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Towards Proper Management of Clayey Soils: 1. No-tillage and Plowing Effects on Soil Physical Properties and Corn Production

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Abstract: A field experiment was conducted in El-Monofia governorate, on a clayey soil to study the effect of some tillage systems (i.e., no- tillage; plowing) on physical properties of clayey soil and its productivity. The tillage methods evaluated were: no-tillage (NT) and plowing tillage (PT) at two depths, 20 and 40 cm. Corn was used as a test plant. Results showed that soil bulk density (SBD) and water stable aggregates (WSA) >0.425 mm in diameter increased significantly under no- tillage (NT) system compared with plowing one. On the other side, total porosity (TP), water stable aggregates (WSA) < 0.425mm in diameter, air field pores at both field capacity and wilting point {AFP(fc) ; AFP(wp)}, saturated hydraulic conductivity(SHC) and corn grain yield increased significantly under plowing tillage (PT) for the two depths compared with no- tillage (NT). The obtained results proved that plowing generally may provide favorable physical conditions to the growth of the crop when compared to no- tillage system.

Key wards: no-tillage, plowing, bulk density, water stable aggregates, air filled pores and saturated hydraulic conductivity.

INTRODUCTION

Fine textured soils including clayey one have intrinsically poor physical properties which requires exerting more efforts to maximize the quality of its properties so that help crops to grow properly. Plows are the primary tools of farmers used to break up the soil. Plowing turns over a layer of earth so that the vegetation growing on top is buried beneath the layer. There are many reasons for plowing, such as opening the soil for aeration and to receive rain and irrigation water. Plowing can also pulverize the soil, making it easier to plant seeds. It is considered one of the common tillage techniques leads to alteration soil physical properties, such as bulk density, soil aggregates, soil water and aeration capacity, and consequently enhancing crops production. More recently, the definition adopted by the Conservation Technology Information Center (CTIC, 1992) is commonly used. CTIC (1992) defines no-tillage involves very minimal mechanical seedbed preparation (narrow band where the seed is placed) and reliance on herbicides or cover crops or both to control weeds. In no-tillage the soil is left undisturbed from harvest to planting, except for possible nutrient injection.

Many investigators stated that tillage operation creates favorable conditions for plant growth via enhancing water movement, soil structure and decreasing soil compaction[1-3]. No-tillage system led to high bulk density compared to plowing due to the reduction in the proportion of macropores. Deep plowing induced breaking down subsoil compaction and decreasing soil bulk density values between 10 and 80 cm depth. [4-6] reported that tillage practices have a strong influence on soil aggregation and structural stability. They concluded that surface soil (0-10cm) under no-tillage contain larger and more stable aggregates than their tilled counterparts due to the combined effects of crop residue accumulation at the surface and the absence of mechanical disturbance in no-till systems. Hamblin[7] pointed out that soil aggregation increased under no- tillage by 10 to 20% in Alfisols, 29% in a Vertisol and 92% in an Entisol. Dalal[8] measured a small but significant increase in soil aggregates > 20 um in a Vertisol after 13 years of no-tillage treatment. Soil aggregation increased from 47% in the tilled treatment to 49% in the no-tillage treatment.

MATERIALS AND METHODS

A field experiment was carried out in El-Monofia governorate (Menouf Center). The soil of the experimental site was clay (21.84% sand , 25.54% silt and 52.62% clay).Its PH was 7.26, EC (dS/m) 2.42, OM(%) 2.18 and

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CaCO3(%) 2.12. The objective of this study was comparing the changes in soil physical properties and productivity of clayey soil under two tillage systems namely, no-tillage (NT) and plowing tillage (PT) at two depths for each. The experimental design was randomized complete blocks with three replications. Plot size was 2 by 3m. Corn (Zea mays) was used as a test plant. All plots received the recommended chemical fertilizers (NPK). The doses were, 120 kg N of ammonium sulphate (20.6% N) + 50 kg P2O5 of superphosphate (15.5%P2O5) + 25 kg K2O/fed.of potassium sulphate (48.7% K2O). The treatments were as follows:

1) No-tillage system, (20; 40cm depths.)
2) Plowing tillage system, (20; 40cm depths)

The corn plants were harvested after 3 months from sowing and dry weight of grains was recorded .Disturbed and undisturbed soil samples were collected before and after planting for determination of different soil physical properties. Undisturbed soil cores were used to determine soil bulk density (SBD) and saturated hydraulic conductivity (SHC) according to the method described by Majumdar[9] Total porosity (TP) was calculated using the values of bulk density and real density (2.65Mg/m3). Water stable aggregate size distribution (WSA) were determined and mean weight diameter (MWD) was calculated according to Black[10].A pressure plate apparatus was used at pressures of 33.0 and 1500 kPa[11]. For the determination of volumetric water content at each pressure potential, soil cores after equilibrium were weighed and placed in the oven at 105 C for 24h to determine the gravimetric water content. Using dry bulk density, the volumetric water content was calculated. By subtracting volumetric water content at each pressure, (i.e., 33 and 1500kPa) from total porosity, air field pores at both field capacity and wilting point were calculated. Particle size distribution was determined by pipette method as described by Majumdar[9]. Soil PH and EC were measured in 1:25 soil water suspension and in soil paste extract, respectively. Organic matter and CaCO3 were determined according to Jackson [12]. Least significant difference (LSD0.05), correlation coefficient and regression equation were performed using Costat software [13].

RESULTS AND DISCUSSIONS

Soil bulk density and total porosity: From the obtained results in Table (1) it is evident that soil bulk density (SBD) values of no-tillage treatment exceeded that of plowing for the two depths (20; 40cm). Also, subsurface layer (40cm depth) of no-tillage had the highest value (1.26 Mg/m3). The results referred also to a noticeable decline in SBD values under plowing tillage (PT) especially that concerning with subsurface layer (40cm) which recorded the highest reduction compared with the same layer for no-tillage treatment. The values of SBD declined from 1.24 to 1.22 Mg/m3 for the depth of 20 cm while reduced from 1.26 to 1.23 Mg/m3 for the depth of 40 cm for no tillage and plowing treatments, respectively. The percent of reduction was 1.61 and 2.38 % for depths of 20 and 40 cm, respectively. On the other hand, the same table showed an increase in the values of TP. The values were higher for the surface layer (20cm) than those of subsurface one (40cm), for both no-tillage and plowing systems. However, plowing tillage owned the highest values for the two depths compared to no-tillage. The values of TP increased from 53.21 and 52.45% for the two depths of no-tillage (20; 40cm) to 53.97 and 53.58% for the same two depths of plowing.

Table 1: Bulk density and total porosity of clayey soil under tillage systems.

Treatments	Depths (cm)	*BD (Mg/m3)	**TP (%)
No-tillage	0-20	1.24	53.21
	20-40	1.26	52.45
Plowing	0-20	1.23	53.58
	20-40	1.23	53.58
LSD 0.05	-------	0.014	0.531

*Bulk density, **Total porosity.

The percent of increase reached 1.41 and 2.15% for the depths of 20and 40 cm, respectively for plowing at the expense of no-tillage system.

Osunbitan *et al*[14] reported that no-tillage had the highest values of SBD (1.28g/cm3) compared with manual tillage (MT), plough-plough tillage (PP) and plough harrow (PH) tillage. It is clear that plowing undoubtedly achieved noticeable differences in both SBD and TP relative to the no-tillage system especially the deep layer (40cm).

Water stable aggregates and mean weight diameter: Fig (1a ; b) illustrated water stable aggregate distribution (WSA) and mean weight diameter (MWD) as affected by no-tillage and plowing at two depths, 20 and 40cm for each. It is obvious generally that WSA have diameters ranged from 8 until 0.425mm were higher under no-tillage at the two depths compared to that of plowing. Also, the values of aggregates under all diameters were greater in the surface layer than that of subsurface one for both no-tillage and plowing. The contrary was found with the aggregates have diameters ranged from 0.425 until 0.106mm, where the smaller aggregates were dominant with plowing than that with no-tillage. This trend proved that no-tillage contributes to conserving the larger

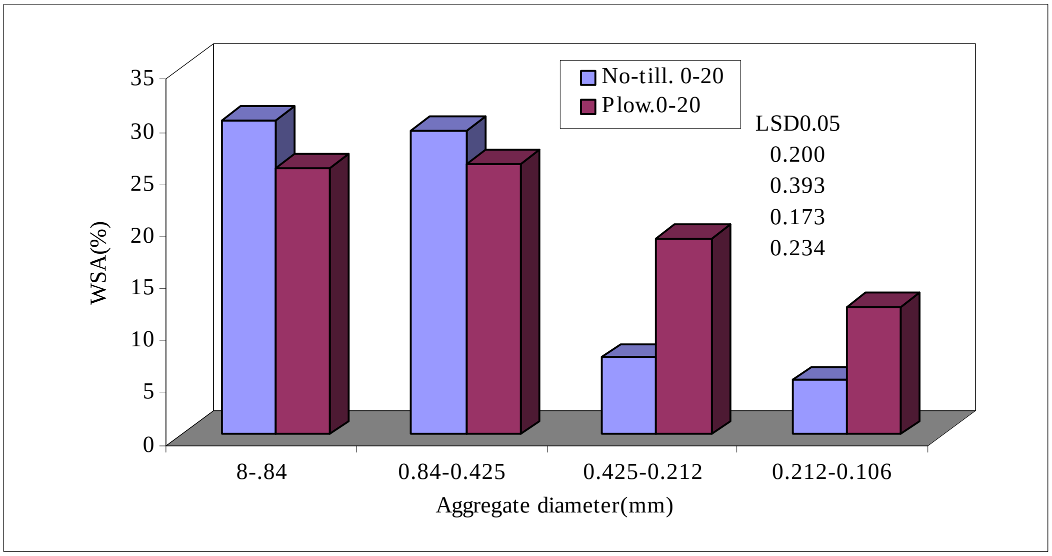

Fig. 1a: Water stable aggregates of clayey soil under tillage.

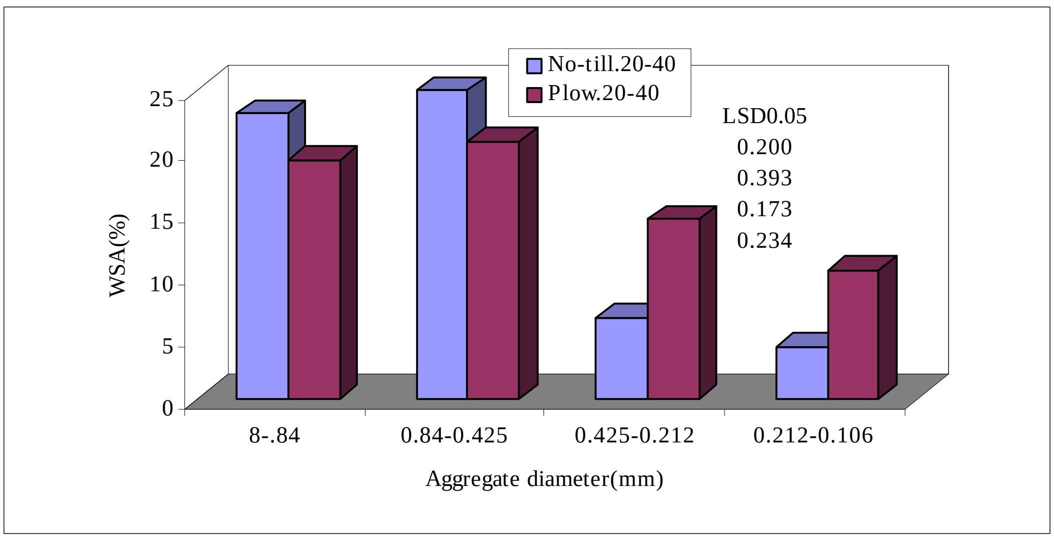

Fig. 1b: Water stable aggregates of clayey soil under tillage.

aggregates at the expense of the smaller ones, whereas plowing tends to alteration the pattern of aggregates towards smaller sizes. The aggregates have diameters ranged from 8-0.84mm under plowing reduced by a value of 15.48 and 16.58% for depths of 20 and 40 cm, respectively compared to no-tillage system. The same trend took place with the aggregates ranged its diameter from 0.84-0.425 mm. The values reduced to 11.21 and 16.53% for the depths of 20 and 40 cm under plowing respectively. Concerning the aggregates ranged from 0.425 to 0.212 mm, an increase in its values amounted to 154.27 and 121.04 % under plowing treatment at depths of 20 and 40cm successively. Compared to no-tillage. For aggregates which its diameter ranged from 0.212 to 0.106mm, the increase amounted to 135.66 and 147.16% for the same depths and applied tillage formerly mentioned.

On the other hand, the results in Fig (1c) showed that the values of mean weight diameter decreased under plowing depths compared with that under no-tillage. It decreased from 2.19 and 2.09 for no-tillage to 1.72 and 1.68 for plowing at the depths of 20 and 40 cm, respectively. The reduction in values of MWD of plowing treatment reached 21.56 and 19.62% for the depths of 20 and 40 cm, respectively compared to no-tillage. It is interesting to notice that the values of MWD coincided with the pattern of aggregate size distribution under applied tillage

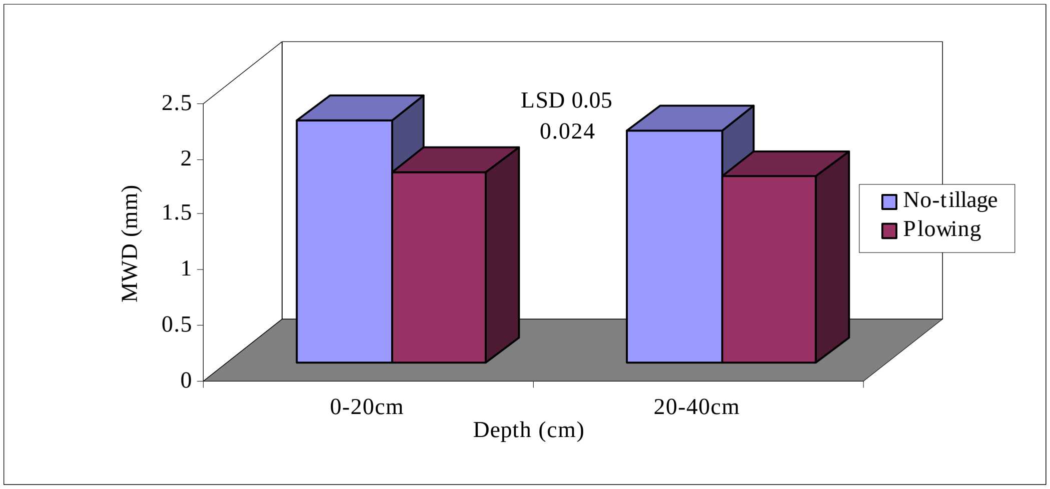

Fig. 1c: Mean weight diameter (MWD) of clayey soil under tillage.

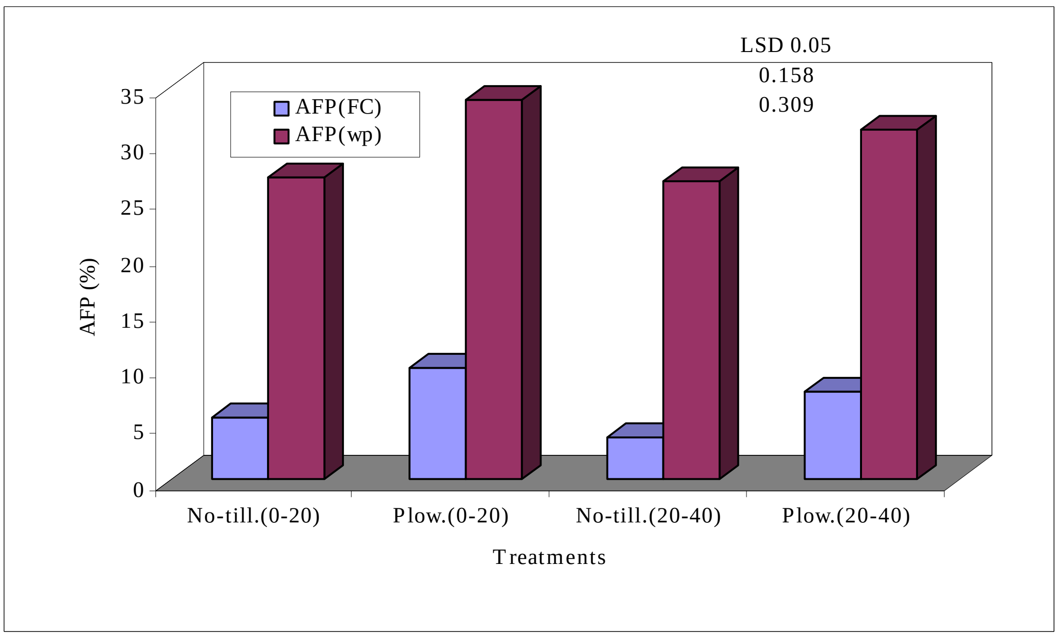

Fig 2: Air filled pores of clayey soil at fiel capacity and wilting point under tillage.

systems. Because of the higher organic matter content, aggregate stability in the surface 10 cm of soil is characteristically higher under zero than conventional tillage[6,15] on the other hand, plowing may promote microbial decomposition by exposing previously inaccessible soil organic matter to microbial attack. It has also been shown that in comparison with zero tillage plowing promotes decomposition of plant residues by increasing contact between soil and the residues[16,17].

The correlation analysis emphasized the high significant correlation coefficients among aggregate fractions, SBD, TP and MWD. The relationships were as follows:

Variables (Y)	(X)	Regression equation	(r)
*Ag (3)	**SBD	Y = 304.719-236.708 X	-0.791
Ag (4)	SBD	Y = 205.965-159.978 X	-0.800
Ag (3)	TP	Y = - 323.353 + 6.288 X	0.789
Ag (4)	TP	Y = - 218.502 + 4.249 X	0.800
Ag (1)	MWD	Y = 4.163 + 10.597 X	0.635
Ag (2)	MWD	Y = 8.114 + 8.910 X	0.695
Ag (3)	MWD	Y = 47.040 – 18.358 X	-0.860
Ag (4)	MWD	Y = 32.140 – 12.577 X	-0.884

*Ag (1, 2, 3, 4) = The aggregates which have diameters of 8-0.84, 0.84-0.425, 0.425- 0.212 and 0.212-0.106mm, respectively.

**SBD, TP; MWD = Soil bulk density, total porosity and mean weight diameter.

The results emphasize the need to apply organic materials to clayey soil during plowing practices to avoid some of its negative effects especially on soil macroaggregates when applied alone and maximizing its efficiency.

Air filled pores: Fig (2) demonstrated significant changes in air filled pores at both 33 and 1500 kPa which represent field capacity and wilting point attendant to no-tillage and plowing.

Air filled pores at field at field capacity were higher under plowing treatment at the depths of 20 and 40cm compared with no-tillage treatment. The values increased from 5.46 and 3.71% for no-tillage to 9.94 and 7.77% for plowing at the two depths, 20 and 40 cm, successively. The percentage of increase reached 82.05 and 109.43 for the two previous depths. With regard to air filled pores at wilting point, an increment in the values amounted to 33.93 and 31.22% for plowing whereas reached 26.96 and 26.66% for no-tillage at the depths of 20 and 40cm. The percentage of increase was 25.85 and 17.10 % for the same previous depths. It is worthy to notice that a pronounced increase in the values of AFP at field capacity exceeded to a great extent that of AFP at wilting point as a result of plowing especially that concerning with subsurface layer (40cm depth) where the percentage of increase appreciably differed in comparison with the surface layer (20cm depth).

The obtained results are in agreement with that mentioned by Hendrix and Bear[16,17] who reported that aeration is generally better in plowed soil and this leads to a more oxidative microbial metabolism under plowing than zero tillage.

Correlation analysis related air filled pores and some parameters under study which had highly significant correlation coefficients (r) are shown as follows:

Variables Y	X	Regression equation	(r)
*AFP(1)	**SBD	Y = 153.349 – 118.394 X	-0.871
AFP(1)	Ag	Y = 1.747 = 0.432 X	0.952
AFP(1)	MWD	Y = 20.677 – 7.209 X	-0.745
AFP(2)	SBD	Y = 207.294 – 143.511 X	-0.796
AFP(2)	Ag	Y = 22.634 + 0.599 X	0.996
AFP(2)	MWD	Y = 50.984 – 11.086 X	0.864

*AFP (1); (2) = Air filled pores at both field capacity and wilting point, respectively.
**SBD, Ag; MWD = Soil bulk density, aggregates have a diameter ranged from 0.425 to 0.212mm and mean weight diameter.

The preceding results are an extremely important trend in clayey soil which mainly is poor in its air capacity particularly the subsurface layer.

Saturated hydraulic conductivity: Data in Table (2) indicate that saturated hydraulic conductivity (SHC) values significantly affected by tillage systems under study. The values showed that surface layer (20cm depth) possessed the higher values, while subsurface layer (40cm depth) owned the lower ones, regardless the type of tillage (i.e., no-tillage or plowing). On the other side, plowing had the highest values for the two depths versus the lowest values for no-tillage. It is also clear that surface layer of plowing recorded the highest value (0.83 cm/h). The values of SHC increased from 0.72 cm/h for no-tillage at 20cm depth to 0.83cm/h for plowing. Regarding the depth of 40cm depth the values increased from 0.66 cm/h for no-tillage to 0.74 cm/h for plowing. The percentage of increase was 15.28 and 12.12 for plowing at the two depths of tillage compared to no-tillage operation.

The results indicated the ability of plowing on creating adequate conditions for water movement in clayey soil compared with no-tillage operation through the proper changes in soil structure parameters such as, soil bulk density, aggregate size distribution and soil pores.

Correlation coefficients (r) of some chosen parameters which had the highest significant correlation with saturated hydraulic conductivity (SHC)

Variables Y	X	Regression equation	(r)
*SHC	#SBD	Y = 3.511 – 2.241 X	-0.566
SHC	MWD	Y = 1.019 - 0.146 X	-0.521
SHC	Ag (1)	Y = 0.607 + 0.011 X	0.838
SHC	Ag (2)	Y = 0.608 + 0.016 X	0.816
SHC	AFP(1)	Y = 0.561 + 0.026 X	0.884
SHC	AFP(2)	Y = 0.203 + 0.018 X	0.821

*SHC= soil hydraulic conductivity
#SBD, MWD, Ag(1);(2), AFP(1);(2) = soil bulk density, mean weight diameter, aggregates have diameters ranged from 0.425-0.212; 0.212-0.106 mm, respectively and air filled pores at both field capacity and wilting point, respectively.

Table 2: Saturated hydraulic conductivity of clayey soil as affected by tillage systems.

Treatments	Depth(cm)	*SHC (cm/h)
No-tillage	0-20	0.72
	20-40	0.66
Plowing	0-20	0.83
	20-40	0.74
LSD 0.05	-------	0.051

*SHC= Saturated hydraulic conductivity.

Yield of corn grains: Results in Table (3) concerning with grains yield of corn refer to useful influence of plowing tillage on the productivity of corn compared with no-tillage. The yield of grains has no changes with respect to

Table 3: Effect of tillage systems on grain yield of corn grown in clayey soil.

Treatments	Depth (cm)	Grain yield (tons/fed.)
No- tillage	0-20	2.57
	20-40	2.57
Plowing	0-20	2.75
	20-40	2.94
LSD 0.05	-------	0.061

no-tillage where the value was 2.57 tons/fed for the two depths of tillage (i.e., 20; 40cm). Regards plowing tillage, the yield was 2.75 and 2.94 tons/fed for the depths of 20 and 40cm, respectively. The percentage of increase under plowing compared with no-tillage was 7.0 and 14.40 for the two depths of tillage, 20 and 40cm, successively. The deep layer (40cm) under plowing had the highest value which denotes to the vital role of plowing on loosening subsurface layer which in turn reflects on facilitating conditions suitable for roots to penetrate deeply and saving the appropriate levels of water and air and increasing the availability of nutrients necessary for plant growth.

Josa and Kosutic[18,19] mentioned that the yield of wheat under no-tillage system was lower than for conventional tillage (CT) and minimum tillage (MT). The greatest average yield of 11.52 t/ha was obtained by CT system. The yield in no-tillage system was 10% lower than the CT system.

The most variables highly correlated with grain yield (GY) of corn included, soil bulk density (SBD), and mean weight diameter (MWD) which were as follows:

Variables Y	Variables X	Regression equation	(r)
GY	SBD	Y = 13.682 – 8.868 X	-0.525
GY	MWD	Y = 4.419 - 0.891 X	-0.742

Generally speaking, the results of the study showed the importance of plowing in improving the physical properties that reflects on water and air capacity of clayey soil and corn production as well. On the other hand, the results denoted also to considered changes in water stable aggregate distribution towards the small diameters at the expense of large ones which required supporting soil structure by adding organic materials during plowing operation to avoid deterioration of soil aggregates on the long-run. So, this issue will be treated in the next paper (part 2).

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