a low C:N ratio, vermicompost is effective in maintaining adequate soil fertility and productivity. (Przemieniecki, 2021) Additionally, it has increased microbial activity that revitalizes soils as well as high porosity, moisture-holding capacity, and microbial activity (Dominguez, 2004). Vermicompost is regarded as a good soil amendment because it contains readily available plant nutrients like nitrates, exchangeable phosphate, soluble potassium, calcium, and magnesium, as well as growth hormones and advantageous enzymes (Bejbaruah, 2013).

Numerous vermicompost tests have been conducted on various plants in Turkey and around the world. Vermicompost was typically used in conjunction with other fertilizers in the experiments, and the outcomes were contrasted based on the control groups. The majority of vermicompost research focuses on how fertilizer affects crop yield and disease. There is a dearth of economic research. The information below includes the findings of some of the product and fertilizer trials. Vermicompost improves the physical, chemical, biological, and microbiological properties of the soils it is used in and has a slow release (increasing agricultural production and reducing nutrient loss) feature. Among its well-known advantages are its ability to act as a soil conditioner, the presence of sufficient amounts of useful plant nutrients, the ability to control some pesticides and plant diseases, the ability to increase product yield by improving soil quality, and the ability to be an affordable and environmentally friendly fertilizer over the long term. To make up for the lack of biological origin in the soil, various vegetable residues, farm manure, chicken manure, garbage compost, and organic industrial wastes can be used. By enhancing the physical, chemical, and biological properties of the soil, these materials supply nutrients to the soil, which has a positive impact on the yield and quality of plant production (Sönmez *et al*., 2002).

Vermicomposting and history of Vermicompost?

The Latin word "vermi" means "worm." As an agricultural input, vermicompost (worm manure) must be used as a nutritive organic fertilizer. Composting with worms is known as vermicomposting. The selection of feedstock and its impact on plant growth are the main topics of vermicomposting research, both in Turkey and internationally (Bellitürk, 2018). An essential organic slow-release fertilizer for protecting Turkey's agricultural soils is vermicompost. Vermiculture, on the other hand, places more of an emphasis on the worms themselves and encourages the production of worm biomass, which can then be sold to new vermicomposting operations or used as animal feed. Vermi-meal, or earthworm meal, has demonstrated excellent production success when fed to a variety of livestock animals and fish (Guerrero, 2009).

Earthworms are vertebrates that belong to the class Oligochaeta and phylum Annelida. The name "earthworm" refers to the fact that these creatures are almost always terrestrial, burrow into moist, fertile soil, and emerge at night to feed. The earthworms are cylindrical, long, thread-like, soft-bodied, elongated creatures with uniform ring-like structures running the length of their bodies. These bodies consist of linearly arranged segments that are externally highlighted by annuli, which are circular grooves (Gajalakshmi & Abbasi 2003). Nearly 4,400 different species of earthworms have been identified worldwide. But only a small percentage of these earthworms are utilized in vermicomposting (Rajendran & Thivyatharsan 2004). Mainly earthworms are divided into two types: (1) Burrowing (2) Non- burrowing.

Vermitechnology is a promising method for recycling organic waste. There is a clear trend toward the recycling and effective utilization of organic residues using novel technologies, many of which are based on biological processes. It is therefore feasible to conserve the available resources, recover natural resources, and, in some cases, address disposal issues and reduce the effects of pollution. Vermicomposting has emerged as a cutting-edge biotechnology for turning agro industrial wastes into products with added value that can be used to enhance the soil's fertility and structure in organic farming (Garg & Gupta 2009).

Philosophers like Pascal and Thoreau have expressed interest in earthworms (Adhikary, 2012). Greece and Egypt were two civilizations that valued the function that earthworms performed in the soil. The first people to acknowledge the earthworm's beneficial role were the ancient Egyptians. Earthworms are sacred, as the Egyptian pharaoh Cleopatra (69–30 B.C.) once declared. She understood the crucial function that worms served in fertilizing the Nile Valley croplands following yearly floods. Earthworm removal in ancient Egypt was a capital offense. For fear of angering the fertility God, Egyptian farmers were forbidden from even touching an earthworm. The earthworm was valued by the Ancient Greeks for contributing significantly to the soil's quality. The Greek philosopher Aristotle (384–322 B.C.) referred to worms as the intestines of the earth (Medany, 2011).

The ancient Indian scientist Sir Surpala suggested adding earthworms to the soil to increase the yield of fruits like pomegranates (Sinha, 2014b). Sir Charles Darwin referred to earthworms as unheralded soldiers of humanity and friends of farmers and claimed that they may be the only living thing in the world to have had such a significant impact on the evolution of life on Earth. Earthworms are actually demonstrating his theories and realizing his dreams. Additionally, they support the theories of eminent Russian scientist Dr. Anatoly Igonin, who once stated: "Nothing and nobody can be compared with earthworms and their positive influence on the entire living Nature; they create soil and improve soil fertility and provide essential biosphere functions: disinfecting, neutralizing, and protective (Sinha *et al*., 2014a).

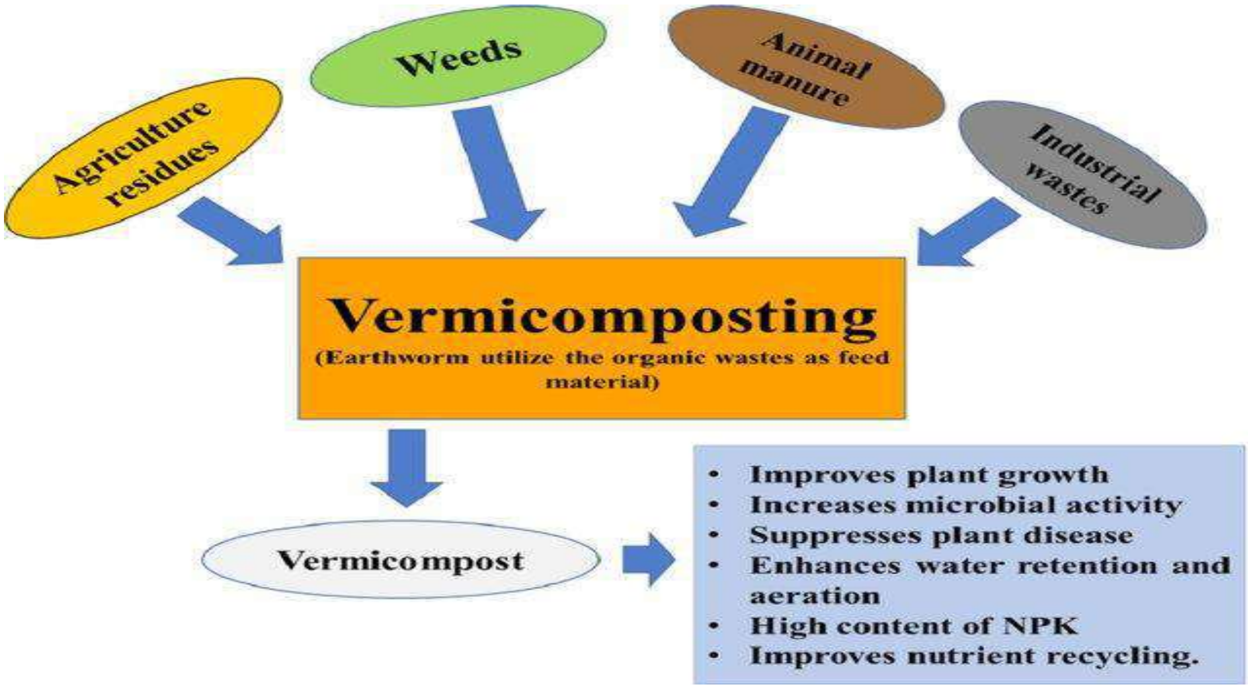

Figure 1. Use of different types of organic wastes in vermicomposting (Singh et al., 2020)

Importance of Vermicompost

Earthworms significantly increase soil fertility, and the result is a significant increase in the amount of mineralized nitrogen that is available for plant growth. An increase in soil nitrogen occurs after earthworm rearing (Ozawa et al, 2005). According to Govindan VS (1988), the body of an earthworm contains 65% protein, 14% fats, 3% ash, and 14% carbohydrate. In most cases, plant roots cannot adapt to the mineral N unless the carbon/nitrogen (C: N) ratio is 20:1 or lower. Earthworms assist in lowering the C: N ratio of fresh organic matter during respiration (Ronald & Donald 1977). Due to their extensive substrate consumption, earthworms are exposed to heavy metals both through their skin and intestine (Morgan & Morgan 1999). Vermiwash contains enzymes that encourage plant growth and boost crop yield and are secreted by earthworms. It includes soluble plant nutrients in addition to a few organic acids, earthworm and microbe mucus, and some organic acids (Shivsubramanian & Ganeshkumar 2004).

Vermicompost has several advantageous uses (Adhikary, 2012): (1) Worm casting, also called worm cast or vermicast, is a biologically active mound made up of numerous bacteria, enzymes, and leftover plant materials that the worms did not digest. (2) A large amount of humus can be found in red worm castings. Clustering of soil particles is aided by humus, which increases the soil's ability to hold water and makes channels for air to pass through. (3) Worm castings are the ideal potting soil for greenhouses, indoor plants, farming, gardening, and other outdoor activities. (4) Humus is thought to help protect against harmful bacteria, nematodes, fungi, and plant pathogens. (5) Castings have nutrients in them that are easily absorbed by plants. (6) Plant Growth Regulating Activity: According to some studies, the high concentrations of nutrients, humic acids, and humates in vermicompost may be the cause of the plants' growth responses, which resemble "hormone induced activity" (7) The worm gut functions like a tiny composting tube, mixing the environment and contaminating the leftovers.

Table 1. Chemical composition of vermicompost (Garg & Gupta, 2009)

Characteristics	Value
Organic carbon, %	9.15 to 17.88
Total Nitrogen, %	0.5 to 0.9
Phosphorus, %	0.1 to 0.26
Potassium %	0.15 to 0.256
Sodium %	0.055 to 0.3
Calcium & magnesium (Meq/100 g)	22.67 to 47.6
Copper; mg kg^{-1}	2.0 to 9.5
Iron, mg kg^{-1}	2.0 to 9.3
Zinc, mg kg^{-1}	5.7 to 9.3
Sulphur, mg kg^{-1}	128.0 to 548.0

Process of Vermicomposting

Cover the cement ring at the bottom with a layer of coconut husk, tiles, or polythene sheeting. Spread a 15-20 cm layer of organic waste material on the polythene sheet. If there is any available rock phosphate, sprinkle it on the waste before applying cow dung slurry. Layers should completely fill the ring. Apply dirt or cow dung to the ring's top. 15 to 20 days should be given for the material to break down. Free selected earthworms (500 to 700) emerge through the cracks after the heat generated by the decomposition of the materials has subsided. Provide protection for the ring with a mesh or gunny bag to stop birds from stealing the earthworms. Sprinkle water every three seconds to keep the earthworms' bodies sufficiently moist and warm. Vermicompost is ready in about 2 months if agricultural waste is used as the substrate and in about 4 weeks if sericulture waste is used. The finished vermicompost is light in weight, black in color, and odor-free. When the compost is prepared, leave it dry for two to three days to make shifting it easier. Compost should be piled in manageable piles, and it should be left out in the open for a few hours or until all the worms have lowered the pile into the bed. Remove the top portion of the manure and filter the lower portion to remove the earthworms from the manure. The various stages of the earthworm's life cycle, carried by the culture in the bed, are cocoons, juveniles, and adults. Change the feed for this culture to fresh, partially decomposed feed. Large earthworms and the leftovers can be fed to fish or poultry. Compost should be bagged and kept in a cool location. Prior to extracting the compost, create a second pile and repeat the process as described above by following the same steps (Nagavallemma *et al*., 2004). The full vermıcompost process has been shown in figure no 2.

Figure 2. An overview of vermicomposting (Malinika,2021)

Studies on vermicompost and its Effect on Soil Chemical, Physical and Biological properties

According to studies on vermicompost, it increases macro pore space of 50 to 500 m, improving the soil's air-water relationship and favorably influencing plant growth (Verma *et al*., 2018). Application of organic matter, including vermicompost, has a positive impact on the pH of the soil, the microbial population, and the activities of the soil's enzymes (Maheswarappa *et al*., 1999). Additionally, it decreases the proportion of chemical species that are water soluble and could potentially pollute the environment (Mitchell & Edwards, 1997). To investigate the effects of various organic N sources, including FYM, Vermicompost, and compost with biofertilizers, on the soil's physical properties, nutrient availability, and biological properties, Kannan *et al*. (2005) conducted a field experiment with tomato. According to their findings, applying vermicompost (75% N) with azospirillum had the greatest impact.

Sreenivas *et al*. (2000) investigated the combined impact of fertilizer and vermicompost application on nitrogen availability in the soil and ridge gourd uptake. The amount of nitrogen that was available in the soil increased significantly as the amount of vermicompost increased, and the highest N uptake was achieved with 50% of the recommended fertilizer rate plus 10 t ha-1 vermicompost. Similar to this, rice plants absorbed the most nitrogen, phosphorus, potassium, and magnesium when fertilizer and vermicompost were applied together (Verma *et al*., 2018). Similar to this, Sailaja Kumari and Ushakumari (2002) examined the impact of enriched vermicompost with rock phosphate on the yield and nutrient uptake by cowpea and found that it outperformed other treatments for the nutrient uptake of major nutrients like N, P, K, S, Ca, and Mg.

Conclusion

Vermicompost is a vital part of organic farming and is crucial for preserving the sustainability and long-term fertility of the soil. Earthworm activity results in the production of vermicompost, which is high in macro- and micronutrients, vitamins, growth hormones, and enzymes like proteases, amylases, lipases, cellulose lyases, and chitinases as well as immobilized microflora. Vermicompost is the best organic manure for improving plant growth and yield in general. In the coming decades, improving soil productivity for agriculture will be a top priority. This is particularly true for agricultural lands where there is a decrease in soil organic matter and where crop, vegetable, and fruit yields are still only moderately high. Application of vermicompost could aid soil and plants in resolving this issue. More consideration will be given to the effects of vermicomposting on soil, plants, and the environment.

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Different tree species effecting the soil sorption properties of post fire areas; A review

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Abstract

Changes in vegetation brought on by fire events are immediately noticeable however, changes in soils take longer to manifest and may be either temporary or permanent in nature. According to studies, the physical, chemical, biological, and geochemical characteristics of soil can change depending on the size, length, and characteristics of the fire as well as the soil, after a fire event. Some of these characteristics play a big part in how well soil may absorb toxins. The effectiveness of remediation techniques used to clean up polluted soils and the soil sorption complex could both be impacted by changes in these qualities. The information on fire-induced changes in soil characteristics by different tree species that affect soil sorption and the variables that control these changes is summarized in this review.

Keywords: Post-fire Soils, Sorption, Forest soils, Remediation, Fire soils.

Introduction

Many reports suggest that the effects of climate change, such as extreme weather occurrences, would lead to a rise in the events of fires worldwide (Beniston et al., 2007; Turco et al., 2018). The southern nations of Europe have historically been the most affected by problem of forest fires. Over 0.8 million acres of forests in Mediterranean nations were damaged by fires just in 2017 (de Rigo et al., 2017). But there are also major flames in central and northern Europe, like in Sweden (San-Miguel-Ayanz et al., 2019). Due to climate change, the forest fires risk is anticipated to rise throughout almost all-around Europe (de Rigo et al., 2017).

The abrupt effects of fire on soils have been well-documented. These effects include nitrogen (N) volatilization from fire burned material, mobilization of (SO_4^{-2}) and (NH_4^+) from organic matter in mineral soils (Certini, 2005), and intensifications in the ionic or other labile fractions of less volatile nutrients (P, K, Ca, and Mg) left in the ash (Neary et al., 1999). Increases in extractable (SO_4^{-2}), exchangeable K^+, NH_4^+, Mg^{2+} and Ca^{2+} as well as pH, are frequently the end results in surface mineral soils. Because mineral soils typically do not reach the temperatures required for organic matter combustion unless fires are quite intense, changes in soil organic C or N are typically minor. The degree of mobilization by fire from organic materials and immobilization with more Ca^{2+} determines how ortho-P availability changes (Lynham et al., 1998; Hauer et al., 1998; Carriera et al., 1996).

Despite the fact that one of the greatest threats to ecosystems are forest fires (Thonicke et al., 2001; Robinne et al., 2020), natural forces also have an impact on the disruption of forests ecosystems and the regrowth of many species in Central Europe including Scots pine and common birch (Dzwonko et al., 2015). Large fires alter forest ecosystems negatively; (Knelman et al., 2015) which show up as altered soil characteristics and the "backflow" of forest ecosystems into secondary succession (Hume et al., 2016). In soils, high temperatures induce a considerable and quick loss of nutrients, especially nitrogen (Neary et al., 2005; Mayer et al., 2020). An increase in soil alkalinity are the main effect of fires (González-Pérez et al., 2004; Neary et al., 2005; Romeo et al., 2020). The most crucial preventative measure after a forest has been burned is the revegetation of postfire areas. The correct choice of tree species for reforestation has an impact on biodiversity, soil biological activity, and soil processes that regenerate (Šnajdr et al., 2013; Pietrzykowski, 2019). Different tree species have different effects on soil qualities. Their canopy closures control how much light reaches the forest floor, which has an impact on the microclimate (Joly et al., 2017; Barbier et al., 2008). After a fire, the forest ecology might not be able to recover naturally or within enough time. The frequency of fires in the area should be considered for reforesting. Following fires, the rates of natural secondary succession could be boosted by the effect of reforestation due to the limited supply of propagules (Ilisson & Chen, 2009).

Common pioneering species utilized in the regeneration of postfire sites in Central Europe include common birch (*Betula pendula* Roth), Scots pine (*Pinus sylvestris* L.), and European larch (*Larix decidua* Mill) (Bojarski & Kaczmarek, 2018; Dzwonko et al., 2015) Additionally, they frequently emerge leading throughout natural secondary succession at the forest sites that have experienced fire or additional disturbances (Ellenberg, 2009). These tree species are well adapted to low fertility soils, have a broad ecological amplitude, and require a lot of light. However, while examining the species composition of reforestation on postfire sites, the impact of tree species on the regenerated forest soil quality should be taken into consideration. According to Vesterdal et al. (2008) and Hobbie et al. (2007), different tree species can change soil's organic C buildup and nutrient (especially N) content and availability. Both factors can be harmed by fire (Certini, 2005).

In order to increase soil fertility, common birch serves as a soil "improver" by substituting more humus with mull (Harrison et al., 1988; Dubois et al., 2020; Miles, 1981; Kanerva & Smolander, 2007). Compared to coniferous trees, this species is identified to raise base saturation and soil pH to favourably alter the contents and availability of nutrients (Jonczak et al., 2020; Hansson et al., 2011). The microbiological features of soils, such as soil enzyme activity and microbial biomass, have also been shown to be positively impacted by birch (Priha et al., 1999; Chodak & Niklinska, 2010; Bradley & Fyles, 1995). Though, Jonczak et al. (2020) concluded that the impact of birch on carbon stock was ambiguous. According to a number of experts, tree species mostly affect the redistribution of carbon (C) among organic and mineral soil horizons rather than the overall C stock (in organic horizons and mineral horizons). In other words, tree species with higher organic horizon C stocks have smaller mineral horizon C stocks (Wiesmeier et al., 2013; Gruba & Socha, 2019). On the other hand, Hüblová and Frouz (2021) found that tree species have a greater influence on total C stock in young soils at an early stage of development (such as in post-mining areas) than in mature soils (such as in post-agricultural and forest sites) as can be seen in fig 1. This study's major objective was to determine the effects of various soil textures and three tree species—European larch (*L. decidua* Mill.), Scots pine (*P. sylvestris* L.), and common birch (*B. pendula* Roth)—on the chemical makeup and carbon stock of fire-affected soils

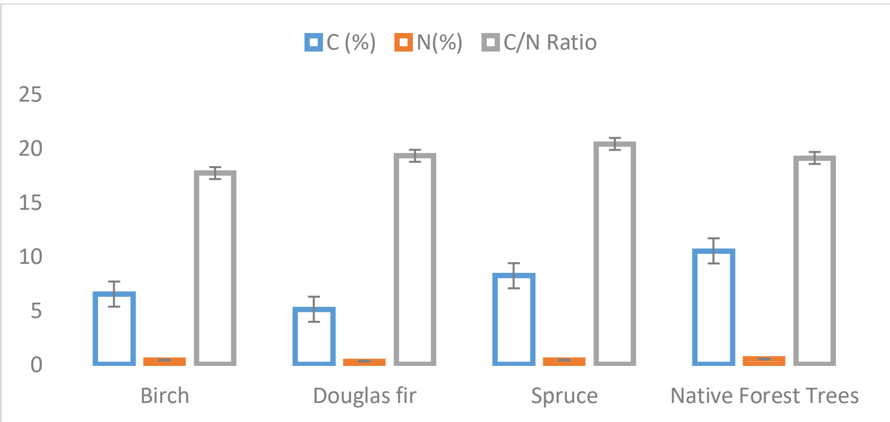

Fig:1 Characteristics of the fraction of the A1 organo-mineral topsoil (0–5 cm) (Judicaël *et al*., 2006)

Fire-induced soil property changes and their impact on soil sorption capacity

Variable amounts of fires have an effect on the physical, chemical, mineralogical, and biological characteristics of the soil, depending on the temperature to which the soil is raised during fire occurrences. Aggregate stability, moisture content, structure, water repellence, colour and texture of soil are among the physical characteristics that are frequently impacted by fire (Certini 2005; Mataix-Solera & Doerr 2004; Badía & Martí 2003; Zihms et al, 2003). Several reserchers have reported in detail the effects of fire on these soil physical parameters (Certini 2005; Mataix-Solera & Doerr 2004; Badí & Martí 2003; Zihms et al, 2003; Doerr E., 2005; Dekker et al., 2005; Zavala et al., 2010; Bryant et al.,2005; DeBano 2000; Zavala et al., 2014; Letey 2001; Stavi et al.,2017; Debano and Krammes 1966; MacDonald & Huffman 2004; Ulery 1993; Ketterings et al., 2000; Neary et al., 2005; and Begum et al., 2009). From 50 °C, where soil moisture characteristics begin to alter, to temperatures exceeding 700 °C, where oxyhydroxides and carbonates are changed to oxides and the pH of the soil rises as a result of the buildup of ash, soil chemical properties are affected (Santín and Doerr 2016). Major and trace element oxide concentrations (Arocena and Opio 2003; Certini 2005; Ngole 2017; Badía & Martí 2003; Hosking 1938; Raison et al., 1985; Bodi et al., 2014; Schaller et al., 2015), soil pH (Arocena and Opio 2003; Certini 2005; Badia and Marti 2003; Xue et al., 2014; Ponder et al., 2009), nutrient content (Certini 2005; Hosking 1938; Tiedemann 1987; Raison et al., 1985), organic matter content and cation exchange capacity, and soil pH are among the chemical characteristics of soil that are allegedly impacted by fires. Both low and high fire intensities can result in soil mineralogical changes, but these changes are more prevalent where the fire is more intense and lasts for a longer period of time. Reynard-Callanan and all (2010), Ngole Jeme (2017), Tan et al. (1986), Zihms et al. (2013), Yusiharni and Robert (2010), Ketterings et al. (2000), Reynard-Callanan et al. (2010), Frost et al. (2003) stated that biological qualities of soil are also impacted by the fire. Several soil chemical processes (Certini, 2005; Santín and Doerr, 2016; Prieto-Fernández et al., 1998), including sorption processes, are affected by changes in these characteristics in various ways.

Fire-induced changes to the soil's textural properties and how they affect soil sorption

According to Falciglia et al. (2011) soil texture can affect the sorption of contaminants in soils by up to 37.1%, with finer soil particles being a prominent factor. This effect has been associated with the cation exchange capacity (CEC) of the different soil particles, which, in accordance with Schulten and Leinweber (2000) rises from 10 mmol/kg in sandy soil to 813 mmol/kg in fine clay.

Although clay and sand have high melting points (460–980°C and 1414°C, respectively), various authors have noted that wildfires have an impact on soil particles and, in turn, soil texture (Certini 2005; Mataix-Solera & Doerr 2004; Badía & Martí 2003). Due to hydroxylation and the collapse of the clay lattice structure, clay particles start to change in structure at 400 °C and can be totally destroyed at 700 °C. The primary reason for this is that secondary minerals predominate in soils' clay components. The majority of sand and silt particles are made of quartz, which has a melting point of 2577 °C and high thermal conductivity. As a result, they are more thermally stable, and are only susceptible to change at extremely high soil temperatures, which are not typically reached during wildfire events. In contrast to sandy and silty soils, clayed soils were shown by Neary et al. (2005) to be more vulnerable to alterations brought on by fire. They attributed this to variations in the mineral content of the two types of soil. After a fire occurrence, sand-sized particles are likely to build up in soils, which will impair the sorption capacity.

Fire's effects on soil mineralogical properties and how they affect soil sorption capacity

According to Reynard-Callanan et al. (2010), changes in soil mineralogy brought on by fire are dependent on the soil's moisture level and depend on the kind of soil. Ngole-Jeme (2017) showed that uncontaminated soils underwent major mineralogy changes at about 300°C, but mine tailings-contaminated soil underwent similar changes only at 500°C. After 4 hours of heating at 300°C and after 2 hours at 500°C, the mineralogy of both contaminated and uncontaminated soils changes (Ngole-Jeme 2017). These alterations could be attributable to the dihydroxylation process, which transforms secondary minerals into primary minerals.

Different tree species used in afforestation after fire events

Forest fires account for nearly 5-10% of the total greenhouse emissions globally, where more than 84% of all the fire emissions originate from tropics (1830 Tg C $year^{-1}$) (Boden et al., 2017; Van Den Werf et al., 2017). They exert their disastrous effects on species composition, enhance erosion and flood risks, shift nutrient and water cycles as well as threaten local livelihood (Shlisky et al., 2009; Scheper et al., 2021). Post-fire ecosystem restoration follows multiple strategies and selecting an appropriate approach is based on numerous factors such as topographical attributes, severity as well as frequency of disturbance, technical capacity, funding and available knowledge (FAO, 2019). Among them, one of the commonly employed strategies to ensure sustained forest recovery is enriched planting, i.e., introducing valuable species to the degraded lands without removing the species already existing (Montagnini et al., 1997). Once a forest has been affected by fire, the most important counteracting step is the revegetation of the post fire site, and proper selection of tree species for reforestation affects the regeneration of major soil processes soil biodiversity as well as biological activity (Šnajdr et al., 2013; Pietrzykowski, 2019). There are multiple ways by which tree species affects the soil properties by regulating the amount of light reaching the forest floor and hence, influencing the microclimatic conditions (Joly et al., 2017), and by interfering with inputs and outputs of essential nutrients particularly C as well as nutrient cycling (Vesterdal et al., 2013; Angst et al., 2019).

In central Europe, different tree species such as common birch (*Betula pendula* Roth), European larch (*Larix decidua* Mill.) and Scots pine (*Pinus sylvestris* L.) have been used during the reforestation of postfire forest sites (Bojarski and Kaczmarek, 2018). These species have also been reported to be the first to occur as a result of secondary succession in the forests generally after a fire event or any other disturbance (Ellenberg, 1988; Dzwonko et al., 2015). They have extensive ecological amplitude, can easily grow on low-fertile soils, and are characterized by rapid growth rate at young age, making them increasingly competitive for weeds (Woś et al., 2021). Common birch offers its significant role as a soil 'improver' and replaces mor humus with mull and thereby, enhances soil fertility (Dubois et al., 2020). It not only increases soil pH as well as base saturation but also exerts positive effects on the soil microbial biomass and soil enzyme activities (Chodak and Niklińska, 2010). Woś et al. (2021) reported that the tree species opted for post-fire regeneration of forest sites are very critical to the properties of regenerating soils and in the restoration of the ecological functioning of the soil. In another study, Enríquez-de-Salamanca (2022) analyzed the post-fire changes in vegetation in two different Mediterranean pine forests and used pine species for their reforestation. The pines were observed to be facing difficulties during the regeneration process, and the problem was attributed to the problem faced by the young seedlings during survival owing to enhanced summer drought conditions. It was concluded that pine species faced significant difficulties in regeneration after fire even for the same species and difficulties faced by the young seedlings was the prime cause behind this. Various researchers have emphasized on the use of re-sprouter species under pine forestation to increase the species diversity and ensure ecosystem resilience to manage different disturbances such as wildfires (Granados et al., 2016).

Organic matter interaction with sorption properties

Numerous organic and inorganic compounds can be sink by naturally existing organic substances, such as dissolved organic matter (DOM). In DOM, carboxyl, phenolic hydroxyls, and alcoholic hydroxyls are the most common functional groups (De Witt *et al.,* 1993). The majority of natural waters have a pH that causes deprotonation in several of these groupings (pH 6-8). Many DOM features, including water solubility, metal binding capability, and buffer capacity, are explained by the resultant anionic charge on the molecules. The transmission of related pollutants in the subsurface environment is thought to be facilitated by the presence of DOM in subsurface water (McCarthy and Zachara 1989). The related contaminants become less mobile as a result of the sorption of DOM on soil during transportation. Additionally, the adsorbed DOM can alter the soil surface's physicochemical characteristics, which may be influenced by the adsorbed DOM (e.g., electrophoretic mobility, colloidal stability, and transport (Kretzschmar et al., 1997; Kretzschmar and Sticher 1997). The soil's organic matter content and capacity to sorb additional organic pollutants may both be increased by the adsorbed DOM coatings. (Torrents and Jayasundera 1997). The three main surface complexation processes—ligand exchange, anion exchange, and hydrophobic interaction—have been proposed as the main methods by which DOM adsorbs onto mineral surfaces. hydrogen bonding, (v) entropic effects, (vi) cation bridging, and (iii) contact.

Experiment on sorption of natural dissolved organic matter on soil

According to (Kretzschmar and Sticher 1997) study's findings, the ligand exchange between DOM and hydroxyl groups on a soil mineral surface is the main cause of DOM adsorption on soil. With a high soil clay concentration encouraging the sorption process, the DOM sorption capacity for soils appears to be related to the soil's clay content. The sorption of DOM is, however, generally hindered by organic matter in the soil, most likely because it blocks the active sites on the mineral surface. The DOM sorption was found to be at its peak at pH 4-5 and to decline as pH was raised further. Ionization of the surface hydroxyls and multiprotic DOM molecules. Finally, the electrical double layer compression action of inert NaCl and the specific binding effect of bivalent ions like Ca^{2+} may both have an impact on the sorption of DOM.

Conclusion

The severity of the burn, which is made up of both intensity and length, greatly influences how forest fires affect soil qualities. Prescribed and wildfires have an impact on biological, physical and chemical characteristics. Ash deposition on the soil surface results from the total or partial combustion of organic matter by fire. As a result, the chemistry of the soil is significantly changed by the addition of ash and partially burned organic components. Ashes deposition from low-intensity fires may increase available nutrients (K^+, Ca^{2+}, Mg^{2+}, PO_4^{3-}, NH_4^+) and pH, however the effects of fire on soil chemical characteristics are highly variable. Due to losses from burning and volatilization, high intensity reduces soil organic matter and total N. In order to prevent high-intensity forest fires and volatilization losses and to enhance the amount of nutrients from ash deposition and mineralization, it is crucial to stabilize burned areas. The fire changes the chemistry of soil and tree species alter the soil ecosystem, so they have positive effect on the sorption properties of soil, but wildfire has the greatest global impact on forest carbon stocks, contributing an estimated 3431 million tonnes of CO^2 into the atmosphere annually.

Table 1. Effect of different tree species on the soil properties

Vegetation	Site	Properties of fire	Type of Soil	Properties of soil	Impact	Reasons for these Impact	References
Wet sclerophyll forest	Queensland, Australia	Low intensity, 2 year burning regime, heat release rate of	Sandy, red to yellow Kandosols	EC pH Total N Total C	Insignificant Insignificant Decreased Decreased	- - Due to N Volatilization Due to CO2 emission	Muqaddas et al. (2015)
Pinus halepensis and Pinus brutia forests	Northern Israel	Low-moderate severity, WF	Sandy clay loam, Lithic Xerorthenth	OM	Increased	Incompletely burned biomass was mixed with soil that had been exposed to direct frost. its OM content	Inbar et al. (2014)
Pinus halepensis forest	Montgrí Massif, Catalonia, Spain	Flame height < 2.5m	Lithic Xerorthent	Available K pH (IAB) EC (IAB) Total C (IAB) Extractable cations (IAB)	Insignificant Insignificant Increased Increased Increased	- - Release of soluble inorganic ions following burning Formation of black C as a result of low fire Low fire severity, and addition of ash and its subsequent mixing in the soil	Alcañiz et al. (2016)
Scots pine moist forest	Southern Poland	High severity, WF	Sapri-Dystric Histosol	Total N pH S OM Base Cations	Decreased Increased Decreased Decreased Increased	Losses through volatilization Complete oxidation and volatilization of minor compounds Burning of organic matte	Dzwonko et al. (2015)

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Remote estimation of the relationship between erosion risk classes using the Neutrosophic Fuzzy-AHP and RE-OSAVI for Sinop Province, Turkey

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Abstract

With the population growth in the world, pressure on the lands is increasing. Erosion, which is a natural process that formed spontaneously, can occur through human activities such as unsuitable land use and destruction of land cover. To decrease the role of erosion, it's crucial to determine the quantity of soil erosion of a region. For this, many methods have been progressed and one of them is called the Neutrosophic Fuzzy-AHP approach. With this study, the erosion risk classes were created with the use of Neutrosophic Fuzzy-AHP and Linear Combination Technique (LCT) using the 7 criteria such as geology, land cover, land use, slope, depth, precipitation, and erodibility of the Sinop Province lands and observed the statistical relationship between the erosion susceptibility index values and Red-Edge Optimized Soil Adjusted (RE-OSAVI) vegetation index values derived from Sentinel-2A image. Results have been shown that with the 0.8101, 0.8138, 0.856, and 0.8179 r^2 values of RE-OSAVI have a high relationship between the erosion susceptibility index values for the low, medium, high, and very high erosion classes, respectively. From the results of this study, we have concluded that, to detect or monitor the soil erosion risk potential using the spectral vegetation indices is encouraging. It has been also recommended that spectral vegetation indexes on different vegetation types and areas on a broad scale can be evaluated using the abilities of Sentinel-2A and ESA-SNAP tool for future studies.

Keywords: Neutrosophic Fuzzy-AHP, erosion risk, Linear Combination Technique, RE-OSAVI, Sentinel-2A.

Introduction

Soil degradation is defined as descending of soil functions or loss of soil functions and it's getting a more serious threat for world terrestrial ecosystems, increasingly. Soil erosion is one of the most crucial reasons to cause soil degradation (Issaka and Ashraf, 2017). Fragmentation, transportation, and accumulation of soil in another place with the factors such as water, wind, glacier, and gravity considered as soil erosion in general. Erosion is increasing as a result of high slope, heavy rainfall after long dry periods, soil properties, topography, climate changes, inappropriate land use and land cover elements. In normally, soil erosion is a natural process that formed spontaneously in the absence of human influence. However, inappropriate land use comes into question with the increase of human influence on natural resources and because of this, the amount of soil erosion has advanced. It has reached a level that causes serious damage to the ecosystem. In order to take decisions to reduce its effect, it is necessary to determine the amount of soil erosion of an area. Many formulas have been developed for this. One of these formulas is the most used method in the world, Revised Universal Soil Loss Equation (RUSLE) (Ranzi et al., 2012). Lately, with the developed techniques such as Geographical Information Systems (GISs), Remote Sensing (RS) and Linear Combination Technique (LCT), by using Multi Criteria Decision Analysis (MCDA) based on Analytical Hierarchic Process (AHP) methods which have been advanced by Saaty (1980), erosion risk areas can be observed and assessed successfully. Experts assess the criteria in the pairwise comparison matrix in AHP method which is one of the most used MCDA methods by giving the exact numbers changing between 1-9 according to the scale that is improved by Saaty. But, in real life problems, the human brain can be inadequate to decide on uncertain circumstances with definite numbers (Özkan et al., 2020). As a result of this, fuzzy logic has been evolved by Zadeh (1965), besides, by Buckley (1985), combination of AHP and fuzzy sets methods have been progressed for uncertain status. One of them is a recent method called as Neutrosophic Fuzzy-AHP (NF-AHP) that was improved by Radwan et al., (2016). The correlation between vegetation indexes like RE-OSAVI or NDVI and plant green area reflectance is related with the chlorophyll content of the leaves (Barnes et al., 2000). So, the erosion risk areas can be reliably predicted. That's why, to forecast whether soil survey studies are necessary, it should be analyzed if spectral vegetation index-based practices are convenient and trustworthy in observing the tendency of erosion.

With this current study, it was aimed to determine the erosion risk classes of Sinop Province with the use of Neutrosophic Fuzzy-AHP approach and to reveal statistical relationship between RE-OSAVI values produced from Sentinel-2A satellite image and erosion susceptibility index values.

Material and Methods

Description of the study area

The study area is the Sinop Province lands, located in the Western Black Sea Region of the Black Sea Region of Turkey (Figure 1).

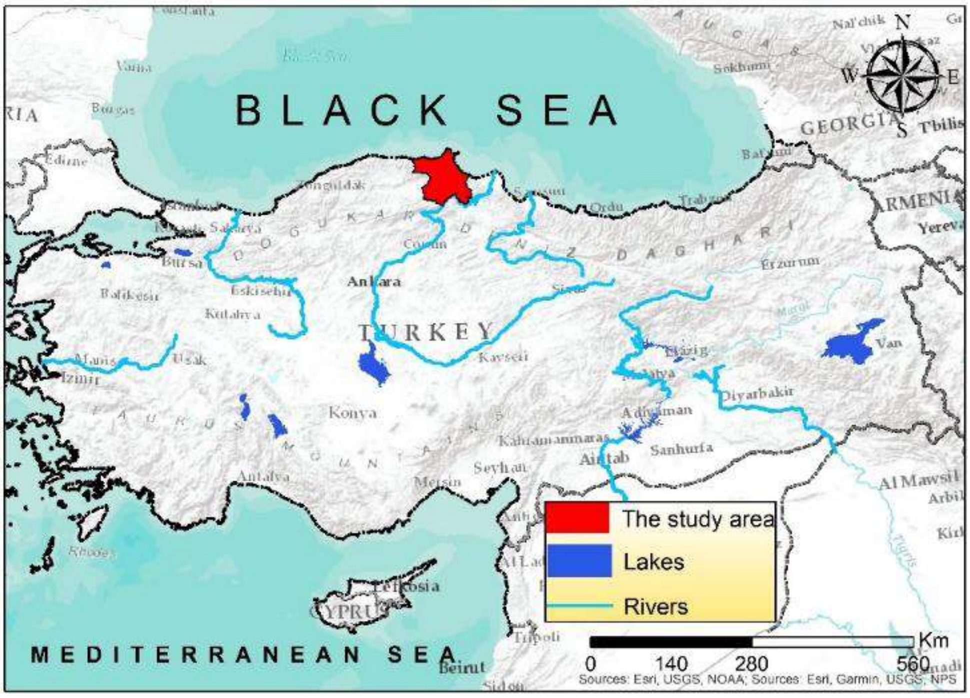

Figure 1. The location map of the study area

Total study area is about 586200 ha and coordinated between 41° 10' 12" -42° 05' 19" N latitudes and 34° 15' 37" -35° 25' 54" E longitude. Sinop Province is surrounded by the Black Sea in the north, Samsun in the southeast, Çorum in the south and Kastamonu in the west. According to the Sinop meteorological station located in the study area, the average annual temperature and rainfall are 14.2 °C and 686.6 mm, respectively. The lowest and the highest elevations of the province are 0 m and 1860 m above the sea level. In this study, a Sentinel-2A satellite image (with WGS84 datum) dated Sun Aug 21st, 2022, of the Sinop Province lands was used. Satellite image was obtained from the United States Geological Survey (USGS) open access center (https://earthexplorer.usgs.gov/). Multispectral Sentinel-2A satellite sensors have a spatial resolution of 10 m in 4 bands, 20 m in 6 bands, and 60 m in the other 3 bands (Dengiz et al., 2022).

Method

Neutrosophic Fuzzy-AHP

In this study, a hybrid model named NF-AHP which was advanced by Radwan et al., (2016) was implemented to create the erosion risk classes of Sinop Province. Neutrosophic set is a preferable alternative comparing the fuzzy sets where indeterminacy cases consist of. A neutrosophic set represented by three factors (T, I, F). (T) is the degree of truthfulness-membership function, (I) is the indeterminacy-membership function and (F) is the falsehood-membership function. The steps of determination of each erosion risk criteria's weights in this study as given below:

Step 1. To create a hierarchy of the criteria of erosion risk classes were defined of the decision-making problem (Radwan et al., 2016).

Step 2. To confront the criteria, the scale suggested by Radwan et al., (2016) was used and a pairwise comparison matrix was created (Kaya et al., 2022) for erosion risk.

Step 3. To check the consistency of the pairwise comparison matrix in this study, Consistency Ratio (CR) which was improved by Xu et al., (2014) was applied.

Step 4. To determine erosion risk criteria, the normalization process which is advanced by Saaty (1977) was applied to the consistent pairwise matrix (Radwan et al., 2016).

Step 5. After the normalization process, sums of rows of the normalized pairwise matrix were divided by the number of parameters (Kaya et al., 2022).

Step 6. Afterwards, the defuzzification process was applied to the neutrosophic weights (Kaya et al., 2022) of erosion risk criteria.

Step 7. At last, normalization operation was applied to the deneutrosophied weights (Aydın et al., 2018).

After determination of the criteria's deneutrosophied weights, Linear Combination Technique (LCT) was used to produce the interpolation map of the erosion risk classes. 7 criteria such as geology, land cover, land use, slope, depth, precipitation, and erodibility were used to create erosion susceptibility map of the Sinop Province, Turkey. In LCT, each parameter considered in the creation of an erosion susceptibility map has been classified into sub-parameters. Weight values between 1 and 4 are given to the classes belonging to the sub-parameters under consideration. The weight values given for these classes take the value 4 if the erosion susceptibility level is high and take the value 1 if the erosion susceptibility level is low (Demirağ Turan et al., 2020). How to calculate total erosion susceptibility index was given as follows (Eq.1):

$$S = \sum_{i=1}^{n} W_i . X_i \qquad (1)$$

Where, S: total erosion susceptibility index, W_i : weight value of i parameter, X_i: sub-criterion score for i parameter, and n = total number of parameters considered.

Red-edge optimized soil adjusted vegetation index (RE-OSAVI)

An updated type of the Soil Vegetation Index (SAVI) family which is advanced by Rondeaux et al., (1996) is named as Red-edge optimized soil adjusted vegetation index (RE-OSAVI). How to calculate RE-OSAVI was given as follows (Eq. 2):

$$\mathrm{RE-OSAVI} = (1 + 0.16) \times [(\mathrm{NIR} - \mathrm{REdge})/(\mathrm{NIR} + \mathrm{REdge} + 0.16)] \qquad (2)$$

RE-OSAVI provides the supplementation of the red-edge band (705 nm) in place of the red band (670 nm) which minimizes the impact of the sub-mass on the red wavelength spectral reflection. This feature makes RE-OSAVI more susceptible to determine the plant biomass reliably. The RE-OSAVI was calculated using the ESA-SNAP 8.0 tool in Sentinel-2A satellite image of Sinop Province.

Results and Discussion

Distribution of erosion risk classes

In this study, a total of 432 surface (0-20 cm) soil samples were taken from the agricultural areas within the boundaries of the study area, mostly according to the grid system with 2.5 x 2.5 km intervals (Demirağ Turan et al., 2020). The 1st force of Inverse Distance Weighted (IDW) created the most appropriate model (RMSE: 0.5195) to produce the interpolation map of the erosion risk (Figure 2).

Erosion risk map was produced by evaluating all the parameters obtained separately with the MCDA approach and LCT. In the present study, land cover (0.3148) and slope (0.2076) were detected as the criteria with highest weight scores. It can be explained why land cover and slope criteria have the highest weight scores. Soil erosion risk increases with the lack of land cover percentage, because the main problem is runoff here. In particular, along the dry season, the first step needs to be taken by managing to decrease the sediment quantity in the rivers (Kairis et al., 2015). In addition, Demirağ Turan and Uzun (2021), in one of their studies have noticed that the areas where land cover is not capable of resisting the erosion or less, and high slopes areas are very risky erosion areas. With the 0.0865 weight score, geology was determined with the lowest weight score. Weights of the other criteria of the research area such as land use, erodibility, soil depth and precipitation have been found as 0.1086, 0.0996, 0.0931, 0.0898 and 0.0865, respectively.

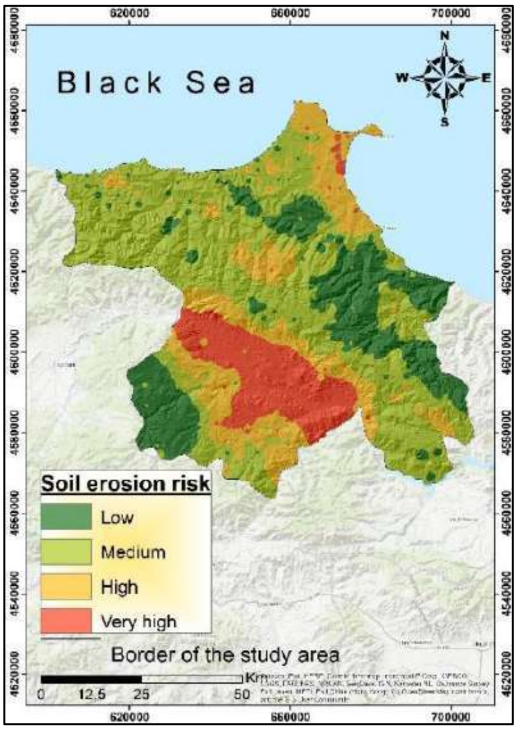

Figure 2. Soil erosion risk map of the study area

The relationship between erosion risk classes and RE-OSAVI

The comparisons have shown that the low, medium, high, and very high erosion risk classes of the Sinop Province have a powerful relationship between the RE-OSAVI values. The r^2 values were obtained as 0.8101, 0.8138, 0.856, and 0.8179 for low, medium, high, and very high erosion risk classes, respectively (Figure 3).

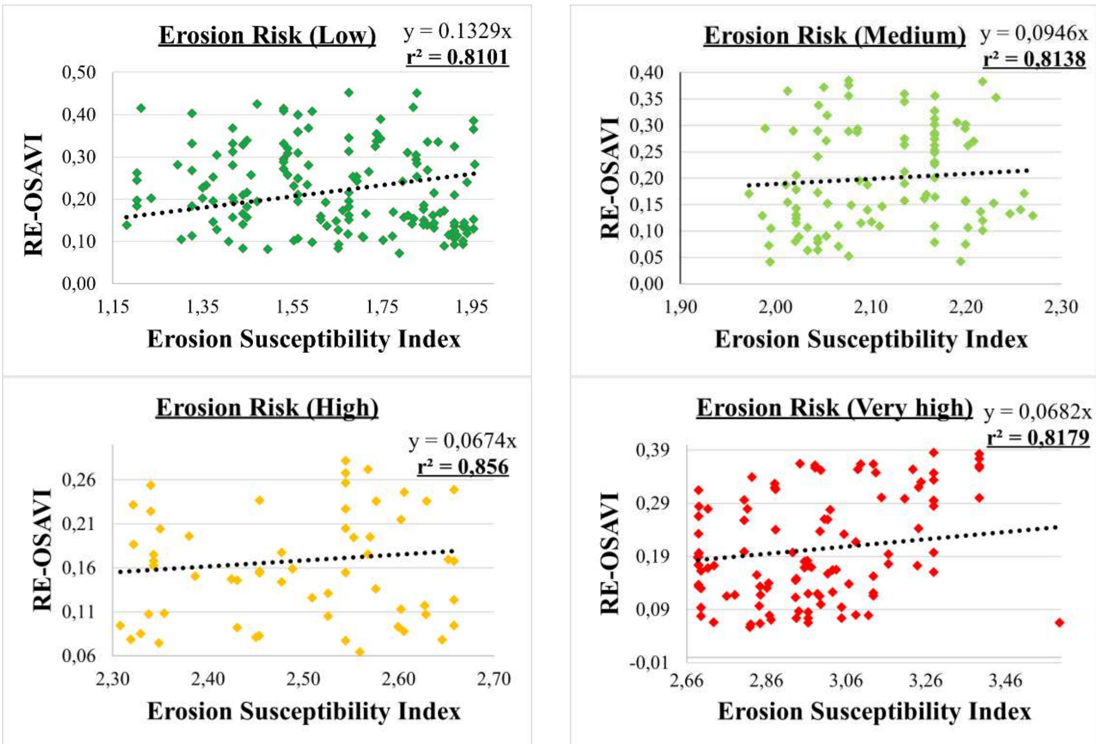

Figure 3. r^2 values of each erosion susceptibility index values of Sinop Province and RE-OSAVI values obtained from Sentinel-2A satellite image dated Sun Aug 21st, 2022

The CORINE-2018 land use land cover map of the study area was given in Figure 4. According to this map, the south part of the study area is covered by forest with the 60% and 20% of the northwest part of the study area is covered by unirrigated agricultural areas (Demirağ Turan et al., 2020). But when the study area is evaluated in terms of slope, the area of approx. 555680 ha (95%) has a high percentage of slope in general which is one of the most important factors triggering erosion (Figure 4).

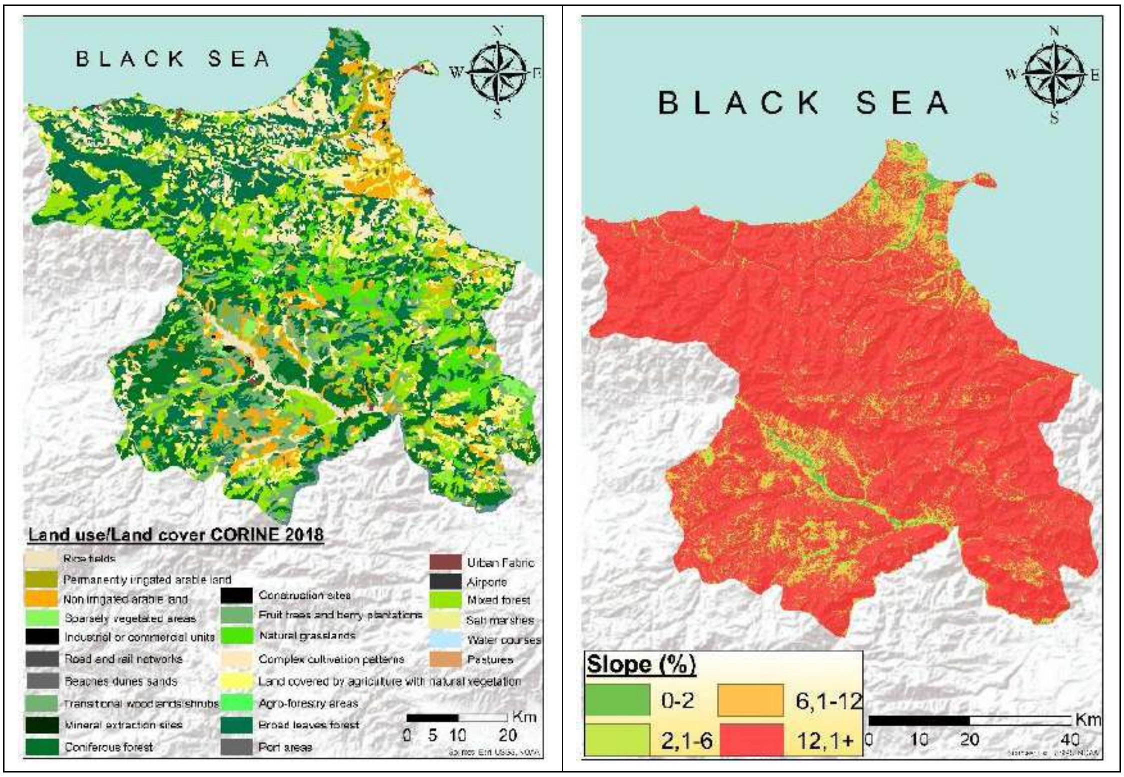

Figure 4. CORINE-2018 land use land cover map and slope map of the study area

Thus, this situation has been determined by RE-OSAVI vegetation index and has been interpreted as a reason why erosion susceptibility risk classes and RE-OSAVI have a strong relationship. Because the study area is located in the black sea region, with intense vegetation cover thanks to high precipitation, the possibility of erosion is low and moderate for the approx. 60% of the study area. Demirağ Turan et al., (2020) has reported that in one of their works, especially the areas where the land cover is weak, and slope is high, agricultural areas and the poor pasture lands are the most sensitive areas to erosion. Distribution map of the RE-OSAVI values obtained from Sentinel-2A satellite image was given in Figure 5.

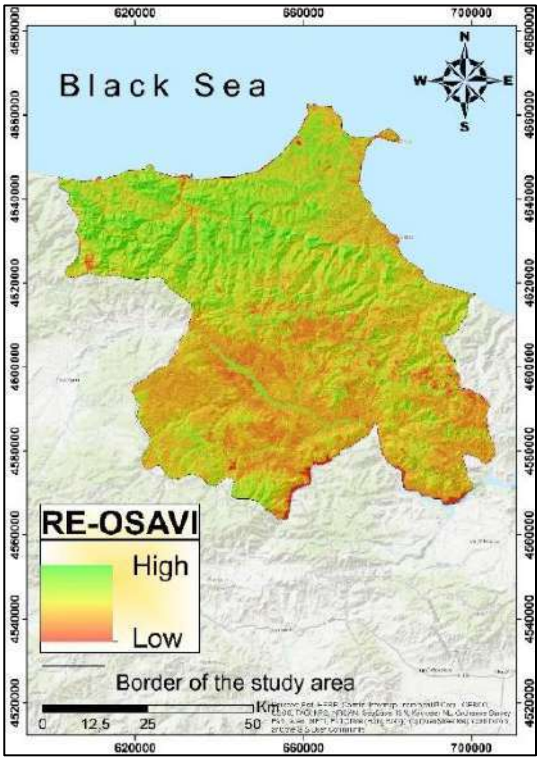

Figure 5. Distribution map of the RE-OSAVI values obtained from Sentinel-2A satellite image dated Sun Aug 21st, 2022

Conclusion

With this study, the statistical relationship between erosion risk classes for Sinop Province lands and the Sentinel-2A derived RE-OSAVI values, and remote estimation of the erosion risk potential has been observed. In this study, it has been concluded that the most accomplished results for the RE-OSAVI were found for the areas which have high (r^2=0.856) and very high (r^2=0.8179) erosion risk potential. Besides that, this study showed that the spectral abilities of Sentinel-2A satellite sensors can be used in further studies to be made in the future with the ESA's Sentinel Applications Platform (SNAP) image processing tool. Consequently, the results have shown that the Sinop Province lands were strongly symbolized by both the erosion risk classes and the RE-OSAVI from Sentinel-2A derived, and that erosion susceptibility index model successfully represented the Sinop Province lands due to by using RE-OSAVI, vegetation density can be determined reliably. It was suggested that vegetation indices can be used to predict erosion risk especially in areas with high slopes and difficult to access and ground control.

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Review of the phytoremediation potential of *Sedum plumbizincicola* for the remediation of contaminated soils

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Abstract

Natural and anthropogenic activities including industrial/agricultural wastes disposal, mining, smelting ores, sewage application to agricultural soils and other waste-generating activities that produce toxic pollutants have become a serious environmental concern in the recent decade. The amount of polluted soils has been increasing in tandem with the rising global population and the spread of urban areas and this have affected agricultural productivity globally. While several methods has been found and adopted for the remediation of contaminated soils, phytoremediation is perceived to be significantly cost-effective and environmentally safe. Although its major setback is the fact that the process is slow. Scientists across the world are working to tirelessly to discover plant species that would make Phytoremediation a must-go-to for remediation processes. Quite a large number of hyperaccumulator plants already exists but the quest to get a more suitable plant with high adsorption capability still makes the search going. The *Sedum plumbizincicola* was recognized in the year 2005 in a Zn-Pb region near a city called Zitong in the western province of Zhejiang, China and has since been used by scientists to clean up the soil. According to a study by Violina (2020), this plant thrives on soils with high levels of heavy metals (2540.8% Zn, 2429.3% Pb, and 51.5 mg/kg Cd). This paper gives an overview of the existence of this plant and its potential for the cleanup of contaminated soils by a critical review of existing literatures.

Keywords: Phytoremediation, Sedum Plumbizincicola, Heavy Metals, Polluted Soils, Soil Cleanup, Sustainable Environment.

Introduction

Soil contaminants like the heavy metals constitute a deep-rooted threat to our environment since they cannot be broken down by any physical or biological mechanism which remains present in soils for a long time (Suman et al., 2018). With the increasing rate of soil degradation, It is required to adopt remediation measures in order to minimize the polluted land and prevent toxic elements from entering our environment at high concentration (Hasan et al., 2019). Plants can reclaim damaged soil and maintain soil fertility by extending their root systems into the soil profile and establishing an ecosystem in the rhizosphere. This allows the plants to accumulate heavy metals even when they are present in very low concentrations and adjust the bioavailability of these metals (Jacob et al., 2018; DalCorso et al., 2019). Utilizing plants to extract and eliminate elemental contaminants from our soils, or to lessen the bioavailability of these pollutants in the soil, is an example of the plant-based strategy known as phytoremediation (Jacob et al., 2018). For phytoremediation to be successful, plants must have substantial biomass, great heavy metal phytoremediation potential, and rapid growth rates (Kramer, 2018).

The plant group hyperaccumulators are typically put to use for this purpose as a result of their high metal tolerance in addition to their capacity to uptake and transport heavy metals in their above-ground parts (Bech et al., 2012). Quite a large number of hyperaccumulator plants already exist (>500). Of this amount, 2 exist for Cadmium, 5 for Asernic, 12 for Manganese, 12 for Zinc, 14 for Lead, 20 for Selenium, 30 for Cobalt, 32 for

Copper, and 450 species exist for Nickel (Van der Ent et al., 2015). In the year 2005, the plant *Sedum plumbizincicola* (Crassulaceae) was first discovered by X. H. Guo and S. B. Zhou ex L. H. Wu. The specific descriptor "plumbizincicola" refers to the fact that the plant was found in parts of western Zhejiang Province, China, that are rich in lead and zinc deposits. Some researchers have documented that the species was a hyperaccumulator of both cadmium and zinc (Wu et al., 2012; Wu et al., 2018; Violina, 2020). The *Sedum plumbizincicola* has the ability of extracting significant amounts of Zn and Cd from contaminated soils, suggesting that it could be a highly effective plant for phytoextraction of metal-affected soils (Ma et al., 2013). The plant *Sedum plumbizincicola* can be described as a heavy metal-tolerant plant which grows regularly in most heavy metal-contaminated soils (51.5 mg/kg Cd, 2429.3 mg/kg Pb, and 2540.8 mg/kg Zn) (Violina, 2020).

Origin and History of *Sedum plumbizincicola*

Sedum is a vast genus of flowering plants in the Crassulaceae family, whose species are generally referred to as stonecrops. The genus is said to have more than 400 species and majority of them are spread across Asia, Europe and North America. More than 60 species of Sedum are found primarily in Asia and Europe, and the most popular species in Europe include *Sedum reflexum, Sedum album, Sedum dasyphyllum, Sedum acre, and Sedum hispanicum* (Thiede and Eggli 2007).

Sedum species are utilized in numerous ways. While some serve as food for larvae, others function as butterfly host plants in the ecosystem (Ziegler and Escalante, Tarsicio 1964; Doyle, 2011). In an effort to identify metal hyperaccumulator plants, X. H. Guo et al., (2005) conducted extensive fieldwork in Zhejiang Province (Zn-Pb mining area) and gathered several specimens. Their research revealed the existence of rare, secluded populations of a plant superficially similar to Sedum alfredii but with 4-merous flowers. Along with four additional species, these were discovered in the counties of Lin'an and Chun'an. Comparing these specimens according to the taxonomy of Sedum in the Flora of China, Zhejiang, Jiangsuo, Anhui, as well as Jiangxi (Fu and Ohba 2001; He 1993; the Jiangsu Institute of Botany 1982; Xue 1986; Jiangsu Institute of Botany 2004), the scientists determined that the observed plant population were distinct from *Sedum alfredii* and argued for their classification as a separate species, *Sedum plumbizincicola* (Wu et al., 2006).

Table 1: The Taxonomy (Scientific Classifiaction) of *Sedum plumbizincicola*

Kingdom	Plantae
Class	Angiosperms
Order	Saxifragales
Family	Crassulaceae
Sub-Family	Sedoideae
Genus	Sedum

USDA, 2022

Characteristics of Sedum Plumbizincicola

Sedum plumbizincicola is a perennial herbaceous plant which has yellowish green appearance. Its roots are fibrous, while its rhizomes are horizontal, slender, and often dark brown in color, measuring 7cm in length and 4-8mm in diameter. Leaves on the branches of the foliage are alternating and typically deciduous, and they are tightly packed toward the stem's distal end. This plant was discovered to be flourishing in typically sandy, acidic, heavily leached, and frequently shallow soils. Because of its impressive hyperaccumulative capacity for zinc and cadmium, this species has great potential as a taxon for use in phytoremediation of heavy metal polluted soils (Wu et al., 2006).

S/N	Study	Author/Year	Elements	Summary of Findings
1.	Phytoremediation potential of wheat intercropped with different densities of *Sedum plumbizincicola* in soil contaminated with cadmium and zinc	(Zou et al., 2021)	Cd, Zn	Soil contaminated with Cd and Zn was more effectively remedied when *S. plumbizincicola* was intercropped with wheat. Soil pH, Cd, and Zn contents all reduced as a result of this plant combination, and these effects only grew worse as the amount of S. plumbizincicola planted increased.
2.	Cadmium uptake and transfer by *Sedum plumbizincicola* using EDTA, tea saponin, and citric acid as activators	(Xue, et al, 2021)	Cd	EDTA, citric acid and tea saponin increased soil accessible Cadmium, *S. plumbizincicol*a biomass, and Cd uptake in Cd-contaminated soil remediation. Its mixture with the various activators lowered soil total Cd by a percentage of 4.64–48.4, its ability to phytoremediate Cd-contaminated soils with EDTA, TS, and CA. In instance, EDTA and *S. plumbizincicola* can remediate Cd-contaminated soil economically and effectively.
3.	Evaluation of phytoremediation potential of five Cd hyperaccumulators in two Cd contaminated soils	(Huang et al., 2020)	Cd	Apart from *S. plumbizincicola*, the accumulator plants studied here showed greater growth in the acidic soil, with a biomass increase of 19.59–39.63% compared to the alkaline soil. High Cd absorption in *S. plumbizincicola* plant tissue (541.36mg kg1) contributed to its success in the alkaline soil.
4.	Phytoremediation potential of *Sedum plumbizincicola*	(Angelova, 2020)	Zn, Pb, Cd	*Sedum plumbizincicola's* properties varied greatly. Pb, Cd, Zn, Cu, Ca, P, Fe, Mn, and Mg accumulate in the leaves and roots, respectively. *Sedum plumbizincicola* hyperaccumulates cadmium, zinc, and lead and may be employed in phytoextraction of heavy metal contaminated soils resulting from its high leaf Cd, Zn, along with Pb concentrations, elevated translocation (TFZn – 4.21, TFCd - 2.11, TFPb – 2.72) and bioconcentration factors (BCFCd - 22.68, BCFZn - 2.20).
5.	Element Case Studies: Cadmium and Zinc	(Wu et al, 2018)	Cd, Zn	Phytoremediation with *S. plumbizincicola* is reported as a promising approach for the cleanup of mildly Cadmium polluted soils without having to suspend regular agricultural output, as shown by the result from a study of all previous field experiments.
6.	The hyperaccumulator Sedum Plumbizincicola harbors metal-resistant endophytic bacteria that improve its phytoextraction capacity in multi-metal contaminated soil	(Ma et al., 2015)	Cd, Pb, Zn	The inoculation of ACC using species, particularly B. pumilus E2S2, tremendiously boosted Cd and Zn (18%) mobilization in thd soil and ensuing tissue uptake by S. plumbizincicola. Beneficial characteristics of plants include the creation of chemicals that promote plant growth, such as siderophore, IAA, and ACC deaminase, or the P solubilization.
7.	Long-term Field Phytoextraction of Zinc/Cadmium Contaminated Soil by Sedum plumbizincicola under Different Agronomic Strategies	(Deng et al., 2015)	Cd, Zn	Soil overall Zn and Cd levels decreased markedly after a prolonged phytoextraction of *S. plumbizincicola* intercropped with maize but did not affect the cereal crop productivity. With higher plant density and increasing remediation time, phytoremediation efficiency increased. This cropping method combines sufficient agricultural productivity with phytoextraction of soil heavy metals.

8.	Effects of organic amendments on Cd, Cu, and Zn bioavailability in soil with repeated Phytoremediation by *Sedum plumbizincicola*	(Wu et al., 2012)	Cd, Cu, Zn	The traditional organic materials (clover with rice straw) were used to accelerate metal uptake a polluted soil utilizing *Sedum plumbizincicola* after repeated phytoextraction. *S. plumbizincicola* had greater Cd contents (by factors of 1.92 and 1.50, respectively) in soil amended with blended rice straw or ground clover than in control soil. A treatment with 3 mmol kg1 EDDS raised Cu, Cd, and Zn concentrations by factors of 60.4, 1.67, and 0.27, respectively.
9.	Effects of multiple heavy metal contamination and repeated phytoextraction by *Sedum plumbizincicola* on soil microbial properties	(Jiang et al., 2010)	Cd, Zn	The findings suggest that *S. plumbizincicola* has the ability to remove Cd and Zn from polluted soils. They also show that using phytoremediation had a positive impact on the hydrolase and microbial activities of the soil, with the soil's quality being successfully restored by the metal phytoextraction process.

Proving Methods of Enhancing S. Pumbizincicola Potential for Phytoremediation.

S. Pumbizincicola is a perennial plant. It can be harvested twice or thrice yearly. However, maintaining a stubble length of 3 to 5 centimeters while cutting has been shown to increase vegetative reproduction (Li et al. 2009). Within the past few years, significant amount of endeavor have been invested toward investigating the viability of simultaneously grain safety and phytoremediation of heavy metal-contaminated soils in China's major food crop areas using *S. plumbizincicola*. The ability of *S. plumbizincicola* to tolerate shade makes it suitable for use as an intercrop with tall straw plants like maize, wheat, sorghum, together with other similar species. This cropping technique produces enough food and extracts soil heavy metals. In their study, they found that long-term phytoextraction using S. plumbizincicola intercropped with maize reduced soil total Zn and Cd but did not alter cereal crop productivity (Deng et al. 2015; Zou et al., 2021).

Additionally, nutrient mangement in soils contributes to the effectiveness of *S. Pumbizincicola* in the cleanup of contaminated soils. For example, the study that was carried out by Shen et al. (2011) revealed that treating the soil with urea and DCD (dicyandiamide, which is an inhibitor of nitrification) was advantageous for the phytoextraction of cadmium by *S. plumbizincicola.* The S. plumbizincicola grows better with sulphur fertilizer, and adding calcium magnesium phosphate (CaMgP) fertilizer minimizes available heavy metals in the soils solution in addition to the risk of contamination of vegetables cultivated afterward (Ren et al., 2013). Acidic soil suits *Sedum plumbizincicola.* For severely or extremely acidic soil, proper lime dose was suggested to benefit *S. plumbizincicola* growth and uptake of metal (Han et al. 2013).

Similarly, the utilization of conventional organic amendments may prove to be both efficient and eco-friendly to our ecosystem in the process of boosting the phytoremediation efficacy of Cd-contaminated soil. Consequently, increasing the bioavailability of metals by *S. pumbizincicola* can be accomplished with the help of organic materials that contain a variety of functional groups. From the investigation conducted by Wu et al., (2012), It was discovered that making amendments to the soil with powdered rice straw or clover powder enhanced the Cd amounts in the shoot of *S. plumbizincicola* by 1.92 and 1.71 times, respectively, relative to the soil that served as a control.

Conclusion

Being a perennial plant, *S. plumbizincicola* has prospects in future remediation of soil contaminated areas. It has been utilized successfully in phytoremediation of contaminated environments especially the elements Cd and Zn. While S. pumbizincicola can be found in a wide range of soil pH conditions at heavy metal contaminated sites, the higher soil Cd availability in alkaline soil makes it an ideal environment for the plant's growth and development, which in turn leads to high amounts of Cd being recorded in its tissues.

It is possible to improve S. plumbizincicola's efficiency in the remediation of heavy metals contaminated sites with the application of appropriate agronomic strategies, such as cultivation management, microbial inoculation, intercropping with other plant species especially plants belonging to the family Poaceae/Gramineae, crop rotation and soil nutrient management. On this note, research into evaluating the effectiveness of this plant in heavy metal remediation, identification of possible strategies that will increase its biomass and its adaptability across different soil types and regions of the world is warranted. This will give a combined advantages of phytoremediation of metal contaminated soil and the production of food in a secure environment.

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Effects of Conditioner Application on Dispersion Ratio in Clayey Soils

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Abstract

The objective of the present investigation is to find out the effect of incorporating of various inorganic and organic amendments Sources such as lime (L), zeolit (Z), polyacrylamide (PAM) and biosolid (BS) on the dispersion ratio. A bulk surface (0–20 cm depth) soil sample was taken from Samsun, in northern part of Turkey. Some soil properties were determined as follows; fine in texture, modarete in organic matter content, low in pH and free of alkaline problem. The soil samples were treated with the inorganic and organic materials at four different levels including the control treatments in a randomized factorial block design. The soil samples were incubated for ten weeks. After the incubation period, corn was grown in all pots. The results can be summarized as organic and inorganic matter treatments decreased dispersion ratio and soil erodibility. Effectiveness of the treatments varied depending on the types and levels of organic and inorganic materials.

Keywords: Dispersion Ratio, Soil Properties, Soil Amendment, pH.

Introduction

Soil physical and chemical properties are important for favorable conditions for combating erosion and crop production. Many practices are known to influence soil physical and chemical properties. These include crop type (Dai et al., 2018), cultivation (Arnhold et.al., 2014) and application of organic residues (Gantzer et al., 1987; Gajic et al., 2006; Gülser and Candemir, 2012; Cercioğlu et al., 2014). Soil degradation involves destruction of soil structure due to loss of organic matter by intensive agriculture practices (Gülser and Candemir, 2006).

Most studies showed that amelioration of soil physical and chemical properties largely based on increases of organic matter content in the soils with using organic and inorganic amendments. Effects of application of organic residues and inorganic amendment soil physical properties are often related to increases in soil organic matter (Özdemir, 1993; Haynes, 2000). Soil organic matter is a dynamic component of the soils that controls many physical, chemical and biological properties of the soil (Carter, 1996). The susceptibility of soil to erosion often increased for soil under annual crops, such as wheat or corn (Angers et al., 1999). Many studies have showed a clear relationship between total soil C and soil erodbility, water retention and hydraulic conductivity (Özdemir, 1993). Benbi et al. (1998), demonstrated that amending coarse-textured soils with conditioners increased organic carbon content and improved saturated hydraulic conductivity, water stable aggregation and water retention. Addition of plant residues into soils is be an excellent enhancer to ensure a sufficient level of SOC and helps preventing soil erosion (Mikha and Rice 2004; Novak et al. 2009). It has been known as one of the best management practices to improve soil nutrients and water holding capability, decrease soil acidity, maintain soil aggregation (Grandy et al. 2002), and reduce the dosage of chemical fertilizers. Lime application improves soil structure in heavily textured soils, thus increasing water infiltration and the ability of roots to penetrate the soil, reducing susceptibility to erosion (Özdemir,1993).

Polyacrylamide (PAM) dissolved in irrigation water (10 mg kg^{-1}) has been extensively used to prevent erosion and increase infiltration in furrow irrigation (Lentz and Sojka, 2000; Lee et.al.,2015). Polyacrylamide with high molecular weight and moderate anionic charge density was found to be most effective in preventing runoff and increasing aggregate stability (Green et al., 2000). Similarly, PAM in concentrations of 5, 10, and 20 mg L^{-1} were found to be effective in controlling runoff and erosion from loamy loess and a grumusol during sprinkler irrigation (Flanagan et al., 1997). Soil losses in all the PAM treatments were significantly lower than those in the control treatment (Levy et al., 1992).

The objective of this investigation is to determine the effects of incorporating various organic and inorganic amendments such as lime (L), zeolit (Z), polyacrylamide (PAM), and biosolid (BS) into acidic clayey soil on the dispersion ratio.

Material and Methods

The soil sample (0-20 cm depth) used in this experiment was taken from field where cultivation is being made in the Köybucak region of Terme district of Samsun province. The lime (L), biosolid (BS), polyacrylamid (PAM) and zeolit (Z) were obtained from different institutions.

The soil samples, after the lime requirements done in 0, 50 and 100 % levels were treated with the inorganic and organic residues at four different levels (BS 0.0, 2.0, 4.0 and 8.0 %; Zeolit 0.0, 0.5, 1.0 and 2.0 %; PAM; 0.0, 15, 30, 60 ppm) including the control treatments, and each treatment was replicated two times in a randomized factorial block design [(3x3x4)x2]. All pots were incubated for ten weeks. After incubation period, corn was grown in all pots. After reaping of the corn, treated soil samples were rubbed by hand and sieved from 2 mm openings sieve. Some physical and chemical properties of soils were determined as fallows; soil organic matter content by a modified Walkley-Black method (Nelson and Sommers, 1982); soil texture by hydrometer methods (Demiralay, 1993) lime requirement by SMP method (Kacar, 1995); pH in 1:2.5 (v:w) soil:water suspension by pH meter (Black, 1965); exchangeable Na by ammonia acetate extraction and cation exchange capacity according to Bower method (U.S. Salinity Laboratory Staff, 1954). Dispersion ratio value was determined according to Bryan method (Bryan, 1968). Statistical analyses of results were done by SPSS computer program.

Results and Discussion

Soil Properties

Some physical and chemical soil properties are given in Table 1. Soil properties can be summarized as; fine in texture (clayey), moderate in organic matter content, low in lime content, low in pH and free of alkaline problem (ESP <15 %), 21.2 meq $100g^{-1}$ of CEC (Soil Survey Staff, 1993).

Table 1. Some physical and chemical properties of the soil

Sand (S), g g-1	0.233
Silt (Si), g g-1	0.365
Clay (C) , g g-1	0.402
Textural class	Clay
pH (1:2.5)	5.4
Organic matter content (OM), %	2.93
Cation exchange capacity (CEC), meq 100g-1 oven-dried soil	21.2
Exchangeable sodium percentage (ESP), %	6.40

Dispersion Ratio

The effects of amendments on the dispersion ratio values depend on the type and level of amendment materials. These situations were given in Table 2. It was observed that the dispersion ratio values of all soils decreased significantly depending on lime and amendment materials. It was suggested that, the increasing dose application of amendment materials into acidic clayey soil decreased dispersion ratio values. It was found that without lime application had the lowest effect on the dispersion ratio when compared with the other applications (Table 2). Also, decreases in the dispersion ratio (as a mean value) according to the lime addition levels were presented in Table 2. It is clearly seen that, zeolit application decreased the dispersion ratio lower than the other amendments. Variance analysis results on the dispersion ratio values are given in Table 3. As shown in this table, dispersion ratio values depending on the lime levels were significantly different at $p<0.01$. The effect of amendment materials (BS, Z and PAM) on the dispersion ratio and their levels were statistically significant. On the other hand, dispersion ratio values according to soils were different at the end of the corn grown period. Mean of square values of the amendment materials ($p<0.01$) and their levels ($p<0.01$) were statistically significant. As shown in Table 3, also interactions between lime-amendment, lime-level, amendments-level, and lime-amendment-level were significant ($p<0.01$). The comparison of mean values statistically are given in Table 4. The differences among the dispersion ratio values were significant at $p<0.01$.

Table 2. Dispersion Rate Values of Soils

Lime doses	Amendments	Doses			
		0	1	2	3
	Biosolid	9,51	5,88	4,62	3,53
K_0	Zeolit	9,51	7,06	7,06	4,71
	PAM	9,51	4,71	3,53	3,53
	Biosolid	5,88	4,48	3,53	2,35
K_1	Zeolit	5,88	5,88	5,70	4,71
	PAM	5,88	3,53	3,53	2,35
	Biosolid	8,24	7,06	4,71	3,53
K_2	Zeolit	8,24	5,88	4,71	3,53
	PAM	8,24	3,53	2,35	1,65

Table 3. Variance analysis of the erosion ratio

Sources	DF	SS	SM	F
Lime (A)	2	9.143	4.571	146.128***
Amendments (B)	2	64.801	32.401	1035.697***
A*B	4	361.681	120.560	3853.733***
Amend. Levels (C)	3	17.185	4.296	137.329***
A*C	6	12.601	2.100	67.131***
B*C	6	11.276	1.879	60.074***
A*B*C	12	16.372	1.364	43.612***
Error	70	2.252	031	
General	107			

*, $p < 0.05$; ** : $p < 0.01$; ***, $p < 0.001$

Conclusion

Using different organic and inorganic amendments as being in present study on acidic and erosion susceptible soils is an effective method to reduce soil erodibility and amend soil properties. Effects of amendments vary depending on conditioners type and application doses. By this way, soil losses decrease, degraded soil properties improve and thus soil quality increases.

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Recyclable organic amendments to improve soil quality

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Abstract

In this study, about a pot incubation experiment will be discussed, where four kinds of organic wastes (banana peel, egg-shell, tea waste, and vermicompost) were applied in a sandy loam soil. This study's main objective is to determine these amendments' effect on enhancing soil quality. The soil was treated with nine treatments such as C (control), BP (banana peel), ES (eggshell), TW (tea waste), VC (vermicompost) with two application rates of 4%, and 8% respectively. A randomized complete block design (RCBD) was used with three replicates for each treatment. After 38 days and 120 days of incubation, pH, electrical conductivity (EC), soil organic carbon (SOC), and soil organic matter (SOM) content of the air-dried soil were measured and these amendments showed significant results on soil properties. With increasing the application doses, soil pH increased in BP and ES, and slightly decreased in TW and VC-amended soil; EC was increased with increasing the application doses of each amendment. Both SOC and SOM content increased by the application of BP, TW, and VC, whereas there is no effect of ES on SOC and SOM. Regarding the incubation period, the pH of BP and ES-amended soil has significantly increased and slightly increased in VC-amended soil with time whereas, that of TW-applied soil has decreased. The effect of BP, ES, and VC was similar during 38 days and 120 days on soil EC; however, TW showed a significant role in improving soil EC with time. SOC and SOM both have increased over time in all of the amendments applied to the soil.

Irrespective of the incubation period, $BP_{4\%}$ and $ES_{4\%}$ were the best for increasing the pH of this nutrient-poor soil; $VC_{8\%}$ was the best option for improving EC. BP, TW, and VC three of these amendments significantly increased SOC and SOM content.

Keywords: Amendment, Electrical Conductivity, Incubation, Nutrient-poor, Organic Waste, Vermicompost.

Introduction

In recent times, using organic fertilizers has become popular to minimize several environmental issues caused by applying inorganic fertilizers. Most farmers apply inorganic fertilizers in their fields to meet the nutrient requirements of soil as they find it easier to regulate precisely the amounts of various nutrients added to the soil by inorganic fertilizers. Besides, their applications are easy, less time-consuming and labor-intensive compared to organic sources. In addition, inorganic fertilizers have an immediate effect on yield output compared to organic sources or fertilizers, which take time to decompose and release nutrients. But the matter of reality is that they are not as economically fit as using expensive commercial fertilizers in their fields for getting higher yields. In addition, it can pose a detrimental impact on the environment as they apply these substances continuously and indiscriminately because of a lack of proper knowledge about fertilization. That's why nowadays experts are encouraging farmers to use organic fertilizer as they have found it very easy to handle, cost-effective, and environmentally friendly. In this study, four types of organic amendments (banana peel, eggshell, tea waste, and vermicompost) were applied to soil to observe their effect on nutrient-poor sandy loam soil. The sandy soils have low soil nutrient contents, a negligible content of carbon (C) stock, and are acidic in reaction (Laghari et al., 2015). These amendments could be a better amendment for sandy and low fertile soils (Sial et al., 2019).

Soil organic matter is a key attribute of soil quality owing to its multidimensional role. It acts as a reservoir of plant nutrients and serves as a substrate for soil microorganisms. The overall general effect of organic matter is to improve soil's physical properties and finally aid in maintaining good soil tilth (Dutta et al., 2003).

Banana Peel is a rich source of starch, crude protein (6-9%) crude fat (38–11%) total dietary fiber, and Polyunsaturated fatty acids particularly Linoleic acid, α-Linoleic acid, pectin, essential amino acids, and macronutrients (K, P, Ca, Mg). It is also a good source of Lignin (6-12%) pectin cellulose (7.6 – 9.6%) hemicelluloses (6.4-9.4%) and galacturonic acid. Micronutrients (Fe and Zn) are also found in higher concentrations in peels compared to pulps (IJSRD, 2015).

Eggshell is a waste material from domestic sources such as poultries, hatcheries, homes, and fast food joints. Literature has shown that eggshell primarily contains lime, calcium (Ca), and protein (Tocan, 1999).

Tea waste contains nutrients such as N, P, K, and a low C:N ratio as compared to other organic amendments.

Vermicomposts are finely-divided mature peat-like materials with high porosity, aeration, drainage, water-holding capacity, and microbial activity which are stabilized by interactions between earthworms and microorganisms in a non-thermophilic process. Vermicompost contains most nutrients in the plant-available form such as nitrates, phosphates, and exchangeable calcium and soluble potassium (Moradi et al., 2014). Due to such high content of nutrients, these organic amendments can provide healthy nutrients to the soil instead of discarding them as waste. The objective of this study was to determine the effect of these amendments on improving soil health and its quality.

Material and Methods

Study area

The sample soil was collected from SRDI (Institute of Soil Science and Research Development) at the University of Chittagong, Hathazari, Bangladesh. Geographically, the studied area of Chittagong University extends between 22°30′ to 22°47′N latitude and 91°58′ to 91°79′E longitude. The soils under the present study are classified as Brown Hill Soils as general soil type. Topographical features were maintained more or less similarly during soil collection. Chittagong region has a sub-tropical climate and is characterized by long summers and short winters. Mean annual precipitation ranges from 2877 to 3842 mm and mean annual temperature varies from 25.5° and 25.7°C. The general information on the study soil and amendments are given in Table 1.

Table 1. Some psychochemical properties of soil and chemical properties of amendments

Properties	Soil	Banana peel	Eggshell	Tea waste	Vermicompost
Textural class	Sandy loam	-	-	-	-
pH	4.85	5.95	7.15	5.30	5.45
EC (mS)	0.103	1.892	0.3	1.086	3.79
OC	0.3956	24.21	1.28	20.43	9.08
OM (%)	0.68	41.74	2.208	35.22	15.65
Field capacity (%)	28.10	-	-	-	-
Maximum water holding capacity (%)	34.08	-	-	-	-

Experimental layout

A pot incubation experiment was carried out in the laboratory of the soil science department at the University of Chittagong (CU). The treatments were control (no organic amendment), and four organic amendments from different origins. The organic amendments were Banana peel (BP), Eggshell (ES), Tea waste (TW), and Vermicompost (VC). The amendments were applied at a rate of 4% and 8%. Therefore, there were nine treatments and three replications (9×3=27 pots). The experiment was arranged in a randomized complete block design (RCBD) (Table 3). All the organic amendments except the VC will be made by ourselves at home. The VC was prepared regularly in the SRDI of CU. That was collected from there.

Table 3: Arrangement of experimental pots

Treatment Number	Treatment name	Treatment symbol	Pot replication	Pot serial
1	Control	C	CR1, CR2, CR3	1, 2, 3
2	Banana peel 4%	$BP_{4\%}$	$BP_{4\%}R1$, $BP_{4\%}R2$, $BP_{4\%}R3$	4, 5, 6
3	Banana peel 8%	$BP_{8\%}$	$BP_{8\%}R1$, $BP_{8\%}R2$, $BP_{8\%}R3$	7, 8, 9
4	Eggshell 4%	$ES_{4\%}$	$ES_{4\%}R1$, $ES_{4\%}R2$, $ES_{4\%}R3$	10, 11, 12
5	Eggshell 8%	$ES_{8\%}$	$ES_{8\%}R1$, $ES_{8\%}R2$, $ES_{8\%}R3$	13, 14, 15
6	Tea waste 4%	$TW_{4\%}$	$TW_{4\%}R1$,$TW_{4\%}R2$,$TW_{4\%}R3$	16, 17, 18
7	Tea waste 8%	$TW_{8\%}$	$TW_{8\%}R1$,$TW_{8\%}R2$, $TW_{8\%}R3$	19, 20, 21
8	Vermicompost 4%	$VC_{4\%}$	$VC_{4\%}R1$,$VC_{4\%}R2$, $VC_{4\%}R3$	22, 23, 24
9	Vermicompost 8%	$VC_{8\%}$	$VC_{8\%}R1$, $VC_{8\%}R2$, $VC_{8\%}R3$	25, 26, 27

Incubation experiment

Exactly 315gm air dry weight soil was kept in each 500 mL plastic container with a lid. The 4 small (3mm diameter) holes were done on the lids for gas exchange. Exactly 12.6 **g** (4%) and 25.2 **g (8%)** from each of the four amendments were measured and mixed with soil thoroughly. Soils after amendment mix-up were kept in the lab under ambient temperature conditions. Frequently the soil samples were moistened with deionized water to bring them to 60% of WHC dry weight. Soil subsamples were taken from each of the 27 pots at **38** and **120 days** of incubation.

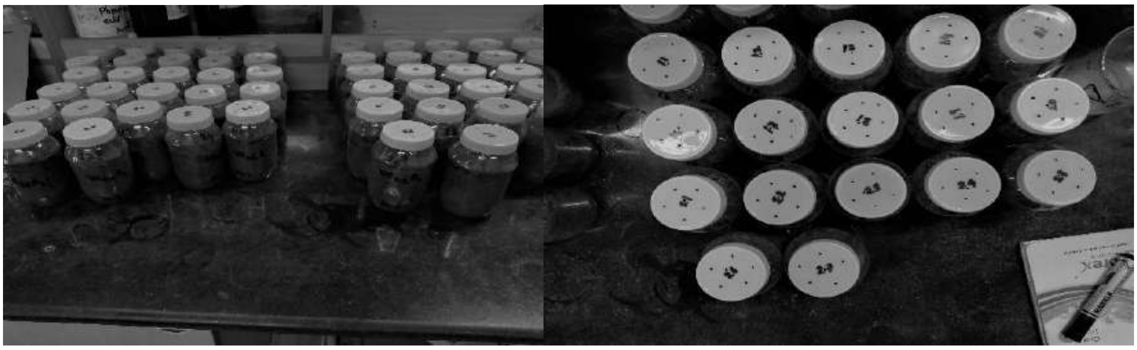

Figure 1: Incubated pots of 38 days (right) and 120 days (left)

Sample preparation for analysis

Soils of all the pots were spread over sheets to be air-dried after 38 days and 120 days of the incubation period. After being air-dried soils were crushed gently and sieved through a 2 mm sieve to be ready for laboratory analysis. The collected soil sample of 38 days of incubation was analyzed for various physicochemical parameters such as pH, EC, total organic carbon, and organic matter content. A similar analysis was also carried out for soil incubated for 120 days.

Figure 2: soil sample spread for being air-dried

Laboratory analysis

The laboratory analysis was performed on air-dried, 2mm sieve-passed soil. Soil pH was measured in 1:2.5 soil:water suspensions using a pH meter and EC (electrical conductivity) was measured on the supernatant of 1:5 soil:water suspension using a conductivity meter (Jackson, 1973).

Organic Carbon of the soil sample was determined by Walkley and Black's wet oxidation method as outlined by Jackson (1973). The organic matter of the soil sample was determined by multiplying the content of organic carbon with a factor of 1.724 (Piper, 1950).

Results and discussion

The result of the chemical analysis of soil samples is shown in tables and graphs respectively. During studies, we have performed experiments on the change in chemical parameters of soil incorporated with banana peel, eggshell, tea waste, and vermicompost. The obtained results are discussed as follows:

Effect on pH:

Soil pH refers to acidity and alkalinity. It is the measure of hydrogen ions (H^+) in the soil. Soil pH can also affect the cation exchange capacity (CEC) and anion exchange capacity (AEC) of soil (IJSRD, 2015). In the present study, the soil pH was found to be increased by the application of banana peel and eggshell. This shows that the alkalinity of soil increases due to the incorporation of these amendments and thus the AEC of soil increases. The AEC in turn benefits plant growth thereby providing extra nutrients to the soil. Whereas soil pH was observed to be decreased in tea waste and vermicompost-amended soil with a high application rate. There was a significant effect of banana peel and eggshell on increasing soil pH over time. A high rate of banana peel would be best for acidic soil; on the other hand, vermicompost for alkaline soil (8.17 and 5.33 in 120 days respectively) (Figure 3 & Table 4).

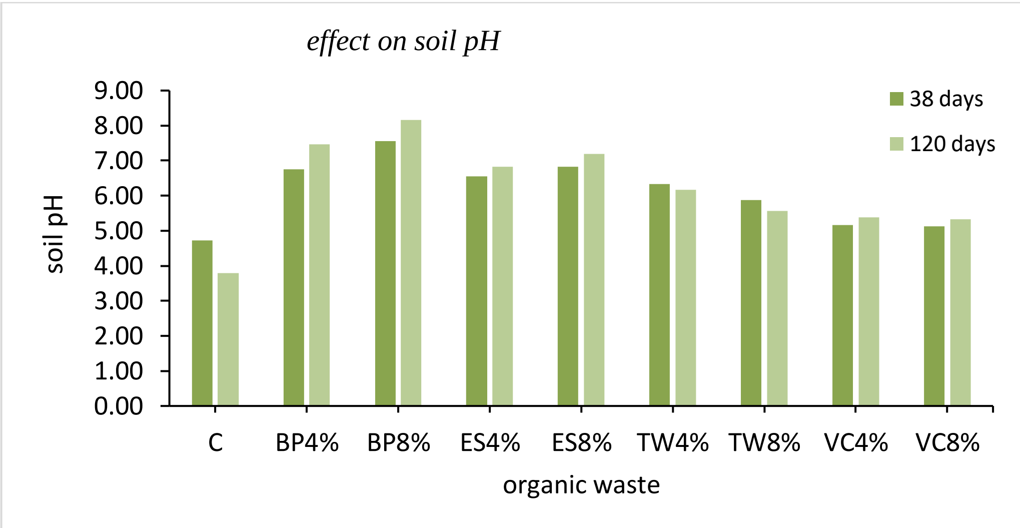

Figure 3: Changing of soil pH with amendments application

Table 4: Effect of organic amendments on soil pH

		pH (mean)	
Serial no	Sample	38 days	120 days
1	C	4.73	3.78
2	$BP_{4\%}$	6.75	7.46
3	$BP_{8\%}$	7.56	8.16
4	$ES_{4\%}$	6.56	6.82
5	$ES_{8\%}$	6.83	7.20
6	$TW_{4\%}$	6.33	6.16
7	$TW_{8\%}$	5.88	5.56
8	$VC_{4\%}$	5.16	5.38
9	$VC_{8\%}$	5.13	5.33

Soil Electrical Conductivity:

Electric conductivity is a measurement that correlates with soil properties. That affects crop productivity including soil texture, cation exchange capacity (CEC), organic matter, and salinity (IJSRD, 2015). In the present study, the EC was found to be increased with the increasing application rate of each amendment which further aids in soil productivity. The role of the incubation period was not significant in terms of altering soil EC. A high dose of vermicompost (1.497 mS) will be a good selection for alkaline soil whereas, that of banana peel (1.035 mS) for acid soil for enhancing EC of soil (Figure 4 & Table 6).

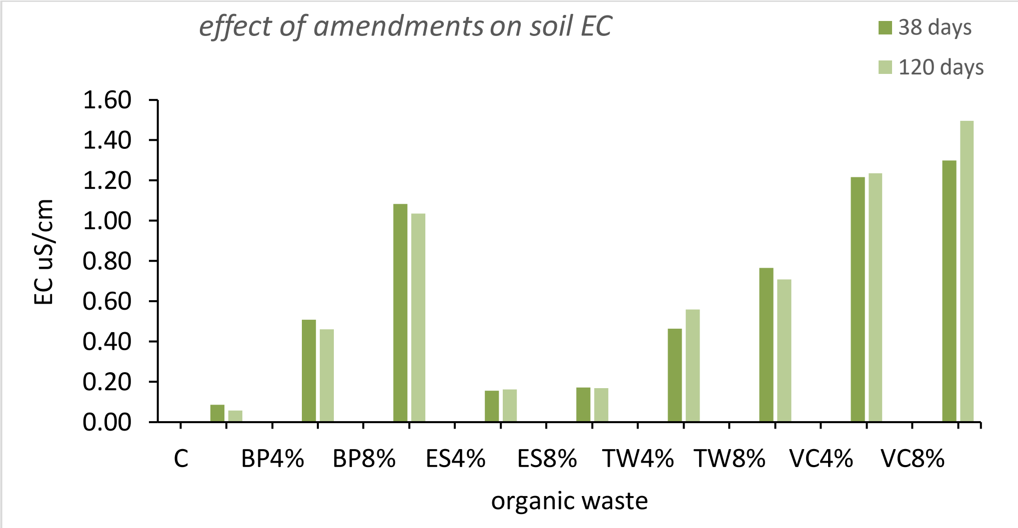

Figure 4: Changing of soil EC with amendments application

Table 6: Effect of organic amendments on soil EC

		EC (mean)	
Serial no	Sample	38 days	120 days
1	C	0.086	0.057
2	$BP_{4\%}$	0.507	0.461
3	$BP_{8\%}$	1.084	1.035
4	$ES_{4\%}$	0.155	0.163
5	$ES_{8\%}$	0.170	0.170
6	$TW_{4\%}$	0.465	0.560
7	$TW_{8\%}$	0.765	0.708
8	$VC_{4\%}$	1.216	1.236
9	$VC_{8\%}$	1.298	1.497

Soil organic carbon and organic matter content

Organic matter contributes to plant growth through its effect on soil's physical, chemical, and biological properties. Organic matter has both indirect and direct effects on the availability of nutrients for plant growth. In this study, it has been found that all of the amendments except eggshells played a crucial role in enhancing the SOC and SOM content. The influence of time was slightly efficient there. From Table 7 and graphical structure 5, it is proved that a high dose of TW and VC (2.655% and 2.268% over 120 days respectively) will be the best solution for facilitating soil with organic matter.

Table 7: Effect of organic amendments on soil OC & OM

		38 days		120 days	
Serial no	Sample	OC % (mean)	OM % (mean)	OC % (mean)	OM % (mean)
1	C	0.42	0.54	0.94	0.73
2	$BP_{4\%}$	0.80	0.94	1.62	1.37
3	$BP_{8\%}$	1.11	1.35	2.33	1.91
4	$ES_{4\%}$	0.45	0.51	0.89	0.78
5	$ES_{8\%}$	0.47	0.55	0.95	0.82
6	$TW_{4\%}$	0.93	0.98	1.69	1.60
7	$TW_{8\%}$	1.37	1.54	2.65	2.35
8	$VC_{4\%}$	1.01	1.09	1.88	1.74
9	$VC_{8\%}$	1.17	1.31	2.26	2.01

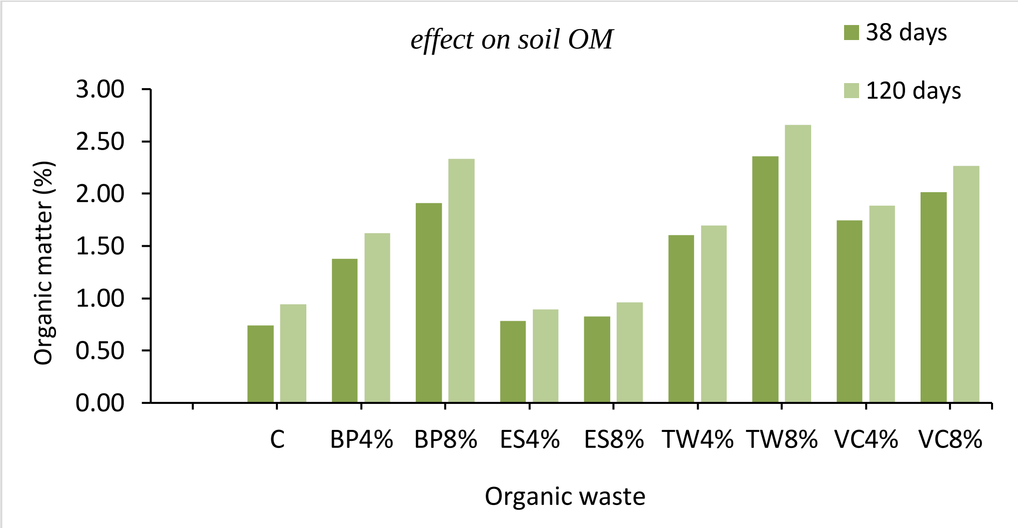

Figure 5: Changing of soil OM with amendments application

Conclusion

In today's world pollution becomes an alarming threat to humans as well as to nature. this environmental issue accelerates with the use of high amounts of inorganic fertilizer in the field. Banana peel, eggshell, tea waste, and vermicompost contain nutrients that are needed by plants to flourish such as potassium(K), nitrogen(N), calcium (Ca), magnesium (Mg), sulfur(S), phosphate (PO_4^{2-}), and sodium (Na). In addition, these also help plants to resist disease. All these are nutrients for the plants and thus we can say that properly dumping these wastes into the soil increases soil productivity. The utilization of these wastes in a proper way is not only useful in increasing soil fertility but also decreasing pollution load and increasing greenery, it is proving to be beneficial for human beings as well as for nature [3]. In this study, these organic amendments have been shown to improve soil health as inorganic fertilizers do which indirectly can protect the environment from being polluted. Thus, these organic amendments may be utilized as fertilizers for soil. The overall conclusion of the study is that the waste materials mainly organic contents are beneficial for the soil in terms of its fertility.

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Potential of using fly ash as amendment for soil characteristics

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Abstract

Fly ash acquired from electric and steam generating plants (power stations) causes removal challenges and environmental concerns. Disposal concerns can be solved by employing these waste materials as a raw source to improve soil characteristics, which is a process carried out to achieve improved geotechnical properties and engineering response of a soil at a site to achieve the needed Stability due to the enhancement of the soil's geotechnical properties. Water content, strength, plasticity, and density are the most often adjusted properties, which can be beneficial for plant. Extensive studies have focused on the impact of fly ash on soil characteristics. Therefore, this review discussed some of these studies, drawing a critical review to find out the effect of fly ash application on soil characteristics. Generally, it can be said that fly ash improved the soil stability, water-holding capacity, bulk density, and raise the low pH in soil. On the other hand, fly ash is beneficial at moderate levels, but higher levels have a significant depressing effect.

Keywords: Fly ash, Soil Amendment, Soil Charactristics, Soil Physical Properties

Introduction

Coal is among the major sources of energy worldwide that covers over one third of electricity generation. According to the latest Key World Energy Statistics by International Energy Agency (IEA 2021). Coal is often the only alternative when low-cost, cleaner energy sources are inadequate to meet growing energy demand. Developing countries use about 55 percent of the world's coal today; this share is expected to grow to 65 percent over the next 15 years. In year 2050, coal will account for more than 20 percent of the world's primary energy. The world coal consumption is projected to increase by 2.2 billion tons, from 5.3 billion tons in year 2001 to 7.5 billion tons in year 2025 (Balat et al. 2004). The intensity of the environmental impacts of coal residues varies between captured and noncaptured residues. Captured residues which represent about 90% of the total amounts of residues produced contain most of the trace element burden and exert their impacts only when they are discharged into the environment. Field and greenhouse experiments have, however, demonstrated some beneficial effects from these residues. They act as a source of some essential elements to plants such as S, Ca, Mo, B, Zn, and possibly Mn. By increasing soil pH, they also have the capacity of being used as acid soil amendment capable of improving soil conditions for proper plant growth under these conditions. Noncaptured particulates emitted to the atmosphere have direct and immediate short-term impact on the environment (Page et al., 1979). Over the past few decades, national governments have required that coal combustion for energy production meet emissions standards for clean air. This has resulted in emissions reduction technologies for dust (fly ash), and efforts to improve overall combustion efficiency (Harris et al. 2019).

Fly Ash

Fly ash is the finer ash produced in a coal fired power station, which is collected using electro-static precipitators, this is also known as Pulverised Fuel Ash (PFA) in some countries, about 85+ % of the ash produced is fly ash (Harris et al. 2020). Emission control devices such as mechanical dust collectors, electrostatic precipitators, scrubbers, etc. are now widely used to reduce the amount of particulates discharged into the atmosphere. Bottom ash and boiler slag are residues collected through openings in the bottom of the firebox and fly ash (sometimes referred to as precipitator ash) refers to both the material cleaned from the flue gas and the particulate material that escapes to the atmosphere (Fig. 1) (Page et al., 1979).

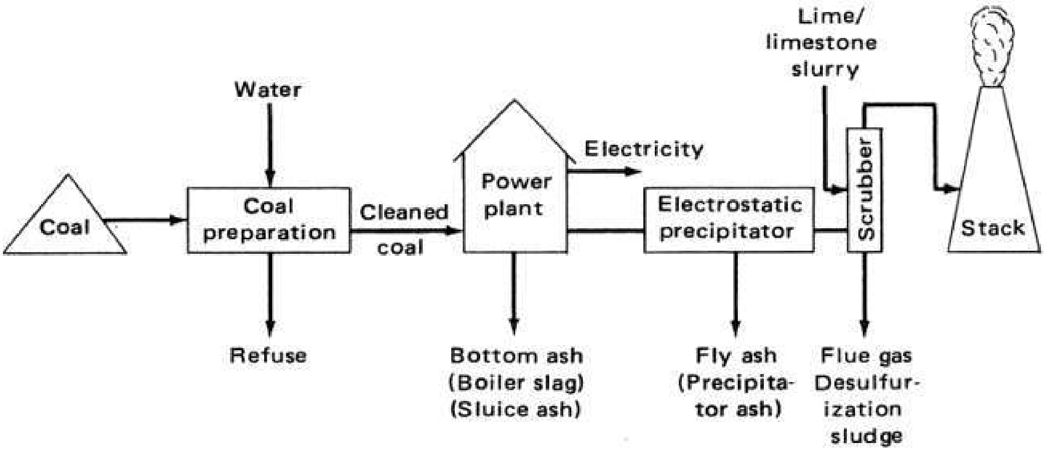

Figure 1. General configuration of a modern coal-fired power plant

Fly ash production and utilization in different countries during 2005 are presented in Figures 2 and 3, respectively. Shows that India generates higher production of fly ash (112 million tons/year) and utilizes lower percentage of fly ash (38%) in respect of other countries while Denmark, Italy and Netherlands generate lower fly ash production (2 million tons/year) and utilize 100% fly ash (Source: http:// www.tifac.org.in).

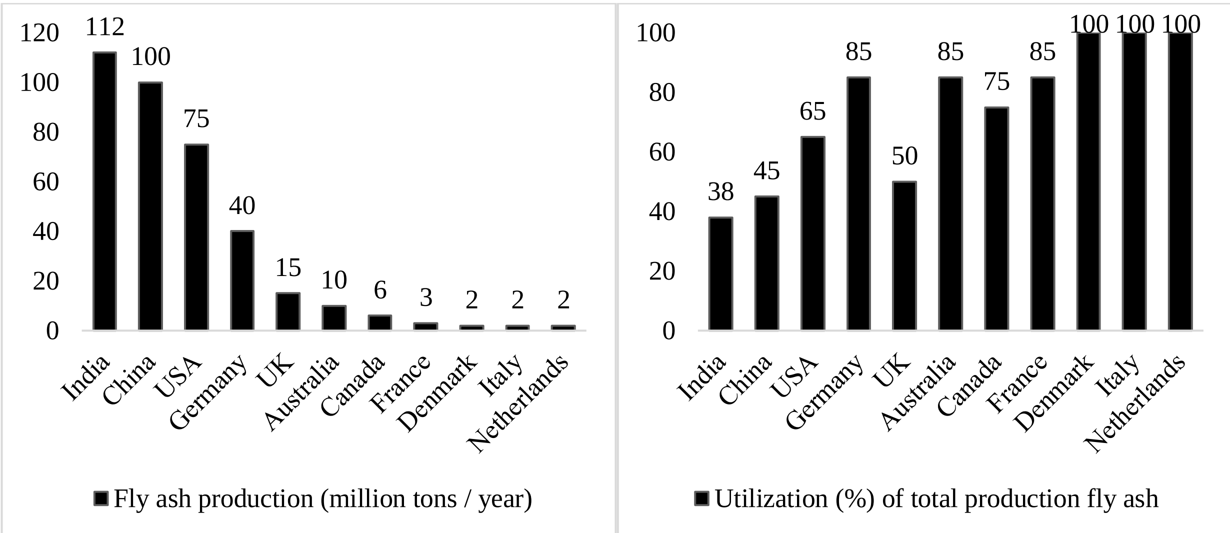

Figure 2. Fly ash production by country (million tons/year) and utilization (%) of total production fly ash by country.

The total amount of fly ash being utilized on a yearly basis has been increasing over the last decade; the amount utilized in comparison to production has remained relatively constant at - 25% (Scheetz et al 1998). However, these uses are insufficient for the complete utilization of fly ash. Its improper disposal causes soil and water contamination posing serious threats to the environment and ecological cycles. In the future, rigorous restrictions for disposal sites, strict environmental regulations, decreasing availability of landfill areas, and growing costs of disposal are expected. Therefore, it is crucial to establish efficient and cost-effective strategies to utilize fly ash in an environment-friendly way (Usman et al. 2022). The generation of coal fly ash is anticipated to increase for many more years, as a result of the world's increasing reliance on coal-fired power generation (Yao et al. 2015). One ton of fly ash requires 0.35 square meters of storage space. A large amount of fly ash is produced and disposed of at the ash treatment site, causing serious environmental problems (Kumar et al. 2022). The impact of fly ash on the environment comes either from the disposal of massive quantities captured or from fine particulates emitted to the atmosphere and eventually falling on the surrounding environs (Page et al., 1979). Some researchers have studied the impact of fly ash treatment on soil quality, hoping to use this industrial waste as an agronomic supplement (Kumar et al. 2022). Fly ash is one of the most complex anthropogenic materials, and its improper disposal has become an environmental concern and resulted in a waste of recoverable resources (Yao et al. 2015).

Characteristics of Fly Ash

The characteristics of fly ash dictate its subsequent use, efficiency, and disposal. It becomes, therefore, highly important to understand its physical, chemical, and mineralogical characteristics before its application (Usman et al. 2022). This industrial waste product is a fine-textured material with most of its particles in the silt and clay size range. It is characterized by low permeability, low bulk density, and high specific surface area (Page et al., 1979). Fly ash occurs as very fine particles having an average diameter of <10 μm and has low to medium bulk density, high surface area and light texture (Jala and Goyal, 2006). The mineralogical, physical, and chemical properties of fly ash depend on the nature of the parent coal, conditions of combustion, type of emission control devices, and storage and handling methods (Adriano et al. 1980). The pH of fly ash varies from 4.5 to 12.0 depending largely on the Sulphur content of the parent coal (Plank and Martens, 1974). The specific gravity of fly ash ranges from 2.1 to 2.6 g/cm3. Mean particle density for non-magnetic and magnetic particles is 2.7 and 3.4 g/cm3, respectively (Natusch and Wallace, 1974). Bulk density of fly ash varies from 1 to 1.8 g/cm^3 while the moisture retention ranges from 6.1% at 15 bar to 13.4% at 1/3 bar (Jala and Goyal, 2006). The main source of the chemical elements in fly ash is, of course, the source coal. By virtue of its origin, coal contains every naturally occurring element. Substantial fractions of the amount of elements entering in coal could, however be lost in the process of coal cleaning. Si, AI, Fe, and Ca are the major components of fly ash (Page et al., 1979). There are mainly two types of ash: Class F (low lime) and Class C (high lime) based on silica, alumina and iron oxide content of fly ash (Jala and Goyal, 2006).

THE EFFECT OF FLY ASH ON SOIL CHARACTERISTICS

The Effect of Fly Ash on Soil Physical Properties

Fly ash addition alters physical properties of soil such as texture, bulk density, water holding capacity and particle size distribution (Chang et al., 1977; Fail and Wochok, 1977; Capp, 1978; Page et al., 1979; Sharma, 1989). Addition of 10% ash increased the water holding capacity by factors of 7.2 and 13.5 for fine and coarse sands, respectively (Campbell et al., 1983). Fly ash particles are small and heavy and can fill the pores between soil particles and increase the density of the soil while maintaining the same volume, thus making the soil more compact. However, with excessive fly ash, the ratios of clay particles and cementitious materials to other substances decrease, leading to decreased soil strength (Chen et al. 2022). A higher value of porosity was observed in the treatments that received higher levels of fly ash, and a higher dose of fly ash significantly increased the water holding capacity of soil. (VP et al. 2022). The increase in maximum water holding capacity in fly ash amended soil was mainly due to the presence of Ca in fly ash that enhanced aggregation through the flocculation of soil particles, keeps the soil friable and that has increased water holding capacity of the soil (VP et al. 2022). Application of fly ash either individually or in combination with farm yard manure (FYM) increased the water retention capacity of the soil mainly attributed to fly ash being microsized particles and porous nature can hold more amount of moisture and reduced bulk density of soil. The calcium present in fly ash along with organic matter provides a congenial atmosphere to stabilize the physical environment (VP et al. 2022).

Soil texture

The addition of appropriate quantities of fly ash can alter the soil texture (Tejasvi and Kumar, 2012) observed that fly ash addition altered sandy loam texture of the soil to sandy silty loam.

Soil bulk density

The grain size distribution especially the silt size range of fly ash affects the bulk density of soil (Tejasvi and Kumar, 2012) observed a marked decrease in bulk density from 1.33 to 1.21 due to amendment of soil with fly ash. Fly ash amendment to a cultivar of agricultural soils tend to decrease the bulk density (Page et al. 1979, 1980). Optimum bulk density improves the soil porosity, the workability of the soil, and the root penetration (Tejasvi and Kumar, 2012).

Soil water holding capacity

The moisture retention capacity of the soil ash mixture increased by 50% than the pure soil (Tejasvi and Kumar, 2012). The fly ash is usually dominated by silt sized particles (Tejasvi, 2012; Adriano,1980; Aitken, 1984; Ghodrati, 1995). Thus fly ash incorporation exert a beneficial effect in soil water holding capacity in sandy soils, as fine textured substances can hold more water than coarse textured substrates (Chang, 1977; Aitken, 1984; Campbell, 1983; Brady,1996; Gangloff, 2000; Tejasvi, 2012).

The Effect of Fly Ash on Soil Chemical Properties

Application of fly ash to acid soils increased the pH and organic carbon, and showed that there was an increase in available N, P_2O_5 and K_2O (VP et al. 2022).

Soil pH

Tejasvi and Kumar (2012) observed a marginal increase in pH of soil ash mixture as compared to soil pH. This was due to the fact that fly ash had neutral pH (7.0) and the experimental soil was slightly acidic (pH 6.7). The initial increase in soil pH after alkaline fly ash amendment is explained by the rapid release of Ca, Na, Al, and OH ions from fly ash (Wong and Wong, 1990).

Soil electrical conductivity

The EC of soil–ash mixture was increased by 11.7% as compared to soil alone (Tejasvi and Kumar, 2012). This result is in agreement with (Kalra et al. 1998) who observed increase in EC values with ash content for all texturally variant soils.

Soil organic carbon

The organic carbon in the soil influences the nature and quality of the soil. It affects the soil texture, water holding capacity, availability of nutrients, etc. The organic carbon values of soil–ash mixture recorded an increase of 10.3% in sandy loam soil in the observation of (Tejasvi and Kumar, 2012). Which is comparable to (Kalra et al. 1998) who observed 11.0% increase in organic carbon values by addition of fly ash in the similar type of soil.

The Effect of Fly Ash on Soil Mechanical Properties

In general, it was observed that class C fly ash is more effective in improving the mechanical properties of the soil compared to class F fly ash. The findings have proven that class C fly ash can be used effectively in the stabilization of clay soils. Class F fly ash can be used with the other additives such as lime or alkali activators to achieve higher mechanical properties in clay soils (Turan et al. 2022).

Soil plasticity and stability

Fly ash greatly reduces the plasticity index of high plasticity soils but has little influence on the plasticity index of low plasticity fine soils (Nalbantoglu, 2004). The maximum dry density of the soil decreases and optimum moisture content increases with increase in the percentage of fly ash in soil (Rajak et al. 2019). Which increases the soil stability thus decreases swilling in high plasticity soils.

The Effect of Fly Ash on Soil Biological Properties

Many researchers studies the effects of fly ash amendment on soil biological properties. Huge number of laboratory incubation studies observed that the addition of unweathered fly ash to sandy soils severely inhibited microbial respiration, numbers, size, enzyme activity and soil nitrogen cycling processes such as nitrification and N mineralization (Arthur et al., 1984; Cerevelli et al., 1986; Wong and Wong, 1986; Pichtel, 1990; Pichtel and Hayes, 1990; Garau et al., 1991).

The Effect of Fly Ash on Soil Fertility in General

The effect of fly ash on soil fertility largely depends upon the properties of original coal and soil. Fly ash, which can be acidic or alkaline depending on the source, can be used to buffer the soil pH (Elseewi et al., 1978). The majority of crops prefer optimum pH values of between 6.5 and 7.0, within which the availability of most nutrients to plants is maximized. Fertility is impaired at very low pH levels as dissolution and bioavailability of Mn and Al that are toxic to plants increases (Pandey and Singh, 2010). Fly ash has been used for correction of Sulphur and boron deficiency in acid soils (Chang et al., 1977).

Recommendations While Using Fly Ash As Amendment For Soil

Because of potential problems of salinity, B, Mo, and Se arising from application of coal ash to soils, these elements should be critically evaluated before large-scale disposal of the by-product on agricultural soils is recommended (Page et al., 1979).

Conclusion

Adding the proper amount of fly ash can change the soil texture, in addition, the bulk density of the soil can be decreased by the fly ash due to its silt size range, which improves soil porosity and penetration of the roots. Due to the small size of fly ash particles, it can fill the pores between soil particles, increase the soil density while maintaining the same volume making it more compact. Fly ash improves the water holding capacity in sandy soils as fine textured substances can hold more water than coarse textured substrates. Also it can be said that the increase in maximum water holding capacity in fly ash amended soil was mainly due to the presence of Ca in fly ash that enhanced aggregation through the flocculation of soil particles, keeps the soil friable and that has increased water holding capacity of the soil.

Fly ash can be used to buffer the soil pH, increasing acid soil pH and organic carbon; moreover, fly ash amended soil showed increase in available N, P_2O_5 and K_2O.

Application of fly ash to a high plasticity soils increases the soil stability thus decreases swilling and reduces the plasticity index, but with addition of excessive fly ash amounts to soil, the ratios of clay particles and cementitious materials to other substances decrease, leading to decreased soil strength. In case of clay soil class C fly ash can be used effectively in the stabilization of clay soils.

Utilization of fly ash as amendment for soil appears to be one of many applicable ways for handling the fly ash waste problem. Since there is production of fly ash that is disposed of rather than utilized, using fly ash more productively would have significant environmental benefits, reducing land, air and water pollution.

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A meta-analysis of heavy metals pollution in European soils under a strong anthropogenic pressure

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Abstract

In the last decades, the continuous industrialization and expansion of European cities is implying a strong anthropogenic pressure that is affecting the heavy metals concentration in soils. The heavy metals contamination in European soils has been deeply investigated through a wide range of field studies. Therefore, an intensive and cohesive study on these publications may help to illustrate the status of soil heavy metals pollution at a larger scale.
The aim of this paper is to provide a comprehensive assessment about heavy metals pollution in European soils based on a meta-analysis of reviewed data. A literature selection of papers published between the years 2000 and 2022 is extracted from the Web of Science database, using an advanced search. After extraction, the data is filtered and categorized, selecting field studies on topsoils in urban areas or heavily affected by human activity. The approach of this work is giving a measure of heavy metal prevalence on European topsoils based on available studies, exploring the spatial distribution and showing the temporal variation of the data. The meta-analysis is carried out using Microsoft Excel, Python and the statistical software R.
Keywords: Contamination, Heavy Metals, Meta-Analysis, Soils.

Introduction

Soil contamination is one of the most important threats to soil resources not only in Europe, but also globally. Before the existence of the LUCAS topsoil survey[1], there was only very coarse scale (1/5000 km2) data available on soil heavy metal concentrations. This sampling density was amplified after the implementation of LUCAS, with a density of 1 site/200 km2 (Tóth et al., 2016). At the present time, with all the data available and the standardization of sampling methods, many research studies have been carried out in the different countries of Europe (de Caritat et Reimann, 2012; Panagos P. et al., 2021); not only to deepen the understanding of the heavy metals that contaminate the continent's soils, but also of the causes that lead to or worsen them, many of which are of anthropogenic origin due to urban sprawl and industrialization.

For this reason, a meta-analysis based on reviewed data is proposed in this paper to provide a comprehensive assessment of heavy metal contamination in European -urban and industrial- soils. The statistical methodology for combining quantitative evidence from studies, known as meta-analysis (Schwarzer et al., 2015), features in almost every systematic review. For example, a meta-analysis has been applied before for determining the heavy metals pollution at a national scale in China, as well as exploring spatial and temporal variations (Ying et al., 2019; Chen et al., 2022).

Literature selection

A comprehensive primary search of research papers, published between the years 2000 and 2022, was performed. The papers should include heavy metals (Cd, Cr, Hg, As, Pb, Cu, Zn and Ni) contents in urban, industrial, or soils under a strong anthropogenic pressure in any country of the European continent. The bibliography search was carried out in the database of Web of Science (WOS) using the key words "heavy metal" or individual element (Cd, Cr, Hg, Pb, As, Cu, Zn, Ni), and "urban" or "industrial" or "anthropogenic", together with "Europe'' and all the European countries names. These key words were combined with boolean operators and wildcards to refine the search. The final query can be found in the appendix to this article ***(Code list A1)***.

To be included in the analysis, these primary studies had to meet these criterions: (i) it must be field study, which monitoring topsoil (up to 20 cm) in European soils under anthropogenic pressure; (ii) it should indicate the country and the number of samples; (iii) it should include mean, range and/or standard deviation values -or enough information to calculate all or some of these values (Hozo et al., 2015), e.g.: mean, median and skewness for calculating the standard deviation following the Pearson's Skewness formula (Kovchegov et al., 2022)-; (iv) the soil samples were prepared and analyzed with acceptable methods and analytical tools.

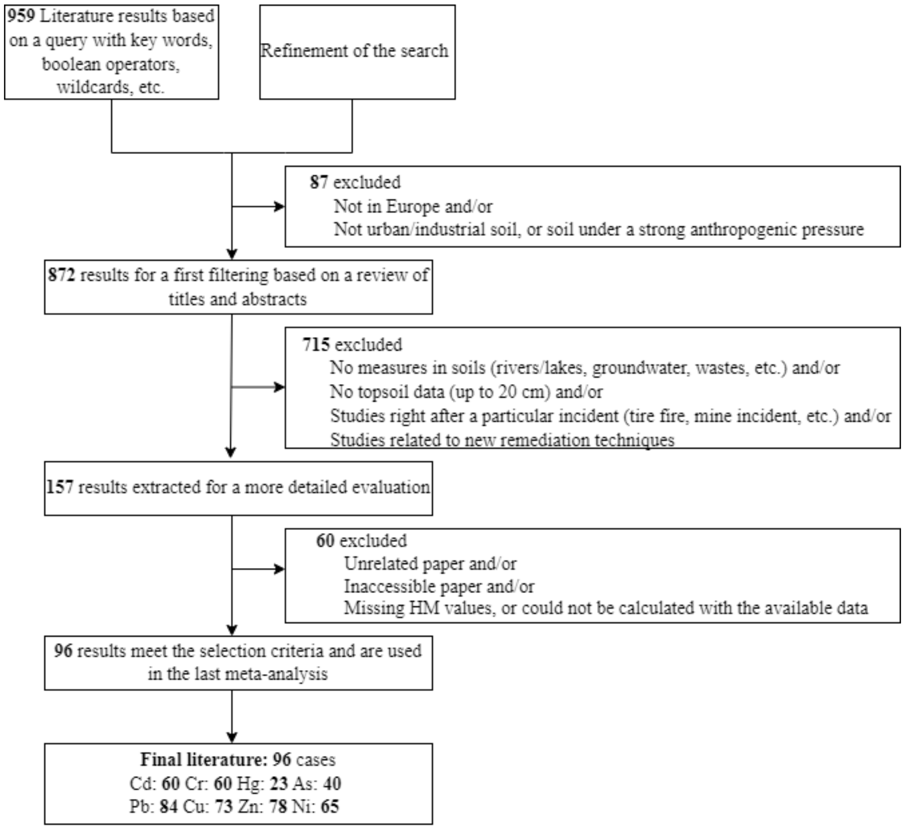

Figure 1. Literature selection flow chart

Data extraction and processing

The database that was firstly extracted directly from Web of Science did not include relevant knowledge for the meta-analysis, as it included more bibliography-related information (editors, addresses, citations, etc.). Therefore, the first thing after the extraction of the database was to modify and re-design it. The original data maintained in the final database was only the following: authors, year, title, abstract, doi and doi-link.

Manually, reviewing the 157 papers separately, the database was restructured, resulting in the following categories: i) case number (simple numbering: 1-157); ii) year; iii) location (country); iv) soil type (urban, industrial, mining, undefined); v) authors; vi) article title; vii) abstract; viii) doi; ix) doi link. Then, related to the content of each paper, two more main categories were added: x) number of samples; xi) the eight (8) selected heavy metals (Cd, Cr, Hg, As, Pb, Cu, Zn and Ni) with three subcategories: mean, range and standard deviation.

After structuring the database, each paper was manually reviewed again to extract the quantitative data concerning the number of samples and the heavy metal contents in the topsoils of each paper, in order to complete the database with this information. As indicated in the subsection *Literature selection*, the mean, range and standard deviation values were searched in the articles. Where these values were not provided directly, but the information necessary to calculate them was available, this was performed with both Microsoft Excel and Python, depending on the complexity of the calculations.

Meta-analysis with R

All the statistical analyses were conducted with RStudio with the metafor (Cheung & Viechtbauer,2010) and dmetar package (Harrer et al., 2021).

Calculation of random effects model of weighted mean values

Meta-analyses are usually done by multilevel models. In these models, the expectation of the studied variable is usually called overall effect size, which is kind of a weighted mean of the effects of each study (Ying et al., 2019). In a meta-analysis, the studies are likely to differ on several aspects at the same time. If this occurs, it can be assumed a considerable between-study heterogeneity. Traditionally, meta-analysts have used Cochran's Q-test -defined as weighted sum of squares (WSS)- to distinguish studies' sampling error from actual between-study heterogeneity (Harrer et al., 2021), being

$$Q = \sum_{k=1}^{k} w_k^{\blacksquare} (\hat{\theta}_k - \hat{\theta})^2$$

Eq 1. Cochran's Q formula, where $\hat{\theta}_k$ is the effect of each study from the summary effect $\hat{\theta}$, weighted by the inverse of the study's variance, wk.

When heterogeneity is present, a random-effects model should be applied as it raises that there may be many reasons for the real differences in the true effect sizes of studies, so it assumes that there is not only

one true effect size but a distribution of true effect sizes. The goal of this model is therefore to estimate the mean of the distribution of true effects, by

$$\hat{\theta} = \frac{\sum_{k=1}^{k} \hat{\theta}_k w_k^*}{\sum_{k=1}^{k} w_k^*}$$

Eq 2. Pooled effect size using the inverse variance method (Harrer et al., 2021), where $\hat{\theta}_k$ is the effect of each study and w_k^* is the weight of that study taking in account heterogeneity.

In this work a random effects model was performed as there exists significant heterogeneity. The log-transformed mean was chosen as effect size, as the concentration is a non-negative magnitude.

Determination of outliers and sensitivity analysis

Extreme between-study heterogeneity may distort the calculated pooled effect estimate, so the pooled effect was reinspected after heterogeneity outliers have been removed. Secondly, a sensitivity analysis comparing the total data and the data without outliers was performed for outlier diagnostics (Cheung & Viechtbauer, 2010). For detecting the outliers, the approach was based on viewing a study as an outlier if its confidence interval does not overlap with the confidence interval of the pooled effect, being the upper bound of the 95% confidence interval lower than the lower bound of the pooled effect confidence interval; or either the lower bound of the 95% confidence interval higher than the upper bound of the pooled effect confidence interval (Harrer et al., 2021).

Subgroup analysis using a meta-regression with categorical factors

The sensitivity analysis was conducted as a sub-group model, taking the outliers as a sub-group of the data. A Q-test was performed evaluating if the differences in the mean were significant between including or excluding outliers. The p-values of this test are included in Table 1. As there is no significant difference between the mean estimation with or without outliers, the model without outliers was chosen as the confidence intervals are more precise.

Once the outliers were eliminated, meta-regression models were made to test the existence of differences between soil types (urban, industrial, mining) and the location of the study. For the location meta-regression, it was chosen to aggregate countries into their respective regions (EuroVoc, 2016), as the amount of studies for some countries was too small to obtain valid results through the meta-regression. Finally, another meta-regression model was performed to evaluate the evolution of the mean values with time.

Table 1. Weighted mean (WM) results, with and without outliers. The 95% confidence intervals are also presented for each case.

	Cd	Cr	Hg	As	Pb	Cu	Zn	Ni
Background (Salminen R., 2005)	0.28	94.80	0.06	11.60	32.60	17.30	68.10	37.30
WM (all data)	1.308	63.422	0.811	19.203	105.127	41.544	172.937	40.422
95% CI (all data)	[0.783, 2.184]	[49.339, 81.523]	[0.199, 3.312]	[11.952, 30.854]	[72.196, 153.079]	[31.057, 55.571]	[131.257, 227.852]	[30.733, 53.165]
WM (excluded outliers)	1.151	60.999	0.373	18.456	102.105	41.778	165.18	32.828
95% CI, excluded outliers	[0.885, 1.497]	[54.738, 67.977]	[0.254, 0.548]	[15.398, 22.121]	[83.666, 124.607]	[36.675, 47.591]	[150.989, 180.704]	[30.022, 35.896]
Q-test (p-value)	0.785	0.829	0.285	0.921	0.876	0.862	0.562	0.237

Results and Discussion

Weighted means

In the Table 1, the results of the weighted means are included. They were compared to background levels, resulting in much higher values. This was expected, as the used studies are about soils with a strong anthropogenic influence and, therefore, subjected to a higher contamination than average soils.

Three different pollution indices were obtained and are given below (Table 2). The index of geoaccumulation (Igeo) ***(Eq 3)*** was introduced by Müller and has been employed in many European studies about trace metals (Zhiyuan et al., 2014). The contamination factor (CF) ***(Eq 4)*** is used to evaluate the level of soil contamination and to infer anthropogenic inputs from the natural ones (Said et al., 2019). These two indices are calculated for each heavy metal separately. However, PLI or pollution load index (***Eq 5***), is based on the geometric average of the CFs. It determines the contribution of all metals in a given place (Hołtra et al., 2020), providing an estimation of soil quality based on the CF values of all metals together.

$$I_{geo} = log_2\left(\frac{C_n}{1.5B_n}\right)$$

Eq 3. Index of geoaccumulation (Igeo), where Cn is the heavy metal concentration in the anthropogenic source and Bn the background value (Hołtra et al., 2020).

$$CF = \frac{C_n}{B_n}$$

Eq 4. Contamination factor (CF), where Cn is the heavy metal concentration in the anthropogenic source and Bn the background value (Hołtra et al., 2020).

$$PLI = \sqrt[n]{C_1 . C_2 ... C_n}$$

Eq 5. Pollution load index (PLI), where Cn is each heavy metal concentration in the anthropogenic source and n the number of heavy metals (Hołtra et al., 2020).

Table 2. Individual pollution indexes for each heavy metal (Igeo; CF) and overall pollution index (PLI) for all the heavy metals together. For the calculation of the indexes, the European background values were used (Salminen et al., 2005).

Substance (symbol)	Cadmium (Cd)	Chrome (Cr)	Mercury (Hg)	Arsenic (As)	Lead (Pb)	Copper (Cu)	Nickel (Ni)	Zinc (Zn)
I_{geo}	1.43	-1.22	2.03	0.09	1.06	0.69	0.69	-0.77
CF	4.05	0.64	6.11	1.59	3.13	2.41	2.43	0.88
PLI = 2.12								

Meta-regression

Influence of soil type

The results of the subgroup analyses by soil type are included in Table 3 and Fig 2. Only the p-values of Cr, Cu and Zn, are statistically significant, which means that for these heavy metals there is a significant difference between the different groups. The most significant p-value result is for Zn, having a much higher mean concentration in mining or urban soil types than industrial. For Cd and, specially, for Cu, the means concentration are more similar between them. However, Cr presents higher concentrations in urban soil, meanwhile, Cu presents higher concentrations in industrial soil type.

Table 3. Weighted means after subgroup analysis of soil type effect. Empty spaces represent not enough data for the group after removing outliers. In groups without significant p-value, the difference between different soil types should not be considered.

	Cd	Cr	Hg	As	Pb	Cu	Zn	Ni
Industrial	1.05	62.87	0.49	16.44	61.09	24.78	49.07	34.51
Mining	1.62	48.48		26.95	200.64	28.44	120.59	29.36
Urban	1.09	69.43	0.40	19.26	77.48	28.30	114.35	31.14
Undefined	0.69	54.57	0.93	15.08	154.59	56.10		34.36
p-value	0.39	0.07	0.24	0.32	0.12	0.08	0.00	0.69

Spatial variability

Results of the subgroup analyses by the EuroVoc regions are included in Table 4 and Figure 3. Only the p-value of As is statistically significant, so it can be affirmed that the highest mean concentration of As takes place in Southern Europe. For the other metals, the difference between different soil types should not be considered. In Figure 4, the pollution load index spatial distribution is shown. The pollution status based on PLI shows the following relationship: Southern Europe > Central and Eastern Europe > Western Europe > Northern Europe.

Table 4. Weighted means by region resulting from subgroup analysis. Empty spaces represent not enough data for the group after removing outliers.

	Cd	Cr	Hg	As	Pb	Cu	Zn	Ni
Central and Eastern Europe	1.23	61.10	0.36	15.10	94.66	43.27	170.21	31.46
Northern Europe						19.15	178.43	
Southern Europe	1.11	63.06	0.39	21.77	104.57	43.64	158.33	33.94
Western Europe	1.20	54.51	0.37	14.34	95.55	29.34	172.97	30.97
p-value	0.95	0.65	0.99	**0.09**	0.93	0.20	0.85	0.73

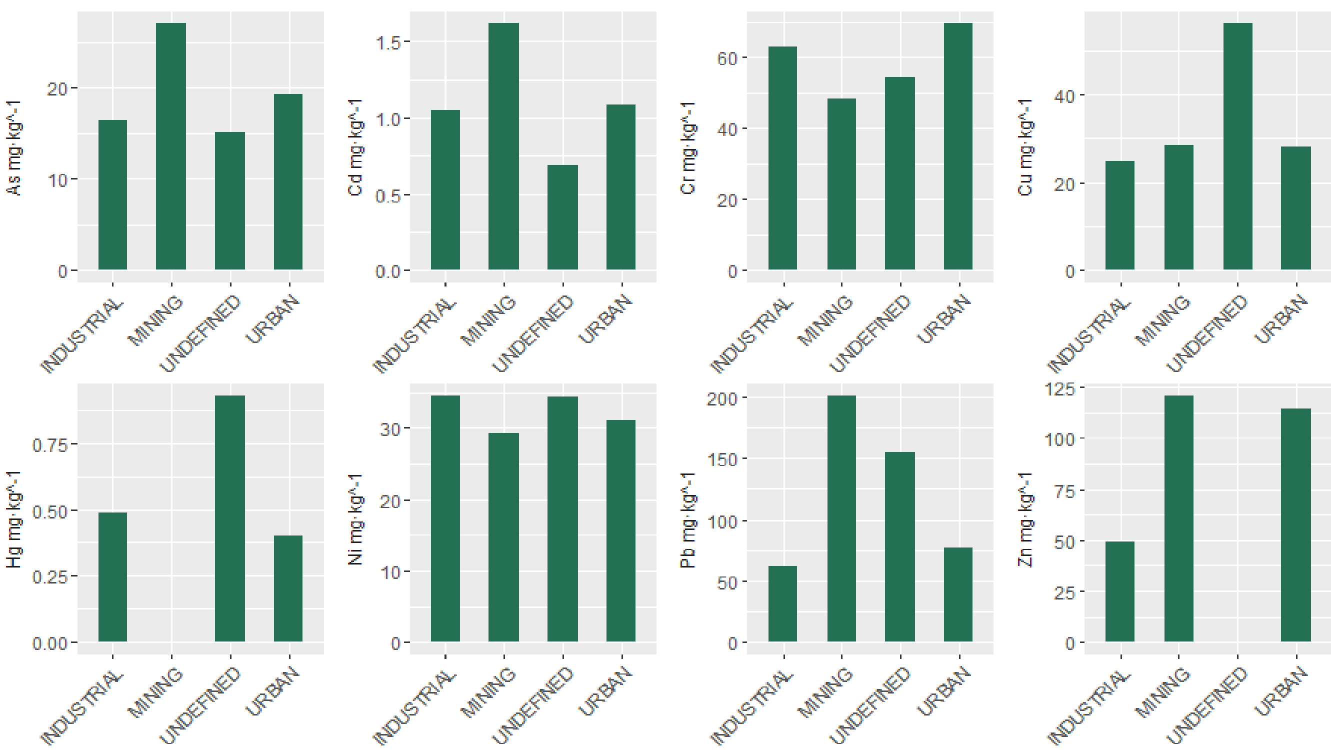

Figure 2. Weighted means of the eight heavy metals accounting for soil type

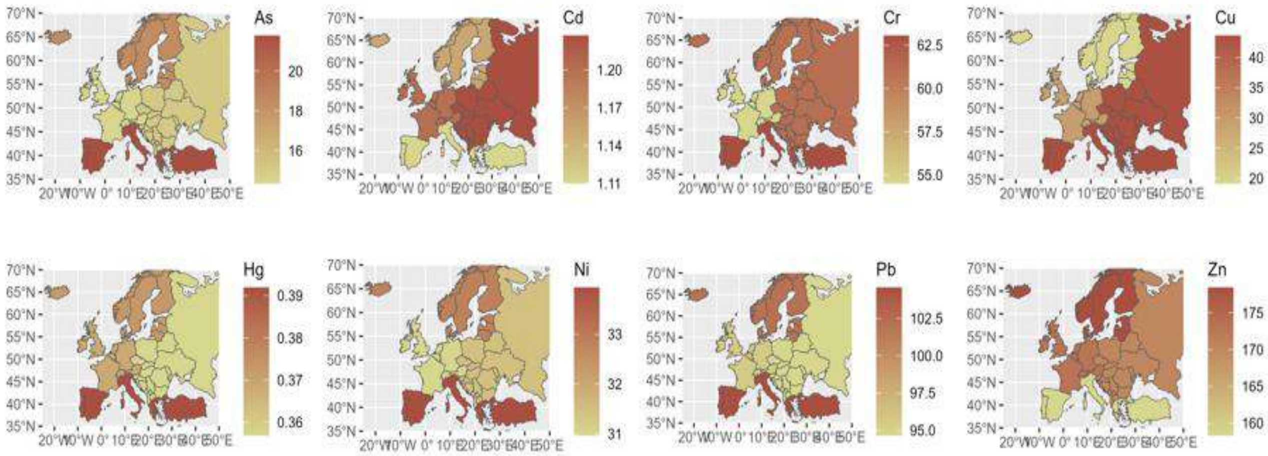

Figure 3. Heavy metals distribution in the European subregions of EuroVoc (EuroVoc, 2016). Global means were used when regional means were not available

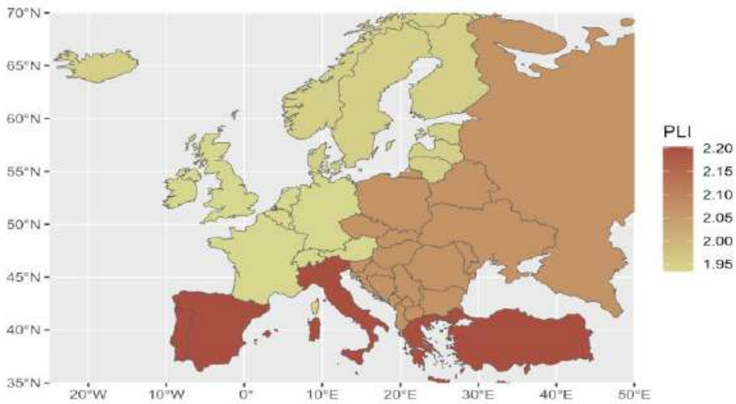

Figure 4. Pollution load index (PLI) in the European subregions of EuroVoc *(EuroVoc, 2016)*

Temporal variability

Results of the subgroup analyses for the years 2000-2022 are included in Figure 5 and Table A1. In Figure 5, it can be seen a slight increase in the average concentrations for the metals Cr and Ni. Besides that, a decrease in Hg, As, Pb or Cu concentrations can be appreciated over time, while Cd and Zn would keep their concentration. However, the F-test of the meta-regression model shows no significant p-value for any metal (all >0.6, available in Table A1), so these differences observed through the years should not be considered.

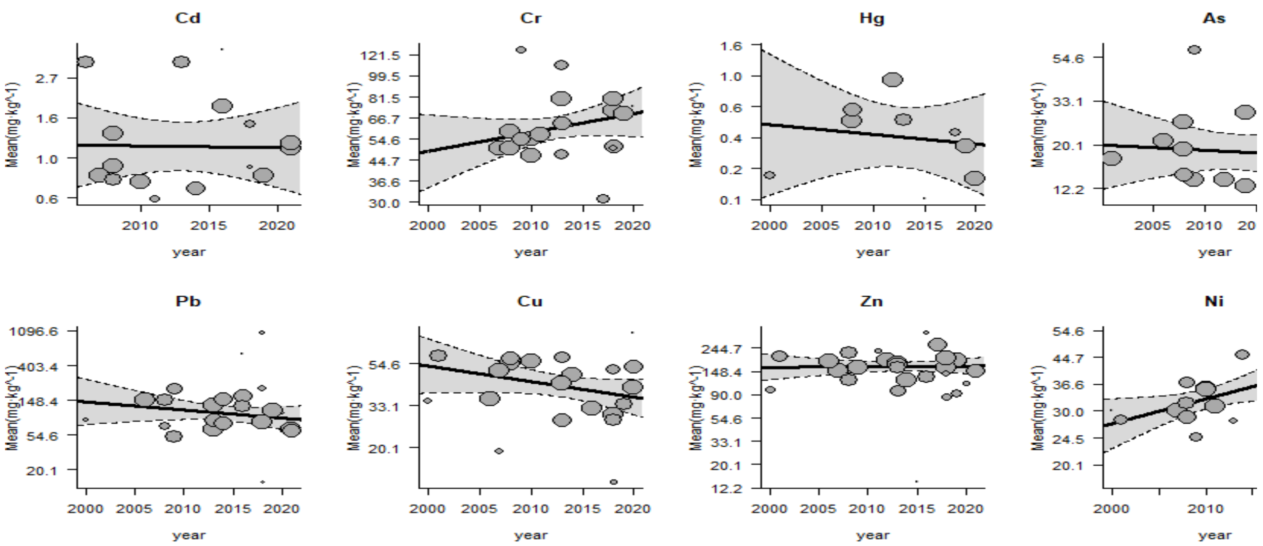

Figure 5. Time variation of the weighted means of the eight heavy metals. Bigger dots represent more influential studies.

Discussion

Going back to the pollution indices results presented before in Table 2, and based on the soil quality assessment following these values (Hołtra et al., 2020), the general contamination of Cr and Ni in the soils of this study would be classified as practically uncontaminated, while the contamination of As, Cu and Zn would be classified as uncontaminated to moderately contaminated. For Cd and Pb, these soils would be classified as moderately contaminated, while Hg would be classified as moderately to heavily contaminated.

Looking now at the contamination factor (CF) index results in Table 2 and comparing them with the soil quality classification based on these values (Hołtra et al., 2020), the general contamination for Cr and Ni would have a classification of low contamination. For As, Cu and Zn, the soil quality in these study cases would be classified as moderate contamination. Finally, the overall pollution for Cd and Pb would be classified as considerable contamination, while for Hg the overall soil quality would be very high contamination.

Initially, the studies focused on measuring the Hg values had a soil type of mining (very close to a mining site), with very high concentrations of this heavy metal in this area. This statement contradicts Figure 2, (Hg graph), but it can be explained because the values in these cases were, indeed, too high, being outliers that were removed later (Table A2). In both Figure 2 and Table A2, it can be also appreciated that Pb and As have the highest concentrations in mining soil type. The same happens with Cd and Zn, but looking at the p-values in Table A2, in these cases the difference to other soil types is not statistically significant.

For the last pollution index, PLI, a result of 2.12 was obtained. This index allows us to assess the overall level of environmental contamination and compared with the soil quality classification that this parameter has associated (Hołtra et al., 2020), the general environmental pollution would be classified as moderately polluted. The results show that the contamination in the different European regions is mainly homogeneous, with the higher concentration of As in southern Europe being the most relevant finding. The PLI by region (Figure 4) classifies Southern Europe and Central Europe as moderately contaminated, while northern and western Europe appears as moderately polluted to unpolluted.

These results can be influenced by the number of studies in each European region. The quantity of studies was as follows: Southern Europe > Central and Eastern Europe > Western Europe > Northern Europe (Figure 5). In regions with a higher number of studies, there could be more studies made in highly contaminated areas (there could be a publication bias). The variability in the distribution of studies also affected the model of geographic variation, as some outliers corresponded to studies in northern Europe, which was already the region with the least amount of data.

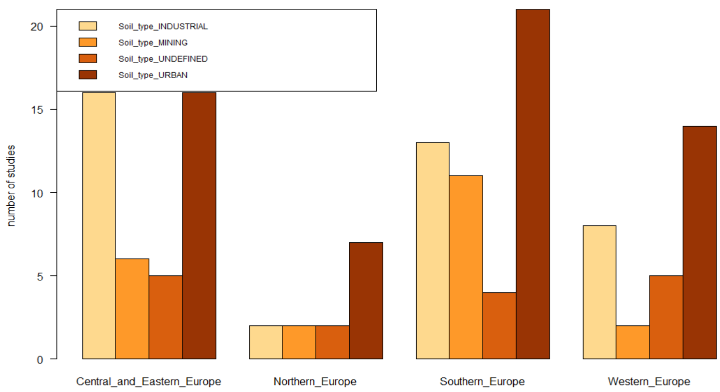

Figure 5. Distribution of studies analyzed by soil type and location

Conclusions

In this paper, a meta-analysis was carried out to assess the overall status of heavy metals pollution in European soils under a strong anthropogenic pressure, such as industrial, mining and urban soils. The weighted mean for each heavy metal, as well as three different pollution indices, was calculated. A meta-regression to study the soil type influence, spatial distribution and temporal variation was also performed.

For some heavy metals, a significant difference in their concentration depending on the contamination source (mining, industrial or urban) was found. It was shown that soils under a strong anthropogenic pressure in Europe are particularly polluted by Cd, Pb and Hg, being mostly homogenous around the continent. However, it's necessary to highlight the high arsenic (As) content in Southern Europe, which should be investigated. In terms of temporal variability, although there is some temporal variation in the presence of these heavy metals in the soils, it is not significant.

As it was indicated in other studies (Binner et al., 2022), future studies should focus on key knowledge gaps, such as clearer definitions and barriers about urban, industrial and soils under anthropogenic pressure in general. At the same time, study methods should be standardized to facilitate comparison of soil heavy metals data from different studies, and unified European safety thresholds, background values and guidelines should be identified for key elements.

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Appendix

Code list A1. WOS database query.

```
(topsoil OR soil* OR ground) NOT (water? OR river? OR sea? OR lake?) AND ("heavy metal?" OR Cd OR Cr OR
Hg OR Pb OR As OR Cu OR Zn OR Ni) AND (contamin* OR pollut* OR distribut*) AND (evaluat* OR assess* OR
measur* OR manag* OR control*) (Abstract) AND (anthropogenic* OR human? OR urban* OR city OR cities)
NOT (health* OR bio*) (All Fields) AND 2000-2022 (Year Published) AND Europe* OR Austria OR Belgium OR
Bulgaria OR Croatia OR Republic of Cyprus OR Czech Republic OR Denmark OR Estonia OR Finland OR France
OR Germany OR Greece OR Hungary OR Ireland OR Italy OR Latvia OR Lithuania OR Luxembourg OR Malta OR
Netherlands OR Poland OR Portugal OR Romania OR Slovakia OR Slovenia OR Spain OR Sweden (Abstract) AND
Europe* OR Austria OR Belgium OR Bulgaria OR Croatia OR Republic of Cyprus OR Czech Republic OR Denmark
OR Estonia OR Finland OR France OR Germany OR Greece OR Hungary OR Ireland OR Italy OR Latvia OR
Lithuania OR Luxembourg OR Malta OR Netherlands OR Poland OR Portugal OR Romania OR Slovakia OR
Slovenia OR Spain OR Sweden (Topic)
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Table A1. p-values of F-test performed on the temporal metaregression model.

	Cd	Cr	Hg	As	Pb	Cu	Zn	Ni
p-value	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69

Table A2. Weighted means after subgroup analysis of soil type effect without outlier removal. In groups without significant p-value, the difference between different soil types should not be considered.

	Cd	Cr	Hg	As	Pb	Cu	Zn	Ni
Industrial	2.25	54.58	0.11	8.57	108.47	44.09	131.90	40.52
Mining	2.91	80.12	102.80	80.44	532.52	69.27	263.95	54.83
Urban	0.35	52.46	0.19	15.03	34.91	34.02	75.68	30.97
Undefined	1.07	49.70	0.61	7.10	55.89	29.51	112.26	31.87
p-value	0.13	0.72	0.00	0.00	0.00	0.40	0.23	0.40

Oil polluted soils: Review

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Abstract

Soil all over the world is threaten by different types of environmental pollution, one of them is oil pollution that usually occurs is sites that have been exposed or found close to area that have been subjected to oil extraction by mankind. Depending on the level of contamination soils can no longer be used to their full potential, therefore the need for soil reclamation arises, which usually involve huge expenditures and time before we could reach partial and total recovery of the soil. The change in soil both physical and chemical properties is the reason why soils become unproductive. In this review, we shall explore crude oil contaminated soil in the world, examine oil components that cause soil to become unproductive especially for agricultural purposes and finally discuss the existing soil remediation methods that have been used.

Keywords: Pollution, Oil, Reclamation, Soil.

Introduction

Oil and gas are the major sources of energy in the world, oil particularly is very important for our society, the industrialized world even considered the 20th century as the age of oil. On the global scale, oil represents 31% of the total energy used, meanwhile gas is only 21% (WEF, 2016). There are several reasons why so far oil remains the main source of energy; it has a high density, it is easy to extract, transport and refine (Alekhina & Yoshino, 2018). Oil as energy increases man's ability to get work done, as a raw material it provides feedstock to the fastest and expanding industries in the world, it provides fuel for agricultural tractors and pumps and has been widely used as a substitute of coal and hydropower (Lalude, 2015). The demand for oil and oil products keep growing, according to statistics annual average rate by 2025 is expected to come close 1mb/d (IEA, 2020).

Despite the various uses of oil, its production has brought severe threats to the environment. Soil pollution by oil is among the major environmental threads because it negatively affects not only water resources but also soil properties. Leakage from underground storage tanks and pipelines, accidental spills during transportation, drilling sites and improper waste disposal practices are usually the origin of soil contamination (Hewelke et al., 2018). Once it occurs, it affects plants' phytotoxic properties and state, soil enzyme activities, nitrogen turnover and soil micro-organisms (Jabbarov et al., 2020). Polycyclic aromatic hydro-carbons also called PAH contained in oil have a negative effect on soil enzymes and fauna (Klamerus-Iwan et al., 2015).

Oil spills endanger public health, imperil drinking water, devastate natural resources and disrupt the economy (EPA, 1999). Various mitigation methods both physical and biological have been used to remediate the situation. This review aims at the investigation of oil production and its spread into the environment, its effects on soil properties and remediation methods

Importance of oil in the world

To understand the importance of oil, it is advised we look at the sectors where it is used. Of course it is difficult to think about a sector that does not use oil as a source of energy or raw material. Oil is needed mainly by sectors such as: industry, navigation, aviation, residential, road, rail and non-energy use sector. Gervais (2019), reported data related to the demand of oil by sector and by region, according to those statistics the sector with the most growing for oil was the non-energy and top regions were Africa and non OECD Europe and Eurasia.

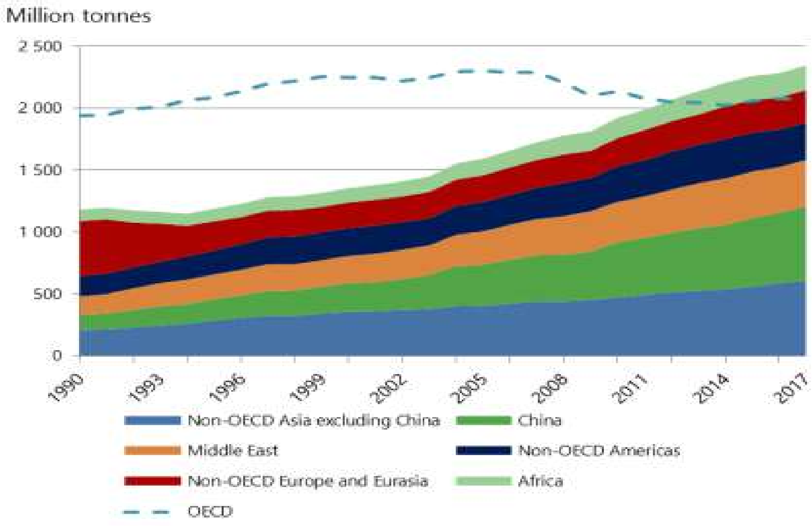

Figure1. Oil demand by region

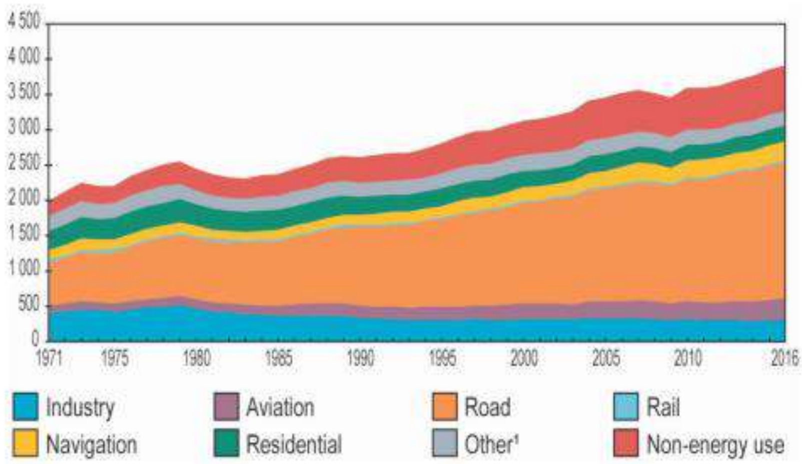

Figure 2. Oil demand by sector

Within the industry sector which include iron and steel, chemical/petrochemicals, non metallic minerals, pulp and paper, food and tobacco, machinery, non ferrous metals, wood, transport, textile, mining and others, oil represent 11% of the world total energy use and comes at the 4th position after electricity, gas and coal (Vandenbussche & Rambech, 2019).

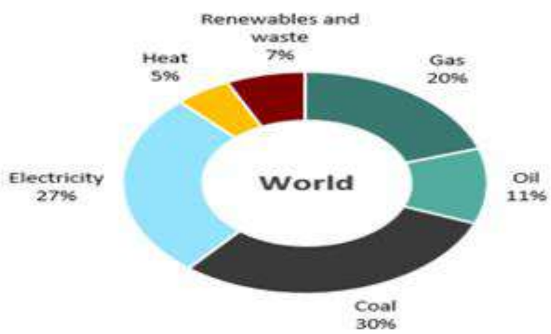

Figure 3. World's energy use

When it comes to agriculture, countries with high level of industrialization can serve as example to illustrate how important oil is and its effect in crop production. In the U.S, oil and oil products such as gasoline, diesel, petroleum, natural gas are used to operate machineries, irrigation and fertilizer production. Among energy related operating cost, more money was spent on fertilizers (Sands et al., 2011)

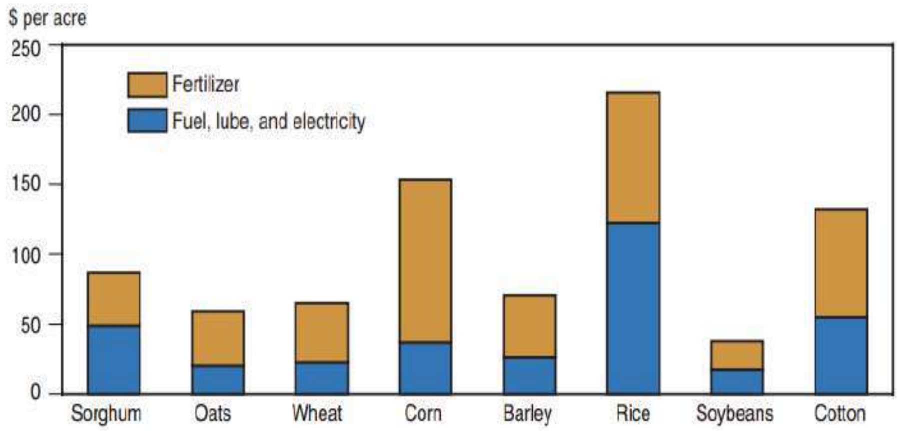

Figure 4. 2007-2008 energy related input on operating cost in the U.S

Crude oil and its effects on soil properties

Petroleum is made up of different compound such as alkanes, cycloalkanes, aromatic compounds (benzene, toluene, ethyl-benzene, xylene), polycyclic aromatics (naphthalene, phenanthrene, anthracene, benzo (a)pyrene), resins, asphaltenes and, in minor amounts, oxygen-, sulfur- and nitrogen containing compounds. It can be classified as light (density 0.65–0.87 g/cm), intermediate (density 0.87–0.91 g/cm) or heavy (0.91–1.05 g/cm). Depending on the origin, crude oil in general will contains 82–85% carbon, 10–14% hydrogen, 0.01–7% sulfur, 0.02–2% nitrogen and 0.1–1% oxygen (Sanborn, 2022).

Soil profile color change is easy to visualize after oil spill; it is due to the coating of soil particle by petroleum film (Abu-Khasan & Makarov, 2021).

The coating of soil particle by petroleum substances increases soil ability to reflect light. Such potential subjects the soil to extreme temperature. Soil particles that have been contaminated by hydrophobic film of high molecular weight lose their ability to absorb and retain moisture, consequently the surface layers in direct contact with film dry out while sub-surface layers remain saturated with water creating air-water unbalance situation that lead t o the development of anaerobic processes (Wang et al., 2021; Hewelke et al., 2018).

An abnormal water condition in soil lower the availability of nutrients to plant, nitrification and ammonification are inhibited. Some reports shows that waters close to petroleum sites have a high amount of sodium, once they move to the soil sorption complex, they replace its pH-balancing cations, causing an increase in Ph (Camenzuli & Freidman, 2015; Klamerus-Iwan et al., 2015).

Petroleum contamination reduces humic and fulvic acids in soil and increases its organic carbon 2-10 folds. However, high carbon content in soil increases C: N ratio and reduces the concentration of important elements such as potassium and phosphorus. All these effect have a negative impact on soil micro-organism and plants.

A study was conducted on the effect oil contamination of the rhizosphere of jojoba plant (*Simmodsia chinensis*), micronutrient analysis shows that 1% increase in petroleum oil reduce soil nitrogen by half, at 3% oil concentration, significant difference in potassium content could be observed, meanwhile phosphorus content was not affected. Plant analysis revealed a gradual increase in sodium within roots and a decrease in shoots with increase in oil concentration, potassium and magnesium content in both roots and shoots dropped, calcium cont increased at the level of shoots and decreased within shoots (Shukry et al., 2013).

Increase in crude oil concentration up to 68.12g/kg increased dry concentration and reduced optimum moisture content. As a result, soil becomes more compacted with less friction due to the lubricity property of oil hydrocarbons that make sand and silt particles more slippery, which increases the amount of particles per unit volume (Zahermand et al., 2020). Odukoya et al. (2019) studied the effect of crude oil contamination on kale (*Brassica oleracea L.*) and lettuce (*Lactuca sativa L.*). He concluded that Crude oil contamination within the range examined did not affect emergence. However, yield and phyto-chemical distributions were affected at some levels of contamination, particularly 10,000 $mg{\cdot}kg^{-1}$ TPH.

The effect of Ph on contaminated soil at 5 and 10% concentration could not be conclusive since on two different sites soil acidity and alkalinity were observed. There was an increase in electrical conductivity and a decrease in other parameters such as moisture, total nitrogen, phosphorus and potassium (Devatha et al., 2019). Another investigation was carried out by Y. Wang et al.(2013) in wetlands. He reported an increase in soil ph in contaminated areas up to 8. Moreover, soil temperature was significantly affected, but the effect varied according to seasons of the year; in May it was significantly lower than uncontaminated sites, meanwhile in august no significant difference was observed in both sites.

Corn and red bean were experimented under different level of oil contamination. Corn was more sensitive than bean and could not germinate at 5% crude oil concentration, shoot and root growth were both affected with increase oil concentration (Baek et al., 2004).

Oil remediation

Remediation of oil contaminated soils can be classified into four categories: biological, physical, chemical and thermal (Varjani, 2017).

Biological remediation

This type of remediation is consist of two methods; phyto-remediation when it involves the use of plants to improve soil quality and microbial remediation when microorganisms are used . In fact, plants possess root enzymes capable of degrading and decompose noxious waste, by using *Mirabilis Jalapa*, 41-63% contamination could be removed (Peng et al., 2009). Phyto-remediation also relies on the potential of plant to take up, accumulate and degrade constituents available in soil and water (Rostami & Azhdarpoor, 2019). Plant species such as *Centrosema brasilianum, Stylosanthes capitata, Calopogonium mucunoides, Brachiaria brizantha, Cyperus aggregatus, Eleusine indica* and *Mirabilis*, as well as plants with extensive root structure and shoot biomass such as *Festuca arundinacea* were quite effective in soil remediation; it was possible to reduce 80- 84% of polyaromatic hydrocarbons (Merkl et al., 2005). This method is known as being very economical; however, it is time consuming , remediation can take approximately 5-7 years, therefore can be use only for long term remediation (Bello, 2007).

During microbial remediation, microorganisms capable of feeding on oil compound such as bacteria, fungi and archaea are used. Through enzymatic reactions, they turn crude oil into carbon dioxide, biomass and water soluble compounds (Stoeckel et al., 2015). An experiment involving the use of bacteria such as *Ochrobactrum sp., Stenotrophomonas maltophilia* and *Pseudomonas aeruginosa* resulted in 80% crude oil (3%v/v) removal (Varjani et al., 2015). Meanwhile, another investigation of soil contaminated by diesel reported 89% removal after a year (Szulc & Ambro, 2014). Microbial remediation might not be applicable in sites riche in substances which are harmful to microorganisms like cadmium, lead and sodium chloride (Mambwe et al., 2021).

Land farming is another method that can be considered as biological. The principle consist in the replication and development of microorganisms under suitable conditions to undertake degradation of the pollutants (Mosbech, 2002) the technique is applied to petroleum hydrocarbons; soil is excavated, dispersed as shallow layer and subjected to different intervention such as improvement of aeration, nutrients, water and minerals to improve microbial activities (Khan et al., 2004). With land farming, only less than 95% contaminants can be removed, but most cases some constituents persist in the soil (Maila & Cloete, 2005). In addition of being time consuming, there is risk this method generates more contaminants than the parent pollutants (Sharma, 2012).

Physical remediation

It includes popular techniques such as soil washing, soil vapor, thermal desorption, sonication, excavation and incineration. Types of soil washing agents can be triton X-100 and sodium dodecyl sulfate (Gitipour et al., 2014). They were found very effective for the removal of benzene, toluene, ethylbenzene and xylene (BTEX) at 95%, 95% and 97% for neutral, basic and acidic pH ranges, but they did not work quite well for polycyclic aromatic hydrocarbons (Achugasim et al., 2011), also they were considered as pollutants.

Soil vapor and thermal desorption were mostly to remove volatile and semi-volatile organic compounds (Khan et al., 2004). The disadvantage of this method is that it could not work effectively for the removal of heavy oils such as diesel and kerosene, and sometimes they could not be removed at all … reports show that thermal method effectiveness depends on temperature and soil types; for instance a temperature of 175^{o}C was necessary to decontaminate diesel polluted sandy and clay soil, meanwhile it took 250oC for clay soil. Similarly, the use of ultrasonic could remove 61 and 49% total petroleum hydrocarbon in 27.6% silt and 55.5% clay soils respectively (Shrestha et al., 2009).

Excavation method of remediation is effective for the removal of both, organic and inorganic contaminants (Osmond et al., 2005). The excavated soil may not be treated, but dumped in a landfill. For this reason, it is considered as the safest and fastest way of remediation (Ahmad et al., 2020). Nevertheless this method not only is old fashion but also costly and time consuming. Remediation by incineration consists in burning contaminated soil at high temperature in an incinerator. During the process, vaporized pollutants can collected and eliminated by pyrolysis (Rushton et al., 2007). After their experiment, (Anthony & Wang, 2006) thought that 800°C could be enough to eliminate all oil contaminants. This method though cheaper when carried out onsite is not environmental friendly because of the presence of volatile and flammable chemical compounds that may cause air pollution (Muzenda, 2014).

Chemical methods

Oxidation

It is a method that uses oxidants that are reactive depending on soil types; some of them include hydrogen peroxide, (H2O2), ozone (O3), permanganate (MnO4-) and persulphate ($S_2O_8^{2-}$). Fenton's reagent which is a combination of hydrogen peroxide and ferric ions (Fe^{3+}) is quite used; ferric iron plays the role of catalyzer while hydrogen peroxide being an oxidizing agent produces hydroxyl ions during the reaction (Ahmad et al., 2020; Sutton et al., 2014). When used under right conditions, Fenton's reaction was found very suitable for the removal of total petroleum hydrocarbons; 48% of TPHs could be remove within two hours (Adipah, 2018). The oxidation might be suitable for highly contaminated soils because good result can be obtained in a short time. However, it might not be effective in soils with low permeability (Mambwe et al., 2021).

Photochemical oxidation

In this method, a catalyst and a contaminant are mixed and irradiated with light (UV or sunlight) which leads to the oxidation of organic pollutants and formation of compounds such as water and carbon dioxide (Liu et al., 2018; Xiang et al., 2011). Soil remediation using photochemical oxidation improves oil solubility and biodegrability. Research have shown that all form of TPHs could be remove using this method, but this depends upon soil moisture since removal was enhanced with increasing soil moisture (Brame et al., 2013).

Conclusion

Oil is a fundamental source of energy needed in various economical sector of our world; we depend on it to run our industries and for the manufacturing of important products such as fertilizers without which agricultural yield might be affected. But this source of energy becomes dangerous when it is spread in the environment; it becomes a source of pollution for soils and water. Soils undergo a drastic change in quality which is dependent on the level of contamination. Toxic chemical in oil substance reduce soil moisture, primary minerals such as nitrogen and potassium, and microbial population. Fortunately, methods have been developed to remediate the problem; they can be biological, physical, thermal or chemical. Some of the practices falling under each category can be quite effective and others not. Nevertheless the adoption of any of the remediation methods discussed above will depend on the level of contamination, expected remediation time and the availability of resources.

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Wind damages monitoring on vine yard to select the right location in Gobustan District

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Abstract

Wind damage impact on the plants is actual question in cultivation for the windy places, long term monitoring is to be carried out before plantations' location determination. Hazardous wind risk for vine yards in Gobustan's agrarian sector was investigated in the paper. Long term monitoring and measurements were realized on the base of remote sensing radar techniques according to Several windsats. The results have been analyzed to Wigner-Ville distribution (WVD), wind speed calculators of Danish Wind Industry Association. Wind roses and were established by using Wind Rose online maker. All wind measurements were realized by using radar techniques of remote sensing method at 2 meters above the earth. In the process of studying several wind sats' results including Azer sky satellite have been utilized. Synchronical wind directions' action was observed in the aerospace sources to reveal the real risks for plantation areas. Geographical distribution of the vine yards in the district have been determined. Average daily, monthly, yearly wind direction and wind speed potentials were determined after the analyses of the wind data. Wind speed data due to10-50 % interval windiest areas have been calculated to the proper methods. Total area wind potential's monogram was developed on the months along the year taking into consideration time and season. Meanly 50% windiest areas average wind speed consists of 4.16 m/sec, maximum wind speed index is observed in December about 1.33 and minimum one in May and August about 0.82. Increasing happens beginning from May, generally in vegetation season wind index is higher. These both directions possess maximum occurrences. The north and the northern west part wind directions are characterized to the west part of the district. Wind potential's impact on the vine yards and geographical suitable part for plantation have been defined for Gobustan district.

Keywords: Wind Radar, Wind Direction, Wind Speed, Monitoring.

Introduction

Wind damage impact on the plants (Poggi et al, 1994) is actual question in cultivation for the windy places, long term monitoring is to be carried out before plantations' location determination (Brunet et al, 2000). Local wind potential differs in the regions depending on some natural and environmental factors. Thus, on the mountainous districts there are the specific wind kinds to the territory. In the agrarian sector wind's role is great as well as (Dupont et al, 2008). So, all effects of the local wind are to be taken into consideration during planting and cultivation of the crops. Generally, wind impact can be appreciated from two facets as negative and positive (Finnigan et al, 1995) ones like other terroir (environmental factors). While planting vine yards and defining vine rows various geographical factors including relief form (Sellier et al, 2008.), climate parameters (Finnigan, 2000) sun orientation and also wind impact are taken into consideration. In semi desert climate condition (Finnigan et al, 2000) wind may be accepted because of the cooling effect during the vegetation. For green vine bushes cooler weather is effective than warm one. This climate condition makes the ripening process be slower. In this case flavors are developed in vine grapes.

Unlike warm weather condition when there is a lot of humidity or wetness in the weather, wind supplies to conceal mildew which has hazardous effect for the crop. Thus, grape ripening occurs to the autumn season when the initial frost begins and wind can prevent it, too. Some natural damages are able to be solved by wind potential of the region. Adaptation to the wind gives the possibility for the grape to have thicker skin which is necessary for flavors' concentration in the wine. In vine yards wind damage is met in the windiest parts of the district in spring and summer seasons in different phases of the vegetation, especially in rapid growing cultivar. Shoots' generation happens in early spring (Bettiga, 1996) when mountain-valley winds are active in this period. Because fyon winds have warm air stream damaging the vine leases and shoots. After having become larger the leaves are face to face with strong wind speed which decreases photosynthesis potential of the plant. Finally less crop yield is gained in harvesting process. For better photosynthesis healthy leaves are demandable which are under wind impact. The major purpose of the research paper is to determine the cultivation locations with mountain-valley wind flow and its damage rate (Bonnardot, 2001) on the wind yards in Gobustan district. Thus, the clockwise wind directions' hazardous impact on wine shoots (Archer, 1989), berry fertilization causing poor fruit sets has to be escaped before the wine yard plantation. That's why total wind potential including wind speed, wind direction should be studied beforehand.

Material and Methods

The selected research area Gobustan has been included into Dagligh Shirvan Economical Region borders, borders with Hajigabul district, Shamakhi district, Khizi district, Absheron peninsula in 40° 32' 3.59" N latitude and 48° 55' 9.59" E longitude. The main relief components consists of rocks, sandstone, mud volcanoes. Wind resistible wild plants growing in Gobustan is juniper *(Juniperus communis),* wild fig *(Ficus carica),* wild pear *(Pyrus communis subsp. pyraster),* honeysuckle**,** (genus *Lonicera*), wild rose (*Rosa acicularis),* wild pomegranate *(Punica granatum)* which has been protected. The agricultural sector consists of 60% grape plantation in comparison with others. Water stock is based on the mountain rivers such as; Pirsaat, Jeyrankechmez, Sumgayit and others little ones.

Climate

Semi arid climate concerns to the district being followed by hot summer and mild winter. Characteristic winds are fyon or west winds (warm wind), and north west winds (cold winds) in Gobustan. Average annual air temperature of Gobustan is 10.5°C, medium values for warm period is 17.5°C and for cold period is 3.4°C. The Soil surface temperature is averagely 12°C. The mean atmospheric precipitation consists of 379 mm/year. Relative humidity is near 72% at 2 meter above the earth surface. Evaporation during four seasons reaches to 872 mm/year. Generally 250 mm average annual precipitation falls down along a year. Early spring and late autumn are mainly rainy seasons having rainiest days in the western part of the district.

Mean wind speed reaches to 6.55m/sec along the years (especially warm period of the year). North (N) and North-North-East (NNE) direction winds at several occurrence and percentages are leader in the region (Climate of Gobustan, 2022).

Figure 1. General view of Qobustan and wind rose for Qobustan

In the research there is a great deal of wind potential in different directions, so vine yard right location determination is actual today. Taking into consideration the relief plastics, remote sensing study in this field has great advantages. This method gives opportunity to reveal the wind potential (wind speed, direction) in any coordinate of Gobustan district.

Results and Discussion

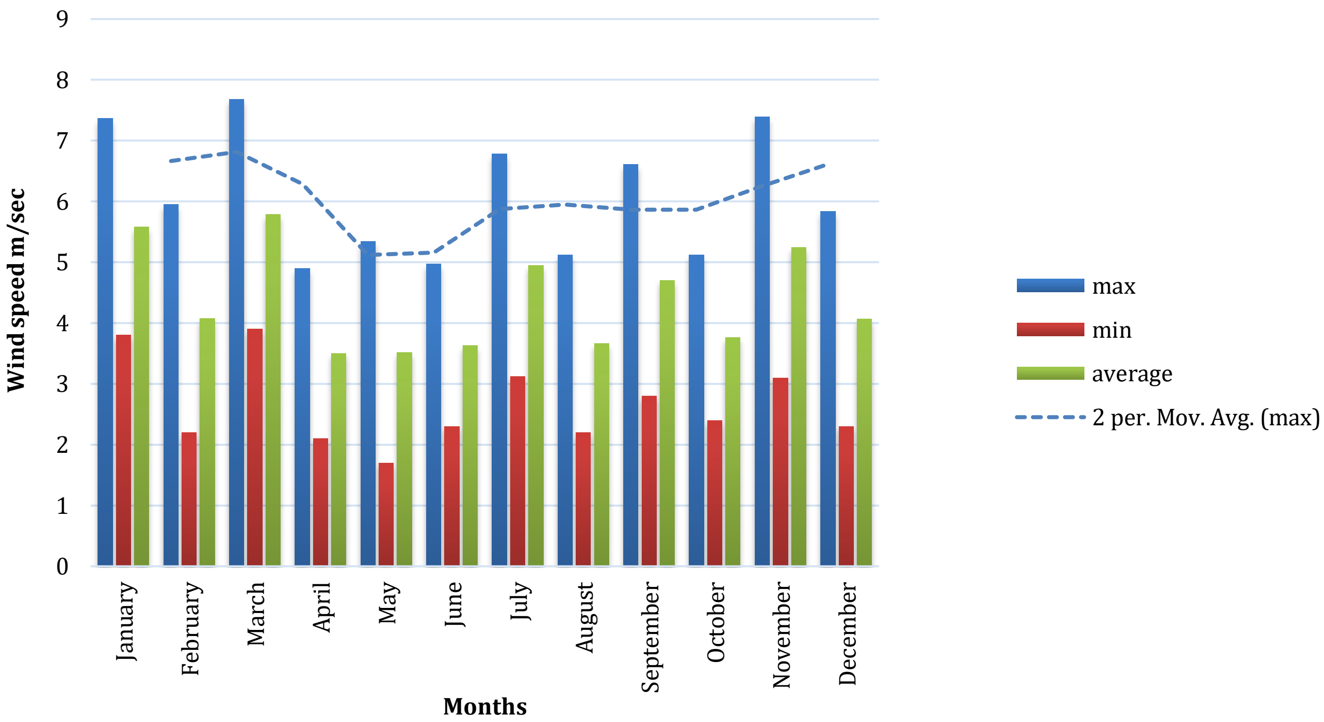
Grapevines has serious wind damage risk in the investigation region. This risk may be physical or mechanical like defoliation, bush withering, shoot breakage (Bonnardot, 2002) and physiological like stomatal conductance weakness causing the poor photosynthesis process in the plant. The both risks can happen either in moderate windy days or strong windy weather (Cala, 1996) conditions. In the research carried out in Gobustan territory practical evident matters have taken into consideration for wind impact on grape yards. One of them is the wind influence on pollination distribution in the bushes. The faded leaves in grape canes show the result of the hazardous wind risk, so destroyed vine cane is getting to die if there is no any connection with the cordon. Practically wind damage is differentiated in comparison with herbicide, insect or diseases having the same results (Dupont et al, 2008). Wind damage is to be prognosed before plantation by choosing the right location depending on vine kinds and wind potentials for cultivation. Thus, wind flow direction, speed and main routs (Carey, 2001) have to be investigated in anyway. If geometrical configuration of the vineyard plantations due to the wind directions is developened, in this case, wind impact reduces practically. So, location choice can solve the existing problem to obtain more effective harvest at the end (Brunet et al, 2000). In stead of perpendicularness, paralellness to the wind direction gives opportunity the vine yards to be saved to escape from the wind breaks. The constant winds lead to the friction by other plants which causes flower sets' loss. The final wind damage is estimated as economical failure in crop yield. Traditional cultivation has several fields in the research district. One of the wide spread gardening is grape growing. Vine yard plantation possesses the historical background. At the same time wind impact is differently appreciated. In early phase of vine bush growth, hazardous wind influence is directly felt. That's why right location of vine yards is to be planned to get the rich harvest in autumn. Thus, wind potential has to be studied. Taking into consideration wind gust and high wind speeds in early spring and autumn, this investigation has been carried out. After the long term measurements and data analyses, the next dependences have been obtained. Mean, average, highest annual wind potential of the district we defined and given below.

As seen from the wind rose (Figure 1) east and north direction winds are repeated. In west direction the highest data are observed, during vegetation period from April till November average wind speed changes between 3-5 m/sec. The warm air stream is replaced with cold one to the autumn. Maximum wind speed is about 7,68 m/sec and minimum index consists of 3,9. It shows that vegetation phase of the vine yard can be faced to hazardous wind impact, therefore right location of the plantation is actual for the region.

In order to know the total wind potential along the year wind index distribution within 24 hours is so necessary in the investigation. So, scattering in wind gusts (highest speed) is revealed. Thus, the dependence between time and wind index was estimated, then given in the following figure.

From this figure within 1 and 3 hours, scattering of wind index is met. Peak date is observed during 2 hours at night. But 12 hour wind index constant stays in 1.4, only 2 hours this index consists of 1.6. half of diurnal period, wind index reaches to 1.4 and this's enough to happen wind damage for the first vegetation phase in vine yard plantations.

From the both graphs according to the wind directions, the proper location can be defined. Middle, north and east parts of the districts are characterized with high wind potential which is terrible for the first stage because of temperature effect. In early May warm wind blow causes plants' wilting and leaves yellowing. So, air stream rout for mountain-valley winds are to be taken. Fyon winds are hazardous for the beginning of the vegetation, too.



Month	Degrees (°)	Direction	Max.	Min.	Ave.
January	265,75	W	7,37	3,80	5,585
February	281,00	WNW	5,95	2,20	4,075
March	238,81	W	7,68	3,90	5,790
April	218,69	SW	4,90	2,10	3,500
May	153,62	SSE	5,34	1,70	3,520
June	108,25	ESE	4,97	2,30	3,635
July	63,56	ENE	6,78	3,12	4,950
August	106,88	ESE	5,12	2,20	3,660
September	61,69	ENE	6,61	2,80	4,705
October	70,62	ENE	5,12	2,40	3,760
November	295,94	WNW	7,39	3,10	5,245
December	257,06	WSW	5,84	2,30	4,070

Figure 3. Maximum, Minimum and Average Wind Speed in Gobustan District at 2 meter

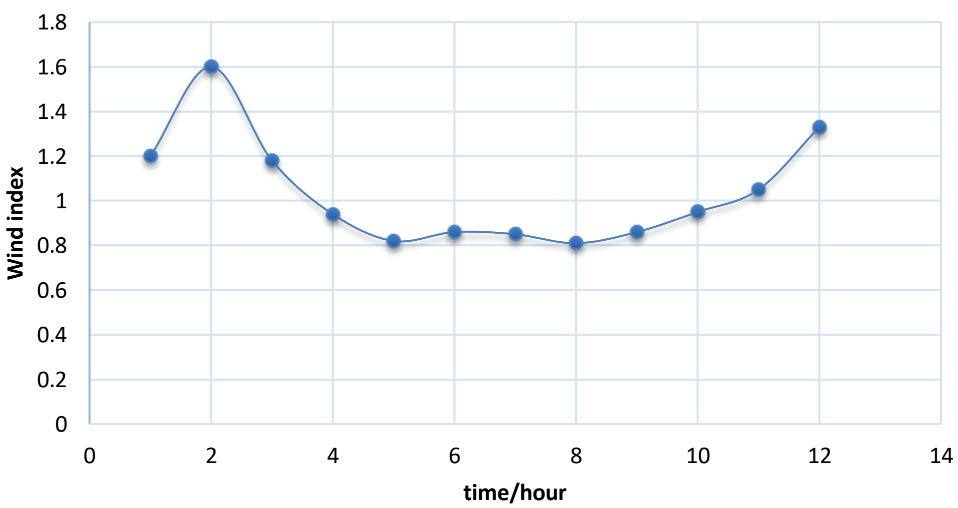


Figure 3. Wind Distribution Index on Time (hour)

Conclusion

Wind potential's impact on the vine yards and geographical suitable part for plantation have been defined for Gobustan district. Therefore total wind potential of Gobustan district was investigated and analyzed for right grape yards location. Wind index distribution on time and minimum, maximum and average wind speed have been determined for the areas of the cultivation zone. Relief, wind potential were compared to find right location for vineyard fields. Finally, it is possible to reduce wind damage for grape yards in Gobustan district to select proper location before cultivation.

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Investigations on soil-borne viruses and their vectors in sugar beet production areas of Ankara and Konya Provinces

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Abstract

Sugar beet (*Beta vulgaris* L.) is widely grown in Turkey as a raw material for the sugar industry. The plant can be affected soil-borne viruses including Beet necrotic yellow vein virus (BNYVV) and Beet black scorch virus (BBSV). A total of 52 soil samples were collected from different sugar beet fields in Ankara and Konya provinces during 2020 growing season. Incidences of BNYVV and BBSV and their vectors *Polymyxa betae* and *Olpidium* spp. were determined by bait plant test using ELISA and root staining techniques. The study showed that BNYVV was very common (78.8%) in the sampled sugar beet fields. Also, all of the root samples investigated were found to be infested with its vector *P. betae*. On the other hand, the vector of the BBSV, *Olpidium* spp. were present (57.7%) in the surveyed region. However, no BBSV infection was detected in any of these samples. This study indicated that BNYVV, the agent of rhizomania disease, and its vector are highly widespread in sugar beet production areas in Ankara and Konya provinces.

Keywords: BNYVV, BBSV, P. betae Olpidium spp, ELISA

Introduction

Sugar beet (*Beta vulgaris* L.) is considered one of the major important cultivated crops in the world. The plant can be infected by different soil-borne viruses including Beet necrotic yellow vein virus (BNYVV), Beet soil-borne virus (BSBV), Beet virus Q (BVQ), Beet soil-borne mosaic virus (BSBMV) and Beet black scorch virus (BBSV). Among them, Beet necrotic yellow vein virus (the genus *Benyvirus*, family *Benyviridae*), the agent of rhizomania disease, causes significant losses in sugar beet worldwide (Biancardi and Tamada, 2016). The disease is characterized by extensive rootlet proliferation from the main taproot leading to a root beard in sugar beet plants. Also, virus-infected taproots display a reduced size, wine glass-like shape and vascular necrosis (Liebe and Varrelmann, 2022). BNYVV is transmitted by soil- inhabiting plasmodiophorid vector *Polymyxa betae* Keskin. Both the virus and its vector can survive in the soil for more than 10 years (Biancardi and Tamada, 2016). BBSV, is member of the genus *Betanecrovirus*, family *Tombusviridae* (Cao et al., 2002). The virus is transmitted by zoospores of the chytrid vector *Olpidium brassicae* in a non-persistent manner (Jiang et al., 1999). BBSV induces severe systemic symptoms of black scorching leaf tips, necrotic fibrous roots and severe stunting of beet plants in China (Zhang et al., 1996). However, the isolates of BBSV obtained from USA and Europe cause no black scorching on the leaves but showing exacerbated symptoms similar to that of BNYVV (Weiland et al., 2007; Gonzalez-Vazquez et al., 2009).

Since its first report in Turkey in 1987 (Koch, 1987), BNYVV has spread in almost all the major sugar beet growing areas within the country (Erdiller and Özgür, 1994; Ozer and Ertunç, 2005; Kaya, 2009; Kutluk Yilmaz and Arli Sokmen, 2010; Kutluk Yilmaz et al., 2016; Yardimci and Culal Kiliç, 2011). Up to now, no BBSV infection has been recorded in sugar beet in Turkey. However, in 2011 and 2016, BBSV-like symptom especially black scorching on the leaves was observed in sugar beet plants in some fields in the Central Anatolia Region of Turkey (Kutluk Yilmaz et al., 2016, 2019). In the present study, the presences of BNYVV and BBSV and their vectors *Polymyxa betae* and *Olpidium* spp. were investigated in Konya and Ankara provinces.

Materials and Methods

Soil sampling and bait plant test

A total of 52 soil samples were randomly collected from sugar beet fields in Ankara and Konya provinces in 2020 (Fig. 1). All soil samples were homogenized and mixed with sterile sand (1 part of soil: 2 parts of sand). Then, seven-day-old sugar beet seedlings from rhizomania-susceptible genotype (cv. Ansa-*rz1*) were planted in 300-ml plastic pots containing each soil sample. The plants were grown under controlled conditions of 12-h photoperiod, at 20°C (night) and 25°C (day) temperatures. After six weeks of growth, plants were removed from pots, the taproot was washed under running water. The roots of plant were divided into two parts. One part was used for investigation of BNYVV and BBSV incidences by ELISA according to Clark and Adams (1977); the other part used for *P. betae* and *Olpidium* spp. detection.

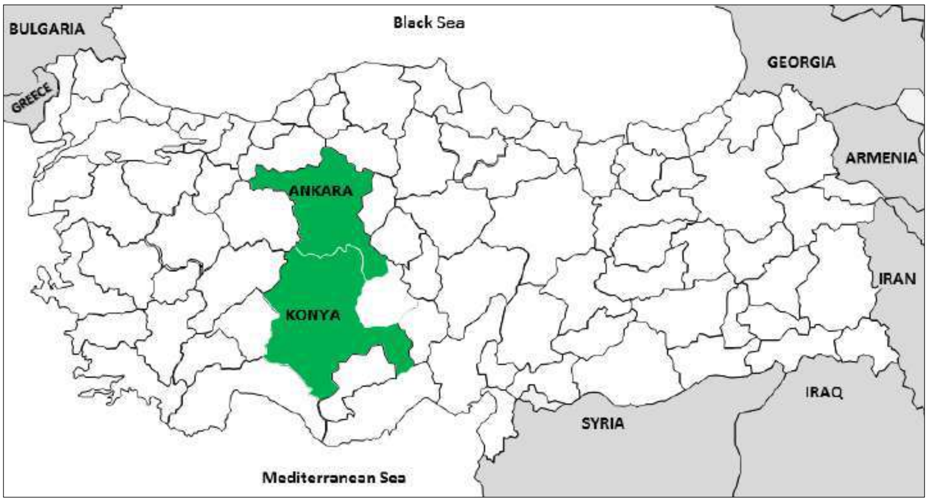

Figure 1. Sugar beet growing areas surveyed in Turkey. The green shaded area in the map shows the provinces surveyed

Enzyme linked immunosorbent assay (ELISA)

A double antibody sandwich-enzyme linked immunosorbent assay (DAS-ELISA) was performed for BNYVV and BBSV using commercial kits (Bioreba, DSMZ, respectively) following the manufacturer's instructions. Absorbance reading at 405 nm were obtained 2 h after substrate incubation by using a microplate reader (Tecan Spectra II), and the samples were considered positive when the absorbance values were two times more than the mean value of the negative controls (Meunier et al., 2003).

Microscopic detection of *P. betae* and *Olpidium* spp.

Root samples were stained with lactophenol containing 0.1% acid fuchsin, and examined using a light microscope (Leica) to detect *P. betae* and *Olpidium* spp. resting spores (Abe and Tamada, 1986).

Results and Discussion

The present study involved major sugar beet growing regions including Konya and Ankara provinces in Anatolian part of Turkey, which covers 28% of the total sugar beet production area of the country. The result of our study showed that sugar beet fields were infected with BNYVV at a rate of 78.8% (41 of the 52 samples) (Table 1). In earlier studies, BNYVV infection were detected in various parts of Turkey including Konya and Ankara provinces (Erdiller and Özgür, 1994; Ozer and Ertunç, 2005; Kaya, 2009; Kutluk Yilmaz and Arli Sokmen, 2010; Kutluk Yilmaz et al., 2016; Yardimci and Culal Kilic, 2011). In the surveys conducted in the same provinces in 2016 and 2017, the incidence of BNYVV (61%) was lower than the current study (Kutluk Yilmaz et al., 2019). This result shows that BNYVV spread rapidly in sugar beet production areas when suitable conditions were available over time. On the other hand, in surveys conducted in neighbouring countries, BNYVV incidences were 47.8-57.8% in Syria (Mouhanna et al., 2002), 52.4% in Iran (Farzadfar et al., 2007), 95% in Greece (Pavli et al., 2010). High incidence of BNYVV in Greece could be due to different sampling method used where the plants with typical BNYVV symptoms were collected, whereas the sampling was random in the current study. Besides this, its vector *P. betae* was common (100%) in sugar beet fields and 21.2% of the roots were infested with aviruliferous *P. betae* cystosori in this study (Table 1) (Figure 2-A).

Table 1. Incidences of BNYVV, BBSV and their vectors *P. betae* and *Olpidium* spp. in the samples collected from sugar beet fields in Ankara and Konya provinces of Turkey

Province	District	Field surveyed	BNYVV	BBSV	*P. betae*	*Olpidium* spp.
Ankara	Ayas	5	5	0	5	3
	Beypazari	3	3	0	3	3
	Sincan	5	5	0	5	2
	Polatlı	11	9	0	11	7
	Haymana	5	1	0	5	2
Konya	Meram	1	1	0	1	0
	Cumra	9	8	0	9	7
	Yunak	13	13	0	13	4
Total (% infection)		52	41 (78.8)	0 (0)	52 (100)	30 (57.7)

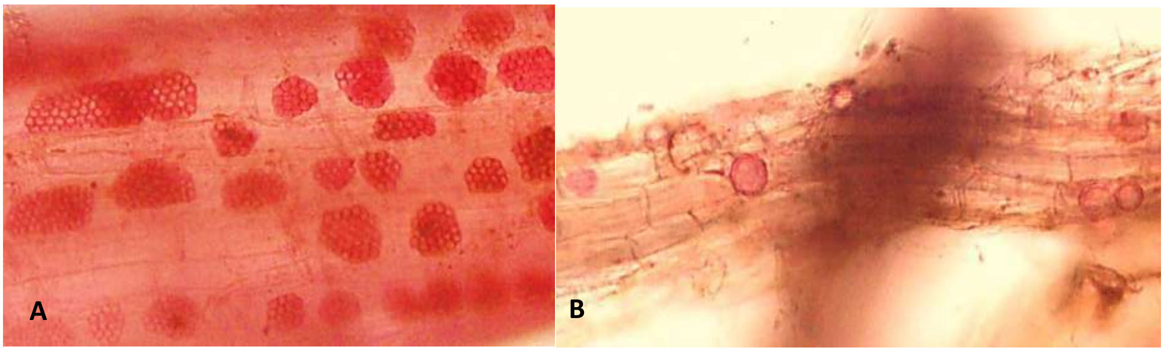

Figure 2. Resting spores of *Polymyxa betae* (A) and *Olpidium* spp. (B) in sugar beet root tissues

In this study, the vector of the BBSV, *Olpidium* spp. was present (57.7%) in the surveyed region (Figure 2-B). However, no BBSV infection was detected in any of these samples by ELISA (Table 1). In earlier studies, the researchers from USA and Europe stated that BBSV was obtained from sugar beet plants with rhizomania-like symptoms, in which BNYVV and/or BSBMV were not detected (Weiland et al., 2007; Gonzalez-Vazquez et al., 2009). Also, BBSV was found to be very common in Iran (33%) (Mehrvar, 2009).

Conclusion

The current study indicated that BNYVV, the agent of rhizomania disease, and its vector are highly widespread in Ankara and Konya provinces. which are among the leading sugar beet production regions of Turkey. The resting spores of *P. betae* can remain in infested soil for long periods. Beet soil-borne viruses are transmitted mainly by the movement of soils containing viruliferous resting spores of the vector, and uninfested fields in the region are at great risk of contamination. Therefore, sanitary precautions are important to prevent disease spread.

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Determination of landslide susceptibility with the help of analytical hierarchical process- Suşehri Example

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Abstract

Landslides are defined as the movement of soil, rock, or rubble mass in the direction of a slope, causing great loss of life and property in our country as well as in the world. In recent years, many approaches and algorithms have been used to reduce the harmful effects of disasters, including landslides. The use of these approaches and methods has facilitated the development of early warning systems for disaster areas or areas exposed to disaster, as well as the production of sensitivity maps. The analytical hierarchical process approach, which systematizes the data and accelerates the decision-making process, is widely used in the evaluation of many criteria. This study was carried out within the borders of Suşehri district of Sivas province it was aimed to determine the landslide susceptibility with AHP by using slope, aspect, precipitation, proximity to a stream, distance to fault lines, distance to roads, land use, soil, lithology, NDVI parameters. According to the landslide susceptibility map, 18.75% of the total 98500 ha study area has a high and very high landslide risk, while 52.30% has a low or very low landslide risk.

Keywords: Analytic Hierarchical Process, Geographic Information Systems, Landslide, Land Use.

Introduction

With the effect of the rapidly increasing population, residential areas continue to grow uncontrollably and the impact of natural disasters is increasing at the same rate. Due to its geographical location, geological structure and climatic characteristics, Turkey is among the countries that suffer the most with the loss of life and property caused by natural disasters. Among natural disasters, landslides with devastating effects and a high damage threshold cause permanent damage that cannot be recovered. In recent years, landslide susceptibility maps have been created in order to reduce the harmful effects of landslides, to determine the landslide hazard dimensions and the affected areas, and to evaluate the possibility of landslide regeneration (Demir, 2018). Landslide susceptibility maps are defined as maps that express the spatial possibility of landslides in an area (Varnes 1984).

In recent years, Geographical Information Systems (GIS) and Remote Sensing techniques have provided great convenience in the preparation of landslide susceptibility maps. Geographic Information Systems, which are frequently preferred in landslide studies by processing, analyzing and preparing the data to be obtained from any field, have been used by many researchers (Lee, 2005; Lee and Pradhan, 2007; Ercanoglu et al., 2008; Das et al., 2010; Pradhan and Youssef, 2010; Akgün et al., 2012; Bednarik et al., 2012; Devkota et al., 2013; Himan et al., 2014; Nourani et al., 2014; Bourenane et al., 2016).In the preparation of the sensitivity map, the frequently used parameters were discussed by literature review. For this purpose, in order to eliminate the uncertainties in the selection of landslides, a literature review was made and a solution was tried to be found.

In the study, 11 parameters including slope, aspect, elevation (DEM), land use, soil classes, lithology, precipitation, NDVI, distance to rivers, distance to fault lines, distance to roads were evaluated.

The aim of this study is to produce a landslide susceptibility map with the Analytical Hierarchical Process approach, taking into account 11 different parameters in the borders of Sivas Province Suşehri District. It is very difficult to determine when and under what conditions landslides may occur. For this reason, the landslide susceptibility map produced is intended to reveal the landslide risk situation of the study area in line with the parameters discussed

Material and Methods

Study area

It is a district of Sivas, located on the western edge of the plain with the same name, in the southwest of the Eastern Black Sea Section of the Black Sea Region. It is surrounded by Akıncılar to the east, İmranlı to the south, Zara to the southwest, Koyulhisar to the west and Şebinkarahisar of Giresun to the north (Figure 1). The study area covers an area of approximately 985 km^2.

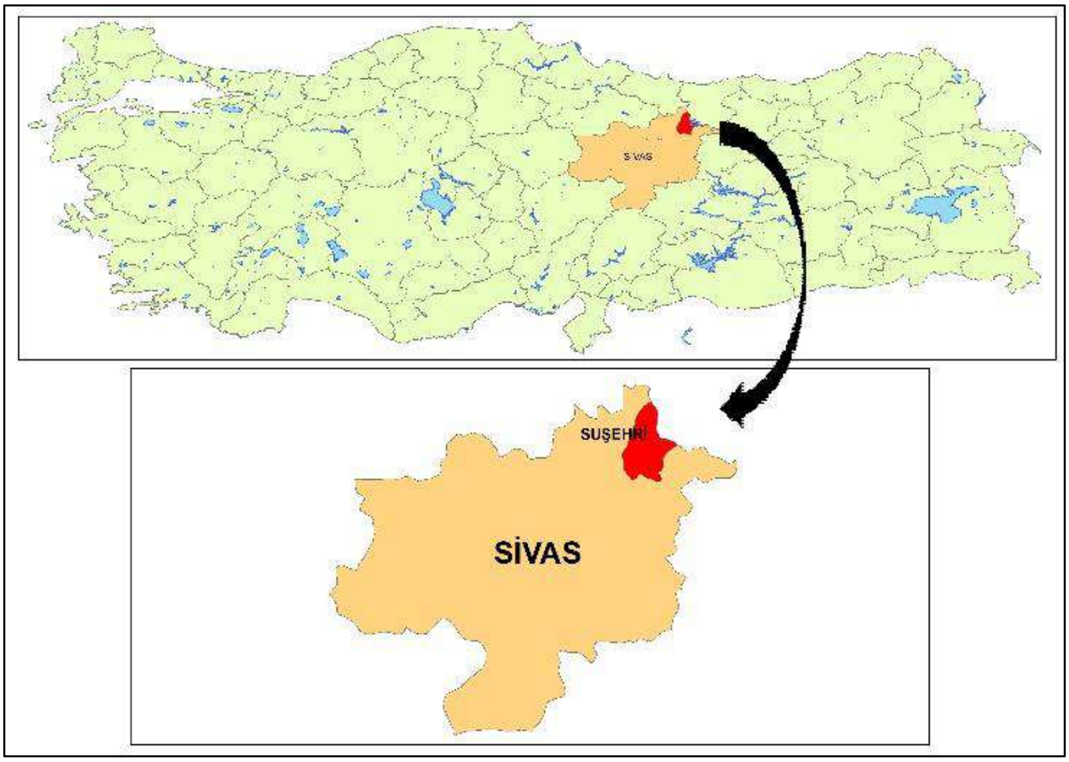

Figure 1. Location map of study area

Since it is located in a border region in terms of geographical features and climatic conditions, both the continental climate of Central Anatolia and the temperate effect of the Black Sea climate are seen here. In addition, the North Anatolian Mountains prevent the district from benefiting from the influence of the sea. For this reason, the summers are dry and the winters are milder than the Central Anatolia Region.

Parameters evaluated in the study

Frequently used in landslide studies after literature review (Kayastha et al., 2013; Demir, 2018; Özşahin, 2018); 11 parameters including slope, aspect, elevation (DEM), land use, soil classes, lithology, precipitation, NDVI, distance to streams, distance to fault lines, distance to roads were taken into consideration. Distribution maps produced for the parameters are given in Figure 2.

Slope: It is one of the most important factors affecting the landslide.

Aspect: The position of the topography against the sun is important in the preparation of sensitivity maps (Guzzetti et al., 1999; Nagarajan et al., 2000).

DEM: It has been reported that the elevation change of the topography is an effective factor in the formation of landslides (Kayastha et al., 2012).

Land use: Forest areas with dense land cover are less affected by landslides than agricultural and residential areas (Dağ, 2007).

Soil: The soil covering the surface of the topography also causes landslides (Özşahin and Kaymaz, 2013).

Litoloji: The effect of lithology on landslide formation is due to the sensitivity of rocks to landslides (Özşahin, 2015).

Precipitation: The soil becomes saturated with water due to precipitation and the soil becomes susceptible to landslides as the groundwater level rises.

NDVI: Areas covered with healthy vegetation are more resistant to landslides than areas with shallow vegetation.

Distance to streams: The distance to the streams factor affects the landslide formation by controlling the saturation degree of the material on the slopes and the stability of the slope (Yalçın, 2008).

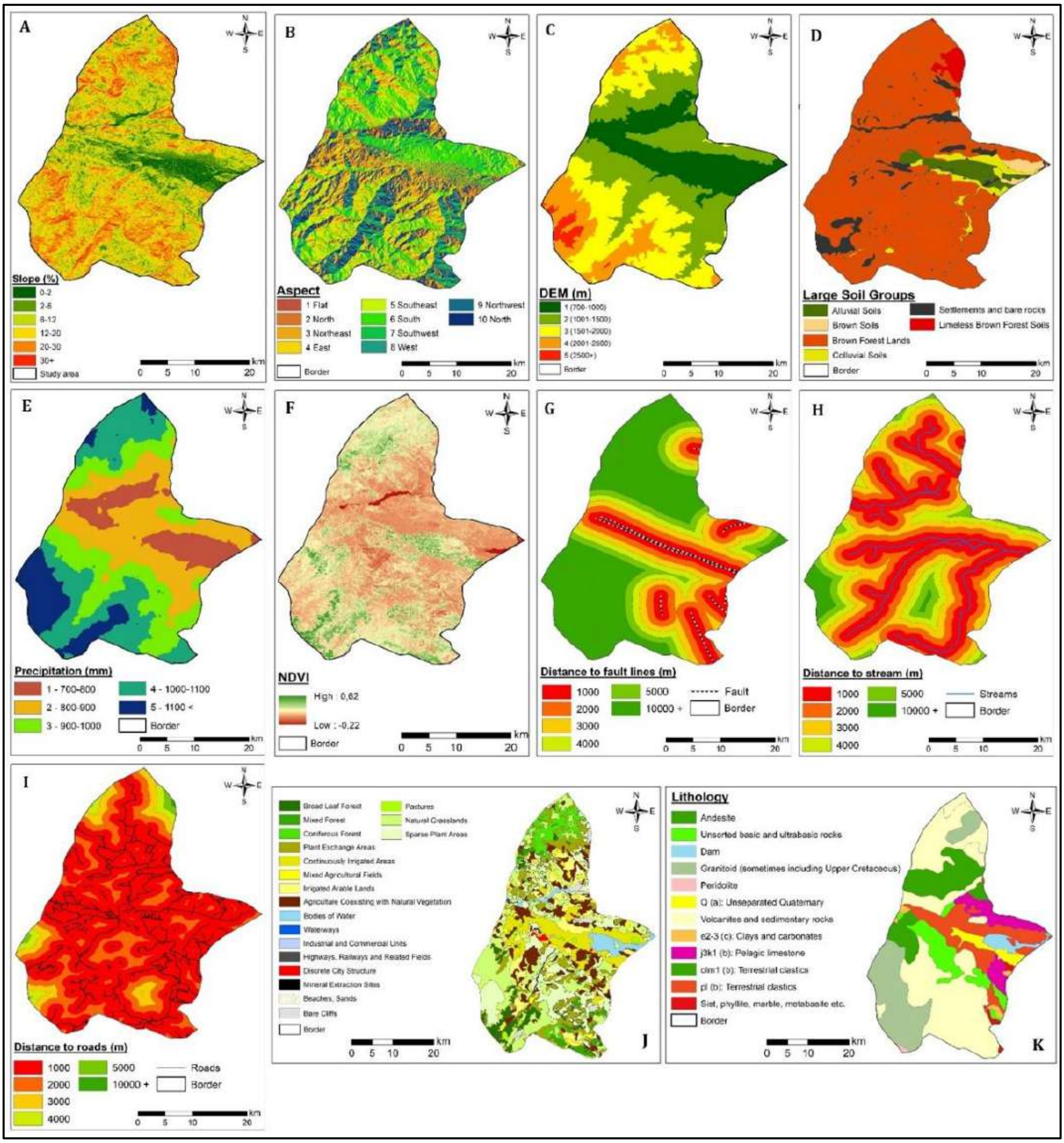

Figure 2. Slope (A), Aspect (B), DEM (C), Large soil groups (D), Precipitation (E), NDVI (F), Distance to fault lines (G), Distance to stream (H), Distance to roads (I), Land use (J), Lithology (K) parameters

Distance to fault lines: Generally, fault planes with high slope values are taken into account in landslide studies as they are quite suitable for landslide formation (Özşahin, 2015).

Distance to roads: Especially on sloping lands, there is a high probability of being exposed to landslides since there is no connection or area that can carry the load of the part on the road.

Analytical Hierarchical Process Approach

Analytical hierarchy process (AHP), a semi-quantitative method in which decisions are made using weights through pairwise relative comparisons without inconsistencies in the decision-making process (Saaty, 1980), consists of five steps: (i) separating a decision problem into its component factors; (ii) arranging these factors in a hierarchical order; (iii) assigning numerical values to determine the relative importance of each factor according to its subjective relationships (Saaty, 1977); (iv) generating a comparison matrix; and (v) computation of the normalized prime eigenvector giving the weights of each factor (Saaty and Vargas, 2001).In AHP, the comparison of factors is made using a scale from 1 to 9 if the factors have a direct relationship and a scale from 1/2 to 1/9 if the factors have an inverse relationship (Saaty, 1977).The preference values for the present study, first for comparison of the causative factors and next for comparison of the classes in each factor. The preference values yield comparison matrices. An important feature of the AHP is that it enables to determine rating inconsistencies by the consistency index (CI), defined as (Saaty, 2000). Then, the scale coefficients were assigned in such a way that the consistency of the percentage importance weights of the determined criteria and alternatives would be valid (Table 1). The validity of the consistency was checked by calculating the consistency index (CI) and ratio (CR). The following procedures were applied to calculate the consistency ratio of matrix A (Shrestha et al., 2004).

$$CR = CI/RI$$

$$CI = (\lambda max - n)/(n-1)$$

Λmax: the largest eigenvalue, n: the order of the comparison matrix. Saaty (1980) developed an average random consistency index (RI) for different matrix orders, CR: consistency ratio, CI: ratio of the consistency index (CI). If CR is greater than 0.1, the comparison matrix is inconsistent and should be revised (Wind and Saaty, 1980; Saaty et al., 2003). Table 1 shows that for the present case all CR values are less than 0.10. The sub-criteria and weight values taken into consideration for the parameters are given in Table 2.

Table 1. Number of order of matrix N, largest eigen value λmax of the preference matrix, consistency index CI, random consistency index RI, and consistency ratio CR, for the landslide causative factors.

Parameters	wi	CR	RI	CI=CR*RI	λmax
Slope (%)	0.30	0.0999	1.51	0.1508	6.7540
Lithology	0.15	0.0864	1.24	0.1071	6.5355
Precipitation (mm)	0.14	0.0816	1.12	0.0914	5.3656
Soil	0.10	0.0731	1.12	0.0818	5.3272
Land Use	0.08	0.0970	1.32	0.1280	7.7680
NDVI	0.06	0.0542	1.12	0.0607	5.2428
DEM (Dijital elevation model)	0.05	0.0547	1.12	0.0612	5.2428
Aspect	0.04	0.0746	0.90	0.0671	4.2013
Distance to Fault Lines	0.03	0.0872	1.24	0.1081	6.5405
Distance to stream	0.03	0.0242	1.24	0.0300	6.1500
Distance to roads (m)	0.02	0.0909	1.24	0.1127	6.5635

The weight values obtained for the parameters discussed in the study were overlapped with the help of ArcGIS 10.8 program. For this, ArcTool Box -Spatial Analysis Tools- Overlay-Weighted Sum module was used. The susceptibility map obtained is categorized into 5 classes (Table 3, Figure 3).

Table 2. Sub-criteria and weight values for the parameters considered in the AHP

Criteria	Layers	Weight Values	Criteria	Layers	Weight Values
Distance to stream	1000 m	0,0191	Distance to Fault Lines	1000 m	0,0085
	2000 m	0,0122		2000 m	0,0051
	3000 m	0,0074		3000 m	0,0036
	4000 m	0,0043		4000 m	0,0021
	5000 m	0,0029		5000 m	0,0012
	10000 m	0,0017		10000 m	0,0005
Land Use	Bare Cliff	0,0278	Distance to roads (m)	1000 m	0,0083
	Mine Quarry	0,0183		2000 m	0,0056
	Pasture	0,0074		3000 m	0,0031
	Forest	0,0020		4000 m	0,0022
	Agricultural Field	0,0035		5000 m	0,0013
	Orchards	0,0051		10000 m	0,0005
	Residential	0,0109	DEM (m)	1) 700-1000	0,0015
Slope	0-2	0,0073		2) 1001-1500	0,0029
	2-6	0,0125		3) 1501-2000	0,0058
	6-12	0,0200		4) 2000-2500	0,0114
	12-20	0,0601		5) 2500 +	0,0220
	20-30	0,0887	Precipitation (mm)	1) 700-800	0,0062
	30+	0,1107		2) 800-900	0,0119
Soil	Alluvial	0,0045		3) 900-1000	0,0218
	Brown Forest Lands	0,0083		4) 1000-1100	0,0385
	Limeless Brown Forest Soils	0,0130		5) 1100 +	0,0712
	Brown Soils	0,0263	NDVI	1) The bare areas	0,0253
	Colluvial Soils	0,0484		2) There is a thicket. but the vegetation is very low	0,0131
Lithology	Granitoid	0,0051		3) Semi-bare areas with Ndvi value close to 0	0,0068
	Andesite	0,0090		4) Moderately healthy plants	0,0034
	Unseparated basic. ultra-basic rocks	0,0160		5) Areas covered with healthy plants as vegetation	0,0018
	Unseparated Quaternary	0,0225	Aspect	North	0,0157
	Terrestrial clastics	0,0425		South	0,0082
	Volkanites and sedimentary rocks	0,0720		East West	0,0050
				Flat Areas	0,0024

Table 3. Spatial and proportional values of landslide susceptibility classes in the study area

Number	Landslide Classes	Landslide Susceptibility Values	Area (Hectares)	Ratio (%)
1	Very Low	0.0058-0.0156	24784.29	25.16
2	Low	0.0156-0.0254	26734.24	27.14
3	Moderate	0.0254-0.0352	31472.10	31.95
4	High	0.0352-0.0450	12388.80	12.58
5	Very High	0.0450-0.0548	3120.58	3.17
		Total	98500.00	100.00

According to the landslide susceptibility map, 18.75% of the total 98500 ha study area has a high and very high landslide risk, while 52.30% has a low and very low landslide risk. Particularly, the northern and southern regions of the study area where the slope is steeper are the areas that are risky in terms of landslides and require more precautions to be taken. Yalçın (2008) tried to determine landslide susceptibility by using 3 different methods such as Analytical hierarchy process (AHP), statistical index (Wi) and weighting factor (Wf) to determine landslide susceptibility in Ardeşen district of Rize province in Turkey and compared the methods. In the study, lithology, weather, slope, aspect, land cover, distance to stream, drainage density and distance to road parameters were taken into account. As a result of the study, 81.3% of the landslide areas entered the high and very high sensitivity areas according to the AHP method, while it was determined as 62.5% in the Wi method and 68.8% in the Wf method. In addition, it was stated in the study that the AHP method gave a more realistic result in determining the true distribution of landslide susceptibility compared to the Wi and Wf methods.

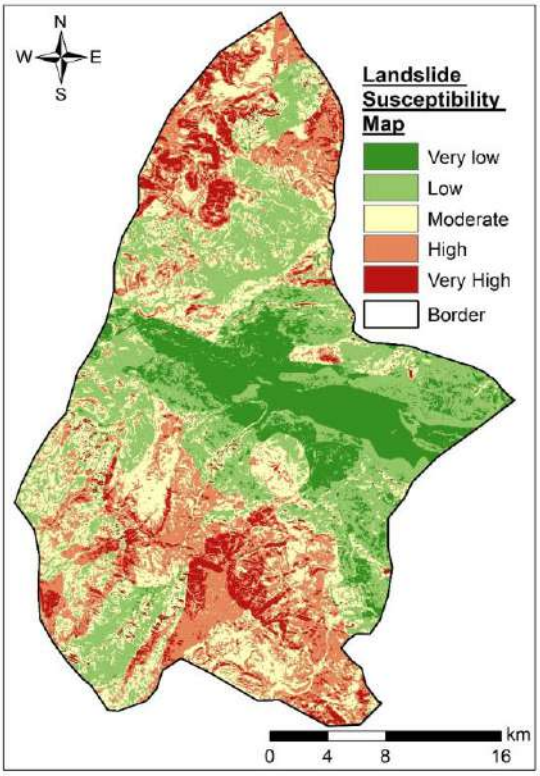

Figure 3. Landslide susceptibility map of study area.

Demir, (2018) evaluated the landslide susceptibility in five categories using the frequency ratio method in Suşehri district of Sivas province. In the study, the parameters of lithology, topographic height, slope slope value, slope slope direction, proximity to the stream, proximity to the road and proximity to the fault, which are thought to be effective in the formation of landslides, were taken into account. In order to test the performance of the susceptibility map and evaluate its success, the map was compared with the landslide locations not used in the model, and the Area Under the Curve (AUC) value was determined as 0.672, indicating that the result could be used in the evaluation of landslide susceptibility. Kayastha et al., (2013) made a landslide susceptibility map in the Tinau basin of Nepali using AHP. Topography, geology, land use and hydrology parameters and landslide susceptibility map were verified by physical and statistical methods. As a result of the study, they stated that the predicted susceptibility levels were in good agreement with the past landslide events.

Conclusion

In recent years, with the use of many models such as artificial intelligence, AHP, linear combination technique in landslide studies, it has contributed to the pre-determination of areas susceptible to landslides. With the study, it was tried to determine the landslide susceptibility by using AHP approach and GIS, taking into account 11 parameters in Suşehri district of Sivas province, where many landslide events have been experienced in the past. Integration of these models, especially with GIS and RS techniques, provides great convenience in terms of managing the lands.

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The changes in growth criteria of lettuce (*Lactuca sativa*) with salicylic acid application under salt stress

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Abstract

In this study, it was aimed to determine the effects of salicylic acid applications on plant growth criteria of lettuce (*Lactuca sativa*) under salt stress conditions. The experiment was conducted according to factorial experimental design with three replications at the controlled chamber room of Soil Science and Plant Nutrition Department of Agricultural Faculty in Yüzüncü Yil University, Türkiye. The total number of 36 pots was used in the experiment and lettuce (*Lactuca sativa*) seedlings were planted in pots including 3 kg soil in each one. Four doses of salicylic acid (SA_0:0, SA_1:1 mM, SA_2:2 mM and SA_3:4 mM) and three doses of NaCl ($NaCl_0$:0, $NaCl_1$:30 and $NaCl_2$:60 mM) were applied to growth media. The experiment was ended after 8 weeks of planting. Plant growth parameters were determined in the harvested plant samples. Generally increasing NaCl doses negatively affected plant growth criteria significantly ($P < 0.01$) while the application of SA positively affected plant growth under NaCl salt condition. The lowest plant height (7.500cm), plant fresh weight (13.933g), plant dry weight (2.167g), leaf number (10.333), plant diameter (4.800 cm), root length (6.433 cm), root weight (0.617g), root diameter (4.133 cm) were determined in the highest dose of $NaCl_2$ without SA application. It has been concluded that 2 mM salicylic acid application is the optimum dose for alleviate of NaCl damages in plant growth. As a result, it was determined that the plant growth parameters increased by increasing the application doses of salicylic acid.

Keywords: NaCl stress, Salicylic acid, Lettuce, Growth parameters.

Introduction

Plants are exposed to different adverse conditions that restrict their living and development conditions in their environment. Unsuitable conditions that affect and prevent metabolism, growth, and development in plants, are known as stress. Stress factors that cause many regressions resulting in low yield in the plant are classified in two ways as abiotic and biotic. Abiotic physical factors; drought, temperature, radiation, mechanical effects while abiotic chemical factors are air pollution, heavy metals, toxins, salts and pH. Biotic factors are wild plants, insects, microorganisms (virus, bacteria and fungi), animals and diseases (Lawlor, 2002; Kacar et al, 2009). Soil salinity is one of the most important sources of abiotic stress in the world agriculture. Salinity is a fundamental environmental factor that limits the growth of plants and the amount of products (Allakhverdiev et al., 2000; Ashraf et al., 2008). Low rainfall, inappropriate and insufficient irrigation, excessive and incorrect fertilization cause salt stress in plants. Salinity is a factor that affects the entire metabolism of the plant, including its morphology and anatomy (Levitt, 1980). Soil and water resources contain large amounts of salt in most arid and semi-arid regions of the world. Excess salt causes osmotic effects, specific ion toxicity and oxidative stress in plants and their products (Munns, 2002). Ion cytotoxicity is due to the loss of functions of proteins due to the displacement of K+ and Na+ in biochemical reactions and conformational changes, as well as the inhibition of non-covalent interaction between amino acids (Zhu, 2002). Plants under salt stress prevent the entry of CO_2 gas by closing their stomata to reduce water loss. As a result, CO_2 fixation decreases (Brugnoli and Lauteri, 1991; Makela et al., 1999). The light energy absorbed by electrons not used in carbon dioxide fixation is used in the activation of O_2, that is, in the synthesis of radicals (Halliwel and Gutteridge, 1985). Choudhury et al. (2013) reported that increasing levels of free radicals in plants under stress damage the cells, especially the membrane lipids that enter the deceleration process and disrupt cell components such as nucleic acids and chlorophyll. The chlorophyll content is also negatively affected by plants under salt stress. Factors such as disruption of general metabolic activities under salt stress and restriction in the uptake of macronutrients such as N, P, and Mg, especially Ca and K, negatively affect chlorophyll activation (Fridovich, 1986; Davies, 1987). High salt concentrations in the soils that cause many disrupts in the metabolic functions of plants lead great reductions in the yields of various crops all over the world (Sekmen et al., 2005, Gülser et al., 2010 a). Salicylic acid is a growth regulator that positively affects salt stress in plants, also stimulates systemic acquired resistance against bacteria, fungi, and viral infections in plants, and causes physiological effects such as increasing nitrate reductase activity and dry matter amount in some plants. In addition, Salicylic acid is used successfully against many abiotic stress factors such as high and low temperatures, water, heavy metal, frost, and drought stress (Raskin, 1992, Kaydan and Yağmur, 2006, Gülser et al., 2010 b, Gülser et al., 2014). The aim of this study is to investigate the effects of the salicylic acid application on the plant growth criteria of lettuce (*Lactuca sativa*) plant under salt stress

Material and Methods

The experiment was conducted according to factorial experimental design with three replications at the controlled chamber room of Soil Science and Plant Nutrition Department of Agricultural Faculty in Yüzüncü Yil University, Türkiye. The total number of 36 pots was used in the experiment and lettuce (*Lactuca sativa*) seedlings were planted in pots including 3 kg soil in each one. Four doses of salicylic acid (SA_0:0, SA_1:1 mM, SA_2:2 mM and SA_3:4 mM) and three doses of NaCl ($NaCl_1$:0, $NaCl_2$:30 and $NaCl_3$:60 mM) were applied to growth media. The experiment was ended after 8 weeks of planting. Plant height, plant fresh weight, plant dry weight, leaf number. plant diameter, root length, root weight, root diameter was determined in the harvested plant samples. Some chemical and physical properties of soil used in the experiment were determined by using of standart soil analysis methods reported by Kacar (1994). Statistical analysis of the findings was carried out using variance analysis using the SPSS software package program as factorial design and the results were grouped according to Duncan multiple comparison tests (SPSS, 2018).

Results and Discussion

According to soil analyses results the experiment soil was loamy, slightly alkaline, non-saline, moderately limely, insufficient in terms of organic matter, phosphorus and zinc content, and sufficient for other nutrients (Table 1).

Table 1. Some chemical and physical properties of soil used in the experiment

Texture	pH	EC	$CaCo_3$	O.M	P	K	Ca	Mg	Fe	Mn	Zn	Cu
		dS m^{-1}	%	%				mg kg^{-1}				
Loamy	7.81	0.36	3.86	1.32	5.50	298	3034	405	5.58	29.84	0.58	0.81

The effects of different salicylic acid and NaCl applications on plant growth criteria were given in Figure 1, Figure 2, Figure 3, Figure 4, and Figure 5.

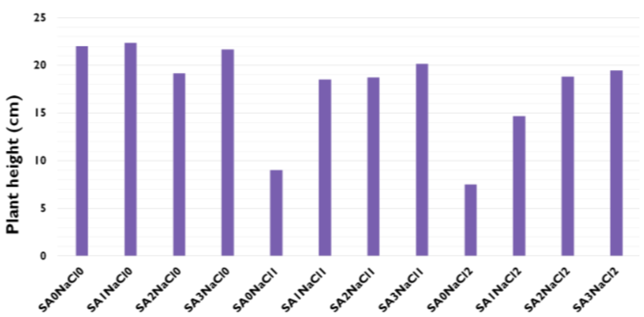

Figure 1. Effects of different NaCl and SA doses on plant height (P <0.01).

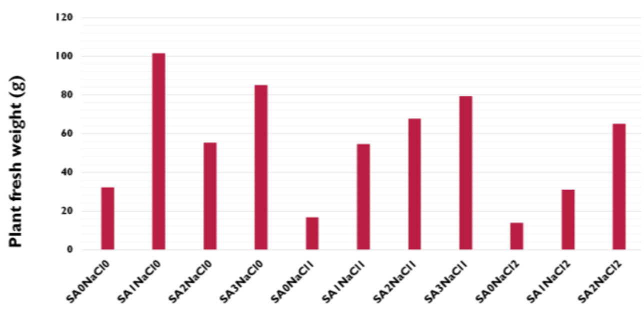

Figure 2. Effects of different NaCl and SA doses on,plant fresh weight (P <0.01).

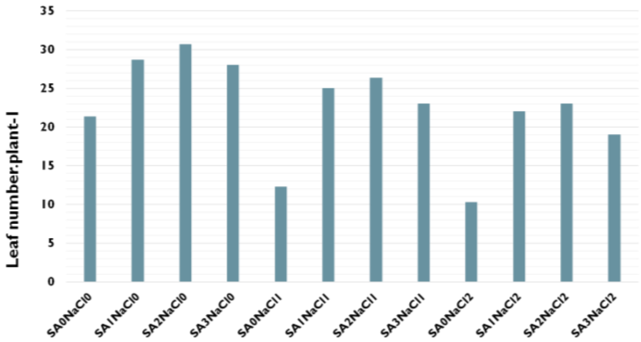

Figure 3. Effects of different NaCl and SA doses on plant leaf number (P <0.01).

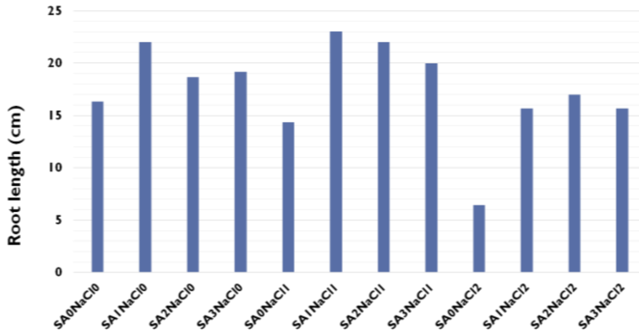

Figure 4. Effects of different NaCl and SA doses on root length (P <0.01).

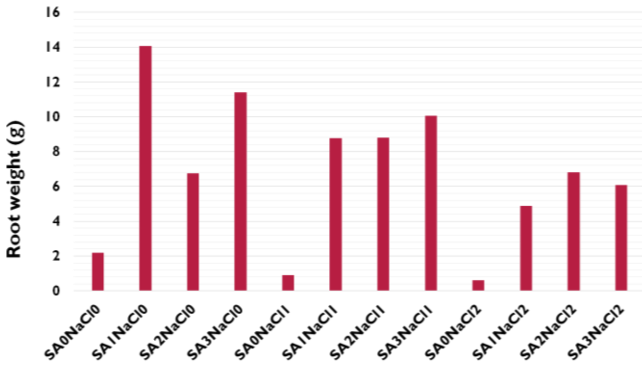

Figure 5. Effects of different NaCl and SA doses on root weight (P <0.01).

In this study increasing NaCl doses negatively affected (P <0.01) plant growth criteria while the application of SA positively (P <0.01) affected plant growth under salt stress. The lowest plant height (7.500cm), plant fresh weight (13.933g), plant dry weight (2.167g), leaf number (10.333), plant diameter (4.800 cm), root length (6.433 cm), root weight (0.617g), root diameter (4.133 cm) were determined in the highest dose of NaCl without SA application. The highest values were in SA1 for plant height (22.333 cm) and plant diameter (12,730 cm) in SA3 for plant fresh weight (85.177 g) and plant dry weight (6.193 g), in SA2 for number of leaves (30.667), root length (22,000), root weight (14,073 g) and root diameter (12,290 cm) were determined in SA1 without the application of NaCl. The results obtained in this study were correspond with results of similar researchers results. It was reported that salicylic acid applications increased planth growth in tomato plant (Sönmez et.al 2012). According to Çanakçı and Munzuroğlu (2004), the water content of bean seedlings without SA treatment exposed to salt stress is lower than the plants treated SA. El-Tayeb (2005) also found the same results in barley plants. Qing-Mao et al., (2007) reported that salicylic acid application may have important effects on cucumber seedlings NaCl tolerance through osmatic regulation, water balance, antioxidation, and membrane stability as well. Damalas and Koutroubas (2022) reported that salicylic acid could be used as a promising compound for increasing sunflower tolerance to abiotic stress. SA was found to improve sunflower growth through osmotic adjustment in the plant, accumulation of osmolytes and improvement of water relations, better scavenging capacity of reactive oxygen species, better protection of the photosystem-II, promotion of endogenous SA anabolism, and signalling.

Conclusion

Generally increasing NaCl doses negatively affected plant growth criteria and decreased plant growth,it was determined that the plant growth increased by increasing salicylic acid doses.In terms of improving the negative effects of NaCl, SA2 (2 mM salicylic acid) applications had positive effects especially on plant height, plant fresh weight, plant dry weight, leaf number, root length and root weight. It has been concluded that 2 mM salicylic acid application is the optimum dose for alleviate of NaCl damages in plant growth. Agricultural soils degraded by salt can cause many dangerous effects on crop plants. Long time and high economic costs are needed for the improvement of agricultural soils and the elimination of the harmful effects of salinity. As in this research, endogenous applications of some plant conditioners such as salicylic acid are suggested as cost-effective solutions that reduce the negative effects of stress factors such as salt stress on productivity.

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System of measures for soil erosion and protection

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Abstract

Due to the cutting down of forests and the constant use of those areas under cultivation for the further development of agriculture, the process of erosion has spread and developed at a large speed. Most of the lands distributed on highly inclined slopes have been subjected to moderate to severe erosion. Also, in the forest zone, due to the fact that such sloping slopes are broken from end to end, and as a result of constant cattle grazing, a severe erosion process is observed. Due to non-observance of agrotechnical rules on such inclined slopes, the soil cover was completely washed away and became unusable. As it is known, the formation and development of the erosion process in any area is mainly related to several factors. Among them, natural factors - surface slope, steepness of slopes, depth of local erosion base, density of gob, flat gob and valley network have a great influence on formation of erosion process and its intensity. Jalilabad cadastral district (area 140471 hectares) included in the Republic of Azerbaijan was chosen as the research area. Based on the geographic information system of the research area we initially selected in order to implement protection measures against soil erosion, a slope and aspect map was drawn up in the ArcGis program, a product of the ESRI company. It should be noted that the tendency to develop the process of erosion and soil washing increases even more. When the surface slope map was drawn up, the area indicators of the areas with a slope of $0-5^0$, $5-10^0$, $10-20^0$ and 20< were calculated according to the relief conditions of the area. Also, in order to draw a slope aspect map, each of the separated contours of the north, northeast, east, southeast, south, southwest, west and northwest slopes on the topographic map was measured separately in 3 repetitions and the distribution of the area according to aspect was determined. In the study area, the area of each species is shown separately.

Keywords: Erosion, Geographic information systems, Cadastre, Slope, Aspect.

Introduction

In order to further develop agriculture in our country, the process of erosion has spread and developed rapidly due to deforestation and constant use of those areas under cultivation. It was directly formed as a result of improper economic activity of people, and currently this process is widespread. Jalilabad cadastral district was taken as a research area to study erosion processes and eliminate these problems. It should be noted that Jalilabad cadastral district has an area of 140471 ha (or 1.2%) and is bordered by Lerik-Yardimli to the south, Lankaran-Astara to the southeast, Mugan-Salyan cadastral district to the north, and Iran to the west along Bolgarchay (Mammadov G.Sh., 1998, 2002, 2003). The area includes the plain and partially foothill areas of Jalilabad administrative district.

According to the relief, Jalilabad region is lowland (south of Mughan plain and part of Lankaran plain) and low-mountainous (northwest part of Buravar range in the east and southeast of the region). The studied area is part of the Lankaran zone and covers the northeastern end of the Alashar-Burovar ridge of the Talish Mountain system. The area has a very fragmented indentation-protrusion relief form in the central and southern part. Its highest point is up to 1000 meters, and some parts in the eastern part are below the ocean level. Anthropogenic, Paleogene and Neogene sediments are spread in the mountainous part. The highest peaks are Burovar (917 m), Malikgasimli (687 m) and Yagublu (663 m) (Alyshanov V.A.,1975).

Material and Methods

In order to study the spread and development of the erosion process in the studied area, field and laboratory research methods were used and maps were drawn up (Aliyev et al 2003; Bulgakov, 2002).

As it is known, formation and development of erosion process in any area is related to several factors. Among them, natural factors - surface slope, steepness of slopes, depth of local erosion base, density of gob, flat gob and valley network have a great influence on formation of erosion process and its intensity (Babaeva, 2005).

Therefore, before starting the field research, based on geographical information systems, in the ArcGis program, a product of the ESRI company, in order to determine the relief of the area and its effect on the development of the erosion process, maps of the surface slope of the area and slope of the slopes were drawn up by us (Mammadov, 2018; https://www.usgs.gov).

Results and Discussion

When drawing up the surface slope map, the following scale was adopted in accordance with the relief conditions of the area: 0-50; 5-100, 10-200 and 20< more (table 1).

In order to create a slope slope map, the contours of the north, northeast, east, southeast, south, southwest, west and northwest slopes on the topographic map were measured and calculated separately in 3 repetitions, and the distribution of the area according to slope was determined.

The formation and development of erosion has a great influence on surface inclination. From these mentioned and other studies, it is known that the tendency to develop the process of erosion and soil washing is increasing (Babayev, 2001, 2003).

From the above, it can be concluded that in any area, it is necessary to draw up and use the surface tendency map in the regulation of surface flows, in the development of basic measures to combat the erosion process, and in the more correct and accurate application of these measures (Ian Williamson et al., 2011).

Table 1. Division according to the scale of territorial surface inclination

№	Groups	Superficial inclination scale in degrees	Area	
			in hectares	percentage
1	Less inclined	$0-5^0$	87941	62,78
2	Inclined	$5-10^0$	23041	16,45
3	Very inclined	$10-20^0$	23626	16,87
4	Dick	20<	5478	3,91
Total:			140086	100

From the prepared inclination map, it is known that individual areas of the territory differ from each other by having different inclinations (Figure 1).

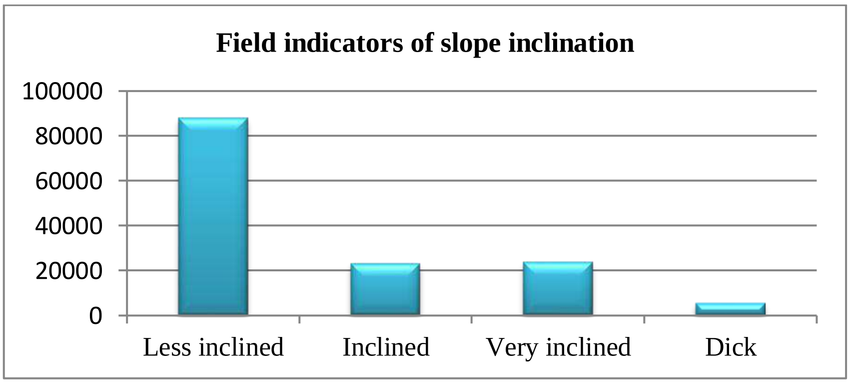

Figure 1

It is mainly used under cultivation with a slope of 0-50. In some areas, vineyards have been planted. It can be said that the weak development of the erosion process was observed on such low slopes.

Areas with a slope of 5-100 are mainly used under grain crops. Vineyards have been planted in these areas. These areas were mostly subjected to weak and moderate erosion process. In such areas, soil fertility decreases, and the productivity of agricultural crops decreases.

Areas with a slope of 10-200 are used under cultivation in the central part. In the south it is under the forest. Some areas are used under fencing.

It should be noted that in some areas, due to the improper use of slopes and without applying any anti-erosion measures, the lands used for cultivation were exposed to the erosion process and left unused after losing their fertility. Areas with a slope of 20-250 cover the southern part of the area and the Malikgasimli ridge extending perpendicularly to the Burovar ridge. In such steep slopes, in most cases, plowing is carried out along the slope, which further accelerates the development of the erosion process. As well as in the process of tillage, the role of slopes has a great influence on the formation of the erosion process (Mammadov et al., 2002). The conducted studies have shown that the southern and western slopes are subject to more erosion processes than the northern and eastern slopes.

It is known that southern and western slopes are more affected by heat than northern and eastern slopes. The sun falling on the southern slopes at a perpendicular speed is drier than the area that aligns these slopes with its rays. Since the soil of the southern slopes is very hot, it breaks into particles more quickly. Thus, if the northern slopes remain frozen for a long time during the winter, on the southern slopes, on the contrary, this situation is subject to frequent freezing and thawing, which leads to the deterioration of the soil structure and the creation of the necessary conditions for plants, as a result of which the southern the slopes have less vegetation than the northern slopes. This creates conditions for rainwater and snow falling on the surface to form a surface flow along the slope and intensive washing of the soil.

The conducted research and observations have shown that the area is exposed to the southern monsoon process. If this situation is not noticeable at first glance in the field of cultivation and pasture, but in the forest area, this situation is noticeable at a very clear speed. Such areas are Kyzildara, Alashar, Sadatli, Burovar, etc. it occupies a larger area near the villages. These slopes have been severely eroded after being deforested.

Taking into account all these points, we consider it appropriate to take into account the slope slope in developing measures to combat the erosion process for the studied area and to draw up a slope slope map for the area (table 2) (McBratney and Mendonca-Santos, 2003; Pobedinsky and Erukov, 2004; Rasouli et al.,2021).

Table 2. Division of terrain slopes according to slope

View of the slopes	By total area	
	Hectares	Percent
Flat	22099	15,78
North	11669	8,33
Northeast	20784	14,84
East	43999	31,41
Southeast	13417	9,58
South	8117	5,79
Southwest	5112	3,65
West	5711	4,08
Northwest	9174	6,55
Total:	140082	100

The eastern alluvial slopes account for the largest share of the area, providing 43,999 hectares or 31.41% of the total area, as opposed to all other alluvial slopes.

Conducted research and observations show that the south-facing slopes in the area are more exposed to the erosion process than other slopes. Since these slopes are heated more by the sun, the soil here breaks down into finer particles more, and the vegetation on these slopes is less developed than on other slopes. It is precisely because the poor development of vegetation cannot prevent the atmospheric sediments falling on these slopes that it causes the formation of surface runoff and intensive washing of the soil. Thus, while 75.6 m^3 of soil was washed from 1 hectare from the north-facing slopes, 134.6 m^3 of soil was washed from the south-facing slopes.

The western slopes make up 5711 hectares or 4.08% of the total area. These slopes are spread mainly in the north-west and west part of the area, in the north-west part they are under cultivation and in the west part they are used as pasture.

Conclusion

The conducted research and observations showed that most of the lands distributed on such highly inclined slopes were subjected to moderate and severe erosion process.

In the forest zone, even inclined slopes have been subjected to a severe erosion process due to the fact that they are broken from end to end and as a result of constant cattle grazing. Due to the non-observance of agrotechnical rules on such inclined slopes, the soil cover was completely washed away and became unusable.

From the above-mentioned, it can be concluded that such a sharp difference in the surface slope in the area and improper use of the slopes allow the erosion process to spread widely. As we have mentioned above, we have drawn up a map of inclination and slope of the Jalilabad cadastral region based on geographic information systems:

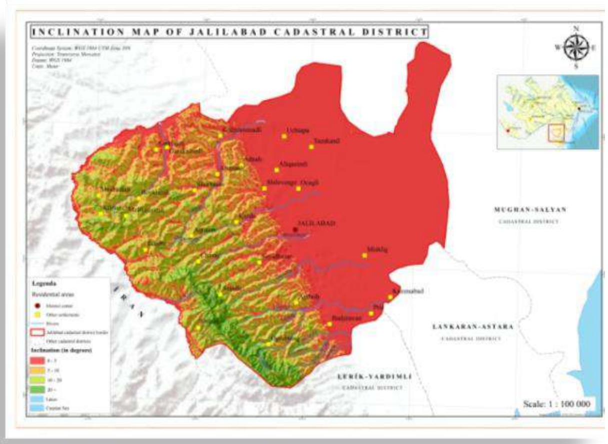

Figure 2. Slope map

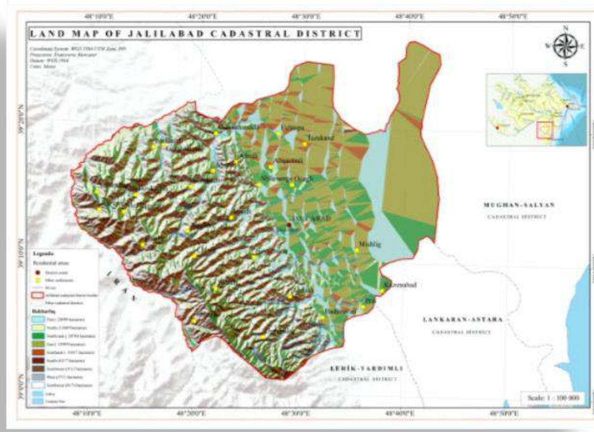

Figure 3. Aspect map

It should be noted that the map is drawn according to the following slopes: north, northeast, east, southeast, south, southwest, west and northwest slopes.

Based on the research carried out in the study area, it can be said that because the north-facing slopes are well protected by vegetation, the erosion process was not observed here. However, the process of erosion has developed due to compliance with forest reclamation, agrotechnical rules and grazing norms in some areas (forest, crop and grazing areas). Such areas are weakly and in some cases moderately eroded.

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Field-scale digital soil mapping of mobile zinc: Combining different digital covariates and comparing geostatistical and machine learning models

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Abstract

It is well documented that the yield of cultivated crops decreases when the amount of mobile zinc in the soil is insufficient. Digital mapping techniques are needed to identify areas with a shortage of plant nutrition elements. In the present research, data collected from the Novosibirsk region (Russia) (50 observations) were used to compare the accuracy of geostatistics (Ordinary kriging (OK)) and machine learning approaches (Lasso Regression (LR) and Random Forest (RF)) to map the concentration of mobile zinc in the upper horizon of the soils in order to determine which method generates maps more accurately. The effectiveness of vegetation indices and morphometric relief factors for digital mapping was assessed using machine learning methods. Fifteen vegetation-based indices were calculated by Landsat 8 OLI (resolution 30 m). Ten morphometric relief parameters were calculated using the digital elevation model SRTM v.3. In the determination of mapping performance of the machine learning and geostatistics techniques for soil mobile zinc, coefficient of determination (R^2), root mean square error (RMSE), and normalized root mean square error (NRMSE) were used through the k-fold cross-validation (n:10, repeated:5). The results of the three models showed that the LR model with lower RMSE (0.43 mg kg^{-1}) and NRMSE (17%) was the best for soil mobile zinc content prediction. The LR and RF models had the advantage of spreading the prediction results over a large area and can be used with fewer samples. The method of OK does not have such advantages, since a large number of samples are needed for its implementation, therefore is not economically profitable. The use of digital mapping methods in agricultural practice is justified since it allows for the management of plant production processes by detecting soil boundaries with a deficit of particular plant nutrition elements on the maps and considered to be key agronomic strategies.

Keywords: Covariates selection, Digital soil mapping, Lasso regression.

Introduction

Micronutrients play an important role in the life of all living organisms, as they affect growth and development, increase yield and product quality (Sharma et al., 2022). Among all micronutrients, zinc plays a special role, since chlorosis (gray-green spots) appears on the leaves of plants grown on soils with insufficient zinc content, after which the leaves die off, which leads to a decrease in the area of the assimilating surface of the leaves and a decrease in yield (Drobkov, 1958). When the amount of other macro- and micronutrients is sufficient for growing crops, then the loss of the crop due to a lack of zinc in the soil is not an economically beneficial event. Therefore, the use of digital mapping methods in the field of agricultural practice is justified and allows you to manage the production process of plants by identifying soil areas with a shortage of certain plant nutrition elements on maps and carrying out appropriate agronomic measures. There are many methods of digital soil mapping, but each of them has its advantages and disadvantages. The disadvantages of geostatistics include the need for a large number of test points, while machine learning methods allow you to make maps with a smaller sample. Both methods depend on georeferenced dataset; however, there is no need of spatial dependency on machine learning (Mendes et. all, 2020). The machine learning approach evaluates the spatial heterogeneity of soil properties according to the SCORPAN model using auxiliary variables, such as morphometric relief parameters calculated from digital elevation models (DEM), as well as vegetation cover parameters calculated from satellite images (Mendes et al., 2020; Kaya et al., 2022).

To understand which method builds maps more accurately, this study evaluates the accuracy of using geostatistics and machine learning to map the content of mobile zinc in the upper horizon of the soil. We have constructed maps of the content of soil mobile zinc by comparing three methods: Ordinary Kriging, Lasso Regression and Random Forest.

Material and Methods

Study area and sampling data

The study area is located in the Novosibirsk oblast (Russian Federation) in a field with a total area of 116 hectares, where 50 samples were taken from the upper soil horizon (depth 0-30 cm) with the coordinate reference of sampling sites using Garmin eTrex Vista GPS receiver. (Figure 1). The study area belongs to the forest-steppe zone with the denudational-accumulative relief.

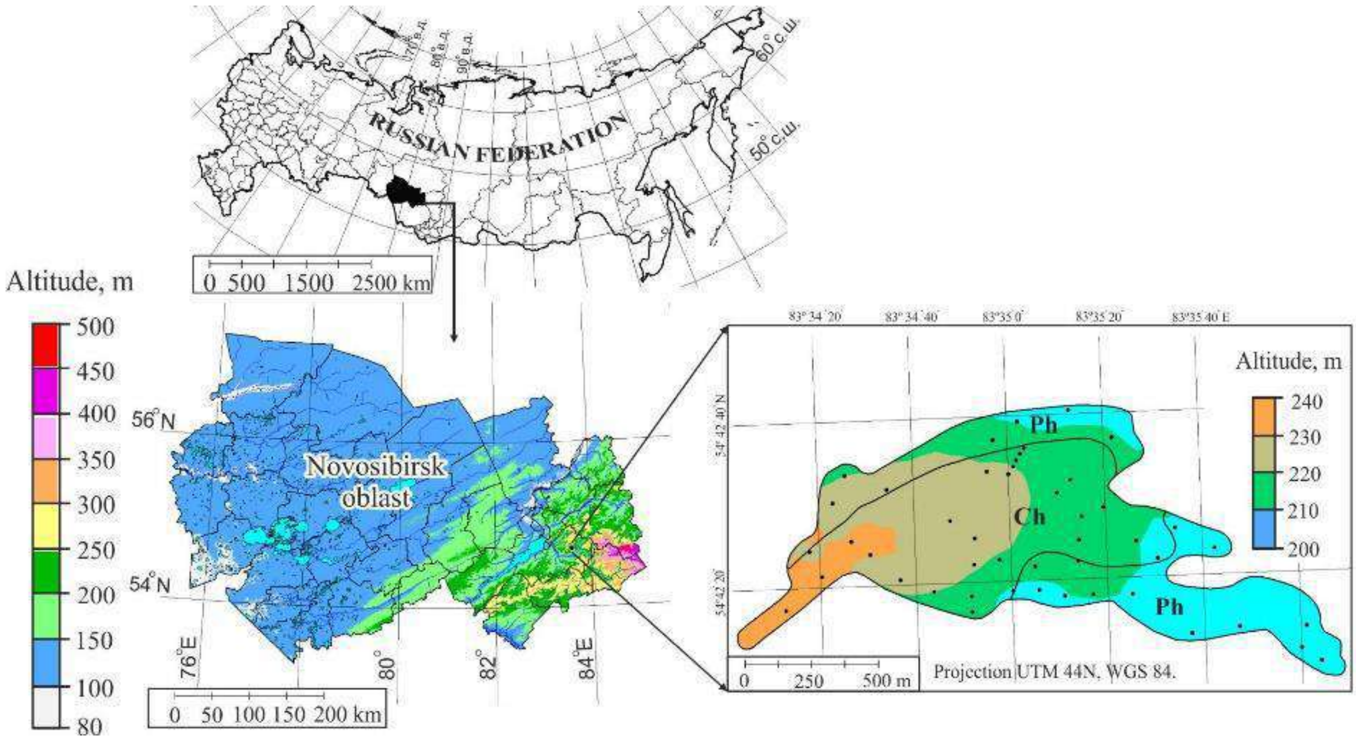

Figure 1. Location of study area with using the DEM (SRTM v.3) as background. Abbreviation: Ch – Luvic Greyzemic Chernozems (Siltic, Aric, Pachic); Ph – Luvic Retic Greyzemic Phaeozems (Siltic, Aric).

According to the international soil classification WRB (IUSS Working Group WRB, 2014), the following soils are distributed in the studied field: Luvic Greyzemic Chernozems (Siltic, Aric, Pachic) and Luvic Retic Greyzemic Phaeozems (Siltic, Aric). The soils are developed from loesslike calcareous loams. The humus content in Luvic Greyzemic Chernozems varied from 3.3 to 7.8%; in Luvic Retic Greyzemic Phaeozems from 2.5 to 5.9% (Gopp and Savenkov 2019).

Mobile form of zinc was extracted from soils samples with an ammonium acetate buffer solution (1 M CH_3COONH_4, pH 4.8), after which its concentration in the solution was determined on an atomic absorption spectrometer.

The degree of intensity of variation (CV, %) was assessed according to the scale proposed by Eliseeva and Yuzbashev (2002): CV<10 %, weak; CV from 10 to 25%, moderate; CV>25%, strong. The correlation analysis was performed using Spearman's rank correlation coefficient (*rs*) with a significance level $p < 0.05$.

Covariates used for DSM

The digital soil mapping approach is based on the SCORPAN concept (soil, climate, organisms, topography, parent material, and spatial location) (McBratney et al., 2003). The satellite-based vegetation indexes production process and all morphometric topographic variables were calculated using the System for Automated Geoscientific Analysis (SAGA) software (Conrad et al. 2015). The WGS 1984 UTM Zone 44N (EPSG :32644) system was used and all covariates used in this study were aligned to the same grid cell resolution (30 m) and extent.

Modelling process

Lasso regression and Random Forest (RF) were used to digital mapping and identify the relationship between soil mobile zinc content (mg kg^{-1}) and covariates. Besides, a linear geostatistical interpolation technique based on weighting the sums of values at adjacent sampled points, ordinary kriging was conducted.

When using LR and RF methods, the usefulness of vegetation indices and morphometric terrain parameters for digital mapping was evaluated. Vegetation indices (NDVI (Normalized Difference Vegetation Index), TVI (Transformed Vegetation Index), DVI (Difference Vegetation Index), TVI (Transformed Vegetation Index), RVI (Ratio Vegetation Index), SAVI (Soil Adjusted Vegetation Index), NRVI (Normalized Ratio Vegetation Index), TSAVI2 (Transformed Soil-Adjusted Vegetation Index), PVI (Perpendicular Vegetation Index), EVI (Enhanced Vegetation Index), MSAVI2 (Modified Soil-Adjusted Vegetation Index) were calculated by Landsat 8 OLI (resolution 30 m) by use SAGA GIS software (Conrad et al. 2015). Morphometric relief parameters (Slope, Aspect, Topographic Wetness Index (TWI), LS-Factor, Stream Power Index (SPI), Topographic Position Index (TPI), Channel Network Base Level (CNBL), Profile Curvature (PrCu), Plan Curvature (PlCu), Convergence Index (CI)) were calculated using the digital elevation model SRTM v.3. (resolution of 2"×1" arcsec at the latitude of Novosibirsk oblast, or about 35×30 m) by use SAGA GIS software.

Comparative modeling approaches were applied for different algorithms to reveal different relationships in a particular field (Wadoux et al., 2021). Conditions with high correlations between environmental variables may generally exist. Accordingly, feature selection algorithms were run in two different machine learning algorithms before modeling in this study. Lasso regression models are called as the regularized or penalized regression model (Ferhatoglu and Miller, 2022). In particular, Lasso is so powerful that it can work for multicollinearity dataset in which the number of variables (Figure 2). Before conducting random forest algorithm, the variable selection was applied with the "rfe" (recursive feature elimination) function in R core environment program (Kuhn 2020) (Figure 3). Lasso regression algorithm were conducted through the "glmnet" (Friedman et. al., 2010; Simon et al., 2011) package and random forest algorithm were conducted through the "randomForest" (Breiman, 2001) package in the R Core Environment program. The importance of the covariates used in the model were calculated using the "VarImp" and "importance" functions in R Core Environment program (R Core Team, 2022). Ordinary kriging was perfomed in Surfer 8.0 software. To evaluate the performance of three various modelling techniques used in this study, statistical criteria including coefficient of determination (R^2), root mean square error (RMSE), and normalized root mean square error (NRMSE) 10-fold cross-validation and five repeatedly calculated (Sakhaee et al., 2022).

Results and Discussion

Descriptive statistics of soil mobile zinc content are given in table 1. According to the gradations (Eliseeva, Yuzbashev, 2002), the intensity of variation was strong and amounted to 56.98%.

Table 1. Descriptive statistics of soil mobile zinc content of the current study area

Variable	Mean	SD	CV	Minimum	Median	Maximum	Skewness	Kurtosis
SI	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}		
Zn	0.93	0.53	56.98	0.34	0.73	2.87	1.79	3.22

Abbreviation: SD: Standard Deviation, CV (%): Coefficient of Variation, Zn: mobile zinc.

According to the gradations of soil mobile zinc provision (Methodological Guidelines, 2003), the studied soils are mostly low provision (less than 2 mg kg^{-1}), with the exception of insignificant areas, where the provision was average (from 2.1 to 5.0 mg kg^{-1}) (Table 1, Figure4). In these areas where the content of soil mobile zinc was higher, the values of vegetation indices (for example NDVI) were also higher (rs=0.48). At the same time, the correlation of mobile zinc with the content of clay (rs=-0.66), available phosphorus (rs=0.59), pre-sowing moisture (rs=0.44) and nitrate nitrogen (rs=0.50) was established (Gopp and Savenkov 2019). The considered soil properties can also be as a covariate for soil mobile zinc however, we tried to find such covariates only among the satellite-based remote sensing and DEM data. Figures 2 and 3 show the results of selecting the most effective covariates used in the LR and RF models.

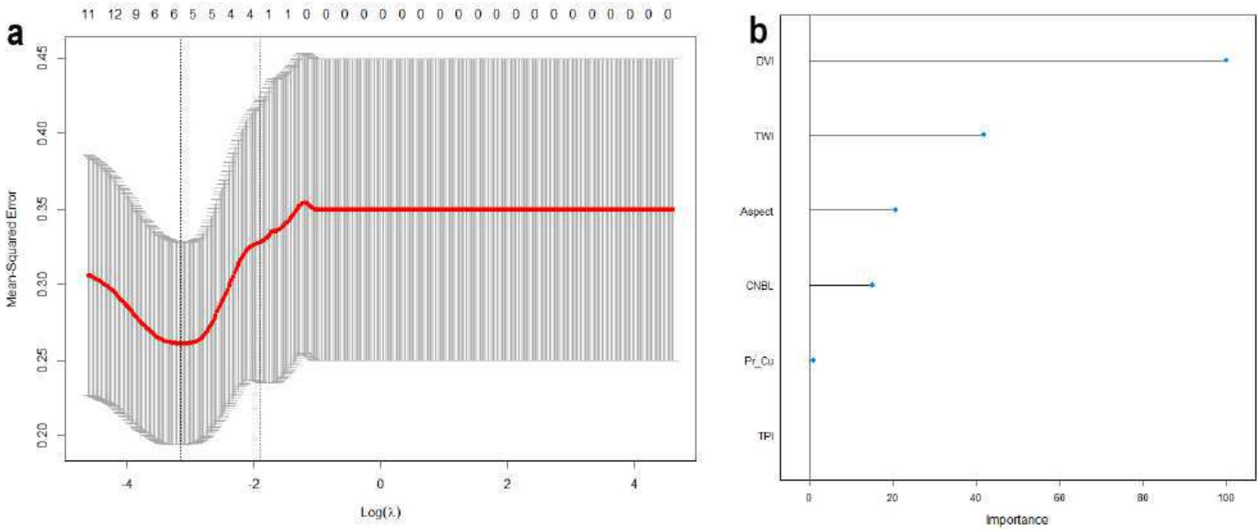

Figure 2. Lasso regression covariate selection results and importance of predictors in modelling process

Abbreviation: DVI: Difference Vegetation Index, TWI: Topographic Wetness Index, CNBL: Channel Network Base Level, Pr_Cu: Profile Curvature, TPI: Topographic Position Index.

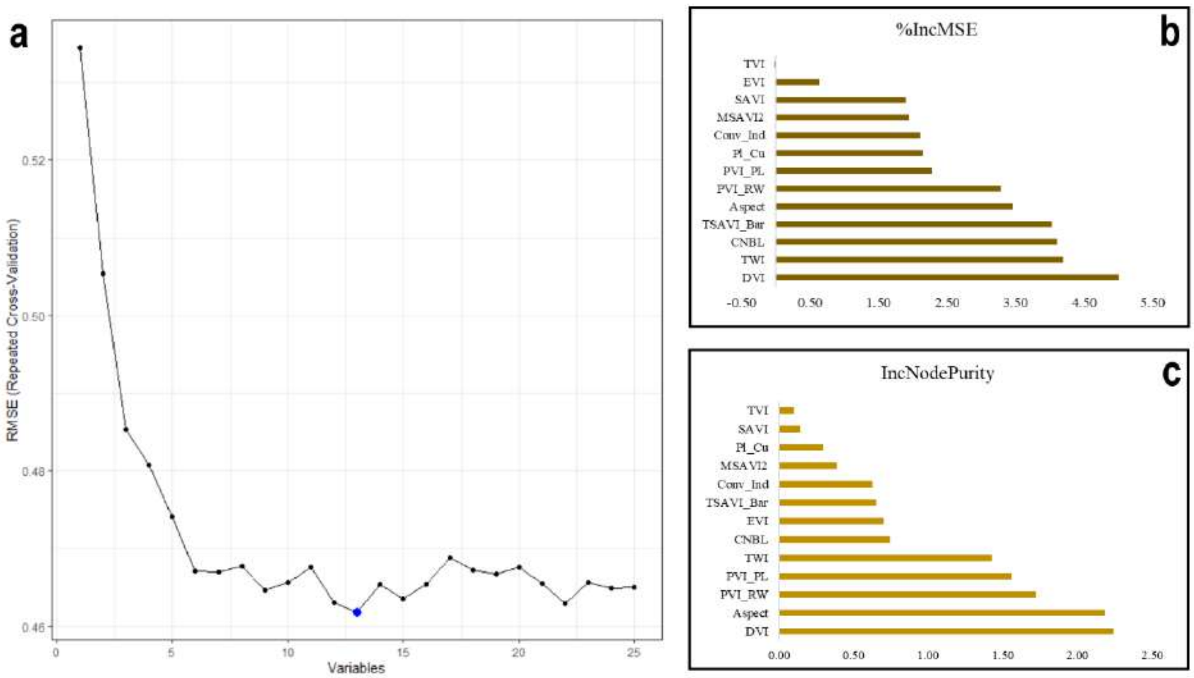

Figure 3. Random forest regression covariate selection results and importance of predictors in modelling process

Abbreviation: DVI: Difference Vegetation Index, PVI_PL: Perpendicular Vegetation Index by Perry and Lautenschlager (1984), PVI_RW: Perpendicular Vegetation Index by Richardson and Wiegand (1977), MSAVI2: Modified Soil-Adjusted Vegetation Index, TVI: Transformed Vegetation Index, SAVI: Soil Adjusted Vegetation Index, TWI: Topographic Wetness Index, CNBL: Channel Network Base Level, EVI: Enhanced Vegetation Index, TSAVI_Bar: Transformed Soil-Adjusted Vegetation by Barret and Guyot (1991), MSAVI2: Modified Soil-Adjusted Vegetation Index, SAVI: Soil Adjusted Vegetation Index, Pl_Cu: Plan Curvature, Conv_Ind: Convergence Index.

Maps constructed by three methods can be considered useful for assessing the content of soil mobile zinc (Fig. 4).

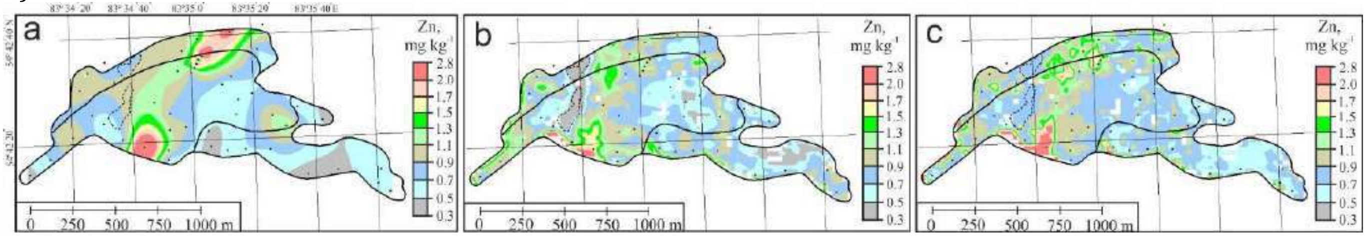

Figure 4. Soil mobile zinc content maps produced with different methods: a – Ordinary kriging; b – Lasso regression; c – Random forest. Dashed line shows crops areas that have been destroyed by the larvae of the May beetle (Melolontha).

On the maps are crops areas that have been destroyed by the larvae of the May beetle (Melolontha). In these areas, the LR model predicted lower values, while the accuracy of the map, estimated by the RMSE and NRMSE value, was the best (Tables 2). The map shows areas with an average provision of soil mobile zinc (from 2.1 to 5.0 mg kg^{-1}), which may be due to the uneven content of zinc-containing minerals.

Table 2. Performance statistics of the regression models used for predicting soil mobile zinc content

Variable	Model	Cross-Validation		
		R^2	RMSE	NRMSE
Zn	Ordinary kriging	0.29	0.49	19.3%
	Lasso regression	0.37	0.43	17.0%
	Random forest regression	0.27	0.48	19.0%

Abbreviation: R2: Determination Coefficient, RMSE: Root Mean Square Error, NRMSE: Normalize Root Mean Square Error

Conclusion

The use of digital mapping methods in the field of agricultural practice is justified and allows to manage the production process of plants by identifying soil areas with a shortage of certain plant nutrition elements on maps and carrying out appropriate agronomic measures. The results of the three models showed that the LR model with lower RMSE (0.43 mg kg^{-1}) and NRMSE (17%) was the best for soil mobile zinc content prediction. The LR and RF models have the advantage of spreading the simulation results over a large area and it can be used with fewer samples. The method of Ordinary kriging does not have such advantages. If vegetation indices are used in models of machine learning methods, then the results of modeling the content of mobile zinc will depend on the condition of crops (for example, damaged crops).

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Effect of Lantana based fertilizer enriched biochar application on soil properties and onion productivity

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Abstract
Biochar is a fine-grained carbon-rich product obtained when biomass such as wood, plant remaining is burned in a closed container with absence of air. Effects of fertilizer enriched biochar on soil properties and crop productivity are the subject of interest in agricultural science in developing countries like Nepal due to the declining soil fertility status. To know the effects of nitrogen (N) enriched biochar on soil properties and onion productivity, four times replicated field experiment was conducted from 19th December to 29th April, 2021 in Bhaktapur, Nepal in Randomized Complete Block Design (RCBD) with six treatments prepared by combining 30 t ha^{-1} biochar with chemical and organic fertilizer. Treatments were: Control (T1), RDF (T2), 1/2 RDF+ Biochar (T3), RDF+ Biochar (T4), Vermicompost + Biochar (T5) and cattle urine+ Biochar(T6). The results showed a significant increase in the onion yield up to 18.62 tha^{-1} and NPK of soil to 0.49 $kgha^{-1}$, 54.02 $kgha^{-1}$ and 58.9 $kgha^{-1}$ with the application of RDF incorporated in biochar (T3). The pH of the soil increased from 4.01 to 5.375 and the OM increased from 2.82 to 4.835 by vermicompost enriched biochar. The B: C ratio for RDF+ biochar (T5) showed a maximum value of 3.25. The study suggests that biochar can be best used as an amendment rather than just fertilizer in combination with RDF to get the best results with onion yield and soil NPK. The addition of biochar also helped to retain moisture for a longer period of time. Thus, biochar can be a viable option to improve soil health and onion productivity.
Keywords: Biochar, RCBD, Treatment, Vermicompost.

Introduction

Biochar is the porous carbonaceous solid produced by thermo-chemical conversion of organic materials in an oxygen limited atmosphere that has physiochemical properties suitable for the safe and long-term storage of carbon in the environment and soil amendment (Hammond et al., 2011). The agricultural use of biochar has been growing and attracting more research interest globally due to its potential benefits to crop production, soil fertility and carbon sequestration. The use of biochar enhanced crop yields; decreased the soil acidity, increased water and nutrient holding capacity, stimulates the nutrient uptake and reduce the greenhouse gas emissions from the soil (Sohi et al., 2009; Quayle, 2010). In the world scenario, biochar is deposited through natural events such as forest and grassland fires (Krull et al., 2008; Skjemstad et al., 2002).

Material and Methods

Description of site and soil

The study was carried out in the field of Katunje, Suryabinayak (1310masl) in Bhaktapur district of Nepal which is located at 27.660514° N latitude and 85.408533° E longitude. The soil of the research site selected was highly acidic and hence suitable to see the effect of biochar on several properties of soil.

Methods

Composite soil sample was collected before field preparation from uncultivated field of Katunjey, Suryabinayak. The experiment was laid out in a randomized complete block design with six treatments and four replications. The detail of the treatment employed for the study is shown in table 2 and the layout of the randomization is presented in figure 1. Superex variety of onion was used for the study. One and half month-old seedling was transplanted in 24 plots of area1*1 m^2 at the spacing of 20 cm between the rows and 10 cm between the plants. FYM @30t/ha and Zinc Sulphate @10 kg/ha was pre applied in the field. The nutrients used in the experiment were: Cattle urine, Urea, Diammonium Phosphate (DAP), Murrate of potash (MOP), Zinc Sulphate and FYM. In the same way, chemical fertilizers were mixed with crushed biochar and incorporated in soil in lines where onion is planned to plant. Land preparation, fertilizer application, UCB application, transplanting, weeding, and hoeing and harvesting was carried out as per the recommended way. First deep ploughing was carried out on 15th December followed by second on 17th December to make the soil well pulverized and friable.

Table 1: Fertilizer dose per plot

Treatments	Biochar (kg)	Urea (gm)			DAP (gm)	MOP (gm)	Vermicompost (kg)	Urine(ml)
		Basal	Split 1	Split 2				
T1	-	-	-	-	-	-	-	
T2	-	14.93	7.465	7.465	34.78	16.67	-	
T3	3	14.93	7.465	7.465	34.78	16.67	-	
T4	3	7.465	3.7325	3.7325	17.39	8.335	-	-
T5	3	-	-	-	-	-	2.5	-
T6	3	-	-	-	-	-		1.33

Twenty-four plots were well prepared and marked according to the experimental design adopted and they were leveled uniformly. Recommended dose of chemical fertilizer 200:160:100 kg/ha NPK was incorporated in soil at the time of transplanting according to the treatments. A full dose of P and K and half dose of N was applied as basal dose and remaining half dose of N was applied in two split doses at 30 and 60 days after transplanting.

Table 2: Different treatments and their combinations

Treatments	Combinations
T1	Control
T2	RDF
T3	RDF treated Biochar @30 t/ha
T4	1/2RDF treated Biochar @30 t/ha
T5	Vermicompost treated biochar @30 t/ha
T6	Cattle urine treated Biochar @30 t/ha

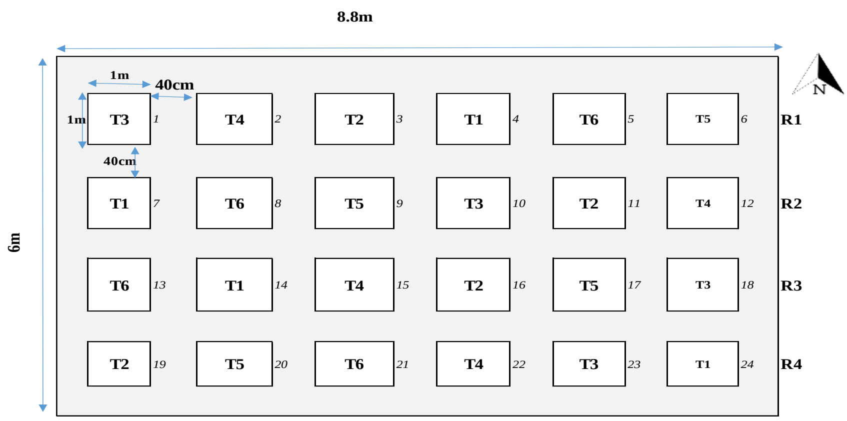

Figure 1: Randomization and layout of experimental plot

Full dose of UCB was applied at the time of transplanting according to the requirement of treatments. The treatments were calculated to fulfill the recommended dose of nitrogen which is 200kg/ha. UCB was applied on the root zone of individual transplanting plant. Onion seedlings were transplanted on 19th of December. The row to row and plant to plant spacing for the onion was maintained at 20cm*10cm respectively. The plot size was maintained at 1m2. The gap between the plots was 40 cm. Treatments were applied to each plot on the basis of randomization principle. Light irrigation was given with the help of watering can just after the seedling transplanting. The crop was ready for harvesting after 130th days of transplanting. All the plants were harvested manually at a time. Harvested plants from each plot were separated and they were weighted separately.

Results and Discussion

Effect of nutrient enriched biochar on the yield and biomass

Treatment effects on bulb weight of onion was significant. The highest bulb weight (18.62t/ha) was observed in RDF enriched biochar followed by vermicompost enriched biochar (15.25), cattle urine enriched biochar, RDF, and 1/2RDF+Biochar. In T3, urea was applied in three split doses. As the onion plants could get nitrogen supplied through split dose of urea even during later stages of growth compared to other treatments, the yield was found higher. The minimum bulb weight (8.45t/ha) was observed with T1 (Control) where no nutrients were added. (Chan et al., 2007) reported no effect on radish yield on application of biochar alone even @100t/ha. However, they got significant improvement of radish yield with the increase application of N enriched biochar.

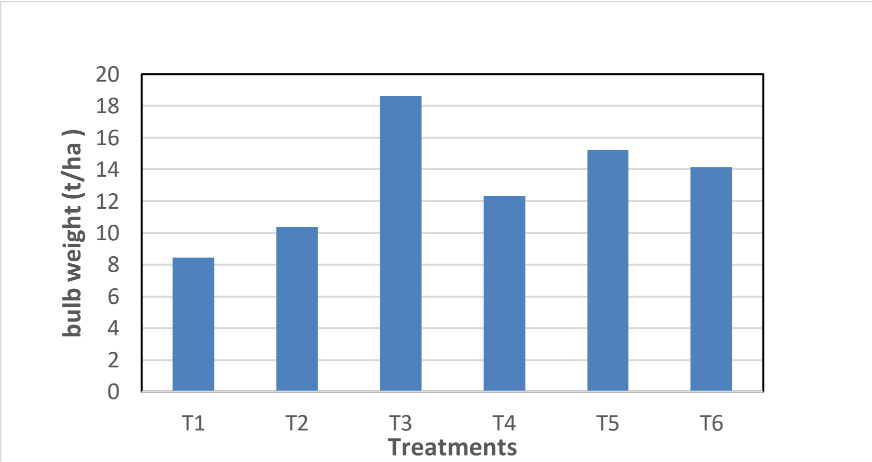

Figure 2: Effect of fertilizer enriched biochar in bulb weight of onion

According to the result, the highest yield of onion was observed in RDF enriched biochar application which could be due to the synchronization of nutrient availability and plant requirement that increases the N use efficiency of crop. (Timilsina et al., 2017) also reported that biochar application increased radish yield at loamy sand soil of Nawalparasi Nepal. (Hamdani, 2017) reported highest (95%) recovery of fertilizers in wheat after application of 1% biochar in addition to 50% of the recommended fertilizer dose. The maximum biomass per plot (2.157kg) was observed in T3 (RDF+Biochar). Highest grain yield and straw yield of rice was found in application of biochar along with the soil test value-based fertilizer (Meena et al., 2020).

Table 3. Effect of biochar on onion yield

Treatment	Bulb diameter (mm)	Biomass (kg/m^2)	Bulb wt. (ton/ha)
T1	21.33a	1.132a	8.45a
T2	23.82ab	1.295b	10.38bc
T3	26.32b	2.157f	18.62e
T4	25.09b	1.505c	12.32b
T5	25.68b	1.827e	15.25a
T6	23.98ab	1.702d	14.15cd
Grand mean	24.37	1.603	13.2
Sem	1.044	0.0359	0.364
CV (%)	8.6	4.5	5.5
LSD	3.147	0.1082	1.097
F value	2.89	107.58	99.46
P value	0.051	<.001	<.001

Effect of biochar on soil characteristics

Soil pH

Soil reaction (pH) is an important soil property as it influences the nutrient availability to plant. The initial sample was collected before the application of treatment which showed very highly acidic pH of 4.01. The final sample was collected at the time of harvesting i.e., 130 days after the transplanting. The maximum pH (5.375) was found in T5 (Vermicompost + Biochar) which was followed by T6 (Cattle urine+ Biochar), ½ RDF + biochar, RDF+ biochar and control treatment. The soil pH decreased to 3.883 in RDF treatment.

Irrespective of treatments and sampling day, the soil pH varied significantly with the treatments. Soil pH was decreased with the application of chemical fertilizer in T2 that could be due to the production of H^+ ions during the mineralization of N fertilizer. Soil pH was found to increase with the application of Biochar in combination with vermicompost and biochar soaked with cattle urine. Application of chemical fertilizer alone(T2) tend to decrease the soil pH but when combined with biochar tends to increase the soil pH. It is evident from this experiment that long term application of chemical fertilizer will certainly decreases the soil pH.

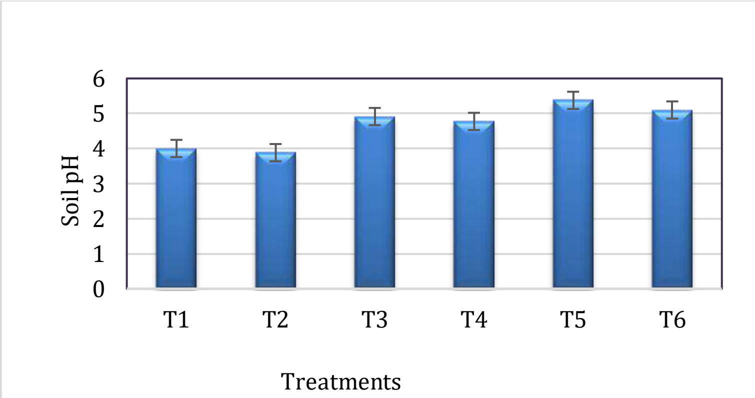

Figure 3: Effect of application of Biochar in soil pH

This experiment supports the general finding that application of chemical fertilizer increases soil acidity. The improved pH of soil in biochar treated plots could be due to release of basic cations into soil due to incorporation of biochar which can participate in exchange reactions and replace the exchangeable Al^{3+} and H^{+} ions on soil exchange complex. Thus, decrease the exchangeable acidity in acidic soil. The pH of biochar is typically greater than 7.0 and may provide benefits when applied to acidic soils. Because pH increases are related to CEC increases, this benefit can be interrelated to biochar's effect on soil pH. Biochar can increase pH by 0.5–1.0 unit in most cases for application rates of 30 Mg per hectare of biochar. (Carter, 2013).

Soil Organic matter (SOM)

Generally, organic matter content is directly proportional to N-content in most stands. It may be due to the release of N, P and S from organic matter. Organic matter influences physical properties of soil such as structure, water holding capacity and resistance to erosion. Amount of N, P and K is found to be less in soils of low organic matter and high in soils of high organic matter (Chaudhuri and Manandhar, 1996). The SOM in initial sample was found 2.82%.

Table 4: Effect of application of fertilizer enriched biochar in soil OM

Treatment	0 DAT	130 DAT	Mean
1	2.82	2.86a	2.84a
2	2.82	2.85a	2.835a
3	2.82	3.755b	3.288b
4	2.82	3.805bc	3.312bc
5	2.82	4.825d	3.822d
6	2.82	3.863c	3.341c
Grand mean		3.66	3.2398
Sem		0.0267	0.01337
CV (%)		1.5	0.8
LSD		0.0806	0.0403
F value		762.14	762.14
P value		<.001	<.001

Perusal of the data in table 9 revealed increase in SOM with the application of biochar which varied significantly with the treatments. With cropping, the microbial activities in the soil increases resulting in higher organic matter in the soil. The final sample was collected at the time of harvesting i.e., 130 days after the transplanting of onion seedling. The maximum OM content (4.825%) was observed in T5 (Vermicompost+ Biochar) which was followed by T6 (Cattle urine+ Biochar) which was 3.863%. The highest carbon content in biochar-amended plots might be responsible for organic carbon build-up and also attributed to the very low-level degradation and recalcitrant nature of biochar in soil. (Trupiano et al., 2017) also reported that combined application of compost and biochar increased soil organic carbon content than unamended soils, which indicated that biochar and compost applications to soil can enhance carbon accumulation and sequestration. Increase in soil organic carbon content was due to stabilized organic carbon through sorption on biochar surfaces and pores and possibly due to enhanced soil aggregation and organo-biochar-clay mineral interactions through cation bridging and ligand exchange reactions in the biochar amended soils.

Available Potash

The potassium content in initial sample was found very low i.e., 52.4 kg/ha. The final sample was collected at 130 days after the transplanting of onion seedling. The maximum available potash (58.9 kg/ha) was observed in T3 (RDF+ Biochar). Application of treatment had shown good effect on availability of soil potassium. Some of the treatments employed even increased available K content of the soil. The results showed significant difference between the applications of biochar in combination with different treatments. However, all application of biochar in soil showed increasing effect on soil potassium. Masulili et al., (2010) also draws similar conclusion in acid sulfate soils and rice growth in West Kalimantan, Indonesia where significant increase in exchangeable potassium was recorded by the application of biochar.

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.

Available Phosphorous

The phosphorus amount in initial sample was observed 26.4 kg/ha (very low). The final sample was collected at the time of harvesting i.e., 130 days after the transplanting. The maximum available phosphorous (54.02 kg/ha) was found in T3 (RDF+ Biochar), which was followed by T4 (1/2RDF+Biochar), T2 (RDF), T5(vermicompost+ biochar) and T6(cattle urine+ biochar). The minimum available phosphorous (22.94 kg/ha) was shown in T1 (Control).

Data in table 5 reveals that there was sharp increase in P_20_5 content in general at the final stage of the crop growth and the different treatments were significant to each other. Application of treatment had shown good effect on availability of soil phosphorus. This finding is in accordance to the findings of (AgusalimMasulili, 2010) where biochar increased the available P due to increase in soil pH making immobile phosphorus available in the soil.

Total Nitrogen

The nitrogen percent in the soil was 0.19 initially. The final sample was collected at the time of harvesting i.e., 130 days after transplanting which showed the maximum total nitrogen in RDF enriched biochar, which was 0.49 followed by ½ RDF enriched biochar, RDF, cattle urine enriched biochar and vermicompost enriched biochar. The minimum nitrogen was found in T1 which was 0.0975. (Chan et al., 2008) also reported the addition of biochar to soil increased total N, available P and available K of soil.

Table 5: Effect of application of biochar on changes in soil nitrogen, phosphorus and potassium

	Nitrogen		Phosphorus		Potash	
Treatment	0 DAT	130 DAT	0 DAT	130 DAT	0 DAT	130 DAT
T1	0.19	0.0975	26.4	22.94a	52.4	44.9a
T2	0.19	0.43	26.4	34.73c	52.4	55.4bc
T3	0.19	0.435	26.4	54.02d	52.4	58.9d
T4	0.19	0.49	26.4	37.33c	52.4	56.1c
T5	0.19	0.2675	26.4	31.31b	52.4	54.95bc
T6	0.19	0.2725	26.4	31.25b	52.4	54.4b
Grand mean		0.332		35.26		54.11
Sem		0.0409		0.938		0.482
CV (%)		22.2		5.3		1.8
LSD		0.1233		2.827		1.453
F value		25.64		122.76		98.28
P value		<.001		<.001		<.001

Economics Analysis

A benefit-cost ratio (BCR) is an indicator showing the relationship between the relative costs and benefits of a proposed project, expressed in monetary terms. If a project has a BCR greater than 1.0, the project is expected to deliver a positive net present value to a firm and its investors.

Benefit Cost Ratio (BCR) = Present value of benefit/Present value of cost

Table 8: Analysis of B: C ratio for each treatment

SN	Treatments	Yield (t/ha)	Cost of cultivation per ha (Rs.)	Cost of Onion per kg (Rs.)	Gross return per ha (Rs.)	Net return per ha (Rs.)	B:C ratio
1	T1(control)	8.45	271100	60	507000	235900	1.87
2	T2(RDF)	10.38	313350	60	622800	309450	1.98
3	T3(RDF+Biochar)	18.62	343350	60	1117200	773850	3.25
4	T4 (1/2RDF+Biochar)	11.32	323225	60	679200	355975	2.10
5	T5(Vermicompost +Biochar)	15.25	653100	60	913000	261900	1.401
6	T6(Cattle urine soaked biochar)	14.15	383100	60	849000	465900	2.21

Use of biochar with RDF showed excellent BCR (3.25) amongst all the treatment. The yield per hectare of RDF enriched biochar significantly higher than other treatments. Cattle urine-soaked biochar showed BCR 2.21 which is higher than that of vermicompost treated biochar even though the yield of cattle urine treated biochar is lower compared to vermicompost treated biochar. This is due to the huge quantity vermicompost that is solely used to fulfill the required dose of nitrogen.

Conclusion

From this research, it can be concluded that biochar mixed with recommended dose of fertilizer is beneficial for the onion production. Biochar with recommended dose of fertilizer gave the higher yield attributing parameters than the control and other treatments. The highest plant biomass, bulb diameter and bulb weight was observed by application of recommended dose fertilizer enriched biochar. Vermicompost enrichment in biochar improved the soil pH and organic matter of soil but residual soil total nitrogen, available phosphorus and potassium significantly improved by application of recommended dose fertilizer enriched biochar. Biochar also increased the moisture holding capacity and pH and thus helped in retention of nutrients and moistures. Therefore, biochar application provides an innovative method for handling excess organic waste to potentially improve soil and plant productivity which ultimately leads to the sustainable soil management.

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Determination and mapping of pH indicators in Kurmukchay basin soils

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Abstract

The research area is located in the north-east of Azerbaijan. The length of the river is 55 km. The river basin covers 56,200 hectares. The main part of the basin is covered by mountains, partly by mountains and plains. Snow in spring, and rainwater in summer and autumn cause flooding in the river. Spring floods last 100-120 days a year. Samples were taken from specific soils of the area during the corresponding period. Based on the collected soil samples, soil pH analysis was carried out (Uereyen and et al.,2019). The pH indicator is used to determine the degree of acidity in the soil. Measuring soil pH plays a very important role as it affects the relative availability of soil nutrients. If the pH indicator is not within the specified limit, the crop will grow poorly and this will increase the potential for soil erosion. Nutrients in soil exist in complex, insoluble complexes, and simple dissolved forms. But for the development of plants, it is important to break down complex compounds into simpler ones. Soil pH is defined as the negative logarithm of hydrogen ion concentration. The pH scale varies from 0 to 14, and pH 7.0 is the neutral point. As the amount of hydrogen ions in the soil increases, the pH of the soil decreases, becoming more acidic. At pH from 7 to 0, the soil becomes increasingly acidic, and at pH from 7 to 14, the soil becomes increasingly alkaline. If the PH increases from 6.5 to 8.0, the absorption of iron, zinc and manganese decreases, while the amount of molybdenum and phosphorus increases. Soil with a very high pH is enriched with carbon dioxide, which absorbs other free ions and harms plant growth (Thomas,G.W,2018) .The results of the analysis were then plotted on a pH map using the Arcgis program.

Keywords: River, Analysis, Ecology, pH, Map.

Introduction

Soil pH is a measure of soil acidity or alkalinity. A pH value is a measure of the concentration of hydrogen ions. Since the concentration of hydrogen ion varies over a wide range, it is from a logarithmic scale (pH): for the use of pH 1, the acidity increases 10 times. A highly acidic soil has a low pH and a high hydrogen ion concentration on the "reverse" scale. Therefore, at full (alkaline) pH values, the hydrogen ion concentration is low (Slessarev et al., 2016). Most soils have pH values between 3.5 and 10. Natural pH settings in areas with full rainfall range from 5 to 7, and in drier areas from 6.5 to 9. Soils can be classified according to pH value:

• 6.5 - 7.5 - neutral
• More than 7.5 - alkaline
• Less than 6.5—acidic, soils with a pH less than 5.5 are considered strongly acidic.

Acid sulfate soils can have extremely acidic pH values (less than pH 4). Natural soil pH is obtained from the rock from which the soil is formed and the processes that affect it, such as climate, vegetation, topography, and time. This energy causes a decrease in pH (increase in acidity) over time. Some agricultural activities can also accelerate the acidification process (Bailey, D., 1996). Soil pH affects the availability of nutrients and chemicals dissolved in soil water and therefore the availability of nutrients to plants. Some foods are more acidic than others. However, soil near neutral pH mineral nutrients are available for plants. (Bargrizan et al., 2017). The formation of strongly acidic soils (pH less than 5.5) can result in poor plant growth of one or more crops:

- aluminum toxicity
- manganese toxicity
- calcium count
- magnesium count
- low levels of essential plant nutrients such as phosphorus and molybdenum.

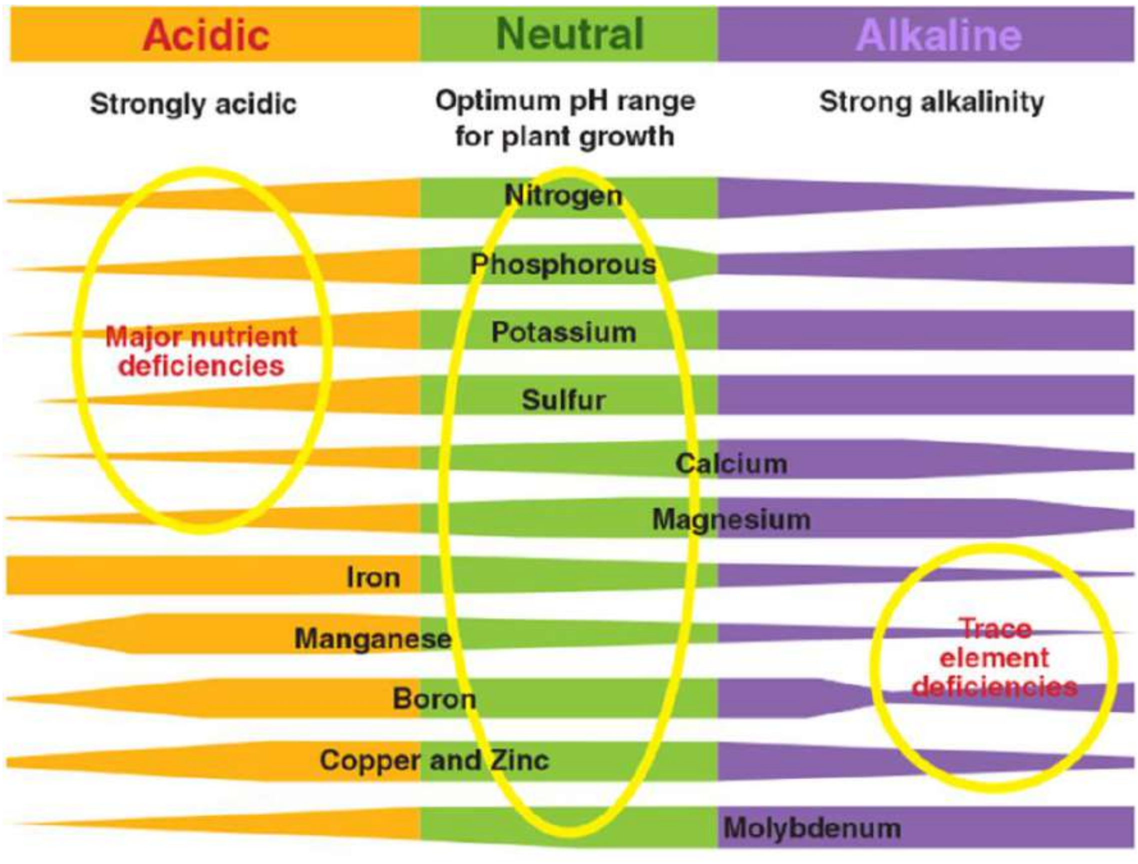

Figure 1. pH elements in soils

Alkaline soils may have problems using nutrients such as zinc, copper, boron, and manganese. Soils with an extremely alkaline pH (greater than 9) may already contain too much sodium. The correct balance is where the soil pH is between 5.5 and 7.5, so it should be at the proper level to measure the soil pH. Changing soil pH problems is important and fixing them with long-term nutrition can be both expensive and difficult (Covington, and et al., 1985).

Material and Methods

Study Area and Data Used

The research area is located in the north-west of Azerbaijan, in Gakh district. The length of the river is 55 km and it passes through the entire region. The area of the river basin covers 562 km^2. The river originates from the border of Dagestan in the south of the Greater Caucasus. Its source is Kunakhaysu and Hamamchayin. The flow of the river is formed mainly from underground and snow water. Snow in spring, and rainwater in summer and autumn cause floods in the river. The spring flood lasts 100-120 days. Heavy rains in summer often cause floods in rivers. The average saltiness of its water is 500-1000 g/cubic m and it is hydro carbonate-calcium. In the Alazan-Eyrichay valley, the river divides into many small branches and is used to irrigate the agricultural fields of the population. A hydroelectric station was built on the Gunakhaysu stream of Kurmukchay. However, it is currently not used.

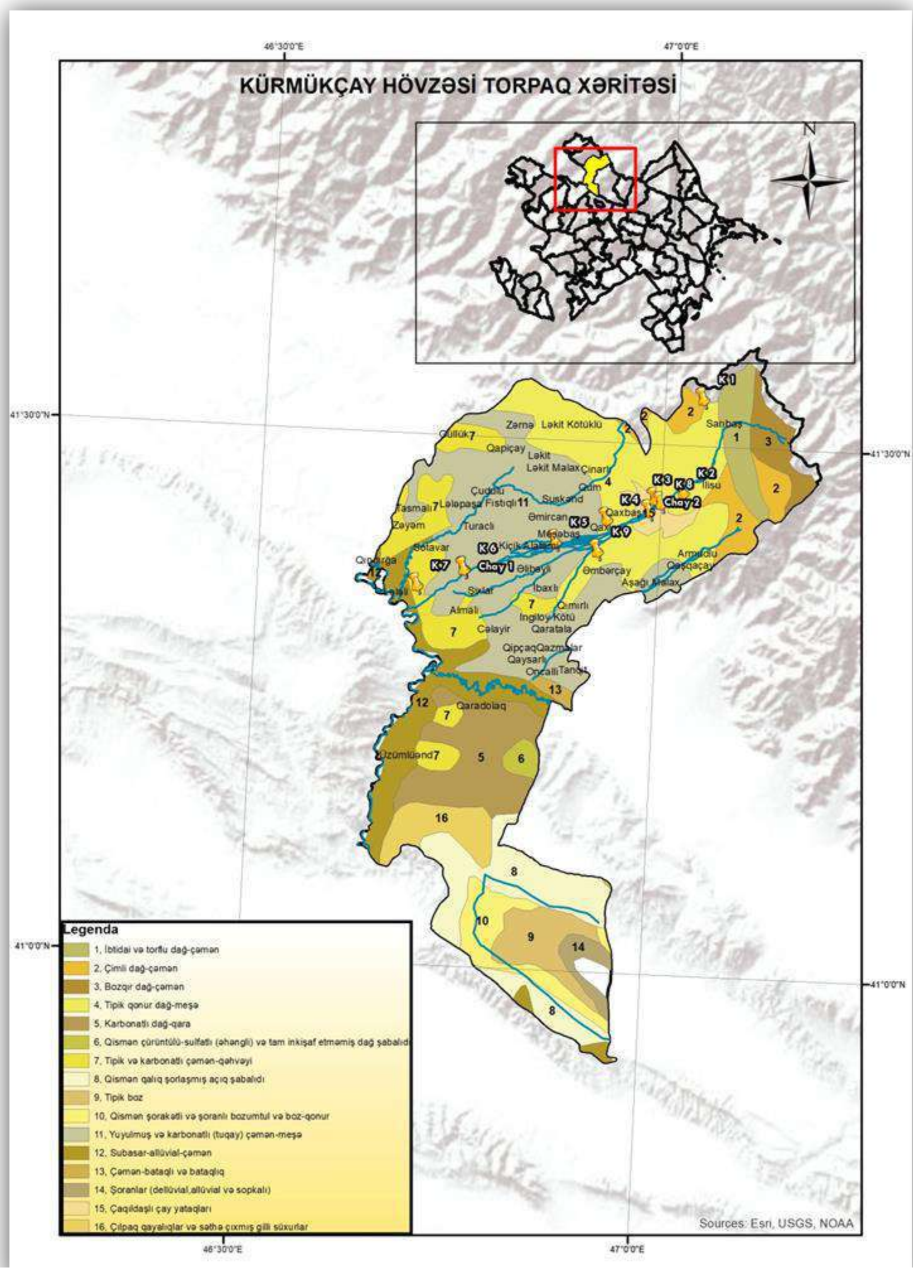

Figure 2. Location map of study area

There are many different ways to measure soil pH. In research I used a 1:5 dilution of soil. First, we collect a soil sample with a clean, dry plastic jar and empty soil samples. Do not touch the soil with your hands to avoid contamination of the sample. Remove any rocks and crush clumps of soil to prevent breakage of the delicate pH Scan glass electrode bulb (Jensen and William B, 2004). Fill your sample soil up to 1:5 and add distilled water to the jar During this method, we took 10 grams soil was weighed into a container and 50 ml of distilled water was added to it. Close the jar tightly and put it in the shaker (SSST method, 2005). Allow the mixed sample to stand for 1 hour to dissolve the salts in the soil. and then I used the thermo Orion Benchtop pH Meter device during ph measurement. We are going to include the test result in your data book for later reference.

As a result of the measurements, we obtained the pH for the Kurmukchay basin area. These results were transferred to the attribute data according to the coordinates of the areas where the soil samples were taken. Arcgis software was used during the creation of maps. The pH data is added to the attribution table and the distribution range of pH in the area is shown by the area interpolation method (Interpolation Method, 2013). Based on the obtained results, the soil maps were constructed at 3 depths. Soil ph indicators are shown on the map at depths of 0-20, 20-40 and 40-100.

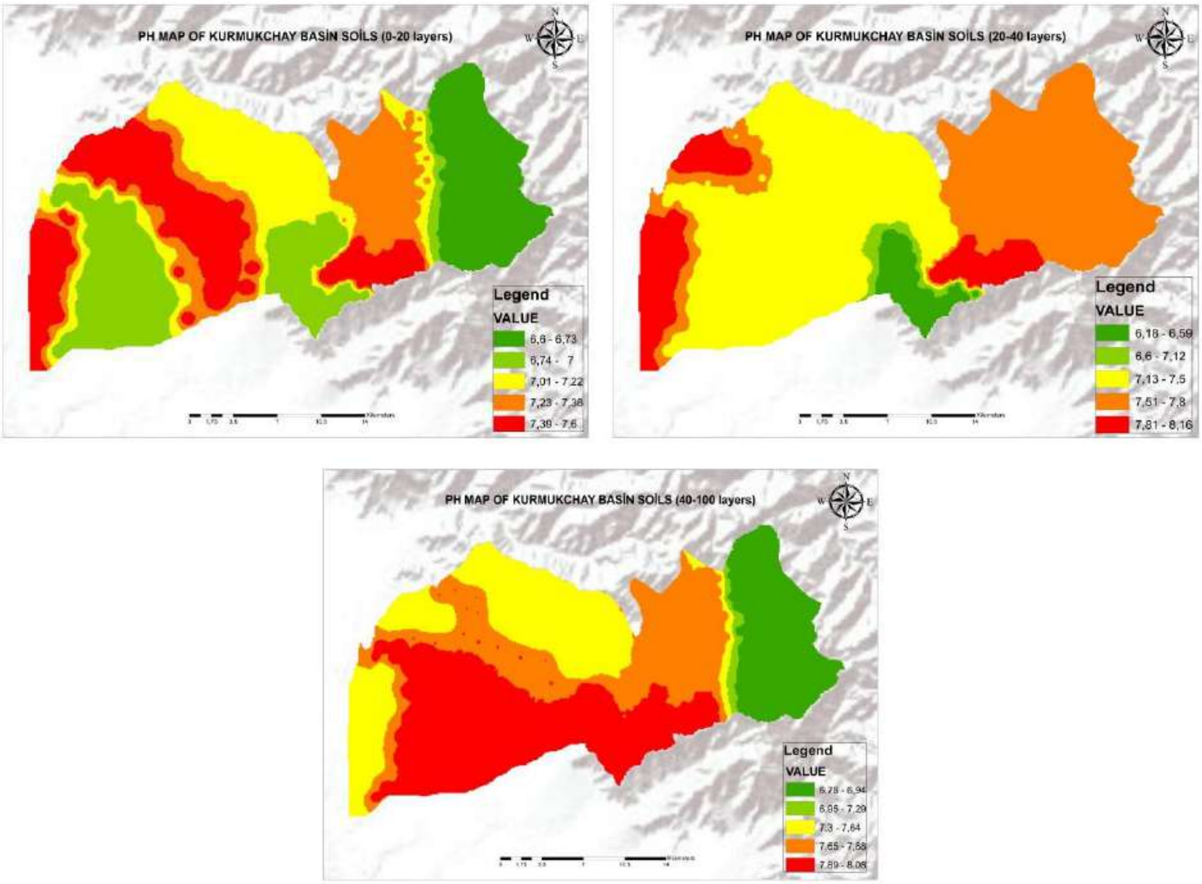

Figure 3. pH Maps of the area at various depths

Conclusion

The analysis of the soil samples taken during the research and as a result the pH data of the soil was obtained and transferred to the soil map. Interpolation mapping of the area gives us a broad picture of the range and intensity of the pH distribution. As we can see from the maps, the alkalinity of the soil increases as we move from the top layer to the bottom. Since these soils are neutral, the availability of essential nutrients is highest, and bacterial and earthworm activity is optimal at this pH (Bailey D, 1996). Taking into account the pH indicator, it is possible to plant barley, wheat, corn, walnuts, hazelnuts, etc. in these areas.

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Effects of pyrolysis temperature and time on biochar production produces

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Abstract

Biochars are generally obtained when biomass is heated around 250-900 °C under very less or no oxygen conditions. Recently biochars are used commonly as a multifunctional material related to carbon sequestration, reduction of N_2O and CH_4, contaminant immobilization, pollutant filtration and soil fertilization. These multifunctional capacities of biochars depend on their chemical and physical properties gained during the pyrolysis process under different conditions. Biochars consist of stable and persistent carbonaceous compounds. At the higher pyrolysis temperatures, usually pH, ash content, total C content, aromatic compounds, specific surface area increase while biochar yield, cation exchange capacity, nitrogen and sulphur compounds decrease. Pyrolysis reaction time is also a factor that changes the properties of biochar, but it is often dominated by pyrolysis temperature. Pyrolysis time may more affect the carbonization degree and yield of biochar especially at low temperatures. As the pyrolysis time increases, a more carbonaceous biochar is obtained.
As a result, production process conditions influence the properties of biochars and their production for specific purposes.
Keywords: Biochar, pyrolysis conditions, stability, chemical properties.

Introduction

Biochar is a carbon rich and porous solid material that is produced by thermal degradation of organic materials in an oxygen-limited conditions (Lehmann and Joseph, 2009). Biochars can be generated from a range of wood materials, crop residues (straw, nutshells, and rice husks), chicken litter, dairy manure, and sewage sludge. The organic portion of biochar has a high carbon content, and the inorganic portion mainly contains minerals such as Ca, Mg, K, and inorganic carbonates, depending on its feedstock type.

Numerous recent studies have highlighted the usefulness of using biochar as a strategy for reducing global warming and managing soil health and productivity (Lehmann, 2007; Gaunt and Lehmann, 2008).

Biochar's potential to mitigate climate change stems from its relatively high C content and resistance to microbial decay, resulting in the slow return of terrestrial organic C to the atmosphere as carbon dioxide (Lehmann, 2007).

The utility of biochar in increasing soil fertility mainly includes, raising soil pH and cation exchange capacity, improving structure stability, water holding capacity, microbial biomass and nutrient availability (Lehmann and Joseph, 2009; Sohi et al, 2009; Yoshida and Antal, 2009; Graber et al, 2010).

Due to its basic nature, biochar can regulate soil pH as a liming agent in acidic soils, and thus liming capacity, which in turn can alleviate aluminium, phosphorus and other elemental stresses, even at times outperforming lime (Hale et al., 2020).

But these functions of biochar are largely related to its properties and the properties of biochar are greatly affected by the feedstock material and the pyrolysis conditions. So, this diversity led to great variability of physical, chemical, nutrient and biological properties in their biochars and consequently have varying influences on soil' response to biochar incorporation (Sohi et al, 2010; Lehmann et al, 2011, Wang et al, 2013).

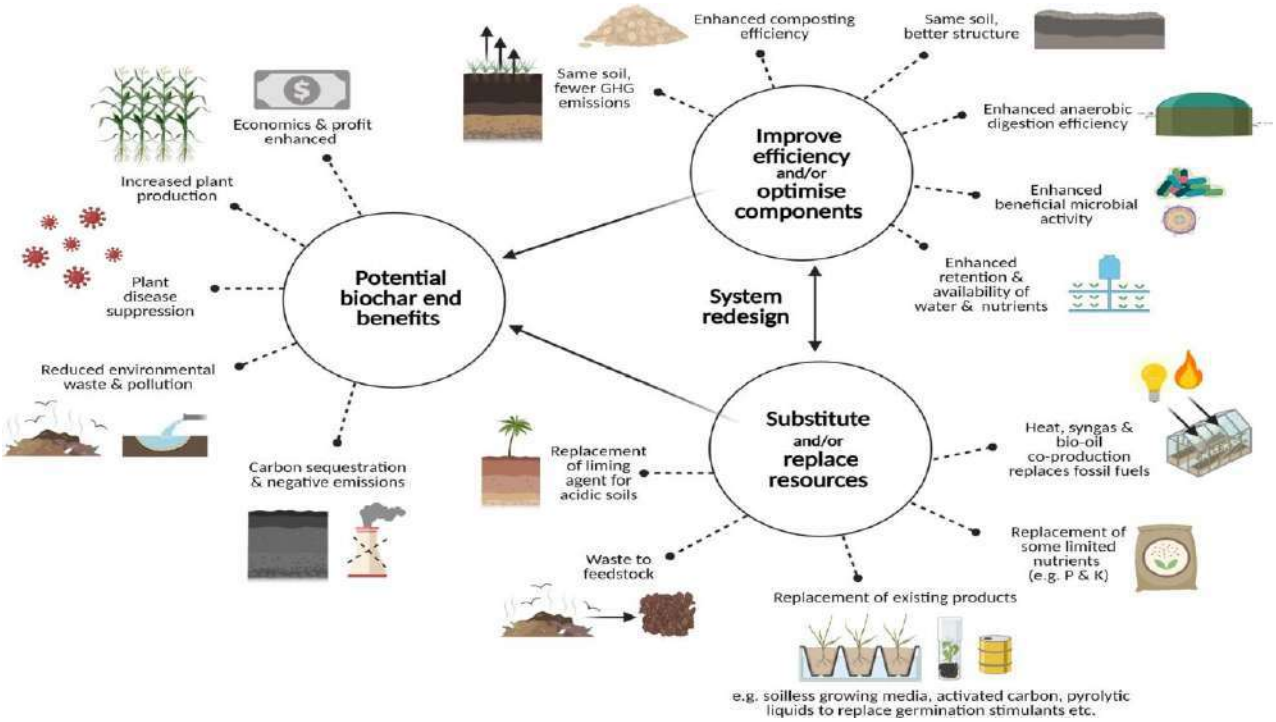

Figure 1. Thee potential role of biochar in intensification of plant-related industries (Pretty, 2018; Möhring et al, 2020; Kochanek et al, 2022)

Pyrolysis parameters includes pyrolysis temperature, heating rate, pressure, residence time and reactor type. During pyrolysis, biomass undergoes a variety of physical, chemical and molecular changes. Although residence time may not affect biochar properties as strongly as pyrolysis temperature, it is important parameter. The different residence time can lead to obvious differences in distribution of product yields among liquid bio-oil, solid biochar and syngas which may impact biochar production rate (Verheijen et al, 2010; Duku et al, 2011).

Therefore, it is critical to evaluate the effect of pyrolysis temperature and residence time on the physicochemical properties of biochar concerning soil improvement, in order to guide the application of biochar in different types of soils. In this study the effect of pyrolysis temperature and residence time on characteristics and chemical composition of the biochar was reviewed.

Pyrolysis temperature

The thermal decomposition of organic matter at 250-900 °C in the absence of oxygen is called pyrolysis (Osayi et al., 2014). Generally, the biochar yield decreases as pyrolysis temperature increases. Wang et al. (2020) used 4 different agricultural wastes (corn straw, wheat straw, rape straw and peanut shell) to investigate the effects of pyrolysis temperature and residence time on biochar production. They reported that the biochar yield dramatically decreased when the pyrolysis temperature increased 300 °C to 500 °C.

Wang et al. (2007) compared the biochars obtained from wood waste and agricultural wastes at different temperatures and residence times in a study they carried out. They showed that wood waste had lower biochar yield than agricultural wastes.

Biochar stability is the determining factor for carbon sequestration potential, and different biochar properties lead to varying biochar stability. Increasing the pyrolysis temperature positively affects the stability of biochar (Crombie et al., 2013; Liu et al., 2014; Han et al., 2018).

Increasing pyrolysis temperature led to higher biochar alkalinity. Zhang et al. (2015) produced biochar from wheat straw and lignosulfonate at different temperatures (200, 400 and 600 °C) and residence times (1h, 2h and 4h). As the pyrolysis temperature increased from 200 to 600, the pH of lignosulfonate and wheat straw increased from 5.79 to 10.96 and from 4.37 to 12.04, respectively.

Research has shown that enrichment with metal oxides, carbonates and minerals and reductions in acidic functional groups are the primary causes of the alkalinity of biochars (Keiluweit et al., 2010; Fidel et al., 2017).

Generally, biochars with high surface area have high porosity and sorption capacity. The porous structure of biochar is related to the high amount of water lost due to dehydration processes during the pyrolysis process

(Yaashikaa et al., 2020). Zhao et al (2018) showed that increasing pyrolysis temperature in biochar samples obtained from rapeseed stem significantly increased the surface area of biochar.

Residence time

Residence time is another critical factor that influences the characteristics and preparation costs of biochar (Han et al, 2017; Huang et al,2018). Sun et al, (2016) examined the effect of the various residence time (0.5, 1, 2, 4, 8 and 24 h), using three different feedstocks (wheat straw, fresh leaves of apricot tree and, platane wood) they reported that the biochar yield decreased with the increase of the residence time and became stable at 8h.

It is known that the effect of residence time at low temperatures is greater than at high temperatures. However, the extension of the residual time at high temperatures changes the surface and internal structure of the biochar (Braadbaart and Poole 2008).

Wang et al, (2019) investigated that the influence of residence times on the general properties and pore characteristics of biochars produced via the co-pyrolysis of sewage sludge and cotton stalks. Prolonged residence times decreased the H/C ratios and surface area, but prolonged residence times had a positive effect on the immobilization of the heavy metals.

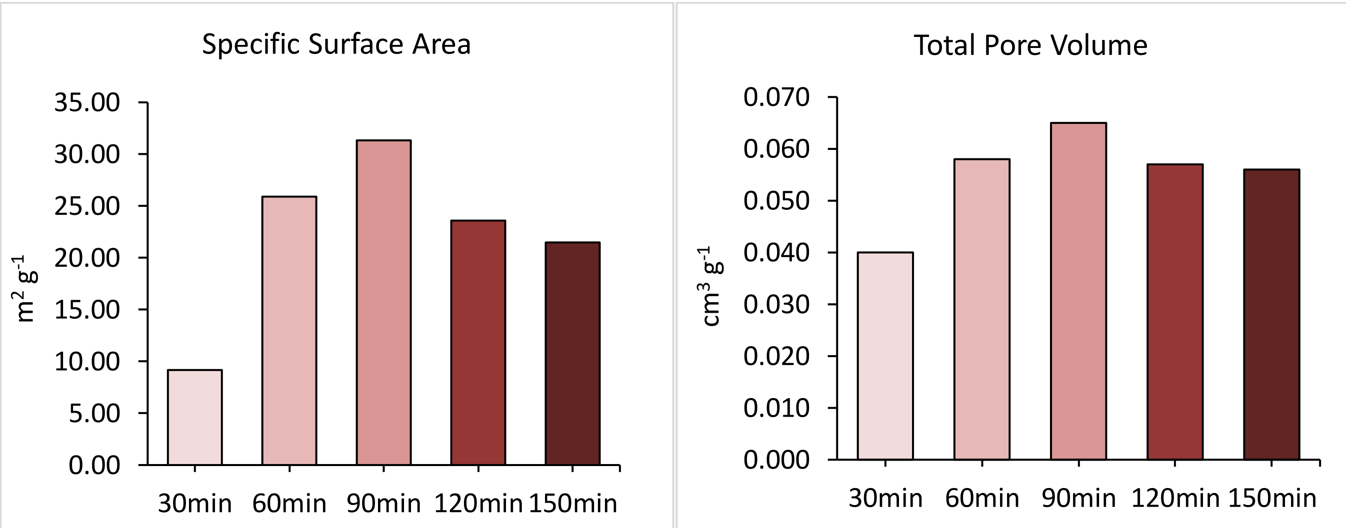

Figure 2. The effect of different residence time on biochar surface area and total pore (Wang et al, 2019)

As the residue time increases from 30 minutes to 90 minutes, the surface area increases but decreases after 90 minutes. A similar trend is observed in total porosity. They stated that this decrease in surface area and total pore volume may be due to the collapse of the pore structure with increasing residence time.

Conclusion

As a results, high pyrolysis temperature may alter the biochar properties such as increasing ash content, BET surface area, pH, total P and Ca contents and decreasing yield, cation exchange capacity (CEC) and total N.

Although residence time may not affect biochar properties as well as the pyrolysis temperature, the different residence time can lead to obvious differences in distribution of product yields among liquid bio-oil, solid biochar and syngas, which may impact biochar production rate.

A biochar having optimum properties should be produced by selecting suitable feedstock and manipulating production conditions according to its use purposes in agricultural production or sustainable soil management systems.

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Environmental problems of technogenic land pollution

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Abstract

A microbiological assessment of gray-brown soil's ecological state of Surakhani oil field area of Absheron Peninsula was carried out. To do this, the total number of heterotrophic, hydrocarbon-oxidizing microorganisms and the ratio between them were determined in the studied samples. The content of hydrocarbons in the samples and the degree of their toxicity to green plants were also determined. The results of the studies showed that in soils with an increase in the content of hydrocarbons, the total number of microorganisms decreased, but the number of hydrocarbon-oxidizing microorganisms in the composition of soil microbiocenosis increased compared to pure soils. The ratio between the number of hydrocarbon-oxidizing and heterotrophic microorganisms in soils varied in the range of 0.07-0.21. This data indicates that in oil-contaminated soils with a high content of hydrocarbons, the structure of microbiocenosis changes compared to pure soils, and about 10-13% of it consists of microorganisms capable of decomposing petroleum hydrocarbons and participating in the processes of self-purification of these soils. Since one of the integral indicators of soil pollution is their toxicity to vegetation, we simultaneously studied the degree of phytotoxicity in soil samples in which the degree of hydrocarbon pollution was studied, which showed that the degree of phytotoxicity directly correlates with the degree of soil contamination with petroleum hydrocarbons. Thus, the data obtained on the total number of microbiota of various biocenoses indicate the creation of new adaptive mechanisms for them, allowing them to adapt to anthropogenic and technogenic effects on the environment, including soil cover, as a result, the biocenosis of oil-contaminated soils is gradually formed. This gives grounds to assert that the natural resources of Absheron as an arid region should be strictly regulated in order not to cross the ecological barrier of dynamic equilibrium between the exploitation of natural resources (soil, surface and groundwater, etc.) and their natural restoration.

Keywords: Hydrocarbons, Microorganisms, Phytotoxicity, Pollution, Soils.

Introduction

Environmental problems in recent years have become "eternal companions" of the process of development of modern civilization, the danger of human-caused global changes in soil cover is steadily increasing (Nadjafova, 2015). Scientists face new challenges in developing scientific foundations for the conservation of soil cover, the most important habitat and genetic diversity of plants, animals and microorganisms, as an indispensable natural resource for agriculture, forestry and water management, as well as to ensure environmentally friendly human living conditions (Nadjafova, Ismailov, 2016).

For Azerbaijan, the development of energy carriers was one of the fundamental problems of the state's economy. However, during the period of extraction of hydrocarbon resources in the Absheron Peninsula, more than 30 thousand hectares of once fertile lands were polluted with oil and petroleum products and went out of circulation (Ismaylov et al.,2015). The purpose of the study is to assess the ecological state of soil cover of Surakhani oilfield area of the Absheron Peninsula.

Material and Methods

The object of the study was gray-brown soil samples of the Surakhani district. According to WRB -Gypsisols. Soil samples were selected in the study area. Mixed soil samples were taken for research using the envelope method. The content of microorganisms in the soil was determined by seeding on nutrient media (Microbiology Workshop, 2015). In soil samples, the total hydrocarbon content was determined by gravimetric method according to PNDF (1998). Phytotoxicity was determined by the germination of watercress seeds (Trofimov et al., 2020)

Results and Discussion

Within the framework of the conducted research, 8 samples of soil were selected from the territory of the Surakhani district.

The studied soil samples were characterized by a heavy granulometric composition. The content of physical clay (<0.01 mm) was 11.0-23.3%. The amount of humus in the upper horizons of soil samples was 0.74-1.04%, in the lower horizons its value sharply increased to 0.32-0.53% (Babayev et al., 2019). Table 1 shows the number of heterotrophic and hydrocarbon-oxidizing microorganisms and the content of hydrocarbons in the studied soil samples.

Table 1. Microbiological indicators and the content of total hydrocarbons in the soil samples of the Surakhani district

№	Indicators			
	Total hydrocarbon content, g/kg of soil	Total number of heterotrophic microorganisms, CFU/g of soil	Number of hydrocarbon-oxidizing microorganisms, CFU/g of soil	Ratio of hydrocarbon-oxidizing microorganisms/ saprotrophs
C	0,1	64200	4540	0,07
1	24,0	12382	2200	0,18
2	36,0	13211	2700	0,21
3	26,1	24342	3140	0,12
4	2,28	39000	4000	0,1
5	2,14	45100	5200	0,11
6	1,62	42400	4300	0,09
7	1,57	41200	5140	0,12
8	2,02	43700	5240	0,12

The results of the studies showed that soil samples in which the content of total hydrocarbons was the highest were characterized by a high number of hydrocarbon-oxidizing microorganisms in the composition of soil microbiocenosis (Table 1). The ratio between the number of hydrocarbon-oxidizing and heterotrophic microorganisms in soil samples was in the range of 0.07-0.21. The data indicates that in oil-contaminated soil samples with a high content of hydrocarbons in the structure of microbiocenosis, about 10-13% is microorganisms capable of decomposing petroleum hydrocarbons and participating in the processes of self-purification of soil samples. When assessing the environmental condition of soil samples, it is necessary to additionally rely on indicators of phytotoxicity, which is one of the integral indicators of soil pollution. Phytotoxicity should be investigated taking into account regional peculiarities.

In this regard, we simultaneously studied the degree of contamination with hydrocarbons in soil samples in which the degree of their phytotoxicity was studied (Table 1).

Table.2. The degree of phytotoxicity of soil soil samples

№	Seed germination, %
Control	99
1	44
2	21
3	41
4	86
5	88
6	93
7	93
8	90

The results presented in Table.2 show that the degree of phytotoxicity correlates with the degree of contamination of soil samples with petroleum products and varies widely – from 99% for non-contaminated soil (control) to 21-93% for contaminated. With an increase in the degree of contamination, the phytotoxicity of the soil increased.

Conclusion

The results on the total number of microbiota of various biocenoses indicate the creation of new adaptive mechanisms for them, allowing them to adapt to anthropogenic and technogenic effects on the environment, including soil cover, as a result of which the biocenosis of oil-contaminated soil samples is gradually formed.

This gives grounds to assert that the natural resources of the arid region, to which Absheron belongs, should be strictly regulated in order not to cross the ecological barrier of dynamic equilibrium between the exploitation of natural resources (soil, surface and groundwater, etc.) and their natural restoration.

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Potential of organic amendments on reclaiming the soil properties affected under alkaline and/or sodic condition

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Abstract

Sodic and/or Alkaline soils are generally associated with poor soil structure and soil properties representing the major land degradation process in the world, especially in arid and semi-arid regions. In order to address this problem, a proper and clear understanding on the effects of sodicity or alkalinity in the soil is necessary and an effective, affordable, and sustainable reclamation approach should be chosen. In this context, the aim of the review was to study the alkalinity and/or sodicity effects on soil properties and explore the potential of a wide range of organic amendments to reclaim sodic soil and maintain soil quality and sustainable production. The presence of dispersive cation Na+ and the several degradation processes (slaking, swelling, and dispersion) involved in sodic soil possess a huge impact on soil physical (undesirable structures, crusting, hard setting, high bulk density, low infiltration rate, hydraulic conductivity, permeability, plant available water holding capacity, weak structural stability) and chemical (pH, SAR, ECe and ESP) properties. The input of various organic sources (compost, farmyard manure, green manure, municipal solid waste, biochar) can be used to recover soils contaminated with salts and sodium. Organic amendments facilitate the leaching of sodium and other salts and better aggregation thereby leading to better structural stability and overall soil properties with no risk to the soil environment. Thus, this organic way of remediation has proved to be environmentally friendly, sustainable, effective as well as practical. Therefore, the potential benefits provided by the organic amendments will open up a new direction of research in the reclamation process.

Keywords: High pH, Soil conditioner, Soil properties, Soil structure.

Introduction

Introduction

Salinization and/or alkalization-related soil deterioration has been a global environmental problem due to its severe negative impacts on agriculture production and sustainability, especially in arid, semi-arid, and coastal regions(Dongli et al., 2015). The majority of the salinity and sodicity problem is natural, but also today's rising environmental issues like climate change, land clearing, irrigation, and global warming have worsened the problem more severely(Leogrande and Vitti, 2019). Globally, it is estimated that at least 20% of the irrigated land has been facing the issue of salinity where the sodic and saline-sodic soil account for about 60% of the salt-affected land (Qadir et al., 2006).

Sodic soils have an exchangeable sodium percentage (ESP) of 15 or more and have relatively low ECe generally less than 4 ds/m at 25°C, resulting in the pH at or above 8.5 (USSLS, 1954). Sodic soils contain sodium salts, primarily Na_2CO_3, that can cause alkaline hydrolysis. In older literature, such soils were referred to as 'alkali' soils. In the past, sodic soils were frequently referred to as "black alkali soils," which refers to the humic substances' dispersion and dissolution, which gives the soil a dark color(Sparks, 2003). Salinity affects plant growth and productivity because of its toxic effect on the plants, while sodicity/ alkalinity has an adverse effect on the soil structure where sodium (Na^+) acts as a dispersing agent causing the soil colloids to spread or disperse out and thus degrading the soil structure which consequently hampers to the physical and hydraulic properties of soil. Therefore, understanding the effect of sodicity and/or alkalinity on the overall properties of soil is very crucial for planning the proper reclamation measures and improvement of soil condition.

The use of amendments as a chelating agent has been one of the effective measures for reclaiming the soil properties affected by alkalinity. Chemical amendments such as gypsum ($CaSO_4 2H_2O$), calcite ($CaCO_3$), and calcium chloride ($CaCl_2$) have been widely used over the world for reclaiming this problematic soil. These amendments have their unique mode of reclaiming the soil, some of them provide calcium (Ca^{2+}) directly to the soil, while some of them replace excess exchangeable sodium (Na^+) and some other solubilize calcite ($CaCO_3$) in calcareous soil(Qadir and Oster, 2002). On the other hand, it has also been demonstrated that various organic sources (compost, farmyard manure, green manure, municipal solid waste, biochar) can be used to recover soils contaminated with salts and sodium which has proved to be more cost-effective, simple to implement, environmentally friendly, sustainable, and effective way of remediation. Organic amendments facilitate the leaching of sodium and other salts and also help in decreasing the exchangeable sodium percentage (ESP), thus ameliorating the soil properties and maintaining proper soil health(Jian-bing et al., 2014). This really can be an exciting area of research being a more sustainable and efficient reclamation method for alkaline or sodic soil that can be applied globally.

This review study aims to discuss the effect of alkalinity on the overall soil properties and also explore the potential of organic amendments in reclaiming the soil properties affected under alkaline conditions.

Classification of Sodic or Alkaline soil

Some of the literature has proposed the classification of sodic soil based on those key properties: sodium adsorption ratio (SAR), electrolyte concentration measured as electrical conductivity (EC) and pH of 1: 5(W/V) soil: water suspensions.

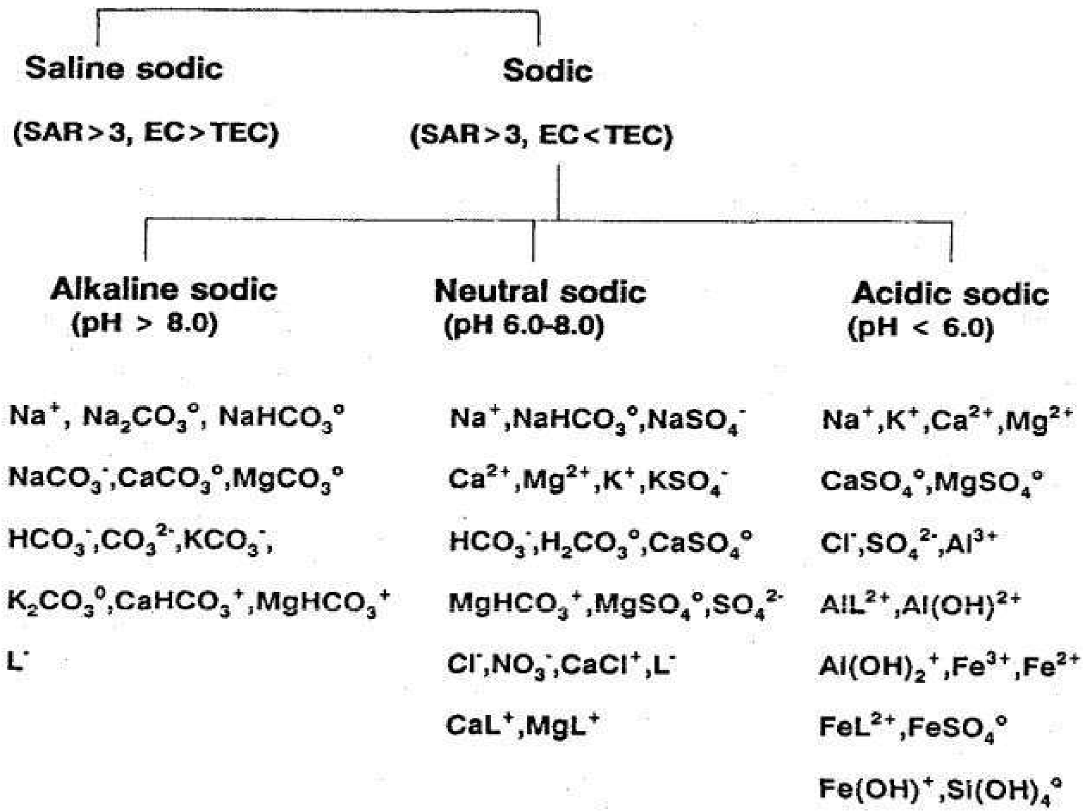

Figure 1. Classification of sodic soils and the predominant chemical species present in the solution. TEC: Total threshold electrolyte concentration and L: Ligands. (Lindsay, 1979; Northcote & Skene, 1972; Rengasamy & Olsson, 1991).

Effect of alkalinity and/or sodicity on soil properties

Sodicity and/or alkalinity are generally associated with poor soil structure and soil properties. The two processes i.e., slaking and dispersion are the common degradation phenomenon involved in sodic soil. Slaking refers to the disaggregation of soil macro aggregates and loss of larger pores while dispersion involves the detachment of individual clay particles from the aggregates (Abu-Sharar et al., 1987; Cass & Sumner, 1966; Qadir et al., 2007). Thus, these processes possess a huge impact on soil properties leading to undesirable structures, crusting, hard setting, high bulk density, low friability, high strength, low infiltration rate, low hydraulic conductivity, plant available water holding capacity, and weak structural stability. Dispersed clay materials in the sodic soil are responsible for clogging the soil pores which then reduces the infiltration and aeration of the soil. Clay swelling occurs in sodic soil because of the dominant double-diffuse layer phenomenon that occurs particularly in the presence of sodium in the soil which is well explained by Qadir et al. (2007). According to McNeal and Coleman (1966), and Jayawardane (1979), swelling of the clay leads to the reduction of hydraulic conductivity of sodic soil by reducing the radius of soil pores. Crust formation (structural crust or seal) i.e., densely packed thin soil layer with high shear strength occurs under the sodic conditions as high sodium destroys the topsoil aggregates through the degradation processes like slaking and dispersion (McIntyre, 1958; Moore & Singer, 1990). Consequently, these adverse impact on the soil leads to poor physical as well as hydraulic properties of the soil. Likewise, Hard setting (massive, compact, and hard conditions in the upper soil layer) is another type of degradation that occurs under sodic conditions during drying which bears great implications on soil properties that lead to low infiltration rate, low hydraulic conductivity, permeability and also hampers the germination, growth, and development of plants(Mullins et al., 1990). According to Shainberg and Letey (1984), the effect of sodicity depends on several soil properties like soil texture, clay mineralogy, free sesquioxide, and soil density. Frenkel et al.(1978) and McNeal et al. (1966), from their studies, concluded that; soil having higher clay contents are more susceptible to sodic condition and leads to a greater reduction in HC of soil. In the study made by Frenkel et al, (1978), the impact of soil bulk density on declining HC under sodic and electrolyte concentration was examined, and concluded that soil sensitivity to high ESP and low electrolyte concentration increased with the rise in bulk density. Therefore, we can find several pieces of literature where the authors have successfully presented the effect of sodicity and/or alkalinity on the various properties of soil.

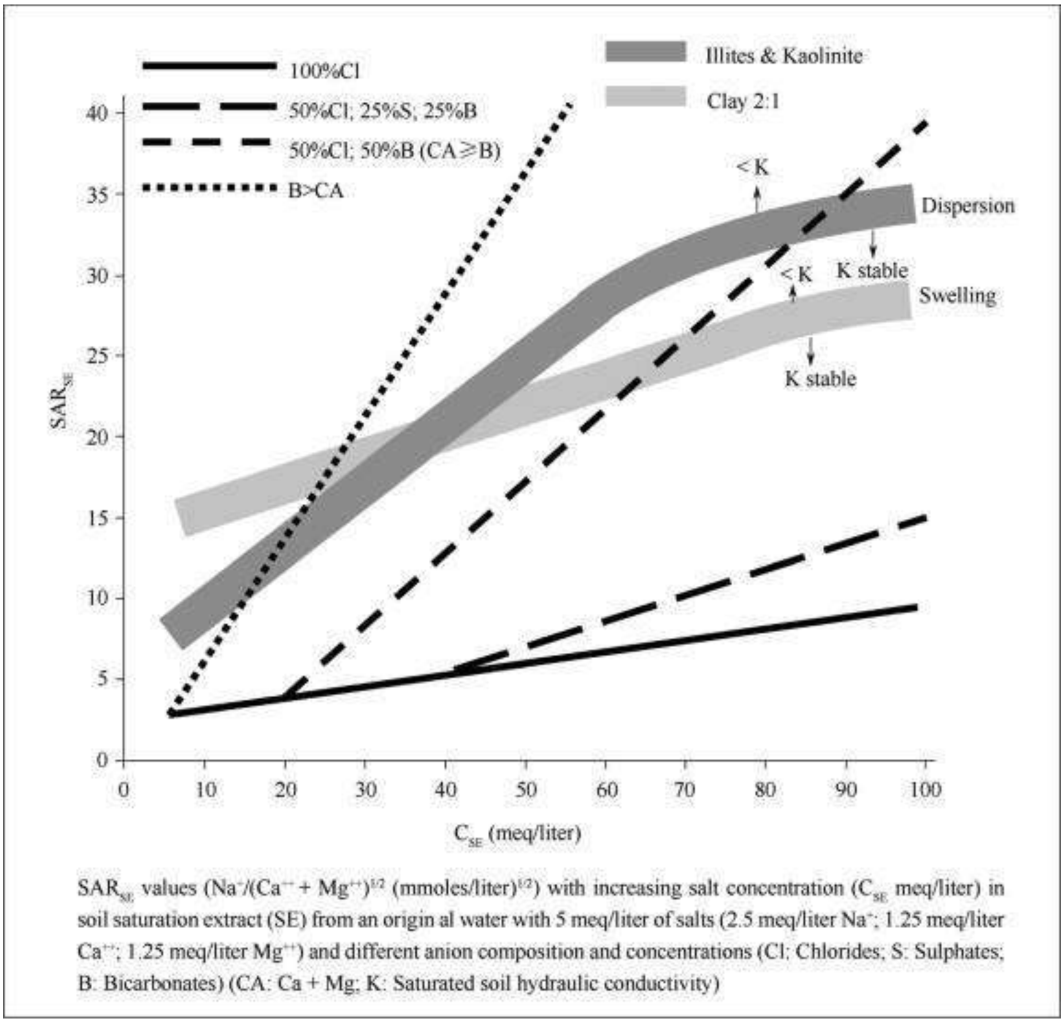

Figure 2: Relationships between salinity and sodicity in soil solution, and their effects on clay dispersion or swelling, as well as soil hydraulic conductivity, for various anionic compositions of the original water and soil clays (Pla, 2014)

Application of Organic amendments on the improvement of soil properties affected under sodic and/or alkaline conditions

The main principle involved in reclaiming the sodic soil is based on either removing or exchanging the soluble sodium, altering the composition of ions of soils with the use of amendments, and also leaching out of sodium salts from the soil profile(Chhabra, 1994; Mahdy, 2011). Chemical amendments like gypsum, sulfuric acid or elemental sulfur, etc. are widely used chemical remediation methods for sodic and/or saline soils (Alcívar et al., 2018; Gupta et al., 2016). However, on the other hand, Organic amendments can be used as a cheaper as well as an effective alternative to chemical amendments for reclaiming degraded sodic soil. Furthermore, the use of organic amendments can significantly improve the physical, chemical, and biological properties of degraded soil. The application of organic matter as amendments not only helps to remediate the saline and/or sodic but also increases the fertility and productivity of the soil. Organic matter content in sodic and/or alkaline soil is very low, thus the addition of organic amendments increases the microbial activity of the soil thereby increasing the organic matter content in soil. Consequently, the increased microbial activity in the soil leads to increase in soil aggregate stability with the release of exo-polysaccharides which in turn decrease bulk density and improve hydraulic properties of soil (Abiven et al., 2009).Organic amendments supply a sufficient amount of available cations (Ca, Mg, K etc.) making great contribution to cation exchange capacity (Oort's et al., 2003), binding the mineral particles to organic polymers and playing an important role in the structural stability of soil aggregates(Leogrande and Vitti, 2019). Likewise, Soil properties like porosity, hydraulic conductivity, water holding capacity, permeability, etc. are significantly improved by the addition of organic amendments as the organic material helps to maintain the proper balance between micro and macro pores which then increases the water infiltration rate facilitating the salt leaching and reducing erosion (Grigg et al., 2006; Shi et al., 2016).

A variety of organic amendments have been used in several studies to remediate saline or sodic soil and proved to be effective in improving the physical, chemical, and biological properties of soil. In a five-year-long study, Tejada et al. (2006) concluded that the application of compost facilitates the steady leach out of salts and Na^+ with an observable increase in plant growth and soil porosity. Wahid et al. (1998), in their experiment, while using farm yard manure (manure), Egyptian clover hay (clover hay), and wheat straw to study the effect of organic matter in improving the soil properties of saline-sodic soil, found that addition of OM to the soil increases the aggregate stability and water holding capacity and decreases pH and EC and also concluded manure to be the most effective as compared to others in reclaiming the degraded soil and improving wheat growth. Likewise, Rahman et al. (1996) reported a significant reduction in ECe and SAR of saline-sodic soils while using different organic amendments in their study.

Conclusion

Soils affected under sodic or alkaline conditions undergoes several degradation processes like swelling, slaking, and dispersion because of which alkaline and/or sodic soil is considered to be one of the major forms of degraded soil with its major impacts on the soil properties, soil health, soil fertility and ultimately production. Alkalinity and/or sodicity have been the major threat to soil degradation globally, thus their reclamation with suitable and effective agronomic measures is a crucial aspect. The application of organic amendments has proven the resilient agriculture practice in recovering this degraded soil and ensured sustainable soil management in an ecofriendly approach. Thus, this review has outlined the effects of sodicity on the properties of soil and also presented the potential advantages of organic measures in reclaiming the sodic or alkaline soil. Apart from this, there are several areas that are still yet to be addressed. The drawbacks associated with the use of organic amendments along with their likely alternatives can be considered for future research.

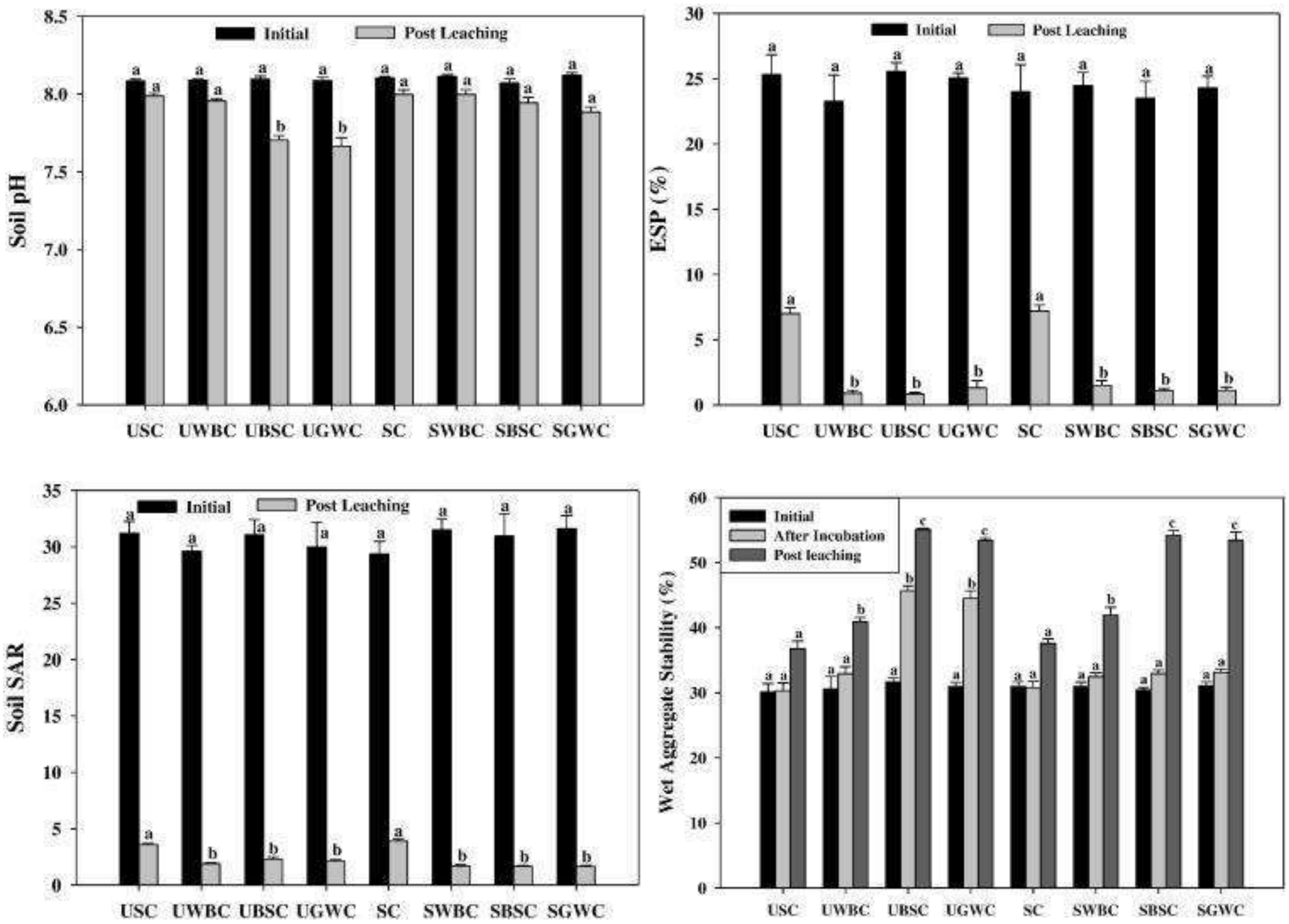

Figure 3: Soil pH , Sodium adsorption ratio, Exchangeable sodium percentage and Soil wet aggregate stability (%) (mean ± s.e.) of soils before and after leaching. Same letters within a column series indicate no significant differences between treatments ($P < 0.05$, Tukey's test)(Chaganti & Crohn, 2015).

USC- Unsterilized control soil, UWBC- Unsterlized soil +unsterilized woodchip biochar, UBSC- Unsterlized soil, +unsterilized biosolids compost, GWC-- Unsterlized soil +unsterilized greenwaste compost, SC- Presterilized control soil, SWBC- Presterilized control soil + Presterilized woodchip biochar, SBSC- Presterilized control soil + Presterilized biosolids compost, SGWC- Presterilized control soil + Presterilized greenwaste compost. Texture- Clay loam (sand- 42%, silt-21%, clay-37%) pH-8.19 ESP (%)-24.3 SAR- 31.3 $(mmol\ l^{-})^{0.5}$

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Use of product containing free nitrogen-fixing bacteria (biofertilizer) as a supplement in nitrogen fertilization of crops

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Abstract

The impacts of chemical fertilizers do not start after application but are initiated from the production stage. Application of them leads to the loss of soil fertility and, consequently, soil degradation. Fortunately, plant growth-promoting bacteria (PGPB) can hinder intensive usage in agricultural practice. They are well-known as plant growth-promoting rhizobacteria (PGPR). Aerobic, free-living, and atmospheric N_2-fixing PGPB have the potential for plant development and nutrient utilization performance, and they can be found in the soil and water. PGPR is commercially available as a biofertilizer, providing promising results due to the scientific research conducted on both introduced soil and cultivated plants. Demand for food and global agricultural crop criteria has been drastically increasing in the last decades. Using bacteria with nitrogen, phosphorus, and potassium (NPK) to increase harvest is possible in a sustainable way. In the present study, the focus is on the reported effect of biofertilizers containing N-fixing bacteria on the physical-chemical properties of the soil, growth, and yield of the highly consumed crops. Modes of action include soil pH, positive plant root development and morphology, assisting in the creation of bio pores, consequently improving water infiltration, increasing cation exchange capacity (CEC), soil organic matter, and the availability of other nutrients. The combination of listed actions can be achieved with a reduced (70% of recommended) amount of chemical NPK fertilizer to meet the world food criteria.

Keywords: Biofertilizer, Biological nitrogen fixation (BNF), Crops, Plant-growth-promoting-bacteria (PGPB), Priestia megaterium, Rhizosphere.

Introduction

Plant growth through chemical fertilizers mostly meets the food criteria of the world. However, plant parameters such as nutritional characteristics and anatomical and morphological features (shoot and root system) will not have sufficient time to mature properly. Some toxic chemical compounds can be accumulated in the organisms. The side effects of fertilizers start from the manufacturing that produces byproducts and gases (CO_2, CH_4). Pollution and waste accumulation from the manufacture cause the most disruptive ecological consequences.

Moreover, when it is applied to the soil in high amounts, it starts to degrade soil fertility and pollute soil and underground water. Hence, environmental and natural ecosystem resource depletion has to be reduced before it threatens all life forms. New agricultural techniques, such as shifting from fertilizers to biofertilizers and manures, can improve soil physicochemical properties and the efficiency of organic and chemical inputs (Chandini et al., 2019).

While NPK and S supplied by additives are crucial for plant production, biofertilizers containing N-fixing bacteria can also contribute directly or indirectly to crop improvement. Application of new environmentally friendly nutrient management methods that intensify soil fertility restoration and maintenance, less resilience on abiotic environmental factors to prevent the long-term plant stresses. Therefore, innovative biological approaches such as biofertilizers containing nitrogen-fixing PGPB are essential in crop productivity increase (Dineshet al., 2013). The PGPB takes part in numerous biofertilizers to substitute intensive synthetic fertilizers. According to Manasa et al. (2021), among the top bio-stimulants and bio-inoculants for the augmentation of agricultural productivity is PGPB. Unfortunately, they only account for a minor portion of the fertilizer in world agriculture (Yakhin et al., 2017). Finding new strains adapted to local soils and climates is still significant (Backer et al., 2018).

In the family Bacillaceae, the genus *Priestia* has rod-shaped bacteria that are mainly Gram-positive (*P. flexa* stains Gram-variable and *P. koreensis* stains Gram-negative) (Brenner et al., 2005). Aerobic members of *Priestia* may be found in various environments, including feces, soil, willow root rhizosphere, and marine sediment. The majority of species are motile, and all are able to form endospores. Priestia spp. can be detected in a range of temperatures between 5 – 48°C however, 28 – 37°C is optimum to thrive. *P. megaterium* is a well-known species of the genus (Gupta et al., 2020).

P. megaterium, also known as *Bacillus megaterium,* has been seen as a considerable industrial microorganism for many years. The species produce many enzymes, including amylases, dehydrogenase, and penicillin amidase. Along with various amino acid dehydrogenases, it also generates corticosteroid modifying enzymes. Additionally, it is utilized in synthesizing compounds with fungicidal and antiviral effects, vitamin B12, pyruvate and etc. (Vary et al., 2007). *P. megaterium* is commercially available these days, and it is called "Nuptak" by the "Daymso" company.

Definitions and Classification of Biofertilizers

The definition of "biofertilizer" is essential before discussing the PGPR as a biofertilizer. A biofertilizer is a product that includes live microorganisms that, when introduced to soil, seeds, or plant surfaces, colonize the rhizosphere or inside and enhance development by augmenting availability and/or the supply of macro-elements to the host. Biofertilizers supply nutrients to the soil by natural nitrogen fixing, phosphorus solubilization, and synthesis of growth-promoting molecules that boost the metabolism. Growth-promoting microorganisms increase soil organic matter (SOM) and rebuild the natural nutrient cycle in the soil. Using biofertilizers to cultivate clean and healthy plants while improving soil fertility is possible. Although they are not yet able to completely replace the use of synthetic fertilizers and pesticides, biofertilizers can be expected to minimize their consumption. The recommended scientific term for these beneficial bacteria is "plant-growth promoting rhizobacteria" (PGPR) because of their various roles (Vessey, 2003).

Organic "eco-friendly" agro-input is supplied through biofertilizers. Long-used biofertilizers usually are Rhizobium, Azotobacter, Azospirilium, and blue-green algae (BGA). Leguminous plants benefit from rhizobium inoculants. Azotobacter may be employed with various vegetable crops, including wheat, maize, potatoes, and cotton. The principal crops for which Azospirillum inoculations are advised are sorghum, millets, wheat, maize, and sugarcane. When employed as inoculants for paddy crops produced in both upland and lowland settings, blue-green algae from the broad cyanobacteria genera Aulosira, Anabaena, and Nostoc have the ability to fix atmospheric nitrogen. Together with the water fern Azolla, Anabaena enriches soils with organic matter and adds up to 60 kg of nitrogen per hectare every season (Watanabe et al., 1991). As a result of their abundance in many types of mineral components (such as potassium, phosphorus, and trace elements), seaweeds are often employed as manure in coastal regions. Clays can be broken down with the aid of seaweed excrement. Ireland is known for its extensive usage of fucus as manure. It is common practice in tropical nations to fertilize fields with the bottom mud of dried-up ponds rich in blue-green algae. A perfect fertilizer might be made from seaweed and blue-green algae.

Application Method of Biofertilizers

P. megaterium is free-living bacteria, and it falls into the biological nitrogen fixation group among five different categories. Most of the bacteria that can fix atmospheric N_2 are suppressed when intensive chemical fertilizers are applied to the soil. Those bacteria (including nodule-forming endophyte kinds) form cysts and stop the mutualistic symbiotic relationship with the plant because plants start to uptake ready N-containing chemical components. The balance in the soil with microorganisms is disrupted. On the other hand, other types of bacteria (except ones that can ammonify the N_2) start to flourish after a few days of fertilizer application, and the number of microorganisms gets many times larger than the pre-application population within three weeks. To prevent natural nitrogen-fixing bacteria from suppression by chemicals and to save the soil from soil fertility reduction at the same time, *P. megaterium* is inoculated after seed germination. Therefore, NPK fertilizer application is divided into a few proportions due to the crop's development needs to achieve the goal.

In such a way, inoculants can convert gas-state nitrogen from air to plant-available ammonia form (Jayathilake et al., 2021).

Effect of Biofertilizers on Chemical Composition

Effect of Biofertilizers on Chemical Composition

A particular portion of the carbohydrates is quickly degraded and exhaled into the atmosphere by the microorganisms, leading to a brief residence period. Physical characteristics of the soil can be modified by soil organic carbon. By aiding in the consolidation of particles into aggregates, it raises the cation exchange capacity (CEC) and the field capacity and improves the structural integrity of clay soils. Carbon is a significant component of soil organic matter, which also contains considerable quantities of vital nutrients, cations, and micro-elements to plant development. It is a barrier to nutrient loss and is essential to the organic acids that enable plants to access minerals. Soil pH is buffered by the organic matter as well. The SOC content is widely acknowledged and has a significant role in the Carbon Cycle, the health of the soil as a whole, and the mitigation of climate change consequences (Kizilkaya, 2020).

According to Zhang et al., (2015), K concentration in the soil solution treated with Azotobacter were noticeably more significant than in non-treated. However, K content in the soil's mineral structure was substantially lower in the microorganism treatments than control groups. Azotobacters might encourage the breakdown of mineral K in the microorganism inoculated treatment that the soil is the only source of K. Multiple studies have supported the ability of Azotobacter species to solubilize potassium (Archana et al., 1991). Other research claimed that inoculation of Azotobacter might increase K solubilization and significantly enhance plant K uptake (Bana et al., 2021).

When nitrogen levels are low, plants start struggling in development since it is one of the most important macro-elements they can get. Nitrogen is an ingredient that can be utilized in both the anion nitrate (NO_3^-) and the cation ammonium (NH_4^+) forms. Although nitrogen is rarely lacking in soil, it is frequently present as complex organic matter that can not be utilized directly. The soil also contains minor amounts of nitrogen in the form of gases, such as molecular nitrogen (N_2), ammonia (NH_3), nitrogen dioxide (NO_2), nitrous oxide (N_2O), and nitric oxide (NO), which are present in the air space between aggregates (Imran et al., 2019).

Fertility and nutrient retention capacity are measured using CEC. Ammonia that is taken up by soil colloids and converted into ammonium hydroxide by soil moisture:

$NH_4^+ + H_2O = NH_4OH$

$[CEC^-]\ NH_4^+$

The following factors determine the amount and how fast ammonia is absorbed from the soil depending on the characteristics like field capacity, humus content, and soil texture. Ammonia is rapidly absorbed in well-treated, heavy, humus-rich, moist soils compared to light, dry soils with less organic matter. The colloids adsorb ammonia, which is why it is weakly moved into it. Over time, ammonia nitrogen (NH_4^+) is nitrified (NO_3^-). Fixed atmospheric nitrogen goes through the alterations changing the soil pH in the following order: (1) alkaline reaction reacting with water in the soil (NH_4OH); (2) return to initial pH; (3) slightly more acidic than the original (HNO_3). Most PGPR and fungi thrive in slightly acidic soil, resulting in fertile soil and high crop yield (Schwab et al., 1989).

Impact of Biofertilizers on Physical Characteristics

When there are rhizospheric interactions, PGPR may invade the rhizosphere, the root's surface, or even the outermost intercellular gaps (McCuly, 2001). These locations are inhospitable to any soil bacterial colonization. A plant alters the soil's chemical and physical properties (including pH, water holding capacity, partial pressure of oxygen, and so on by its exudates) in comparison to the bulk soil, which may have an impact on a PGPR's potential to colonize the rhizosphere (Xu, 2001). Usually, PGPR refers to the applying soil microbes to the availability, stimulation, and absorption of mineral nutrients. The approach that PGPR function as biofertilizers is either directly by assisting in nutrient supply to the host or indirectly by favorably impacting root development or promoting other advantageous symbiotic connections. All PGPR can not be used as biofertilizers. Primary PGPR aid in the suppression of disease-inducing microorganisms, which in turn enables the development of plants (Zehnder et al., 2001).

Soil is the foundation for agricultural crop production, and microbial activity is critical to improving soil health for healthy crop growth. Microorganisms play a crucial role in forming a complex link between plants and soil. Soil microbes are living components of soil that perform various valuable functions in the soil system. Microbes aid in biological processes, such as organic carbon conversion and nitrogen fixation. Furthermore, they increased nutrient availability to the crops (Toor and Adnan, 2020). Soil microorganisms, including bacteria, algae, fungi, actinomycetes, protozoa, and infective agents such as viruses, are bodies among the vast resources of microscopic diversity (Andreote et al., 2014). A fundamental goal is to improve soil quality, plant nutrition, and plant health, also Soil microorganisms' role in agriculture (Lugtenberg, 2016). People generally believe that microbes cause disease. Organic matter will be decomposed in the soil with the help of these microorganisms (Schulz, 2013). Therefore, many bacterial species have been observed to be used in mineralizing biological contaminants in soil, i.e., bioremediation of soil pollutants (Zaidi et al., 2006). As a result, the current review focuses on the role of beneficial microorganisms in agricultural crop production.

Plant mutualistic symbionts that are beneficial include multifunctional arbuscular mycorrhizal (AM) fungi and nitrogen-fixing bacteria. Rhizobia are diverse taxonomic classifications of bacteria that can fix nitrogen to create a mutually helpful with legume plants (De Brugin and Hungaria., 2022). Concerning the classification system of nitrogen-fixing symbioses, it should be noted that nitrogenase genes exist in various microbial taxa (Gyaneshwar et al., 2011). In addition to the nutrient cycle, before and/or after bacteria's life cycle, they can still be beneficial for the soil being eaten by nematodes which indirectly assist in the creation of bioturbation (relatively large compared to other soil pores). The bio-pores form zones of preferential water flow, accelerating water infiltration and reducing water runoff after rainy weather. Increased soil organic matter and sticky gums secreted by bacteria and fungi bind particles into aggregates while improving structural integrity of clay soil and allow greater aeration of the soil. Hence, resistance to water and wind erosion gets stronger keeping nutrients in the soil.

Effect of Biofertilizers on the Growth and Yielding

Another essential quality that biofertilizers (some nitrogen-fixing bacteria in Table 1) produce is 1-aminocyclopropane 1-carboxylate (ACC) deaminase (Omer et al., 2016). When present in excessive amounts, ethylene can hinder plant development or even cause plant death. ACC deaminase-producing organism lowers ethylene levels in plants (Glick et al., 2007). By reducing the amounts of ACC in plants, this enzyme causes the ethylene precursor ACC to be broken down into ammonia and –ketobutyrate (Sagaar et al., 2020; Aasfar et al., 2021).

Table 1. List of N-fixing plant growth-promoting rhizobacteria (PGPR) that positively effect on different crops productivity

Crops	Biofertilizers	Sample references
Wheat	*Azospirillum* sp., *Azotobacter* sp., *Bacillus polymyxa*, Cyanobacteria	(Namvar and Khandan, 2013; El-Gamal et al., 2015;)
Maize	*Azospirillum* sp., *Azotobacter* sp., *Klebsiella pneumoniae* 342, *Pantoea agglomerans* P101 and P102	(Rigss et al. 2001; Ikhwan et al., 2021; Pourjani et al., 2022)
Rice	*Azospirillum* sp., *Azoarcus* sp., *Burkholderia* sp., Cyanobacteria, *Herbaspirillum* sp.	(Mia et al., 2013; dos Santos et al. 2019; Zang et al., 2015)
Sorghum	*Gluconacetobacter diazotrophicus*, *Herbaspirillum* sp.	(Sahai and Tilak, 2015; dos Santos et al. 2017)
Sugarcane	*Gluconacetobacter diazotrophicus, Herbaspirillum* sp.	(Antunes et al., 2019; Carnerio et al. 2021)

Saini et al., (2004) demonstrated that increased yield and biomass of sorghum and chickpea could be obtained with a combination of 50% of recommended chemical fertilizer, inoculated seeds by Rhizobium and P-solubilizing bacteria (PSB), and farm yard manure. Akbari et al., (2011) reported that grain production, plant height, biological output, and harvest index of sunflowers were all increased by a combination of NPK and bio-fertilizers. Additionally, the introduction of bio-fertilizers in environments with stress might lessen its impacts and increase root development (Khan et al., 2017; Santosh et al., 2013).

As mentioned above, bio-fertilizers should not be applied as chemical fertilizers due to the suppression of bacteria. It can be introduced after germinating seeds or at least after a few days of applying chemicals. For instance, 20% NPK + *P. megaterium* + 25% NPK + 25% NPK to reduces 30% of the total fertilizer amount. In Figure 1, the experiment has been conducted on tomatoes to observe the effect of the microorganism with and without chemical fertilizer compounds by six treatments (100% of NPK, *P.megaterium* + 100% NPK, the biofertilizer + 70% NPK, 70% NPK, *P. megaterium* + 40% NPK, and 40% NPK of the recommended amount). The root length under the influence of biofertilizer and less amount of NPK from recommended has significant positive development compared to the application of only chemical fertilizer. It should be noted that the root in the Nuptak + 70% NPK treatment has more significant than the Nuptak + NPK (100%) and 100% chemical NPK. However, the flowers are usually correlated with the yield. In this case, it produces 10.17 in average when they have 10.5 and 10.83 pieces. Although it has slightly fewer flowers than them, it shows that eco-friendly fertilizer containing living bacteria (*P. megaterium*) can reduce the intensive agricultural utilization of NPK by 30% (Figure 1).

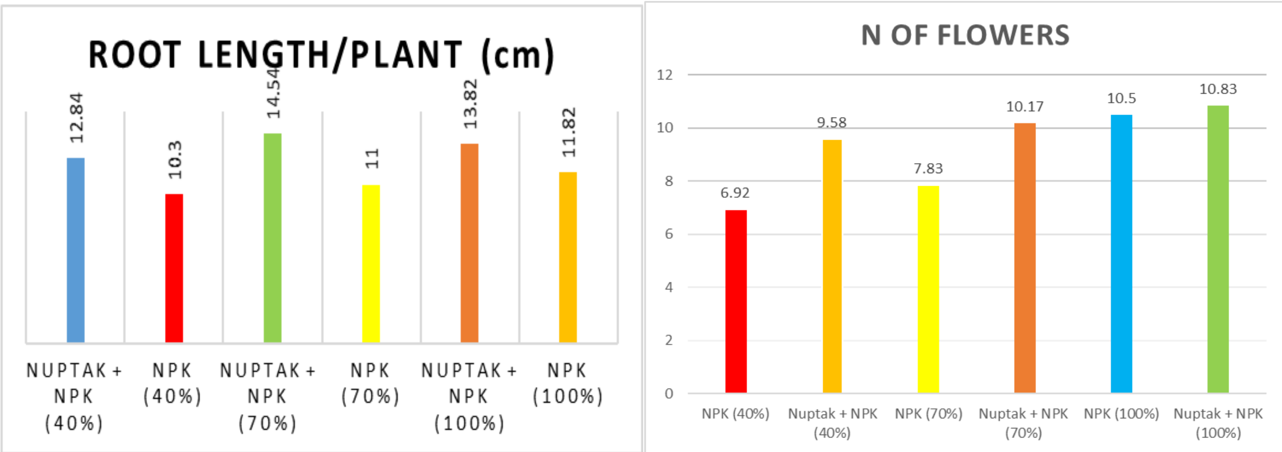

Figure 1. Effect of bio-fertilizer (P. megaterium) on tomatoes' root length and number of flowers under six different treatment

Conclusion

Numerous tests have conclusively shown the value of nitrogen-fixing bacteria as a microbial inoculant. These favourable outcomes through BNF and mineralization of organic residues in the soil can be associated with the enhanced nutritional availability of N, P, C, and S, the development of phytopathogen inhibitors, the stimulation of other rhizospheric bacteria, and the production of physiologically active compounds. They may synthesize plant growth-promoting compounds that assist the availability of extra nutrients' (P, K, and Zn) stimulation for improved plant nutrition while providing non-leguminous plants with a considerable quantity of nitrogen. Applying PGPR had an advantage over chemical fertilizers in terms of how it positively affected the agronomic characteristics of crops. In order to increase crop output, co-inoculation of biofertilizers and NPK can act as a mixed fertilizer or dual-purpose fertilizer. Based on extensive research in various conditions (ex. agroclimatic zones), the possibilities of this combined application to increase crop yield might be further investigated

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Physical and chemical properties of the Black Sea Region hazelnut growing soils

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Abstract

Hazelnut plant is generally grown in sloping areas in the Black Sea Region of Türkiye, 60 km inland from the coast and up to 750 m altitude, where the annual average temperature is 13-16ºC, the precipitation is above 700 mm, and the relative moisture does not fall below 60% in summer. In the areas where hazelnuts are grown in the Black Sea region, the physical and chemical properties of the soil deteriorate as a result of the effect of precipitation and incorrect agricultural practices. In addition, the high slope of the lands of the region causes the soils to be exposed to erosion. In this study, the characteristics of the soils used for hazelnut cultivation were determined. The lowest coefficient of variation was determined in pH (16.10%) and the highest coefficient of variation was determined in lime content (262.65%) among the soil properties of hazelnut growing areas. While saturation and pH value showed a coefficient of variation below 25%, other productivity parameters had a coefficient of variation above 25%, and the properties examined between the sampled areas showed high variability. The saturation (%) values of the soils were compared in terms of provinces, the lowest coefficient of variation was found in Artvin lands (8.59%), and the highest coefficient of variation was found in Ordu (27.34%). The pH values of the soils were compared in terms of provinces, the lowest coefficient of variation was found in Artvin soils (3.70%), and the highest coefficient of variation was found in Sakarya soils (15.51%). The lime values of the soils were compared in terms of provinces, the lowest coefficient of variation was found in Artvin soils (0%), and the highest coefficient of variation was found in Giresun soils (677,14%).

Keywords: Black Sea region, Hazelnut, Hazelnut Growing Soils, pH, Soil Properties.

Introduction

Although hazelnut is a humid temperate climate plant, it is sensitive to drought. It is more affected by drought in places where the soil depth is low and in the south directions. It requires high humidity during the growing period. Hazelnuts can be grown in deep, well-drained soils rich in organic matter with a pH between 6.0 and 7.5 in terms of soil demand. In addition, the development of hazelnut plant is limited in compacted and clay soils and dry and lime soils (Köksal,2018).

When the climate and soil requirements of the hazelnut plant, which is strategically important, are evaluated, the most suitable place for cultivation and production is the Black Sea Region. However, as a result of climate change and unconscious practices, the local soil characteristics remain insufficient in yield and quality specific to the product. In this regard, plant nutrition is important in order to increase the yield in the existing garden. In order to determine the nutritional status of the hazelnut plant, the sufficiency level of the nutrient elements in the soil, the soil conditions affecting the uptake of the nutrient element by the plants and the antagonistic interactions in the transport mechanism should be well determined. The reason for product and quality losses in case of unbalanced and inadequate nutrition; It is the fact that the nutrient in the soil is sufficient but its usefulness is low depending on the soil properties or that some environmental factors limit the usefulness of the nutrient (Güneş et al. 2000).

In this study, it was aimed to determine the physical and chemical properties of the soils in some provinces where hazelnut cultivation is carried out in the Black Sea Region.

Material and Methods

In a total of 3182 surface soil samples (0-20 cm), soil texture (% saturation), soil reaction (pH), electrical conductivity (EC, dS/m), lime (%),organic matter(%), available phosphorus (P_2O_5) and available potassium (K_2O) was determined.

The soil samples used in the study are the soil samples analyzed in the Hazelnut Research Institute Soil Analysis Laboratory of the provinces of Giresun, Ordu, Trabzon, Düzce, Sakarya, Tokat, Bartın, Zonguldak, and Artvin in 2018 and later.

The soil texture, saturation of soil with water (Bower, 1965),

The soil reaction, measured from saturation paste (Richards, 1954),

The electrical conductivity, measured from saturation paste (Richards, 1954),

The organic matter, Determining the organic carbon in the soil according to the Walkey-Black method with wet oxidation and calculating the amount of organic matter from there (Walkley,1946),

The lime content; The soil sample was treated with dilute hydrochloric acid and measured with a Scheibler Calcimeter (Çağlar, 1949),

The available phosphorus, By revealing the phosphorus with sodium bicarbonate solution and reducing it in the blue color environment, the intensity of the blue color is read in the spectrophotometer with the standards prepared under the same conditions and containing the amount of phosphorus (Olsen, 1954),

The available potassium, in the samples was determined by 1 N NH4OAc extraction (Kacar, 1984).

Descriptive statistical analyzes of the results were made and graphics were prepared.

Results and Discussion

Some Physical and Chemical Properties of Hazelnut Cultivated Soils;

Descriptive statistics of the physical and chemical analysis results of soil samples from Artvin, Bartın, Düzce, Giresun, Ordu, Sakarya, Tokat, Trabzon, Zonguldak provinces are given in Table 1.

Table 1. Descriptive statistics of some physical and chemical properties of soils

Soil Properties	Minimum	Maximum	Mean	Std. Deviation	Coefficient Of Variation (%)	Skewness	Kurtosis
SAT, %	23,00	126,00	55,72	11,81	21,19	0,67	1,93
EC, dS/m	0,098	3,849	0,330	0,35	106,06	2,70	11,05
pH	3,56	8,17	5,34	0,86	16,10	0,66	-0,03
CaCO3, %	0,00	33,00	0,83	2,18	262,65	7,77	83,83
OM, %	0,01	13,83	2,59	1,65	63,70	1,32	3,82
P_2O_5, kg/da	0,01	139,52	8,12	11,84	145,81	4,21	23,38
K_2O, kg/da	0,00	179,86	26,52	22,10	83,33	2,44	8,59

The lowest coefficient of variation was determined in pH (16.10%) and the highest coefficient of variation was determined in lime content (262.65%) among the investigated soil properties of hazelnut growing areas (Table 1). While saturation and pH value showed a coefficient of variation below 25%, other productivity parameters had a coefficient of variation above 25%, and the properties examined between the sampled areas showed high variability.

Soil texture (% saturation); When the saturation (%) values of hazelnut growing areas on the basis of provinces are examined; Artvin province lands 59%-72%, Bartın province 57%-94%, Düzce province 41%-72%, Giresun province 23%-118%, Ordu province 33%-126%, Sakarya province 38%-81%, Tokat province 33%-52%, Trabzon province 23%-85% and Zonguldak province 52%-99% (Table 2). When the saturation (%) values of the soils were compared in terms of provinces, the lowest coefficient of variation was found in Artvin lands (8.59%), and the highest coefficient of variation was found in Ordu (27.34%). 56.3% of the soils of hazelnut growing areas are in clay-loam (CL), 34% are loamy (L) and 8.4% are in clayey (C) body class.

Table 2. Descriptor of the saturation (%) values of the soils according to the provincial distribution statistics

Provinces	Minimum	Maximum	Mean	Std. Deviation	Coefficient Of Variation (%)	Skewness	Kurtosis
Artvin	59,00	72,00	66,75	5,74	8,59	-1,01	0,28
Bartın	57,00	94,00	74,50	10,21	13,70	0,22	0,72
Düzce	41,00	72,00	56,21	8,31	14,78	0,00	-1,14
Giresun	23,00	118,00	57,61	9,89	17,17	0,32	1,77
Ordu	33,00	126,00	62,11	16,98	27,34	0,94	0,61
Sakarya	38,00	81,00	52,17	9,51	18,23	1,53	4,23
Tokat	33,00	52,00	45,09	5,96	13,22	-0,75	-0,01
Trabzon	23,00	85,00	45,32	8,25	18,20	0,52	1,24
Zonguldak	52,00	99,00	68,55	12,64	18,44	0,99	0,26
General	23,00	126,00	55,72	11,81	21,19	0,67	1,93

Electrical conductivity (EC, dS/m); When the electrical conductivity values of the hazelnut growing areas are examined on a provincial basis; The territory of Artvin province is 0.099-0.101 dS/m, the territory of Bartın province is 0.323-0.8 dS/m, the territory of Düzce province is 0.099-1.068 dS/m, the territory of Giresun province is 0.098-2.401 dS/m, the territory of Ordu province is 0.099-3.849 dS/m m, Sakarya province lands varied between 0.099-1.287 dS/m, Tokat province lands 0.132-0.540 dS/m, Trabzon province lands 0.098-1.983 dS/m, and Zonguldak province lands ranged between 0.099-0.632 dS/m (Table 8.3). When the electrical conductivity values of the soils were compared in terms of provinces, the lowest coefficient of variation was found in Artvin soils (1%), while the highest coefficient of variation was found in Sakarya soils (109.09%). 94.47% of the soils of the hazelnut growing areas are in the salt-free class, 4.59% lightly salted, 0.91% salty and 0.03% moderately salty.

Table 3. Descriptor of the electrical conductivity (EC) values of the soils according to the provincial distribution statistics

Provinces	Minimum	Maximum	Mean	Std. Deviation	Coefficient Of Variation (%)	Skewness	Kurtosis
Artvin	0,09	0,10	0,10	0,00	1,00	0,000	1,50
Bartın	0,32	0,8	0,53	0,18	34,65	0,41	-1,35
Düzce	0,09	1,06	0,22	0,20	90,50	2,46	6,57
Giresun	0,09	2,40	0,24	0,25	102,46	3,25	14,75
Ordu	0,09	3,84	0,48	0,52	107,88	2,83	10,34
Sakarya	0,09	1,2	0,27	0,30	109,09	2,79	8,24
Tokat	0,13	0,54	0,32	0,14	42,55	0,15	-1,27
Trabzon	0,09	1,98	0,56	0,41	72,06	1,02	0,68
Zonguldak	0,09	0,63	0,38	0,15	38,96	-0,24	-0,38
General	0,09	3,84	0,33	0,35	106,06	2,70	11,05

Soil reaction (pH); When the pH values of the hazelnut growing areas are examined on a provincial basis; The territory of Artvin province 4.42-4.82, the territory of Bartın province 5.57-7.54, the territory of Düzce province 4.64-7.72, the territory of Giresun province 3.56-8.13, the territory of Ordu province 3.89 -8.13, Sakarya province lands 4.65-7.47, Tokat province lands 5.15-7.03, Trabzon province lands 3.94-7.52 and Zonguldak province lands 5.32-7.77 has shown (Table 4).

Table 4. Descriptor of the soil reaction (pH) values of the soils according to the provincial distribution statistics

Provinces	Minimum	Maximum	Mean	Std. Deviation	Coefficient Of Variation(%)	Skewness	Kurtosis
Artvin	4,42	4,82	4,59	0,17	3,70	0,98	0,92
Bartın	5,57	7,54	7,01	0,61	8,70	-1,56	2,63
Düzce	4,64	7,72	6,05	0,75	12,40	0,13	-0,55
Giresun	3,56	8,13	5,13	0,78	15,20	0,95	1,05
Ordu	3,89	8,17	5,68	0,79	13,91	0,66	0,58
Sakarya	4,65	7,47	6,06	0,94	15,51	-0,27	-1,48
Tokat	5,15	7,03	5,94	0,64	10,77	0,35	-1,24
Trabzon	3,94	7,52	5,77	0,83	14,38	1,27	9,87
Zonguldak	5,32	7,77	6,76	0,70	10,35	-0,31	-0,52
General	3,56	8,17	5,34	0,86	16,10	0,66	-0,03

The lime content; When the lime (CaCO3) values of the hazelnut growing areas are examined on a provincial basis; Artvin province 0%, Bartın province 0%-10,17%, Düzce province 0%-3.95%, Giresun province 0%-33%, Ordu province 0.10%-9,57%, Sakarya province lands 0.89%-4.86%, Tokat province 0.56%-2.60%, Trabzon province lands 0.15-6.75% and Zonguldak province 1.33%-4.29% has varied (Table 5).

Table 5**.** Descriptor of the lime content (%) values of the soils according to the provincial distribution statistics

Provinces	Minimum	Maximum	Mean	Std. Deviation	Coefficient Of Variation (%)	Skewness	Kurtosis
Artvin	0,00	0,00	0,00	0,00	0,00	,	,
Bartın	0,00	10,17	2,42	3,04	125,62	2,20	5,10
Düzce	0,00	3,95	0,19	0,69	363,16	4,15	18,54
Giresun	0,00	33,00	0,35	2,37	677,14	9,31	96,79
Ordu	0,10	9,57	1,95	1,37	70,26	2,08	6,59
Sakarya	0,89	4,86	2,89	1,11	38,41	0,05	-0,60
Tokat	0,56	2,60	1,45	0,55	37,93	0,66	1,00
Trabzon	0,15	6,75	1,83	1,09	59,56	1,29	2,27
Zonguldak	1,33	4,29	2,64	0,89	33,71	0,30	-0,95
General	0,00	33,00	0,83	2,18	262,65	7,77	83,83

Organic matter (%); When the organic matter values of the hazelnut growing areas are examined on a provincial basis; Artvin province lands 1.64%-5.38%, Bartın province lands 0.10-3.20%, Düzce province lands 0.79-5.88%, Giresun province lands 0.01%-9.04%, Ordu province lands 0.03-10.51%, Sakarya province lands 0.32-4.66%, Tokat province 1.81%, Trabzon province lands 0.08-13.83% and Zonguldak province 0% It varied between 39-4.97% (Table 6).

Table 6. Descriptor of the organic matter (%); values of the soils according to the provincial distribution statistics

Provinces	Minimum	Maximum	Mean	Std. Deviation	Coefficient Of Variation (%)	Skewness	Kurtosis
Artvin	1,64	5,38	4,13	1,72	41,64	-1,62	2,51
Bartın	0,10	3,20	2,12	1,10	51,88	-1,13	0,20
Düzce	0,79	5,88	2,56	0,95	37,10	0,79	1,75
Giresun	0,01	9,04	2,66	1,49	56,01	0,96	1,37
Ordu	0,03	10,51	2,27	2,94	129,51	1,47	0,93
Sakarya	0,32	4,66	1,56	2,07	132,69	1,92	3,69
Tokat	1,81	1,81	1,81	,	,	,	,
Trabzon	0,08	13,83	1,53	2,82	184,31	3,02	8,99
Zonguldak	0,39	4,97	2,91	1,39	47,77	-0,44	0,02
General	0,01	13,83	2,59	1,65	63,71	1,32	3,82

The available phosphorus;When the available phosphorus values of hazelnut growing areas are examined on a provincial basis; Artvin province lands 2.58-5.50 kg/da, Bartın province lands 2.43-10.16 kg/ha, Düzce province soil 1.83-35.63 kg/ha, Giresun province lands 0.01-139.52 kg/ha, Ordu province lands 0.01-81.12 kg/da, Sakarya province lands 0.25-20.68 kg/ha, Tokat province soil 1.26-24.34 kg/ha, Trabzon province lands 0 .35-84.62 kg/da and Zonguldak province soils varied between 2.21-10.83 kg/da (Table 7).

Table 7. Descriptor of the available phosphorus; values of the soils according to the provincial distribution statistics

Provinces	Minimum	Maximum	Mean	Std. Deviation	Coefficient Of Variation(%)	Skewness	Kurtosis
Artvin	2,58	5,50	3,94	1,52	38,58	0,09	-5,43
Bartın	2,43	10,16	5,67	2,48	43,74	0,91	0,12
Düzce	1,83	35,63	7,00	5,66	80,86	3,22	12,98
Giresun	0,01	139,52	8,33	12,21	146,58	4,42	25,68
Ordu	0,01	81,12	6,60	8,88	134,54	4,23	25,17
Sakarya	0,25	20,68	4,25	4,43	104,23	3,25	12,40
Tokat	1,26	24,34	10,89	7,57	69,51	0,38	-0,83
Trabzon	0,35	84,62	8,54	12,70	148,71	3,09	10,39
Zonguldak	2,21	10,83	5,50	2,22	40,36	0,70	0,09
General	0,01	139,52	8,12	11,84	145,81	4,21	23,38

The available potassium; When the available potassium values of the hazelnut growing areas are examined on a provincial basis; Artvin province lands 9.06-18.48 kg/da, Bartın province lands 13.54-56.04 kg/ha, Düzce province lands 6.63-59.65 kg/da, Giresun province soils 0.35-119 .30 kg/da, Ordu province lands 0.01-162.33 kg/da, Sakarya province lands 10.15-30.13 kg/ha, Tokat province lands 17.17-49.11 kg/ha, Trabzon province soils varied between 0-179.86 kg/da and Zonguldak province soils varied between 16.87-71.40 kg/da (Table 8).

Table 8**.** Descriptor of the available potassium; values of the soils according to the provincial distribution statistics

Provinces	Minimum	Maximum	Mean	Std. Deviation	Coefficient Of Variation(%)	Skewness	Kurtosis
Artvin	9,06	18,48	14,31	3,92	27,39	-0,79	1,55
Bartın	13,54	56,04	34,48	15,28	44,31	0,01	-1,42
Düzce	6,63	59,65	21,93	11,47	52,30	1,15	1,75
Giresun	0,35	119,30	26,67	19,88	74,54	1,86	4,34
Ordu	0,01	162,33	27,60	21,64	78,40	2,87	12,26
Sakarya	10,15	30,13	17,69	5,71	32,28	1,06	0,37
Tokat	17,17	49,11	35,19	9,96	28,30	-0,26	-0,55
Trabzon	0,00	179,86	25,58	29,77	116,38	2,73	8,39
Zonguldak	16,87	71,40	35,59	14,37	40,38	0,73	0,20
General	0,00	179,86	26,52	22,10	83,33	2,44	8,59

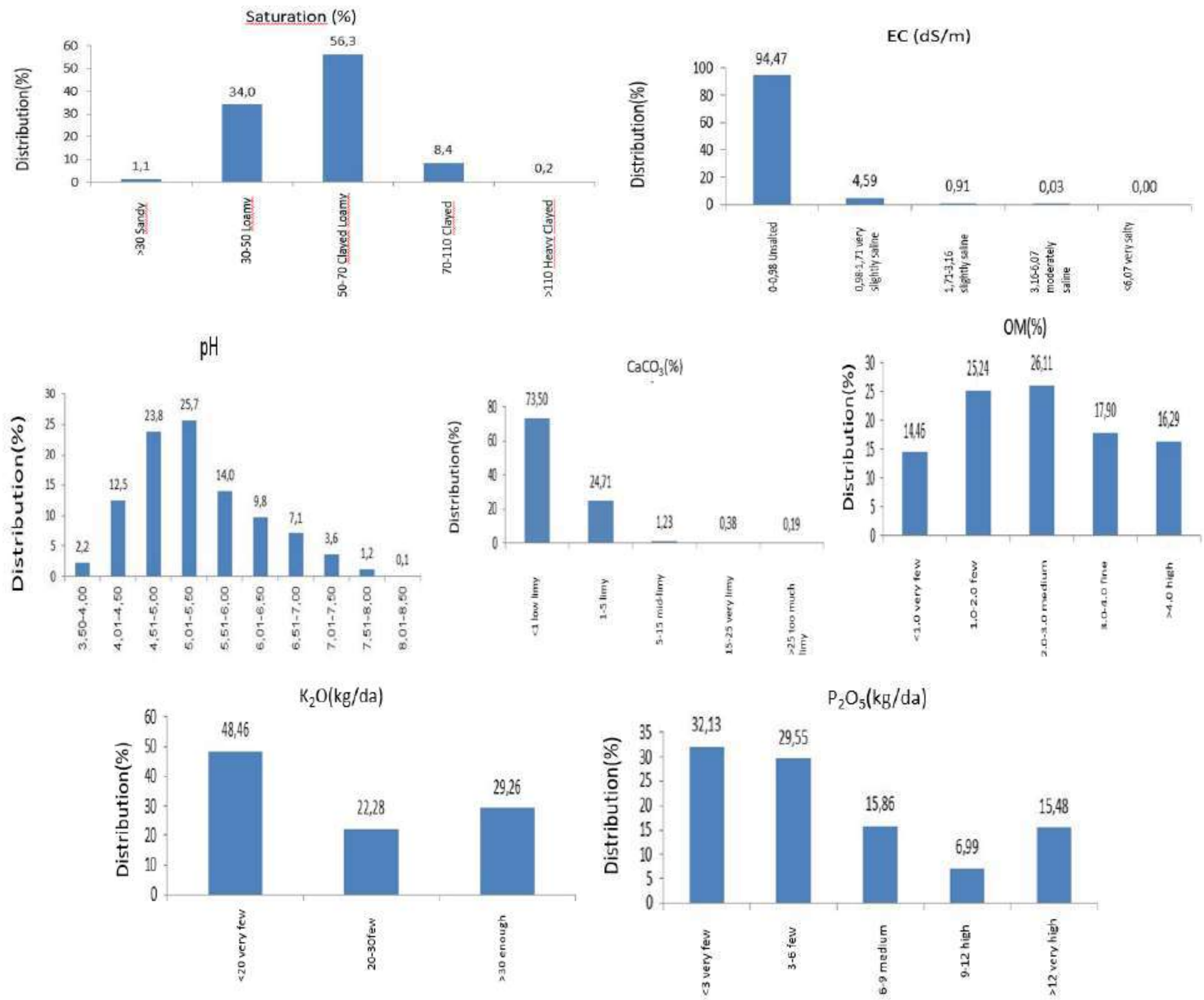

Figure 1: Class distribution of soil properties

Conclusion

When the saturation (%) values of the soils were compared in terms of provinces, the lowest coefficient of variation was found in Artvin lands (8.59%), and the highest coefficient of variation was found in Ordu (27.34%). 56.3% of the soils of hazelnut growing areas are in clay-loam (CL), 34% are loamy (L) and 8.4% are in clayey (C) body class. The fact that the soils have a significant ratio of clay-loam and loamy texture shows that the soil will show sensitivity to erosion and will lead to losses over time.

When the electrical conductivity values of the soils were compared in terms of provinces, the lowest coefficient of variation was found in Artvin soils (1%), while the highest coefficient of variation was found in Sakarya soils (109.09%). 94.47% of the soils of the hazelnut growing areas are in the salt-free class, 4.59% lightly salted, 0.91% salty and 0.03% moderately salty. Soluble salts can be easily taken up by plants. Salt compounds entering the plant body have a toxic effect on the plant by disrupting nutrition and metabolism. In addition, with the increase of salt concentration in the soil, it becomes difficult for the plant to take water from the soil, the structure of the soil deteriorates, and plant growth slows down or even stops. Some plants are more sensitive to salinity, while others are more tolerant. The salt tolerance of the hazelnut plant is sensitive and its EC value is <2.0 dS/m (FAO, 1976; Kotuby et al., 1997; Bayraklı, 1998; Kanber et al., 1992).

When the pH values of the soils were compared in terms of provinces, the lowest coefficient of variation was found in Artvin soils (3.70%), and the highest coefficient of variation was found in Sakarya soils (15.51%). 14.5% of the soils of hazelnut growing areas are strongly acid, 49.5% very acid, 23.8% medium acid, 10.7% neutral and 1.3% slightly alkaline. Aktaş (1995) states that soil pH affects the release of plant nutrients by decomposition events, their solubility and their storage by ion sequestrants.

When the lime values of the soils were compared in terms of provinces, the lowest coefficient of variation was found in Artvin soils (0%), and the highest coefficient of variation was found in Giresun soils (677,14%). Soils of hazelnut growing areas are classified as 73.50% low calcareous, 24.71% calcareous, 1.23% moderately calcareous, 0.38% more calcareous and 0.19% very calcareous. takes. The reason for the lack of lime content in the local soil is due to the effect of precipitation and the practices of the producers.

When the organic matter values of the soils were compared in terms of provinces, the lowest coefficient of variation was found in Tokat soils (0%), and the highest coefficient of variation was found in Trabzon (184.31%). When the soils of hazelnut growing areas are evaluated in terms of organic matter content, 14.46% is very low, 25.24% is low, 26.11% is medium, 17.90% is good and 16.29% is high. is located. The fact that the organic matter content is generally sufficient in the soil is due to the fact that the forest area is open to agriculture and there is no cultivated agriculture.

When the available phosphorus values of the soils were compared in terms of provinces, the lowest coefficient of variation was found in Artvin (38.58%), while the highest coefficient of variation was found in Trabzon (148.71%). When the soils of hazelnut growing areas are evaluated in terms of available phosphorus content, 32.13% is very low, 29.55% is low, 15.86% is medium, 6.99% is high and 15.48% is very high. class (Ülgen & Yurtsever, 1995). The low phosphorus content of soils is due to the fact that the pH is generally below 6.5, and therefore the usefulness of phosphorus decreases by precipitating with cations such as Fe, Al and Mn, which are in excess in the soil (Kacar and Katkat, 1997).

When the available potassium values of the soils were compared in terms of provinces, the lowest coefficient of variation was found in Artvin soils (27.39%), and the highest coefficient of variation was found in Trabzon soils (116.38%). When the soils of hazelnut growing areas are evaluated in terms of available potassium content, 48.46% are in the very low, 22.28% low and 29.26% sufficient class. Kacar and Katkat (1998), potassium in the soil is less usable by plants; They stated that factors such as the type and amount of clay, temperature, freezing and thawing, wetting and drying, soil pH, organic matter and reaction time are effective.

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Hazelnut cultivation in the Black Sea region in Türkiye: Future challenges and sustainable solutions

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Abstract
It is predicted that in many parts of the world agriculture will face various challenges due to the effects of climate change. In addition to that, conventional agricultural practices such as tillage and use of mineral fertilizers and pesticides often have detrimental effects on the environment and result in loss of soil fertility which further exacerbate the loss of agricultural effectiveness. Organic agriculture encompasses a set of practices that help make food production more sustainable and agricultural systems more resilient and resistant. Most of the world's hazelnut production is concentrated in Blacksea Region of Turkey. In this article, we present the current status of hazelnut cultivation in this region and the challenges that are predicted to arise due to the changing climate. We will describe the effects that conventional agricultural practices have on the environment, particularly on soil properties, processes and microbial communities and compare these to the effects of organic production practices. Considering the established approach to hazelnut cultivation in the region and local conditions we will present some appropriate practices that could be adapted in order to make the hazelnut production more sustainable.

Keywords: Blacksea Region, Climate Change, Hazelnut, Organic Agriculture, Soil Quality.

Introduction

Conventional agriculture production systems are normally defined as cropping areas where synthetic agricultural products are used for fertilization and enhanced development of crops, suppression of weeds and protection against pests and diseases. Generally these are combined with continuous monocropping cultivation and frequent use of primary (moldboard tillage) and secondary tillage (disc and/or harrowing) operations, especially as a weed control, improvement of the soil environment for the root growth and seedbed preparation for the annual crops (Sumberg, 2022). A large number of studies have reported that the practices commonly used in conventional agriculture have a detrimental effect on soil ecosystems, on populations of pollinators, birds and soil invertebrate and surface and underground water resources. Among the soil parameters it is the soil organic matter content that is considered of paramount importance to soil health as it influences many of other soil properties (Bashir, 2021). It is an important binding agent of soil particles that enables the creation of soil aggregates. Soil aggregation improves soil physical condition by decreasing bulk density, enabling good drainage capacity and aeration by pore size distribution, improving water infiltration, and hydraulic conductivity (Papadopoulos, 2011). The tillage represents a substantial disturbance for the soil microorganisms and generally negatively impacts soil organic matter (Castellano-Hinjosa, 2020).

Inappropriate and excessive use of fertilizers can be detrimental for the environment since nitrogen is prone to leaching and displacement by surface runoff. This results in groundwater pollution and causes algal blooms which severely damages aquatic ecosystems (Zhibiao, 2021). It has also been reported that the use of certain nitrogen fertilizers causes soil acidification which affects clay minerals, reducing the CEC of the soil and nutrient availability for plants (Goulding, 2016). Many pesticides that are often used in agriculture don't degrade easily and sometimes cause changes in the chemical environment which are detrimental to soil macro and microorganisms affecting their biomass, activity and biodiversity (Johnsen, 2001). The erosion is also accelerated in the soils with poor soil particle aggregation (Pulleman, 2006). It causes the loss of the topsoil rich with organic matter and exposes the subsoil and reduces the soil depth which makes it less fertile for the crops (Abiven, 2009). In face of the increasing food demand of the growing global population the loss of the topsoil layer and the reduction of its fertility poses a threat to global food security. It is therefore important to re-evaluate activities which can cause detrimental effects on soil fertility and replace them with more suitable practices that would help to stop and to reverse the processes of fertility loss.

Agriculture is expected to face a number of challenges in the future due to the effects of climate change and unsustainable agricultural practices. The changes in mean temperatures, climate variability and extreme weather events (droughts, extreme temperatures, tropical storms, heavy rainfall and floods) will impact agriculture directly whereas the changes in the population distributions of pests and diseases will have indirect effects. Climate change will also impact soil processes and consequently its fertility. Soil formation and development will be affected by the changes in temperature and precipitation as well as nutrient availability and acquisition by plants. The changes in the biological activity of the soils will have an effect on the carbon cycle dynamic and the nutrient transformation. The increase of temperature can result in loss of organic matter and soil structure, reduction in the moisture content and increase in respiration and mineralization rate. The increase in the rainfall increases soil moisture, nutrient leaching and loss of nitrogen by volatilization, increases reduction of iron and nitrates, organic matter and enhances surface runoff and soil loss due to erosion. The reduction in the rainfall on the other hand reduces availability of nutrients and organic matter and can result in soil salinization. The increase in CO_2 concentration can increase the amount of carbon available to soil microorganisms, increases soil organic matter, water use efficiency by plants and accelerates nutrient cycling in the soil (Pareek, 2017).

To satisfy the food demands of the growing world population and to make the agricultural production system more resilient and resistant to climate change as well as maintain the healthy and fertile soils the introduction of more sustainable agricultural practices is required. One of the alternatives to the conventional agricultural practices is organic farming which encompasses principles and practices that strive towards sustainability (Willer, 2022). With the expansion of organic farming across the world, numerous studies were made to compare the performance of organic and conventional agriculture in terms of yield and economic impacts. In the following part we will describe the predicted effects that the climate change will have on hazelnut production in the Blacksea region and discuss some of the beneficial effects of organic practices which could be introduced in the hazelnut production in order to make it more sustainable.

Material and Methods

Hazelnut (*Corylus avellana* L.) is a perennial woody crop that requires specific climatic conditions for its yield production. Generally, the altitudes, where frost risk is rare, are suitable for hazelnut growing, and those areas receive sufficient and regular precipitation unless there is an extreme weather event. It thrives the best in humid and temperate climate and requires regular precipitation throughout the year. The most efficient growth is registered at 755 mm of total annual precipitation and the average annual temperature between 13-16 C. It can cope relatively well with the temperatures below 0 C although when experiencing temperatures below -8 C and above 36 C the fruit development is disturbed. Hazelnut flowers from January to April and the fruit is produced from May to July (Nazan, 2020).

The world's main hazelnut producing countries today are Turkey, Italy, USA and Azerbaijan. The biggest actor in the world hazelnut market is Turkey with 66% of the world hazelnut production and 76% of total world export in 2019 (FAO, 2022). In Turkey approximately 60% of hazelnut production is concentrated in the Eastern Blacksea Region, especially in the provinces of Ordu, Giresun and Trabzon. According to the export reports hazelnut constitutes 12% of agricultural exports and 1.5% of general exports of the country (TUİK, 2016). Organic cultivation covered approximately 2,2% of its total agricultural land in 2019 (Cakirli et al, 2021) and organic nuts exports were valued at about 30% of the total organic exports of Turkey in 2021 (TÜİK, 2022).

Most commonly used nitrogen fertilizer in the hazelnut orchards of Turkey's Samsun region was found to be calcium ammonium nitrate (236 kg/Ha) coupled with farm manure (2500 kg/Ha) which are used in the stated quantities every year according to study. Phosphorus fertilizer in the form of triple superphosphate is generally used once every three years at a rate of 47 kg/Ha (Demiryurek, 2008). Hazelnut producers apply pesticides at least once per year in the late May or early June when Hazelnut weevil, a main hazelnut pest, starts to be active. Different species of pests have their periods of activity stretching from April to August and the farmers frequently apply pesticides more than once, especially if the symptoms and rise in insect populations are visible on the plantations. The most commonly used groups of pesticides are carbamates and organophosphates (Tuncer, 2015).

Results and Discussion

In the future Turkey will experience three accelerating trends: rising temperatures, dehydration, and rising sea levels. This will most likely lead to more frequent and more severe weather events and conditions throughout the year (Parmesan, 2022). Turkey can be described as experiencing a fast transition to intensified agriculture and unsustainable agricultural practices. Abandonment of less productive lands and over-exploitation of fertile soils have been cited as important concerns (Hossain, 2020). It is estimated that 79% of the total land area is degraded due to wind erosion (Senol and Bayramin 2013). On the other hand, 50% and 30% of land in Turkey is affected respectively by natural and irrigation-induced soil salinity, whereas 0.4% and 8% are alkaline or saline-alkaline soils, respectively (Senol and Bayramin 2013). Because of the long periods of continuous agricultural production Turkey's soils have very low organic matter contents and more than 70% of the lands have less than 2% organic matter content (Parmesan, 2022)

Considering the region's topography where hazelnut is grown in Turkey, the excessive precipitation can increase the frequencies of landslides and floods. An increase in mean annual temperatures may lead to shift in hazelnut's phonological periods. It can also cause premature start of flowering and fruit development and maturation which can greatly decrease quality and yield. Extreme conditions such as prolonged periods of summer droughts also lead to reduced yield since the hazelnuts don't reach their full size and mature completely. Certain level of humidity in the summer months is necessary for full development of the fruit and in case of premature flowering and early maturation due to higher spring temperatures and insufficient precipitation the yields can be reduced in half. In some of the areas the hazelnut cultivation will become increasingly difficult but on the other hand some areas will become suitable for the cultivation due to increase in temperatures (i.e. higher altitudes) (Nazan, 2020).

Soils under organic management generally have higher organic matter content and soil carbon stocks which can be attributed to a diverse carbon input in the forms of organic fertilizers (compost, manure) and by various practices (crop rotation, mulching, cover crops). This consequently establishes more stable soil structure than conventionally managed soils (McClelland, 2021). The tillage intensity was reported to be a particularly important factor influencing aggregate stability by reduction of total carbon and light organic matter content lowering macroaggregate formation. Organic soils were also reported to have a higher carbon mineralisation and higher humification level (Bonanomi, 2016, Trinchera, 2015). When coupled with an increase in soil nutrient and energy pools (higher total organic carbon and nitrogen), a better efficiency in organic matter turnover it was suggested that organic managed soils could be considered as more conservative systems in terms of nutrient and energy cycling (Trinchera, 2015).

Biological parameters were also shown to differ between the farming practices. In the meta-analysis Lori et al (2017) calculated that under organic management an average microbial was 41% higher, biomass carbon 51% higher and microbial biomass nitrogen 59% higher. Dehydrogenase activity was on average 74% greater under organic management, the metabolic quotient displayed a reduction of 4% in organic compared to conventional farming systems. Protease and urease activity were increased by 84% and 32% under organic management. It is important to add that the increases in microbial biomass were apparent in all climatic zones and the effect sizes did not significantly differ between climatic zones (Lori, 2017). A meta-analysis by Rundlöf (2016) indicates that on average species richness is 30% higher. There are, however, large variations between organism groups, with a richness increased particularly for arthropods (Kamau, 2018), plants and pollinators and possibly predators and birds, but less influence on and insufficient knowledge for other groups (Reeve, 2010). Systems not receiving manure harbored a dispersed and functionally more versatile community that was characterized by groups of presumably oligotrophic organisms adapted to nutrient-limited environments. Systems receiving organic fertilizer were characterized by specific microbial guilds known to be involved in degradation of complex organic compounds such as manure and compost (Hartman, 2014). A community change is also noted in a study by Neha (2022) by a shift in the fungal to bacterial ratio which was remarkably greater in soil subjected to organic treatment. It is strongly recommended that in order to maintain the quality of soil structure and healthy soil microbe community the use of inorganic fertilizer should be abandoned and much more of the farm manure should be used in the future (Nazan et al, 2020).

The use of living mulch and cover crops to suppress the growth of weeds were also found to increase organic matter content of the soil and its light fraction (Ding, 2006) and were also recommended to adopt in the hazelnut management programs (Isik, 2014). Soil organic carbon was found higher also on sloping terrains with cover crops which suggest its beneficial effect on reduction erodibility of soil (Novara, 2019). There has also been observed a positive correlation between the plant biodiversity, availability and diversity of root exudates and soil microbial diversity (Castellano-Hinjosa, 2020). The enhancement of microbiome also increases the abundance of genes involved in degradation of plant material and cycling of nutrients (C, N and P) (Hallama, 2021) which significantly increases the sequestrations of soil organic carbon and reduces nitrogen leaching (Abdalla, 2019). Study by Strickland (2019) reported that cover crops have led to such an effect also in the short term period. They observed a 64% increase of NH_4^+ and 30% decrease in NO_3^- indicating a shift toward less mobile N forms in soil. Additionally there was observed an increase in active microbial biomass and bioavailable carbon which indicates a higher potential for carbon sequestration.

Climate change may induce higher metabolic, survival, developmental, and reproductive rates in plant pests (Raza, 2022) and spread the global distribution of soil borne diseases (Delgado-Baquerizo, 2020). It will have a significant influence on the behavior of insects, as insects are cold-blooded organisms and thus particularly sensitive to temperature changes. Through direct effects on the life cycle of insects, it will impact the distribution and severity of damage to crops. It is also possible that host plant tolerance or resistance to pests decreases because of stressful conditions brought upon by climate change (Raza, 2022).

There are a number of alternatives that can reduce chemical control of pests including: introduction of predatory species and pest resistant hazelnut varieties, use of pheromone traps and use of entomopathogen species of nematodes, fungi or bacteria (Yaman, 2003). Among the beneficial biocontrol microorganisms that are found to be strongly positively correlated with organic practices is *Bionectria* which is known to be insect and mycoparasite and *Beauveria bassiana* a entomopathogenic fungus. On the other hand several members of pathogenic *Fusarium* were found to be negatively correlated with a system where manure was used (Hartman, 2015). Some species of microorganisms consistently show a considerable antagonistic effect against different pathogen species and could be used in the hazelnut plantations as preventive biocontrol measure to reduce the occurrence of the broad spectrum of fungal diseases (i.e. *Trichoderma sp*. and *Bacillus subtilis*) (Woo, 2022; Sagar, 2022) . *Trichoderma sp.* can also be used in combination with fungicides and was reported to be the least affected by boscalid, kresoxim methyl and sulphur containing products (Yıldırım, 2020). One way of effective biocontrol of pathogens that use the pruning cuts as an entry point for the infection of the plant's vascular system is the inoculation of pruning wounds with competitive or antibiotic producing microorganisms. A treatment with *Trichoderma* species was found to greatly suppress the occurrence of disease symptoms and also enabled faster healing of the pruning cut that did the use of fungicides (Polard-Flamand, 2022)

Another effective way of protecting and enhancing the growth of the hazelnut plants is the use of ectomycorrhizal fungi and plant growth-promoting bacteria. Such microorganisms enhance the water acquisition by plant, they help to mobilize and transport nutrients to the roots, they produce plant hormones that induce systemic changes in plants, they protect the plant from pathogens by competition and direct elimination from the rhizosphere by secondary metabolites and they enable faster communication among individual plants. Symbiotic relationship results in improvement of plant metabolism and stress response and tolerance, increase nutrient content (Alvarez, 2009), improve shot, root and vigor of plant and increase photosynthetic rate and yield of plant (Ahluwalia, 2021). Hazelnuts form ectomycorrhizal connections with many species of fungi. Some of the fungi species, however, are of particular interest for the use as a biofertilizer due to their effectiveness and the fact that they can produced in cultures on liquid or solid medium (*Siullius, Laccaria, Amanita, Pisolithus, Rhizopogon* and *Hebeloma*) (Domínguez-Núñez, 2019).

Conclusion

The climate change and predominating agricultural practices have the capacity to affect the soil's chemical, physical and biological properties in ways that lead to reduced fertility. Considering the growing world's population and it's consequent food demands it is a neccessity to protect the agricultural soils from degradation and adapt practices that would make agricultutal systems more resillient and resistant. Organic agriculture presents many alternative solutions to so-called conventional practices. Organic practices help to increase soil fertility by numerous ways as: improving its capacity to retain water, nutrients and its resistance to erosion as well as supporting a complex and diverse web of microbial interactions. In our case study we found that the production of hazelnut is predicted to face some challenges due to climate change and that some of those (i.e. phenological shifts, droughts) will be increasingly difficult to cope with at the present hazelnut growing locations. There are, however, a number of practices that are appropriate for the hazelnut cultivation and can help to mitigate the climate effects as well as maintain the soil fertility in the future. Practices such as application of farm manure, planting of cover crops, application of microorganisms for biocontrol and biofertilization are recommended in order to make hazelnut production more resistant and resillient.

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Composting process of organic materials

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Abstract
Composting is the biological conversion of organic wastes from an amorphous dark brown to a black colloidal humus-like substance under optimum conditions of temperature, humidity and ventilation. Although there are 3 different main composting methods, the windrow method is commonly used in many composting facilities. At the beginning of composting process, the most followed parameters are C/N ratio, moisture content, bulk density, porosity, and oxygen level of the compost pile. Temperature, pH, N and OC content of compost material are main monitored parameters during the composting process. During the composting, the temperature of the pile must rise around 55 °C at the thermophilic stage. To reduce harmful microorganisms in compost material, the compost pile should stay in thermophilic stage at least 3 or 5 days. During the maturation phase of the compost, the pH value is expected to approach neutral and stabilize. And finally, although the final C/N ratio will depend heavily on the initial material used, generally a mature compost should have a C/N ratio of 10 to 15 and mature the pile temperature should be equal to outside temperature. As a conclusion, a well composted material should have a high humification degree and not harm the plants when applied.

Keywords: Organic waste, Compost, Composting process, Soil fertility.

Introduction

Increase of global population together with urbanization and industrialization has lead to fast generation of complex solid wastes (Diener et al., 2011; Mata-Alvarez et al., 2000; Singh et al., 2014). Sewage and bottom sludge, paper, industry and food industry wastes, municipal and large industrial plant wastes are among the organic wastes that occur in large quantities (Hoornweg and Bhada-Tat, 2012; Kaza et al., 2018). In addition to the wastes generated by agricultural practices, wastes such as leaves, branches, bark, fruits of trees and plants grown in both urban and rural areas and wastes, agricultural wastes processed in industrial areas and wastes remaining as a result of animal production are important agricultural wastes (Aykut, 2021). Landfill and incineration have until now been the most widely used means of solid waste disposal throughout the world, the land filling of biodegradable waste is proven to contribute to environmental degradation, mainly through the production of highly polluting leachate and methane gas (Agrawal, 1990; Bontoux and Leone 1997; Christensen, 2011; Memon, 2010; Miller, 2000; Shekdar, 2009).

Regardless of their origin, the use of these wastes in agriculture will have positive economic and environmental effects. One of the best ways to safely reuse these residues in agriculture, and even the most important, is to use them as a source of organic matter in the soil by composting. In addition to being a good source of organic matter, compost has been reported in many studies to contain many nutrients in its structure (Durmuş and Kizilkaya, 2018; Kizilkaya et al., 2012; Kizilkaya and Hepşen, 2014).

Agriculture is an indispensable production sector that is necessary for people to continue their lives. In this sector, it is desired that the benefit to be obtained from the unit area is the highest. It is a fact that the applications made in agricultural production, the chemicals and synthetic substances used threaten the natural balance and human health. This situation has led scientists and agricultural sectors to seek various solutions. Increasing the use of organic fertilizers, involving microorganisms in agriculture, and trying to expand the organic farming system are among these solutions. In this case, the process that needs to be done is to get to know the natural environment and especially our lands, which is the natural environment where agricultural production is intense, and to ensure that its productivity is preserved. For this purpose, compost production from organic materials that can be used instead of chemical fertilizers or that will reduce the use of chemical fertilizers is seen as an important alternative (Yüksel, 2010; Karayılmazlar et al., 2011; Yılmaz 2012; Koç, 2013).

There are different definitions of the composting process. Composting is a natural process that turns organic material into a dark rich substance, this substance called compost is a wonderful conditioner for soil, during composting microorganisms such as bacteria and fungi break down complex organic. Compounds into simpler substances and produce carbon dioxide, water, minerals and stabilized organic matter (compost). According to Hubbe et al. (2010), composting is as the controlled aerobic conversion of mixed organic materials into a form that is suitable for addition to soil. The process produces heat, which can destroy pathogens (disease causing microorganisms)and weed seeds (Tweib et al., 2011). It can be defined as the decomposition of organic wastes with the help of microorganisms by imitating the optimum levels of decomposition and stabilization processes of organic wastes under natural conditions. Although, there are two fundamental types of composting aerobic and anaerobic, the most preferred composting type is aerobic composting in terms of both compost quality and environmental pollution. There are currently three types of composting systems (windrows, aerated static pile, in-vessel) are the most widely used (Deportes et al., 1995; Dinçer et al., 1996; Anonymous, 1998). The most preferred aerobic composting method of facilities is the Windrow method. In this review, initial and monitoring parameters of composting process were examined.

Parameters of composting process

At the beginning of composting process, the most followed parameters are C/N ratio, moisture content, bulk density, porosity, and oxygen level of the compost pile (Choi, 1999; Hubbe et al., 2010; Tweib et al., 2011; Durmuş and Kizilkaya, 2018).

One of the most important parameters to be considered to obtain well decomposed and stabilized compost is the C/N ratio of the compost material. The C/N ratios of plant, animal and urban organic wastes are different from each other. It has been reported in many studies that microorganisms that are active in during the composting process use 1 unit of nitrogen for each 30 units of carbon (Choi, 1999; Tisdale et al., 1993; Hyvönen et al., 1996; Gaur, 1997; Dinçer et al., 2003; Lekasi et al. 2003). The C/N ratio of 25- 35:1 is generally considered optimum (Gaur, 1997). If the ratio is less or more than the specified C/N ratio, the microorganism activity will not be at the desired levels, and there may be losses of nutrients and the stabilization process of the composted organic waste will not be fully completed (Mishra, 1992; Haug, 1993; Barker, 1997). Therefore, before the process starts, the C/N ratio of organic waste must be balanced.

One of the important initial parameters that should be considered during the preparation of compost is the provision of appropriate moisture content. The ideal moisture value range is known as 40-60% (Willson, 1989; Gaur, 1997). Problems may arise if proper humidity is not set throughout the process. For example, if the moisture content is below 40%, the microbial activity in the environment is minimized, and if it falls below 10%, it stops completely. In case of excess, the aeration capacity of the pile will decrease and the microorganism activity will be adversely affected.

Particles size affects oxygen movement into the pile, as well as microbial and enzymatic access to the substrate (Zia et al., 2003). Bulky organic materials should be chopped or shredded to reduce particle size to the range of 1-5 cm. On the other hand if too small, the organic materials should be mixed with a bulking agent like wooden matter (Gaur, 1997). The composting process begins as a result of combining organic materials of suitable quality. The raw material (vegetable, domestic, etc.) is first mixed in a suitable place so that it receives enough oxygen to react. Since the oxygen in the environment will decrease from the beginning of the process, the aerobic decomposition rate decreases. If the oxygen demand of the environment cannot be met, composting stops. For this reason, ventilation (mixing process) must be continuous to meet the oxygen demand of the environment. In large enterprises, the continuity of oxygen is not only provided by the mixing process, but also with the help of fans or blowers that give air to the environment (Öztürk, 2017)

Temperature, pH, N and OC content of compost material are main monitored parameters during the composting process (Roger et al., 1991; Gaur, 1997; Roman et al., 2015; Azim et al., 2018; Durmuş and Kizilkaya, 2018).

During the composting, the temperature of the pile must rise around 55-60 °C at the thermophilic stage. To reduce harmful microorganisms in compost material, the compost pile should stay in thermophilic stage at least 3-5 days. Monitoring of the temperature of the compost pile is required to insure the removal of pathogens microorganism in the, while keeping the microbial community in optimal conditions (Roger et al., 1991; Gaur, 1997; Azim et al., 2018). Although the temperature change and duration vary according to the organic waste used, it is usually as seen in Figure 1 during composting. As a result, end of the composting process temperature of pile should be equal the outside temperature Figure 1.

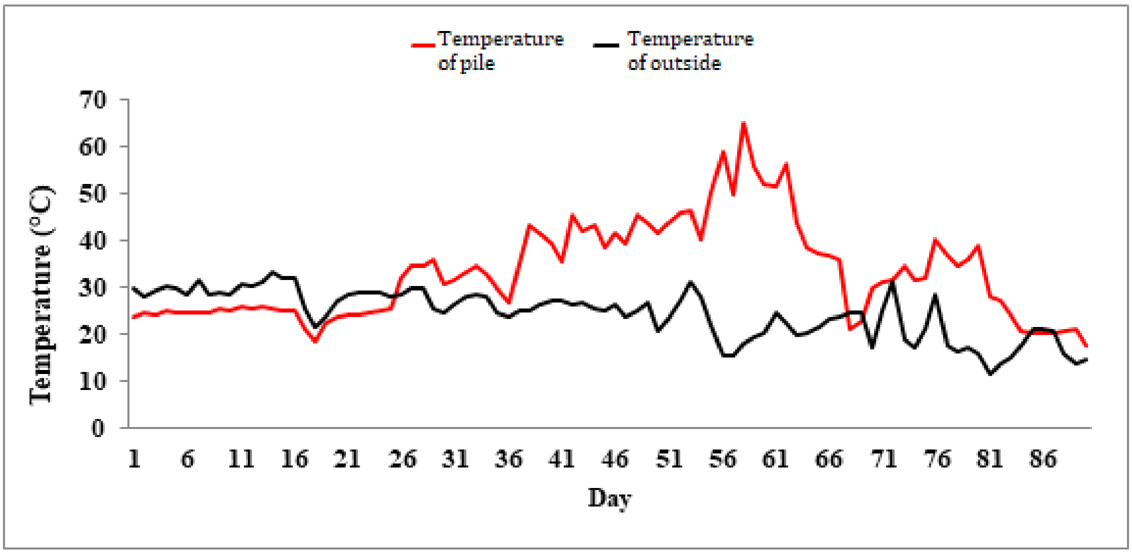

Figure 1. Change of temperature of compost pile (Durmuş, 2019)

There is no spesific pH value of compost material (Gaur, 1997) as different organic wastes usable for composting have a range of pH from 5 to 12 (Willson, 1989). The change in pH values of the compost pile may vary according to the initial pH value of the organic waste used. The pH changes several times during composting. But, basicly, there are four phases; acid-genesis phase, alkalization phase, pH stabilization phase, stable phase (Poincelot 1972). During the maturation phase of the compost, the pH value is expected to approach neutral and stabilize (Figure 2).

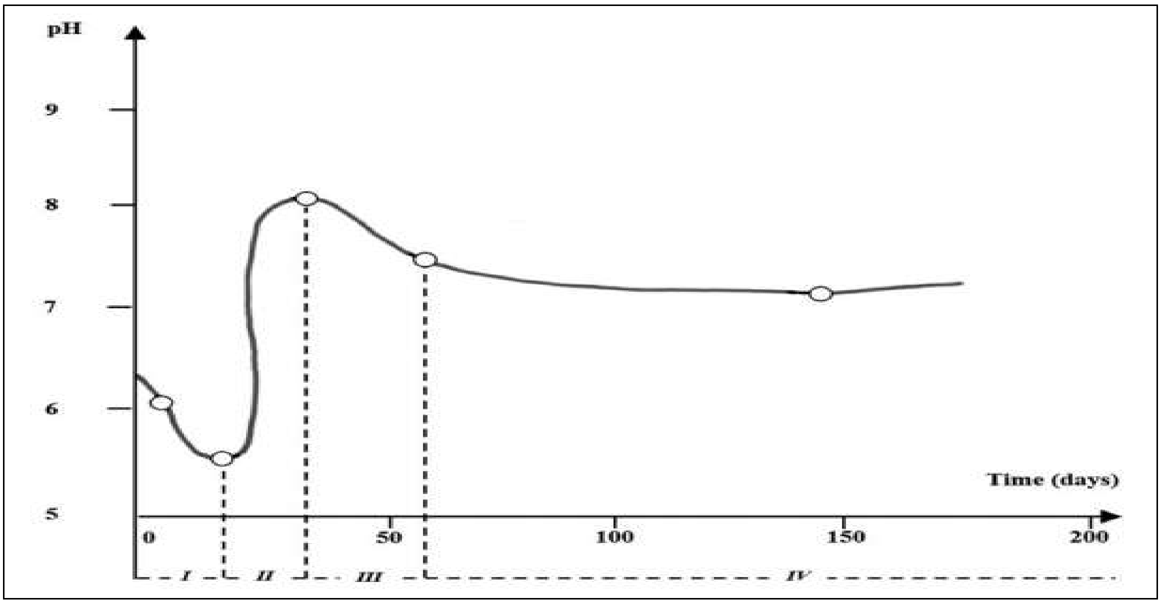

Figure 2. pH evolution curve during composting (Poincelot 1972).

And finally, generally, the C/N ratio of the compost pile should be expected to decrease as seen in the Figure 3. Although the final C/N ratio will depend heavily on the initial material used, generally a mature compost should have a C/N ratio of 10 to 15 (Michel and Reddy 1998; Beck-Friiset al. 2003).

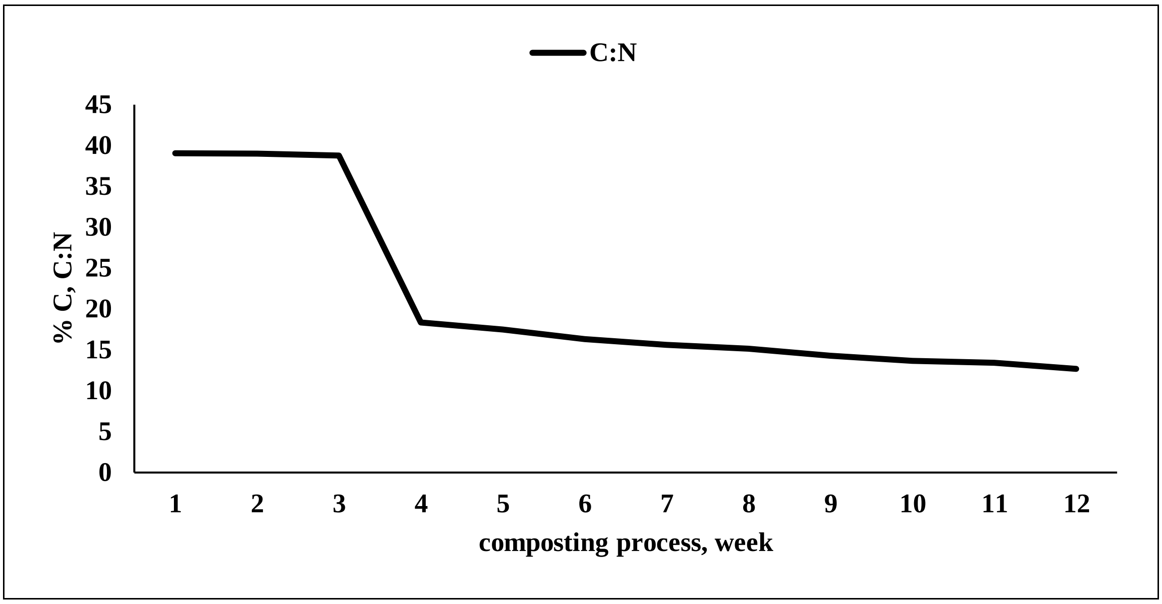

Figure 3. Change of C/N ratio of compost pile

Conclusion

The practice of composting has been known for a long time. A lot of empirical methods have allowed users to determine the start-up and monitoring of composts well before the rise of modern science. The literature review showed that there are many parameters that can be considered for start-up and monitoring of composting process. If it is desired to obtain a well-ripened quality compost, these parameters must be at optimum values. Therefore, scientists have a great responsibility to perform simple field test for monitoring the composting process. When the parameters are followed in accordance with the literature, it is possible to obtain a high-quality compost that is rich in nutrients and does not harm the plant.

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Importance of silicon in agriculture

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Abstract

Sustainable agriculture emerges as a system that protects the environment and natural agricultural resources, has lower production costs and higher net returns. As the basic principles of sustainable agriculture in the world, minimum amount of agricultural chemicals should be used in order to protect the environment and increase productivity. The use of different chemicals to increase crop productivity may have adverse effects on ecosystems. Due to the rapid increase in human population, the demand for nutrition needs continues increase in food production. However, biotic and abiotic stresses caused by pests and climate change significantly reduce crop productivity in agriculture. Silicon can act as an anti-stress agent and play a protective role against abiotic and biotic environmental stresses. Silicon can provide economic and ecological benefits in plant growing. Silicon is also an advantage for sustainable agriculture, as it is the second most abundant element in the world. Extractable forms of Si in soil include amorphous, active and water-soluble silicon element. Plants generally can uptake Si as the forms of orthosilicic (H_4SiO_4) or silicic acid ($Si(OH)_4$) through their roots. The availability of Si by the plant depends on the humidity, temperature, pH and the accompanying ions in the adsorption-desorption process of silicon in the soil. Especially in recent years, soil and foliar Si treatments have been made against Si deficiency in plants. In this review, the importance and applications of silicon for agriculture are emphasized.

Keywords: Silicon, Stress, Nutrition, Plant, Crop production.

Introduction

Decreased soil fertility and abiotic-biotic stress factors on the plant cause crop losses (Ata-Ul-Karim et al., 2020). As a result of these negative effects, silicon applications (Rastogi et al., 2019) have become an important tool for sustainable agriculture (Zargar et al., 2019). Silicon (Si), a mineral substrate for many plants, is a tetravalent metalloid (Imtiaz et al., 2016). Extractable forms of silicon in soil; It exists as amorphous, active and water-soluble. Silicon, which is found in different forms in the soil, is especially abundant in quartz and silicates (Sommer et al., 2006). Silicon often combines with other elements and turns into forms that cannot be taken by plants (Luyckxet al., 2017). Useless silicon forms other than water-soluble silicon are converted into orthosilicic acid (H4SiO4) and monosilicylic acid (Si(OH) form at the end of various processes and transform into usable form (Thakralet al., 2021).The use of silicon by plants; silicon content of soils, moisture status, reaction (It is affected by factors such as pH) and accompanying ions in the adsorption-desorption process of silicon (Puppe, 2020; Schalleret al., 2021). Silicon applications can be made from the soil and leaves in order to minimize the damage in these stress factors. Silicon can increase the yield parameters as well as help the plants to resist against various stress factors.

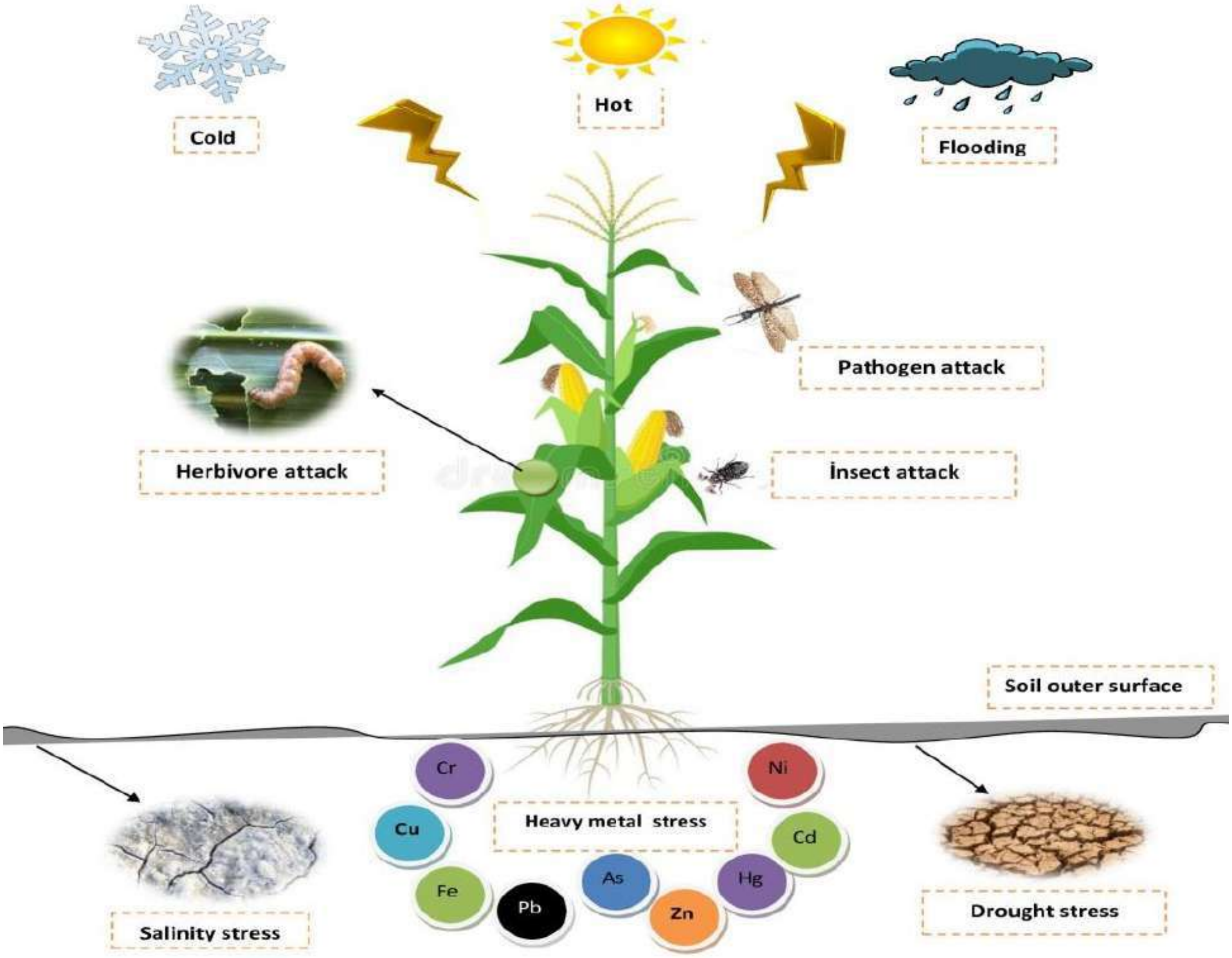

Figure 1. Abiotic and biotic stresses factors

Silicon in soil

Silicon (Si) constitutes 25% of the earth's crust (Adrees et al., 2015; Zaid et al., 2018). It is generally found in rocks and soils as silicates formed by elements such as silicon dioxide (SiO2) or oxygen, aluminum, magnesium, calcium, sodium potassium, iron. Si availability is different in various soil types (Yan et al., 2018). It varies between 200-300 g Si kg-1 in clay soils and 450 g Si kg-1 in sandy soils. Although the total Si content in the soil varies according to the soil types, it is around 30% on average. Most mineral soils; primary silicate minerals (e.g. olivine, augite, hornblende, quartz, feldspar-orthoclase, plagioclase, albite and mica), secondary silicate minerals (clay minerals such as illite, vermiculite, montmorillonite, chlorite and kaolinite) and amorphous (non-crystalline) allophone ,opal It consists of minerals such as Si. The main sources of Si taken up by the plant in the soil are the adsorption or desorption of primary and secondary mineral silicates. (Zaid et al., 2018). In addition to these, silicon deficiency can be seen in soils with acid character, low base saturation and high organic matter (Foy, 1992; Snyderet al., 1986). In this type of soil, silicon becomes useless by forming complexes with Fe, Al, heavy metals and organic matter (Farmeret al., 2005).

Silicon in plant

Silicon concentration in most plants; phosphorus (P), sulfur (S), calcium (Ca) and magnesium (Mg) in similar amounts. Sometimes it can be as high as nitrogen (N) and potassium (K) concentrations (Casey et al., 2003). The fact that silicon has a high concentration for plant growth indicates that it is important for plants. Silicon is found in the range of 0.1-1% by weight in plant tissues (Epstein, 1994). It has been determined that the accumulation of silicon increases resistance to fungal diseases and insect damage, strengthens the plant body, increases photosynthetic activity, improves transpiration (Liang et al., 2007) and increases the number of tillering (Fauteux et al., 2005). In addition, in abiotic stress studies on plants, it has been proven that silicon increases plant resistance/tolerance against manganese, aluminum, cadmium stresses, salt stress and drought. These beneficial effects of silicon on plant growth are due to the accumulation of silicon in the forms of amorphous silica (SiO2.nH2O) and opal phytolite. Plants take silicon in the form of monosilicic acid (Si(OH)4) and H3SiO4 - ions with their roots (Fraysse et al., 2010). Silicon uptake of plants that do not accumulate silicon is slower, while those that accumulate silicon are faster (Ma, 2004). Silicon is taken up by plants in three ways. These are active, passive and reflexive reception. These uptake patterns can vary from plant to plant and depending on the monosilicic acid (Si(OH)4] concentration on the plant root (Kacar and Katkat, 1998). The movement of silicon from low to high concentrations is expressed as active transport of silicic acid. This is characteristic for wheatgrass and especially for plants that accumulate silicon such as rice and sugar cane (Tamai and Ma, 2003). It is accepted that other plants take up silicon by passive adsorption. Silica in the form of monosilicic acid taken by passive adsorption is carried to the leaves and shoots by tranpiratory current, passing through the stem cell membranes.

Silicon fertilization

Silicon fertilizers have been known in the world since the middle of the 18th century. It has increased production in many countries by 20-30% annually since 2000 (Korndorfer, 2005). Extensive use of silicon in the form of fertilizers and soil reclamation is necessary to solve sustainable agriculture and ecological problems. Silicon is an agriculturally important fertilizer that increases the tolerance of the plant against abiotic and biotic stresses. The application of silicon fertilizers has significant economic and ecological benefits; It supports soil health in different aspects by resisting insect attacks and diseases, metal stabilization, alleviating salt stress, and strengthening protective properties against climatic conditions (Debona et al., 2017; Etesami and Jeong, 2018; Imtiaz et al, 2016). In addition, silicon acts as a regulator of physical and chemical properties in the soil, increases the soil's water holding capacity and ion absorption. For this reason, chemical fertilizers containing silicon can be applied successfully on soils with silicon deficiency. Si fertilizers have had numerous laboratory applications and field trials since 1840. As a result of these studies, silicon can be found in rice (Oryzasativa L.), barley (Hordeumvulgare L.), wheat (TriticumvulgareVil), corn (Zeamays L.), sugarcane, cucumber (Cucumussativa L.), tomato (LycopersiconesculentumMill), citrus fruits (Citrustaiten) etc. It has been found to be useful in various products such as These applied fertilizers contain various silicates (Gascho, 2001; Haynes, 2014; Liang et al., 2015). The most common silicates are calcium silicate, fine silica, and sodium silicate. Their usefulness is dependent on their reactivity rather than their total Si content. For example, inorganic materials such as quartz, clays, micas and feldspars, although rich in silicon, are poor sources of silicon-fertilizer due to the low solubility of silicon.

Silicon combined fertilizer applications appear in three ways. These; silicate fertilizer applications, silicic acid-containing fertilizer applications and fertilizer applications containing other Si compounds such as silica nanoparticles (nano-SiO_2). When silicate fertilizer applications are examined.

In a study, the effect of calcium silicate on rice root growth and tolerance to salinity stress was investigated. It has been observed that rice improves root anatomical features by increasing epidermis thickness, cortex thickness, stele diameter and root diameter (Rachmawati et al., 2021). In a study in which potassium silicate was applied to rapeseed plants in arid environments, it was observed that rapeseed genotypes increased agronomic properties, water use efficiency and oil quality (Shirani et al., 2022). With the application of an amorphous silica-based fertilizer (ASF) to two varieties of table grapes grown in a semi-arid climate, fruit production (6-22%), bunch weight (11%), fruit crispness (20%), total soluble solids content (13%). -20), macro-micronutrient accumulation (12-45%) and an increase in photosynthetic efficiency (5-33%) were observed (Do et al., 2022).

Fertilizer applications containing silicic acid clearly showed that the immature population of both whitefly and tomato leaf miner on the tomato crop in the greenhouse was significantly reduced. In addition, it has been stated that silicon is more effective in reducing the population density of pests when applied from the foliage (Alyousuf et al., 2022). In another study, silicylic acid was applied to wheat plants under drought stress. It increased growth characteristics, antioxidant defense mechanisms, and tolerance to osmolyte accumulation. (Parveen et al., 2021). In the study conducted by Rajabi et al., (2022), it was observed that the application of silicic acid to the leaves of the sorghum plant under the influence of salinity increased photon retention, reduced salinity stress and improved the plant.

When fertilizer applications containing other Si compounds such as silica nanoparticles (nano-SiO_2) are examined; It has been reported that the use of nano-silica provides significant increases in the yield of wheat plants under salinity stress conditions and that N, P, K, Si contents increase the uptake of nutrients (Ayman et al., 2020). Al-Zandi (2019), found increases in germination percentage and growth parameters with silica nanoparticle application to white corn (Sorghumbicolor L) under drought and water stress. Finally, it was stated that the application of nano-silica to wheat (Triticum aestivumL.) significantly increased the dry biomass of shoots, roots and grains in the plant (Ali et al., 2019).

Conclusion

Climate change and land degradation threaten food security. Sustainability of agricultural production; it can be inhibited by various abiotic stresses such as salinity, metal toxicity, nutrient imbalance, high temperature and radiation. It is also inhibited by biotic stresses such as fungi, bacterial diseases and other pests. Silicon plays an important role in combating such stress factors. In the review, it is clearly seen that when silicon is given to plants as silicic acid, it is an effective application in reducing the effects of both abiotic and biotic stress factors. It is predicted that in the future, silicon will be effective in sustainable agriculture and will be used as a common fertilizer. Therefore, studies on nano-silicon applications should be increased.

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Relationship between land surface temperature and moisture of soils in Shamakhi District

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Abstract

Land Surface Temperature (LST) and Normalized Difference Soil Moisture (NDMI) is one of the significant indicators to understand the changes on the surface of estimated environmental impacts. These indicators help us to evaluate land use/land cover changes and climate processes. Monitoring of the relationship between LST and NDMI values of soils is necessary to make an appropriate decision about the environmental status of regions. This paper, generally shows a correlation between LST and NDMI and vegetation for Shamakhi District. To find out the moisture of soils and vegetation we used NDMI. That uses NIR and SWIR bands to display moisture. To do this task we take Landsat Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) data with help of remote sensing, and geographic information system (GIS) techniques. The research is based on the data from September of 2022 year. The results show the relationships between land surface temperature and moisture in the study area. The spatial distribution of LST ranged from 13°C to 38°C. The relationship between Land Surface Temperature and NDMI is an inversely proportional relation (R^2 = 0.57) and on the grounds 500 random points were selected. In the plain areas of Shamakhi LST indicators are high respectively 27° and 39° but NDMI indicators are low. Whereas temperature indicators are low, NDMI indicators are high here. These indicators are suitable for forest and agricultural areas. As a result, that correlation between determing data will allow to determine both the drought monitoring and the suitability of the area during planting.

Keywords: Land surface temperature, Normalized difference moisture index, Ecology, remote sensing.

Introduction

LST and NDMI are essential parameters in many areas of research, such as global enviromental changes, and agricultural and hydrological processes. LST can provide important information about the physical-biological processes of the surface properties (Orhan et al.,2014). Calculating soil moisture and land surface temperature from remotely sensed images is the needed factor for monitoring climate which plays a role in many environmental processes (Rajeshwari et al.,2014). Analyzing these indicators can provide us to know about growing vegetation. For monitoring land surface temperature, moisture of soil, and vegetation we used LST and NDMI which can be estimated from Landsat Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) (Landsat 8 Science Data Users Handbook., 2015)]. NDMI is used to determine vegetation water content and to monitor droughts. It is computed as a ratio between the NIR and SWIR values (Taloor et al., 2020).

Material and Methods

Study Area and Data Used

The study area Shamakhi District is located in the southern foothills of the Main Caucasus Range and belongs to the Mountainous Shirvan Economic Region as shown in Figure 1. It lies between 48°40' east longitude and 40°38' north latitude.

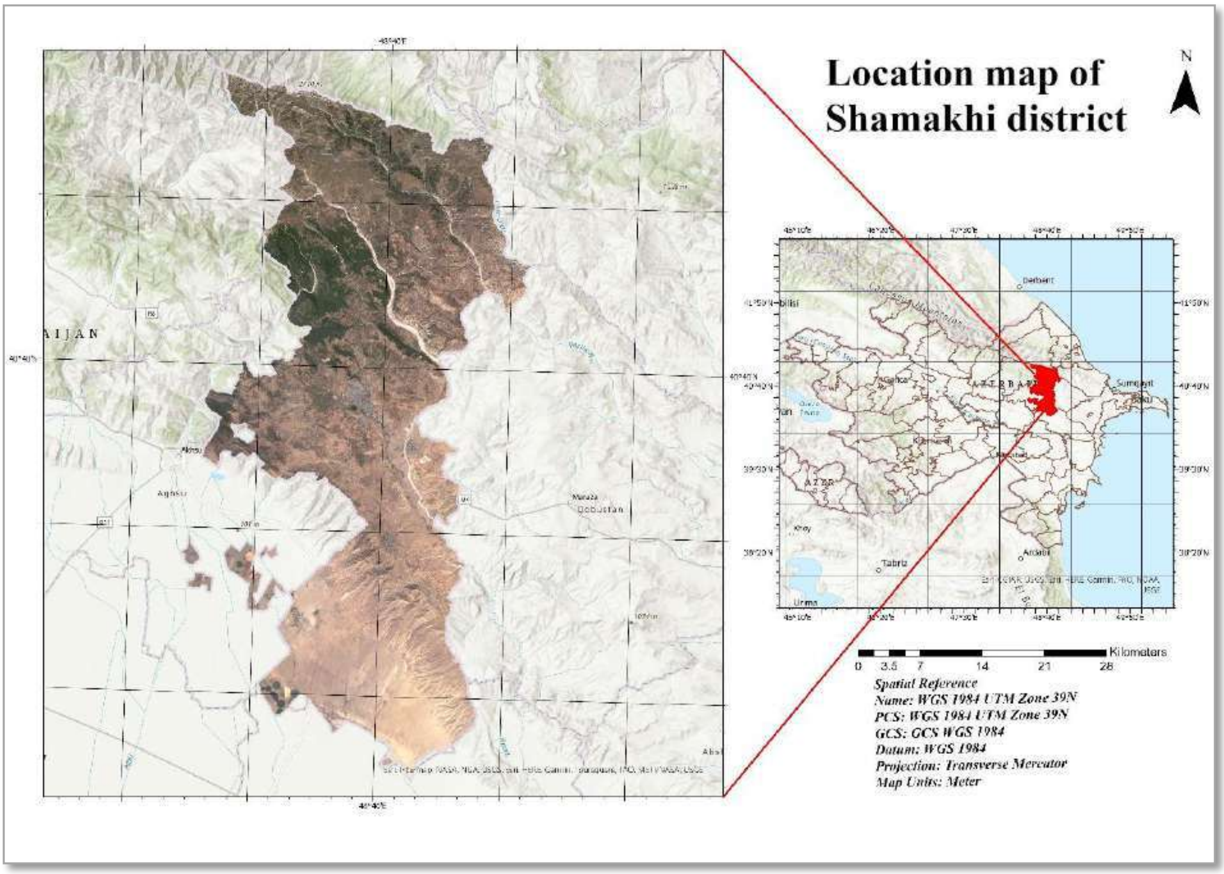

Figure 1. Location map of study area

The main source of data in this research are satellite images from Landsat 8 OLI (Operational Land Imager), and TIRs (Thermal Infrared Sensor) which are downloaded free from the United States Geological Survey (USGS) site. Satellite data over the Shamakhi district of September 2022 were used for use current purpose. The methodology applied in this research is illustrated in Figure 2.

Methods

Firstly, we used the raw data of remote sensing for preparing calculation processes of LST and NDMI. Second, the spectral indices are applied to carry out equations of LST. There are a different way of calculating and estimating land surface temperature (LST), to do that like Split-Window (SW), Dual-Angle (DA), and Single-Channel (SC). In this research we will use the Split-Window, the thermal bands and NDVI are acquired for the study area (Yasir et al.,2020).

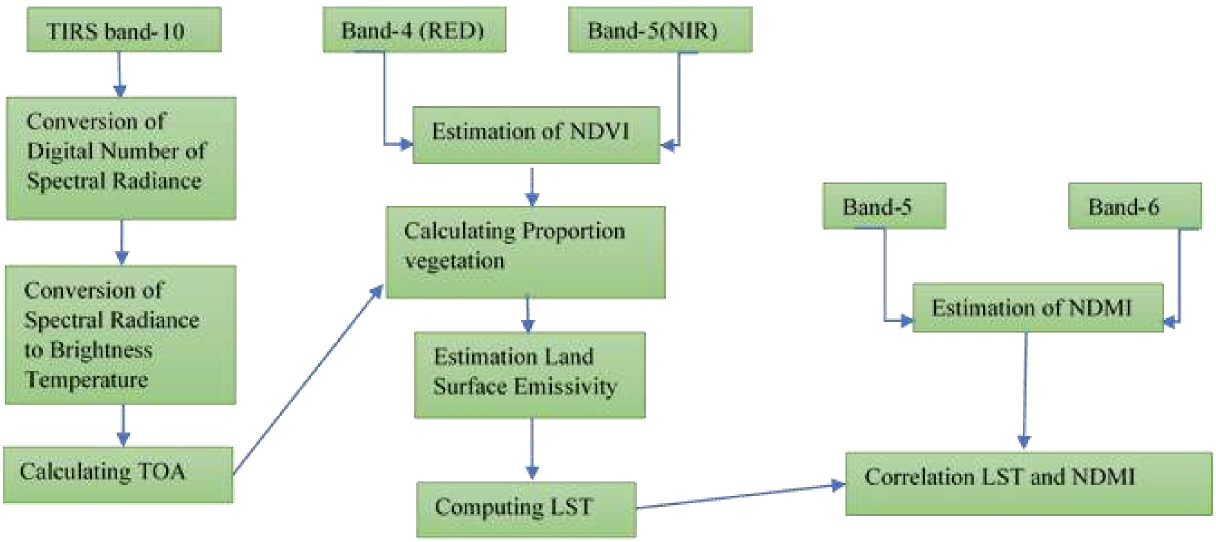

Figure 2. Methodology flow chart of the study

For estimation of LST we used the following Equation 1

*LST=BT/1+(W*BT/P*ln(e))* where: (1)

LST: land surface temperature; BT:brightness temperature; Wavelength; p:1438; e/LSE:land surface emissivity.

Brightness temperature is the temperature is used to produce the radiance perceived by the sensor, it is the temperature that was received by satellite at the time that the image was taken (Tan et al.,2020). It is not the real temperature on the ground (Ibrahim et al.,2018). For this reason TIRS band data can transformed from spectral radiance to brightness temperature. To do this task using thermal constants from the metadata file, we can convert spectral radiance to brightness temperature (Equation 2,3).

$T=k_2/\ln(k_1/L\lambda+1)-272.15$ where: K_1 and K_2: Thermal constant and $L\lambda$: Top of Atmospheric spectral radiance (TOA) (2)

$L\lambda=ML*Q\mathit{cal}+AL$ where: ML: Band specific multiplicative rescaling factor and AL: Band specific additive rescaling factor, Qcal: band 10/11 image. (3)

Next step have estimated land surface emissivity [Sobrino et al.,2008]. For this processing we used Normalized Difference Vegetation Index (NDVI) method, taking into account the proportion of vegetation (Pv), then LST in Celsius is determined. The formula of proportion vegetation (Pv) and land surface emissivity (e) shown below (Equation 4 and ,5).

$Pv= (NDVI-NDVI_{min}/NDVI_{max}- NDVI_{min})^2$ (4)

$e=0.004*PV+0.9$ (5)

After doing all the mentioned processes, LST was calculated using the Equation 1.

Later, for detects moisture levels in soils and vegetation we take Normalized Difference Moisture Index. The NDMI can be used to monitor water content in crops, moisture of soils, determine farm zones with water stress and etc. As we know drought conditions can obliterate the entire yield. NDMI can detect water stress at an early stage, before the problem has gone out of hand. Using NDMI we can magnify crop growth. All of this makes NDMI an excellent farm tool. For computing NDMI indeed NIR and SWIR band combinations [Baret et al,.2002]. Estimation NDMI shown in Equation 6

NDMI =(Band 5 – Band 6) / (Band 5 + Band 6) (6)

Results and Discussion

In this case for our study area, the land surface temperature was estimated by the single-channel from TIRS (Thermal Infrared Sensor) data of the Landsat 8 OLI and NDMI calculating NIR and SWIR reflectance. The spatial distribution of surface temperature (LST) and NDMI shown in Figure 3.

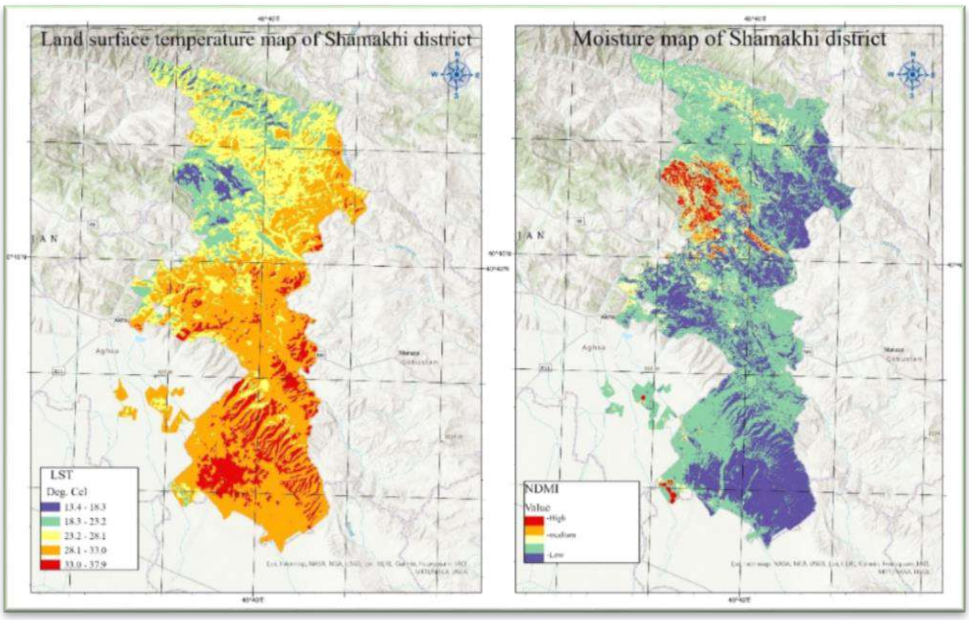

Figure 3. Land surface temperature (LST) and NDMI map of the study area

In the Figure 3. LST ranged from 13˚C to 38˚C, high surface temperatures (23˚C -38˚C) are shown by the dark red areas which mean the far south and southeast part of the study. Also in this part of the study area we can see that low NDMI values which described by the dark blue. In the northeast part of the region, LST values are low like, 13˚C-23˚C, shown by the green and blue. And these areas NDMI values are high or medium which shown red in the map. The effect of the NDMI was significant and negatively correlated with the LST. With an increase in the NDMI, the LST decreased significantly. These indicators are suitable for forest and agricultural areas. The result was analyzed using 500 control points with helping GIS, and the correlation coefficient between Land surface temperature values and NDMI was $R^2 = 0.58$ over the study area. In terms of the correlation of LST and NDMI shown in Figure 4.

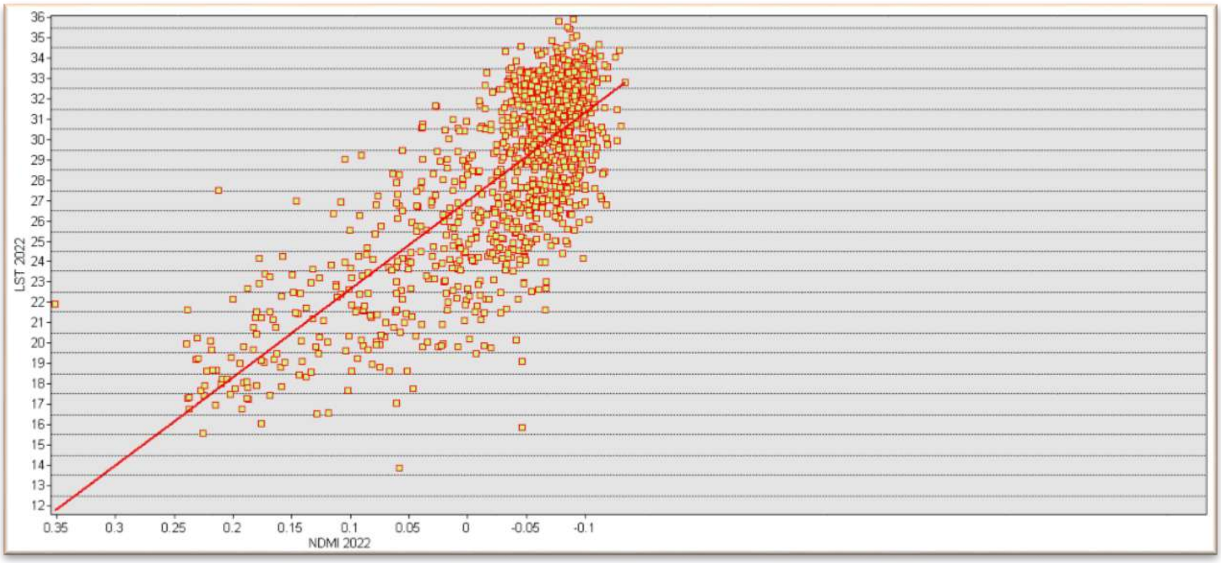

Figure 4 .Correlation between Land surface temperature (LST) and NDMI

Conclusion

This study extracted LST from Landsat 8 OLI data using a single-window algorithm. The spatial distribution, characteristics and quantitative relationships of LST and the NDMI, are determined. The main conclusions were as follows to estimate LST and NDMI we can control the decreased probability of vegetation growing and increase plant productivity (Hulley et al,.2019). Using remote sensing methods, we can provide a range of surface temperatures across a region also demonstrate its spatial pattern.

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Water stress efficacy on soil borne diseases

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Abstract

The global drought, which has been tracked for almost two decades, has shown continuous fluctuation in soil moisture and a severe drought affecting 70% of the land globally. To date, it has been observed that drought has adverse effects on agricultural and economical structures in many countries such as; the USA, France, Russia, Türkiye, Afghanistan, Iran, Mongolia, China, Brazil, Thailand, and also in many continents; Australia and Africa. Türkiye is among the countries that will experience drought problems in the most of its agricultural lands and there are significant differences between regions in this issue. Also, significantly reducing soil water availability in drought condition could suppress soil microbial biomass and activities. Moreover, the structures of microbial communities can change under drought conditions. Drought-tolerant groups with higher water acquisition capacities and lower nutrient requirements, such as fungi and Gram+ bacteria, can continue their activities. It is known that *Fusarium culmorum* and *F. pseudograminearum*, which cause significant crown rot in cereal plants, and *Bipolaris sorokiniana,* which is the root rot agent, develop better in drought-stressed areas and cause severe diseases in plants in Türkiye. Many studies showed that there is a strong negative correlation between plant water relations and root rot severity in many cultivated plants. On the other hand, soil is a very complex environment. Therefore, it is not easy to discover and predict microbial community structure and activity in soil. The type of soil, especially its organic matter content and vegetation type, is a very important factor in determining the changes that occur in the structure and activity of soil microorganisms, and subsequently in enzyme activities, carbon and nitrogen cycles. Comprehensive analyzes of microbial genome sequences, particularly those that are drought resistant, for genes encoding drought stress-related compounds appear to be a promising tool of how microorganisms cope with such harsh conditions.

Keywords: Bacteria, Drought, Pathogens, Root rot fungi, Soil microorganisms.

Introduction

Under climate change, drought is one of the most important abiotic stresses threatening agricultural production worldwide (Lesk et al., 2016). Drought alone causes higher annual crop yield losses than all plant pathogens combined (Naylor and Coleman-Derr., 2018). Drought affects plant-water potential and turgor by interfering with plant functions and altering plant physiological and morphological characteristics (Rahdari and Hoseini, 2012).

Drought inhibits photosynthetic activity in plants by causing a decrease in CO_2 assimilation rate, disruption of primary photosynthetic reaction and degradation of pigments (Kerry et al., 2018). Other enzymes involved in nutrient uptake, translocation, and nutrient metabolism are also affected by drought. One of these enzymes is the enzyme nitrate reductase, which causes a decrease in nitrate taken from the soil (Kapoor et al., 2020). The transpiration rate due to lack of water also reduces plant nutrient uptake and nutrient utilization efficiency. Thus, nutrient diffusion and mass flow of water-soluble nutrients such as nitrate, sulfate, Ca, Mg and Si are reduced (Selvakumar et al., 2012). In addition, drought causes oxidative stress by inducing free radicals that affect antioxidant defenses and reactive oxygen species (ROS) such as superoxide radicals, hydrogen peroxide, and hydroxyl radicals.

Irrigation techniques have been used to develop drought-resistant varieties through traditional plant breeding techniques and genetic engineering (Eisenstein, 2013). Alternatively, plant-associated microorganisms and viruses provide a sustainable benefit for crop productivity and stress resistance under climate change conditions (Xu et al., 2008; Martins et al., 2014, 2018; Nadeem et al., 2014).

A recent research has revealed the potential of native plant-associated bacteria to be inoculated into plants under drought conditions to promote plant growth (Bonatelli et al., 2021). Tolerance genes, pigment production for drying protection, production of thermostable enzymes against UV radiation, the production of intracellular osmolytes can be stimulated to allow local bacteria to tolerate high temperatures (Kavamura et al., 2013). Exploring microbiome functions to understand how ecological processes provide a promising strategy for describing events that occur during systems of prolonged drought. Identifying microbiome functions is an important step that enables plants to regulate drought stress in order to develop ecological systems in a future world climate that will be sustainable. The most studied plant-associated organisms are plant growth promoting rhizobacteria (PGPR) (Ngumbi and Kloepper, 2016; Martins et al., 2018b; Ullah et al., 2019).

Drought and Soil Borne Plant Pathogenic Fungi

Changes in climate and temperature can rapidly change pathogen populations. maize, *Fusarium verticillioides* and *Aspergillus flavus* outweigh *Fusarium graminearum* in drought and warmer growing conditions. Therefore, while there is a decrease in the spike blight disease, the fungal biomass and DON accumulation at high temperatures also decrease. But increased temperatures can also cause mycotoxigenic infections by fungi such as *Aspergillus flavus*, which produce much more dangerous carcinogenic aflatoxins (Dövényi-Nagy et al, 2020; Damianidis et al, 2018).

Fusarium crown rot (FCR), caused by various *Fusarium* species, is an important disease of cereals in many semi-arid regions around the world. To clarify what effects drought stress might have on FCR development, quantitative PCR was used to analyze the infection process of *F. pseudograminearum* in barley. Drought stress has been reported to prolong the initial infection stage but increase the proliferation and spread of Fusarium pathogens after the initial infection stage. Under drought stress, invading hyphae have often been observed to re-emerge from the stoma and re-invade the surrounding epidermis cells. It was observed that drought stress significantly increased trichome length and density, especially in susceptible genotypes, and trichome length and density were positively related to the fungal biomass *of F. pseudograminearum* in plants. This showed that drought increased the severity of FCR disease (Liu and Liu, 2016).

In a study with chickpea plants, different irrigation regimes were applied to supply mild to severe drought stress, and the percent natural occurrence of the pathogen was considered as pathogen stress. Compared to well-watered field conditions, increased rates of fungal diseases such as dry root rot (DRR) caused by *Rhizoctonia bataticola* and black root rot (BRR) caused by *Fusarium solani* have been observed under severe drought stress. Similar to field experiments, pot experiments also showed severe disease symptoms of DRR and BRR only in the presence of drought compared to pathogen stress.

Drought Stress, Trichoderma, Endophytes and Mycorrhizae

Fungal root endophytes, such as some strains in the genus *Trichoderma*, have parallel reciprocal roles compared to mycorrhizal fungi (AMF), enhances plant growth and resistance to abiotic and biotic stresses (Harman and Uphoff, 2019). One main difference is that, compared to AMF, Trichoderma is relatively easy to develop and has long been applied in agriculture (Field et al., 2021; Khan et al., 2021). Beneficial fungal isolates of *Trichoderma*, the free-living avirulent plant symbiont, have been considered an opportunistic (Harman et al., 2004). It has attracted scientific attention because of its symbiotic activities and its role in protecting plants against various diseases. *Trichoderma* as an antagonist of fungal pathogens with its defensive abilities and even nematodes have different mechanisms: They use some mechanisms such as, space and nutrients with other fungi, production of antifungal metabolites (antibiotics) and very effective mycoparasitism.

Drought stress alleviating mechanisms employed by plant-associated bacteria, fungi, and viruses. Bacteria, fungi, and viruses are members of the plant microbiome living in different plant compartments, on plant surfaces (epiphytes) and inside plant tissues (endophytes).

Plant endophytes reside within healthy plant tissues and live without causing any damage or disease to the host plant. Some fungal endophytes support plant growth despite environmental factors such as drought, temperature, and salinity (Yang et al., 2013). Under water stress, capsicum plants inoculated with the endophytic fungus *Penicillium resedanum* LK6 have been reported to significantly increase plant growth and yield parameters, peroxidase, catalase and polyphenol oxidase, capsaicin gene phenylpropanoid biosynthesis content (Khan et al., 2014).

Drought stress affects many physiological events such as gas exchange and water relations, pigments, organic solutes, lipid peroxidation and electrolyte leakage. Severe drought is also responsible for the generation of reactive oxygen species (ROS) that are harmful to cells. However, certain antioxidants are available in plants to defend themselves against these ROS. Plants interact with certain microorganisms, such as fungi, which enhance their growth during stress. Mycorrhiza is closely related to fungi and plant roots, and the mycorrhizal relationship has been shown to increase crop growth, biomass, and mineral uptake under normal and arid conditions (Hameed et al. 2014).

Drought Stress and Bacteria

There is widespread interrelationship between plants and bacterial communities in soil (Naylor and Coleman-Derr, 2018) and includes rhizobacteria and bacteria. In the rhizosphere (soil in close enough to the root to be influenced by root exudates release) and bacterial endophytes found in the interior of the roots (Berg et al., 2014) which has been reported to contain approximately 10^9–10^{11} bacterial cells per gram soil, not only does it often out number plant host cells, it also out numbers humans on Earth (Berg et al., 2016).

Plant-associated bacteria can also be found above ground. They are found in the phyllosphere, in tissues such as buds, flowers, and leaves, and in plant tissues (endophytes), as well as survival structures on the pathogen, eg sclerotia (Martins et al., 2015). These bacteria associated with plants can increase the tolerance and resistance of plants to biotic and abiotic stresses such as pests, drought, salinity and pH imbalances (Martins et al., 2013, 2018b; Goswami and Deka, 2020). They are used as biological control agents against plant pathogens and the production of antimicrobial compounds such as phytohormones and siderophores increase the optimal growth by altering the plant immune response (Kim et al., 2012).

Commonly known plant growth promoting rhizobacteria as rhizobacterial drought tolerance enhancers (Beneduzi et al., 2012; Timmusk et al., 2013) have several mechanisms. Drought has an impact on plants as well as on soil. The process of drought resistance and resilience (RIDER) caused by rhizobacteria includes several physiological and biochemical mechanisms, changes in phytohormonal activity, aminocyclopropane-1-carboxylate deaminase production, deaminase, to reduce the ethylene level in roots, accumulation of osmolytes that confer drought tolerance in plants, bacterial exopolysaccharide (EPS) production), microbial volatile organic compounds (mVOCs) production, antioxidant defense (Porcel et al., 2014; Kumar and Verma, 2018); and stimulation of stress-responsive genes by PGPR (Poude et al. 2021).

Drought Stress and virus

Viruses are microscopic infectious agents and they depend on living host cells for their reproduction. They are often studied in connection with the diseases they cause, viruses. As such, they are typically considered pathogenic parasites, but there is increasing evidence that some viruses confer beneficial properties to their hosts. These examples arise from the necessity for the hosts to enhance the performance of the host under certain conditions for the viruses themselves to survive, and thus for the hosts to provide the necessary functions for their survival, due to obligatory mutual symbiotic relationships (Poudel et al, 2021).

A few examples of the beneficial effects of viruses on their hosts include situations where virus infection increases tolerance to heat or drought in the host. For example, virus infection of a fungal endophyte *Curvularia protuberata*, has been shown to mediate the enhancement of the fungus's ability. In geothermal soils of Yellowstone National Park, USA, a double-stranded RNA mycovirus, *Curvularia* thermal tolerance virus (CThTV), is present in the plant to confer heat tolerance on the tropical panic grass *Dichanthelium lanuginosum*. However, the fungal isolates lost the ability to confer thermal tolerance, so host survival was not possible (Márquez et al., 2007). Treatment from symbionts has shown that virus infection can improve drought tolerance while tolerance is restored upon reintroduction of the virus in various plants (Xu et al.,2008), In the study with Nicotiana benthamiana plants, the plants were kept in water-deficient conditions, with any of the four RNA viruses: Brome mosaic virus (BMV), Cucumber mosaic virus (CMV), Tobacco mosaic virus or TobaccoWhen rattle virus was infected, it delayed the onset of drought symptoms.

Conclusion

Plant microbiomes have the potential to provide plant resistance to abiotic and biotic stresses, including drought. Manipulation of the microbiome is promising for the use of these microbial isolates in agriculture. The microbial community in the root microbiome supports plant growth by regulating the synthesis of phytohormones, osmolytes, organic acids, improved nutritional intake, enhanced antioxidant system, and upregulation of stress-resistant genes. However, further studies at the molecular level are required to understand the exact mechanism of stress tolerance conferred by the diverse microbial community.

To avoid many of the challenges that drought brings to agricultural production, micro-organisms must have more than one feature. For example, through PGPR and molecular mechanisms, microbiomes affect plants and interact with them during stress. As a result, greater emphasis may be placed on drought-tolerant bacteria and associated microbiomes as well as naturally drought-adapted crop species. Although viruses are viewed as pathogenic parasites, interestingly they can confer drought tolerance on host plants. Since AMFs also help plants exposed to drought stress, they create drought tolerance in the plant. To make progress on this, it is essential to understand the chemical signaling and molecular mechanisms.

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Potential role of salicylic acid on drought stress tolerance of strawberry plants

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Abstract

Drought is considered as one of the main environmental stresses across the globe that adversely affect plant growth, economic outcome, and environmentally sustainable productivity. Drought stress is characterized by reduction of water content, diminished leaf water potential and turgor loss, closure of stomata and decrease in cell enlargement and reduces plant growth by affecting various physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrates, nutrient metabolism and growth regulators. To navigate this environmental stress, salicylic acid (SA), an endogenous plant growth regulator that is known to be significantly affecting the productivity, growth, photosynthesis, plant water relations, and antioxidant enzyme activities of plants exposed to various biotic and abiotic stresses. Nowadays, one of the most widely grown and demandable fruit plants among people is strawberry. Strawberry plants require extreme water and are vulnerable to drought. Strawberry has a shallow root system, large leaf area, and high-water content in fruits, therefore, it uses large amounts of water. Water deficit will limit plant growth, particularly during the vegetative and reproductive stages in strawberry plants. This review was aimed to determine the potential role of salicylic acid on growth, yield and drought stress tolerance of strawberry plants.

Keywords: Drought stress tolerance, Growth, Physiological and biochemical processes, Strawberry, Salicylic acid, Yield.

Introduction

Global warming is one of the most prominent challenge in the present era. Global warming is caused by the increased concentration of greenhouse gases (GHGs) in the atmosphere and leads to a phenomenon widely known as 'greenhouse affect'. Climate change has affected many abiotic factors like drought, pattern of rainfall, flooding, solar radiation and temperature, which are adversely affecting the productivity of major crops (Mohamed et al., 2019). Expansion of agriculture to semi-arid and arid regions with the use of intensive irrigation will increase secondary salinization as a result of changes in the hydrologic balance of the soil between water applied (irrigation or rainfall) and water used by crops (transpiration). Moreover, the faster-than-predicted change in global climate and the different available scenarios for climate change suggest an increase in aridity for the semi-arid regions of the globe and the Mediterranean region in the near future. Together with overpopulation this will lead to an overexploitation of water resources for agriculture purposes, increased constraints to plant growth and survival and therefore to realizing crop yield potential (Chaves et al., 2002; Passioura, 2007).

Strawberry is a type of fruit whose production (8,337,099 tons) is increasing day by day in the world. The fact that it is rich in antioxidants, organic acids and phenolic compounds increases the interest in this fruit species. In 2020 more than 8,861,381 tons of strawberries were produced worldwide (FAO 2020). China ranks first with a production of 3,221,557 tons, followed by the USA (1,055,963 tons), Egypt (597,029 tons), Mexico

(557,514 tons), Turkiye (546,525 tons) (FAO, 2020). Although strawberries are grown mainly in open field in the world and in Turkiye, there is an increasing trend towards greenhouse cultivation due to the advantages of high productivity and fruit quality, protection from adverse climatic conditions, ease of harvest and workmanship. It is inevitable that global warming, which affects the whole world, will also affect strawberry cultivation, which has a significant trade volume in the world and in Turkiye. Strawberries require extreme water and are vulnerable to drought. Water deficit is a crucial restraint factor at the initial phase of plant growth and establishment (Shao et al., 2008). Drought stress is one of the foremost abiotic stresses negatively affecting of plant growth and biological processes. Exposure of plants to drought stress associated with increased leaf temperature diminishes leaf water potential, relative water contents (RWC), and transpiration rate (Halder, 2003). Drought stress affects the physiological processes of plants, for example, formation of secondary metabolites that lead to accumulation of endogenous reactive oxygen species (ROS) and increased toxins (Farooq et al., 2009).

Hence, drought stress not only reduces the yield or productivity of plants by hindering normal physiological processes (Hasanuzzaman et al., 2013; Hasanuzzaman et al., 2017) but also can result in ROS related lipid peroxidation, super molecule degradation and polymer fragmentation, ultimately causing death to the plants (Foyer et al., 2001). Water deficit is also a major factor limiting growth, stomata conductance and net photosynthesis of strawberry plants (Dehghanipoodeh et al., 2018) (Figure 1).

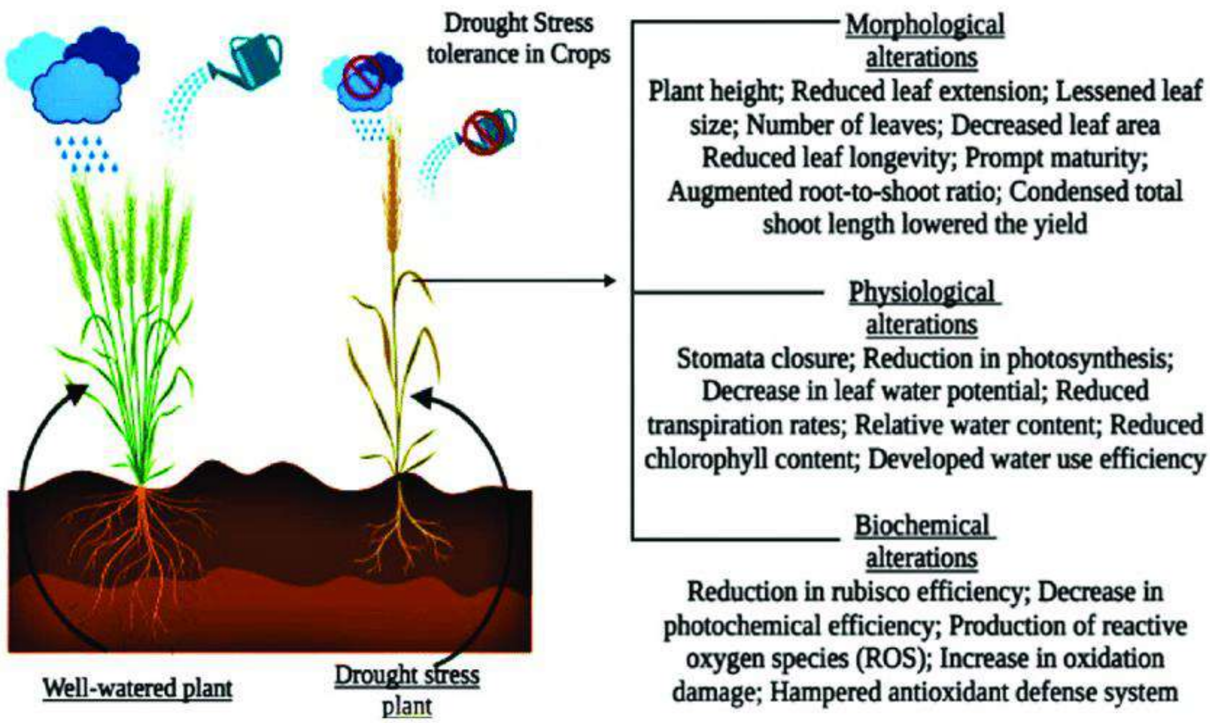

Figure 1. Morphological, physiological and biochemical response of plants to drought stress (Wahab et al., 2022)

One of the current challenges in agricultural practice and research today is how to cope with the abiotic stresses, particularly drought, in an economically and at the same time environmentally sustainable approach. Salicylic acid (SA), a naturally occurring plant hormone, acts as an important signaling molecule and enhances tolerance of treated plants against biotic stresses (Khan et al., 2012). Salicylic acid also has a vital role in plant growth, ion uptake, and nutrient transport within the plant. A significant role for salicylic acid has been suggested in plant water relations, photosynthesis, and growth in plants (Arfan et al., 2007). In this review, we aimed to provide an overview of potential role of salicylic acid on growth, yield and drought stress tolerance of strawberry plants.

Salicylic acid (SA): A plant growth regulator

The word “salicylic” is derived from Salix, which is the Latin name for the willow tree (Salix alba). Salicin, the glucoside of salicylic alcohol, was first isolated in 1826 from willow bark, and a large amount of the substance was successfully isolated in 1828. Salicin was then converted into a sugar and an aromatic compound that, upon oxidation, becomes SA. SA, a 2-hydroxybenzoic acid, has a colorless crystalline structure and is widely used in organic synthesis, including the synthesis of aspirin, also known as acetylsalicylic acid. Plants generally contain a few micrograms of SA or less per gram of fresh weight (Raskin, 1992), either in a free state or in a glycosylated, methylated, glucose–ester, or amino acid conjugate form (Dempsey et al., 2011). Since salicylic acid (SA) was discovered as an elicitor of tobacco plants inducing the resistance against Tobacco mosaic virus in 1979, many reports suggest that SA indeed is a key plant hormone regulating plant immunity. In addition, recent studies indicate that SA can regulate many different responses, such as tolerance to abiotic stress, plant growth and development, and soil microbiome.

Effect of SA on growth and yield of strawberry under drought stress condition

Drought is the most important one of abiotic stress factors that negatively influence the growth and production of plants. Drought has an impact on the plant growth and development (Klamkowski et al., 2006; Chaves et al., 2009). Drought had significantly impacts changes in plant morphology, physiology and biochemistry. Damages caused by drought stress in plants appear as growth and developmental retardation, especially by inhibiting photosynthesis. Drought conditions result in inhibiting photosynthetic pigment formation, causing damage to chloroplasts, disrupting the electron transport chain, resulting in the formation of active oxygen derivatives that cause photo oxidative damage (Figure 1). Drought is associated with reduction in leaf thickness (Santacruz et al., 1984). Leaves are generally thicker under water stress (Moreno-Sotomayor et al., 2002). Thick leaves are the characteristic features of drought stressed plants, as reported by Sam et al. (2000) in tomato. High leaf thickness is often related to drought tolerance (Chandra et al., 2004).

The plant hormone ABA (abscisic acid) accumulates under-water deficit conditions and plays a major role in response and tolerance to dehydration. Closure of stomata and induction of the expression of multiple genes involved in defense against the water deficit are known functions of ABA. The amount of ABAs in xylem saps increases substantially under reduced water availability in the soil, and this results in an increased ABA concentration in different compartments of the leaf. Another well-known effect of drought in plants is the decrease in plasma membrane ATPase activity (PM-ATPase). Low PM-ATPase increases the cell wall pH and lead to the formation of ABA. ABA^- cannot penetrate the plasma membrane and translocate toward the guard cell by the water stream in the leaf apoplasm. High ABA concentration around guard cell results in stomata closure and help to conserve water. Drought stress affects the growth, dry mater and harvestable yield in a number of plant species, but the tolerance of any species to this stress varies remarkably. A branched root system has been associated with drought tolerance and high biomass production primarily due to its ability to absorb more water from the soil and transport it to the above-ground parts for photosynthesis. In addition to other factors, changes in photosynthetic pigments are of paramount importance to drought tolerance. Of the two photosynthetic pigments classes, carotenoids show multifarious roles in drought tolerance including light harvesting and protection from oxidative damage caused by drought. Thus, increased contents specifically of carotenoids are important for stress tolerance (Jaleel et al., 2009).

Drought stress causes considerable yield reduction in most crops including strawberry. Strawberry is one of the crops that require adequate irrigation to achieve satisfying commercial yields (Serrano et al., 1992). In regions suffering from water deficits due to insufficient rainfall and limited water resources for irrigation, the strawberry will experience water shortages limiting the production. Klamkowski et al. (2008) reported that drought stress reduced the leaf area in all strawberry cultivars including Elsanta, Elkat and Salut. Chlorophyll activity is critical in drought resistance which was declined during water stress in two varieties of strawberry (Ghaderi, 2011). Similarly, Kirnak et al. (2001) reported that chlorophyll content was reduced by 55% under drought stress conditions compared to control. Ödemiş et al. (2020) studied the responses of drought stress in strawberry cultivar 'Camarosa' under greenhouse and reported that drought stress decreased stomatal conductivity, total chlorophyll content, photosynthetic quantum yield, photosynthetically active radiation, leaf water content, leaf area, and leaf number but increased leaf surface temperature. Ghaderi et al. (2011) observed that a decrease in the amount of water available in the soil causes decreases in leaf proportional water content, membrane stability index, CO_2 assimilation rate, stomatal conductivity, transpiration, protein, soluble carbohydrate content and chlorophyll levels. Adak et al., (2018) studied yield, quality and biochemical properties of various strawberry cultivars (Camarosa, Albion, Amiga and Rubygem) under different irrigation regimes (control: 30%; water stress: 15% drainage). They reported that fruit weight was declined by 59.72% and the yield per unit area by 63.62% under water stress conditions as compared to control. Water stress increased all biochemical features in fruits such as total phenol, total anthocyanin, antioxidant activity and sugar contents.

SA plays an important role in the regulation of a number of vital processes and growth in plants (Raskin, 1992). Exogenous application of SA may also influence a range of developmental and physiological processes, e.g., seed germination and fruit yield (Cutt et al., 1992), transpiration rate (Larque-Saavedra, 1979), stomatal closure (Rai et al., 1986), membrane permeability (Barkosky et al., 1993), growth and photosynthesis (El-

Tayeb, 2005; Khodary, 2004). Lolaei et al. (2012) noted that salicylic acid delayed the ripening of strawberry and improved fruit yield and quality. Jamali et al. (2011) reported that a salicylic acid treatment at 2 mM increased root and shoot fresh weights, number of inflorescences, fruit yield, and fruit quality. Hayat et al. (2010) reported that SA can effectively alleviate toxic effects resulting from exposure to various abiotic stresses in plants. Based on different reports SA enhanced the leaf area and dry matter production in strawberry (Ghaderi et al., 2015) under drought or salinity stress. Ibrahim et al. (2021) reported that water stress significantly affected plant growth, transpiration rate, net photosynthesis, stomatal conductance, leaf relative water content, number of flowers and fruits, proline content, length, diameter, weight and total soluble solid of fruit of strawberry cultivars (Earlibrite, California and Sweet Charlie). Salicylic acid treated strawberry plants observed 11% increase in chlorophyll content compared to untreated plants (Jamali et al., 2011), reflecting improved fruit yield (Raskin, 1992). Hasan et al. (2021) reported that SA at 4mM concentration on strawberry cv. Chandler improved plant height (14.60 cm), number of leaves per plant (5.27), leaf area (68.40 cm^2), and average fruit weight (13.53 g) and postharvest parameters like total soluble solids (5.10^{o} Brix), ascorbic acid (12.41mg/100 ml) and total sugar contents (6.54 %).

Impact of SA on the drought stress tolerance of strawberry plants

Plants under drought and salinity stress promote the production of ROS (Reactive oxygen species) that lead to cause oxidative stress and damage the biomolecules like proteins, lipids and nucleic acid (Smirnoff, 1993; Panda et al., 2003b). Drought conditions bring about quantitative and qualitative changes in plant proteins. In general, proteins in the plant leaves decrease during water deficiency due to the suppressed synthesis, more specifically in C3 than in C4 plants. Water stress alters gene expression and consequently, the synthesis of new proteins and mRNAs. The main proteins synthesized in response to water stress are Late embryogenesis abundant proteins (LEA), desiccation stress protein, proteins those respond to ABA, dehydrins, cold regulation proteins, proteases, enzymes required for the biosynthesis of various osmoprotectants, the detoxification enzymes (SOD, CAT, APX, POD, GR). In addition, protein factors involved in the regulation of signal transduction and gene expression, such as protein kinases and transcription factors are also synthesized. The majority of these stress response proteins are dehydrin-like proteins, which accumulate during seed production and embryo maturation of many higher plants as well as in water stressed seedlings. Osmotic regulation of plants is an important way to reduce osmotic potentials and maintain turgor pressure in order to resist stress, and ultimately adapt to arid environments. Furthermore, osmotic adjustment is physiological characteristic linked to drought tolerance in plants, including the strawberry (Grant et al., 2010). Soluble carbohydrates and proline content are two crucial factors actively involved in osmotic regulation (Pinheiro et al., 2004).

Exogenous SA applications reduce the negative effects of drought by reducing oxidative damage, especially by regulating important enzymatic pathways (Alam et al., 2013). The underlying mechanisms of SA-induced abiotic stress tolerance include that SA-mediated (1) accumulation of osmolytes, such as glycine betaine, proline, soluble sugars and amines, which can help maintain osmotic homeostasis, (2) regulation of mineral nutrition uptake, (3) enhanced reactive oxygen species scavenging activity, (4) enhanced secondary metabolite production, such as terpenes, phenolics, and compounds with nitrogen (alkaloids, cyanogenic glucosides, non-protein amino acids) and sulfur (glutathione, glucosinolates, phytoalexins, thionins, defensins, and allinin), and (5) regulation of other hormone pathways (Horváth et al., 2007; Khan et al., 2015) (Figure 2). Exogenously applied salicylic acid also improves drought tolerance and enhances growth and final harvest of the plants under water scarcity (Miura et al., 2014). Tariq et al. (2002) observed that the exogenous application of salicylic acid enhanced the drought and salinity resistance of plants. The accumulation of MDA in strawberry leaves treated with 0.1 and 1.0 mmol L^{-1} SA was significantly reduced, thus reduced the membrane lipid peroxidation, enhance the stability of membrane systems and improve the drought resistance of strawberry.

Reactive oxygen species (ROS) of plants are mainly in the form of superoxide anion (O_2), hydrogen peroxide (H_2O_2) and hydroxyl radicals (•OH). Some studies indicated that exogenous SA could induce activity of leaf SOD and POD, which are detoxification enzymes, of wheat maize under osmotic stress, and thereby reduce super oxide anion radical (O_2^-) production (Shang et al., 2007). They further reported that certain concentration (0.1–1.0 mmol L^{-1}) of SA applied before drought induced SOD, POD and CAT activity in strawberry leaves at the early stage of stress and also improved the drought tolerance of strawberry.

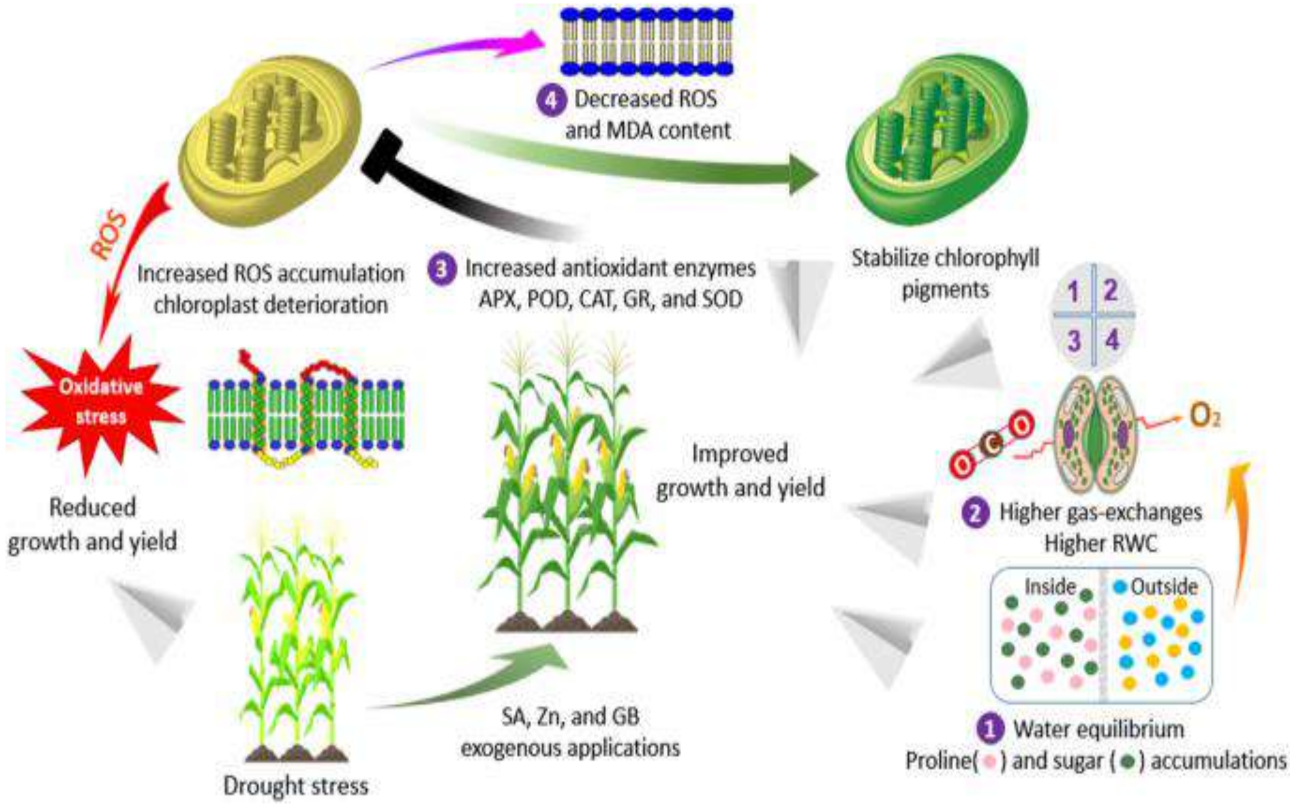

Figure 2. Role of Salicylic acid on growth, yield and drought stress tolerance of plant (Shemi et al., 2021)

Conclusion

Conclusions

The changes in the climatic condition all over the world under the influence of global warming is creating unusual weather phenomena often in the form of water deficit or in the form of floods and waterlogging. Drought is severe of these two dues to the prolonged exposure of plants to a water deficient condition. Drought conditions result in this; inhibiting photosynthetic pigment formation, causing damage to chloroplasts, disrupting the electron transport chain, resulting in the formation of active oxygen derivatives that cause photo oxidative damage. Drought stress causes considerable yield reduction in most crops including strawberry. Salicylic acid plays an important role in the regulation of the abiotic stress responses. Exogenous applications of SA to different crop species have been shown to elicit effects on yield and yield components. Leaf application of strawberry plants with SA and water regimes, independently or their relations, stimulate the growth of strawberry plants by means of increasing of the biosynthesis of pigments in photosynthesis, enhancing yield of strawberry thus SA enhanced value and nutritional value.

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The use of leonardite in agriculture

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Abstract

Chemical fertilizers and pesticides used in agricultural activities disrupt the balance of nature and cause negative effects on public health. Since the continuously use of nitrogen and phosphorus trade fertilizers pollutes the nature, it is a reality that the use of organic fertilizers should be emphasized in order to minimize the use of commercial fertilizers. From this point of view, there is a need for completely natural organic resources that don't harmful effect the populations, and enable the sustainable use of soils and contribute to the reduction of environmental pollution. One of these substances is leonardite raw material, which could improve the physical, chemical and biological properties of the soil. Leonardite is essentially a soil conditioner and its active ingredient is humic and fulvic acids. By the leonardite applications, we can increase the organic matter level of the soil to a certain extent. In addition, while sufficient amount of organic matter (around 10%) has positive effects, more of it (28% and above) causes harmful effects in terms of the uptake of some nutrients. In order to avoid some negative effects on yield or yield characteristics in crop production, leonardite material should be applied as a soil regulatory in sufficient quantities in agriculture, but it should be pay attention its unsufficient quantities or excessive applications. Also, it regulates the soil pH and structure perfectly, and not harmful effect the environment and also removes the pollutans in the soil. In the application of leonardite to the soil, it was determined that the most appropriate dose and amounts for different plants changed between 2-5% and 75-100 kg/da. For his reason, they must be applied to the soil at varying rates depending on the soil and leonardite characteristics and plant type.

Keywords: Leonardite application, Soil, Plant

Introduction

Leonardite is an organic substance that has not yet reached the coal state and separated from soft brown coal with its high oxidation and high humic acid content at the end of the coal formation process, also it was formed in the lignite beds by humification process that lasted for 70 million years (Figure 1). The most important difference that distinguishes leonardite from lignite has a high percentage of oxygen and does not have the opportunity to use it as a fuel (Engin and Cöcen, 2012). At the same time, leonardite is a kind of soil called as gidya, which has a muddy structure on the lake floors, its color varies from gray, gray-brown to blackish, is rich in nutrients, oxygen and water-dwelling organisms, contains various amounts of organic matter, and is formed as a result of excessive decomposition of plants in layers containing algae (Engin et al., 2012).

Figure 1. Leonardite extracted from lignite deposit

Humic acid, fulvic acid and ulmic acid obtained from this raw material have many uses in agriculture such as cosmetics in pharmaceutical industry and from drilling industry to animal feed and filter systems. On the other hand, it has been reported that humic and fulvic acids have effects on increasing the surface area in the soil and this is effective on capillary rooting and especially on the access of low mobility nutrients such as phosphorus to plant roots (Noroozharaf and Kaviani 2018).

The organic matter in leonardite, in the clay soils can reduce the plasticity, cohesion, stickiness, etc. (Oades and Waters, 1991). It increases the macropores from the physical properties of the soil and organic colloids swells to fill the cracks and macro pores in the soil due to the binding of nutrients and it causes a decrease in hydraulic conductivity. Also, high organic carbon contents can even reduce soil compressibility at high moisture levels in clay and silty clay soils (Smith et al, 1997). In sandy soils, leonardite not only increases the micropores, cation exchange capacity and water holding capacity, but also facilitates the cultivation of the soil (Karaman et al., 2012). Due to the different affinities of humic and fulvic acids on nutritional elements due to excessive leonardite applications, it may cause a binding effect on their usefulness, as well as a deficiency or toxicity effect. For example, as a result of the strong binding of some plant nutrients such as Fe, Mn and Zn, especially Cu due to excess organic matter chelation, their availability may decrease or cause their deficiencies (Kacar and Katkat, 2009; Turan and Horuz, 2012).

Leonardite is essentially a soil conditioner and its active ingredient is humic and fulvic acids. In terms of uptake of plant nutrients in the soil, low effect or ineffectiveness due to under-applications and some direct or indirect negative effects may occur due to excessive applications (Kulikova et al, 2005). With Leonardite applications, we can increase the organic matter level of the soil to a certain level, however, it should not be forgotten that while sufficient amount of organic matter (around 10%) has positive effects, more of it (28% and above) may cause harmful effects. Therefore, in order to avoid some negative effects on yield or yield components in plant production, it should be paid attention to avoid insufficient or excessive application of leonardite material in agriculture as a soil conditioner. As a result of the research and examination of leonardite since the 1960s, it can be used as a source of humic acid and it has pioneered studies on humic acid in the world (Olivella et al., 2002).

In this study, the effects of the use of leonardite in agriculture on physical, chemical and biological properties of soils and on plant nutrient uptake were investigated.

Fundamental Features of Leonardite

Leonardite contains high humic acid, due to this effect, most of the studies have carried out cover topics such as its use as fertilizer, its effect on plant yield, fertilizer value, organic matter content and humic substance content. Depending on the severity of metamorphism and humification, the humic acid content of leonardite varies between 50% and 80%., which has a black-brown appearance and a hardness that can be easily crumbled by hand, and its density is 0.75-0.85 gr/cm^3 and pH value is 3-5. Also, its solubility is high in 1% KOH and NaOH solution, but it low in water. Its solution is black shiny, foamy, colloidal and oily in appearance. It dissolves easily in the saturation sludge prepared with soil pH value of 8–9 (Anonimous, 2019). Leonardite is classified in Table 1 as low, medium and high quality according to its composition and composition (Anonymous, 2007).

Table 1. Leonardite quality classification

Composition	Low quality	Medium quality	High quality
Humic acid content %	35-50	50-65	68-85
The amount of organic matter %	Minimum 35	Minimum 50	Minimum 65
pH value	6,5±1	5,5±1	4±1
C/N	21±1	19,1	17±1
Specific weight (gr/cm3	1,4±0,1	1,2±0,1	0,8±0,1
Solubility in basic solution	Low	Middle	High

Benefical Effects of Leonardite

The use of leonardite in agriculture is in the form of solid (granules or pellets) or humates (liquid or powder) obtained by extraction of leonardite (Figure 2). (Engin and Cöcen, 2012). Leonardite can be used in agriculture as the main raw material in the production of humic acid concentrate (humate) and as a soil conditioner in organic agriculture.

Figure 2. Solid (granules or pellets) or humates (liquid or powder) obtained by extraction of leonardite

It is possible to collect the benefits of humic acid in three groups as physical, chemical and biological. The importance of using leonardite in organic agriculture is increasing day by day. Considering plant yield and quality, the advantages of using leonardite are as follows (İstanbulluoğlu, 2012):

- Leonardite (or humic acid) perfectly regulates and improves the structure of the soil,
- Promotes aggregate formation in soils
- It prevents soil compaction and provides better aeration
- Increases the water permeability of the soil
- Increases the organic matter content of sandy soils
- Increases the surface area, water holding capacity, CEC and buffering capacity of sandy soils by increasing the micropores
- In clay soils, it enters between the clay particles and prevents them from becoming concrete and thus loosens the heavy soils
- Increases the water holding capacity of the soil
- Increases the cation exchange capacity of soils
- Protects soil moisture by reducing water losses against drought
- Provides better use of solar energy as it darkens the soil color
- It increases the beneficial microorganism activities in the soil

- Increases chlorophyll and photosynthesis in leaves
- Stimulates enzymes in plants
- It plays a role in chelating plant nutrients of humic and fulvic acids in its content
- Due to the organic acids it contains, it reduces the fixation of K and NH_4 by getting between the clay layers
- It covers the surfaces of Al, Fe and Mn in acid soils and prevents P fixation by dissolving lime in calcareous soils
- By increasing soil pH with Gidya type calcareous leonardite applications
- It has a stabilizing effect on soil reaction by lowering soil pH in Leonardite applications
- Humic and fulvic acids formed due to Leonardite applications reduce unwanted soil salinity stress conditions by keeping Na ions on their negative surfaces and CI ions on their positive surfaces
- Humic substances prevent the uptake of some toxic elements (heavy metals, etc.) and phytopathological elements, thus promoting plant growth
- When used in sufficient amount, it affects yield and efficiency factors positively
- Better quality, lively, healthy, nutritious and standard products are obtained
- Significant earliness is provided
- In case of using fertilizer, it reduces the amount of fertilizer used
- It does not harm the environment and removes the existing pollution in the soil

The Effects of Leonardite on Agriculture

The organic matter level of leonardite used in agriculture is above 50%, and its 40% humic acid content provides an important advantage. In addition, the appropriate pH (6.5%) level and being salt-free provide great benefits in the agricultural use of leonardite (Anonymous, 2007).

Sesveren and Taş (2018) studied the effects of different leonardite levels on water consumption and some growth parameters in curly leaf salad (Lactuva sativa var. crispa) by mixing 0%, 5%, 10% and 20% by weight of leonardite into the potting soil. They made some analyzes to observe how the physical properties of soils with leonardite were added after harvest. The properties of the soils used in the study at the beginning of the trial are shown in Table 2 and the properties after the trial are shown in Table 3.

Table 2. Some properties of the soil at the beginning of the trial.

Depth	Texture Class	OM (%)	pH	EC (%)	Lime (%)	BD (mg)	FC (m^3/m)
0-30	(SCL)	2,78	7,29	0,096	0,84	1,13	0,31

SCL: Sandy clay loam; BD:Bulk density; FC: Field capacity

Table 3. Some properties of the soil at the end of the trial.

Leonardite (%)	pH	EC (dS/m)	Lime (%)	BD (g/cm^3)	Clay (%)	Mil (%)	Sand (%)
L0	6,03	0,123	9,11	1,38	30,00	28,26	41,74
L5	6,98	0,420	8,75	1,36	47,35	10,86	41,79
L10	7,06	0,675	8,21	1,35	28,06	35,67	36,28
L20	7,17	0,640	9,46	1,27	38,63	19,53	41,84

EC: Electrical conductivity

Kolay et al., (2016) applied 6 different doses of leonardite (0, 50, 100, 150, 200 and 250 kg/da) in a trial with wheat plant. As a result of the study, it was found that leonardite applied in different amounts had no effect on soil organic matter, soil moisture and bulk weight, but had a reducing effect on penetration resistance. The decrease in soil penetration resistance with Leonardite application is a positive result considering the high penetration resistance values measured immediately after harvest. This shows that leonardite can be used for soil improvement.

Özge et al., (2020) reported that leonardite application at different doses (0, 25, 50, 75, 100 and 125 kg/ da) increased the yield of chickpea (Cicer arietium L.) and also improved its yield characteristics. They reported that 100 kg/da leonardite application gave the highest values in both years of the study in terms of all the properties examined, and the lowest values were achieved in the control.

Pertuit et al. (2001) reported that leonardite application did not affect plant height. In previous studies, İmamoğlu (2019), Azcona et al. (2011) and Özel (2011) stated that it increased the plant height, Ergönül (2011) stated that it decreased the plant height, and Dinç (2014) stated that it did not increase the plant height compared to the control. The plant height values obtained from this study were determined by İmamoğlu (2019), Azcona et al. (2011) and Özel (2011) showed that while they were similar to the results obtained, they differed from the results of other studies. It is thought that these differences are caused by the climatic and soil conditions in which the plants are grown, the plants grown and the doses of leonardite or humic acid used.

Topcuoğlu and Önal (2006), it was determined that leonardite (at 1% and 2% levels) applied to the soil in greenhouse conditions increased the fruit yield of the tomato plant. It was reported that N, Fe, Zn, Mn contents in the leaf tissue of tomato plant increased with increasing applications of leonardite, but no significant change was detected in fruit quality criteria.

Karakiliç et al. (2021) In the study on the effect of leonardite applications on yield and mineral nutrition of sultani seedless grape variety (Vitis vinifera L.), it was determined that different leonardite levels applied from the soil (L0= control, L1= 500 g/omca, L2= 1000 g/omca, L3= 1500 g/omca) fresh grape yield per vine (kg/omca) and potassium (K) content of grape leaves, phosphorus (P), calcium (Ca), magnesium (Mg), iron (Fe), Zinc (Zn), Manganese (Mn) and Copper (Cu) contents were found to be statistically significant. They reported that the most appropriate leonardite application dose in terms of grape yield was 1000 g leonardite/omca (L2 application).

Işık and Sinan (2020) investigated the effects of leonardite and nitrogen application on the yield and quality characteristics of sesame plants under second crop conditions. They studied 4 different doses of leonardite (L0:control, L5:50 kg, L7.5:75 kg and L10:100kg/da) and four different doses of nitrogen (N2.5:2.5 kg, N5: 5 kg, N7.5: 7.5 kg and N10: 10 kg N da^{-1}). As a result of their study, it was found that the effects of leonardite and nitrogen application on the number of capsules per plant, seed yield, oil ratio, protein ratio of the sesame plant in the second crop sesame cultivation in the Çukurova Region are significant, but plant height, number of branches, first capsule height, branch height, was no effect on 1000 grain weight properties. Also they reported that the highest seed yield was obtained from L7.5:75 kg/da leonardite and N7.5:7.5 kg N/da application, and the maximum number of capsules per plant was obtained from the L0 and N7.5:7.5 kg N/da application.

Küçükyumuk et al. (2014) investigated the effects of leonardite and mycorrhiza on pepper plant growth and nutrient uptake with leonardite. They stated that the plants treated with Leonardite developed better and although mycorrhiza application did not have a positive effect on plant growth, it had a positive effect on some nutrient concentrations in the plant. According to the results of their research, the use of leonardite and mycorrhiza together in plant production would be beneficial in agricultural production.

Haidari (2022) was investigated to the greenhouse study the effect of leonardite treated with potassium hydroxide (KOH) on the growth of maize plant (Zea mays L. cv. Karadeniz yıldızı). In the the study, leonardite was applied at the rates of 0.5%, 1.0%, 1.5% and 2.0% and KOH was applied at the rate of control (0.0%), 1.25%, 2.5%, 3.75% and 5.0%. The researcer reported that the highest biomass development (stem + leaf dry matter amount) and plant height were obtained from 2% leonardite and 3.75%KOH applications.

Conclusion

The leonardite that contains due to the organic matter and humic acids, it is not only increases the amount of organic matter in the soil and positively affects their physical, chemical and biological properties, but also increases the uptake of plant nutrients by chelating them. Therefore, considering the increasing world population, it is very important the use of leonardite in agriculture both the increased crop yield and its quality.

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