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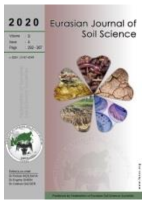

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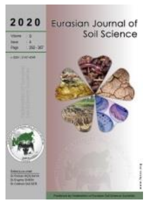

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Vermicomposting of agro-industrial waste by-product of the sugar industry

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Abstract

The objective of the study was to investigate the survival of earthworm *Eisenia fetida* during vermicomposting of Sugar Industry wastes. These wastes are called Decanter sludge (DS) and Press filter waste soil (PKF). To achieve the objective a laboratory-based experiment was performed 12 weeks under controlled conditions. Eleven different mixtures were prepared by mixing DS, PKF and farmyard manure (FYM) in different ratios. During the incubation time, earthworms survived in treatments which included less than 50% DS or 50% PKF. The number of earthworms increased significantly in all treatments from 6 to 90 (P<0.05) during the experiment period. Chemical properties (pH, EC, OM, Total Nitrogen, Lime) and heavy metal contents of sugar industry vermicomposts were in accordance with the standard compost limits. Results of the present study indicated that the worms did not live in the medium containing more than 50% of the PKF and 50% of the DS. Vermicompost can be obtained from production wastes of sugar factory by applying vermicompost process on Decanter Sludge at the maximum ratio of 50% or its mix with PKF along with FYM. Use of DS and PKF as feed materials for vermicomposting can assist to turn the wastes into precious materials.

Keywords: Sugar waste, decanter sludge, farmyard manure, press filter waste soil, vermicompost, *Eisenia fetida*.

Introduction

The agriculture of sugar beet in Turkey has spread around the country apart from the Mediterranean and Southeast Anatolia Regions. According to the 2017 data of the Turkish Statistical Institute, for the agriculture of sugar beet, the total plantation area is 3,392,171 hectares, production is 20,828,316 tons and the yield is 6140 tons (Anonymous, 2017). Furthermore, in some European countries, the yield reaches up to 7000-8000 kg ha^{-1}. It is known that this difference is because of the climate and farming techniques. Of late, around the world, the recycling of waste products has become a point of interest. As is with every industry, waste products occur while treating the raw materials in the sugar industry as well. PKF and DS are among the waste products of the sugar factories. In the production process of sugar, juice treatment is done in order to both decrease the color materials to a large extent and destroy the building blocks of color materials that are expected to occur in the future; in other words, the juice treatment is made to remove the materials, apart from sugar, in the raw juice. The juice treatment is generally carried out in five stages. These are: i) First Liming, ii) Second Liming, iii) First Carbonation, iv) Second Carbonation, and v) Separation of juice from sediment by filtering and obtaining a watery juice (Ozkan, 2014). In the first carbonation, the muddy juice is precipitated in the decanter. Decanters are based on the principle of sludge particles' precipitation to the bottom because of the difference in intensity. Clear juice accumulates on the decanter, while sludge is left at the bottom. This sludge is named as decanter sludge. Press filter waste soil (PKF) is what is obtained after the carbonation process and separated from juice through filtration. When the amount of these waste

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products in Turkey is taken into consideration, it is seen that PKF is annually 220,000 tons and DS is 125,000 tons. The sugar factory's wastes are stored in an open field in Turkey and there is a major disposal problem for them. Although fairly rich in organic nutrients, they find little use as agricultural fertilizer. The primary reason for this is the insoluble and imbalanced nature of the nutrient content in these wastes (Bhat et al., 2016). Revaluation of these waste products and decreasing the load on environmental pollution are rather important.

For the treatment of these waste products, vermicomposting is used as a better method in order to deal with this existing problem. Vermicomposting is a removal technique for solid wastes as an environment-friendly and cost-effective technique to turn these waste products by worms into a valuable material for land grading. Kumar et al. (2012) left different agricultural-industrial wastes, which had been left for pre-decomposition, to composting for 12 weeks by using *Eudrilus eugeniae* in a pilot study for vermicomposting. As a result of the study, they determined that the decanter sludge can be used in vermicomposting and benefited to separate and increase the quality of vermicomposting. Dotaniya et al. (2016) stated that the chemical, physical and biological features of soil are developed and the product quality and fertility are increased by implementing the by-products of sugar industry like decanter sludge and residue; furthermore, these products can decrease the use of chemical fertilizers. In their study, Umar and Sharif (2013) studied the high-added value fertilizer potential of the sugar industry and the transformation of these products into vermicompost. They stated that the released vermicompost products are more valuable and their chemical characteristics such as heavy metal contents were within the limits of the usable values and that these products can be used as organic fertilizers in agricultural areas. Sepperumal and Selvanayagam (2015) reported the bagasse wastes at various dosages to composting for 8 weeks, and then to vermicomposting with the worms species such as *Perionyx excavatus*, *Eisenia fetida* for 8 weeks. As the result of their study, they stated that the vermicomposting process can be a different alternative choice for the recycle of the sugar industry's waste into a beneficial product, which can be used in agriculture.

The objective of this study was to estimate the potential of converting the sugar industrial waste DS (Decanter sludge) and PKF (Press filter waste) into vermicompost and to state the suitable ratio of wastes and FYM (farmyard manure) required for proper growth of earthworms.

Material and Methods

Materials Description

The earthworms and farmyard manure (FYM) used in this experiment were obtained from a private company, after all the Decanter Sludge (DS) and Press filter waste soil (PKF) came from a sugar plant in the city of Konya, Turkey. After the waste materials are dried and sieved, total elemental analysis is performed on the XRF to reveal the contents of the feed materials. The analysis results were given in Table 1.

Table 1. Initial physicochemical parameters of the feed materials

Materials	OM, %	pH	EC, dS m^{-1}	$CaCO_3$,%	N,%	CaO,%	P_2O_5,%	K_2O,%
DS	15.27	7.39	0.33	16.42	1.05	10.38	0.15	1.51
PKF	10.36	8.61	1.67	56.78	0.62	54.16	0.41	0.10
FYM	49.00	8.51	2.08	10.92	1.68	8.45	1.19	2.08
Materials	**Fe_2O_3, %**	**Ni,mg kg^{-1}**	**Cu,mg kg^{-1}**	**Zn,mg kg^{-1}**	**Pb,mg kg^{-1}**	**Cd,mg kg^{-1}**	**Cr,mg kg^{-1}**	**Hg,mg kg^{-1}**
DS	4.03	59.90	23.40	62.80	20.10	<0.05	65.00	1.20
PKF	0.16	3.20	7.10	13.90	2.50	<0.05	69.50	1.20

Experimental Set Up

DS, PKF, and FYM were mixed in different quantities to produce eleven mixtures for incubation experiment. Different combination of DS, PKF, and farmyard manure (FYM) were mixed according to the proportions mentioned below.

Treatments are T_1: 25% DS+ 75% FYM; T_2: 30% DS + 70% FYM; T_3: 40% DS + 60% FYM; T_4: 50% DS + 50% FYM; T_5: 20% DS + 20% PKF + 60% FYM; T_6: 25% DS + 25% PKF + 50% FYM; T_7: 70% DS + 30% FYM; T_8: 50% PKF Soil + 50% FYM; T_9: 70% PKF + 30% FYM; T_{10}: 100% DS; T_{11}: 100% PKF.

The mixtures, which contained different proportions of the feed materials and which were covered with gauze, were set to optimum 65 ± 10% humidity. Six adult worms (*Eisenia fetida*) were applied to each of the mixtures and the plastic pots were operated to incubation in the dark in a climate chamber at 21^{o}C. The incubation experiment was run in plastic pots, on a dry weight basis, of volume 2500 cc in triplicates. Two kg of feed materials was added uniformly in all the eleven treatments for the study. The moisture content of all mixtures was conserved at 65 ± 10% by distilled water. During the experiment, no additional any waste was included at any stage in any pots. When incubation experiment is over, worms were picked up of each pot and obtained vermicompost materials were air dried and kept for all analysis.

Physicochemical parameters and nutrient contents

The physico-chemical characteristic analysis was conducted on a dry weight basis. Each treatment was analyzed in triplicate. The parameters of pH and EC were stated in a distilled water suspension of each concentration in the rate of 1:10 using Consort C3010 multi-parameter analyzer. Total organic carbon (TOC) was determined according to Nelson and Sommers (1982), Total nitrogen (TN) was measured by Bremner and Mulvaney (1982). Total carbonate content determined by using the Scheibler calcimeter (Jackson, 1962). The amount of total Fe, Cu, Zn, Ni, Cd, Cr, Pb in digested samples were determined by the ICP-OES (Perkin Elmer DV 2100) by Kamitani and Kaneko (2007).

Statistical analysis

"ANOVA" was used to figure out the significant differences among different factors. All treatment means were compared with the (LSD) at a 5% level of potentiality. All statistical analyses were performed using Windows Minitab software program (version 17.0).

Results and Discussion

Twenty-four hours after worms were added, worms could not survive to include more than 50% DS or PKF treatments (T7-T11). Similar results were obtained in three repeated applications and it was decided that the worms did not live in the medium containing more than 50% of the PKF and 50% of the DS. For this reason, treatments between T7-T11 were removed from the experimental program. In the incubation experiment, the worms adapted to the environmental condition of T1- T6 treatments. For this reason, the incubation experiment was continued in these mixtures.

Number and weight of earthworms *(Eisenia fetida)*

Best suitable mixture for the highest survival of worms was determined by observing growth rate, weight, and mortality. All treatments were performed for 12 weeks and there were survival problems in some treatments during the incubation period. Earthworms survived in treatments which included less than 50% DS or PKF. Nevertheless, FYM was mixed with the PKF in half, while the worms did not live in practice, the worms lived in practice where the FYM was mixed with the DS halfway. According to this result, DS is more suitable for earthworms as environment than PKF. The number of worms increased significantly in all treatments from 6 to 90 ($P<0.05$). Worms indicated different behavior in the way of growth in varied treatments. A number of earthworms were found in the treatments T5 (87) and T6 (90) which were significantly higher ($P<0.05$) from all other treatments (Table 2). The average weight of earthworms was found in the treatments T5 (37,70) and T6 (39,81) which were significantly higher ($P<0.05$) from all other treatments. According to Sangwan et al. (2010), 100% cow dung is the best place for *Eisenia fetida* grown. As indicated by Edwards and Fletcher (1988), the volatile gases, such as CO_2, NO_2 could influence the living of earthworms.

Table 2. Number and weight of worms at the end of the incubation experiment

Applications	Number of Worms	Weight of Worms (g)
T_1	62b	30.49b
T_2	77ab	35.09ab
T_3	71b	29.95b
T_4	78ab	34.07ab
T_5	87a	37.70a
T_6	90a	39.81a
LSD<0.05	13.36	5.68

Physico-chemical parameters and nutrient contents of the feed mixtures in different treatments

The results of the analyses of TOC, TN, C/N ratio, pH, EC, lime, total Cd, Pb, Cr, Zn, Cu, Fe, Ni in the vermicompost samples for T1-T6 treatments, derived at the end of incubation, are stated in Tables 3.

The highest TOC and TN were found in the mixture of T1 (25% DS + 75% FM), and the lowest was found the mixture of T6 (25% DS + 25% PKF + 50% FYM). The number of FYM decreases was reduced organic carbon percentage of vermicompost samples. Loss of organic carbon might be because of microbial respiration and decomposition of natural organic matter (Kaushik and Garg, 2003). According to Prakash and Karmegam (2010), changes in microbial populations are closely associated with vermicompost materials. Plaza et al. (2005) reported that the increase of total N mostly referred to decomposition of C-rich materials and, likely the situation of bacteria (N-fixing). One of the reports on vermicomposting (Umar and Sharif, 2013) reported in a different result. It is showed that organic carbon loss may be in charge of nitrogen enhancement and earthworms also impact on nitrogen cycle changes in manure. In general, the amount of organic C decreases during vermicomposting, while the total N coverage increases (Kızılkaya and Hepşen, 2007; Fatehi and Seayegan, 2010).

The PKF based vermicompost had a higher electrical conductivity (EC) and $CaCO_3$ content than DS+FYM based vermicompost. The T1 application is only lower in number than the others, and in fact, T1 application and T2, T3, and T4 are statistically the same groups (P< 0.05). Kirven (1986) reports that EC values at 2-4 dS m^{-1} for organic materials should be considered moderate, and EC at 4-6 levels should be considered high. Even if the French and Turkish standards on composted EC content are not of a limit value, none of the vermicomposts obtained in this work have exceeded the value specified by Kirven. According to Ansari and Rajpersaud (2012), there was a significant decrease in EC of the initial materials as the vermicomposting process proceeded until a lower EC was attained.

Table 3. Physical and chemical parameters in the vermicompost at the end of the experiment

Applications	T_1	T_2	T_3	T_4	T_5	T_6	NFU[a] Standard	TG[b] Standard	LSD<0.05
TOC, %	43.24a	42.92a	34.56b	30.96b	36.50ab	30.40b	< 15 to 25 % of total matter	<20%	6.510
TN, %	1.60a	1.39a	1.45a	1.23a	1.18a	1.14a	< 1 %*	<0.5*	0.573
P_2O_5, %	1.29	1.23	1.02	1.15	1.35	1.30	< 1 %*	-*	0.480
K_2O, %	2.43a	2.50a	2.52a	2.56a	2.10ab	2.05b	< 1 %*	-*	0,542
C/N	13.51ab	15.43a	11.92b	12.59b	15.46a	13.34ab	> 8	8-22	3.180
$CaCO_3$, %	10.73b	10.15b	10.82b	9.95b	23.08a	24.09a	-	-	6.575
pH	8.41a	8.36a	8.46a	8.51a	8.76a	8.88a	-	-	0.969
EC, dS m^{-1}	1.19b	1.58ab	1.41b	1.26b	1.84a	1.89a	-	-	0.341
Fe, %	0.39	0.50	0.37	0.39	0.31	0.31	-	-	0.150
Cu, mg kg^{-1}	24.60	20.40	18.10	16.10	20.60	19.80	300	450	9.20
Zn, mg kg^{-1}	59.00	55.10	48.00	45.90	46.00	50.00	600	1100	13.06
Ni, mg kg^{-1}	86.90a	84.40a	83.80a	87.00a	64.30b	66.40b	60	120	6.45
Pb, mg kg^{-1}	17.72a	19.55a	12.59ab	10.92b	8.15b	7.25b	180	150	6.48
Cd, mg kg^{-1}	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	3	3	-
Cr, mg kg^{-1}	70.68	60.3	77.67	64.66b	72.70	75.10	120	350	8.13

The PKF based vermicompost had a higher electrical conductivity (EC) and $CaCO_3$ content than DS+FYM based vermicompost. The T1 application is only lower in number than the others, and in fact, T1 application and T2, T3, and T4 are statistically the same groups (P< 0.05). Kirven (1986) reports that EC values at 2-4 dS m^{-1} for organic materials should be considered moderate, and EC at 4-6 levels should be considered high. Even if the French and Turkish standards on composted EC content are not of a limit value, none of the vermicomposts obtained in this work have exceeded the value specified by Kirven. According to Ansari and Rajpersaud (2012), there was a significant decrease in EC of the initial materials as the vermicomposting process proceeded until a lower EC was attained.

On the other hand, there is an increase in EC may have been due to the loss of weight of organic matter and release of different minerals such as phosphate, ammonium, and potassium as suggested by researchers (Garg et al., 2006; Kaviraj and Sharma, 2003; Khwairakpam and Bhargava, 2009; Hait and Tare, 2011). EC is a good demonstration of the suitability of vermicompost materials, and Kitturmath et al. (2007) have stated as press mud in agro-industrial wastes the electrical conductivity of ranged from 0.76 ds m^{-1} to 1.15 ds m^{-1}.

The heavy metal contents of the vermicompost are below the standard values specified in the Turkish Organic Manure Regulation and also French NFU 44051 Standard, and its productivity parameters are of equal quality to those of earthworm manure available in the market (Table 3). The heavy metal content of the organic material used in the vermicomposting significantly influences the compost content. Gupta and Garg (2008) have stated that if vermicompost obtained from sewage sludge, there is an increase in heavy metal concentration. In this study, although the vermicomposts obtained from sugar factory wastes contain heavy metals below the limit values, the heavy metal contents must be followed whilst the compost is obtained from such wastes. Therefore in vermicompost materials, thus the metal contamination in vermicompost is a severe problem, it should not apply directly to agricultural areas.

Conclusion

In this study, it was researched whether vermicompost could be done from DS and PKF which are sugar factory wastes. Eleven orders of DS with PKF and FYM were vermicomposted using a type of earthworm (*Eisenia fetida*) and the living conditions of worms in vermicompost materials were stated in varied feed mixtures. All treatments have a C/N ratio which fulfills the French regulation NFU 44051 standard and the

Turkish Government standard. According to the French Standard, all the treatments vermicompost nearly fulfill the Standard limit value for heavy metals. There is only one heavy metal (Ni) which very close to the limit value of French standards (60 mg kg^{-1} for Ni). But all vermicompost's Ni contents are well below the limit values in the Turkish standard (120 mg kg^{-1} for Ni). The $CaCO_3$ content was higher in treatment T5 (20% DS + 20% PKF + 60% FYM) and treatment T6 (25% DS + 25% PKF + 50% FYM) treatments than that in the T1-T4 treatments because of PKF. PKF has higher $CaCO_3$ as compared to DS and FYM (Table 1). The composts in T1-T4 treatments have a good agronomic quality and a low contaminant and $CaCO_3$, which make them suitable for all agricultural lands and crops. It was possible to obtain the vermicompost by mixing the DS alone or as a 50% mixture with PKF (at most 50%) with the burned FYM as the other half, adding the *Eisenia fetida* into the mixture, composting the mixture for about 12 weeks in the dark under the conditions of an average temperature of 21°C and 65±10% humidity. Our results demonstrate that earthworms survived in treatments which included less than 50% DS or PKF. This study revealed that byproducts of sugar industry can be instumental turned into precious vermicompost with epigeic earthworms *Eisenia fetida.*

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Soil quality assessment for olive groves areas of Menderes District, Izmir-Turkey

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Abstract

This study was carried out to determine assessment of soil quality for olive groves areas of Akçaköy, Çatalca, Efemçukuru, Görece and Yeniköy villages in Menderes district of Izmir-Turkey. The surface soil samples (0-20 cm) were taken from 19 olive groves areas of Menderes District. Soil physical and chemical quality indicators were analyzed and classified in 4 suitability classes for olive production. In olive groves areas, soil reaction (pH) gave positive correlations with clay, exch. Ca, $CaCO_3$ contents, and significant negative correlations with sand, available Fe, Mn and Zn contents. Soil organic matter (OM) content showed significant positive correlations with EC, P, exch. Ca and a significant negative correlation with bulk density. Electrical conductivity (EC) values gave significant positive correlations with clay, OM, exch. Ca contents. Soil quality index values for the olive groves areas ranged between 0.44 and 0.77 with a mean of 0.60. The olive groves areas at Akçaköy and Çatalca villages of Menderes District were generally suitable for olive production. According to the soil quality index (SQI) values, only one of the 19 olive groves areas was found in very suitable (S1:1.00-0.75) class, the other areas were classified as 8 in suitable (S2:0.75-060), 6 in marginal suitable (S3:0.60-0.50) and 4 in non-suitable (N:<0.50) for olive growth. The most restricting soil factors for olive growth generally became low OM, low nutrient contents and high clay and sand contents than that of suggested levels. The SQI values had significant positive relations with silt content of the soils while they gave negative correlations with clay and sand contents. It indicates that moderate or loamy soil textural classes are important for high olive production. The SQI values also gave a significant positive correlation with olive yields. Evaluation of soil physical and chemical properties with a SQI value is important for assessment of olive groves areas in sustainable soil management system.

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Keywords: Soil quality, olive, yield, soil properties.

Introduction

Soil quality plays a great role in plant growth and production with biological transformations, degradation of organic matter, hydrological cycle and chemical reactions in soil. Soil quality covers the functions of sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation within natural or managed ecosystem boundaries (Karlen et al., 1997). Sustainable soil management practices for a specific crop production can be controlled by chemical, physical, and biological soil properties and their interactions (Sofo et al., 2010; Fountas et al., 2011; Palese et al. 2014; Calabrese et al., 2015).

Although olive trees can grow up several soil types, they grow and produce well in moderate or coarse textured soils within a wide range of pH from moderately acid (5.6) to moderately alkaline (8.5) and well drained calcareous soils (El-Kholy, 2010). Fountas et al. (2010) studied on site-specific management in an

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olive tree plantation area in Greece with measuring the penetration resistance, soil texture, soil organic matter, pH, phosphorus, nitrate N, potassium, Mg, Zn, Mn, Fe, B and Ca contents in surface soil samples (0-30 cm) taken a 30-m systematic sampling grid. They found that organic matter content was 22% greater and penetration resistance was 26% less under no-tillage areas, and there was a considerable spatial variation in yield and soil properties. López-Granados et al. (2004) investigated soil variation and site-specific fertilization of nutrients in olive groves farms in southern Spain depending on the spatial variation of leaf nutrients. Calabrese et al. (2015) studied the short-term effects of the grassing on biodiversity and soil quality of Mediterranean ancient olive orchards. They found that few soil quality indicators had responsiveness in indicating the effects of management systems and of the grassing on biodiversity and soil properties. They concluded that there was a clear positive influence of the organic management systems on some soil quality parameters and on biodiversity. Sofo et al. (2010) compared to effects of sustainable and conventional practices on the composition, functional and metabolic diversity of soil microbial communities in a Mediterranean olive orchard. They found that sustainable agricultural practices stimulated soil microorganism activity and improved olive yield and fruit quality. Palese et al. (2014) studied the effect of soil management on soil physical characteristics and water storage in a mature rainfed olive orchard. They found that sustainable soil management techniques, such as cover cropping and pruning recycling, had higher autumn–winter rainwater storage in the soil than the conventional technique based on tillage.

Most soil properties show interaction each other generally related with land use, land characteristics and management practices (Ekberli and Kerimova, 2005; Karaca and Gülser, 2015; Karaca et al., 2018; Kars and Ekberli, 2020). Many studies related to land suitability for crop cultivation have been conducted in different areas (Mandal et al. 2002; Lake et al. 2009; Khormali et al, 2012). Lake et al. (2009) studied land suitability for olive production using simple limitation method. They found that the most limiting factors of land characteristics for olive production were topography, coarse fragement, shallow soil depth, salinity and alkalinity. Similarly Khormali et al. (2009) studied the effects of some soil and topographic characteristics on tea production. They found that solum thickness, thickness of the epipedons, clay content, organic carbon, total nitrogen, carbonate, and exchangeable magnesium were significantly different on different slope positions in the near surface layers, but the differences were not reflected in the tea yield.

Olives are cultivated on 864.000 ha area which comprises 2.3% of agricultural land and 22% of horticultural land in Turkey (Anonymous, 2018). Mediterranean and Aegean regions are the main regions for olive production in Turkey. Most of olive groves areas with 75% are on mountainous land and only 8% of total olive production is under irrigation. While the mean olive production in Turkey between 2010 and 2019 was 1.698.446 ton/year, total olive productions for tables and oil were 415.000 and 1.110.000 tons in 2019, respectively (TUIK 2020). According to these values, the annual mean total olive production in Turkey can be estimated as 1.96 ton/ha year. Chatzistathis et al. (2009) determined that soil types impacted on nutrient uptake and utilization efficiency by olive trees. Álvarez et al. (2007) reported that differences in some soil properties and management effect on specific soil properties varied between soil types. They suggest that farm and soil type should be taken a careful consideration in any attempt to evaluate soil condition in olive groves. There is not much study about soil quality evaluation for a specific crop production. Recently Doğan and Gülser (2019) studied the assessment of soil quality for vineyard fields in western Anatolia. The objective of this study was to determine assessment of soil quality for olive groves areas located in some villages of Menderes District, Izmir-Turkey.

Material and Methods

The village names and locations of 19 olive groves areas of Menderes District of Izmir-Turkey are given in Table 1. In the study, 19 surface soil samples (0-20 cm) were taken from Akçaköy (3), Çatalca (4), Görece (5), Efemçukuru (2) and Yeniköy (5) villages located on the elevations between 138 and 617 m above sea level. After the harvest season completed in 2011, the olive yield (ton/ha) was also recorded for each field.

Some properties of the soil samples were determined using the following methods: particle size distribution by the hydrometer method (Day, 1965); bulk density (BD) by soil core method (Demiralay, 1993), soil reaction (pH) in 1:1 (w:v) soil water suspension by pH meter; electrical conductivity (EC_{25}ºC) in the same suspension by EC meter; and exchangeable cations (Ca, Mg, K, Na) by ammonium acetate extraction (Kacar, 1994), available phosphorus by Olsen's method (Olsen et al., 1954), DTPA extractable Fe, Mn, Zn, Cu according to Lindsay and Norvell (1978). The soil organic matter content was determined by the modified Walkley-Black method (Kacar, 1994). The lime content was determined by Scheibler Calcimeter (Nelson, 1982). Exchangeable Ca, Mg, K and Na (ECaP, EMgP, EKP, ENaP) were calculated with dividing an exch. cation by the sum of exch. cations.

Table 1. Villages and locations of olive groves areas in Menderes District, Izmir-Turkey

Location	Coordinates		Elevation (m)	Location	Coordinates		Elevation (m)
	North 'N'	East 'E'			North 'N'	East 'E'	
Akçaköy-1	38°14.675'	27°05.628'	154	Çatalca-1	38°15.875'	27°04.509'	201
Akçaköy-2	38°15.108'	27°05.873'	145	Çatalca-2	38°15.274'	27°04.485'	179
Akçaköy-3	38°15.616'	27°06.121'	145	Çatalca-3	38°15.838'	27°04.489'	195
Efemçukuru-1	38°16.740'	26°57.939'	617	Çatalca-4	38°15.283'	27°04.774'	189
Efemçukuru-2	38°16.787'	26°57.872'	615	Görece-1	38°16.486'	27°07.721'	138
Yeniköy-1	38°12.271'	27°01.835'	216	Görece-2	38°16.179'	27°07.242'	145
Yeniköy-2	38°12.787'	27°02.497'	202	Görece-3	38°16.352'	27°07.579'	143
Yeniköy-3	38°14.793'	27°03.508'	202	Görece-4	38°16.805'	27°07.870'	174
Yeniköy-4	38°12.351'	27°01.512'	192	Görece-5	38°16.793'	27°07.559'	148
Yeniköy-5	38°12.317'	27°01.782'	219				

To determine the soil quality index values for each olive groves area, the following geometric mean equation was used

$$SQI = \sqrt[n]{a_1 . a_2 . a_3 \ldots\ a_n}$$

where; SQI: soil quality index; a: score of each soil parameter between 1.0 and 0.2 given in Table 2, n is number of soil parameter.

SQI values for olive groves areas were classified as; S_1: between 1.00 – 0.75 as very suitable S_2: between 0.75 – 0.60 as suitable S_3: between 0.60 – 0.50 as marginal suitable and N: < 0.50 as non-suitable for vineyard growth.

The correlations among the research data were performed using the SPSS 17 software package programme.

Results and Discussion

Soil Properties of Some Olive Groves Areas in Menderes District

According to the descriptive statistics of research data given in Table 2, clay content of the areas varied between 10.18% and 41.23% with a mean of 22.13%. While only one area had clay (C) soil textural class, the soil textural classes of the other areas were sandy loam (SL) in 9, sandy clay loam (SCL) in 5, clay loam (CL) in 2, sandy clay (SC) and loam (L). Olive trees generally grow well in moderate to coarse textural and well drained soils (Tombesi and Tombesi, 2007; Chatzistathis et al. 2010; El-Kholy, 2010). Álvarez et al. (2007) reported that soil textural classes in organic and natural olive groves areas in southern Spain were loam or sandy loam. In this study, the soils of olive groves areas have generally coarse or moderate textural classes. The bulk density (Db) values of the soils varied between 1.05 g/cm³ and 1.64 g/cm³. Palese et al. (2014) reported that bulk density values of surface soils (0-20 cm) under sustainable and conventional management in a rainfed olive orchard varied between 1.23 g/cm³ and 1.52 g/cm³. An ideal bulk density to root growth based on sandy loams and loams textural soils should be lower than 1.40 g/cm³ (Leake 2001; Soil Qual. Ins. Staff, 1999). If the bulk density value of these textural soils is higher than 1.63 g/cm³, it may affect plant root growth (Soil Qual. Ins. Staff, 1999). While the Db values of 9 olive groves areas were lower than 1.40 g/cm³, the Db values of 9 areas were between 1.40 g/cm³ and 1.63 g/cm³.

The soil pH values ranged from 5.90 to 7.95 were classified as neutral in 8, slightly acid in 4, moderately acid in 3, slightly alkaline in 1 and moderately alkaline in 3 olive groves areas. An ideal soil pH level for olive growth should be between 6.0 and 7.0 (Leake, 2001). The most suitable soil pH in terms of olive growth is neutral, 10 soil samples were found to be in the ideal pH range. The electrical conductivity of the soils varied between 0.15 dS/m and 0.73 dS/m. According to the classification of Soil Quality Ins. Staff (1999), all of the soils were found in non-saline class. The lime contents of the soils ranged between 0.04% and 54.03%. Ferreira Llamas (1984), reported that lime content range in soil for ideal olive growth should be between 9% and 19%, but olive also groves in the lime content higher than these values in soil. In this study only for soil had lime content values greater than 19%. Gálvez et al. (2004) found that there is a negative correlation between lime content in 0-30 cm soil depth and olive canopy development, the canopy growth restricted when the lime content in soil increased to 58-68 % levels. In this study, there is not much lime content in soils to restrict olive growth.

Table 2. Descriptive statistics for some soil properties, soil quality index values and olive yields (n=19).

	Minimum	Maximum	Mean	Std. Dev.	Skewness	Kurtosis
Clay, %	10.18	41.23	22.13	9.13	0.714	-0.451
Silt, %	14.36	39.95	22.89	7.03	0.891	0.478
Sand, %	26.13	72.55	54.97	12.67	-1.29	1.11
Bulk density, g/cm^3	1.05	1.64	1.38	0.17	-0.35	-1.03
pH (1:1)	5.90	7.95	6.84	0.65	0.140	-1.064
EC, dS/m	0.15	0.73	0.35	0.16	0.798	0.144
$CaCO_3$, %	0.04	54.03	8.84	15.15	1.905	3.266
Organic Matter, %	0.20	2.88	1.55	0.72	0.114	-0.617
Av. P, mg/kg	1.98	94.15	24.16	24.29	1.760	2.874
K, cmol/kg	0.11	0.74	0.33	0.17	0.812	0.222
Ca, cmol/kg	4.06	27.68	12.75	7.60	0.360	-1.150
Mg, cmol/kg	1.01	8.87	3.45	2.13	1.279	0.940
Na, cmol/kg	0.23	0.50	0.31	0.07	1.477	1.936
Exch. K (EKP), %	0.47	8.95	2.73	2.46	1.542	1.523
Exch. Ca (ECaP), %	57.13	90.40	72.87	10.49	0.122	-1.348
Exch. Mg (EMgP), %	7.69	37.36	22.07	8.57	0.027	-1.048
Exch. Na (ENaP), %	0.86	4.84	2.33	1.14	0.639	-0.434
Fe, mg/kg	3.50	23.40	11.24	7.44	0.574	-1.295
Cu, mg/kg	0.50	2.52	1.38	0.62	0.460	-0.776
Mn, mg/kg	7.60	155.76	36.95	41.32	2.268	4.598
Zn, mg/kg	4.78	392.20	59.18	88.04	3.307	12.402
Soil quality index (SQI)	0.44	0.77	0.60	0.10	-0.108	-0.860
Olive yield, ton/ha	1.50	5.00	1.87	1.49	1.040	0.212

The organic matter contents of the soils ranged from 0.20% to 2.88% (Table 2). Ferreira Llamas (1984) reported that soil organic matter content should be at least 1.0% level for olive growth. The organic matter content level of surface soil should be around 3.0% for ideal olive growth (Leake, 2001). While the organic matter contents of 5 soil samples in this study were lower than 1.0%, organic matter contents of 11 soil samples were between 1.0% and 2.5%. The organic matter content of 3 soil samples were only found as suitable for olive growth. The available phosphorus contents were between 1.98 mg/kg and 94.15 mg/kg with a mean of 24.16 mg/kg. Leake (2001) reported that available phosphorus content in soil should be higher than 20 mg/kg, and it should be around 50 mg/kg for ideal olive growth. In this study, available P contents of 12 soil samples were lower than 20 mg/kg and classified as deficient.

The K content and exch. K percentage (EKP) of the soil samples were between 0.11 and 0.74 cmol/kg, and 0.47% and 8.955, respectively. Researchers reported that the K content of soils should be at least 0.26 cmol/kg for good quality olive production and exch. K percentage in soil should be between 3% - 10% for ideal olive growth (Ferreira Llamas 1984; Leake 2001). While the exch. K percentages of 5 soils were more than 3%, the others were lower than this value and classified as K deficient for olive growth. The Ca contents and exch. Ca percentages (ECaP) of the soils were found as between 4.06 cmol/kg and 27.68 cmol/kg, and between 57.13% and 90.40%, respectively (Table 2). The Mg contents and exch. Mg percentages (ECaP) of the soils were between 1.01 cmol/kg and 8.87 cmol/kg, and between 7.69% and 37.36%, respectively. The ECaP and EMgP of olive groves soils should be between 65-75% and between 12-15% (Leake 2001; Du Preez 2005). The ECaP values of 6 soil samples were found less than 65% and the others were higher than this critical value. While the EMgP values of 2 soil samples were found to be less than 12%, 5 of them were between 12-150% and 9 of them were higher than 15%. The Na contents and exch. Na percentages (ENaP) of the soils were found as between 0.23 cmol/kg and 0.50 cmol/kg, and between 0.86% and 4.84%, respectively. The ideal range of ENaP for olive growth was suggested as less than 7.0% (Leake 2001). In this study all olive groves areas had lower ENaP than this critical value. The mean values of available Fe, Cu, Mn, and Zn contents of the soils were 11.24, 1.38, 36.95 and 59.18 mg/kg, respectively (Table 2). Fernández-Escobar (2010) reported that the critical values of DTPA extractable Fe, Cu, Mn and Zn in soil for olive growth are 3 mg/kg, 0.2 mg/kg, 1.4 mg/kg and 0.8 mg/kg, respectively. According to micronutrients, soil requirements for olive growth were suggested as 5-8 mg Mn/kg, 3-5 mg Cu/kg and 10 mg Zn/kg (Du Preez, 2005).

Soil Quality Classification for Olive Groves Areas

The selected soil quality indicators were classified between 1.00 (ideal) and 0.20 (poor) according to the soil requirements of olive plant in the literatures (Ferreira Llamas 1984; Soil Qual. Ins. Staff, 1999; Leake, 2001; Du Preez 2005; Álvarez et al. 2007; Tombesi and Tombesi, 2007; Fernández-Escobar 2010; Chatzistathis et al. 2010; El-Kholy, 2010; Palese et al. 2014) and given in Table 3.

Table 3. Suitable classes of some soil properties for olive growth.

Suitable classes	Ideal	Good	Moderate	Poor
Score	**1.0**	**0.8**	**0.5**	**0.2**
Soil texture*	L, SCL	CL, SiCL, SiL	C, SiC	others
Bulk density, g/cm^3	<1.2	1.2-1.4	1.4-1.6	>1.6
pH (1:1)	6.8-7.3	6.0-6.8 or 7.3-8.0	6.0-5.0 or 8.0-8.5	<5.0 or >8.5
EC dS/m	<2.7	2.7-3.8	3.8-6.0	>6.0
Organic matter, %	>2.5	2.5-2	2-1	<1
Phosphorus, mg/kg	50-20	20-10	10-5	<5
Ca, cmol/kg	>12	12-10	10-8	<8
Mg, cmol/kg	>2	2-1.6	1.6-1.2	<1.2
K, cmol/kg	>0.60	0.60-0.40	0.40-0.20	<0.20
$CaCO_3$, %	9-19	7-9 or 19-22	7-5 or 22-25	<5 or >25
Zn, mg/kg	>15	15-10	10-5	<5
Mn, mg/kg	>8	8-5	5-2	<2
Cu, mg/kg	>5	5-3	3-1	<1
Fe, mg/kg	>5	5-2	2-1	>1

*L: loam, Si: silt, C: clay, S: sand

The soil quality index values calculated for the olive groves areas varied between 0.44 and 0.77 with a mean of 0.60 (Table 2). The olive groves areas at Akçaköy and Çatalca villages were generally found to be suitable for olive production (Figure 1A). The 4 olive groves areas at Efemçukuru, Görece and Yeniköy villages were found to be non-suitable for olive growth and classified in N class. According to the frequency distribution of soil quality classes given in Figure 1B, only one (5.3%) of the 19 olive groves areas was determined as very suitable (S1) class, and the other areas were classified as; 8 areas (42%) in suitable (S2), 6 areas (31.6%) in marginal suitable (S3) and 4 areas (21%) in non-suitable (N) class for olive growth.

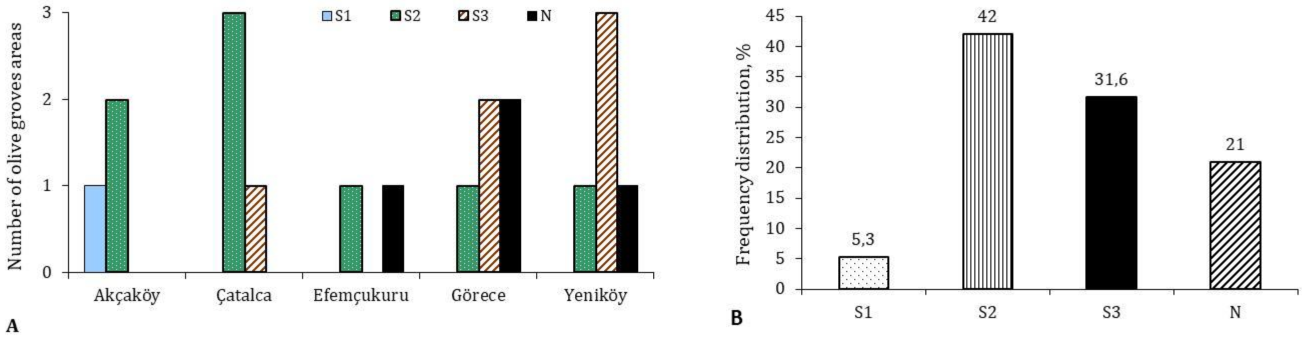

Figure 1. A) Soil quality classification of olive groves areas at different locations; B) Frequency distribution of soil quality classes (S_1:very suitable S_2: suitable, S_3:marginal suitable, N:non-suitable).

Restricting soil factors for olive growth in the areas classified as S_2 generally became lower OM, exch. K and $CaCO_3$ contents than that of the suggested levels. Non suitable soil texture, lower OM, exch, Ca, exch. K, $CaCO_3$ and available Cu contents were the restricting soil factors for olive groves areas classified as S_3. Except EC, available Zn, Mn and Fe contents, all physical and chemical soil properties of the olive groves areas classified as non-suitable (N) were lower than that of the suggested levels. Lake et al. (2009) determined that the most important restricting factors for olive production were coarse fragment, shallow soil depth, salinity and alkalinity. Leake (2001) indicated that most soils in the areas of interest to olive growers can suffer the some productivity problems such as; low organic matter content. Low to very low soil fertility, a strong texture contrast between surface and sub horizons, acidity and sodicity. Doğan and Gülser (2019) reported that the restricting soil factors for vine growth fields classified as suitable (S2) and marginally suitable (S3) classes generally became low pH, lower organic matter, P, Fe, Mn, Cu, Mg and K contents than that of suggested levels.

The correlation matrix among the soil properties are given in Table 4. Soil reaction (pH) had positive relations with clay, exch. Ca, $CaCO_3$ contents, significant negative relations with sand, available Fe, Mn and Zn contents. Organic matter (OM) content had significant positive correlations with EC, P, exch. Ca and a significant negative correlation with Db. Electrical conductivity (EC) values had significant positive correlations with clay, OM, exch. Ca contents. There were also significant positive correlations among DTPA extractable micro nutrient contents of soils. Gülser et al. (2015) reported that compost and organic residue applications to soil in a hazelnut orchard increased plant available nutrient contents of the soil and OM content had significant positive relations with EC, exch. Ca, and sum of exch. cations. In another study, Candemir and Gülser (2011) determined that soil bulk density decreased with organic waste addition, and bulk density had generally significant negative relations with OM and other soil properties. They reported that the soil quality indicators of clay and loamy sand soils improved by different agricultural waste applications.

Table 4. Correlation matrix among the soil properties of vineyard fields.

	Si	S	Db	pH	EC	OM	P	K	Ca	Mg	Na	$CaCO_3$	Fe	Cu	Mn	Zn
C	0.22	**-0.84****	-0.45	**0.60****	**0.48***	0.27	-0.11	0.02	**0.68****	**0.51***	**0.51***	**0.66****	**-0.62****	-0.23	-0.36	-0.25
Si		**-0.71****	0.06	0.27	0.05	0.13	0.09	-0.21	0.20	-0.38	-0.10	0.29	-0.08	-0.23	-0.08	-0.12
S				**-0.58****	-0.37	-0.27	0.03	0.10	**-0.60****	-0.16	-0.31	**-0.64****	**0.49***	0.29	0.31	0.25
Db				-0.04	-0.43	**-0.56***	0.05	-0.21	**-0.73****	**-0.61****	-0.20	-0.16	0.19	0.11	-0.18	-0.12
pH					0.18	-0.01	-0.07	-0.28	**0.54***	0.14	0.19	**0.61****	**-0.78****	-0.26	**-0.64****	**-0.52***
EC						**0.57****	0.23	0.09	**0.51***	0.32	0.36	0.20	-0.18	0.41	0.14	0.41
OM							**0.49***	0.44	**0.54***	0.01	-0.04	0.08	0.03	0.25	0.10	0.23
P								**0.54***	0.08	-0.10	0.31	-0.16	0.21	0.30	-0.15	-0.08
K									-0.06	0.23	0.19	-0.16	0.32	0.08	-0.14	-0.12
Ca										**0.47***	0.27	0.41	**-0.66****	-0.11	-0.32	-0.20
Mg											**0.61****	0.23	-0.40	-0.18	-0.19	-0.22
Na												0.09	-0.32	-0.13	-0.18	-0.14
$CaCO_3$													-0.43	-0.33	-0.33	-0.29
Fe														0.40	**0.69****	**0.57***
Cu															0.33	**0.58****
Mn																**0.88****

** significant at 0.01 level, *significant at 0.05 level.

According to the correlation matrix among the SQI, olive yield and soil properties, the SQI values had a significant positive correlation with silt content while SQI values gave negative correlations with clay and sand contents of soils (Table 5). It indicates that olive trees grow very well in well drained moderate textural soils. Soil quality index values of the olive groves areas had also a significant positive correlation with olive yields at 5% level (Figure 2). The olive yields had positive correlations with Si, Db, OM, P, exch. K, available Fe, Cu and Zn contents of the soils and negative correlations with clay, sand, pH, exch. Ca, Mg Na, $CaCO_3$ and available Mn contents (Table 5).

Table 5. Relationships among the soil quality index (SQI) values, grape yield and soil properties.

	O. Yield	C	Si	S	Db	pH	EC	OM	P
SQI	0.458*	-0.159	0.574*	-0.204	0.151	0.068	-0.024	0.098	0.243
Olive Yield	1	-0.174	0.300	-0.040	0.192	-0.069	0.228	0.375	0.187

	K	Ca	Mg	Na	$CaCO_3$	Fe	Cu	Mn	Zn
SQI	0.077	-0.025	-0.181	-0.173	0.093	-0.003	-0.361	-0.230	-0.356
Olive Yield	0.136	-0.024	-0.269	-0.352	-0.098	0.054	0.341	-0.048	0.062

In this study, soil OM contents generally were lower than 3.5%, which is a major threshold for soil OM level, and a potentially serious decline in soil quality occurs below this value (Loveland and Webb, 2003). Generally increasing soil OM content increased soil nutrient contents, olive yield and SQI values and reduced bulk density values. Soil organic matter improves soil structure and soil physical quality by increasing porosity and reducing bulk density (Gülser, 2004; Gülser 2006; Candemir and Gülser 2011). There are functional relationships between plant nutrition, fertility and soil properties (Ekberli and Kerimova, 2008; Bayram and Gülser, 2018). Demir and Gülser (2015) reported that the compost application improved soil quality with increasing the water holding capacity, EC, OM content, exch. Mg, K and available P contents and decreasing Db, pH, Na and Ca contents, and increased tomato yield under greenhouse condition. In this study, the olive yields increased with increasing SQI values due to moderate textural class, high OM, nutrient contents.

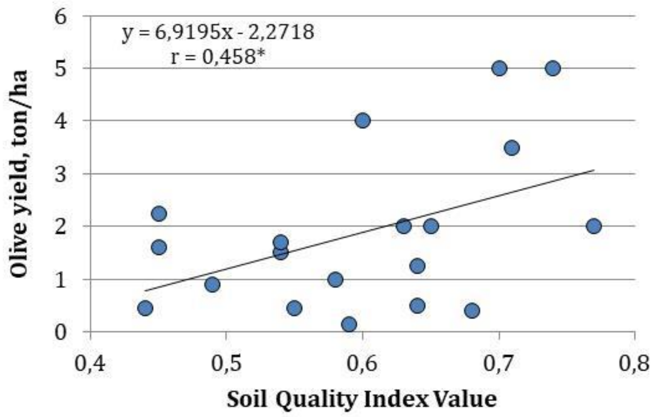

Figure 2. Relationship between soil quality index values and olive yields

Conclusion

In this study, soil quality of 19 different olive groves areas located in Menderes district of İzmir-Turkey were assessed according to soil quality indicators. While the most of olive groves areas (47.3%) classified in very suitable (S_1) and suitable (S_2) classes, the other areas were classified as marginal suitable (31.6% S_3) and non-suitable (21% N) classes for olive growth. Restricting soil factors for olive growth were generally low soil OM, lime and nutrient contents. Generally low OM and exch. K and Ca contents, high clay and sand contents of the soils reduced soil quality for olive growth. The moderate or loamy textural classes are important for olive production. The olive yields of the areas had a significant positive correlation with SQI values which increased by increasing the suitable soil physical and chemical characteristics of the olive groves areas. It can be concluded that soil quality of the olive groves areas plays an important role for high olive production and it should be considered in sustainable soil management systems.

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Transformation of soil texture schemes and determination of water-physical properties of soils

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Abstract

Measuring soil water-physical properties is laborious, time-consuming, and expensive. That provokes a lot of scientists to estimate them which action is troubled by the usage of different soil texture classification systems. The study proposes a rapid, reliable, and universally applicable methodology for soil textural transformations between different classification systems. The method of discrete mathematics is applied to make the conversion of particle-size classes from the Kachinsky system, which is used in Bulgaria to the International systems. Three different data sources were used to determine the water-physical properties of soils from textural data - 376 soil profiles from Bulgaria, extraction from the SoilGrids system for the Plovdiv district in Bulgaria and data from CanSIS/NSDB database. The relationship between the dependent variables field capacity (FC), wilting point (WP) and bulk density (BD), and independent variables sand, silt, and clay soil content was sought in the form of a regression equation. The applied stepwise regression procedure produces a close dependence between the soil texture and its water-physical properties.

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Introduction

In the near past, the Bulgarian experience in applying methods tried to unify the most used soil texture schemes and to find equations for estimating soil properties from soil texture data. Kolev et al. (1996) determined a regression model to convert from a texture-based soil classification system used in Bulgaria to the classification system described in Van Keulen and Wolf (1986). They show also that soil moisture content at complete saturation, field capacity and wilting point can be predicted from soil texture data using the exponential approach suggested by Van Keulen. Another study determines the coefficients in the regression dependencies between the measured W33 and W1500 (in % by mass) - these are field capacity (FC) and wilting point (WP), and the content of clay (Cl) and organic carbon (OC) from the horizons of the 4 profiles (Dimitrov and Kercheva, 2016).

Rousseva (1997) defined closed-form models of exponential and power-law for data transformations between the three worldwide used soil texture schemes: Kachinsky's (Kachinsky, 1956), the International system suggested by Robinson (1927) and approved by the Second International Congress of Soil Science in Leningrad (Sokolovsky and Kachinsky, 1930), and USDA (Soil Survey Staff, 2017). The author defines that exponential function describes better fine-textured soils, while closed-form power functions recreate better coarse-textured soils. The defined functions represent cumulative particle-size distribution curves.

Nowadays we need a rapid, reliable, and universally applicable methodology for soil textural transformations between different classification systems and for determining the water-physical properties of soils from textural data. It was suggested that it would seem wise for most countries to consider adopting

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the particle-size limits and texture classes of the USDA/FAO system (Minasny and McBratney, 2001). They presented empirical equations to convert between the two systems.

Measuring soil water-physical properties is laborious, time-consuming, and expensive. That is why many scientists (Van Genuchten, 1980; Van Genuchten and Nielsen, 1985; Van Keulen and Wolf, 1986) try to define a way to predict them. The prediction of soil water-physical properties is also embarrassed by the usage of different soil texture classification systems.

Vereecken et al. (1989) already established relations for estimating the parameters of a modified Van Genuchten equation from basic soil properties based on 182 measured moisture retention characteristics (MRC). Using nonlinear regression the authors evaluated the link between soil data as bulk density, carbon content, and particle size distribution and the estimated values of the four Van Genuchten equation parameters for a wide range of textures. They defined that the parameters of the modified Van Genuchten equation, describing MRC, can be estimated as a function of those three soil properties with reliable accuracy.

An equation for water conductivity was derived depending on sand and clay content (in %), and the moisture content using 230 data points (Saxton et al., 1986). Several equations for soil water characteristic estimates are given in (Saxton and Rawls, 2006). Some of them are moisture regressions with independent variables sand, clay, and organic matter. Forty-eight pedotransfer equations of the bulk density depending on the sand, silt, clay, and organic matter have been evaluated (Abdelbaki, 2018). Børgesen et al. (2008) found that introducing measured water content as a predictor generally gave lower errors for water retention predictions. Manrique et al. (1991) show that available water capacity was not related to the organic carbon content in almost all types of soils. Some research shows that cation exchange capacity was a more important factor for estimating field capacity and wilting point than clay and organic matter content (Nourbakhs et al., 2004). Soil bulk density is mainly related to the soil carbon content (Rodríguez-Lado et al., 2015).

A review of research (Fredlund et al., 1997) showed two approaches in the prediction of the soil-water characteristic curve (SWCC) from grain-size. The first approach uses a statistical estimation of properties describing the SWCC from grain-size and volume-mass properties (Ahuja et al., 1985). The second approach was theoretical and involved converting the grain-size distribution to a pore-size distribution which was then developed into an SWCC (Arya and Paris, 1981). Shein et al. (2014) made a comparative evaluation of different methods of obtaining hydrophysical information for accurate predictive modeling to forecast water movement in soils. But all the results are given only for one type of soil. The book of Pachepsky and Rawls (2004) provides the unique compendium of pedotransfer functions and shows how the value of soil data can be increased by using them in pedotransfer functions to predict soil hydrologic and related properties.

A major drawback of several results is that they determine the water-physical properties depending on thetexture only for particular soil types. In the United States, twelve major soil texture classifications are defined by the United States Department of Agriculture (Soil Survey Staff, 2017), (Figure 1).

We offer a generalized approach that relates these properties to all soil types and soil profile horizons.

A new Bulgarian transformation methodology of soil textural classification from Bulgarian (adopted Kachinsky's) to the ISSS and the USDA systems is suggested. And more important we propose a method for determining the water-physical properties of soils (field capacity, wilting point, and soil bulk density), based on data on the particle-size distributions of the soil on which the crops are grown.

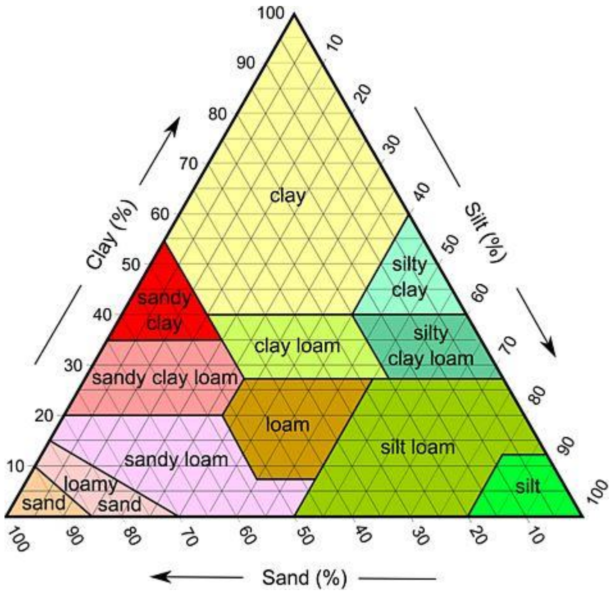

Figure1. Soil textural classification used by the United States Department of Agriculture

Material and Methods

Particle-size classes (mm) when determining soil texture in Bulgaria follow the system of Kachinsky (Kachinsky, 1943; 1965; Antipov Karatev, 1960):

(<0.001); (0.001-0.005); (0.005-0.01); (0.01-0.05); (0.05-0.25); (0.25-1.0); (>1.0).

In the description of soil profiles we found the next (Figure 2):

Effective diameter mechanical elements of soil (mm)	Kachinsky Classification 1937		Bulgarian Classification		
> 3	Stones		> 3	Stones	
2 - 3	Gravel		1 - 3	Gravel	
1 - 2	Sand	large			
0.5 - 1.0		medium	0.5 - 1.0	Sand	large
0.25 - 0.5		small	0.25 - 0.5		medium
0.05 - 0.25			0.05 - 0.25		small
0.01 - 0.05	Silt	large	0.01 - 0.05	Silt (dust)	large
0.005 - 0.01		medium	0.005 - 0.01		medium
0.002 - 0.005		small	0.001 - 0.005		small
0.001 - 0.002					
0.0005 - 0.001	Clay	rough	< 0.001	Clay	
0.0001 - 0.0005		thin			
< 0.0001		coloids			
> 0.01	Physical sand		> 0.01	Physical sand	
< 0.01	Physical clay		< 0.01	Physical clay	

Figure 2. Comparison of Kachinsky 1937 classification and Bulgarian (adopted Kachinsky's) classification of particle size classes.

It is not compatible with the International and USDA systems for determination of Clay, Silt and Sand content in the soil. As noted, in the classification of Kachinsky, except these three classes, are adopted and more fractional divisions within individual fractions. The exact physical justification for such a more fractional division of Kachinsky in his writings does not give. This is the first serious moment to discuss the possibilities of transition from one classification to another (Shein, 2009). It is the reason for application by us the apparatus of discrete mathematics in the following way.

We now define a set (Rosen, 2012).

Definition 1. A set is an unordered collection of objects, called elements or members of the set.

A real interval x is a nonempty set of real numbers

$$A = [a, b] = \{x \mid a \leq x \leq b\}$$

where a is called the infimum and b is called the supremum.

Definition 2. Let A and B be sets. The intersection of the sets A and B, denoted by A ∩ B is the set containing those elements in both A and B.

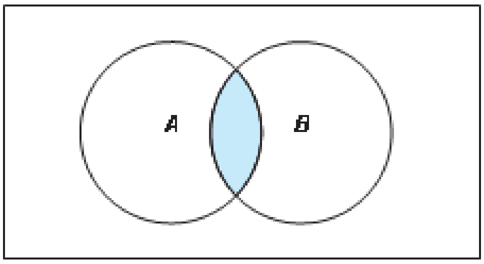

Figure 3. Venn diagram of the intersection of A and B. A ∩ B is shaded.

The Venn diagram shown in Figure 3 represents the intersection of two sets A and B. The shaded area that is within both the circles representing the sets A and B is the area that represents the intersection of A and B. The intersection obeys to the next laws:

Commutative law A ∩ B = B ∩ A

Associative law A ∩ (B ∩ C) = (A ∩ B) ∩ C

We apply these results from discrete mathematics to make the conversion of particle-size classes from the Kachinsky system, which is used in Bulgaria to the International system.

Let A = [a1, b1] and B = [a2, b2],

then A ∩ B = [max (a1, a2), min (b1, b2)]

The measurement of soil bulk density is expensive and time-consuming, thus it is a parameter often excluded from ordinary soil analyses. Pedotransfer functions have been proposed as an alternate solution to determine soil bulk density from soil texture and soil organic matter content (Rodríguez-Lado, 2015). In our study data from 376 determinations of soil texture (measured in % by Kachinsky's method) and water-physical properties - field capacity in mm (FC), wilting point in mm (WP) and bulk density in g.cm^{-3} (BD) from different profiles of Bulgarian soils were the objects of our analysis (Teoharov et al., 2009; Dilkova, 2014). As determinations of soil organic carbon (SOC) content were not available for many of these profiles, SOC is not included in our analysis. Below are the statistical properties of variables in the analysis (Table 1).

Table 1. Descriptive Statistics (Bulgarian Soils)

Variable	Valid N	Mean	Median	Minimum	Maximum	Std.Dev.	Skewness	Kurtosis
FC	345	57.24	46.00	5.00	216.00	36.4796	1.6174	2.8769
WP	297	14.90	14.07	2.80	41.80	6.9901	0.7247	0.5365
BD	345	1.40	1.41	0.97	1.85	0.1612	-0.1664	-0.1918
Sand	376	42.14	40.15	16.78	82.68	14.0166	0.5751	-0.3241
Silt	376	20.47	20.20	7.70	46.53	5.6575	0.5196	0.8475
Clay	376	33.64	33.24	4.93	61.05	14.2417	0.0396	-1.0987

To reduce the gap between soil data demand and availability, ISRIC (International Soil Reference Information Centre) released a Global Soil Information system called "SoilGrids" (Hengl et al., 2017). The most recent and improved version of the SoilGrids system at 250m resolution provides global predictions for standard numeric soil properties (organic carbon, bulk density, cation exchange capacity, pH, soil texture fractions, and coarse fragments, soil water content at 33kPa and soil water content at 1500kPa). We made extraction from data file at 10 cm soil depth for the Plovdiv district in Bulgaria containing predicted values of the same variables. Here are their statistical properties (Table 2).

Table 2. Descriptive Statistics (Plovdiv district)

Variable	Valid N	Mean	Median	Minimum	Maximum	Std.Dev.	Skewness	Kurtosis
FC	264311	33.06	33.00	23.00	47.00	1.9223	-0.0157	-0.6275
WP	264311	15.25	16.00	7.00	25.00	2.1421	0.3926	0.0622
BD	264311	1.29	1.35	0.61	1.66	0.1774	0.6884	0.6965
Sand	264311	36.08	36.00	12.00	58.00	6.8423	0.1713	0.5595
Silt	264311	40.26	40.00	22.00	52.00	2.8555	-0.0468	-0.4911
Clay	264311	23.66	24.00	8.00	48.00	5.0258	-0.0711	-0.3980

It is evident that a very large number of point data are available for our analysis.

To make comparisons with data from another country we select data from CanSIS/NSDB database, which is explained in the Manual (MacDonald and Valentine, 1992). Below are their statistical properties (Table 3).

Table 3. Descriptive Statistics (Canadian Soils)

Variable	Valid N	Mean	Median	Minimum	Maximum	Std.Dev.	Skewness	Kurtosis
FC	54274	27.03	28.00	0.00	70.00	11.6470	-0.0553	-0.8312
WP	54274	14.23	14.00	0.00	50.00	7.7475	0.3695	-0.5024
BD	54274	1.41	1.40	0.10	2.13	0.1812	-0.0137	2.1839
Sand	54274	44.92	43.00	0.00	100.00	26.6372	0.1936	-1.0346
Silt	54274	33.30	34.00	0.00	94.00	16.7135	0.1172	-0.3662
Clay	54274	21.78	18.00	0.00	96.00	16.2006	1.1272	1.1713

Having such a large amount of data on soil texture and water-physical properties is a prerequisite for drawing reliable conclusions about the relationships between them.

Results and Discussion

Bulgarian intervals follow Kachinsky's system and they do not correspond to USDA and ISSS classes. We are considering the ISSS intervals before FAO (2006) guidelines. Two of the intervals (0.001 - 0.005) and (0.01 - 0.05) should be split into parts to conform to the ISSS system.

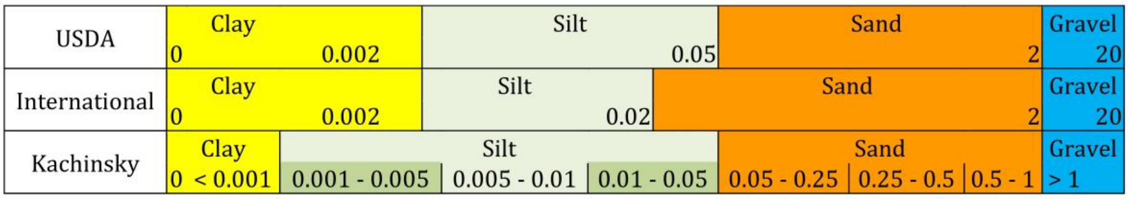

Figure 4. Relationships particle-size (mm) of the USDA, ISSS, and Kachinsky systems.

Applying the exposed method from discrete mathematics is obtained with MATLAB code:

K1 = [0.001,0.002,0.003,0.004,0.005]; Kachinsky interval (0.001 - 0.005)
I1 = [0.001,0.002]; ISSS interval (0.001 - 0.002)
Clay = intersect (K1, I1); = (0.001,0.002), (Figure 5)

Analogous

K2 = [0.01,0.02,0.03,0.04,0.05]; Kachinsky interval (0.01 - 0.05)
I2 = [0.01,0.02]; ISSS interval (0.01 - 0.02)
Silt = intersect (K2, I2); = (0.01,0.02), (Figure 6)

Figure 5. Splitting interval K1 in proportion 1:3.

Figure 6. Splitting interval K2 in proportion 1:3.

Here we have formulas for conversion from Bulgarian (adopted Kachinsky's) to the ISSS system, which are used in our analysis:

Clay = (<0.001) + 1/4(0.001-0.005);
Silt = 3/4(0.001-0.005) + (0.005-0.01) + 1/4(0.01-0.05);
Sand = 3/4(0.01-0.05) + (0.05-0.25) + (0.25-1.0) + (>1.0);
Gravel = 100 - (<0.001) + (0.001-0.005) + (0.005-0.01) + (0.01-0.05) + (0.05-0.25) + (0.25-1.0) + (>1.0).

Interpolation of the intervals is linear, which gives easier and better approximation than results derived according to the logarithmic scale.

Bulgarian intervals also do not correspond to the USDA and classes. The interval (0.001 - 0.005) should be split into parts to conform to the USDA system. The corresponding MATLAB code is:

K1 = [0.001,0.002,0.003,0.004,0.005]; Kachinsky interval (0.001 - 0.005)
US1 = [0.001,0.002]; USDA interval (0.001 - 0.002)
Clay = intersect (K1, US1); = (0.001,0.002), see Figure 5 and 7.

Next

K1 = [0.001,0.002,0.003,0.004,0.005]; Kachinsky interval (0.001 - 0.005)
K2 = [0.005,0.01]; Kachinsky interval (0.005 - 0.01)
K3 = [0.01,0.05]; Kachinsky interval (0.01 - 0.05)
US2 = [0.002,0.05]; USDA interval (0.002 - 0.05)
K = union (K1, K2); K = union (K, K3); Combining 3 Kachinsky intervals into
K = [0.001,0.002,0.003,0.004,0.005,0.01,0.05];
Silt = intersect (K, US2); = (0.002,0.05) (Figure 7)

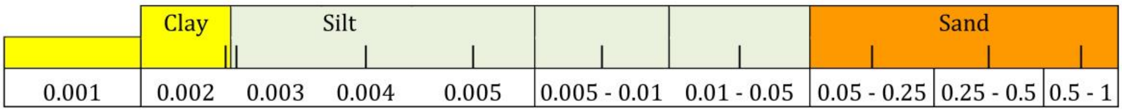

Figure 7. Splitting interval K1 in proportion 1:3 and combining with K2 and K3 intervals.

Here we have formulas for conversion from Kachinsky to the USDA system, which are used in our analysis:

Clay = (<0.001) + 1/4(0.001-0.005);
Silt = 3/4(0.001-0.005) + (0.005-0.01) + (0.01-0.05);
Sand = (0.05-0.25) + (0.25-1.0) + (>1.0);
Gravel = 100 - (<0.001) + (0.001-0.005) + (0.005-0.01) + (0.01-0.05) + (0.05-0.25) +(0.25-1.0) + (>1.0).

Continuous pedo-transfer functions (PTF) consisted of multiple linear regression models predicting soil moisture content are using several combinations of independent soil variables (Dobarco et al., 2019). The choice of the soil variables used as arguments for continuous PTFs was based on their correlations with soil moisture content and the evaluation of multicollinearity among variables. The independent variables clay content, sand content, soil organic carbon, and bulk density were chosen to elaborate the PTFs for all horizons.

The disadvantage of this approach is that it does not include the silt content but includes the bulk density, which is one of the dependent variables to be regressed. Also, several regression procedures (stepwise regression, etc.) are known based on the consistent use of some criterion for the significance of the regression coefficients. These procedures are dangerous and can lead to meaningless results, since the latter depends on the pre-selected level of significance, the actual order in which the variables are included or excluded from the model and no biological constraints on the variables are taken into account. For these reasons, the generation of different models is done by reverse elimination, starting with the model containing all possible members for a given class of models and rejecting the members one by one in succession. The selection procedure ends when the external criterion the corrected coefficient of multiple determination reaches its maximum value (Sadovski, 1998). This is equivalent to the condition that all regression coefficients have values greater than their errors, i.e. the criterion $t > 1$.

The relationship between the dependent variables Y field capacity, wilting point and bulk density, and independent variables soil sand, silt, and clay content was sought in the form of the following regression equation:

$$Y = b0 + b1 \times Sand + b2 \times Silt + b3 \times Clay.$$

Applying this selection procedure, it turns out that the constant term of the equation is zero (b0 = 0), and thus we obtain the following results from the regression analysis for the Bulgarian soils, for Plovdiv district and the Canadian soils.

a) Regression equations for Bulgarian soils:

$FC = 0.2718 \times Sand + 0.2497 \times Silt + 1.2323 \times Clay$, Adjusted $R^2 = 0.755$.
$F(3,335) = 347.74$, Std. Err. of estimate: 33.436.

$WP = 0.0190 \times Sand + 0.0253 \times Silt + 0.3922 \times Clay$, Adjusted $R^2 = 0.928$.
$F(3,286) = 1236.1$, Std. Err. of estimate: 4.4356.

$BD = 0.0172 \times Sand + 0.0133 \times Silt + 0.0138 \times Clay$, Adjusted $R^2 = 0.986$.
$F(3,335) = 7867.5$, Std. Err. of estimate: 0.16677.

b) Regression equations for Plovdiv district:

$FC = 0.2992 \times Sand + 0.2869 \times Silt + 0.4527 \times Clay$, Adjusted $R^2 = 0.997$.
$F(3,264308) = 3083E+4$, Std. Err. of estimate: 1.7675.

$WP = 0.0747 \times Sand + 0.0922 \times Silt + 0.3765 \times Clay$, Adjusted $R^2 = 0.928$.
$F(3,264308) = 7911E+3$, Std. Err. of estimate: 1.6157.

$BD = 0.0033 \times Sand + 0.0150 \times Silt + 0.0241 \times Clay$, Adjusted $R^2 = 0.986$.
$F(3,264308) = 9150E+3$, Std. Err. of estimate: 0.12718.

c) Regression equations for Canadian soils:

$FC = 0.0756 \times Sand + 0.3336 \times Silt + 0.5749 \times Clay$, Adjusted $R^2 = 0.965$.
$F(3,54271) = 5013E+2$, Std. Err. of estimate: 5.4926.

$WP = 0.0281 \times Sand + 0.1304 \times Silt + 0.3958 \times Clay$, Adjusted $R^2 = 0.942$.
$F(3,54271) = 2918E+2$, Std. Err. of estimate: 3.9137.

$BD = 0.0154 \times Sand + 0.0127 \times Silt + 0.0137 \times Clay$, Adjusted $R^2 = 0.986$.
$F(3,54271) = 1243E+3$, Std. Err. of estimate: 0.1705.

Remark: Determinations of the three textural classes do not give a sum of 100%, so they may be considered as almost independent variables.

The results obtained show a well-expressed close dependence between the soil texture and its water-physical properties. It is natural to expect that the corresponding coefficients in the regression equations for the individual water-physical properties will be different for different territories and countries. This difference can be explained by the different conditions in the formation of the soil cover and should be related to the local climatic conditions, respectively to the ecological zoning under the Köppen-Geiger system.

Conclusion

The method of discrete mathematics is applied to make the conversion of particle-size classes from the Kachinsky system, which is used in Bulgaria to the International systems. Corresponding conversion formulas have been found to convert Bulgarian intervals of particle distribution to USDA and ISSS particle-size system. On the data basis of 376 soil profiles from Bulgaria, extraction from the SoilGrids system for the Plovdiv district in Bulgaria and data from CanSIS/NSDB database determinations of soil texture and water-physical properties (field capacity, wilting point, and bulk density) are analyzed. Having such a large amount of data is a prerequisite for drawing reliable conclusions about the relationships between them. The established regression equations have a high coefficient of determination which means they can, therefore, be used to determine water-physical properties of soils from soil texture. The coefficients of regression equations for different territories will differ. This is easily explained by their difference in their ecological zoning. A future study of the relationship between the soil texture and the classes of Köppen for different territories is envisaged.

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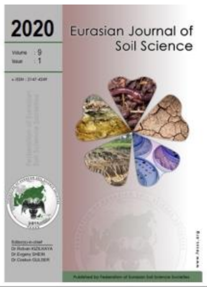

Changes in some soil properties of wheat fields under conventional and reduced tillage systems in Northern Iraq

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Abstract

In this study, the effects of reduced tillage (RT) and conventional tillage (CT) systems on some soil properties of wheat fields in Northern Iraq (Duhok Province) under a hot and dry climatic condition were investigated. This study was carried out in a randomized plot design with four replications at three locations (Bardrash, Sumail, and Zakho) in the seasons 2017-2018. Four fields in each location at Duhok Province were equally separated into two groups for CT and RT systems. A group of 24 soil samples for each tillage system were taken from the locations. Soil organic matter content, pH, EC, bulk density and total porosity values were significantly ($p<0.05$) affected by different tillage systems. Soil pH, EC and bulk density values generally significantly reduced with the RT compared with CT. On the other hand, soil OM content and total porosity were significantly increased with the RT system in all locations under a hot and dry climatic condition. In all locations, RT system decreased bulk density and increased total porosity with conserving soil OM due to preventing from rapid mineralization. However, rapid mineralization of soil OM in the CT system under dry climate condition caused increases in EC which indicated that there were high soluble ions in soil solution.

Keywords: Soil properties, conventional tillage, reduced tillage, wheat.

Introduction

Wheat (*Triticum* spp.) is one of the main crops used for human food and animal feed in temperate and dry-land areas around the world. The main factors influencing the production and yield of wheat are generally crop rotation, tillage system, and plant residue managements. In northern Iraq, rainfed agriculture with intensive cereal cultivation for decades resulted in reduced wheat productivity due to topsoil loss and degradation of many fields (Izaurralde et al., 2006; Brunel et al., 2011), hence, early symptoms of erosion are undetectable by simple observations (Fenton et al., 2005; Larney et al., 2009). In traditional tillage, depth of topsoil and clay content increase as a consequence of mixing with finer particles from lower horizons; this material has low levels of organic matter, and these characteristics are then transferred to the new upper horizon (Frye et al., 1982; Christensen and McElyea, 1988; Gülser et al. 2016). Furthermore, the loss of topsoil is followed by an increase in bulk density, structural deterioration, and alteration of the total porosity with various suppressing effects on crop yield (Gollany et al., 1992; Malhi et al., 1994). Thus, the depth of topsoil has been proved a significant parameter in determining soil quality and land productivity (Larney et al., 2009).

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Reduced tillage (RT) in the developing systems with wheat residue mulching in the northern Iraq is an alternative technology to protect the sub-soil against compaction and erosion by water. It can reduce water run-off throughout the year, reduce evaporative loses and increase water infiltration and also can increase the stability of the soil by increasing organic matter content as well as a source of nutrients particularly P, K, Mg and biological activity (Dexter et al., 2004; Czyz and Dexter, 2008; Malecka et al., 2016; Gajda et al., 2017). Reduced tillage affects some soil physical properties in the top layers such as; bulk density (Gajda et al., 2017), water content, aggregate stability (Rasmussen, 1999) and soil physical quality (Dexter, 2004). Horak et al. (2014) studied the short-termeffects of conventional and reduced tillage with and without nitrogen fertilizer applications on soil respiration rate during 40 days. They reported that there was not a significant difference in CO_2 emmision rates between conventional and reduced tillage systems. Ali et al. (2016) determined the effects of zero tillage and conventional tillage practices and row spacing on growth and yield of wheat. They found that zero tillage significantly enhanced yield components of wheat plants as compared to conventional tillage, and zero tillage and narrow row spacing (15 cm) had higher wheat yield for the wheat-maize rotation system in semi-arid regions. Vakali et al. (2011) determined that reduced tillage practices improved soil physical and biological properties without detrimentally affecting root growth of cereals under organic farming.

In the developing regions of Northern Iraq, crop yields decreases because of variety of reasons, such as lack of adequate tillage equipment and inadequate knowledge of farmers about the management of crop residues, the persistence of heavy residues in wet soil, pest and disease problems, weed control (Hejazi et al., 2010). Growing without crop rotation with heavy residues and stubble burning after harvesting for rapid seed preparation leads to loss of soil organic matter and reduction of fertility. The aim of this research was to compare the effects of conventional and reduced tillage systems on some soil properties of rainfed wheat grown fields located in Duhok Province of Northern Iraq having a dry climatic condition.

Material and Methods

The experimental locations were selected from the local wheat farmer's fields at Bardrash, Sumail, and Zakho of Duhok Province in the Northern Iraq (Table 1, Figure 1). The climate of geographical sites showed considerable fluctuations during different parts a year; summer temperature reaches to up 40°C, while winter experiences frequent frosty spells particularly in December and January. The average distribution of precipitation and dominant temperatures at these sites between 2010 and 2018 are shown in Figure 2.

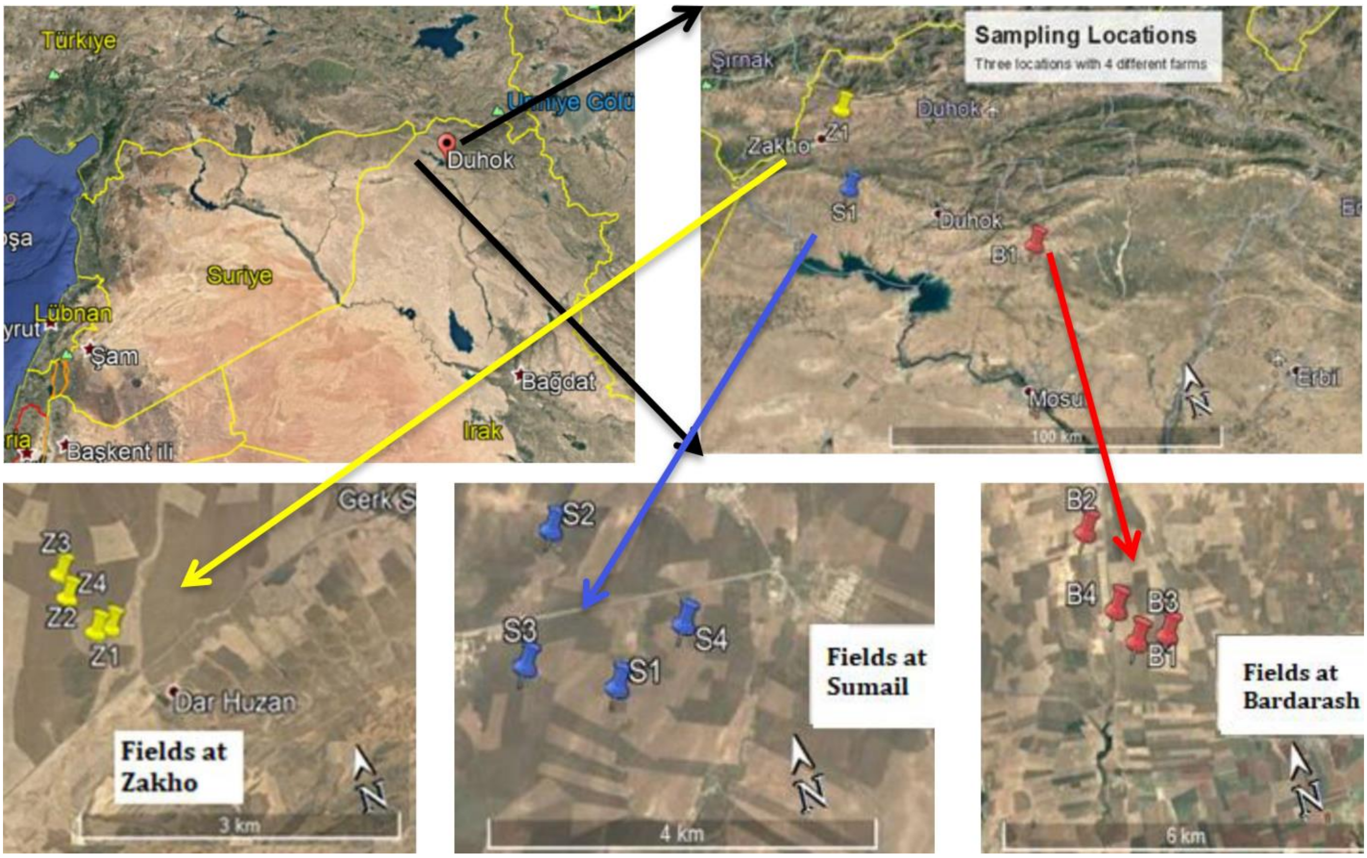

Figure 1. Locations of experimental sites Zakho, Sumail, and Bardarash.

Table 1. Geographical position of the experimental locations

Locations	Latitude N	Longitude E	Elevation, m
Bardarash	36.5018° N	43.5848° E	420
Sumail	36.8608° N	42.8476° E	525
Zakho	37.1505° N	42.6727° E	510

The study was carried out in a randomized plot design using conventional tillage (CT) and reduced tillage (RT) systems with four replications at three locations (Bardrash, Sumail, and Zakho) between 2017 and 2018. Four fields in each location were equally separated into two groups for CT and RT practices. Moldboard plow for CT system and chisel plow shanks for RT system were used for seedbed preparation before wheat cultivation. This research only covers some characteristics of the soil before planting. Experimental fields had been used for wheat production mainly for a long time. Moldboard and chisel plow shanks were used twice before winter wheat seed cultivation on May and July in both 2017 and 2018. Moldboard plow was used for 30 cm depth, and chisel plow shanks was used for 5-10 cm depth. The total sets of 48 surface soil samples (0-30 cm) were taken from all sampling locations as 24 samples for each tillage practice belong to CT and RT.

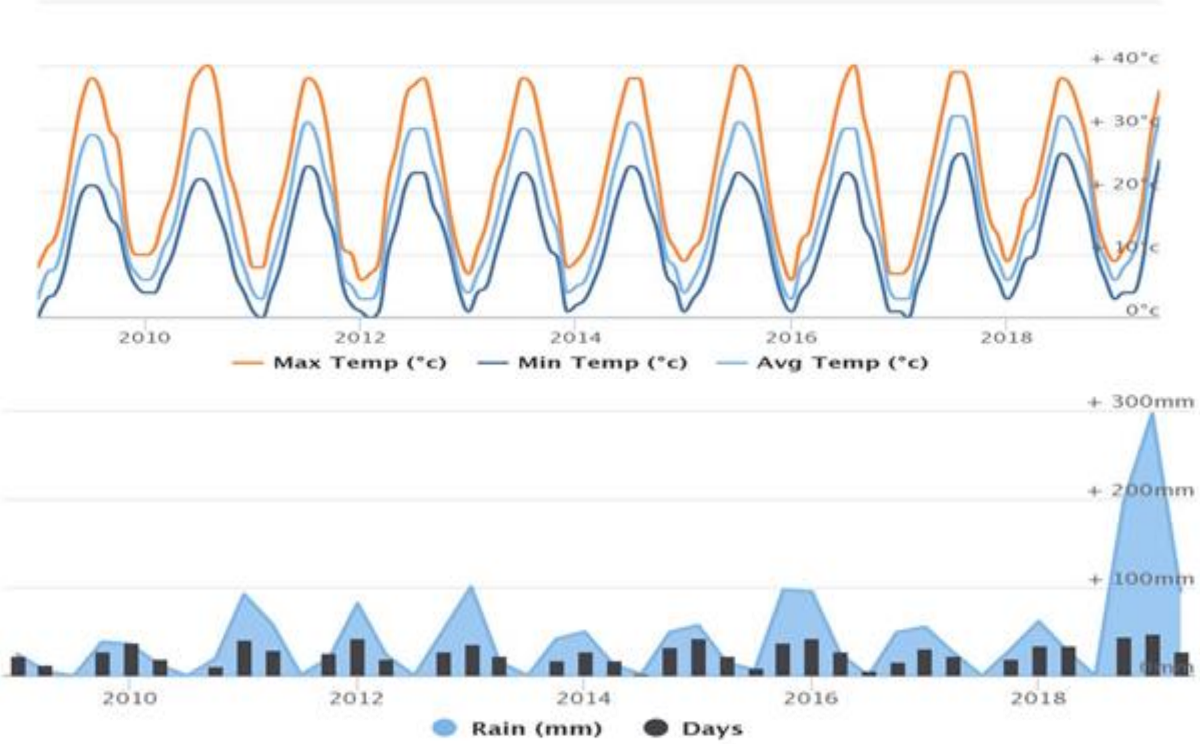

Figure 2. Meteorological data of Duhok Province (World weather online).

The soil samples were analyzed in the University of Duhok, College of Agricultural Engineering during 2017-2018. Main properties of soil were analyzed as; soil texture by Bouyoucos hydrometer method (Black, 1965), pH measured in 1: 2.5 (w:v) in soil: water suspension by pH-meter, electrical conductivity (EC) at the same suspension by EC-meter, soil organic matter (OM) by the wet oxidation method (Walkley-Black) with $K_2Cr_2O_7$, lime ($CaCO_3$) content by Scheibler Calcimeter method (Kacar, 1994). Bulk density (BD) was determined after soil core collection by oven-drying field-moist soil for 24 h at 105 ºC and weighing the soil samples before and after drying (USDA, 2001). Total porosity (F) was calculated using the bulk density values in the equation; F=1-(BD/2.65). According to soil properties given in Table 2, soils in experimental locations have generally fine textural classes (clay in Zakho and silty clay in Bardarash and Sumail), moderately alkaline, non-saline, limy and low in organic matter content (Soil Survey Division Staff, 1993).

Table 2. Some soil properties at experimental locations

Locations	Textural class	pH (1:2,5)	EC, dS/m	$CaCO_3$, %	OM, %
Bardarash	Silty clay	8,60	0,38	17,25	2,00
Sumail	Silty clay	8,25	0,36	17,35	1,85
Zakho	Clay	8,35	0,32	21,15	1,90

Data were statistically analyzed using SAS software (ver. 9.1; SAS Institute Inc., Cary, NC). Values expressed, as percentages were arcsine transformed and then analyzed. Analysis of variance ANOVA was performed at the $p \leq 0.05$ level and the mean values obtained for different treatments were compared according to Duncan's Multiple Range Test.

Results and Discussion

The effects of CT and RT on some soil properties are given in Table 3. There were significant differences among soil properties obtained from different tillage systems. The mean values of pH, EC and BD in the fields under CT were higher than that under RT. However, the mean values of OM and F in the fields under CT were lower than that under RT. The mean values of pH, EC and BD reduced as 3,4%, 29,6% and 4,7% with RT compared with CT, respectively. The mean values of OM and F increased as 16,3% and 7,6% with RT compared with CT, respectively.

Table 3. Effect of conventional tillage (CT) and reduced tillage (RT) systems on mean values of some soil properties.

	pH (1:2,5)	EC, dS/m	OM, %	BD, g/cm^3	F, %
CT	8,56	0,42	1,78	1,64	37,98
RT	8,27	0,29	2,07	1,57	40,88

OM: organic matter, BD: bulk density, F: total porosity

The changes in soil pH and EC values at different locations by the tillage systems are given in Figures 3 and 4. The soil pH values, except Bardarash, significantly reduced with RT application. The highest decrease in soil pH was determined at Sumail location as 6,2%. Rhoton et al. (1993) found that no-tillage plots in different soil types had higher organic C, exchangeable cations and acidity than conventional tillage plots. Similarly, Hussain et al. (1999) determined that moldboard plow had higher soil pH value (6,4) than chisel plow (6,2) in a silt loam soil. Lilienfein et al. (2000) reported that under no till, the average soil solution pH (5,5) significantly and EC (0.205 dS/m) were lower than pH (6.0) and EC (0.224 dS/m) in conventional tillage, and total organic C content in no till was higher than under conventional tillage. In this study, EC values in CT at different locations were significantly higher than that in RT. The highest reduction in EC as 31,6% in RT was determined at Zakho location compared with CT. In soil solution, EC value reflects dissolved nutrient elements in anion and cation forms and is one of the most important parameters for monitoring organic-matter mineralization in soils (De Neve et al. 2000; Candemir and Gülser 2011). Borie et al. (2006) reported that higher C, N, S, total P and fulvic acid-P concentrations and pH occurred in an Ultisol soil under no till and RT than under CT after wheat harvest. In this study carried out under dry climatic condition, soil OM in CT system had more rapid mineralization rate than RT system due to undisturbing soil aggregates and increasing aeration all experimental fields. This mineralization of OM content reflected on the EC values of the soil samples taken from CT plots (Figure 4). Therefore, soil organic matter contents at different locations under RT practice were significantly higher than that under CT (Figure 5). Reducing soil tillage increased soil OM content by 10,5% at Bardarash, 30,2 % at Sumail and 9,9% at Zakho locations. Soil OM content increases with reducing tillage systems (Rhoton et al. 1993; Lilienfein et al. 2000). Ernst and Emmerling (2009) determined that soil organic C content was increased in the topsoil under reduced tillage compared to ploughing. Six et al. (1999) reported that soil tillage strongly affects the amount and type of particulate soil OM contents associated with aggregates. Organic C sequestration in no till was greater than conventional tillage due to slower turnover of macroaggregates in no till. Also, it is known that the decomposition rate of soil organic matter depends on climatic conditions; the tillage effect on soil OM decomposition is lower in cooler regions than in hotter and more arid regions (Soon et al., 2007). In this study, RT system in hot and dry climatic locations helped preventing to organic matter decomposition in soil compared with CT system.

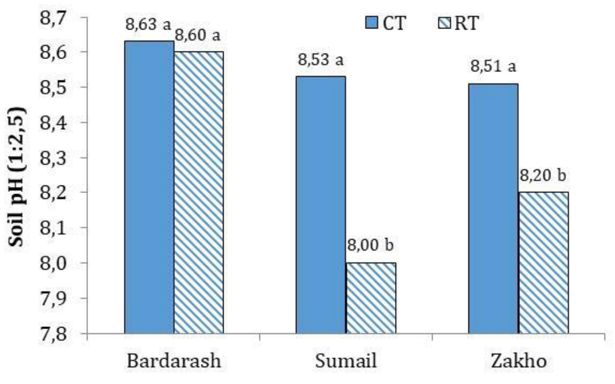

Figure 3. Effects of conventional (CT) and reduced (RT) tillage systems on soil pH.

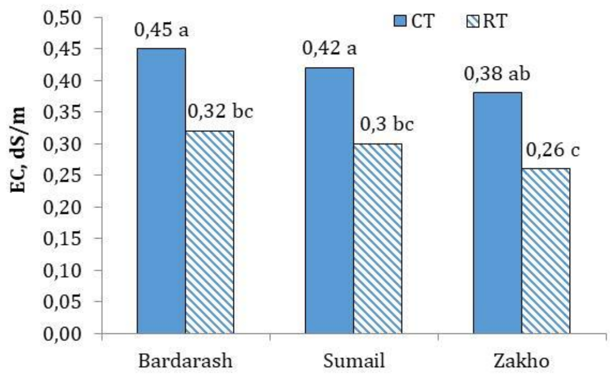

Figure 4. Effects of conventional (CT) and reduced (RT) tillage systems on EC.

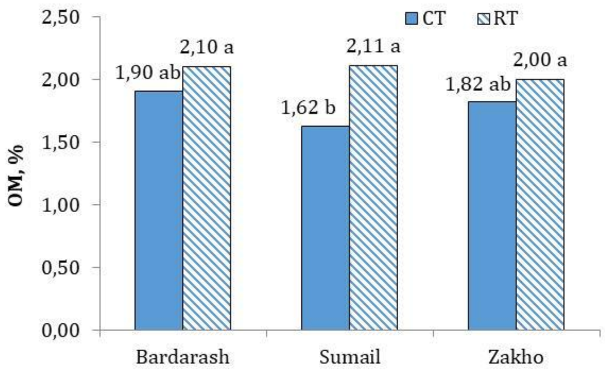

Figure 5. Effects of conventional (CT) and reduced (RT) tillage systems on soil organic matter (OM) content.

The bulk density values in all experimental fields under CT system were higher than that under RT system (Figure 6). According to CT system, the bulk density values in fields under RT system decreased as 4,8% in Bardarash, 4,7% in Sumail and 4,4% in Zakho locations. Grant and Lafond (1993) determined that the bulk density values at 5 cm interval of 0-15 cm layer of a clay soil depth were lower for minimum tillage system (0,90 to 1,29 g/cm^3) than conventional tillage system (0,99 to 1,33 g/cm^3). Gülser (2004) found that increasing soil organic matter content due to crop treatments decreased bulk density with increasing total porosity. Many studies reported that soil organic matter content gives a significant negative correlation with bulk density and a significant positive correlation with totalporosity (Candemir and Gülser, 2011; Demir and Gülser, 2015). In this study, increasing soil OM contents in RT system caused to decrease the bulk density values in each location. Similarly, the total porosity values in RT system were greater than that in CT system (Figure 7). Selvi et al. (2019) determined that soil penetration resistance within 0-40 cm depth of a clay soil varied between 0,78 MPa and 1,20 MPa for fall chisel plowing and those values were lower than the values ranged between 0,81 MPa and 1,40 MPa for fall moldboard plowing. It is known that increasing the total porosity or decreasing bulk density causes to decreases in soil penetration resistance values. Gülser and Candemir (2012) reported that increasing total porosity and soil moisture content by the application of organic residues decreased penetration resistance of a clay soil. In another study, Gülser (2006) indicated that increasing macroaggregation in a clay soil due to forage cropping caused increases in organic matter content and decreases in bulk density and penetration resistance. In this study, RT system increased total porosity with preventing organic matter content in soil while CT system decreased total porosity with reducing organic matter content due to rapid mineralization under hot and dry climatic conditions. Percentage increases in the values of total porosity with RT over CT were determined as 8,1% in Bardarash, 8,3% in Sumail and 6,6% in Zakho locations. The effect of RT on total porosity was more effective on the silty clay textural fields in Bardarash and Sumail than the clay textural field in Zakho.

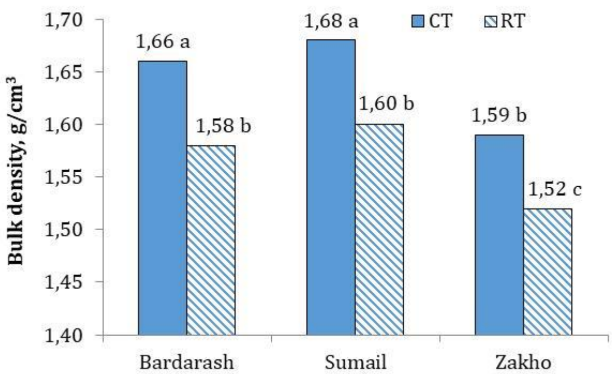

Figure 6. Effects of conventional (CT) and reduced (RT) tillage systems on soil bulk density.

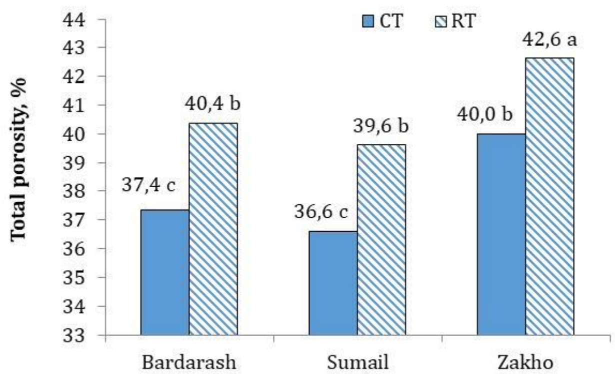

Figure 7. Effects of conventional (CT) and reduced (RT) tillage systems on total porosity.

Conclusion

The effects of CT and RT systems on some soil properties of rainfed wheat grown fields of Bardarash, Sumail and Zakho located on Duhok Province under a hot and dry climatic condition were investigated in this study. While the values of soil pH, EC and bulk density significantly reduced with the RT over the CT system, soil OM content and total porosity were significantly increased with the RT system in all locations under a hot and dry climatic condition. The RT system reduced bulk density and increased total porosity with conserving soil OM content due to preventing from rapid mineralization rate under a hot and dry climatic condition. However, rapid mineralization of soil OM in the CT system under dry climate caused increases in EC which indicated the higher soluble ions in soil solution. This study showed that RT systems in fields under hot and dry climatic conditions are very important to prevent and improve soil physical and chemical properties.

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Assessment of climatic variability on optimal N in long-term rice cropping system

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Abstract

Climatic variability is one of the most significant factors influencing year-to-year crop production, even in high yielding and high-technology agricultural areas. Many studies have attributed variation in yield and crop response to N fertilizer in general terms to differences in varietal characteristics, but few attempts have been made to systematically disentangle the contributions of the genotype from other factors as climatic conditions. In this study, we used ORYZA V3 rice crop model to evaluate impact of climatic variability on optimum nitrogen application rate in rice cropping system. The results show that, solar radiation and N management practices play important roles in the response of N in grain yield. Maximum and minimum temperature has less effect on the grain yield compared to the solar radiation. Optimum N was higher in the dry season compared with the early wet season. Optimum N rate for the grain yield was around 200, 150 and 100. Nutrient use efficiency (NUE) was higher in early wet season (EWS) and late set season (LWS) in higher rate of nitrogen compared to the dry season (DS). Observed grain yield and simulated grain yield was almost similar in both seasons. The ORYZA simulation model performs well for estimating optimum N application.

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Introduction

Irrigated rice fields in Asia contribute about 70% to global rice production and provide the staple food to nearly half of the world's population (Bouman et al., 2007). Rice yields vary strongly (<2 - >15 MT ha^{-1}) across Asia depending on location and variety (Horie et al., 1997; Ying et al., 1998). Climatic variability is one of the most significant factors influencing year-to-year crop production, even in high yielding and high-technology agricultural areas. Dobermann et al. (2003) reported yields from different locations in Asia, ranging from 3.6 - 5.3 MT ha^{-1} for local varieties without external nutrient inputs, which were probably limited by indigenous soil N supply (Cassman, 1999). The effect of N fertilization is variety-specific and depends on the climatic conditions (Van Keulen, 1977). Horie et al. (1997) and Ying et al. (1998) demonstrated that with sufficient N supply, yields were 40% higher in subtropical areas than in tropical areas.

Many studies have attributed variation in yield and crop response to N fertilizer in general terms to differences in varietal characteristics, but few attempts have been made to systematically disentangle the contributions of the genotype from other factors as climatic conditions. Simulation models, which are simplified representations of a complex reality, are useful tools to explore and disentangle effects of interacting factors on crop growth and development (Bauman et al., 1996).

In this study, we used the rice growth model ORYZA V3 to assess variation of N fertilizer rate and N use efficiency across seasons and years, as related to climatic conditions, to identify adaptation options for N adjustment, such as rate and distributions of N fertilizer with patterns of climatic conditions and to evaluate predictive capacity of historical weather data for different seasons in N management. We evaluated, as well, the variation among genotypes of these responses and we have attempted to develop specific association between climatic conditions and optimum nitrogen rate for our genotypes of study.

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Material and Methods

Methodological framework

Crop models help in the evaluation of cropping system productivity variations with long term variation of climatic conditions. In this study, we used ORYZA V3 rice crop model to evaluate impact of climatic variability on optimum nitrogen application rate in rice cropping system. Crop modeling is a useful tool to explore conditions that are not available within experimental field conditions. The model ORYZA V3 was then calibrated and validated using the data from the LTCCE IRRI (Embedded plots) field experiments. Rice yield under various nitrogen managements was simulated to estimate optimum nitrogen application for each year covering period from 1985 to 2015 (using long-term historical weather data).

Optimum nitrogen application rate (N optimum) was defined as the amount of total nitrogen applied at which an acceptable profitable grain yield is obtained and above which additional application of nitrogen will provide no significant benefit in yield or in profitability (Witt et al., 1998, 2000). N optimum was computed using linear and nonlinear regression between nitrogen application rates and simulated yield within the period from 1985 to 2015. Long term actual yield data from the LTCEE was also used to compare actual variability and the simulated N optimum to validate the approach and to define an approach assisting in developing recommendation for nitrogen management with changing climatic conditions. These simulations were run for the two varieties in this study.

Model description

The rice crop model ORYZA V3 used for the simulation studies is an updated version of the model ORYZA 2000 (Bouman et al., 2001) which has been improved to account for the interaction of water and nitrogen on rice crop growth and with more mechanistic approach in rice crop functioning under limited environmental conditions (Li et al., 2016). This crop model simulates the growth, development and water balance of rice crop under potential, water-limited and N-limited environments with a daily time step.

Field experiments

The experiment was conducted during the early wet season 2015 and 2016, and dry season 2016 and 2017 in the embedded plots of the LTCCE (IRRI). Two contrasting varieties were used to evaluate variability among varieties in yield and N use efficiency. The experiment was designed in split plot with 3 varieties but only two varieties were included in this study. Variety was the main plot and 6 N rates were considered as the sub-plots. These treatments were replicated four times (total of 72 plotss) in each season and year.

Data used for model calibration and validation

The ORYZA V3 model required different data inputs to compute daily production of plant parts dry matter and phenological developmental rate during the cropping season. Among these data are variables characterizing the environmental conditions of production, namely, weather and the soil. The model required, as well, inputs providing details of the crop management and the variety.

Climatic data

Daily weather data on total solar radiation (KJ m^{-2} d^{-1}), average minimum and maximum temperature (^{0}C), vapor pressure deficit (kPa), windspeed (m s^{-1}), and total rainfall (mm d^{-1}) were collected from 1983 to 2015, from IRRI website (https://irri.org/climate).

Soil Data

Physical and chemical properties of the soil of the experimental field were characterized from soil samplings. Variables considered were soil texture (sand, clay content, and bulk density), pH, and Organic C, N at different layers.

Crop Data

Total above ground biomass at different key stages and the grain yield data were collected for early wet season (EWS) 2015 and 2016, dry season (DS) 2016 and 2017 from the embedded plots of the LTCCE, IRRI .

Date of sowing, emergence, transplanting, panicle initiation, flowering, and maturity were also recorded from these experiments. Data from DS 2017 and EWS 2016 was used for the model parameterization and for the crop parameters calibration. During these experiments, stem, green leaves, dead leaves and panicle dry weight, green leaf area and leaf area index, grain yield were collected. Data from DS 2016 and EWS 2015 was used for the model simulation outputs validation. These data are totals of above ground biomass and grain yield.

Model parameterization

We estimated the crop parameters needed for ORYZA V3 to simulate the two varieties of study, V4 (IRRI-146 which is also known as NSIC Rc 158) and V8 (IR2-10-L1-Y1-L). We followed the procedure described by Bouman (2007), using the calibration data set from EWS 2016 and DS 2017, to estimate the initialization value for the model crop parameters. DRATES application was used to calculate parameters related to the crop phenology using the recorded dates of emergence, panicle initiation, flowering, and maturity. PARAM application was used to calculate the factor of biomass partitioning among plant organs (stem, green leaves, dead leaves, and panicle).

Model calibration

Calibration is the process of definingand fine-tuning the model parameters to ensure model ability to simulate existing conditions of production. The calibration procedure for the ORYZA V3 model parameters is well described in the users' manual (https://irri.org)

We used the auto calibration application for ORYZA model V3 to calibrate the parameters of leaf growth and biomass partitioning set to obtain parameter values that minimize the errors between simulated and the observed data for the totals of above ground and panicle biomass.

Model Validation

The independent data set (2015 EWS and 2016 DS) of V4 and V8 varieties under the experimental conditions of the embedded plots of IRRI LTCEE was used to evaluate performance of the model simulating biomass production and grain yield. We computed the statistical parameters to assess the goodness of fit between observed and simulated values. The simulated and measured grain yield and total above ground biomass were graphically compared and the linear regression provided the slope (α), intercept (β), and coefficient of determination (R^2) of the linear regression between observed (X) and simulated (Y) values. The absolute root mean square errors (RMSEa) and normalized root mean square errors (RMSEn) were also calculated to evaluate the level of accuracy of the model in simulating rice crop growth and yield. These parameters were computed as following:

RMSE absolute $=\left(\sum_{i=i,\ldots n}(Y_{I-}O_i)^2\right)^{0.5}/\ n$

RMSE normalized (%) $=100\ \left(\left(\sum_{i=1,..n}(Y_i - O_i)^2/n\right)^{0.5}/\bar{O}\right.$

Where, Yi and O_i are simulated and measured values, respectively, and O is the mean of all values, and n is the number of measurements.

Scenario Analysis

Simulation using the two varieties V4 (IRRI 146) and V8 (IR2-10-L1-Y1-L), and different rates of N was performed over 32 years (1983-2015). In addition of the six nitrogen management used in the LTCEE, 10 fertilizer N rates (0, 60, 90, 120, 150,180, 240, 300, 360 and 390 kg ha^{-1}) were used. The total amount was proportionally split into three application times (23, 44 and 57 DAT). Bilinear regression between simulated rice yield and the gradient of nitrogen rate application was done to define optimum nitrogen for each year.

Variability of the N optimum with years was then analyzed and correlation analysis of its variation with climatic variables as solar radiation, maximum and minimum temperature was perfomed using excel. Linear regression between optimum N and climatic variables was used to define the rate of variation of optimum N with unit of variation of the climatic variables. Validation of the linear and nonlinear regression between optimum N and climatic conditions was carried out using the long term yield data from the long term continuous cropping experiment (LTCCE) of IRRI. Grain yield data over the 32 years was then gathered from the historical records of the LTCCE of IRRI. As the rate of nitrogen and varieties were different in different years and season across the 32 years, the average yield was computed and collected for each rate, season and years.

Results

Climatic variability during the period 1983-2015

Daily solar radiation, rainfall, average minimum temperature and maximum temperature of 3 rice cropping seasons are shown in Figure 1. Incident solar radiation was observed higher during the dry season and was lower during the late wet season. Maximum and minimum temperatures were observed to be almost similar during the DS and EWS, whereas during LWS, mximum and minimum temperature was observed lower throughout the year except in 1996. The average rainfall was observed highest during the EWS and LWS and lowest during the DS. Rainfall fluctuated within the years both in the EWS and DS.

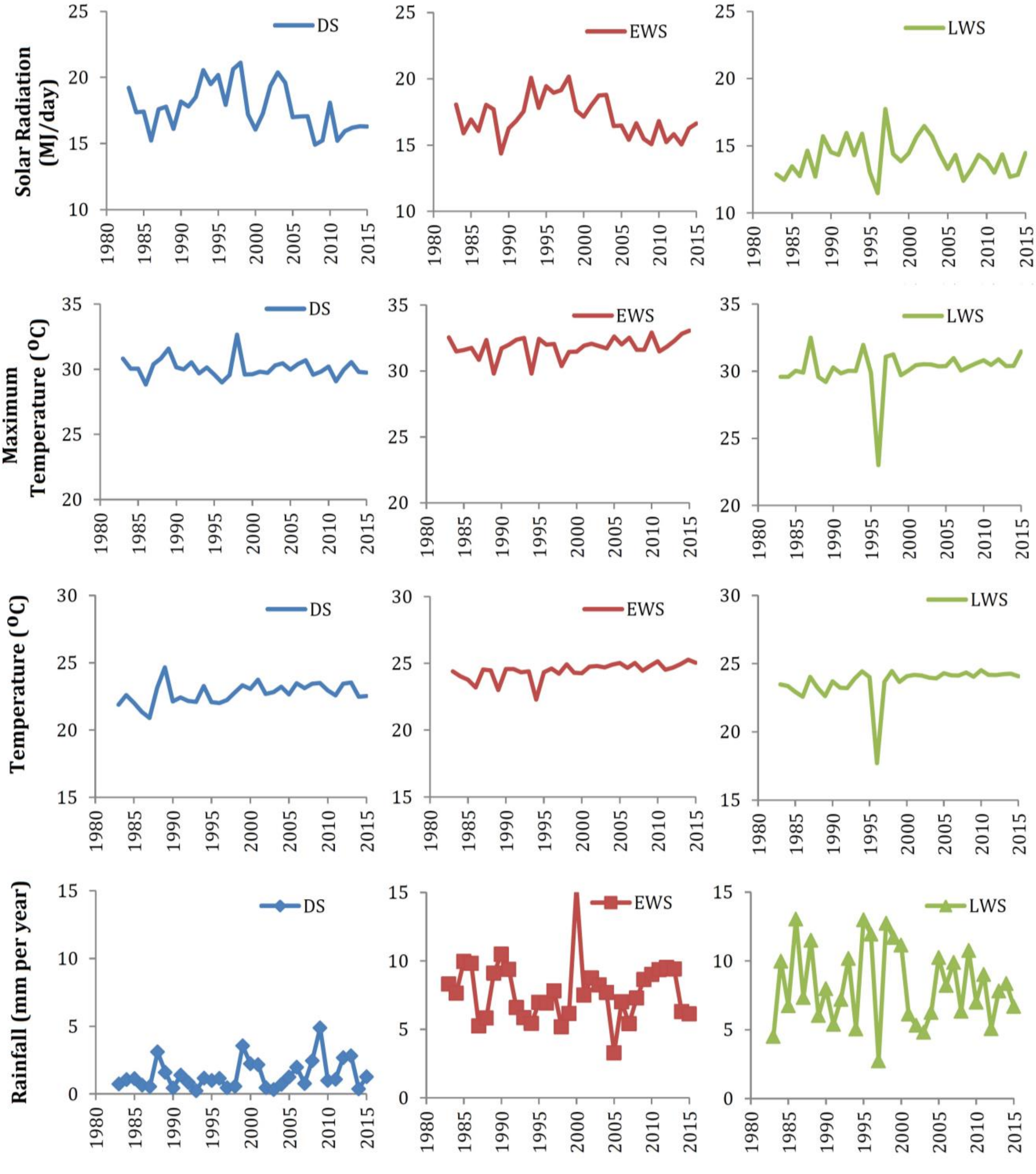

Figure 1. Trends of Solar radiation, maximum temperature, minimum temperature, Rainfall across 32 years in 3 different seasons.

Assessment of grain yield across the year and season

Grain yield of 3 different seasons across the 32 years is shown in Figure 2. Observed grain yield declined until 1992, both in the DS and EWS. In the LWS, grain yield fluctuated within the years. In the DS, grain yield was observed higher with higher N rate application. In the EWS and LWS, grain yield was almost similar in all treatment levels of nitrogen except in the 0 level of nitrogen.

Adaptation options for N adjustment to pattern of climatic conditions.

Figures 3a and 3b show the grain yield and nitrogen use efficiency under different rates of nitrogen. In the DS, we observed an in increasing nitrogen trend towards the grain, giving the high yield with highest rate of nitrogen (200 kg ha^{-1}). Similarly, the nitrogen use efficiency (NUE) was higher in the 100 kg h^{-1} of nitrogen and stared to shift downward with higher rate of N. In the EWS and LWS, N response functions started to shift downward at 150 and 100 kg ha^{-1} of N for grain yield. Similarly, the slope shifted downward at 50 kg ha^{-1} of N for the NUE both in the EWS and DS.

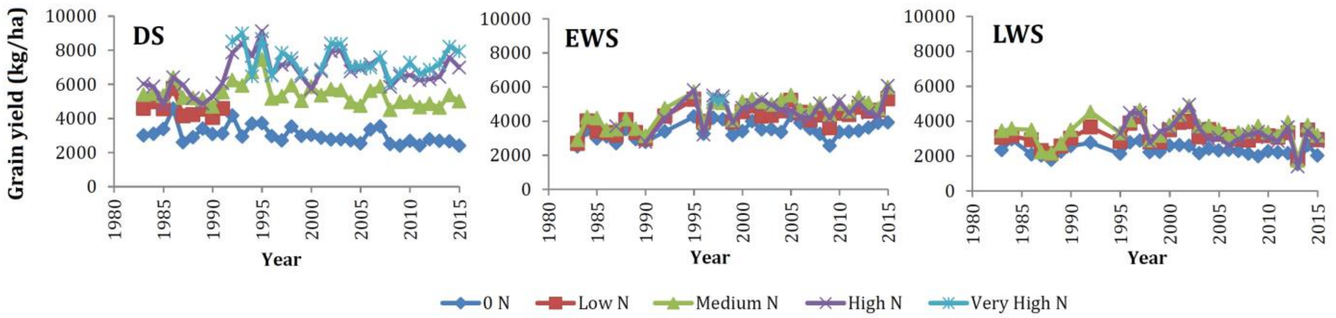

Figure 2. Trends of grain yield in 3 different seasons across the 32 years from LTCCE of IRRI.

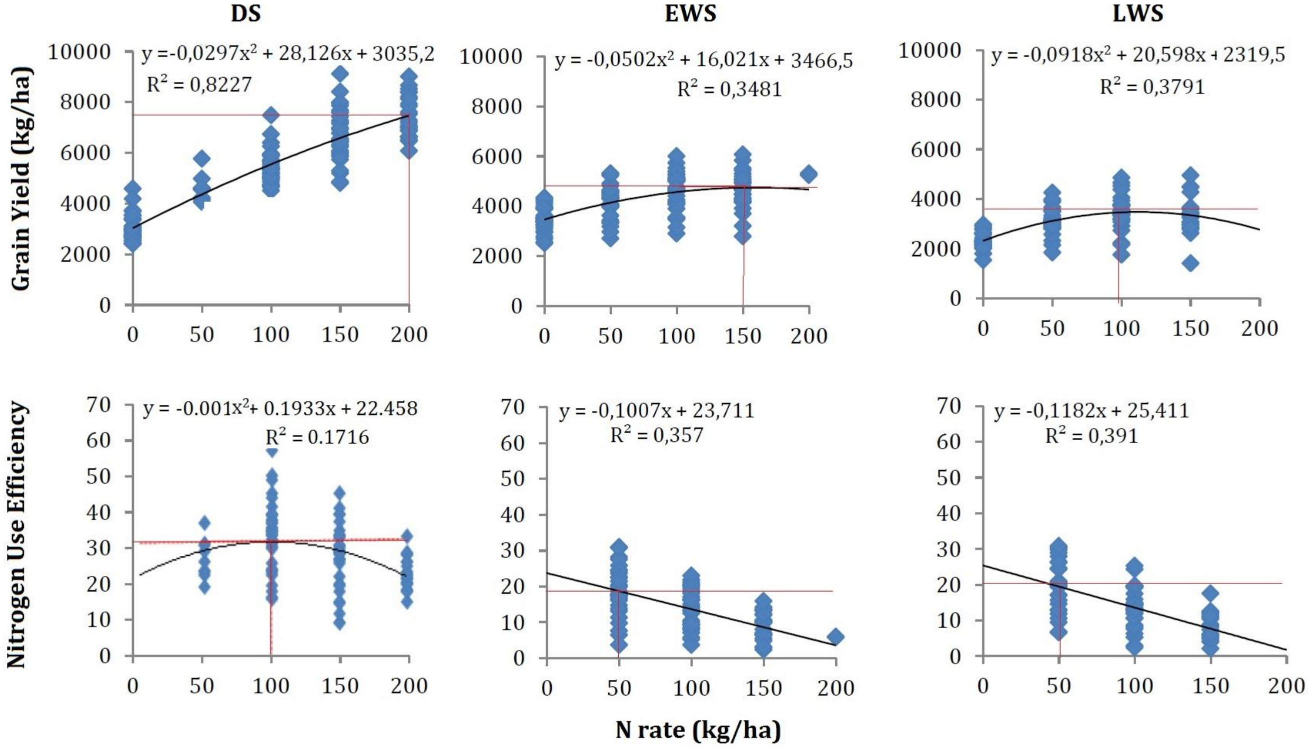

Figure 3. Grain yield (a) and Nitrogen use efficiency (b) in different rates of nitrogen in long term experiment IRRI

Model Evaluation for Optimum N

Figure 4 shows the results of the simulated optimum N for 32 years. Here, we can see that the simulated Optimum N is in the range of 170 to 200 kg ha^{-1} in DS except 2007. In the EWS, simulated optimum N is in the range of 120 to 170 kg of N ha^{-1}.

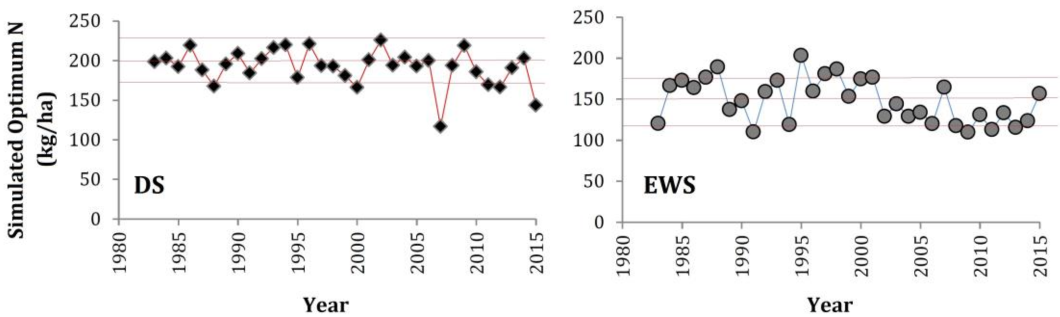

Figure 4. Simulated Optimum N across the 32 years in DS and EWS.

Relationship between simulated optimum N v/s climatic parameters

The Optimum N required was estimated from Oryza 2000 V3. Average climatic parameters such as radiation, minimum air temperature and maximum air temperature were calculated for the period between transplanting and physiological maturity (harvesting time). The correlation between simulated N requirement and the above mentioned climatic parameters are shown in Figure 5 and Figure 6. Significant negative correlation between optimum N and minimum air temperature was observed in EWS for V8. However, positive correlation was observed in all treatments between optimum N and solar radiation. Negative correlations were observed between optimum N and air temperature (both minimum and maximum air temperatures) all cases except for V4 during EWS.

Early wet season

Linear regression between simulated optimum N and weather parameters for early wet season are shown in Figure 5. We observed a positive and strong relationship between optimum N and solar radiation. However, we could not find a strong relationship between optimum N and air temperature in any cases, except for V8 with minimum air temperature.

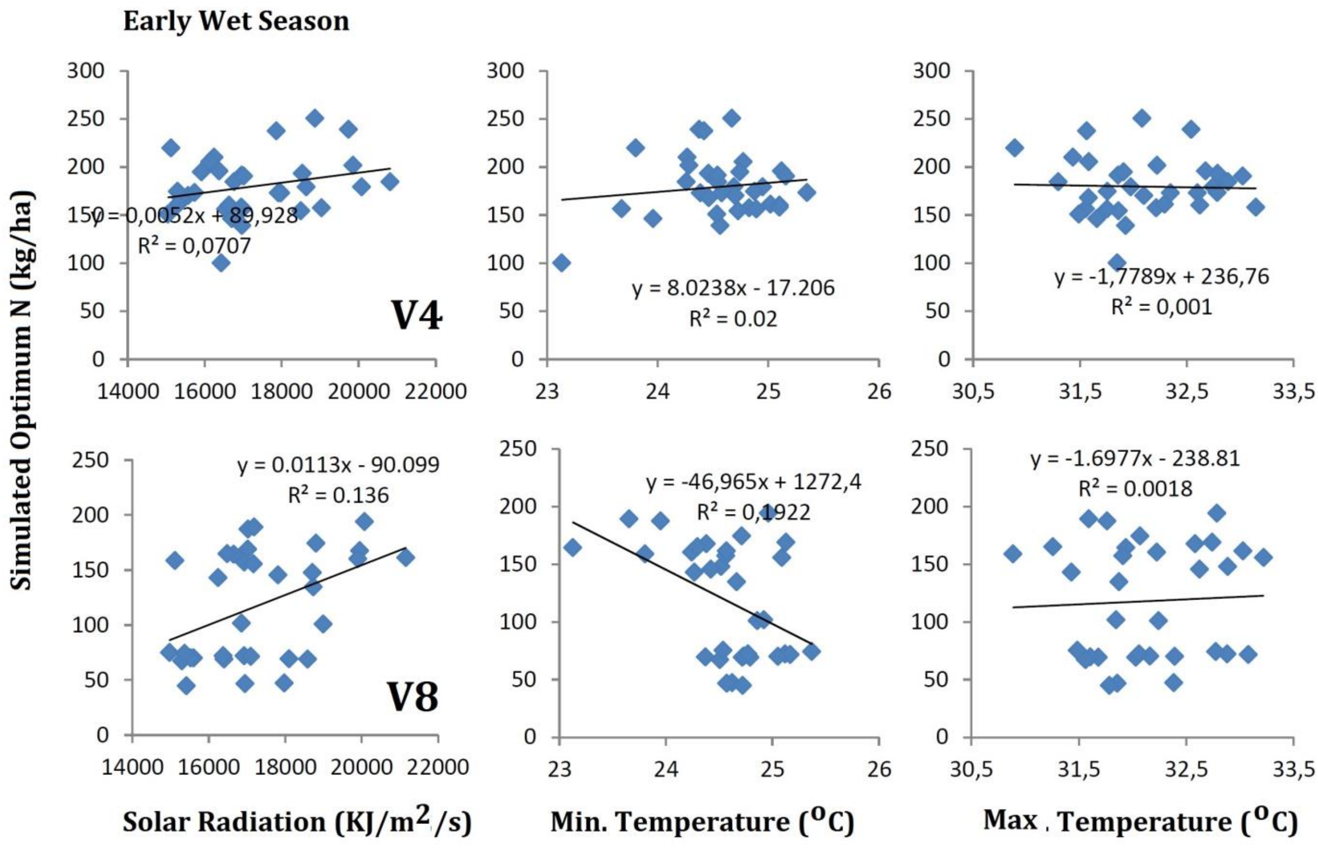

Figure 5. Linear regressions between simulated optimum N and weather parameters during early wet season

Dry season

Linear regression between simulated optimum N and weather parameters for dry season are shown in Figure 6. Strong and positive relation between optimum N and solar radiation was found for V4 only. V8 found weak and positive relationship between optimum N and solar radiation. The relationships between optimum N and air temperatures were significant in the dry season.

Discussion

The yield decline was observed until the 1991 DS. (Flinn and De Datta, 1984) explained that the reason for the decline in grain yield before 1992 was because of the B toxicity and Zn deficiency and alkaline irrigation water. After 1992, various changes occurred in the design of the long term experiment and its crop management (Dobermann, 2000). In 1993 and 1994, chlorophyll meter (SPAD 502, Minolta, Ramsey, NJ) readings of the uppermost fully expanded leaf (Y-leaf) were used to determine the timing of N topdressings based on thresholds established by Peng et al. (1996). In the 1994 and 1995 DS, $ZnSO_4$ was also applied as a blanket application to the plots to provide 10 kg ha^{-1}. Yield increase after 1992 do not support the hypothesis that B toxicity or Zn deficiency had much effect on the yield decline and reversal. The irrigation water source has not been changed and is not among those known for occasional high B concentrations at the experimental site (Cayton, 1985).

Improved crop N supply (increased N supply from fertilizer to the root system, increased N rate and timing etc.) might be the major factor responsible for increased rice yields after 1991. The Dry Season (DS) yield was higher compared to the EWS and LWS which can be the result of the higher solar radiation in DS compared to the EWS and LWS. Dobermann et al (2000) also reported that 54% of the change in rice yields was due to increase in solar radiation in the long term continuous rice cropping system of IRRI. Yang et al (2008) explained the yield gap between dry season and wet season with the higher radiation in dry season.

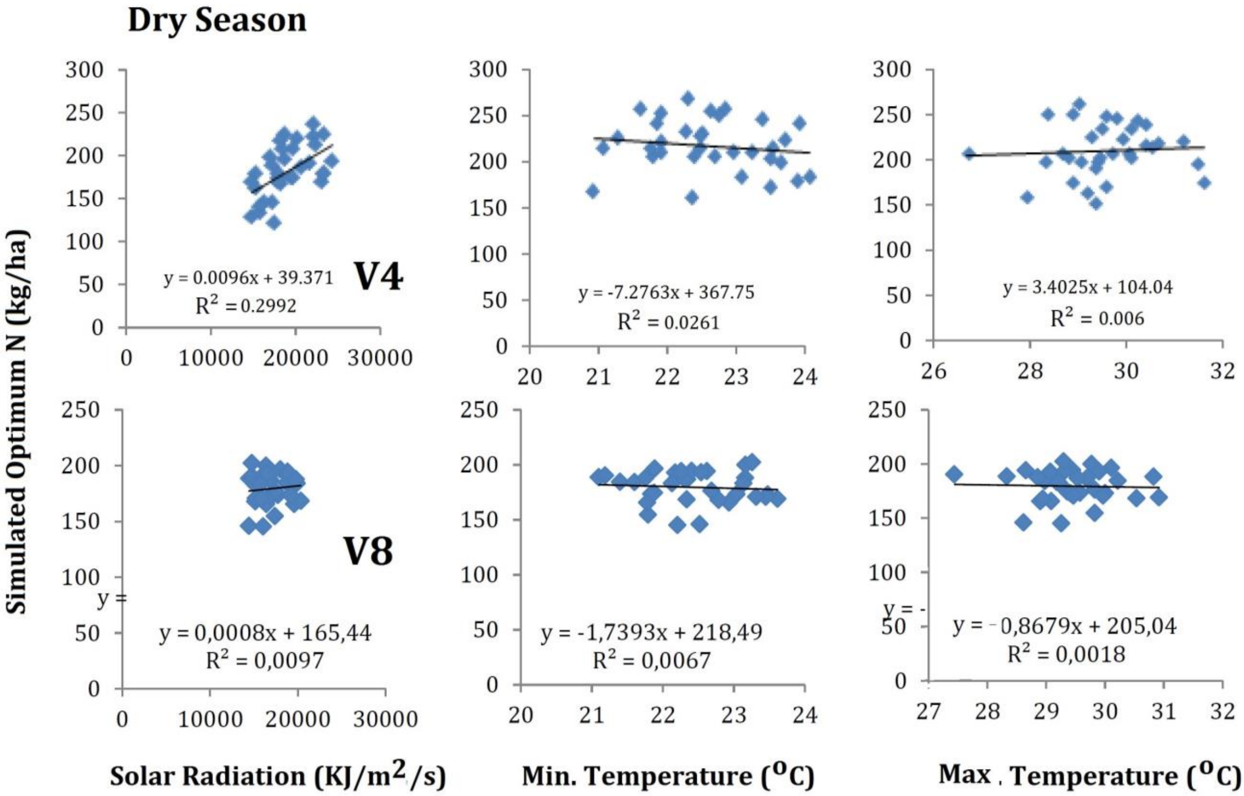

Figure 6. Linear regressions between simulated optimum N and weather parameters during dry season.

In the DS, with increased rate of nitrogen, the grain yield also increased. Based on these results, we can say that in the DS, to get the higher grain yield, we can apply N by up to 200 kg ha^{-1}. However, in the EWS, grain yield increased up to the 150 and started to shift downward. Moreover in the LWS, grain yield was maximum in 100 kg ha^{-1} and after that started to decline. Hence, our results indicate that the optimum N for EWS is 150 kg ha^{-1} and 100 kg ha^{-1} for LWS.

Greater NUE was achieved in the DS with 100 kg ha^{-1} and the NUE has decreased after 100 which indicates that, with higher rates of the nitrogen application, the NUE decreases. In the EWS and LWS, the NUE was greater at 50 kg ha^{-1} and also decreases with increased N rate. Decreases in N uptake efficiency at higher N rates have also been reported by Eagle et al. (2001) and Timsina et al. (2001) .

Optimum N from the observed data (Figure 2) and optimum N from simulated data (Figure 4) shows the similar results both in the DS and EWS. The optimum N in observed data and optimum N in simulated data in the DS and EWS were ±200 kg ha^{-1} and ±150 kg ha^{-1} respectively. If we compare between the DS and EWS, the optimum N in the DS shows higher optimum than in the EWS. This explains that the Oryza 2000 V3 model performs well for optimum N application. Small anomalies between years explain the sensitivity of Oryza 2000 V3 while estimating optimum N.

Conclusion

From our study, we can say that solar radiation and N management practices play important roles in the response of N in grain yield. Maximum and minimum temperature have less effect on the grain yield compared to the solar radiation. Optimum N was higher in the dry season compared with the EWS. Optimum N rate for the grain yield was around 200, 150 and 100. NUE was higher in EWS and LWS in higher rate of nitrogen compared to the DS. Observed grain yield and simulated grain yield was almost similar in both seasons. The ORYZA simulation model performs well for estimating optimum N application.

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Effect of organic amendment on properties and nutrient loss of soils of selected parent material

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Abstract

Soils of Southeastern Nigeria like those of other humid tropical countries are prone to leaching due to high rainfall resulting in low fertility, nutrient status, and crop yield. Evaluating the effects of selected organic amendments on retention of nutrients in soils is of major concern and formed the purpose of the study. Soil samples were collected from Asu River Group, (ARG), Bende Ameki Group (BAG), Coastal Plain Sand (CPS) and Falsebedded Sand Stone (FBS) which were the four respective parent materials studied. Three replicates of 10 kg of prepared samples from each parent material were bagged and thereafter applied with 10 tons ha^{-1} each of poultry (PD) and goat droppings (PD, GD). The thoroughly mixed combinations laid in a completely randomized design (CRD) were allowed to blend for three months after which, samples were collected from each bag and analyzed. The remaining amended soils were subjected to a rainfall simulation which enabled the collection of sediment yield which was also analyzed to determine the nutrients in them. Generated soil data were analyzed with analyses of variance (ANOVA). Means were separated using the least significant difference (LSD) at 5% probability level. The result showed that soil organic carbon increased from 15.80 – 17.70, 6.90 - 14.20, 7.10 – 13.90 and 11.39 - 17.50 gkg^{-1} in ARG, BAG, CPS and FBS respectively before and after amendment and later decreased to 10.8, 11.30, 6.70, and 8.30 g kg^{-1} in the sediment yield following simulation. Similarly, there were significant losses of about 23.52, 60.85; 60.00 and 47.20 % of total nitrogen to detached soils in the respective lithologies. Total nitrogen and available phosphorus losses in the soils followed the order: CPS > FBS > BAG > ARG and FBS > CPS > BAG > ARG respectively.

Keywords: Erosion, Nutrient retention, Organic amendment, Runoff, Rainfall simulation, Sediment yield.

Introduction

The expanding human population and the need to meet nutritionally her food have made sustainable soil management front line issue of concern globally and in sub-Saharan Africa in particular. Igwe (2000) defined soil as non renewable vital resource whose degradation rate is rapidly high.

Most soils of sub-Saharan Africa are strongly weathered with low nutrient status thus leading to lower crop yields (Juo and Wilding, 1996; Omotayo et al., 2009). Agriculture, in particular, contributes significantly to erosion and sedimentation which are issues of concern globally. Major sediment delivered to Oceans and Rivers are generated through it (Igwe, 2000). A lot of soil nutrients namely nitrogen, phosphorous together with calcium, potassium, magnesium and organic matter are lost on an annual basis through erosion

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(Aoyama et al., 1999) to the extent that they must be replaced by fertilizer. Nutrient loss in soil takes place by various means including runoff and sedimentation (Igwe, 2000, Meena et al., 2017), volatilization, leaching, and crop removal (Enwezor et al., 1981) and can vary with climate, parent material, and land use. Nutrient losses in crop fields under cultivation contribute to degradation (Bertol et al., 2003). Runoff and sediments can be obtained through rainfall simulation processes (Sheikh et al., 2017) where rain fell with controlled duration, intensity and drop size, which are factors that make soil erosion studies difficult (Igwe, 2003).

The poor economic base of the rural farmers who need a low-cost input as an alternative to mineral fertilization to boost harvest makes the use of organic manures eminent. Several researchers (Vitosh et al., 1988; Stewart, 1991; Aoyama et al., 1999; Nyakatawa et al., 2001, Zhou et al., 2018) working under different cropping conditions globally have reported that organic manure addition to the soil improves soil condition by increasing the organic matter content.

Apart from Igwe (2000), studies on nutrient losses in eroded sediments in Nigerian soils are scarce; none is in existence on nutrient retention of the selected soils after application of amendments.

In the above connection, the principal aim of the work was to determine the effect of organic amendments on nutrient retention of soils of selected parent materials under simulated rainfall in southeastern Nigeria.

Other specific objectives include to: ascertain the effect of the amendment on the soil properties, determine the nutrient content of sediments obtained after rainfall simulation, and determine some degree of association that exists among selected soil properties.

Material and Methods

Study location

Soil samples from four parent materials namely, Asu River group (ARG) located on Latitude $5^0 27^1 11^{11}$ N and Longitude $7^0 31^1 50.04^{11}$E, Bende Ameki Group (BAG) on Latitude $5^0 53.3.6^1$N and Longitude $7^0 33^1$ 16.0^{11}E, Coastal Plain Sand (CPS) or Benin formation on Latitude $5^0 22^1$N and Longitude 7^0 $9^1 34^{11}$ E and False bedded Sandstone (FBS) on Latitude $5^0 50^1$N and Longitude $7^0 16^1$E respectively enabled the study to be conducted on research farm of Federal University of Technology Owerri, Nigeria. The farm has its global coordinates as $5^0 21^1 21^{11}$ N Latitude and $7^0 11^1 01^{11}$E Longitude.

Climatic conditions

The study area belongs to the humid tropical climate. The maximum and minimum temperature is 27ºC and 18ºC all through the year. The annual rainfall ranged from 1500 – 2500 mm (NIMET, 2012). The burning of bush for agriculture and other purposes such as deforestation for timber and allied products (Ibeanu and Umeji, 2003) and increased human population have distorted the natural forest vegetation. The major occupations of the people are rice, cassava; yam and oil palm production and processing, mining and hunting are also practiced.

Experimental design and field studies

Completely randomized design (CRD) was used in laying the research where the four parent material and two organic amendments served as treatments. They were replicated trice. Soil augers were used to collect soil from a depth of 0-15 cm. Collected soil samples were prepared for laboratory analyses by air-drying, and allowing it to pass through 2 mm diameter mesh.

Soil Organic Amendments application

The organic amendments were analyzed before use (Table 1). In a 10kg of soil collected from each parent material, 10 tons ha^{-1} of organic amendment viz: poultry droppings, (PD), goat dropping (GD) separately was applied and thoroughly mixed with the soil after curing. At the end of the experiment after three months, samples were respectively picked from all the pots for analyses where as the rest or remaining samples where used for rainfall simulation.

Table 1. Composition of the amendments used for the study.

Property	Units	Goat dropping	Poultry dropping
pH water		7.25	7.08
Organic carbon	g kg^{-1}	194.50	223.00
Total Nitrogen	g kg^{-1}	18.70	21.10
Available Phosphorus	mg kg^{-1}	1.87	2.10
Exchangeable calcium	$cmolkg^{-1}$	22.23	23.80
Exchangeable magnesium	$cmolkg^{-1}$	15.41	24.41
Exchangeable sodium	$cmolkg^{-1}$	2.18	1.17
Exchangeable potassium	$cmolkg^{-1}$	10.03	3.88

Rainfall simulation

This was carried out according to the procedure of (Meyer and Harmon, 1979; Igwe, 2000). Here, amended soils were packed in a soil bin with dimensions of 30 cm x 10cm x 12 cm. The soil bin was inclined at a slope between 1-2% representing the slope of the area. Rainfall at an intensity of 90 mm hr^{-1} from a height of 2m was allowed to fall on it for a maximum period of 30 minutes. Runoff water was collected in a bowel placed at the opening of the soil bin at every five (5) minutes to avoid overflow. The runoff was allowed to settle for 48 hours to enable sedimentation. Thereafter, sediment yield was air dried, weighed and analyzed.

Laboratory analyses

Grain size was determined by Gee and Or (2002) method. Bulk density was measured as Grossman and Reinsch (2002) recommended. Soil pH was determined in 1:2.5 soil liquid ratios in water and KCl, using pH meter (Hendershort et al., 1993). Organic carbon was determined using wet oxidation method described by Nelson and Sommers (1982). Total nitrogen was determined by Kjeldahl digestion method using concentrated H_2SO_4 and a sodium copper sulfate catalyst mixture (Bremner, 1996). Brady and Weil (1999) documented the method used for effective cation exchange capacity. Available phosphorus was extracted as Bray and Kurtz, (1945) documented. Exchangeable potassium and sodium were extracted with 1N neutral ammonium acetate NH4OAC and determined photometrically using flame photometer (Thomas, 1982). Exchangeable acidity was measured titrimetically (Mclean, 1982). Exchangeable magnesium and calcium were determined using ethylene diamine tetra-acetic acid (EDTA) (Thomas, 1982). Percentage losses were computed as the difference in the amount or value of a property after amendment and that in eroded sediment divided by the amount after amendment multiplied by 100.

Data analyses

Data analyses were carried out with ANOVA. The means that were significant were separated using the least significant difference (LSD) at a probability level of 5%. Correlation was computed using SPSS 15.0 for windows evaluation version (2006).

Results and Discussion

Physical properties of studies soil

The results of the physical properties of the soil before and after amendment are displayed in Tables 2 and 3 respectively. Significant (P<0.05) variations among particle size fractions were observed. Sand proportion ranged from 505.07 to 886.53 gkg^{-1} in ARG and BAG. Clay and silt fractions ranged from 93.67 to 213.04 gkg^{-1} and 12.79 – 348.66 gkg^{-1} in BAG to FBS; CPS and ARG respectively (Table 2). The soils were texturally classified as loam in ARG, loamy sand in BAG and CPS and sandy clay loam in FBS. Agim et al. (2012a), Igwe and Okebalama (2006) reported similar textures in soils of the area. Sandy texture reflects the parent material, (Enwezor et al., 1990), climate (Esser et al. 1992). Clay fraction values were low to intermediate (Ben- Hur et al. 1985) and ranged from 93.67 – 213.04 gkg^{-1} (Table 2). Silt fraction values were low (Akamigbo and Asadu, 1983). Bulk density was significantly (P <0.05) lowest in soils of Falsebedded sandstone 1.43 gcm^{-3} while the highest (1.61) gcm^{-3} occurred in soils under Bende Ameki Group. This result was in tandem with sand and sandy loam textures of the tropics (Mbah, 2006). The higher bulk density found in BAG to that over CPS which is comparable to the results of Chikezie et al. (2010) under the same parent material was due to the gravelly parent material type and their organic matter content. Evanylo and McGuinn (2000) observed that bulk density values of 1.55 to < 1.65 gcm^{-3} can critically affect or restrict root growth and development in silt loams. Low soil bulk density facilitates an increase in pore spaces, root growth, and penetration and infiltration capacities.

Table 2. Mean values of physical properties of studied soils before amendment.

PM	sand, gkg^{-1}	silt, gkg^{-1}	clay, gkg^{-1}	textural class	SCR	Dℓb, g/cm^3	TP, %
ARG	505.07	348.66	146.27	L	2.38	1.47	44.61
BAG	886.53	19.80	93.67	LS	0.21	1.61	39.33
CPS	874.67	12.79	112.54	LS	0.11	1.58	40.46
FBS	545.06	241.90	213.04	SCL	1.13	1.43	46.11
LSD (P<0.05)	23.23*	NS	11.19*		0.02*	0.21*	1.20*

ARG=Asu River Group, BAG=Bende Ameki, Group, CPS=Coastal plain sand, FBS=Falsebedded sandstone, Dℓb =Bulk density, TP=Total Porosity, L=loam, SL=Sandy loam, SCL=Sandy clay loam, LSD=Least significant difference, *=significant, NS=Not significant.

On the other hand, there were significant (P<0.05) lower sand fraction in all locations following amendment (Table 3). Silt fraction was lower in ARG (348.66 - 285.09 gkg^{-1}) and FBS (241.90 – 198.60 gkg^{-1}) compared to BAG (19.80 -94.62 gkg^{-1}) and (12.79-77.42 gkg^{-1}) in CPS after amendment Table 3 respectively. Recorded values of percentage sand, silt and clay fractions found in amended soils were in line with the finding of Ewulo et al. (2008) and Mbagwu, (1992). Bulk density had significant (P<0.05) lower values recorded in poultry than in goat droppings amended soil with exception of ARG soil were the same value was recorded. (Table 3).

Table 3.Effect of organic amendment on physical properties.

PM	O A	Sand, gkg^{-1}	Silt, gkg^{-1}	Clay, gkg^{-1}	Textural class	Dℓb, gcm^{-3}	TP, %
ARG	GD	400.20	260.03	240.17	SCL	1.41	46.87
	PD	478.00	310.16	211.84	SCL	1.41	46.87
	LSD(P<0.05)	20.33*	11.32*	3.22*		NS	NS
	Mean	439.10	285.09	226.01	SCL	1.41	46.87
BAG	GD	811.93	104.59	83.45	LS	1.61	39.34
	PD	809.15	84.65	106.20	LS	1.58	40.47
	LSD(P<0.05)	17.22*	20.34*	4.33*		0.67*	2.33*
	Mean	810.54	94.62	94.83	LS	1.59	40.00
CPS	GD	875.66	39.12	85.55	LS	1.52	42.72
	PD	717.12	115.71	167.15	SL	1.49	43.86
	LSD(P<0.05)	16.44*	23.33*	11.23*		0.03*	1.65*
	Mean	796.39	77.42	126.35	SL	1.51	48.70
FBS	GD	572.08	210.00	217.92	SCL	1.41	46.87
	PD	577.20	187.20	235.60	SCL	1.38	48.00
	LSD(P<0.05)	15.78*	24.44*	10.12*		0.32*	1.2
	Mean	574.64	198.60	226.76	SCL	1.39	47.44
*LSD (P<0.05)		23.34*	NS	7.44*		0.02*	1.23*

Dℓb =Bulk density ,TP=Total Porosity, SL=Sandy loam, SCL=Sandy clay loam, LS=Loamy sand, LSD=Least significant difference, *=significant, NS=Not significant,.*LSD=Least significant difference separating the means.

Soil chemical properties

The results of the chemical properties of studied soil before and after amendment are presented in Tables 4 and 5 respectively. Result noted significant differences (P<0.05) in soil pH. Soil in BAG had highest pH (5.48) while that under FBS had lowest pH (4.74) (Table 4). These results were rated medium which is mostly the preferred range for most crops. Lower values indicate possibility of aluminum toxicity (Landon, 1991). Soil organic carbon differed significantly (P < 0.05) with the highest value 15.80 gkg^{-1} occuring in ARG while BAG had the least 12.4 gkg^{-1} (Table 4). Effective cation exchange capacity showed significantly higher values in soils of Bende Ameki Group 8.85 cmolkg^{-1} and least in CPS 3.84 cmolkg^{-1}. The results are similar to that of Agim, 2016. The soil organic matter which was generally very low, less than 12 gkg^{-1} except in ARG is typical of the soil of the area (Landon,1991). The low soil organic carbon was as a result of its fast mineralization rates as Stewart (1991) opined. Total nitrogen varied significantly (P< 0.05) among parent material and ranged from 0.6 – 1.40 gkg^{-1}. The values were rated very low in comparison to the value of 1.5gkg^{-1} critical and are typical of tropical soils (Landon, 1991). Effective cation exchange capacity followed the trend ARG > BAG>FBS>CPS (Table 4). Values of ECEC less than 5 and between 5-15 cmolkg^{-1} are quoted by Landon (1991) as very low to low. These values are below the critical limits for soils of Southeastern Nigeria (Enwezor et al., 1990), suggesting poor fertility status of the soil.

Table 4. Mean values of the initial chemical properties of studied soils before amendment.

PM	pH	SOC	TN	AP,	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	TEB	TEA	ECEC
		gkg^{-1}		mgkg^{-1}	cmolkg^{-1}						
ARG	4.93	15.80	1.40	5.40	2.53	1.67	0.12	0.29	4.61	2.92	7.53
BAG	5.48	6.90	1.10	4.00	3.90	1.87	0.10	0.26	6.13	2.72	8.85
CPS	5.08	7.10	0.60	2.10	0.96	0.47	0.10	0.24	1.77	2.07	3.84
FBS	4.74	11.30	1.00	3.11	1.41	2.13	0.12	0.26	3.92	2.33	6.25
LSD (P<0.05)	0.33*	0.41*	0.05*	NS	0.21*	0.14*	NS	NS	0.95*	0.27*	1.75*

PM=Parent material, NS= Not significant, *=Significant at 5% probability level; *LSD=Least significant difference, TEA=Total exchangeable acidity, TEB=Total exchangeable bases, SOC=Soil organic carbon, TN=Total Nitrogen, AP=Available phosphorus.

Effect of organic amendment on chemical properties of studied soils

Soil pH was significantly (P<0.05) increased after amendment in all studied soils. The result followed the trend BAG>CPS>ARG>FBS (Table 5) respectively. The increased soil pH as a result of the applied amendments supports the findings of Egball (2002) and Mucheru (2003). The rise in soil pH could have been caused by the masking of hydrogen ion by the amendment. This has the capability of controlling the buffer characteristics as well as the ability to neutralize soil acidity (Wong et al., 1998) by increasing the basic cations in the soil. The Goat dropping increased soil pH more in soils of BAG and FBS than poultry dropping which had better performance in soils of ARG. The result is in line with (Aoyama et al., 1999; Mbah and Mbagwu, 2006, Akanni and Ojeniyi, 2008; Adeleye et al., 2010). This result could be attributed to the reduction of aluminum ions concentration in soil solution and in exchangeable sites as a result of exchangeable calcium content of the goat dropping. Increase in soil pH encourages nitrification by increasing bacterial activity and nitrification of organic matter.

Table 5. Effect of poultry dropping and goat dropping on the studied soil after amendment

PM	O.A	pH	SOC	TN	AP	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	TEA	ECEC
			gkg^{-1}		mgkg^{-1}	cmolkg^{-1}					
ARG	GD	5.35	17.90	1.80	18.65	3.72	1.59	0.13	0.28	2.04	7.76
	PD	5.41	17.40	1.50	18.22	3.50	1.45	0.13	0.34	2.32	7.74
	LSD(P<0.05)	0.02*	NS	0.45*	NS	0.04*	0.03*	NS	NS	1.10	0.22
	Mean	5.38	17.70	1.70	18.44	3.61	1.52	0.13	0.31	2.18	7.75
BAG	GD	5.59	13.30	1.30	15.72	4.52	2.09	0.11	0.30	1.67	8.69
	PD	5.53	15.50	1.90	15.21	4.29	2.05	0.11	0.29	1.69	8.43
	LSD(P<0.05)	1.10	1.00	0.87	0.31	1.13	NS	NS	NS	NS	0.21
	Mean	5.56	14.20	1.60	15.46	4.41	2.07	0.11	0.30	1.68	8.57
CPS	GD	5.52	15.40	1.30	12.20	1.75	0.87	0.11	0.26	1.70	4.69
	PD	5.52	12.50	1.60	13.07	1.76	0.64	0.12	0.27	1.55	4.34
	LSD(P<0.05)	NS	1.11	0.31	0.76	NS	0.01	NS	NS	0.02	1.00
	Mean	5.52	13.90	1.50	12.64	1.74	0.76	0.12	0.27	1.63	4.52
FBS	GD	5.58	19.40	1.80	12.92	6.53	3.87	0.12	0.29	1.36	12.17
	PD	5.53	15.60	1.40	13.66	5.60	4.09	0.12	0.32	1.19	11.32
	LSD(P<0.05)	0.32	2.11	0.05	0.22	1.00	0.24	NS	0.43	1.55	2.76
	Mean	5.56	17.50	1.61	13.29	6.07	3.98	0.12	0.31	1.27	11.75
*LSD(P<0.05)		0.27*	0.05*	NS	NS	1.00*	NS	NS	NS	NS	1.20*

PM=Parent material, ,O.A.=Organic amendment, GD=Goat dropping, PD=Poultry dropping, NS= Not significant, *=Significant at 5% probability level; LSD=Least significant difference, TEA=Total exchangeable acidity, TEB=Total exchangeable bases, BS=Base saturation, SOC=Soil organic carbon, TN=Total Nitrogen, AP=Available phosphorus.

Similar to soil pH, organic carbon significantly (P<0.05) increased compared to their initial values in the following order: ARG (15.80 – 17.70 gkg^{-1}) > FBS (11.30 –17.50) > CPS (7.10–13.90) > Bende (6.90–14.20 gkg^{-1}) (Table 4 and 5) respectively. Agim, (2016) had a similar result. Studies of Aoyama et al. (1999), Nyakatawa et al. (2001), Ayeni et al. (2008), Mbah and Onweremadu (2009) and Uwah et al, (2014) reported increase in SOC upon the use of manure as amendment. Rise et al. (2006) ascribed the increased soil organic carbon through application of amendment to decomposition of organic manure. Organic matter plays major roles in moisture retention, nutrient availability, an increase in the exchange sites of soil. Apart from the above, it encourages aggregation and reduces erosion, etc. On the other hand, goat dropping increased soil organic carbon in soils of ARG, CPS, and FBS compared to poultry droppings. Boateng et al. (2006) observed a decrease in soil SOC following poultry manure application. Phosphorus and nitrogen were affected significantly (P<0.05) by amendments compared to their initial values before the commencement of the study. The values after amendment in some of the soils were a little above the key value of 1.5 g kg^{-1} (Senjobi and Ogunkunle, 2011; Ahukemere et al., 2012). Similarly, values of available phosphorus in soils of ARG and BAG (18.44 and 15.46 mgkg^{-1}) (Table 5) after the amendment were above the critical values of 15 mgkg^{-1} for southeastern Nigeria soils as documented by Enwezor et al. (1990). Those of CPS and FBS (12.64 and 13.29 mgkg^{-1}) were below the critical limits above but better than those without amendment (Table 4). Increased total nitrogen and available phosphorus following amendment is a reflection of parent material, organic manure decomposition, land use etc. Uwah et al. (2014) attributed increased N and P following amendment to increase in microbial activities leading to the enhanced decomposition of the organic forms of N and P. Goat dropping improved total nitrogen in ARG and FBS more than poultry dropping which gave better results in CPS and BAG. Poultry dropping gave better results in ARG and BAG with respect to available phosphorous while goat dropping performed better in improving the phosphorus status of the soil in CPS and FBS (Table 5). The result is similar to Akanni and Ojeniyi (2008) who noted the highest available levels of nitrogen and phosphorus in poultry manure-amended soil compared to other animal manures. Total exchangeable bases (TEB) which were higher in amended soil ranged from 2.89 -10.48 cmolkg^{-1} in CPS and FBS (Table 4) . Higher values reflect the level of acidity of the soil.

Result also showed that the values of effective cation exchange capacity were low (Landon 1991), however, improved values were recorded in amended soils compared to their initial values in the following order: ARG (7.53-7.75 cmolkg^{-1}) > FBS (6.25–11.75 cmolkg^{-1}) > BAG (8.85–8.57 cmolkg^{-1}) > CPS (3.84–4.52 cmolkg^{-1}) respectively (Table 3 and 4). The lower values of ECEC are indication of soil's poor retention of nutrients and water. Result also showed that goat dropping contributed significantly to effective cation exchange capacity than poultry dropping. Mbagwu (1992) and Agim (2016), in their study of the area found that goat dropping contributed higher CEC compared to unburned and burnt rice husks. Magnesium and calcium dominated the exchange sites as indicated by the result of ECEC.

Chemical properties of sediments following rainfall simulation

The result of the effect of organic amendment on chemical parameters of the sediments is recorded in Table 6. The result showed that soil nutrients are washed out from the farm through runoff water. Soil pH has significantly (P <0.05) lower values in detached soil particles compared to that found after amendment in all studied soil. The trend is closely related to the pH of the original soil and was attributable to rainfall which causes leaching. Soil organic carbon decreased from 17.70 gkg-1 after amendment (Table 5) to 10.80 gkg^{-1} (Table 6) translating to 38.98 % loss in eroded sediments in ARG, (14.20 to 11.30 gkg^{-1} about 22.81% loss in BAG, 13.90 – 6.70, about 51.86 % loss in CPS and 17.50 to 8.30 gkg^{-1} about 26.95 % loss in FBS respectively. The status of organic matter and nitrogen in soils is taken as an indicator of soil fertility and soil quality (Ahukaemere et al., 2012), and their loss could be detrimental to crop growth and development and high erosion. Loss of organic matter from the soil leads to low soil structure, high bulk density, low CEC, high runoff and thus high erosion. FAO (1978) reported that a decrease in soil organic matter could lead to fast biological diminution of the soil. Organic matter plays very crucial roles in the exchange complex of tropical soils which is adjudged to be very low in clay activity.

Table 6. Effect of amendment on sediment yield following rainfall simulation.

PM	O.A	pH	SOC	TN	AP	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	TEA	ECEC
			gkg^{-1}		mgkg^{-1}	cmolkg^{-1}					
ARG	GD	5.95	12.66	1.10	18.00	2.80	0.56	0.13	0.19	0.24	3.92
	PD	5.29	9.00	1.40	18.20	3.50	1.07	0.12	0.14	0.28	5.11
	LSD(P<0.05)	0.66*	2.33*	0.07*	NS	0.43*	0.06*	0.04*	0.22*	NS	1.00*
	Mean	5.62	10.80	1.30	18.10	3.15	0.82	0.12	0.17	0.26	4.52
BAG	GD	6.19	12.20	1.10	13.40	3.20	1.33	0.11	0.10	0.72	5.46
	PD	6.09	10.30	1.00	14.48	3.60	1.67	0.09	0.13	0.44	5.93
	LSD(P<0.05)	0.06*	1.34*	NS	0.06*	NS	0.23*	0.54*	NS	NS	0.05*
	Mean	6.14	11.30	1.10	14.10	3.40	1.50	0.10	0.12	0.58	5.70
CPS	GD	5.91	4.01	0.30	12.00	1.04	0.64	0.09	0.06	0.16	1.99
	PD	5.83	9.42	0.80	10.20	1.12	0.76	0.08	0.12	0.16	2.24
	LSD(P<0.05)	1.10*	0.45*	0.09*	1.32*	NS	0.03*	NS	0.04*	NS	0.45*
	Mean	5.87	6.70	0.60	11.10	1.08	0.70	0.09	0.09	0.16	2.12
FBS	GD	5.64	9.00	0.40	9.10	2.68	0.33	0.11	0.15	0.32	3.59
	PD	5.32	14.90	1.30	11.90	3.10	3.00	0.12	0.13	0.24	6.59
	LSD(P<0.05)	1.98*	2.10*	0.04*	1.15*	1.00*	2.32*	NS	0.06*	NS	2.11*
	Mean	5.48	8.30	0.85	10.50	2.89	1.67	0.12	0.14	0.28	5.10
*LSD(P<0.05)		1.2*	0.22*	NS	1.65*	NS	0.003*	NS	NS	NS	0.98*

PM=Parent material, O.A=Organic amendment, NS= Not significant, *=Significant at 5% probability level; LSD=Least significant difference,*LSD= Least significant different separating the means, AP=Available phosphorus, TEA=Total exchangeable acidity, TEB=Total exchangeable bases, BS=Base saturation,*=Significant at 5% probability level.

Comparison of nutrient loss from studied soil to effect of organic amendment applied

In comparison to the level of nutrients loss following rainfall simulation, between the two organic amendments used, higher losses of organic carbon were noted in poultry dropping amended soil under ARG, BAG, and in FBS respectively while the reverse was the case for CPS (Figure 1a). Boateng et al., (2006) observed lower levels of SOC in soil amended with poultry dropping. On the other hand, Kibet et al. (2014) found a similar trend in soil detached from Central Southeast Nigeria though not in amended soil. The level of organic matter retention in these soils is very important owing to its function on aggregate stability, water retention, maintenance of soil tilth and minimizing erosion. Result also showed loss of total nitrogen though not significant in detached soil particles following simulation (Figures 1c). Poultry dropping trapped more of total nitrogen on ARG, CPS, and FBS than that of goat dropping in soil under BAG (Figure 1b). Kibet et al. (2014) attributed high loss of nitrogen in eroded sediments to their high dissolution in water which mobilizes it irrespective of the quantity in the soil. They found a mean value of 0.071 kg ha^{-1} after 120 minutes of continuous dry and wet runs of high-intensity rainfall. Awodum et al. (2007) found increased nitrogen, phosphorus potassium, calcium and pH, in soil amended with goat dropping compared to NPK fertilizer. Available phosphorus loss followed the trend: ARG, BAG, and FBS under goat dropping amended and CPS under poultry dropping amended soil (Figure 1c). Loss of phosphorus in the eroded sediments is attributed to its absorption to the soil complex and poses a greater risk because of euthrophication if deposited in rivers. Phosphorus is an essential plant nutrient necessary for higher plant yield, therefore the application of P fertilizer to the soil especially when tilled during high rainfall should be minimized to avoid washing away through runoff to rivers and oceans thus causing pollution lowering their quality.

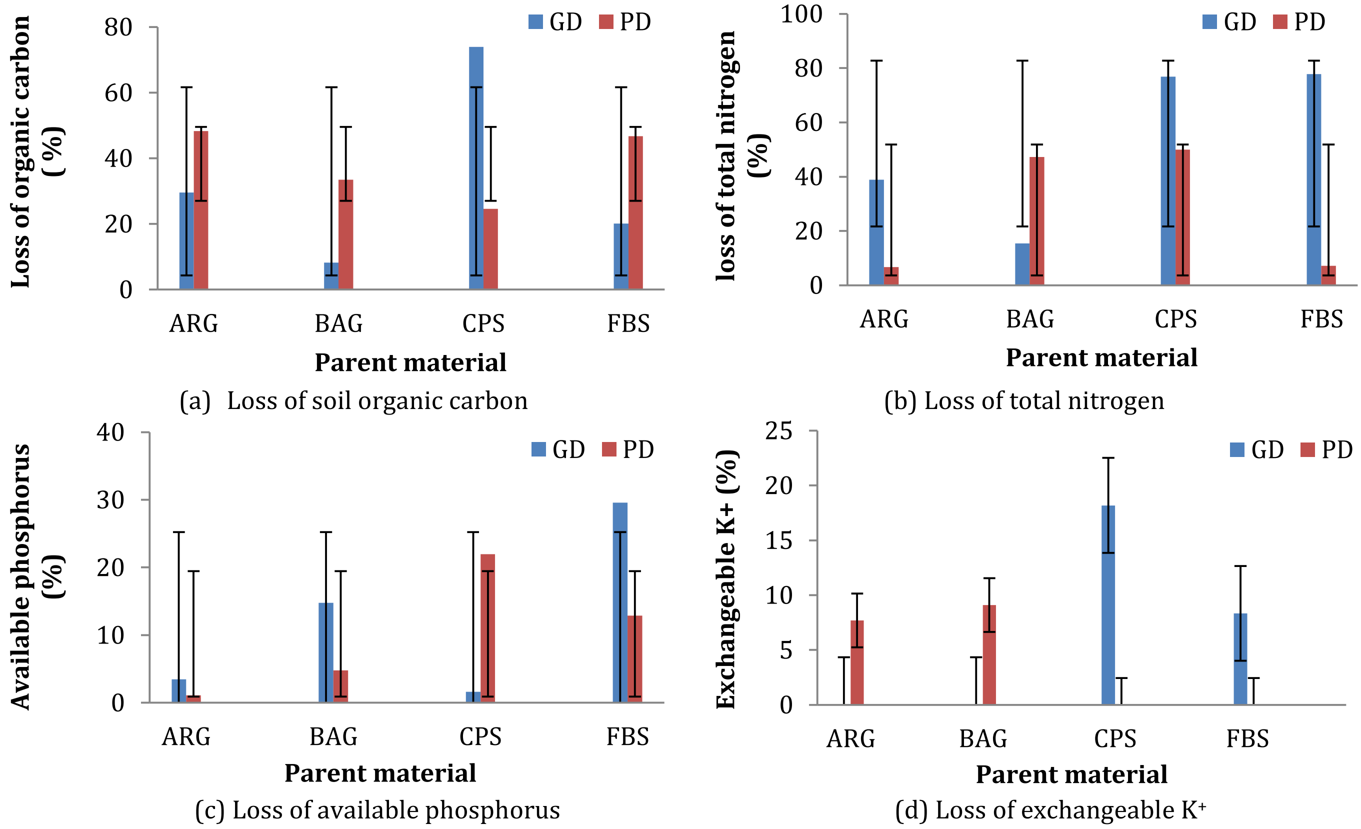

Figure 1. Loss of soil nutrients from amended soil following simulation.

Correlation of organic carbon with selected soil properties.

In Table 7, the relationship or correlation between organic carbon and selected soil properties are shown. Significant ($P<0.05$) positive relationships of soil organic carbon with total nitrogen ($r^2 = 0.35$), available phosphorus ($r^2 = 0.39$) clay fraction ($r^2 = 0.55$) and effective cation exchange capacity ($r^2 = 0.23$) respectively and negatively related to bulk density ($r^2 = -0.55$). The negative value obtained between soil organic carbon and bulk density is an indication of dissociation that exists between them. The other results showed that about 35%, 39%, 55% and 23 % of the value of total nitrogen, phosphorus, clay, and effective cation exchange capacity are contributed by organic matter all things being equal (Agim et al., 2012a,b) found a similar relationship between soil organic carbon and other properties.

Table 7.Correlation of soil organic carbon with selected soil properties.

Soil property	Correlation coefficient. (r^2)	Level of Significance 5%
pH H_2O	0.21	Significant
Organic carbon	0.99	Highly significant
Total Nitrogen	0.35	Significant
Available Phosphorus	0.39	Significant
Effective cation exchange capacity	0.23	Significant
Clay fraction	0.55	Significant
Bulk density	-0.55	Highly significant
Total porosity	0.30	Significant

Conclusion

The study showed significant improvement in soil properties following organic amendments. There were significant losses of in eroded sediments which followed the order: CPS>ARG>FBS>BAG. With respect to soil nutrient retention by organic amendments, goat dropping prevented more of the soil nutrients from washing away from the studied soil than that of poultry dropping. We recommend that organic amendments especially goat dropping be applied in our soils, practices such as contour bonds that will trap sediment on site be adopted in the farm. Afforestation and mulching should be practiced in order to reduce the direct impact of rainfall on the soil be carried out.

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Evaluation of quality of groundwater in irrigation using fuzzy logic in the Bafra Plain, Northern Turkey

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Abstract

The quality of groundwater plays an important role in irrigation management and planning. The most commonly used method when classifying the irrigation water quality is the United States Soil Laboratory (USSL) diagram. Fuzzy logic approach is one of the widely used methods produced more precise and accurate results according to the USSL diagram. A rule-based, fuzzy logic irrigation water quality (FL-IWQ) were evaluated by using electrical conductivity (EC), sodium adsorption ratio (SAR), and residual sodium carbonate (RSC) values of groundwater in irrigation, in Bafra plain. The FL-IWQ defuzzification methods-center of area (COA), mean of maxima (MOM), least of maxima (LOM), and (SOM) were selected and compared with quality values of groundwater in irrigation. Based on the results of the FL-IWQ defuzzification methods with quality values of groundwater in irrigation, the determination of coefficients for COA, MOM, SOM and LOM were 0.9874, 0.9755, 0,9574 and 0.9453, respectively. Results obtained from FL-IWQ revealed that there has been 93% general agreement with the results obtained from the USSL diagram and RSC classification. The developed fuzzy model produced more reliable results for groundwater in irrigation than that of the USSL-diagram and RSC classification. The study suggests using proposed fuzzy model as a promising alternative to the traditional ones for classifying the quality of groundwater in irrigation under uncertain conditions.

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Introduction

Determination of irrigation water quality is an important activity in agricultural water management and planning. The ionic composition of the water has a significant effect on plant growth. Irrigation with insufficient quality water can retard plant growth and contaminate the soil and make the farmland less suitable due to salinity.

Complete chemical analysis is required to accurately determine the quality of irrigation water. When analyzing irrigation water, calcium, magnesium, sodium and potassium cations and carbonate, bicarbonate, chlorine, sulfate, nitrate or nitrite salts anions, and boron content should be determined. pH, total salinity, sodium adsorption rate, percent sodium, persistent sodium carbonate also should be determined.

Historically, many diagrammatic and graphical techniques have been used to represent the hydrochemical properties of water in determining irrigation water quality (Pipe, 1944; Stiff, 1951; USSL, 1954; Wilcox, 1955; Schoeller, 1962). These can be difficult to interpret, especially under the condition of lacking of precision of irrigation water samples. United States Salinity Laboratory (Richards, 1954) and Wilcox (1955) are the most widely used diagrams. These diagram includes the electrical conductivity and sodium values of the waters. The percentage of soluble sodium (SSP), Kelly's ratio (KR), residual sodium carbonate (RSC), and permeability index (PI) are used, except for the US Salinity Laboratory (USSL), which is widely used to determine the quality of irrigation water.

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In spite of the fact that different classification systems have been experienced by many researchers (Laluraj and Gopinath, 2006; Priya and Arulaj, 2011), many uncertainties arise when deciding water quality. In irrigation practices, quality parameters should be interpreted based on the complex data and presented in an understandable and useful way.

It is difficult to select inputs and outputs precisely when modeling water quality. In this context, fuzzy logic plays an important role to convert complex input variables to simple output variables. Many studies have used fuzzy logic to arrive at a simple output. Therefore, classification systems that can deal with uncertainty need to emerge with an intuitive approach to produce simple results to deal with the situation. As a mathematical tool, fuzzy logic converts complex expressions into mathematical terms and back into simple outputs (McNeil and Thro, 1994). It has been demonstrated that it can be successful with the fuzzy logic approach in solving complex problems (McKone and Deshpande, 2005). There have been lots of studies focusing on the classification of water quality of fuzzy logic applications, especially on drinking, waste, river water, etc. Hovever, there has been a few studies on quality of groundwater in irrigation.

Recently, the use of fuzzy logic has become widespread in the field of water quality assessment. Ocampo-Duque et al. (2006) examined the water quality of rivers by using a fuzzy logic approach and suggested a water quality index. Mirabbasi et al. (2008) used the Mamdani fuzzy inference system as a decision support system to classify irrigation water quality. Alavi et al. (2010) used an adaptive fuzzy extraction system (ANFIS) instead of the USSL diagram in the assessment of irrigation water quality. Priya (2013) evaluated the quality of irrigation water in the Karunya Basin in India using the Fuzzy Logic approach. Vadiati et al. (2019) performed three different fuzzy logic approaches named Mamdani, Sugeno, and Larsen to determine water quality.

The study aimed to develop a fuzzy logic system, to determine the quality of groundwater in irrigation by means of fuzzy logic approach based on the data come from 61 different samples taken from Bafra Plain of Samsun province, Turkey and to classify groundwater in irrigation according to the USSL diagram and RSC.

Material and Methods

The study area lies in the Black Sea coastal region of Samsun (41º30'–41º 45' latitude and 35 º 30'–36º 15' longitude) in Northern Turkey (Figure 1). The soils of study area were formed from alluvium on different elevations. The current climate in the region is semi-humid.

Fuzzy Inference System (FIS) were developed and used to determine the quality of the groundwater in irrigation in this study. Membership functions SAR, EC, RSC were developed based on three important parameters, and rules were defined for a Fuzzy Inference System to evaluate irrigation water quality. The fuzzy model was validated using groundwater quality data collected from the Bafra plain. Based on two parameters such as SAR and EC, the FIS classes were elicited.

Groundwater samples were collected from the 61 groundwater wells in August of 2007. All samples were filtered with a 0.45µm filter before analysis, sealed in polyethylene bottles, and stored at 4ºC before analysis. Electrical conductivities (EC) of groundwater samples were measured in situ. Calcium (Ca^{2+}) was analyzed titrimetrically, using standard EDTA. Magnesium (Mg^{2+}) was calculated by taking the differential value between TH and Ca^{2+} concentrations. Sodium (Na^{+}) and potassium (K^{+}) were measured, using a flame photometer. Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^{2-}) were estimated by titrating with HCl.

USSL-diagram, which is a well-known diagram for irrigation water classification (Figure 2) interprets the hydro-chemical analysis of irrigation water. In the diagram, the vertical axis depicts the sodium adsorption ratio (SAR), while the horizontal axis depicts the electrical conductivity (EC). Irrigation water can be classified into the following four categories, based on the EC value:

Table 1. Salinity Classification According to Electrical Conductivity Value

Category	Description	EC	Note
C1	Low-salinity water	$(EC\ (\mu S/cm) < 50\ )$	can be used for each type of soil and plant
C2	Medium-salinity water	$(250 < EC\ (\mu S/cm) < 750)$	can be used for all plants if a moderate amount of leaching occurs
C3	High-salinity water	$(750 < EC\ (\mu S/cm) < 2250)$	cannot be used on soils with restricted drainage, some plants tolerate
C4	Very high salinity water	$(2250 < EC\ (\mu S/cm))$	the soil must be permeable and the drainage must be adequate

In addition to this, plants tolerating salinity should be chosen. The USSL-diagram can be divided into the following four categories, based on SAR criteria:

Table 2. Classification of Irrigation Waters according to SAR values

Category	Description	Note
S1	Low sodium content water	can be used in each type of soil
S2	Medium sodium content water	may produce harmful levels of exchangeable sodium in most soils and will require special soil management such as adding gypsum and organic matters to the soil
S3	High sodium content water	
S4	Very high sodium content water	generally unsuitable for irrigation

The irrigation waters classification concerning SAR is primarily based on the effect of exchangeable sodium on the soil's physical condition. In relation with Mg and Ca, it is another alternative measure of the sodium content. Although not frequently used, this value may appear in some water quality reports. If the RSC > 2.5, the water is not appropriate for irrigation. Wheras, the water is considered to be safe, if the RSC < 1.25.

The research suggests a new method for evaluating irrigation water quality by combining the concentration values of EC and SAR in the USSL-diagram and RSC values through a Mamdani FL-IWQ model.

According to the classification of irrigation water EC (Richards, 1954) water having EC from 0 to 5000 µS/cm is classified into fourth classes. However, the study area salinity values from 0 to 10840 mS / cm vary. Therefore, the EC value of 5000 µS/cm above the water that is added to a separate. This kind of water should not be used strictly for irrigation. Therefore, when creating rules for all groups, this critical value of the irrigation water created by using SAR and RSC was expressed as an "extremely bad".

The following equation was used to calculate the SAR (concentrations are expressed in meq/l):

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

There has been another alternative measure of the sodium content based on Mg and Ca. Although this measure has been used in some water quality reports, it is not widespread. RSC was calculated using the following equation.

$$RSC = (HCO_3^{-} + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$$

If the RSC value, which is calcultated by using above formula, is larger than 1.25, the irrigation water is considered safe. Wheras, the water is not appropriate for irrigation, if the RSC > 2.5.

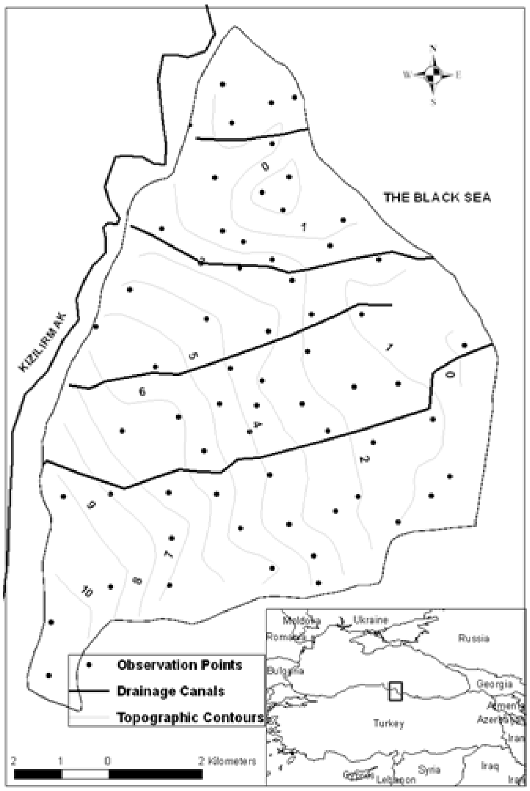


Figure 1. Location and general layout of the study area of topographic contour map with 1.0 m contour interval

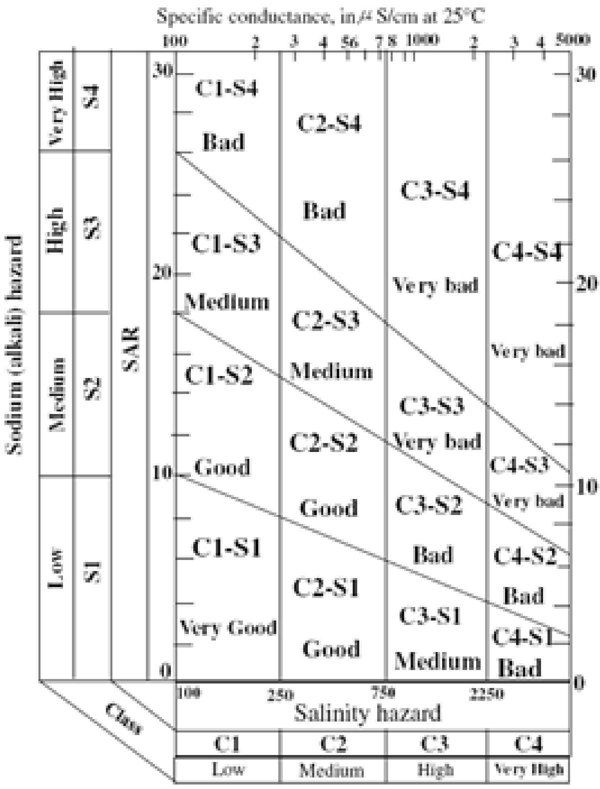


Figure 2. USSL-diagram for classification of irrigation waters (After Richard, 1954)

Development of the fuzzy-rule model

FL-IWQ rules were modeled using the MATLAB® 2010Rb version and the Fuzzy Logic Tool Box Mamdani system. Membership functions and rules for the fuzzy inference system were developed through the examination and interpretation of data observed from the Bafra plain groundwater. Figure 2 shows the block diagram explaining the FL-IWQ modeling.

Identifying the fuzzy input and output variables was the first step in designing the FL-IWQ. Selected three inputs were the difference of RSC, EC, and SAR. The irrigation water quality was defined as a single fuzzy output variable. In second step, the range (universe of discourse) of the inputs and output variables was elicited by examining data.

RSC, EC, SAR and IWQ values belonging Bafra plain varied between (-17.8 to 15.2), (0-10840 µS/cm), (0-35) and (1-6), respectively. Membership functions were selected as trapezoidal and triangle, depending on the intervals chosen in many fuzzy applications. As shown in Figure 4a, RSC consists of three membership functions represented by triangular shapes. The EC consisted of five trapezoidal membership functions while that of Sodium Adsorption Rate (SAR) were four trapezoidal membership functions. Irrigation water quality (IWQ) had six trapezoidal membership functions. They were shown in Figure 4b. Figure 4 (c - d) showed membership functions for RSC and irrigation water quality. Totally 60 rules were created according to the Mamdani system.

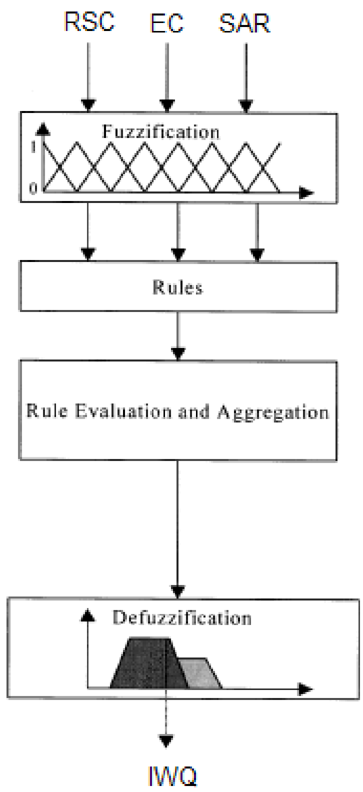


Figure 3. The development of a fuzzy IWQ inference system

RSC

$$\mathrm{RSC}(i1) = \begin{cases} i1; & -17{,}8 \le i1 \le 15{,}2 \\ 0\,; & otherwise \end{cases}$$

EC

$$\mathrm{EC}(i2) = \begin{cases} i2; & 0 \le i2 \le 10840 \\ 0, & otherwise \end{cases}$$

SAR

$$\mathrm{SAR}(i3) = \begin{cases} i3, & 0 \le i3 \le 35 \\ 0, & otherwise \end{cases}$$

IWQ

$$\mathrm{IWQ}(Q1) = \begin{cases} Q1, & 1 \le Q1 \le 6 \\ 0, & otherwise \end{cases}$$

RSC

$$\mu_{low}(i_1) = \begin{cases} 1 & ; \quad İ_1 < -17{,}8 \\ \frac{1{,}3-İ_1}{1{,}3-1{,}2} & ; \quad 1{,}2 \le İ_1 \le 1{,}3 \\ 0 & ; İ_1 > 1{,}3 \end{cases}$$

$$\mu_{low}(i_1) = \left\{\frac{1}{1{,}2} + \frac{0{,}9}{1{,}21} + \ldots\ldots\ldots + \frac{0{,}1}{1{,}29} + \frac{0}{1{,}3}\right.$$

$$\mu_{mid}(i_1) = \begin{cases} \frac{İ_1-1{,}2}{1{,}3-1{,}2} & ; \quad 1{,}2 \le İ_1 \le 1{,}3 \\ 1\,; & 1{,}3 \le İ_1 \le 1{,}8 \\ \frac{2{,}5-İ_1}{2{,}5-1{,}8} & ; \quad 1{,}8 \le İ_1 \le 2{,}5 \end{cases}$$

$$\mu_{mid}(i_1) = \left\{\frac{0}{1{,}2} + \frac{0{,}1}{1{,}21} + \ldots\ldots\ldots + \frac{0{,}9}{1{,}29} + \frac{1}{1{,}3} + \frac{0{,}97}{1{,}87} + \frac{0{,}8}{1{,}94} + \ldots\ldots\ldots + \frac{0{,}1}{2{,}43} + \frac{0}{2{,}5}\right\}$$

$$\mu_{high}(i_1) = \begin{cases} \frac{İ_1-1{,}8}{15{,}2-1{,}8}; & 1{,}8 \le İ_1 \le 15{,}2 \\ 1 & \ge 15{,}2 \end{cases}$$

$$\mu_{high}(i_1) = \left\{\frac{0}{1{,}8} + \frac{0{,}1}{3{,}14} + \ldots\ldots\ldots + \frac{0{,}8}{12{,}52} + \frac{0{,}9}{13{,}86} + \frac{1}{15{,}2}\right.$$

EC

$$\mu_{low}(i_2) = \begin{cases} 1 \;; \quad İ_2 < 0 \\ \frac{350-İ_2}{350-200} \end{cases}$$

$$\mu_{low}(i_2) = \left\{ \frac{1}{200} + \frac{0,9}{215} + \frac{0,8}{230} + \dots\dots\dots + \frac{0,1}{335} + \frac{0}{350} \right.$$

$$\mu_{mid}(i_2) = \begin{cases} \frac{İ_2 - 200}{1,3-1,2} \;; \quad 200 \le İ_2 \le 350 \\ 1 \;; \quad 350 \le İ_2 \le 600 \\ \frac{900-İ_2}{900-600} \;; \quad 600 \le İ_2 \le 900 \end{cases}$$

SAR

$$\mu_{low}(İ_3) = \begin{cases} 1; \quad İ_3 < 0 \\ \frac{9-İ_3}{9-2} \;; \quad 2 \le İ_3 \le 9 \end{cases}$$

$$\mu_{low}(İ_3) = \{ \frac{1}{2} + \frac{0,9}{2,7} + .\dots\dots\dots. + \frac{0,1}{8,3} + \frac{0}{9} \}$$

$$\mu_{mid}(İ_3) = \begin{cases} \frac{İ_3-2}{9-2} \;; \quad 2 \le İ_3 \le 9 \\ \frac{İ_7-İ_3}{İ_7-9} \;; \quad 9 \le İ_3 \le 17 \end{cases}$$

$$\mu_{mid}(İ_3) = \{ \frac{0}{2} + \frac{0,1}{2,7} + \dots\dots\dots\dots.. + \frac{0,9}{8,3} + \frac{1}{9} + \frac{0,9}{9,8} + \frac{0,8}{10,6} + \dots\dots\dots\dots. + \frac{0,1}{16,2} + \frac{0}{17} \}$$

$$\mu_{high}(İ_3) = \begin{cases} \frac{İ_3-6}{17-6} \;; \quad 6 \le İ_3 \le 17 \\ \frac{25-İ_3}{25-17} \;; \quad 17 \le İ_3 \le 25 \end{cases}$$

$$\mu_{high}(İ_3) = \{ \frac{0}{6} + \frac{0,1}{7,1} + \dots\dots\dots.. + \frac{0,8}{14,8} + \frac{0,9}{15,9} + \frac{1}{17} + \frac{0,9}{17,8} + \frac{0,8}{18,6} + \dots\dots\dots.. + \frac{0,1}{24,2} + \frac{0}{25} \}$$

$$\mu_{veryhigh}(İ_3) = \begin{cases} \frac{İ_3-11}{25-11}; \quad 11 \le İ_3 \le 25 \\ 1; \quad 25 \le İ_3 \le 35 \\ 1; \quad İ_3 \ge 35 \end{cases}$$

$$\mu_{veryhigh}(İ_3) = \{ \frac{0}{11} + \frac{0,1}{12,4} + \dots\dots\dots. + \frac{0,9}{23,6} + \frac{1}{25} \}$$

IWQ

$$\mu_{verygood}(Q_1) = \begin{cases} 1; \quad Q_1 \le 1,5 \\ \frac{2-Q_1}{2-1,5} \;; \quad 1,5 \le Q_1 \le 2 \end{cases}$$

$$\mu_{verygood}(Q_1) = \{ \frac{1}{1,5} + \frac{0,9}{1,55} + \dots\dots\dots\dots\dots + \frac{0,1}{1,95} + \frac{0}{2} \}$$

$$\mu_{good}(Q_1) = \begin{cases} \frac{1,5-Q_1}{2-1,5} \;; \quad 1,5 \le Q_1 \le 2 \\ \frac{2,5-Q_1}{2,5-2} \;; \quad 2 \le Q_1 \le 2,5 \end{cases}$$

$$\mu_{good}(Q_1) = \{ \frac{0}{1,5} + \frac{0,1}{1,55} + \dots\dots\dots\dots.. \frac{0,9}{1,55} + \frac{1}{2} + \frac{0,9}{2,05} + \frac{0,8}{2,1} + \dots\dots\dots\dots.. + \frac{0,1}{2,45} + \frac{0}{2,5} \}$$

$$\mu_{medium}\,(Q_1) = \begin{cases} \frac{Q_1-2}{2,5-2}\;; & 2 \le Q_1 \le 2,5 \\ 1; & 2,5 \le Q_1 \le 3,5 \\ \frac{4-Q_1}{4-3,5}\;; & 2,5 \le Q_1 \le 3,5 \end{cases}$$

$$\mu_{medium}\,(Q_1) = \left\{\frac{0}{2} + \frac{0,1}{2,01} + \cdots + \frac{0,9}{2,45} + \frac{1}{2,5} + \cdots + \frac{1}{3,5} + \frac{0,9}{3,55} + \frac{0,8}{3,6} + \cdots + \frac{0,1}{3,95} + \frac{0}{4}\right\}$$

$$\mu_{bad}\,(Q_1) = \left\{\begin{matrix} \frac{Q_1-3,5}{4-3,5}\;; & 3,5 \le Q_1 \le 4 \\ \frac{4,5-Q_1}{4,5-4}\;; & 4 \le Q_1 \le 4,5 \end{matrix}\right\}$$

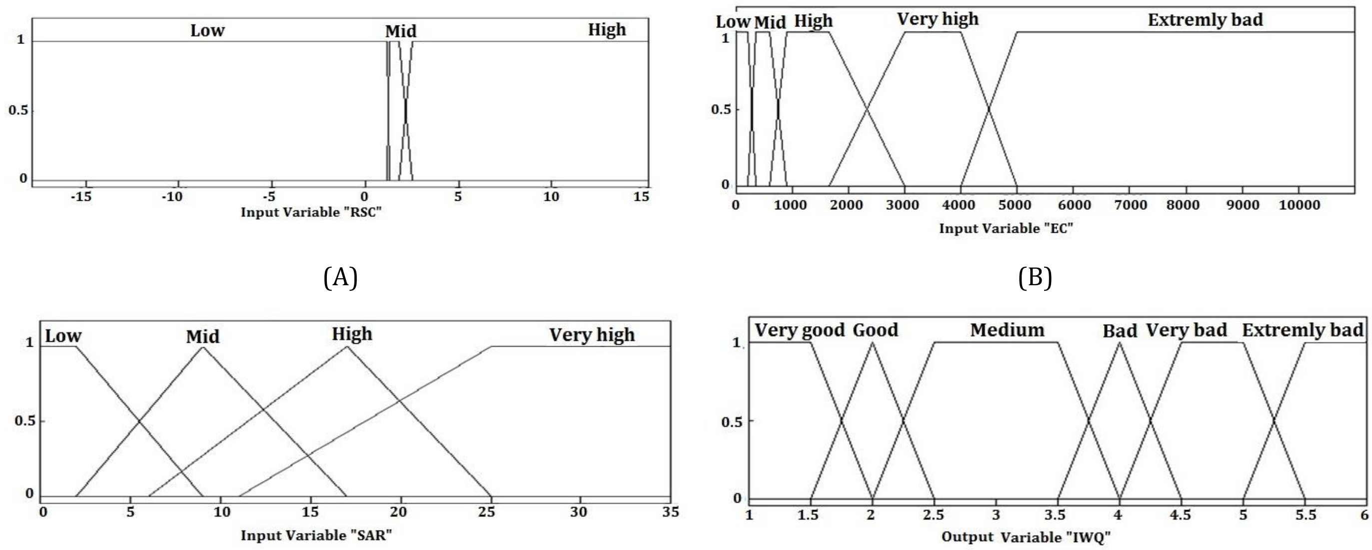
$$\mu_{bad}\,(Q_1) = \left\{\frac{0}{3,5} + \frac{0,1}{3,55} + \cdots + \frac{0,9}{3,95} + \frac{1}{4} + \frac{0,9}{4,05} + \frac{0,8}{4,10} + \cdots + \frac{0,1}{4,45} + \frac{0}{4,5}\right\}$$

$$\mu_{verybad}\,(Q_1) = \left\{\begin{matrix} \frac{Q_1-1}{4,5-4}\;; & 4 \le Q_1 \le 4,5 \\ 1; & 4,5 \le Q_1 \le 5 \\ \frac{5,5-Q_1}{5,5-5}; & 5 \le Q_1 \le 5,5 \end{matrix}\right\}$$

$$\mu_{verybad}\,(Q_1) = \left\{\frac{0}{4} + \frac{0,1}{4,05} + \cdots + \frac{0,8}{4.40} + \frac{0,9}{4,45} + \frac{1}{4,5} + \cdots + \frac{0,9}{5,05} + \frac{0,8}{5,10} + \cdots + \frac{0,1}{5,45} + \frac{0}{5,5}\right\}$$

$$\mu_{extremelybad}\,(Q_1) = \left\{\begin{matrix} \frac{Q_1-5}{5,5-5}\;; & 5 \le Q_1 \le 5,5 \\ 1\;; & 5,5 \le Q_1 \le 6 \end{matrix}\right\}$$

$$\mu_{extremelybad}\,(Q_1) = \left\{\frac{0}{5} + \frac{0,1}{5,05} + \cdots + \frac{0,9}{5,45} + \frac{1}{5,5}\right\}$$



(A) (B)

(C) (D)

Figure 4. (A) The input fuzzy membership functions for RSC (B) the input fuzzy membership functions for EC (C) the input fuzzy membership functions for SAR (D) the output membership functions for fuzzy IWQ

Fuzzification

The measured input values that were transformed into FL-IWQ values were depicted Figure 4. Three input measurements, which were 3690 µS/cm, 5, 96, and -2, 8 of *EC*, SAR, and RSC respectively, used to clarify the situation. The intersection of the value of 5,96 and both low and medium SAR membership produced 48 % grade in the low set and a 52 % grade in the medium set. The value of 3690 µS/cm intersected the very high SAR membership sets. The value of RSC (- 2, 8) has a full (100%) grade in the low set and 0% membership in the rest of the sets. The values of EC and SAR intersected two fuzzy sets.

Fuzzy rules

For writing rules, fuzzification permits the use of literal names rather than actual numbers. As there were five EC, four SAR, and three residual sodium carbonate (RSC) categories, a set of 60 rules were developed.

The matrices of category named representing IWQ rules at low, medium, and high residual sodium carbonate (RSC) were depicted in Tables 3–5.

Table 3. Rules for irrigation water quality (IWQ) at low residual sodium carbonate

	Sodium Adsorption Ratio			
	Low	Mid	High	Very High
Low	Very Good	Very Good	Good	Medium
Mid	Very Good	Good	Good	Medium
High	Good	Good	Medium	Bad
Very High	Medium	Medium	Bad	Very Bad
Extremely	Extremely Bad	Extremely Bad	Extremely Bad	Extremely Bad

Table 4. Rules for irrigation water quality (IWQ) at medium residual sodium carbonate

	Sodium Adsorption Ratio			
	Low	Mid	High	Very High
Low	Very Good	Good	Good	Medium
Mid	Good	Good	Good	Medium
High	Medium	Medium	Bad	Very Bad
Very High	Bad	Bad	Very Bad	Very Bad
Extremely	Extremely Bad	Extremely Bad	Extremely Bad	Extremely Bad

Table 5. Rules for irrigation water quality (IWQ) at high residual sodium carbonate

	Sodium Adsorption Ratio			
	Low	Mid	High	Very High
Low	Medium	Bad	Bad	Bad
Mid	Medium	Bad	Bad	Very Bad
High	Bad	Bad	Very Bad	Very Bad
Very High	Very Bad	Very Bad	Very Bad	Very Bad
Extremely	Extremely Bad	Extremely Bad	Extremely Bad	Extremely Bad

Each of the rule had a premise consisting of three antecedents connected by 'AND' operator, and at the end consisting of a single IWQ consequence. Through the fuzzification process, the antecedent expressions were replaced by membership grades (μ). A maximum combination of eight rules could fire at a time, since each of the input membership function was restricted to only two values (μ). Example of a subset of these rules were given below:

1. IF EC is low AND SAR is low AND *RSC* is low THEN IWQ is VG.
2. IF EC is mid AND SAR is low AND *RSC* is mid THEN IWQ is GD
3. IF EC is high AND SAR is mid AND *RSC* is mid THEN IWQ is MD
4. IF EC is very high AND SAR is high AND *RSC* is high THEN IWQ is VB

In this list, the FL-IWQ rule order did not affect the final irrigation water quality value. Ensuring a FL-IWQ value between one and six for any input condition was the solely objective.

Rule evaluation and aggregation

Irrigation water quality (IWG) values were determined from rules satisfied during the evaluation process by using the MIN-MAX inference method. The consequent fuzzy union was restricted to the minimum of the predicate truth, while the output fuzzy region was updated by taking the maximum of the minimized fuzzy sets. The minimum operator limits certainty of the overall irrigation water quality (IWQ) was the least certain input observation. The final IWQ membership function was obtained using the MAX composition procedure.

Defuzzification

Each of the center of area or the center of gravity (COA), the mean of maxima (MOM), least of maxima (LOM), and (SOM) defuzzification methods were tested. To test FL-IWG, independent comparisons were performed for EC, SAR, and RSC.

Model evaluation indicators

Scatter plot and Taylor diagram were used for exploring the accuracy and performance of the fuzzy logic mamdani approach. The scatter plot reflected the distribution of expert and fuzzy logic model points along with the 1: 1 axis. Since the correlation coefficient (r), RMSE, and standard deviation (SD) could be obtained, the Taylor diagram was preferred (Cemek et al., 2020).

Results and Discussion

The study evaluated the quality of irrigation water by using fuzzy Mamdani approach based on EC, SAR, and RSC of sample irrigation water and different classification criteria. For this purpose, the water EC, SAR, and RSC values formed according to the 60-rule. The FL-IWQ defuzzification methods was followed using center of area (COA), mean of maxima (MOM), least of maxima (LOM), and (SOM) when comparing quality values of groundwater in irrigation. Groundwater in irrigation was classified by using the values of COA, mom, solid and lom presented in Figure 5. The blue estimation was observed for COA (R^2 = 0.9874), mom (R^2 = 0.9755), solid (R^2 = 0.9574) and lom (R^2 = 0.9453), respectively. Centroid produced the best result for quality of irrigation water.

Mirabbasi et al (2008), Priya (2013), Vadiati et al (2019) preferred the Mamdani approach when classifying irrigation water by using a fuzzy logic approach, while Alavi et al (2010) used the Sugeno approach. Mirabbasi et al (2008) preferred using EC and SAR as input variables, while that of SAR, EC, chloride and sulfate for Priya (2013), EC and SAR for Alavi et al (2010), and EC, SAR, MAR, SSP, KR, RSC and PI for Vadiati et al (2019). The study used EC, SAR, and RSC as input variables for groundwater in irrigation in Bafra plain of Samsun province. Based on the research findings, the fuzzy logic approach produced very successful results compared to traditional graphical methods.

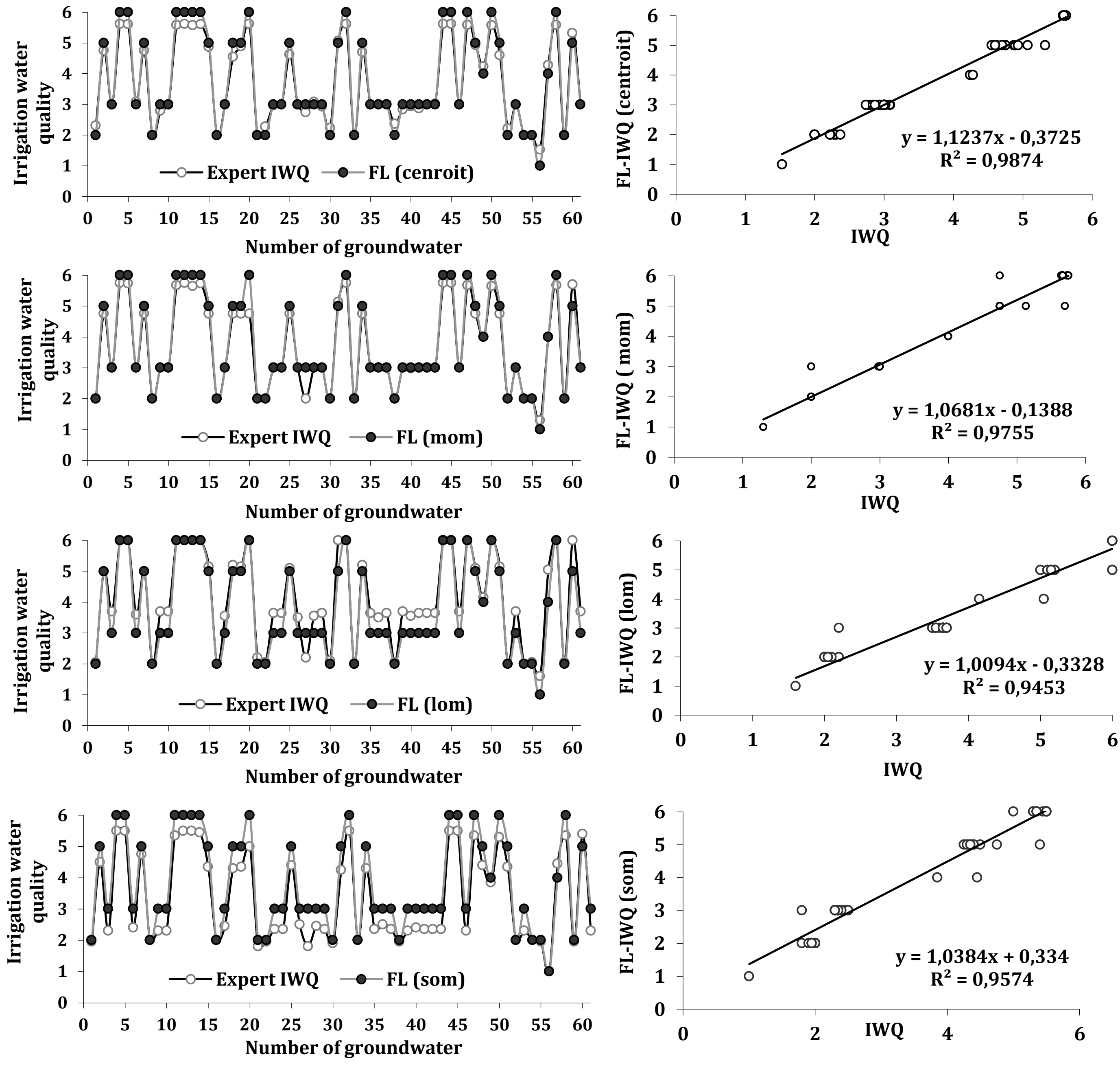


Figure 5. Comparison of expert irrigation water quality and fuzzy logic results of different defuzzification methods

Table 6 presented the output scores, fuzzy evaluation, IWQ and agreement of evaluation based on the results of the comparative analysis associated with well. The agreement evaluation value was 93%, on average. The model results showed that the wells numbered 1, 20, 25, and 40 were "good" and its agreement varied from 26% to 59%. The range of EC, SAR and RSC values of these wells for EC, SAR and RSC were 1728 µS/cm - 1798 µS/cm, 1.38 - 3.45 and -7.50 - 0.10, respectively. Based on the EC values, sample irrigation waters were included in to the upper group in terms of salinity, while the reverse was the case for tahe values of SAR and RSC. It was observed that there was a difference in the output results due to EC values. As for the wells numbered 30 and 60, they were included into "Very bad" group and its agreement varied from 86% to 36%. EC, SAR, and RSC values of well 30 were 4500 µS/cm, 25, 24, and 14.8, respectively, while that of well numbered 60 were 4780 µS/ cm, 13.91, and 8.40, respectively. The EC values of these wells were very close to the upper group limit of 5000 µS/cm.

Table 6. Evaluation results of FL-IWQ with ECW, SAR and RSC expert for groundwater in irrigation purpose

Well No	Output score	Fuzzy Evaluation	IWQ	Agreement of Evaluations (%)
1	2.31	41 %medium and 59 %Good	Good	59
5	5.61	100 % Extremely Bad	Extremely bad	100
10	3.00	100 % Medium	Medium	100
15	4.87	100 % Very Bad	Very bad	100
20	2.28	56% Medium and 44 % Good	Good	44
25	2.23	54% Good and 46 % Medium	Good	54
30	5.07	86 % Very bad and 14 % Extremely Bad	Very bad	86
35	3.00	100 % Medium	Medium	100
40	2.37	74 % Medium and % 26 Good	Good	26
45	5.62	100 % Extremely bad	Extremely bad	100
50	4.24	52 % Bad and 48 % Very Bad	Bad	52
55	2.00	100 % Good	Good	100
60	5.32	64 Extremely bad and 36 very bad	Very bad	64
61	3.00	100 % Medium	Medium	100
			Average	93

There have been different methods used when classfying the irrigation or drinking water worldwide. In general, the values of EC, SAR, RSC, Cl, Na of waters have been used in irrigation water classification. However, different irrigation water classes have been produced according to different parameters in classical methods, resulting in confusion when determining the the quality of the irrigation water and uncertainty arise on whether the water is suitable for irrigation. In some cases, irrigation water is suitable when focusing on the values EC and SAR, while the reverse was the case when focusing on the value of RSC, That is wahy, the study clarified the irrigation water class by evaluating all of these quality parameters together.

Classical irrigation water classification methods led to misspesification when the values of water quality parameters are close to the limit values. For example, irrigation water with an EC value of 800 µS/cm and water with 2200 µS/cm is included into C3 in terms of EC, while its effects on plant yield are very different from C3. Evaluation of agreement between the FL-IWQ obtained outputs and expert knowledge is an important phase in FL-IWQ construction. It means that the system could produce associated with the different conditions that can be presented.

Table 6 showed the comparative results of EC, SAR, RSC, and FL-IWQ. The results showed that the FL-IWQ method could rank water quality samples with 93 % general agreement, apart from samples that lie in class's borders. In the FL-IWQ method, according to RSC, SAR, and EC of each water sample, a score assigned to be between (1-6).

Figure 6 presented the standard deviation (SD) and correlation coefficient (R) values of observed and modelled estimates comparatively for COA, MOM, LOM, and SOM methods with experiment. This diagram represents. Figure 6 also showed the centered root mean squared error (RMSE) difference (Taylor, 2001). The best estimation model is selected by the point with a higher R and lower RMSE (Küçüktopcu and Cemek, 2020; Cemek et al., 2020). It was clear from the evidence obtained Figure 6 that the COA model result was much closer to the data point of experiment compared to the results the other models generated.

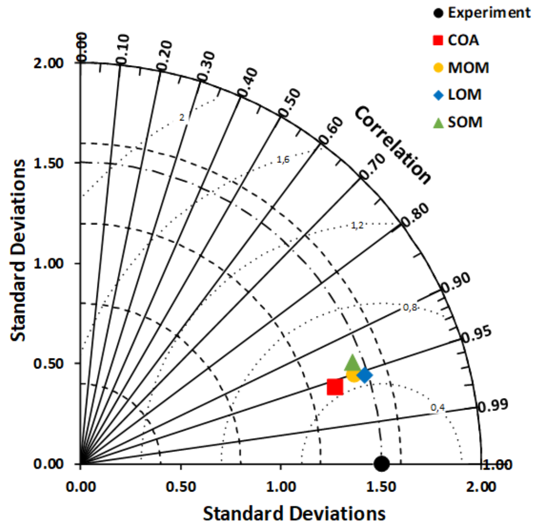


Figure 6. Comparison of the performances of different defuzzification methods with the Taylor diagram

Conclusion

Uncertainties in the classification of irrigation water quality make it difficult to decide on the use of groundwater for irrigation for agricultural use. In this study, the center of the area (COA), mean of maxima (MOM), least of maxima (LOM), and (SOM) was used to cope with uncertainty problem. The best results were obtained from COA. It was clear from the light of the research findings that fuzzy logic approach was more appropriate than traditional when classifying irrigation water quality. The study suggests new approach by comabining digitizing groundwater quality samples using fuzzy logic approaches, expert evaluation, and linguistic expressions for deciding the use of irrigation water. Fuzzy logic models produced more consistent results compared to traditional methods. Fuzzy inference method is suitable for irrigation water quality assessment due to its integrated decision-making mechanism based on important irrigation indices. Given the uncertainties in the measurement and analysis of parameters such as EC, SAR, and RSC during model development, this study base revealed a more reliable and flexible method for water quality assessment than traditional methods.

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The effects of whey application on the soil biological properties and plant growth

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Abstract

Whey is an industrial dairy by-product. Whey proteins present in whey are valuable functional ingredients with a variety of applications. Because of high investment and management costs, many medium and small-scale cheese manufacturing plants choose the way to waste whey by discharging it to land without refining while large companies prefer to evaluate it. In this experiment were investigated the effects of whey application on some growth parameters of test plant and soil biological properties. For this purpose, greenhouse experiment was conducted to determine the effects of different whey powder solution (6% dry matter) such as no demineralized whey powder (NDWP), 50% demineralized whey powder (50% DWP) and whey protein powder (WPP) on maize growth and biological properties of soils using increasing application rates (0, 50, 100, 150 and 200 ml/kg) as three replication. At the end of the study generally, all whey treatments influenced the soil microbiological properties in comparison with the control, indicating activation by microorganisms. The addition of different doses of different whey solutions caused a rapid and significant increase in microbial biomass C, soil respiration, dehydrogenase activity and catalase activity in soil; this increase was especially noticeable in soils treated with NDWP and 50% DWP. Similarly, addition of 50% DWP to the soil increased values of plant height, fresh plant weight and fresh root weight compared to the control and other whey. Whey has a positive effect on soil biological properties. In conclusion, we can say that this waste product, which has high nutrient element content, could be used in fertilization practices especially as a nitrogen source and multi-perspective studies need to be carried out on this topic.

Keywords: Microbial biomass, Soil respiration, Whey powder, Soil biological properties.

Introduction

Whey is the liquid that remains after the separation of casein and fat during milk coagulation in cheese production. The composition of whey varies depending on the type of cheese and the production technique or the liquid of curdled milk. Whey can be found in liquid, powder, granule and other solid forms depending on the state of processing. Whey is rich in lactose and serum proteins (α-lactalbumin, β-lactoglobulin) it includes and is a liquid with high nutritional value. Whey is a left over product whose recovery is highly important and at the same time one of the most important raw materials of the biotechnology sector. Production of 1 kg of cheese generates approximately 9 kg of whey (Robbins et al., 1996). The current world production of whey is about 125 million tonnes, in which about 64% is produced in European countries and 24% in North America (Naik et al., 2009).

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According to the data from 2012, total cheese production in Turkey is 564.031 tons (TUIK, 2012). Although big enterprises prefer to make use of whey, many middle and small scale cheese factories prefer to drain the remaining whey to the land without refining or making use of it due to high investment and operational expenses. Utilization of whey by means of alternative techniques and products is important in terms of the economy, environmental health and nutrition.

It is stated that whey can be used as fertilizer with doing little or no harm to the environment and can be applied to the soil. Several researchers, on the other hand, state that whey would have a positive effect on soil when used as plant nutrient and particularly for fertilization purposes (Watson, 1978; Ryder, 1980; Sienkiewicz and Riedel, 1990) and whey is a nutrient source for agricultural products (Wisconsin Department of Agriculture). Again, some researchers studied the effects of whey on plant development and soil properties and found out that the use of whey improved soil aggregation and maintained an increase in yield in the first and second year after the application (Sharratt et al., 1962; Peterson et al., 1979). Furthermore, the use of whey improves the physical and chemical properties of the soil and increases the aggregate stability and the infiltration rate of sodic soils (Jones et al., 1993; Lehrsch et al., 1994) and acidic soils (Watson et al., 1977; Kelling and Peterson, 1981). Whey increases the infiltration rate in sodic soils by decreasing Exchangeable Sodium Percentage (ESP), Sodium Adsorption Ratio (SAR) and pH values (Jones et al., 1993).

Whey is a good nitrogen source for plant production. The constituents of whey which are important for manuring and microbiological growth are N, P, K, S, Ca, Na, Mg, lactose and proteins (Morris, 1985). It is used for manuring purposes not only to encourage plant growth but may also increase the microorganism population in the soil (Reddy et al., 1987; Özrenk et al., 2003).Whey and straw additions formed higher soil biomass-C contents and C_{mic}/C_{org} ratios compared to vegetable oil. Fungal contributions to biomass-C dominated over bacterial contributions in whey and straw-amended soil (Sonnleitner et al., 2003a).

The present study was conducted because there are a limited number of studies on the effects of whey on certain biological characteristics of soil and plant production, the chemical properties of whey give it the potential to be used as a biological fertilizer and some researchers recommend the use of whey as a complete fertilizer (Wendorff, 2012) similar to animal manure. For this purpose, maize was used as test plant in the pot experiment and three whey samples with different properties were regularly applied to the plants after the sowing process. Certain biological properties of the soil were investigated after harvesting the plants.

Material and Methods

Material

For this purpose, greenhouse experiment was conducted to determine the effects of different whey powder solutions such as non-demineralized whey powder (NDWP), 50% demineralized whey powder (50% DWP) and whey protein powder (WPP) on BC 532 type maize (*Zea mays L. indentata S.)* growth and biological properties of soils using increasing application rates (0, 50, 100, 150 and 200 ml/kg soil) as three replication. The soil used in the experiment was taken from a depth of 0-20 cm from streambed located in the Campus district of Konya province.

The general analyses of this soil, which was used as growth medium, were conducted at the laboratory of Konya Commodity Exchange. Soil pH was slightly alkaline and calcareous. The soil was salt-free with low organic content and soil texture was sandy-loam (Table 1).

Table 1. Certain physical and chemical characteristics of the soil

pH (1:2.5)	: 7.46	P (mg kg^{-1})	: 3.00
EC (1:5 µS cm^{-1})	: 479	Fe (mg kg^{-1})	: 5.87
Organic matter (%)	: 0.125	Cu (mg kg^{-1})	: 0.345
$CaCO_3$ (%)	: 10.05	Mn (mg kg^{-1})	: 8.677
Ca (mg kg^{-1})	: 4185	Zn (mg kg^{-1})	: 0.216
Mg (mg kg^{-1})	: 216.7	Na (mg kg^{-1})	: 45.08
K_2O (meq 100 g^{-1})	: 0.174		

In the experiment, which was set up in the greenhouse in March 2011, 10 maize seeds were planted in each 3-kilogram-pot. After the germination of the plants, a thinning process was applied to leave 6 seedlings in each pot. As mentioned above, three different types of whey powder solutions were applied to the pots in four different doses twice a week [(demineralized whey powder (NDWP), 50% demineralized whey powder (50% DWP) and whey protein powder (WPP)]. The whey used in the study was obtained from the producer in dried powder form (ENKA Dairy and Food Products Co., Konya, Turkey) and solutions were prepared with water at doses of 0, 50, 100, 150 and 200 ml/kg soil before the application and then given to the pots (6% dry matter). Also, the test plants were irrigated by using pure water after the planting process. The results of the analysis performed on the whey powder applied to the pots are presented in Table 2. Plants were harvested after 10 weeks; and plant height, weight, growth and root weight were measured. The following analyses were performed on the soils in the pots after the harvesting process.

Table 2. Compositions of whey powder used in the experiments

Composition	50% DWP*	NDWP	WPP
Dry matter (%)	96.5	96.5	95
Fat (%)	1	0.5	6
Protein (%)	7	6	75
Ash (%)	4.5	9	4
Lactose (%)	82	78	6
pH	6.20	6.20	6.35
Salt (%)	3.5	7.0	3.4
Coliform bacteria, *E. coli*, yeast and mold (CFU/g)	0	0	0

* 50% DWP: 50% demineralized whey powder; NDWP: non demineralized whey powder; WPP: whey protein powder

Method

Microbial biomass carbon and basal soil respiration

Microbial biomass carbon (C_{mic}) was determined by the substrate-induced respiration method of by Anderson and Domsch (Anderson and Domsch, 1978). The carbon dioxide (CO_2) production rate was measured hourly using the method described by Anderson (1982). The pattern of respiratory response was recorded for 4 h. Microbial biomass carbon (C_{mic}) was calculated from the maximum initial respiratory response in terms of mg C g^{-1} soil as 40.04 mg CO_2 g^{-1} + 3.75. Data are expressed as mg C g^{-1} dry sample.

Basal soil respiration (BSR) at field capacity (CO_2 production at 22 ^{0}C without addition of glucose) was measured, as reported by Anderson (1982), by alkali [barium hydroxide [$Ba(OH)_2.8H_2O$] + barium chloride ($BaCl_2$)] absorption of the CO_2 produced during the 24h incubation period, followed by titration of the residual OH^- with standardized hydrochloric acid, after adding three drops of phenolphthalein as an indicator. Data are expressed as mg CO_2-C g^{-1} dry sample.

Enzyme activities

Dehydrogenase activity (DHA) was determined according to Pepper et al. (1995). To 6 g of sample, 30 mg of glucose, 1 mL of 3% TTC (2,3,5 triphenyltetrazoliumchlorid) solution, and 2.5 mL of pure water were added. The samples were incubated for 24 h at 37^{0}C. The formation of TPF (1,3,5 triphenylformazan) was determined spectrophotometrically at 485 nm, and results are expressed as µg TPF g^{-1} dry sample.

Catalase activity (CA) was measured by the method of Beck (1971). Ten mL of phosphate buffer (pH 7) and 5 mL of a 3% hydrogen peroxide (H_2O_2) substrate solution were added to 5 g of sample. The volume (mL) of O_2 released within 3 min at 20^{0}C was determined. Three replicates of each sample were tested, and controls were tested in the same way, but with the addition of 2 mL of 6.5% (w/v) NaN_3. Results are expressed as mL O_2 g^{-1} dry sample.

Analysis of minerals

In the analysis of minerals, a microwave system (MARS 5, CEM Corporation, Matthews, NC) was used for acid digestion of all the plants. Samples were prepared in triplicate runs (Anonymous, 1998). Mineral concentrations (mg kg^{-1}) were determined by inductively coupled plasma atomic emission spectrometry (CCD Simultaneous ICP-AES, Varian, Palo Alto, CA) with an automatic sampler system. Nitrogen contents of samples were analyzed with Kjeldahl N method (Jones, 2001).

Colour measurements

Colour measurements were performed using a Minolta Chroma Meter CR-400 (Minolta, Osaka, Japan). Light/dark chromaticity (L*), green/red chromaticity (a*) and blue/yellow chromaticity (b*) were determined according to the CIELab colour space system. The instrument was calibrated with a white reference tile (L^* = 97.10, a^* = −4.88, b^* = 7.04) before the measurements (Wrolstad and Smith, 2014).

Statistical analysis

The data obtained through the measurements were statistically analyzed using Minitab and Mstat software (Yurtsever, 1984).

Results

Significant changes were observed in plant weight depending on the use of different whey solutions (Table 3) ($p<0.01$). The highest mean value was observed in plants in which 50% DWP solution was used. Plant weights increased depending on the increasing doses of 50% DWP solution. The use of NDWP solution above 100 mg/kg caused significant decreases in plant weights. Considering plant weight values, it was determined that the use of WPP solution at 50 ml/kg would be suitable. Plant root weights varied between approximately 27.72-43.90 g. The lowest root weight was observed in plants with 200 ml/kg application of NDWP solution. Increasing doses of 50% DWP solution did not cause significant differences in root weights ($p>0.01$).

Table 3. The effect of whey applications on plant growing parameters and soil biological properties

Whey applications*	Whey doses (ml/kg soil)	Plant weight (g)	Root weight (g)	Cmic	BSR	CA	DHA
50% DWP	0	32.87 c†	33.98	12.06 d	0.86 d	163.39 c	1.74 c
	50	38.30 c	35.80	16.96 d	1.80 c	203.03 b	4.42 b
	100	41.96 bc	37.69	33.74 c	2.32 c	292.71 a	7.26 a
	150	53.44 ab	50.31	44.91 b	3.59 b	177.63 bc	7.81 a
	200	60.68 a	49.04	69.41 a	4.91 a	157.14 c	7.32 a
	Mean	45.45	41.36 A‡	35.42 A	2.70 A	198.78 B	5.71 C
NDWP	0	41.47 b	35.01 a	11.60 d	0.84 d	153.52 c	2.43 c
	50	81.19 a	54.93 a	42.98 a	1.53 c	304.97 a	14.82 a
	100	68.23 a	43.07 a	30.13 b	2.17 b	255.52 b	11.51 b
	150	5.80 c	4.96 b	22.36 c	2.48 a	174.02 c	9.96 b
	200	0.81 c	0.64 b	16.44 d	2.02 b	162.72 c	10.17 b
	Mean	39.50	27.72 B	24.70 B	1.81 B	210.15 A	9.78 A
WPP	0	46.65 a	43.79 ab	19.38 d	0.86 d	153.67 a	1.48 d
	50	53.49 a	55.94 a	29.60 c	1.61 c	139.03 a	5.47 c
	100	33.34 b	38.74 b	32.68 c	2.33 a	111.91 b	8.09 b
	150	33.63 b	34.37 b	44.77 b	2.11 b	85.38 c	9.91 a
	200	42.48 ab	46.64 ab	61.89 a	1.80 c	57.14 d	9.95 a
	Mean	41.92	43.90 A	37.66 A	1.74 B	109.43 C	6.98 B

Cmic: Microbial biomass C (mg CO_2-C/g dry soil 24h) ; BSR : Basal soil respiration (mg CO_2-C/g dry soil 24h);
CA : Catalase activity (ml O_2/g dry soil 3 min.); DHA: Dehydrogenase activity (mg TPF/g dry soil 24h)
* 50% DWP: 50% demineralized whey powder; NDWP: non demineralized whey powder; WPP: whey protein powder
† Means in the same columns with different small letters are significantly different (*p<0.01*) into same application.
‡ Means in the same columns with different capital letters are significantly different (*p<0.01*) among different applications

Plant growth rates (%) are presented in Figure 1. An increase was observed in the growth rate in plants with 50% DWP application depending on the rate of usage. The use of NDWP resulted in the lowest plant growth rate. Shoot development was not observed in plants through 200 ml/kg application.

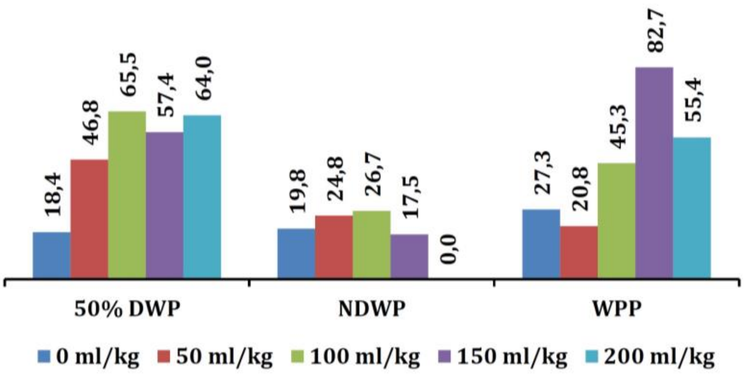

Figure 1. Plant growth rates (%)

The highest growth rate was observed in plants with 150 ml/kg WPP application. Basal soil respiration values varied between 0.84-4.91 mg CO_2-C/g dry soil. The highest mean value was observed with the use of 50% DWP solution and significantly increased depending on the usage rate of 50% DWP ($p<0.01$). The same tendency was observed also in other whey solutions. The respective 150 and 100 ml/kg soil overdoses of NDWP and WPP solutions caused a decrease in basal soil respiration values. The catalase activity of the soils was significantly affected by the use of different whey solutions ($p<0.01$). The highest mean value (210.15 ml O_2/g) was determined in soils with the use of NDWP solution. The 100 ml/kg soil overdose of 50% DWP solution caused significant decreases in catalase activity. The lowest catalase activity values in the soil samples were observed through the use of WPP solution. The increasing use of WPP and NDWP solutions caused sharp decreases in catalase activity. The dehydrogenase activity in the soil samples reached the highest mean values through the use of NDWP>WPP>50% DWP solutions. All whey solution applications resulted in higher dehydrogenase activity compared to control samples. In contrast to other solutions, the increasing use of NDWP caused a significant decrease in dehydrogenase activity ($p<0.01$). For 50% DWP solution, doses of 150-200 ml/kg soil provided similar dehydrogenase activities ($p>0.01$). The highest mean N content in plants was observed in the samples with 50% DWP application (Table 4).

Table 4. The effect of whey applications on plant mineral contents

Whey applications*	Whey doses (ml/kg soil)	%			mg/kg							
		N	K	P	Ca	Mg	S	Fe	Zn	Mn	Cu	B
50% DWP	0	1.71	3.12 ^{ab}	1.09	5800	2582	3070	105.3	11.23	68.49	2.52	14.72
	50	1.13	1.45 ^{b}	0.54	8658	2566	3036	308.1	17.45	92.80	3.39	14.45
	100	1.62	3.71 ^{a}	1.33	5396	2421	3072	115.7	15.71	77.06	3.23	12.78
	150	2.51	3.38 ^{a}	1.07	7224	2717	3018	228.7	17.35	92.98	4.62	15.20
	200	2.25	2.92 ^{ab}	0.96	7207	2933	2997	87.2	17.28	67.49	3.61	21.68
	Mean	1.84^{A‡}	2.92	0.99	6857	2644 ^{A}	3038 ^{A}	169.0	15.80	79.76	3.47	15.76 ^{A}
NDWP	0	2.22 ^{a}	2.85	0.76	5854 ^{b}	2895 ^{ab}	3060 ^{a}	113.6	30.66^{b}	67.78	2.96 ^{ab}	13.15 ^{bc}
	50	1.97 ^{ab}	2.41	0.51	5732 ^{b}	2564 ^{b}	3022 ^{ab}	94.8	11.92^{b}	58.92	2.15 ^{b}	14.58 ^{abc}
	100	1.03 ^{c}	2.50	0.83	5160 ^{b}	2340 ^{b}	2982 ^{abc}	101.8	45.59^{ab}	61.16	1.70 ^{b}	11.78 ^{c}
	150	1.27 ^{bc}	2.57	0.57	6983 ^{ab}	3451 ^{a}	2939 ^{c}	117.1	76.90^{a}	63.98	4.64 ^{a}	19.92 ^{a}
	200	1.08 ^{c}	2.75	0.70	8294 ^{a}	3477 ^{a}	2943 ^{bc}	139.9	26.95^{b}	66.59	4.63 ^{a}	17.88 ^{ab}
	Mean	1.51 ^{B}	2.62	0.67	6405	2945 ^{A}	2989 ^{A}	113.4	38.40	63.69	3.22	15.46 ^{A}
WPP	0	1.85 ^{a}	3.03	0.87	6783	2408	2944 ^{a}	75.9	18.46^{b}	64.05	2.88	14.24
	50	1.13 ^{b}	2.88	0.76	4585	1982	2610 ^{b}	83.6	44.76^{a}	66.27	1.67	12.22
	100	1.53 ^{ab}	2.77	0.63	4757	2059	2646 ^{b}	55.6	29.24 ^{ab}	62.00	1.64	12.39
	150	1.23 ^{ab}	2.69	0.74	6381	2555	2801 ^{ab}	87.5	30.90 ^{ab}	57.70	2.82	9.52
	200	1.32 ^{ab}	3.43	1.23	6066	2036	2823 ^{ab}	73.4	33.87 ^{ab}	77.56	1.83	10.04
	Mean	1.41 ^{B}	2.96	0.85	5714	2208 ^{B}	2765 ^{B}	75.2	31.45	65.52	2.17	11.68 ^{B}

* 50% DWP: 50% demineralized whey powder; NDWP: non demineralized whey powder; WPP: whey protein powder

† Means in the same columns with different small letters are significantly different (*p<0.01*) into same application.

‡ Means in the same columns with different capital letters are significantly different (*p<0.01*) among different applications.

The increasing use of NDWP solution significantly decreased the N content ($p<0.01$). The use of WPP solution at doses of 100-200 ml/kg soil revealed an N accumulation close to that in the control group. P, Fe and Mn contents of the plants were found to be between 0.51-1.33, 55.6-308.1 and 57.70-92.80 mg/kg, respectively. The use of 50% DWP and WPP solutions did not cause any significant differences in the Ca, Mg, Cu and B contents of the plants. Compared to the control group, the use of NDWP at dose of 200 ml/kg caused increases 41.68% in Ca content. The lowest mean value in terms of Mg content was observed in plants with WPP application. A significant decrease was observed in S content of the plants with the increasing use of NDWP ($p<0.01$). The usage doses of WPP solution provided S contents that were close to one another, whereas the use of 50% DWP did not reveal a significant difference. The highest mean Zn value was observed in plants with the use of NDWP solution. In terms of Cu content, a difference was observed in plants only through NDWP application depending on the doses applied. The highest L value (brightness) was observed in plants with 50% DWP application (Figure 2). The use of 50% DWP caused an increase in the brightness values of the plants up to a usage of 150 ml/kg. The use of NDWP solution caused a sharp decrease in the brightness values of the plants. Color values could not be measured for the 200 ml/kg soil NDWP application due to the death of the plants. The a values of the plants showed significant differences depending on the whey solutions applied to the plants.

All doses of 50% DWP solution resulted in a greener leaf color compared to those of the control group samples. An increase was observed in the red color intensity of the leaves with increasing doses of NDWP. The highest red color intensity was determined in plant leaves with 150 ml/kg NDWP application. All uses of WPP solution resulted in higher green color intensity compared to control except for the 50 ml/kg dose. The b values of the leaves increased in plants with increasing doses of 50% DWP and WPP solutions. It was found that the leaves had the highest yellow color intensity with the use of 50% DWP solution. A decrease was observed in b values depending on the use of NDWP solution.

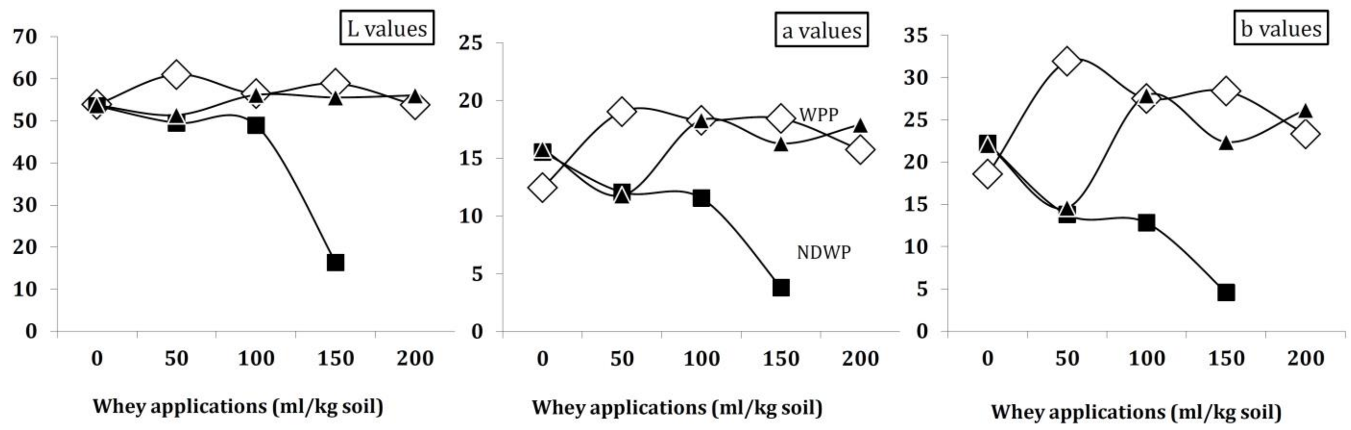

Figure 2. The effect of whey solutions on plant leaf color

Discussion

Increases between 40.63-47.53% were observed in microbial biomass C ratio depending on the usage rate of 50% DWP solution. The highest mean microbial biomass was determined in soils with 50% DWP and WPP application. In contrast to other solutions, microbial biomass significantly decreased depending on the usage rate of NDWP ($p<0.01$). This byproduct, which pollutes the environment and negatively affects plant and animal life by consuming the oxygen in the water when dumped into rivers or lakes, should be used with utmost care when being used as fertilizer in fields and pasture lands, because if whey is not applied to the soil in a careful and controlled way, it could cause cereal plants or pasture grass to stay thin and weak depending on climate, geographical structure and soil properties. For this reason, it is pointed out that it would be correct to apply whey to pasture lands and soil in periods when rainfall is plentiful, like spring (Konar and Arioglu, 1987).

It was reported that whey brought an increase in yield, improved soil structure, and increased the water holding capacity and porosity of the soil (Watson, 1978; Sienkiewicz and Riedel, 1990), increased aggregate stability and infiltration rate in sodic soils (Watson et al., 1977; Lehrsch et al., 1994) and acidic soils (Kelling and Peterson, 1981). Whey applications maintained higher soil biomass-C contents and Cmic/Corg ratio compared to that of straw and vegetable oil; furthermore, fungal contributions to biomass-C dominated over bacterial contributions in whey and straw-amended soil (Sonnleitner et al., 2003a). Protein N existing in whey is converted into inorganic nitrogen in soil and can be used by plants. Besides, whey is rich in nutrients and certain carbon compounds like lactose and is an energy source for microorganisms (Morris 1985; Morissey, 1985). It was reported in certain studies that whey increases the bacterial and fungal population in the soil (Sonnleitner et al., 2003a,b). Acid whey can also improve the physical condition of sodic soil (Robbins and Lehrsch, 1992). Addition of whey soluble salts to the soil solution should reduce the diffuse double-layer thicknesses of clay domains, thus encouraging clay flocculation (Lehrsch et al., 1993). This improved aggregation will increase the proportion of larger soil pores thereby increasing the flux density of both water and air through the soil profile (Hillel, 1982). Stimulation of aerobic microbiological activity by adding and incorporating whey lactose will produce polysaccharides that will stabilize aggregates (Allison, 1968). Bridges of divalent cations and organic matter (Edwards and Bremner, 1967) will bond soil particles to one another, also increasing aggregate stability. The use of NDWP and WPP solutions did not have an effect on the K content of the plants ($p>0.01$). The use of 50% DWP solution at doses of 100-150 ml/kg soil maintained a higher K accumulation compared to that of the control group. The Ca^{2+}, Mg^{2+} and K^{+} in the whey will also tend to lower the soil solution pH since they are not hydrated at low ionic strengths as is Na^{+}. All of these processes will speed the leaching of exchangeable Na from a sodic soil profile when sufficient water is passed through the soil. The lowered pH will make most micronutrient cations more available to plants grown on the reclaimed site. In addition, micronutrients in the applied whey (Radford et al., 1986) should be available to crops. It should not be forgotten that in case whey is dumped into the environment without being refined, this process should be carried out under control; the amount of protein nitrogen that will be obtained from whey should be calculated so that nitrogenous fertilizer is not given more than the plant needs during the chemical fertilization process and excessive nitrogen might cause pollution problems. As it was also found in the present study, whey has a positive effect on soil biological properties. In conclusion, we can say that this waste product, which has high nutrient element content, could be used in fertilization practices especially as a nitrogen source and multi-perspective studies need to be carried out on this topic.

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Mechanisms of copper immobilization in Fluvisol after the carbon sorbent applying

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Abstract

Biochar is widely used sorbent for soil remediation but the mechanism of its effect on immobilization of metals and particular processes of metal transformation are still unclear. We designed an incubation experiment to investigate the impact of wood biochar to copper (Cu) contamination in Calcaric Fluvisols Loamic. The efficiency of biochar implementation for reduction of Cu mobility in soil has been studied using combined method of heavy metal fractioning (Minkina et al., 2013). It was shown that the use of sorbent into polluted soil results in the change of fraction-group composition of metal compounds, fixation of Cu due to reduction of weakly bound forms and increase of the part of residual and metal fractions strongly bound with organic matter. Decrease of pollutant mobility occurs along an increase of the dose of a sorbent. The greater effect was observed after use of biochar in the concentration 2.5 %. Thus, the present study demonstrates the possible remediation of soil contaminated by heavy metals using biochar and provides a particular strategy for remediation of soils contaminated with Cu.

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Introduction

In present, heavy metal (HM) pollution brings the serious threat to the environment. Metals are not biodegradable over time and accumulate in environmental objects posing a threat to various links of the trophic chains (Kabata-Pendias, 2011). HM pollution results to deterioration of soil quality and loss of soil functions (Schloter et al., 2017; Wang et al., 2017) that brings a danger to human health (Wood et al., 2016; Shen et al., 2017). Therefore, the soil remediation polluted with HM became the most studied and global problem (Zota et al., 2009; Violante et al., 2010; Ju et al., 2019).

Recently, various methods of soil cleaning from HMs and preventing their migration into adjacent environments have been developed and tested. In particular, carbon sorbents (for example, activated carbon and biochar), which include the products of thermal treatment of materials of plant and animal origin as well as some industrial wastes are widely used for the immobilization of HMs in soil (Kars and Dengiz, 2020; Burachevskaya et al., 2020). Due to the large specific surface area and high porosity, their introduction into

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soil reduces the bioavailability of pollutants (Houben et al., 2013; Ahmad et al., 2018), toxicity, and accumulation in living organisms (Wang et al., 2020). The use of biochar is becoming more popular since it has sorption properties similar to activated carbon, but is much cheaper (Ahmad et al., 2014; Huggins et al., 2016). Biochar is a solid high-carbon material obtained by thermal decomposition of biomass in conditions of complete or partial absence of oxygen (Cao and Harris, 2010). Use of biochar provides with some advantages such as available sources of raw materials, low cost, environmental safety, and the possibility of large-scale implementation. Biochar is recognized as a "green" cost-effective ameliorant for recovery of the environment (Rees et al., 2014), stabilization of HM in soils and reduction of their accumulation by the plants (Lomaglio et al., 2017; Poucke et al., 2018). In addition to immobilization of pollutants, the use of biochar has a positive effect on the chemical properties of soil such as changes of pH, cation exchange capacity, and the content of nutrients (Warnock et al., 2007) that provides the important advantages for this remediation method (Laird et al., 2010).

The purpose of the study is to analyze the efficiency of biochar for copper immobilization in contaminated soil using a combined fractionation scheme.

Material and Methods

The studies were carried out as a model experiment on Calcaric Fluvisol (Loamic) (at the depth 0-20 cm) collected in the Severnyi Donets River floodplain (Kamensk-Shakhtinskii district, Rostov oblast, Russia). The analyzed soil is characterized by following physical and chemical properties: C_{org}–4.3%; pH 7.5; exchangeable cations (Ca^{2+}+Mg^{2+}) – 38.1 cM(+)/kg; $CaCO_3$ – 0.6%; content of physical clay – 55.8%, silt – 32.0%, Cu – 43.7 mg/kg. Soil was added with carbon sorbent in a dose 2.5_{mass} % per 20-cm arable soil layer that corresponds to approximately 500 kg/100 m^2 or 50 t/ha.

Cooper (Cu) in a dose of 10 APC (1320 mg/kg) (GN 2.1.7.2511-09, 2009) per the pure element was used as a pollutant. Before the experiment, soil samples were dried, grinded to the particles < 1 mm, plant roots and large inclusions were removed. 1000-g samples of soil were placed into the 2 L vessels, supplied with dry Cu oxide, and thoroughly mixed with a glass rod. After 6 months of incubation of soil with metal, biochar was introduced into the vessels in the doses 1% and 2.5% at the depth 20 cm, corresponding to approximately 200 kg/100 m^2 and 500 kg/100 m^2 or 20 t/ha and 50 t/ha. In a month after addition of the sorbent, the dry soil was grinded and sifted through a sieve with a 1 mm hole for further analyzes. Experiment was carried out in three replications tat natural illumination. Optimal moisture in the vessels was maintained at 60 % of total water capacity over whole experiment period.

Biochar for the experiment was produced by pyrolysis of birch wood on retort equipment according to GOST 7657-84 (GOST 7657-84, 1976) grade A, class 1 (pyrolysis temperature 550°C, biochar fractions 3-5 mm). Measurements of the specific surface area and porosity were carried out on a volumetric analyzer ASAP 2020 by the low-temperature nitrogen adsorption. Biochar characterized with following parameters: specific surface area – 540 m^2/g, total volume of pores – 0.81 cm^3/g; volume of micropores (< 2 nm) – 0.63 cm^3/g, mesopores (2–500 nm) – 0.04 cm^3/g, and macropores (>500 nm) – 0.14 cm^3/g.

The surface area of biochar was also analyzed using laser scanning confocal microscopy (3D- scanning laser microscope (Keyence VK-9700) with a violet laser wavelength of 408 nm, which allows distinguishing of the parts in three planes with a resolution up to 200–300 nm) to design 3D models of microrelief of the biochar sample (Figure 1). Considering that the size of macropores is 500 nm and more, the values of surface area measured by optical and sorption methods can be compared. The measurement of the surface area was carried out by calculation of the average value of the area of identical sections of the 10×10 μm sample (red square), placed randomly within the studied area. The sample was measured in 10 replications. It was found that the biochar sample has a sufficiently large integral surface area 797.439±81 μm^2.

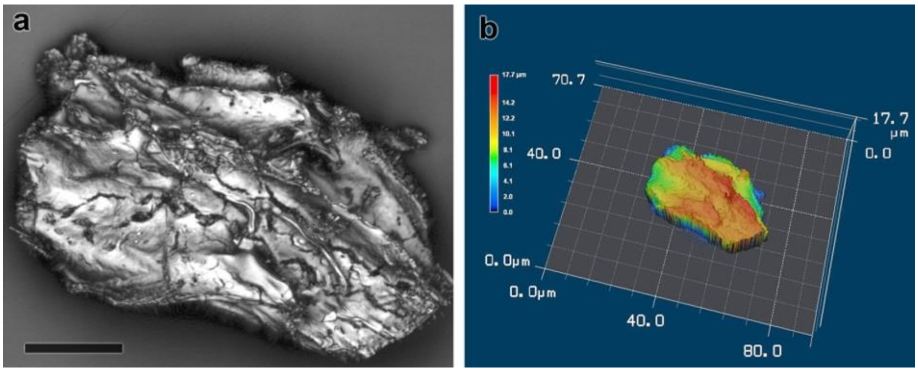

Figure1. Biochar sample and its 3D microrelief model obtained using laser scanning confocal microscopy. Scale: 10 μm.

Results Discussion

The total contents of C, H and N in the carbonaceous sorbents were determined using a CHN elemental analyzer (TOC-L CPN Shimadzu, Japan). Ash content was measured by heating sorbents at 650 ˚C for 3 h and O content was calculated by mass difference. Molar ratios of elements, often used to estimate the aromaticity (H/C ratio) and polarity (O/C, (O+ N)/C are also provided in Table 1.

Table 1. Elemental composition of biochar

C	N	H	O	Ash	H/C	O/C	(N + O)/C
		%					
74.3	2.3	2.7	12.9	7.8	0.43	0.13	0.16

The IR spectra were measured on an FSM-1202 spectrometer in transmission mode using a DTGS detector. The spectra were acquired in the range from 4000 to 400 cm $^{-1}$ with a resolution of 4 cm^{-1} and 100 scans. 200 mg KBr pellet of 13 mm in diameter was used as a reference sample. Studied samples with mass of 0.06 mg were ground and milled with KBr and pressed into pellet of total mass 200 mg.

IR spectrum of biochar (Figure 2) demonstrated strong and broad band near at 3100-3600 cm^{-1} which was attributed to O-H stretching vibrations (Li and Chen, 2018) from hydroxyl functional groups or adsorbed water. Narrow peaks at 2918 and 2846 cm^{-1} probably related to asymmetric and symmetric stretching vibrations of aliphatic C-H groups of cellulose, respectively (Lamaming et al., 2015). Bands near 1570 and 1476 cm^{-1} could be attributed to C=C stretching and (sp^3) C-H bending vibrations, respectively. Strong and broad peak at 900-1250 cm^{-1} was assigned to -C-O-C- symmetric stretching or phenolic functional groups and ethers (Li and Chen, 2018).

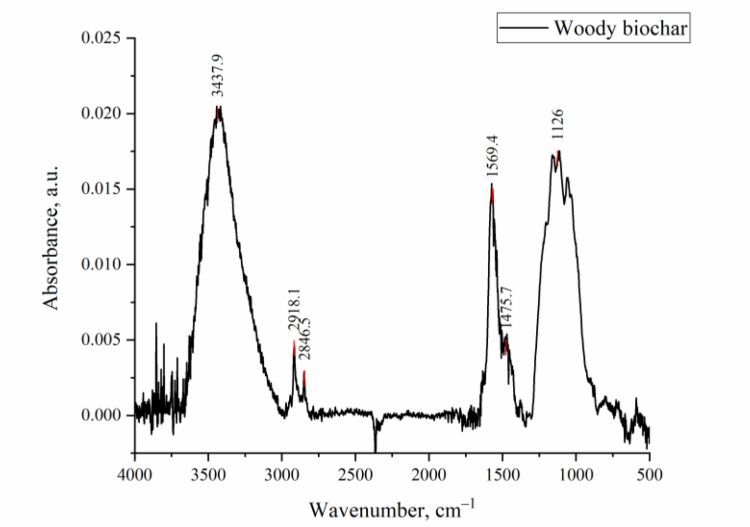

Figure 2. The FTIR spectra of biochar

The study of the mechanisms of Cu immobilization in Fluvisol after the introduction of a carbonaceous sorbent was carried out using a combined fractionation scheme (Minkina et al., 2013), which makes possible to determine the composition of loosely (LB) and strongly bound (SB) HM-containing compounds in details, comparing other methods and follow the dynamics of the bound strength of metals and main soil components. This scheme is based on a combination of the results obtained by the Tessier method (Tessier et al., 1979) and parallel extractions (Minkina et al., 2018). The content of metal in fractions included in LB and SB groups of compounds was determined by the analytical and computational methods (Figure 3).

The efficiency of biochar for the remediation of contaminated soils was studied using a combined fractionation scheme since the analysis of changes in the fractional-group composition of Cu-containing compounds in the remediation conditions allows a deeper understanding of the mechanism of the sorbent effect on the immobilization of metal, the redistribution of metal compounds, and their transformation processes.

The domination of strongly bound Cu compounds (92% of total fractions), which is mainly supported by the retention of metal by primary and secondary minerals (66 %) was observed in uncontaminated meadow soil (control) (Table 2). Mobility of Cu in soils was low (8%) and represented mainly by specifically adsorbed metal compounds.

The content of all forms of Cu increases with artificial soil contamination and their ratio increases (up to 38%) in the content of LB compounds (Table 2). The content of complex and specifically adsorbed metal compounds adsorbed on Fe and Mn oxides increases significantly. The majority of the metal fraction associated with aluminosilicates remains in the composition of SB of Cu compounds, however its relative content decreases until 41 % under anthropogenic load. Organic matter is actively involved in the retention of Cu both in strongly and weakly bound state.

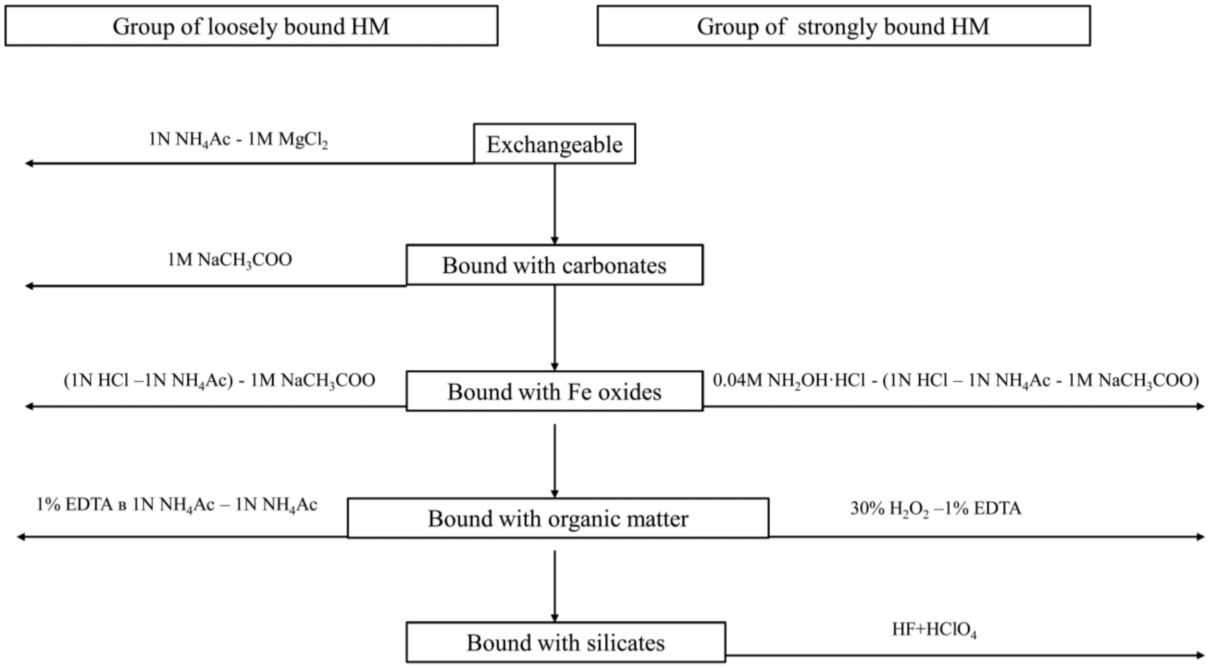

Figure 3. A combined fractionation scheme of HM-containing compounds in soil (Minkina et al., 2013).

The introduction of biochar caused changes in the ratio of the formed groups of metal compounds and their constituent fractions (Table 2). It has been shown that the sorbent has a significant effect on the transformation of Cu compounds in soil and introduction of sorbent decreased the metal mobility due to formation of SB compounds in all variants of the experiment.

Table 2. Distribution of Cu by forms and groups of compounds in the experimental meadow soil in the presence of biochar

Variant	Loosely bound compounds				Strongly bound compounds with			Sum of fractions	LB/SB, % of sum
	exchangeable	complex	specifically absorbed		organic matter	Fe oxide	silicates		
			on carbonates	on Fe ad Mn oxide					
Control	0,2	0,8	1,6	0,7	8,3	3,2	28,9	43,7	8/92
	0,0	2,0	4,0	2,0	19,0	7,0	66,0		
Cu	27,1	216,4	81,2	189,3	175,8	108,3	554,5	1352,6	38/62
	2,0	16,0	6,0	14,0	13,0	8,0	41,0		
Cu + 1% biochar	13,6	122,4	68,1	108,8	271,9	136,1	639,3	1360,2	23/77
	1,0	9,0	5,0	8,0	20,0	10,0	47,0		
Cu + 2,5% biochar	9,4	67,4	53,9	57,6	350,9	121,3	687,4	1347,9	14/86
	1,0	5,0	4,0	4,0	26,0	9,0	51,0		

The relative content of LB metal compounds after use of biochar in dose 2.5 % is almost equal to control variant with simultaneous redistribution of fractional-group composition of metal. In all fractions of LB cooper compounds, an increase of metal content both in absolute and relative concentrations was observed after introduction of carbonaceous sorbent into contaminated soils.

The higher metal content (up to 13 %) in fraction related with organic matter was noted. This trend can be related with the content of organic matter in soil which actively adsorbing Cu ions. Coal consists of one to two thirds of amorphous carbon, a part of which burn during activation forming pores of different diameter that results in extension of specific adsorbing surface as well as an increase of the content of organic matter in soil (O'Connor et al., 2018). The higher content of organic matter in soil due to addition of biochar can transform the instable Cu into the less mobile fractions, for example related with organic matter. Functional groups (such as -OH, -COOH, -C = O- and C = N) on the biochar surface are also involved into interaction with metal forming the complexes and extending specific adsorption of metal. The content of residual fraction is also increasing that indicates the strong fixation of metal in soil in the presence of sorbent.

Conclusion

Results showed the introduction of a highly porous carbonaceous sorbent (biochar) into the contaminated soil immobilized the mobile Cu compounds. An increase of a dose of sorbent in soil causes the more expressed changes of the content of loosely bound compounds with metal. The presented results showed possible remediation strategies using biochar for soil contaminated by Cu.

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Effects of land and plant managements on soil erodibility in the Turhal District of Tokat, Turkey

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Abstract

In this study, changes in the erodibility (sensitivity to erosion) values of soils under different land and plant managements (sunflower, wheat, vegetables, sugar beets, alfalfa fields as well as orchards, meadows and pastures) were examined in the Turhal district of Tokat province, Turkey. Physical and chemical properties of surface soil samples along with land management practices against erosion were investigated for their impact on sensitivity to erosion. The sensitivity of the soil samples were found to be in the following order: Meadows< orchards<wheat<sunflowers<pastures<sugar beets<alfalfa<vegetables. The findings show that fundamental soil characteristics, and especially clay and organic matter content, were effective in shaping the soil structure and therefore the erodibility, as well as the way the land was used. The most suitable parametric values in soil characteristics were observed in the meadows, and the worst values were observed in the soil where vegetables beets were planted.

Keywords: Soil properties, plant management, erosion ratio.

Introduction

The preservation and improvement of multi-functional properties of lands are important for meeting the needs of the increasing population, developing economies and agricultural sustainability. Erosion adversely impacts the life cycle of soil by restricting its multi-functional properties (Tunç and Schröder, 2010). The effect of erosion on plant development is linked to reduced depths of roots, deterioration of soil structure, decrease in beneficial water reserves, loss of organic matter, and nutrition imbalance (Lal and Moldenhauer, 1987; Yılmaz et. al., 2007; Cebel et al., 2013). Fight against the negative effects of erosion in agricultural areas and the improvement of efficiency involve employing many options such as land management, soil management and plant management. The most general approach is to take necessary steps by identifying the level of impact or contribution of practices effective against soil erodibility by reducing the risk of potential erosion in these soils ahead and by increasing plant development, along with a suitable land management planning (Lal and Moldenhauer, 1987; Fleige and Horn, 2000; Başkan et al., 2011; Özdemir, 2013). The way a land is used and changes in vegetation significantly affect the organic matter, physical characteristics and erodibility (Francis and Thomes, 1990; Lal et al., 2018). Celik (2004) carried out a research study based on forests, pastures and agricultural areas. He found that the organic matter, bulk density, aggregate stability and erosion sensitivity of the soil had statistically significant changes due to the transformation of the forest and pasture areas into agricultural use. Eraslan et al. (2017) examined the relationship between the erosion sensitivities of the soil in the İnebolu Basin, the way the land was used and the vegetation cover on the land. They emphasized that there were statistically significant relationships between the sensitivity to erosion and clay content; and between vegetation cover and coverage. Parlak et al. (2015) examined the impact of pasture reclamation practices on soil erosion. They emphasized that there were significant differences in soil loss and bulk density values among protected and unprotected parcels.

It is known that plant root development in soils has an important positive effect on soil physical properties, especially structural development and stability (Iç et al, 2010; Iç and Gülser, 2012). Hacımüftüoğlu (2012)

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examined the physical, chemical and mechanical properties of these samples, and assessed the effects of the cultivated plants on the structural parameters of the soil sampledfrom the farmland of Faculty of Agriculture in Atatürk University where sunflowers, wheat, beans, corn, potatoes and alfalfa plants grown. They found that there were significant differences in the structural parameters and characteristics of the soil based on the types of the plants grown. The best parameter value in the soil samples was from the areas where alfalfa cultivated, and the worst value was from the soil where potatoes and corn cultivated.

This study was carried out to identify the effects of land and plant managements on physical and chemical soil characteristics and the sensitivity of soil against erosion, in the fields where sunflowers, wheat, vegetables, orchards, sugar beets, meadows, pastures and alfalfa plants were cultivated in the Turhal district of Tokat, Turkey.

Material and Methods

The research area is located within the boundaries of Turhal district of Tokat in the Central Black Sea region. Cereals are the main agricultural product in the district. In addition, tomatoes, sugar beets, sunflowers for oil production, feed crops (common vetch, alfalfa, corn for silage) and many types of fruit and vegetables are grown. A continental-temperate climate reigns in the region which is located in the transition zone between the Central Black Sea Region and the Central Anatolia Region. The average annual temperature is 12.9 °C, and the average annual rainfall is 413.3 mm in the region (DMİGM, 2006).

This study was carried out with 24 surface (0-20cm) soil samples taken from 3 different fields for 8 different land use (wheat, sunflowers, sugar beets, vegetables, alfalfa, orchards, meadows and pastures over three years) after harvesting.

Methods

Soil amples were analyzed using the standard methods as follows (Jones, 2001). Particle size distribution was determined by using the Bouyoucos hydrometer method. Soil pH (1:2.5) was detected using a pH-meter with glass electrode. Electrical conductivity was measured by using an electrical conductivity instrument with glass electrode. Organic matter content was identified by using the Walkley-Black method. Moisture contents at the field capacity (0.33 atm) and wilting point (15.0 atm) were detected by using a pressure plate. Lime content was measured by using a Scheibler Calcimeter, cation exchange capacity (CEC) by using the "Bower" method (Richards, 1954), and aggregate stability by using the wet sieving method (Demiralay, 1993). The dispersion rate was determined by using the silt + clay content values determined before and after the soil was dispersed in water (Özdemir, 2013). The soil erodibility factor was calculated by using the equation developed by Wischmeir and Smith (1978). The erosion rate was determined by using the moisture equivalent and clay content (Özdemir, 2013) with silt + clay content determined before and after the dispersion of the soil in water. Descriptive statistics for the obtained data and correlations among the soil properties were done using SPSS 11.0 software.

Results Discussion

Table 1 shows the statistical features determined in the soil samples taken from 24 land parcels hosting 8 different practices of land use (wheat, sunflowers, vegetables, orchards, sugar beets, meadows, pastures, and alfalfa cultivation) in the Turhal district of Tokat province. The soil samples had textures ranging from coarse to fine. The sand content of the soil samples ranged from 20.20% to 65.50%, silt content from 19.30% to 45.10%, and clay content from 1.40% to 41.20%. pH values of the soil samples (1:2.5 earth-water) usually varied within the limits of moderately alkaline soil and was approximately 7.93 on average (Table 1). The soil samples had lime content ranging from moderately (8.90%) to very (39.50%) calcareous. Organic matter content in the soil samples had mostly a moderate level ranging from very little (0.50%) to very high (3.40%). The exchangeable sodium percentage in the soil samples was less than 15%, and there was no problem of alkalinity (Hazelton and Murphy, 2007).

The erosion rate statistics identified in the soil samples taken from the (24) field s under (8) different land use conditions in the Turhal region is given in Table 1. Figure 1 shows the relationships between erosion rate averages and the way the lands were used. Table 2 shows the correlations between erosion rates and the soil characteristics. The erosion rates of the soil samples varied from 1.90% to 79.60%, and the average value was 14.72% (Table 1). Erosion rate is a parameter that is employed to examine erosion sensitivity of soil, and any soil with a ratio smaller than 10% are considered resistant to erosion (Morgan, 2005). Among the soil parcels in the research site, the erosion rate in the samples higher than 10% limit value was found in 2 parcels of sunflower, 1 parcel of alfalfa, 3 parcels of vegetables, 2 parcels of sugar beets and 1 parcel of pasture. The soils in question can be said to be susceptible to erosion and the others are resistant to erosion.

Table 1. Statistics of physical and chemical properties of soil samples and erosion sensitivity values

Land use	**Wheat**			**Pastures**			**Orchards**			**Sunflowers**			**Alfalfa cultivation**			**Vegetables**			**Sugar beets**			**Meadows**		
Soil properties	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
S, %	23.6	20.2	25.6	47.1	28.0	65.5	30.2	27.5	33.7	48.7	44.2	55.4	33.4	23.7	47.9	54.5	45.1	61.6	44.7	32.8	52.7	33.3	32.8	35.6
Si, %	37.7	36.4	39.6	28.8	19.3	38.9	36.2	33.6	38.2	31.3	29.8	39.3	44.0	42.2	45.1	39.2	34.7	42.8	37.8	33.3	40.7	30.6	25.4	34.1
C, %	38.5	37.5	40.2	24.0	7.5	33.3	33.5	28.3	37.1	17.4	5.5	24.4	22.5	7.4	31.1	6.2	1.4	13.7	17.3	11.5	26.6	35.4	30.4	41.1
pH, (1:2.5)	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	8.0	8.0	8.01	8.0	7.9	8.0	8.0	7.9	8.1	7.9	7.9	7.9	7.9	7.9	7.9
EC, $ds.m^{-1}$	0.4	0.3	0.5	0.4	0.2	0.5	0.5	0.4	0.7	0.5	0.3	0. 8	0.5	0.5	0.6	0.4	0.3	0.5	0.3	0.3	0.4	0.5	0.4	0.64
L, %	14.1	12.3	15.5	17.5	11.7	21.5	19.1	16.2	23.4	18.6	11.2	24.6	20.0	15.3	23	11.1	8.9	12.7	22.2	16.8	29.9	29.7	23.2	39.5
OM, %	2.6	2.0	3.0	1.0	0.6	1.4	2.5	1.4	3.2	3.0	2.3	3.4	2.9	2.6	3.1	2.2	1.7	2.8	1.1	0.5	1.7	2.2	1.8	2.8
ENa, %	8.2	4.6	11.2	5.4	4.2	6.5	4.9	2.2	6.6	2.1	1.7	2.7	1.8	1.3	2.3	1.6	1.4	1.7	2.0	1.1	2.6	2.3	1.1	3.9
CEC, $me100g^{-1}$	27.0	23.5	29.1	19.4	15.6	24.1	25.8	20.1	33.4	35.2	30.1	38.3	39.5	33.0	49.3	37.1	32.3	42.2	45.3	40.2	50.7	46.7	43.4	51.2
FC, %	40.8	37.4	49.3	27.1	17.6	32.0	37.7	31.3	40.4	26.5	21.4	31.9	31.3	26.2	40.3	23.2	17.4	31.1	25.8	18.1	29.5	33.4	27.3	36.5
WP, %	22.5	20.8	25.5	15.4	10.7	18.4	20.9	16.2	24.2	14.4	11.1	20.2	15.3	16.8	21.3	11.4	9.3	15.6	13.5	11.8	16.5	19.7	19.2	20.1
AS, %	41.0	30.2	48.6	36.1	17.2	48.6	34.4	22.7	43.5	38.7	12.9	62.9	24.4	13.9	37.2	13.2	9.2	17.6	23.2	9.4	40.3	56.9	46.2	62.9
DR,%	7.3	5.3	8.3	13.1	5.2	25.9	6.8	5.5	8.8	12.7	6.2	33.2	22.4	5.5	53.7	33.9	12.6	79.6	17.1	7.1	26.1	4.2	1.9	6.6
ER, %	7.3	5.3	8.3	13.1	5.2	25.9	6.9	5.5	8.9	12.7	6.2	33.2	22.4	5.5	53.7	33.9	12.6	79.6	17.1	7.1	26.1	4.2	1.9	6.6
K	0.019	0.018	0.021	0.020	0.012	0.024	0.019	0.015	0.024	0.021	0.016	0.028	0.028	0.024	0.035	0.034	0.028	0.039	0.031	0.026	0.036	0.018	0.012	0.024

S: Sand, Si: Silt, C: Clay, OM: Organic matter, L: Lime, ENa: exchangeable sodium, EC: Electrical conductivity, CEC: Cation exchange capacity, FC: Field capacity, WP: Wilting point, AS: Aggregate stability, DR: Dispersion ratio , K: Soil erodibility factor, ER: Erosion ratio.

An analysis of the mutual relationships between the land use and erosion rate showed that sensitivity to erosion was influenced by basic soil characteristics and the ways the land was used. The tendency to erosion increased as the intensity of use increased, and parcels with a light texture and low organic matter were more sensitive to erosion (Table 1, Table 2). Kanar and Dengiz (2015) conducted a study in the Madendere Basin and examined the differences in the erosion sensitivity of the soil based on the way the land was used and the vegetation cover on the land. They stated that the sensitivity to erosion was affected by land use. Karagül (1994) found that an erosion-resistant structure was formed in the soils of meadows and forest areas, and an erosion-sensitive structure was formed in agricultural areas. The researcher stated that this situation was related to the structure that had been shaped for many years in the fields of meadows and pastures, and that the situation in agricultural areas was related to the insufficient development of a stable structure because of the continuous tillage of the land.

When the soil samples were sorted in ascending order in terms of erosion rates, the meadow-covered parcels (1.90%) with the smallest proportion were found to be in the first place, while the parcels where vegetables were produced with the largest proportion (79.60%) were last. It was found that the soil samples were in the following order: meadows < orchards < wheat < sunflowers < pastures < sugar beets < alfalfa < vegetables. These findings show that basic soil characteristics, and especially clay and organic matter content, were effective in shaping the structure and therefore the sensitivity to erosion, as well as the way the land was used (Figure 1, Table 1). Özdemir (2015) and Benbi (1998) obtained similar findings in their research.

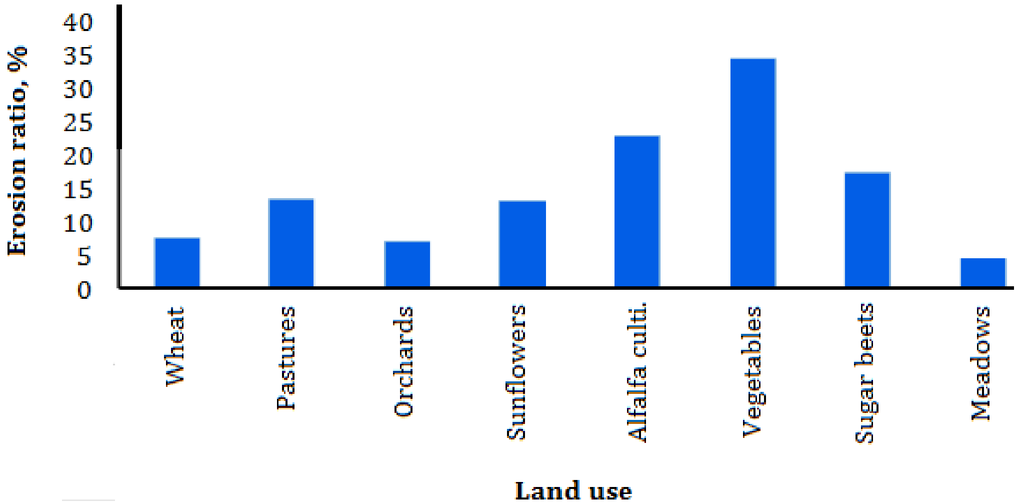

Figure 1. Change in erosion rates depending on the way the land was used

Erosion rate negatively correlated with the clay content (–0.635**), organic matter (–0.316*), lime content (-0.362*), field capacity (–0.590**), wilting point (–0.667**) values of the soil samples, and positively correlated with the sand content (0.518**) values of the soil samples significantly (Table 2). Gülser (2006) determined that aggregation is related to soil structure and different forage cropping treatments had positive effects on aggregation and aggregate stability by increasing soil organic carbon content, compared to the fallow control treatment of the clay soil.

Table 2. Correlation matrix for physical and chemical properties of soil samples

	S	Si	C	OM	L	EC	CEC	FC	WP	AS	DR	ER
Si	-0,253	1										
C	-0,892**	-0,212	1									
OM	-0,607**	0,036	0,597**	1								
L	-0,185	-0,379**	0,364*	0,283	1							
EC	-0,337*	0,361*	0,172	0,365*	0,010	1						
CEC	-0,055	0,216	-0,045	0,247	0,494**	0,113	1					
FC	-0,891**	0,021	0,891**	0,589**	0,182	0,309*	-0,038	1				
WP	-0,807**	-0,138	0,880**	0,538**	0,199	0,377**	-0,158	0,881**	1			
AS	-0,577**	-0,426**	0,782**	0,593**	0,456**	0,128	0,072	0,586**	0,664**	1		
DR	0,676**	-0,050	-0,659**	-0,588**	-0,362*	-0,449**	-0,241	-0,685**	-0,575**	-0,598**	1	
ER	0,518**	0,239	-0,635**	-0,316*	-0,337*	-0,247	0,049	-0,590**	-0,667**	-0,546**	0,622**	1
K	0,478**	0,662**	-0,792**	-0,487**	-0,377**	-0,062	0,207	-0,631**	-0,767**	-0,741**	0,440**	0,653**

**: Significant at 1% level, *: Significant at 5% level, S: Sand, Si: Silt, C: Clay, OM: Organic matter, L: Lime, EC: Electrical conductivity, CEC: Cation exchange capacity, FC: Field capacity, WP: Wilting point, AS: Aggregate stability, DR: Dispersion ratio, K: Soil erodibility factor, ER: Erosion ratio.

On the other hand, the erosion rates of the soil samples were found to have significantly positive correlations with the dispersion rate (0.622**) and K factor (0.653**) values, which are the parameters used in assessing structural stability, at 1% level, and significantly negative correlation with aggregate stability (-0.546**) at 1% level (Table 2). Different researchers have obtained similar findings in their studies in different regions (García-Orenes et.al., 2009; Özdemir et al., 2015; Saygın et al., 2017). Gülser (2004) found that cropping treatments improved infiltration ratio by increasing sructural stability and porosity that can lead to the benefits of reduced erosion and improved soil water storage.

Conclusion

Sensitivity of soils to erosion in Turhal district was found to be affected by the land use, The lands used as meadow and pasture areas had soil structure more resistant to erosion than the lands used for vegetables production. Sensitivity to erosion was found to be affected by fundamental soil characteristics and especially clay and organic matter content. The parcels with high clay and organic matter content were determined to be more resistant to erosion. When the agricultural fields were considered, the sensitivity to erosion increased as the intensity of tillage increased and as the organic matter content of the soil decreased. It was observed that the fields involving the cultivation of feed crops created a structure that was more resistant than the parcels that required intensive tillage. In this respect, it will be useful to pay attention to these issues when deciding on alternation systems.

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