Scientific Papers. Series A. Agronomy, Vol. LIX, 2016
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

QUALITY ASSESSMENT OF AN IRRIGATED FLUVISOL

Valerian CERBARI[1], Gheorghe STEGARESCU[2]

[1]Institute of Soil Science, Agrochemistry and Soil Protection "N. Dimo", 100 Ialoveni Street, Chisinau, Republic of Moldova
[2]State Agrarian University of Moldova, 42 Mircesti Street, Chisinau, Republic of Moldova

Corresponding author email: gstegarescu.eco@gmail.com

Abstract

Irrigated fields are playing an important role in assuring world population with qualitative food products. However intensive cultivation combined with irrigation lead to negative changes in soil physical and chemical properties. There have been done few comprehensive studies on how irrigation affects soil physical fertility. This article presents an evaluation of an irrigated Fluvisol from the Inferior Dniester floodplain, in the Republic of Moldova. The results reveal that 50 years of irrigation and intensive cultivation of Eutric Fluvisol with clay texture had a negative impact on the soil physical quality. Low inputs of organic fertilizer lead to a decrease in soil organic carbon content, negatively influencing soil properties. Major changes were reflected in the distribution of structural aggregates, so that the proportion of clods in the first layer was moderate (38.2%), but in the subsequent layer was very high (81.7%). Due to the high clay content, it has a high water stability of macroaggregates in both 0-20 cm and 20-38 cm layer. The results also show that soil has an increased bulk density, low total porosity which is decreasing with the depth, and high compaction degree. This study will be used as a start point for the future research of the utilization of the cover crops in irrigated agriculture.

Key words: *irrigation, fluvisol, soil physical properties, conventional tillage.*

INTRODUCTION

Nowadays agriculture is facing major challenges in producing more food, but also to achieve to fulfil the purposes of sustainable agriculture, where production is simultaneously environmentally friendly, socially fair and economically beneficial (Wezel et al., 2014).
Irrigation became one of the most powerful innovation 6000 years ago. Agricultural lands were intensively irrigated leading to water shortages, soil salinization and soil degradation (Stranieri, 1999). The increasing number of world population and current trends of climate change are the major constraints to meet the food production demand. Therefore, the importance of irrigated soils should not be underestimated, as the food security is an important goal to achieve.
It is already known that "a good soil physical quality is one that is "strong" enough to maintain good structure, hold crops upright, and resist erosion and compaction; but also "weak" enough to allow unrestricted root growth and proliferation of soil flora and fauna" (Reynolds et al., 2002). Good soil physical state contributes to a better water retention and water infiltration (Martens, 1992). Previously was studied that intensive crop production can cause the degradation of the physical quality of agricultural soils (Abu-Hamda et al., 2000; Dexter, 2004; Pilatti et al., 2006). Some specific studies have shown that irrigation practices are playing an important role in soil degradation especially in structure degradation (Pagliai et al., 2004). Also, there was observed that irrigation has a negative effect on soil total porosity and structural porosity (Mathieu, 1982). More than that combined with conventional tillage as well has a negative impact on the soil physical properties (Crittenden et al., 2015; Özgöz, 2009). However, there have been few rigorous studies on how irrigation affects soil physical properties was related by some authors (Murray and Grant, 2007).
The main purpose of the study was, to assess the impact of agriculture on fluvisols physical properties under irrigation. To demonstrate the importance of this study and its application in the future, a fluvisol under irrigation regime will be investigated.

MATERIALS AND METHODS

The study area is located in the Dniester river meadow, South-Eastern part of Republic of Moldova (46°74'07.2" N, 29°62'69.2" E). The soil is a Eutric Fluvisol according to FAO classification. The territory of the study site was a marshy area due to periodical floods. Around 60 years ago soils were dried as a consequence of installed drainage system. The area is used for irrigation and tilled already for 50 years. As a result soils already have their own specific regimes different from the natural, unusual for floodplain soils. The water used for irrigation has a good quality. The climate of the region is, characterized by annual medium temperatures of 9-11°C, and annual medium precipitations of 490-510 mm.

In order to assess what is, the present soil qualitative state 4 profiles were made in a triangle form. The principal profile is settled in the center with a depth of 2 m, and another three profiles are located around it, each of them having 1 m depth, the distance between them is 50 m. All of them were described from the morphological point of view, following the profile method. In the field were taken samples for the determination of the bulk density using the cylinder method in 3 repetitions for each horizon. The texture was determined using pipette method, but first, the soil was prepared according to Kaczynski method.

Further were taken samples from 0-20 and 20-38 cm depth to measure aggregate composition, macroaggregates (0.25-10mm), micro-aggregates (<0.25mm) and clods (>10mm) using dry method (Sainju, 2006) and wet sieving method by Savinov to measure the aggregates water stability. From soil physical parameters were calculated also the total porosity and degree of compaction. Another parameter that was determined in the laboratory was hygroscopicity by an air-drying method in the drying stove at a temperature of 105°C. Hygroscopicity of the soil is the phenomenon of attraction and retention of water molecules on the surface of soil elementary particles, spread in the gaseous phase of the soil. Also, it was determined the maximum hygroscopic moisture through Nikolaev method (Gajić, 2002), which depends on the soil texture, being higher for clay soils and lower for sandy soils. Soil density was determined using pycnometer method. Total N content was determined by the Kjeldahl method and soil pH was measured in H_2O (Mattigod and Zachara, 1996). The soil organic carbon was determined (SOC) by using Tiurin method (Mebius, 1960). All the samples were taken from the different depths according to the identified horizons.

RESULTS AND DISCUSSIONS

Soil profile description

The morphological organization of this soil profile due to the deposition of alluvial deposits is very variable in width and depth. Also due to the low frequency of the flooding processes and the construction of drainage system, the upper part of the soil profile is more or less homogenous and it is completed by buried and gleyic horizons in the inferior part. The Abhg layer, at the depth of 79-95 cm, is characterized by a humus horizon, formed in the prehistoric period. Under this horizon can be highlighted a gley layer divided by thin humus layers. The morphological characteristic of the principal soil profile is presented in Figure 1.

The soil profile is characterized by a homogenous texture. The medium content of the physical clay in arable layer varies from 82.6% to 88.7 % and the fine clay content constitutes 49.4-61.8 %. That proves that the bottom layer has a high concentration of clay material. From a qualitative point of view this soil with such concentration of clay represents a difficult object for irrigation because it has a low permeability for water, and reduced capacity for infiltration.

Soil aggregates distribution (dry sieving)

According to the obtained results, the proportion of clods was 38.2%, macroaggregates – 64.8% and microaggregates 1.8%, in the upper layer. But the 20-38 cm layer has lower quality as the a number of clods is higher and it constitutes 81.7%, macroaggregates 20.1% and 1.1% for microaggregates. From an agronomic point of view, the favorable dimensions of aggregates for plants are formed by aggregates of 10-7 mm to 0.5-0.25 mm.

Soil aggregates water stability (wet sieving)

The results are showing that aggregates from layers, 0-20 cm, and 20-38 cm, have a high stability of the aggregates, because of the extremely high content of clay. As it can be seen from the Figure 2, the distribution of aggregates that have a high water stability is the following 31.4% for 2-1 mm, 25% for <0.25 mm, in the first layer. The bottom layer has 23% for 3-2 mm, 28.4% for 2-1 mm and 21.5% for <0.25 mm aggregates

The high water stability of aggregates can be explained by that fact that it has a heavy texture, which gives to the soil the property of having low permeability.

In that case, it is a negative characteristic which makes the soil have low resistance to compaction. The stability of aggregates is important for a good water and air regime of the soil, which plays an important role for plants.

Figure 1. The soil profile characteristics: Ahp1 (0-20)-Ahp2(20-38)- ABh(38-57)- Bhg(57-80)- Abhg (80-95)-Bbhgk(95-115)- Gk1(115-135)- G 2(135-160)- G 3(160-200)

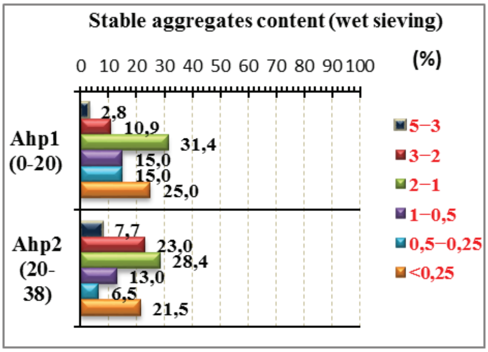

Figure 2. Aggregates water stability distribution by size, %

Hygroscopicity of the soil and maximum hygroscopic moisture

The soil hygroscopicity is proportionally related to the humus content and to fines of the soil particles. In the irrigated fluvisol soil the hygroscopicity varies from 6.6±0.9 % in the arable layer to 9.1 % ±0.5 % in the gley horizon. This is due to high content of clay. The precision of the determinations varies between 7.1-9.8 %. The variation coefficient is 5.7% in the upper horizon to 19.6% in the deeper horizons.

The maximum hygroscopic moisture constitutes 9.6-12.0 %. The square mean deviation value equals 0.3-0.4%. The precision of the determinations of the mean values is 2.9-3.9% and variation coefficient 6.3-7.8%.

Soil bulk density and density

The bulk density of the soil is characterized by a value of 1.23±0.14 g/cm^3 in the arable layer and with the depth, the bulk density increases till 1.44±0.08 g/cm^3. The 0-20 cm layer has an optimal value of the bulk density but the deeper soil horizons are affected by compaction. This can be easily observed in Figure 3.

The density of the soil profiles varies between 2.65±0.14% in the upper horizon or arable horizon to 2.75±0.13% at a depth of 95-110 cm. The precision of the indicators mean varies from 1.86% to 3.03%, variation coefficient does not exceed 6.1 %.

From the graph, it can be revealed that this soil has a heavy mineralogical composition and lower organic part. The higher the density concentration the lower will be the organic content.

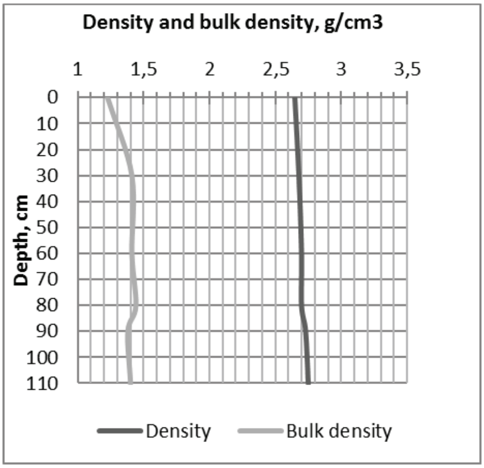

Figure 3. Variation of the soil profile density and bulk density

Soil total porosity and compaction

The total porosity of the studied soils profiles is not homogenous. The values of the total porosity of the irrigated fluvisol soil are relatively medium in the recent arable layer 0-20 cm (53.7±0.9%). Due to its medium structure in the superior layer (0-20 cm) the soil profile has a moderate total porosity. That can't be said about the underlying layers where the total porosity is suddenly decreasing to 49.4±0.5%. Soil total porosity depends on the soil texture, aggregates structure, soil organic matter content and microbiological activity in the soil (Jordán et al., 2010).

The highly related parameter to the soil organic matter content is also the degree of compaction which has a low value in the superior layer 0-20 cm - 3.3±1.3% and high values in the underlying horizons - 16.0±1.2%. According to the obtained results, the eutric fluvisol is characterized by a moderate degree of compaction of the superior horizons and a high degree of compaction in the underlying horizons 11.5-16.0 % (standard deviation ±0.8 and ±1.2 %). Soil compaction adversely affects soil physical fertility, particularly storage and supply of water and nutrients, through increasing soil bulk density, decreasing porosity, increasing soil strength, decreasing soil water infiltration, and water holding capacity (Hamza and Anderson, 2005).

Soil chemical properties

According to the obtained results demonstrated in Table 1, it can be undoubtedly reported that the soil is slightly alkaline. The soil pH varies between 8.0-8.1±0.3. As for soil organic carbon (SOC), it can be observed that the first layer has 2.98% of SOC and is decreasing till 2.29% at the depth of 79 cm.

Table 1. Soil chemical characteristics of the fluvisol

Depth, cm	pH	SOC, %	N total, %	C:N
0-20	8.0±0.3	2.98±0.45	0.153±0.094	10.7±0.7
20-38	8.0±0.3	2.71±0.44	0.153±0.067	10.3±0.7
38-58	8.1±0.3	2.51±0.33	0.149±0.075	9.8±0.5
58-79	8.1±0.3	2.27±0.49	-	-
79-95	8.1±0.3	2.69±0.31	-	-
95-111	8.0±0.3	2.18±0.32	-	-

What is interesting for this parameter is that the SOC increases at the depth of 79-95 cm to 2.69% and again decreases from the depth of 95 cm. That proves that this horizon was buried as a result of the previous flooding depositions.

The results show a low SOC that can appear also as a result of intensive tillage and irrigation. The increase and maintenance of the SOC are the major problem for this soils to keep the soil quality and production capacity in long-term.

The present findings also support Gajic (2013) study which concluded that tillage of fluvisol leads to significant deterioration of soil physical properties, bulk density, and total porosity, but also negative changes of soil organic matter (Gajici et al., 2010; Gajić, 2013). The study made by Naranjo et al. (2006) have shown that after practicing monoculture on fluvisol from Mexico the decline in total N, organic carbon, P and available K occurred after 10 years of sugarcane cultivation, despite that the fluvisols assured yield increases by 67,7 during 30 years due to fertilization (Naranjo de la F. et al., 2006).

Even if irrigation is widely thought to provide 40 % of the world's food from around 17 % of the cultivated area (Thenkabail et al., 2009). There is still little information on how irrigation affects soil physical fertility. What is known till now, and it was proved by other authors is that there is a decline in organic matter content on irrigated fields (Nunes et al., 2007).

Studied fluvisol is under conventional tillage for a long time. It is already known that tillage

has a negative effect on soil physical properties in irrigated conditions and can lead to an increased bulk density (Alletto and Coquet, 2009). But anyway the medium structural composition of aggregates in the first layer of the profile is the result especially of the plowing, harrowing and other agricultural activities (Hermawan and Bomke, 1997). Soil tillage can have also a significant effect on soil porosity on a silt loam fluvisol soil in irrigated conditions reports Cameira (2003). Reinert et al. (2015) found that heavy machinery leads to soil compaction which is in good agreement with the results of the present study.
Researchers have studied the effect of organic matter on the soil physical properties (Franzluebbers, 2002; Hubbard et al., 2013; Dunjana et al., 2012; Papadopoulos et al., 2014). Thus, organic soil management is needed to improve soil structure and increase soil organic matter. But still further researches are needed to study the effects of organic agriculture on irrigated fluvisol.

CONCLUSIONS

The purpose of the current study was to evaluate the impact of agriculture on the fluvisol under an irrigated regime. The following conclusions can be drawn from the present study, intensive tillage, irrigation and low quantities of organic fertilizers had negative effects on soil physical state. The present agricultural management lead to an increase of bulk density, decreased soil porosity, soil structure degradation, and an increase of soil compaction of the Eutric Fluvisol. Also, the high clay content makes these soil a difficult object for irrigation. Anyway, more detailed study is needed regarding the effects of the irrigation on the soils. This research will serve as a base for future studies and it can be also as a source for new studies.

ACKNOWLEDGEMENTS

The research was carried out at the Institute of Soil Science, Agrochemistry and Soil Protection "N. Dimo".

REFERENCES

Abu-Hamdeh N.H., Al-Widyan M.I., 2000. Effect of axle load, tires inflation pressure, and tillage system on soil physical properties and crop yield of a Jordanian soil. Transactions of the American Society of Agricultural Engineers, 43(1):13-21.

Alleto L., Coquet Y., 2009. Temporal and spatial variability of soil bulk density and near-saturated hydraulic conductivity under two contrasted tillage management systems. Geoderma, 152(1-2):85-94.

Cameira M., 2003. Soil macropore dynamics affected by tillage and irrigation for a silty loam alluvial soil in southern Portugal. Soil and Tillage Research, 70(2):131-140.

Crittenden S.J., Poot N., Heinen M., van Balen D.J.M., Pulleman M.M. Soil physical quality in contrasting tillage systems in organic and conventional farming. Soil and Tillage Research, 120:136-144.

Dexter A.R., 2004. Soil physical quality Part I. Theory, effects of soil texture, density, and organic matter, and effects on root growth. Geoderma, 120:201-214.

Dunjana N., Nyamugafata P., Shumba A., Nyamangara J., Zingore S., 2012. Effects of cattle manure on selected soil physical properties of smallholder farms on two soils of Murewa, Zimbabwe. Soil Use and Management, 28(2):221-228.

Franzluebbers A., 2002. Water infiltration and soil structure related to organic matter and its stratification with depth. Soil and Tillage Research, 66(2):197-205.

Gajić B., 2013. Physical properties and organic matter of Fluvisols under forest, grassland, and 100 years of conventional tillage. Geoderma, 200-201:114-119.

Gajić B., Živković M., 2002. Specific area of smonitzas of aleksinac valley. Journal of Agricultural Sciences, 47(1):19-27.

Gajić B., Durovic N., Dugalic G., 2010. Composition and stability of soil aggregates in Fluvisols under forest, meadows and 100 years of conventional tillage. Journal of Plant Nutrition and Soil Science, 173(4):502-509.

Hamza M.A., Anderson W.K., 2005. Soil compaction in cropping systems. Soil and Tillage Research, 82(2):121-145.

Hermawan, B., Bomke, A.A., 1997. Effects of winter cover crops and successive spring tillage on soil aggregation. Soil and Tillage Research, 44(1-2):109-120.

Hubbard R.K., Strickland T.C., Phatak S., 2013. Effects of cover crop systems on soil physical properties and carbon/nitrogen relationships in the coastal plain of southeastern USA. Soil and Tillage Research, 126:276-283.

Jordan A., Zavala L.M., Gil J., 2010. Effects of mulching on soil physical properties and runoff under semi-arid conditions in southern Spain. Catena, 81(1):77-85.

Martens D.A., Frankenberg W.T., 1992. Modification of infiltration rates in an organic amended irrigated soil. Agronomy Journal, 84(4):707.

Mathieu C., 1982. Effects of irrigation on the structure of heavy clay soils in north-east Morocco. Soil and Tillage Research, 2(4):311-329.

Mattigod S.V., Zachara J.M., 1996. Equlibrium modelling in soil chemistry. In: Bigham, J.M., Chemical Methods Part 3. Methods of Soil Analysis, Soil Science Society of America, American Society of Agronomy, Madison, Wisconsin, 1312-1352.

Mebius L.J., 1960. A rapid method for the determination of organic carbon in soil. Analytica chimica Acta, 22:120-124.

Murray R.S., Grant C.D., 2007. The impact of irrigation on soil structure. The National Program for Sustainable Irrigation (Land & Water Australia), Canberra.

Naranjo de la F.J., Salgado-García S., Lagunes-Espinoza L.C., Carrillo-Avila E., Palma-López D.J., 2006.Changes in the properties of a Mexican Fluvisol following 30 years of sugarcane cultivation. Soil and Tillage Reseach, 88(1-2):160-167.

Özgöz E., 2009. Long-term conventional tillage effect on spatial variability of some soil physical properties. Journal of Sustainable Agriculture, 33(2):142-160.

Pagliai M., Vignozzi N., Pellegrini S., 2004. Soil structure and the effect of management practices. Soil and Tillage Research, 79(2):131-143.

Papadopoulos A., Bird N., Whitmore A., Mooney S.J., 2014. Does organic management lead to enhanced soil physical quality?. Geoderma, 213:435-443.

Pilatti M.A., Imhoff S., Ghiberto P., Marano R.P., 2006. Changes in some physical properties of Mollisols induced by supplemental irrigation. Geoderma, 133(3-4):431-443.

Reinert D.J., Albuquerque J.A., Reichert J.M., Aita C., Cubilla A.M.M., 2015. Bulk density critical limits for normal root growth of cover crops. Revista Brasileira de Ciencia do Solo, 32(5): 1805-1816.

Reynolds W., Bowman B.T., Drury C.F., Tan C.S., Lu X., 2002. Indicators of good soil physical quality: density and storage parameters. Geoderma, 110(1-2):131-146. Sainju, U.M., 2006. Carbon and Nitrogen pools in soil aggregates separated by dry and wet sieving methods. Soil Science, 171(12):937-949.

Stranieri F.N., Postel S., 1999. Pillar of Sand: can the irrigation last?. Geographical Review, 89(3):463.

Thenkabail P.S., Biradar C.M., Noojipady P., Dheeravath V., Li Y., Velpuri M., Gumma M., Gangalakunta O.R.P., 2009. Global irrigated area map (GIAM), derived from remote sensing, for the end of the last millennium. International Journal of Remote Sensing, 30(4):3679-37733.

Wezel A., Casagrande M., Celette F., Vian J.F., Ferrer A., Peigné J., 2014. Agroecological practices for sustainable agriculture. A review. Agronomy for Sustainable Development, 34(1):1-20.