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Soil Water Content in Tillage Induced System

Igor Bogunovic, Ivica Kisic

Department of General Agronomy, Faculty of Agriculture, University of Zagreb, Svetošimunska 25, 10000 Zagreb, Croatia (ibogunovic@agr.hr)

Abstract

Global climate change became obvious and affects all beings on this planet. Agricultural production is no exception, and is faced with long periods of unfavorable climatic conditions for crop production. Increasing weather anomalies are evident in Croatia in the last two decades. They are characterized by ever increasing dry periods and increased average air temperature. Therefore soil management is gaining more importance with views to retain soil moisture. Longtime stationary field experiment was conducted in Central Croatia near the Daruvar (N 45°33', E 17°01'), characterized by perhumid to humid climatic conditions. Recently, Croatia faced more years with distinct water deficit in the summer months. The experiment consisted of six different tillage systems, no-tillage and five conventional tillage systems. This paper is aimed to give optimal tillage system for soil moisture retention at various depths and tillage impact on cultural plant yield. During the 2012 information about soil moisture were taken at 5 occasions since June to October. Samples were taken from the depth of 0-20 cm, 20-40 cm, 40-60 cm and 60-80 cm, in three replications. Statistical data evaluation showed significant differences in soil moisture between all tillage systems at all depths. Soil moisture content varied at depth 0-20 cm from 205.4 to 909.6 m^3 ha^{-1}, at depth 20-40 cm from 337.0 to 813.6 m^3 ha^{-1}, at depth 40-60 cm from 342.8 to 792.6 m^3 ha^{-1} and at depth 60-80 cm from 367.4 to 837.1 m^3 ha^{-1} depending on the measurement. No-till soil had from 25% less to 8% more stored soil water (0-80 cm) than other tilled plots in summer period during 2012. Results from 2012 suggest that, up to now, no-tillage could replace conventional tillage without adverse effects on soil water content in the Central Croatia. For wider application of no-tillage system in crop production of Central Croatia, further detailed research work is necessary to be able to talk about new trend.

Key words: climate change, water conservation, tillage, soil water content

Introduction

Climate change impacts are major threat for agriculture crop production. Two most important climatic factors, precipitation and air temperature, are under great changes in the last two decades in Central Croatia. Precipitation is the major source of natural water supply. There are two major characteristics of that; one is the amount of water and the other is the distribution. Depending on the crop, plants require 250-400 g of water to build 1 g of dry matter, in north geographic latitude between 45 and 47 degrees (Jolankai and Birkas, 2007). As the request of cultural plant maximum yields, it has greater water demands, especially in the period of higher transpiration. In these areas, the rainfall is highly variable from year to year and during the growing season.

Current trends in Central Croatia, around Daruvar, indicate that there has been an decrease in average annual precipitation of summer months in the last decade to 34.4 mm, with extremes in distribution. Simultaneously, there is an increase of 0.3^{0}C in the average annual air temperature in the last decade. Increasing temperatures during the summer months is even more pronounced and is 0.6^0C, indicating the climate change intensity (source: National Weather Service, Daruvar station, year 2001-2012). Temperature directly affects the most of life processes: photosynthesis, respiration, transpiration, water inhibition, and mineral uptake. Availability of soil water has turned into a problem in most parts of the country. Water shortages during growing season already played a critical detrimental role in winter wheat and maize yields in Croatia (Šestak et al., 2012). Majority of the adverse impact is caused by water shortages during critical phenophases. The last decades in Croatia is all more years with distinct water deficit in the summer months (Bašić et al., 2000).

The prospects of crop production development in closely connected with the soil moisture regime in soil, but tillage has great influence on soil moisture management. Water storage efficiencies varied with soil texture and soil organic matter, depending on tillage intensity. Tillage change soil water content, soil temperature, aeration, and the degree of mixing of crop residues within the soil matrix. Most farmers nurture habit of opening winter furrow for storage moisture. Due to the uncertain nature of rainfall distribution, the timing of primary tillage was a key factor for soil water conservation.

At the present time in Croatia the conventional tillage system dominates, which usually consists of two or more actions, the first of which involves moalboard plowing and others finer treatments for the seedbed preparation. Conventional tillage characterized by the tillage of the whole surface, and uses one way ploughing. No-tillage and conservation tillage is a promising alternative to traditional tillage for crop production in Moslavina region. In Croatia the trend of reduced tillage is based on the recognition of disadvantages of conventional one, including high costs. A lot of papers have been written to study the positive effects of no-tillage system on the physical characteristics of soils and moisture retention, but a small number of those who have investigated for longer period in the ecological conditions of the continental Croatia. Authors generally receive a more favorable impact on soil moisture content in the reduced tillage compared to conventional tillage (Ashraf et al., 1999; Fabrizzi et al., 2005; Hussain et al., 1999; Husnjak et al., 2002; Lampurlanes, 2001; Košutić et al., 2001; Špoljar et al., 2011). No-tillage increases infiltration and reduce evaporation compared with the conventional tillage. The adoption of these systems would reduce production costs and help to achieve the requirements for protection of soil and water resources imposed by the current Common Agricultural Policy of the European Union (Lopez et al., 1996).

Under changes of major climate characteristics in Central Croatia in the last two decades, soil and water conservation is an issue of primary concern in this region. It is necessary to assess the long-term dynamics of the available water content. This paper will try to give an answer which is the most convenient way of soil management in order to retain soil moisture for achieving high crop yields for adaptation of the agricultural practices to the climatic changes.

Material and methods

Long term tillage and crop management practices trial was established in 1994. Prior to the establishment of the experimental plots site have been conventionally tilled. Site is located 15 km southwest of Daruvar (45°33’ N, 17°02’ E, elevation 133 m) in Moslavina region, Central Croatia. The soil is mapped as Albic Stagnosol (according to FAO classification 1990) with a slope of 9%. The experimental design consists of six plots. Soil on the experiment belongs by its texture to sandy loam. Climate is semihumid to humid with annual precipitation of 878 mm and average annual temperature of 10.6^0C (Meteorological and hydrological institute of Croatia).

Tillage systems differed in tools that were used, depth and direction of tillage. Six tillage systems and implements, which were included in some system, are as follows: Check treatment (CT) – ploughing and other operations up and down the slope, black fallow; Conventional ploughing (25-30 cm) up and down the slope (CP) – other operations depending on the crop also up and down the slope; No-tillage system (NT) – no-till planter, sowing directly in mulch; Ploughing across of slope (PA) – conventional ploughing (25-30 cm) across of slope, other operations depending on the crop also across of slope; Deep ploughing (50 cm) across of slope (DP) – operation repeats after termination of prolonged effect (every 3-4 years when crop rotation allows), other operations on conventional way depending on the crop; Conventional ploughing across of slope (30 cm) with subsoiling to the depth of 60 cm (SUB) – subsoiling repeats after termination of prolonged effect (every 3 years when crop rotation allows), other operations depending on the crop.

Table 1. Particle size distribution on Stagnic Luvisols (from Kisic et al., 2002)

Soil depth (cm)	Soil horizon	Coarse sand (2-0.2 µm)	Texture (g kg^{-1})			Texture class
			Fine sand (0.2-0.02 µm)	Silt (0.02-0.002 µm)	Clay (<0.002 µm)	
0-24	Ap+Eg	18	586	242	154	Sandy loam
24-35	Eg+Btg	21	571	260	148	Sandy loam
35-95	Btg	5	545	254	196	Sandy loam

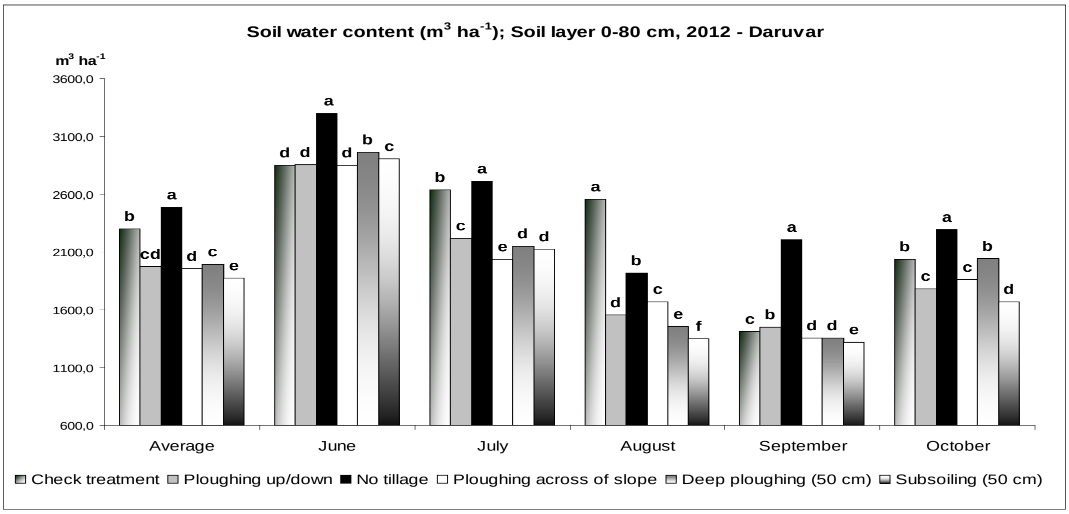
Water content measured by hand sampling probe during five terms, from June to October at selected crop growth stages, once a month. Soil water content was determined gravimetrically to a depth of 80 cm in 20 cm increments, in three replicates. Water content was converted to a volume basis using bulk densities previously determined by Kopecky's cylinders (100 cm^3) from each depth increment, in three replicates. Observed data were subjected to analysis of variance (ANOVA) using SAS Institute 9.1.3 and mean values were separated by Fisher's LSD test at $P \leq 0.05$.

Results and discussion

Average soil water content at depth 0-80 cm (Figure 1) is 2097.0 m^3 ha^{-1}. Observing the entire depth (0-80 cm), the highest average soil water content showed NT system (2487.0 m^3 ha^{-1}), while the lowest average amount of water showed SUB system 1873.0 m^3 ha^{-1}. Same results were obtained by Košutić et al. (2001) in applying no-tillage compared to other tillage systems in conditions of the northwest Slavonia. Špoljar et al. (2011) obtained more favorable results concerning the content of physiologically active and optimal soil moisture mainly on the reduced tillage treatments in similar soil and environmental conditions like this experiment.

In conventional tillage system highest soil water content showed CT system with 2299.1 m^3 ha^{-1} and SUB system had lowest results (1873.2 m^3 ha^{-1}). Statistically significant differences of whole profile (0-80 cm) were recorded between NT and conventional tillage and their different system of conventional tillage systems, except between CP, DP or PA. Observing each measurement there is a significant difference between all tillage systems in all months. Lowest soil water content had SUB (1317.3 m^3 ha^{-1}) in September and highest NT in June (3298.3 m^3 ha^{-1}). Significantly, the greatest amount of soil water contain NT in four of the five measurements, while is in August immediately after CT. In conventional tillage systems, except mentioned CT, best results showed DP system. Lowest results in soil water retention had SUB system in three of five measurements and PA system in two measurements. Results indicate that soil water recharge during growing season was greater under NT system than under different conventional tillage systems, probably due to reduced soil water evaporation because of crop residue on the soil. Soil water depletion during the growing season essentially followed the same pattern under all tillage systems, except the CT system in August. This can be justified by black fallow and rain that fell the day before sampling.

Soil water content always increased with depth to the layer of 60 cm and at depth 60-80 cm is reduced in most of tillage systems. It is similar to the situation that obtained Unger and Jones (1998) in dryland conditions of US Great Plains.



*Different letters means differ significantly ($p<0.05$)

Figure 1. Soil water content (m^3 ha^{-1}) – average and separate values

The average soil water content for all tillage systems and depths (in layers of 20 cm) was 523.8 m^3 ha^{-1}. The average moisture for all investigation depths (in layers of 20 cm) per particular tillage systems (Table 2) ranged from 562.3 m^3 ha^{-1} (CT), 472.3 m^3 ha^{-1}(CP), 601.0 m^3 ha^{-1} (NT), 476.5 m^3 ha^{-1} (PA), 487.5 m^3 ha^{-1}, (DP) to 453.6 m^3 ha^{-1} (SUB).

Table 2. Soil water content (m^3 ha^{-1}) in soil layers – average and separate values

Tillage system	Depth (cm)	Average	June	July	August	September	October
	0-20	511.9	675.6	498.1	541.5	239.2	604.8
	20-40	539.2	646.0	646.1	640.3	381.1	382.7
CT	40-60	635.8	768.3	733.0	680.0	401.1	596.4
	60-80	562.3	758.6	772.1	701.5	388.0	382.4
	Average	562.3	712.1	662.3	640.8	352.3	491.6
	0-20	422.6	682.9	346.3	277.1	257.5	549.3
	20-40	488.5	719.3	530.7	384.2	395.0	413.1
CP	40-60	505.9	726.7	583.1	409.7	401.9	408.3
	60-80	472.3	730.0	757.0	486.9	395.8	411.4
	Average	472.3	714.7	554.3	389.5	362.6	445.5
	0-20	585.6	909.6	571.7	534.3	362.7	549.5
	20-40	613.9	759.1	674.4	399.4	508.3	728.5
NT	40-60	603.6	792.6	708.2	491.7	641.0	384.4
	60-80	601.0	837.1	760.4	493.1	697.1	632.0
	Average	601.0	824.6	678.7	479.6	552.3	573.6
	0-20	457.7	697.8	313.1	445.1	259.4	573.4
	20-40	476.3	705.1	450.2	415.1	350.3	460.7
PA	40-60	495.3	737.5	581.2	399.2	359.8	398.9
	60-80	476.5	710.8	695.7	411.3	389.8	431.8
	Average	476.5	712.8	510.1	417.7	339.8	466.2

DP	0-20	427.2	697.5	357.3	310.6	229.9	540.8
	20-40	510.0	813.6	508.5	379.6	359.0	489.5
	40-60	525.1	692.9	575.8	372.9	360.3	623.6
	60-80	487.5	756.0	706.8	394.5	404.5	392.4
	Average	487.5	740.0	537.1	364.4	338.4	511.6
SUB	0-20	404.1	725.0	365.8	302.4	205.4	421.8
	20-40	489.7	760.2	499.2	337.0	337.6	514.8
	40-60	455.7	674.6	575.6	342.8	363.7	321.8
	60-80	464.9	747.1	682.2	367.4	410.5	410.8
	Average	453.6	726.7	530.7	337.4	329.3	417.3

*Values in the rows marked with different letters differ significantly ($p<0.05$)

Statistically significant differences of water content in soil layers were recorded between NT and conventional tillage and their different variant of conventional tillage systems, at each measurement (Figure 2-5). Jabro et al. (2008) had no significant difference in soil water content between conventional tillage systems, but their research was in dryland conditions. The lowest average water content per particular tillage systems at the depth of 0-20 cm, 40-60 cm and 60-80 cm was determined in SUB systems and at depth 20-40 cm in PA system, while the highest average moisture content at all four depths were recorded in NT system. Different results are obtained from Lopez et al. (1996) suggest that soil water depletion under the NT treatment was confined more to the upper soil layers than for the conventional tillage in semi-arid areas of Spain. It is caused by different climate conditions, and at the end of growing season NT system markedly higher residual water content in the NT plots due to more rapidly depleted soil water under conventional tillage. Špoljar et al. (2011) had significant differences in moisture measurements at depth 0-30 cm between conventional tillage systems, and lowest amounts of soil water had in more intensive conventional systems. Similar results had Hussain et al., 1999; Husnjak et al., 2002; Lampurlanes, 2001; Košutić et al., 2001.

Highest average of soil water content in conventional systems recorded in CT in all four depths, followed by DP and CP (Table 2).

At the depths of 60-80 cm between PA, DP and SUB systems was no statistically significant difference. Average soil water values of summer months in 2012 point to the trend of increased moisture in NT and CT or DP tillage systems compared to others conventional tillage systems. In conventional tillage practice the adoption to soil moisture content is lower. This result is similar to previous papers (Greb et al., 1967, 1970; Unger and Wiese, 1979) that show improving water conservation with increasing amounts of crop residues in NT system retained on the surface.

Figure 2. Soil water content (m^3 ha^{-1}) at depth 0-20 cm

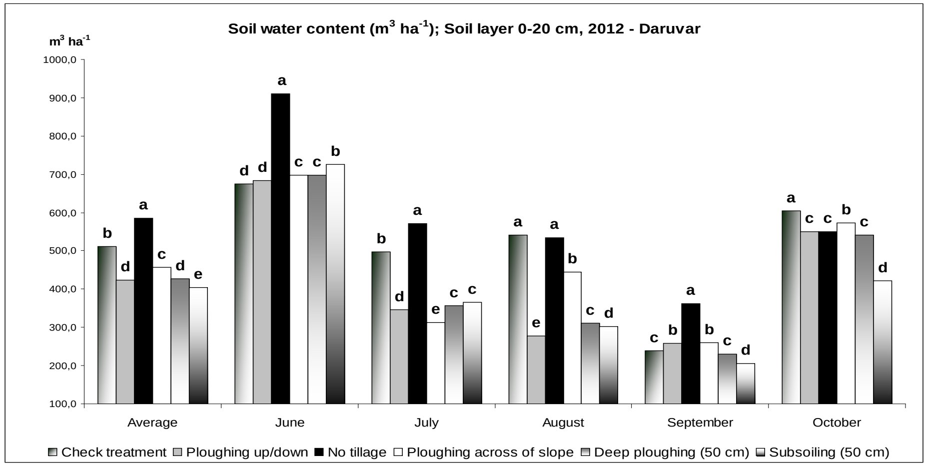


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Figure 3. Soil water content (m^3 ha^{-1}) at depth 20-40 cm

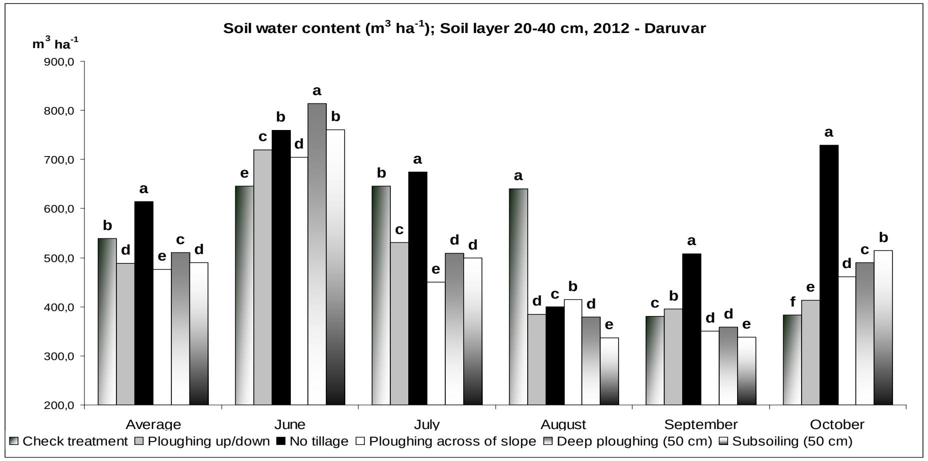

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Figure 4. Soil water content (m^3 ha^{-1}) at depth 40-60 cm

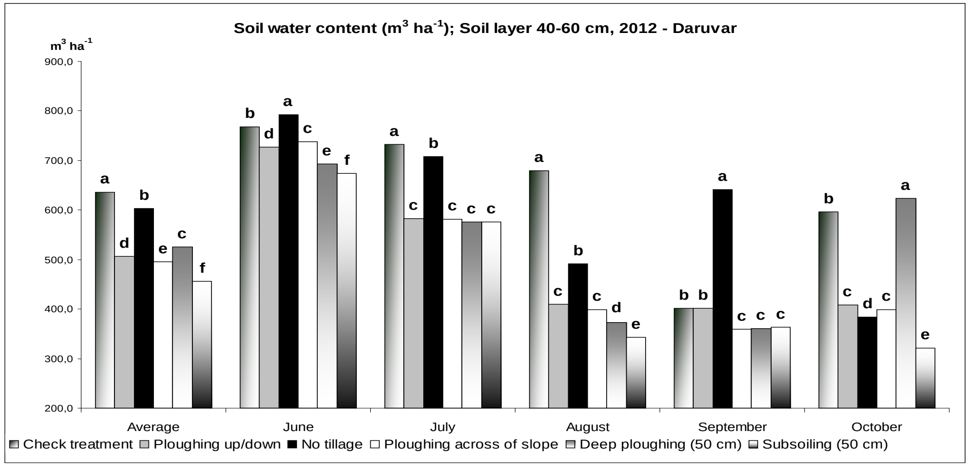

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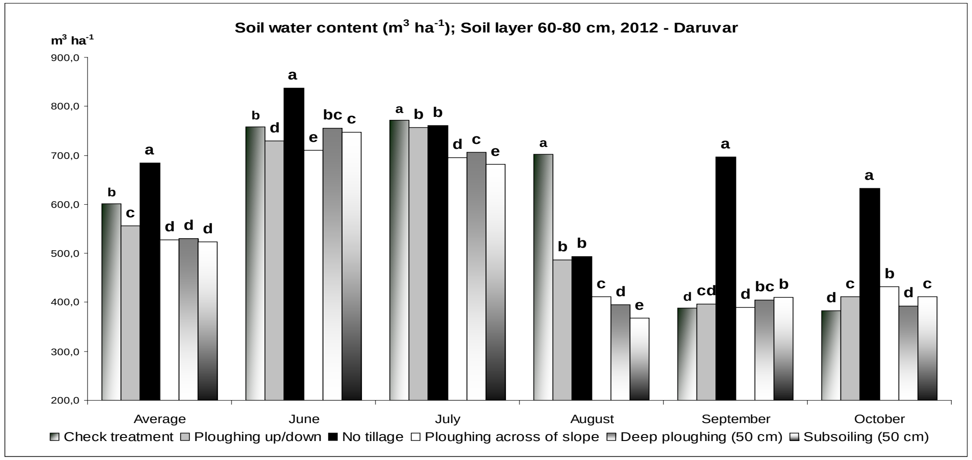
Figure 5. Soil water content (m^3 ha^{-1}) at depth 60-80 cm



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Conclusions

Statistically significant differences in soil water content were determined between all tillage systems. Best results of average soil water values are in NT, and CT or DP variant of conventional tillage systems compared to others conventional tillage systems. Greater infiltration and lower surface evaporation are advantages associated with the soil structure created by non-inverting tillage in NT variant. Soil water was more limiting under CT variants than under NT system. SUB system shown the lowest soil water content. There is concern, however, whether long-term use of reduced tillage or NT will result in soil physical conditions that impair crop yields. Results from 2012 of our long-term tillage study suggest that NT, could replace CT without adverse effects on soil water content in the main cropping areas in Moslavina region (Continental Croatia). On the contrary, NT was a viable alternative to CT in the most semi-humid to humid zones due to its appropriate ability for soil water storage detected even at the beginning of the growing season. The results generally showed that tillage intensity effectively altered soil water content between NT and conventional tillage systems, but minimally affects the conventional tillage systems except the black fallow (CT) variant. SUB can improve the water infiltration and storage in year period with precipitation surplus, but cannot decrease the moisture loss in dry and average seasons. It is necessary to use adaptable tillage processes to improve water infiltration through alleviation of the compacted status (soil loosening, subsoiling) and to moderate the moisture loss (mulching). Average soil water values of summer months in 2012 point to the trend of increased moisture in NT and CT or DP conventional tillage systems compared to others variant of conventional tillage systems.

Considering the complexity of applying reduced tillage or no-tillage treatments, in our case no-tillage, for application of a new soil tillage technology, further detailed research work is necessary.

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