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EFFECT OF TILLAGE ON SPATIOTEMPORAL VARIABILITY OF SOIL HYDROPHYSICAL PROPERTIES AND PRODUCTIVITY OF WHEAT – MAIZE UNDER CALCAREOUS SOIL CONDITIONS AT EL-NUBARIA

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ABSTRACT: *Two field experiments were conducted during winter season of 1999/2000 for wheat and summer season 2000 for maize to study the effect of no-till (zero tillage) and three plowing depth (20,40 and 60 cm) and their residual effect on soil hydrophysical properties, wheat / maize productivity and spatiotemporal variability of soil bulk density and soil penetration resistance. A Randomized Complete Block Design (RCBD) with three replication was used.*

The results indicated that increasing plowing depth significantly decreased soil bulk density values and penetration resistance values in surface, subsurface and deep layers. Bulk density and penetration resistance values increased with time as fallow: Harvest time values of maize > Harvest time values of wheat > Beginning of growing season values. Data showed that significantly increased hydraulic conductivity values with increasing plowing depth. While it decrease at the end of season of wheat and maize.

Total soil porosity was higher in the treated soils than in no-till. The highest total porosity values in surface and subsurface layers were observed with plowing to 60 cm depth. It was increased to 53.58 % in surface layer and to 53.20 and 52.08 % in subsurface and deep layers with increment rate 5.90, 11.88 and 10.43 % repetitively. The results indicated the decrease in total porosity values with time, it decreased from 53.58 % to 51.76 % in surface layer by decrement rate 3.4 % with to 60 cm depth, while it was decreased to 50 % and 49.81 % by decrement rate 6 % and 4 % for subsurface and deep layers respectively. The data showed that increase in air porosity values with plowing depths in comparison to no-till for all soil layers, while it was decreased with time. The highest air porosity values were observed with plowing to 60-cm depth in deep layers. It increased to 28.10, 23.60 and 27.21 % in deep, subsurface and surface layers with increment rate 44.9 %, 50.8 % and 40.9 %, respectively. The results revealed decrease in water storage porosity values with plowing depths and increases in it's values with time, under the same plowing depth (to 60 cm) and for all soil layers. The data showed an increase in total drainable pores and quick drainable pores values with plowing depth in comparison to no-till for all soil layers which it was decreased with time. The highest total drainable pores and quick drainable *pores values were observed with plowing to 60 cm depth in surface layer. Total drainable pores was increased to 46.72, 42.60 and 34.68% for surface, subsurface and deep layers with plowing to 60 cm depth, which quick drainable pores volume was increased to 31.58, 28.57 and 24.70% for the same soil layers and plowing depth, respectively.*

Increasing of plowing depth up to 60 cm has resulted in increasing of the cumulative infiltration rate to the highest value (2.39, 3.08 and 2.06 cm/hr), in the beginning of the season and the end of growing season for wheat and maize, respectively. The fine aggregates (< 0.25 mm) decreased with plowing depth but the coarse aggregates (> 0.25 mm) increased with plowing depth. The fine aggregates increased with the end of maize more than the wheat season. The same trend of structure coefficient (S.C.) was noticed.

Lastly, data reveal that crop production of wheat and maize, expressed as grain yield has significantly increased from 2.71 and 7.90 ton/ha at zero tillage to 3.80 and 10.59 ton/ha at 40 cm plowing depth in wheat and maize, respectively. Statistical analysis showed that insignificant increased between 40 cm and 60 cm plowing depth. The spatial continuity of soil bulk density and penetration resistance increases from low to high with increasing plowing depth in different soil layer using kriging techniques. The spatial uniformity of soil bulk density and penetration resistance increases with time.

Key Words: *Tillage, plowing depth, bulk density, penetration resistance, infiltration rate, pore size distribution, water stable aggregates, calcareous soil, kriging, spatial and temporal variability.*

INTRODUCTION

Calcareous soils are characterized by low organic matter contents, unstable aggregates, and are particularly vulnerable to compacting, crusting. These poor physical conditions limit plant-available water, air movement to the roots, restrict seed germination, seedling emergence, and root growth and consequently plant-yielding ability. The adverse effects of soil compaction on crop growth have been recognized for seasons and years. Bulk density and soil strength are two physical properties, which quantify soil compaction.

Tillage is considered as a technique that plays an important role in soil and water conservation where the process of infiltration, runoff, and evaporation are involved. Tillage is defined as the mechanical manipulation of the soil aimed at improving soil conditions affecting crop production (Hellil, 1982). The intensity of tillage, different tillage systems affect the physical properties of soil, such as water content, bulk density, penetration resistance, and soil porosity. Changes in soil physical properties might be expected to develop slowly after the initiation of conservation tillage.

Tillage loosens the soil and decreases soil bulk density and penetration resistance by increasing soil macroporosity (Hill et al. 1985). Compaction results in decreased air-filled porosity (macroporosity) of surface soil and contributes to higher bulk density and more dense soil under no-till than under modbourd plowing (Blevins et al., 1984). Cassel et al. (1995) found bulk densities of 1.56, 1.48 and 1.46 Mg m-3 after 2 years of no-till (NT), chisel plow (CP), and moldboard plow (MP), respectively, in sandy loam. Bulk density also increased significantly with depth in tillage treatments.

Some researchers have reported that tillage decreased bulk density with no effect on penetration resistance. These changes in soil physical properties attributable to tillage are not stable immediately after the initiation of the tillage system and require long-term study.

Hussain et al., (1998) found that the higher bulk density with NT system than with the MP system was attributed to a lower proportion of macropores. Cone penetration resistance was consistently higher with the NT system at 8-cm depth at planting or at 25 days after planting, but resistance values were below root inhibiting resistance. No-till increased the water filled porosity because of the maintenance of soil aggregate stability, but the lack of tillage resulted in decreased air-porosity with time.

Farmers want to enhancing plant growth and maximizing yields. Philips and Kirkland (1962) and Morris (1975) reported corn yield reductions of 10 to 22 percent due to compaction. For each 1 kg/m^3 increase in bulk density, a decrease in maize grain yields of 18% relative to the yield on a noncompacted plot (Canarache et al., 1984). Increased soil compaction can reduce yields in potatoes of up to 22 percent (Saini and Lantagne, 1974). Similar effects were obtained by Feldman and Domier, 1970 on wheat growth. These results illustrate the potential for compaction to depress crop yields. Extremely dense soil impedes root growth and thereby limits water consumption of plants. Vepraskas and Wagger (1990) and Dunker et al., (1995) reported that sub-soiling significantly increased corn yield over shallow tillage.

Soil strength is an indicator of how easily roots can penetrate soil. Cone index is a measure of soil strength and is measured using a penetrometer. The magnitude of mechanical impedance to root penetration, which decreases plant growth, is also unknown. Sojka et al., (1990) studied the effect of penentrometer resistance on sunflower. A soil strength corresponding to a penetrometer resistance of 2 MPa produces some root restriction and a resistance of 3 MPa creates a total barrier to root elongation. Murdock et al., (1995) showed that a penetrometer measurement of 2 MPa generally regarded as sufficient to hinder the growth and development of crops.

Rahman and Islam (1989) indicated that sub-soiling significantly lowered the bulk density of the surface (0-10 cm) soil layer by 0.04-0.09 g cm^{-3} and the 10-30 cm layer by 0.19-0.32 g cm^3. Results reported by Maderia et al., (1989) showed that deep plowing induced the decrease in soil bulk density values between 10 and 80 cm depth. Bledsoe et al., (1992) evaluated the effect of four plowing depths (20, 40, 60, and 80 cm) on the bulk density values and penetrometer resistance decreased and root length densities and corn yield increased with increasing plowing depth.

Vittal et al., (1983) reveled that both initial and final infiltration rates increased with deep plowing. Mapa et al., (1986) reported that infiltration rate of tilled soil layer is very high immediately after tillage, then decrease with time as the soil settles or as surface seal forms.

The objectives of this research were to study the effect of different plowing depths and residual effect on: 1- Soil hydrophysical properties, 2- Wheat and maize productivity and 3- Spatial and temporal variability of soil bulk density and soil penetration resistance.

MATERIALS AND METHODS

I- Field experiments:

Two field experiments were conducted during winter season of 1999/2000 for wheat and summer season 2000 for maize at the Research Farm of Nubaria Agriculture Research Station, Agric. Res. Center (ARC), Egypt. Experiments were carried out to test the effect of no-till and three plowing depths in wheat and residual plowing effect in maize. The plowing depths were 20 cm, 40 cm and 60 cm. A Randomized Complete Block Design (RCBD) with three replications was used. Average depths of plowing were measured from the deepest point of the blade up to the soil surface.

Soil samples from the experimental site were collected before planting and analyzed for particle size distribution, soil pH, electrical conductivity (EC) of saturation extract, organic matter (O.M) and calcium carbonate contents, (Black, 1965). Results of the analysis are presented in Table 1.

Table 1: Some soil physical and chemical properties at the experimental site

Soil depth (cm)	Particle size distribution (%)				Texture class	$CaCO_3$ %	OM %	pH	EC dS/m
	Coarse sand	Fine sand	Silt	Clay					
0-30	12.8	63.80	10.40	13.00	Sandy loam	28.70	0.36	8.32	3.50
30-60	7.60	59.60	14.20	18.60	Sandy clay loam	32.80	0.48	8.37	3.28

II- Soil physical analysis:

Bulk density (Db), total soil porosity (E) and hydraulic conductivity (Kh):

The undisturbed soil samples were taken using soil cores to determine bulk density and hydraulic conductivity using constant head method (Klute,

1965). Total soil porosity was calculated as a percentage by using the equation of $E = (1 - Db/Dr) \times 100$.
Where; Db : Bulk density , Dr : Real density .

Soil penetration resistance:

The pocket penetrometer was used to measure soil resistance to deformation forces (Black, 1965). The penetrometer was pushed steady into the soil. The maximum deformation of the spring, as the piston needle is pushed into soil has been correlated with unconfined compressive strength of Ton / Ft^2. The values of unconfined compressive strength of soil are calibrated directly on a scale on the piston barrel. It could be expressed in terms of consistency according to Black 1965 as follows: Very soft: < 0.25, Soft: 0.25 - 0.50, Medium: 0.5-1.00, Stiff: 1.00-2.00, Very stiff: 2.00- 4.00 and Hard: > 4.00.

Pore size distribution:

- Pore size distribution was determined according to the equation:

$$P = (2 \sigma \cos \theta)/r$$

Where r is pore radius, σ is surface tension of water (σ = 72 dyne / cm), θ is the contact angle and P is the applied pressure. When contact angle equals zero, the pore diameter corresponds to pressure 0.1, 0.33 and 10 bars is equal to 28.8, 8.62, and 0.288 micron, respectively. (De Leenher and De Boodt, 1965) classified the pore space to pore with a diameter > 28.8 μ as quick drainable pores, while those with diameters 28.8-8.62 μ as slow drainable pores and total drainable pores as the pores with diameters > 8.62 micron.

- Soil pore size distribution was determined using the method by Nizeyimana and Olson (1988). Soil clods were collected from each plot with depth for different plowing depths. Bulk density of these undisturbed clods was determined at 33 kPa. Water contents of < 2 mm sived soil samples were determined at 1500 kPa. Various pore size distribution volumes were calculated using the following equations:

Total porosity (TP) = $[1 - (\rho m / \rho s)]$
Water storage porosity (WSP) = $(\theta m - \theta \pi)$
Residual porosity (RP) = $\theta \pi$
Air porosity (AP) = TP – (WSP + RP)

Where;

ρm = bulk density at 33 Kpa ,
ρs = partical density of soil soilds (2.65 Mg / m^3),
θm = volmetric water contents at 33 kPa, and
$\theta \pi$ = volmetric water contents at 1500 kPa

Infiltration functions:

Infiltration rate using the double ring infilometer technique (Walker 1989) was measured.

- Cumulative infiltration values were calculated according to relation given by Kostiakov-Lewis as:-

$$Z = k\,r^{a}$$

- Infiltration rate values were calculated according to relation given by Kostiakov-Lewis :-

$$I = a\,k\,r^{a-1}$$

in which,

Z= cumulative infiltration in units of volume per unit length per unit width;
r= intake opportunity time;
k and a = empirical constants; and
I = infiltration rate.

Water stable aggregates:

Wet sieving was carried out using the wet sieving technique described by Yoder (1936) and modified by Ibrahim (1964). The wet sieving stability (WSS) was calculated using the equation:

$$WSS = (m/M)\,100$$

where; m= the weight of water stable aggregates fraction and M = weight of the soil sample used.

Structure coefficient values (SC) were calculated as suggested by El-Shafei and Ragab (1975).

$$SC = \frac{\%\ \text{aggregates} > 0.25\ \text{mm diameter}}{\%\ \text{aggregates} < 0.25\ \text{mm diameter}}$$

Data were statistically analyzed using Costat software (1985).

III- Spatial and temporal variability analysis:

Sixteen observation sites were selected represent different soil compaction variability according to grid systematic design to test soil bulk density and penetration resistance in three depths (0-20, 20-40 and 40-60 cm) at beginning of growing season and end wheat and maize seasons, (Fig 1).

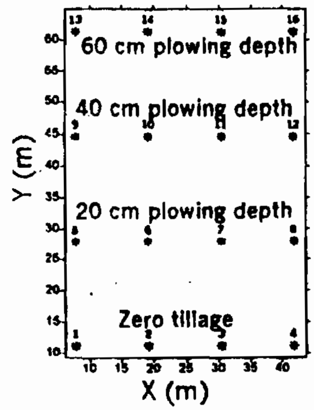


Fig (1): Grid sampling sites design according to different plowing depths in the field experiment

Contour maps of soil bulk density and penetration resistance were developed according to Kriging technique. The Kriging method is optimal in a sense that the weights of local averaging are chosen to give unbiased estimates while keeping the estimation variance at minimum (Webster, 1985). Surfer Software (1994) was used to draw the maps.

RESULTS AND DISCUSION

I- Effect of plowing depth on hydrophysical properties:

1- Soil bulk density:

Data in Table (2) showed that, in general, increasing plowing depth significantly decreased soil bulk density values in surface, subsurface and deep layers. The same trend was noticed at the end of growing season for wheat and maize. The results indicated that soil bulk density values after applying plowing depth treatments (beginning of growing season) were less than those at harvest time for wheat and maize.

Increasing soil bulk density values by the end of growing season in wheat and maize can be attributed to movement of fine particles of the soil with irrigation water and blocking soil pores. Rahman and Islam (1989), Madeira et al., (1989), Bledsoe et al., (1992), Hill et al., (1985) and Dao (1996) have stated that mechanical disturbance and water movement on soil surface and through the profile can redistribute and reorient fine particles filling secondary and large primary pores and resulting in layers with very small pores.

2- Soil penetration resistance:

Data in Table (2) indicate that increasing plowing depth significantly decreased penetration resistance values in surface, subsurface and deep layers. The results also showed that after harvest time of wheat, the data of penetration resistance values increased more than those the beginning of growing season. Penetration resistance values increased as fallow: Harvest time values of maize > Harvest time values of wheat > Beginning of growing season values. The no-till treatment consistently resulted in significantly higher penetrometer resistance than most or all of the other treatments (Van Doren et al., 1977) and (Wander et al., 1999).

3- Hydraulic conductivity (Kh):

Data in Table (2) showed that significantly increased hydraulic conductivity values with increasing plowing depth. On the other hand, the hydraulic conductivity decreased with end of wheat and maize seasons. Increasing soil Kh by increasing soil surface roughness and breaking surface crusts (Bordovsky et al., 1998).

Table (2): Effect of plowing depth on bulk density (Db gm^{-3}) , penetration resistance (PR ton ft^{-2}) and hydraulic conductivity (Kh cm hr^{-1}).

Plowing depth (cm)	Db g cm^{-3}			PR ton ft^{-2}			Kh cm hr^{-1}		
	Begin	End of season		Begin	End of season		Begin	End of season	
		Wheat	Maize		Wheat	Maize		Wheat	Maize
Surface layer (0-20 cm)									
0	1.31a	1.36a	1.46a	1.50a	2.23a	3.35a	1.22d	1.08d	0.78d
20	1.27b	1.32b	1.43a	0.68b	1.78b	3.10ab	1.52c	1.42c	1.01c
40	1.24c	1.27c	1.36b	0.50b	0.90c	3.00b	1.80b	1.61b	1.27b
60	1.23c	1.19d	1.28c	0.43b	0.68c	0.88c	2.24a	1.88a	1.48a
Subsurface layer (20-40 cm)									
0	1.39a	1.45a	1.53a	1.70a	2.70a	3.65a	0.95d	0.93d	0.67c
20	1.32b	1.39b	1.42b	1.43b	2.18b	3.53a	1.32c	1.21c	1.03b
40	1.26c	1.32c	1.37c	1.28b	1.73c	3.50a	1.63b	1.35b	1.21a
60	1.24c	1.26d	1.28d	0.75c	1.30d	1.73b	1.79a	1.56a	1.27a
Deep layer (40-60 cm)									
0	1.40a	1.47a	1.54a	1.93 a	3.18a	4.00a	0.89c	0.84c	0.69d
20	1.37b	1.38b	1.45b	1.63 b	2.55b	3.90a	1.18b	1.08b	0.86c
40	1.30c	1.33c	1.39c	1.53 bc	1.38c	3.40b	1.31b	1.31a	1.00b
60	1.27d	1.30d	1.33d	1.28 c	1.30c	2.30c	1.55a	1.43a	1.16a3

* Mean values having the same letter (s) are not significantly different based on L.S.D $_{0.05}$

4- Pore size distribution:

Data in Tables (3 and 4) present the values of soil total porosity as related to the different tillage depths during two successive seasons, winter season 1999/2000 and summer season 2000.

Table (3): Effect of plowing depth on total porosity (TP), water storage porosity (WSP), residual porosity (RP) and air porosity (AP).

Plowing Depth (cm)	TP %			WSP %			RP %			AP %		
	Begin	End of season		Begin	End of season		Begin	End of season		Begin	End of season	
		Wheat	Maize		Wheat	Maize		Wheat	Maize		Wheat	Maize
Surface layer (0-20 cm)												
0	50.56 c	48.67 d	44.90 d	13.30 a	14.75 a	19.78 a	17.63 a	15.70 a	14.59 a	19.63 d	18.22 d	10.53 d
20	52.07 b	50.18 c	46.03 c	12.90 b	14.48 b	16.65 b	16.43 b	14.58 b	13.70 b	22.74 c	21.12 c	15.68 c
40	53.20 a	52.08 b	48.67 b	12.55 ab	12.53 c	15.57 c	14.58 c	13.48 c	12.51 c	26.07 b	26.07 b	20.59 b
60	53.58 a	53.09 a	51.76 a	11.33 a	11.55 c	12.83 c	13.60 d	12.23 d	11.72 d	28.65 a	29.31 a	27.21 a
Subsurface layer (20-40 cm)												
0	47.55 d	45.28 d	45.16 d	13.65 a	15.08 a	16.53 a	15.88 a	14.16 a	13.43 a	18.02 d	16.04 d	12..30 c
20	50.18 c	47.55 c	44.53 c	13.05 b	14.53 b	13.68 b	14.84 b	13.60 b	11.80 b	22.29 c	19.42 c	19.05 b
40	52.45 b	50.18 b	46.48 b	12.15 c	13.23 c	15.45 c	13.48 c	12.27 c	11.37 c	26.82 b	24.68 b	19.66 b
60	53.20 a	52.45 a	50.00 a	11.27 d	12.45 d	16.53 d	12.70 d	11.63 d	9.87 d	29.23 a	28.73 a	23.60 a
Deep layer (40-60 cm)												
0	47.16 d	44.52 d	41.88 d	11.63 a	13.10 a	14.83 a	14.70 a	13.43 a	12.65 a	20.83 d	17.99 d	14.40 d
20	48.30 c	47.92 c	45.28 c	11.32 ab	12.58 b	14.20 ab	13.98 b	12.33 b	12.30 b	23.00 c	20.37 c	18.78 c
40	50.94 b	49.81 b	47.54 b	10.43 b	11.65 c	13.28 b	12.55 c	10.88 c	10.76 c	27.96 b	27.28 b	23.50 b
60	52.08 a	50.94 a	49.81 a	9.48 c	10.00 d	12.15 c	11.53 d	10.33 d	9.56 d	31.07 a	30.61 a	28.10 a

* Mean values having the same letter (s) are not significantly different based on L.S.D $_{0.05}$

Table (4): Effect of plowing depth on total drainable porosity (TDP), quick drainable porosity (QDP) and slow drainable porosity (SDP).

Plowing depth (cm)	TDP %			QDP %			SDP %		
	Begin	End of season		Begin	End of season		Begin	End of season	
		Wheat	Maize		Wheat	Maize		Wheat	Maize
Surface layer (0-20 cm)									
0	36.55 d	32.64 d	29.63 d	11.20 d	8.60 d	7.60 d	25.35 a	24.04 a	22.03 a
20	39.70 c	34.65 c	31.63 c	15.50 c	13.27 c	11.70 c	24.20 b	21.38 b	19.93 b
40	43.68 b	38.70 b	33.66 b	23.60 b	20.70 b	17.37 b	20.08 c	18.00 c	16.29 c
60	46.72 a	41.32 a	36.80 a	31.58 a	26.67 a	23.50 a	15.14 d	14.66 d	13.30 d
Subsurface layer (20-40 cm)									
0	29.76 d	26.47 d	24.67 d	7.57 d	5.63 d	5.43 d	22.19 a	20.84 a	19.24 a
20	32.48 c	29.55 c	26.15 c	14.50 c	12.80 c	9.65 c	17.98 b	16.75 c	15.65 c
40	38.52 b	32.55 b	29.55 b	21.50 b	18.73 b	16.63 b	17.02 c	13.82 b	12.92 b
60	42.60 a	36.83 a	32.63 a	28.57 a	25.60 a	22.45 a	14.03 d	11.23 a	10.18 d
Deep layer (40-60 cm)									
0	24.61 d	22.80 d	21.78 d	7.38 d	5.50 d	3.28 d	17.23 a	18.30 a	18.50 a
20	28.49 c	26.41 c	26.00 c	14.75 c	10.65 c	8.53 c	13.74 b	15.76 b	17.47 b
40	31.48 b	29.56 b	27.70 b	18.35 b	14.50 b	11.50 b	13.13 c	15.06 c	16.20 c
60	34.68 a	32.35 a	30.55 a	24.70 a	21.33 a	18.35 a	9.98 d	11.02 d	12.20 d

* Mean values having the same letter (s) are not significantly different based on L.S.D $_{0.05}$

The interaction effect clearly indicates that, total soil porosity was higher in the treated soils than in no-till. The highest total porosity values were observed with plowing to 60 cm depth in surface and subsurface layers (Table 3). It was increased to 53.58 in surface layer and to 53.20 and 52.08 in subsurface and deep layers with increment rate 5.90, 11.88 and 10.43 % repetitively. To observe the tillage effect on soil porosity with time, the results indicated the decrease in total porosity values with time, it decreased from 53.58 to 51.76% in surface layer by decrement rate 3.4 % with to 60 cm depth, while it was decreased to 50 and 49.81% by decrement rate 6% and 4% for subsurface and deep layers respectively. In general, total soil porosity values were decreased with soil layers depth and with time, (Hill et al., 1985).

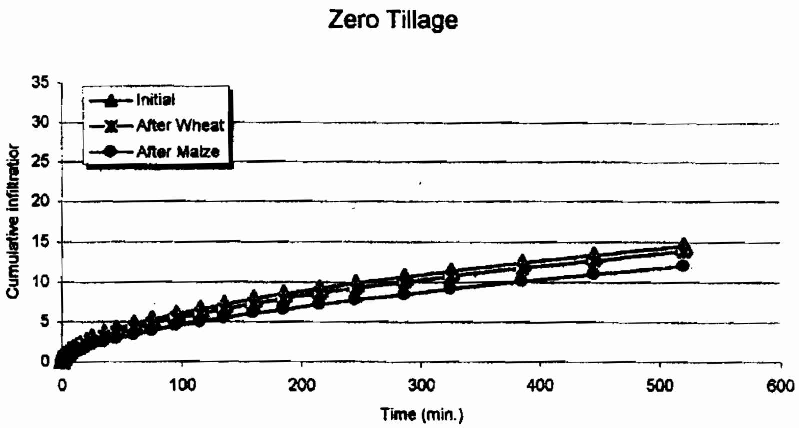
Regarding the water storage porosity (WSP), which is important for soil moister retention (storing available water) and the air porosity (AP), which is important for soil aeration. The data showed an increase in air porosity values with plowing depths in comparison to no-till for all soil layers, while it was decreased with time. Thus the highest air porosity values were observed with plowing to 60 cm depth in deep layers. It increased to 28.10, 23.60 and 27.21% in deep, subsurface and surface layers with increment rate 44.9%, 50.8% and 40.9 %, respectively. In the contrary that the results revealed decrease in water storage porosity values with plowing depths and increases in it's values with time, under the same plowing depth (60 cm) and for all soil layers, (Hussain et al., 1998).

Data in table (4) revealed that the no-till treatments soil had less total drainable pores and macropore volume (quick drainable pores) and had more micropore volume (slow drainable pores), than the tilled soils. Regarding, the total or quick drainable pores, which are very important for improvement soil drainage and soil aeration, the data showed on increase in total drainable pores and quick drainable pores values with plowing depth in comparison to no-till for all soil layers which it was decreased with time. The highest total drainable pores and quick drainable pores values were observed with plowing to 60 cm depth in surface layer. Total drainable pores was increased to 46.72, 42.60 and 34.68% for surface, subsurface and deep layers with plowing to 60 cm depth, which quick drainable pores volume was increased to 31.58, 28.57 and 24.70% for the same soil layers and plowing depth, respectively. In the contrary that the results revealed an decrease in micropore values (slow drainable pores) with plowing depths and increases in its values with time, under the same plowing depth (60 cm) and for all soil layers.

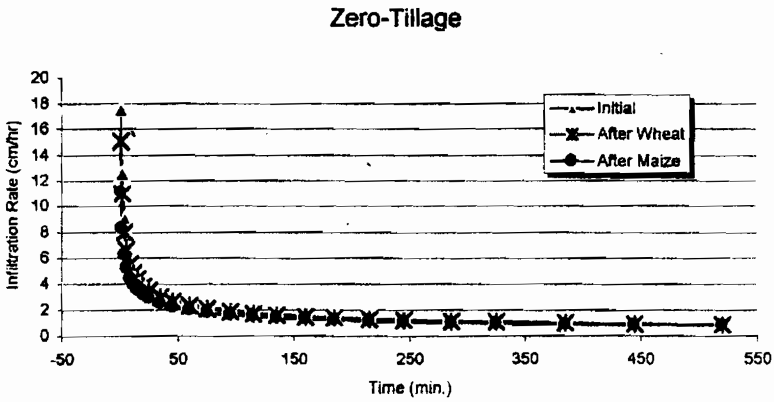
5- Soil infiltration rate:

Effect of plowing depth and residual impact on the measured infiltration rate at the beginning and the end of the growing seasons is illustrated in Figures 2 to 5.

Results of infiltration rate values are presented in Table (5). It is revealed that increasing of plowing depth up to 60 cm has resulted in increasing of the cumulative infiltration rate to the highest value (2.39, 3.08 and 2.06 cm/hr), in the beginning of the season and the end of growing season for wheat and maize, respectively. The lowest value was obtained with no-till (zero tillage), which reached (0.87, 0.87 and 0.80 cm/hr) in the beginning of the season and the end of growing season for wheat and maize, respectively. The increase of infiltration rate values were order: the end of growing season for wheat > the beginning of the season > the end of growing season for maize. This textural makeup has the size components to effectively fill the available void space with solids. Rearrangement of soil particles or filtration of finer particles into soil pores caused the decline in water infiltration, as water moved into the profile. Such surface sealing processes have been described by Gupta etal. (1992). Cropping seems to have increased infiltration rate value because cultivation can increase infiltration rate value by increasing soil surface roughness and breaking surface crusts (Bordovsky et al. 1998). Kladivko 1994 showed that infiltration rate value was also higher under the reduced tillage system. This may have been due, in part, to a higher amount of microaggregates and, in part, to higher numbers of large continuous macropores in the reduced tillage system. Increasing plowing depth increased cumulative and infiltration rate values. The results agreed with reported by Mapa et al., (1986), Lindstrom and Onstad (1984) and Rahman and Islam (1989).

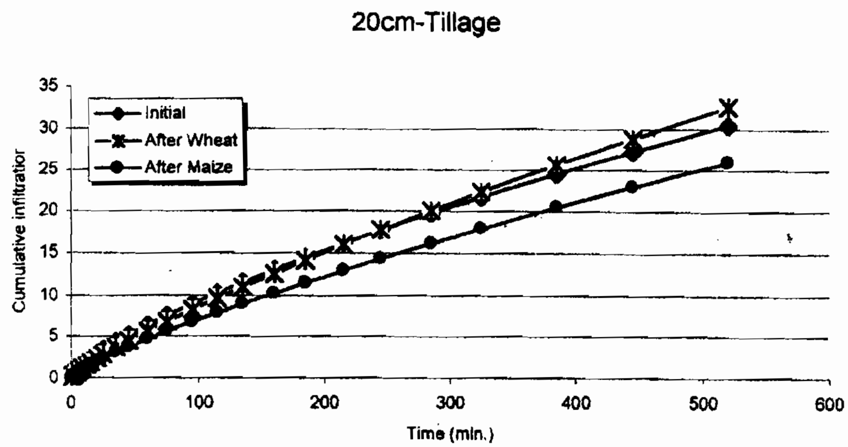


$$Z = 0.5638\ t^{0.5197}\ \text{cm} \qquad \text{(Intial)}$$
$$Z = 0.4618\ t^{0.5438}\ \text{cm} \qquad \text{(After wheat)}$$
$$Z = 0.3193\ t^{0.5799}\ \text{cm} \qquad \text{(After maize)}$$

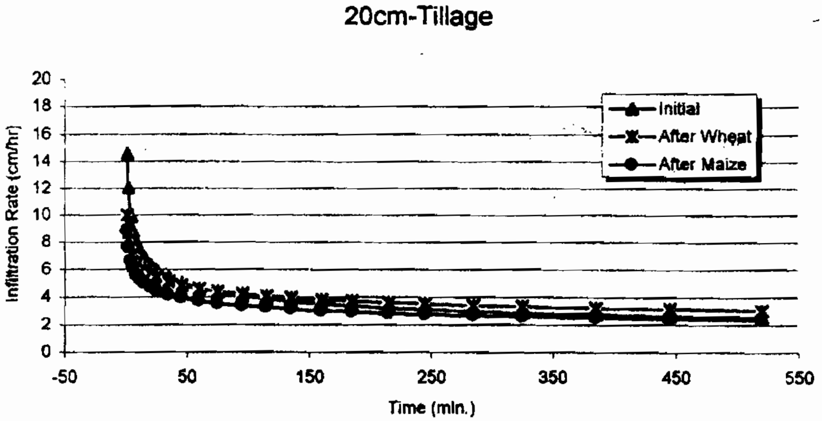


$$I = 17.58\ t^{-0.4803}\ \text{cm/hr} \qquad \text{(Intial)}$$
$$I = 15.072\ t^{-0.4562}\ \text{cm/hr} \qquad \text{(After wheat)}$$
$$I = 11.112\ t^{-0.4201}\ \text{cm/hr} \qquad \text{(After maize)}$$

Fig (2): Effect of zero tillage treatment on cumulative infiltration and infiltration rate (cm/hr) for intial, end of growing wheat and maize seasons.

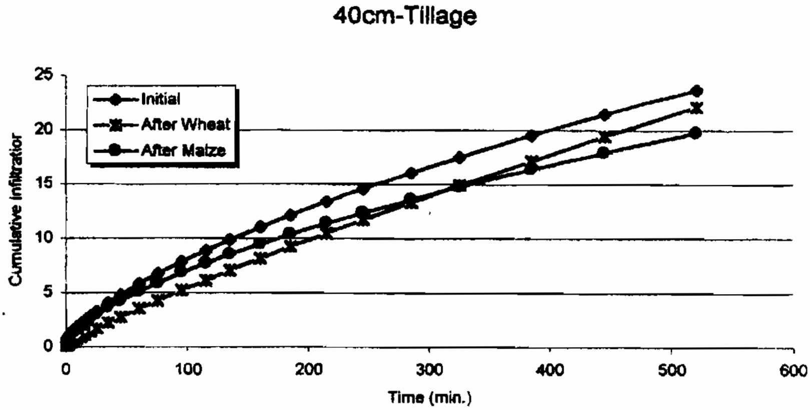


$Z = 0.3377\ t^{0.72}$ cm (Intial)
$Z = 0.2052\ t^{0.811}$ cm (After wheat)
$Z = 0.1861\ t^{0.0.7898}$ cm (After maize)

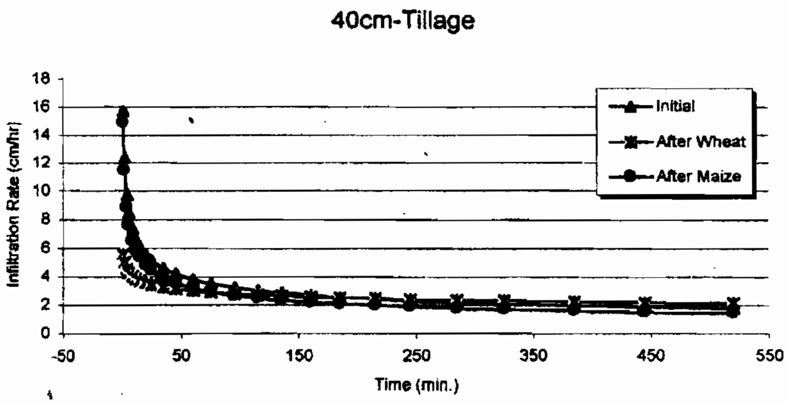


$I = 14.586\ t^{-0.28}$ cm/hr (Intial)
$I = 9.984\ t^{-0.189}$ cm/hr (After wheat)
$I = 8.82\ t^{-0.2102}$ cm/hr (After maize)

Fig (3): Effect of 20 cm plowing depth treatment on cumulative infiltration and infiltration rate (cm/hr) for intial, end of growing wheat and maize seasons.

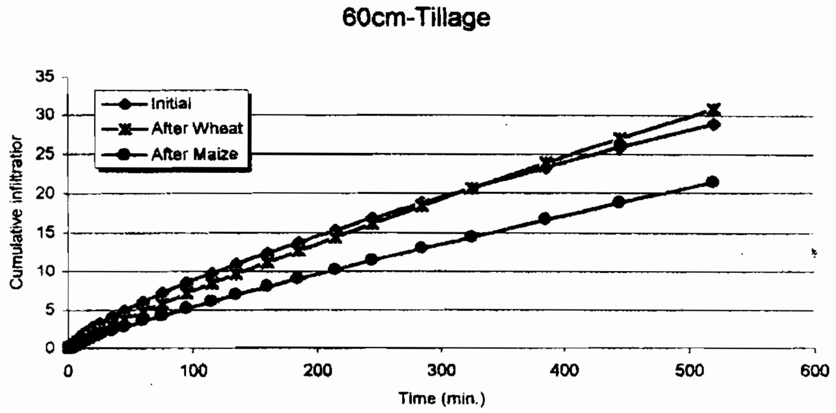


$$Z = 0.4025\ t^{0.6523} \quad cm \quad \text{(Intial)}$$
$$Z = 0.1104\ t^{0.8479} \quad cm \quad \text{(After wheat)}$$
$$Z = 0.3975\ t^{0.6246} \quad cm \quad \text{(After maize)}$$



$$I = 15.756\ t^{-0.3477} \quad cm/hr \quad \text{(Intial)}$$
$$I = 5.616\ t^{-0.1521} \quad cm/hr \quad \text{(After wheat)}$$
$$I = 14.898\ t^{-0.3754} \quad cm/hr \quad \text{(After maize)}$$

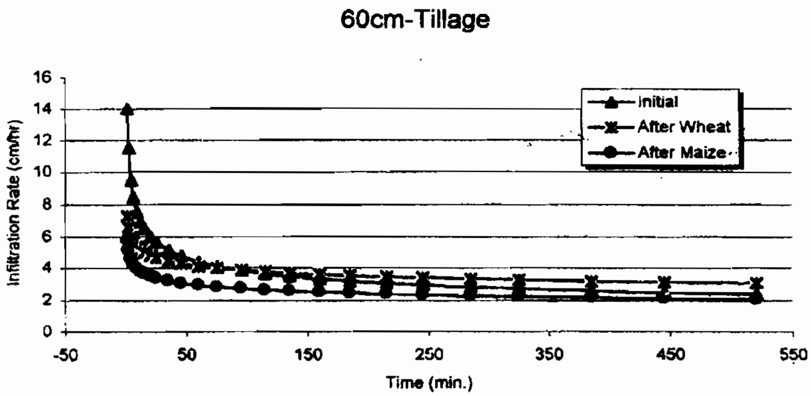
Fig (4): Effect of 40 cm plowing depth treatment on cumulative infiltration and infiltration rate (cm/hr) for intial, end of growing wheat and maize seasons.



$Z = 0.3253\ t^{0.7175}$ cm (Intial)

$Z = 0.1401\ t^{0.863}$ cm (After wheat)

$Z = 0.1156\ t^{0.8352}$ cm (After maize)



$I = 14.004\ t^{-0.2825}$ cm/hr (Intial)

$I = 7.26\ t^{-0.137}$ cm/hr (After wheat)

$I = 5.778\ t^{-0.1648}$ cm/hr (After maize)

Fig (5): Effect of 60 cm plowing depth treatment on cumulative infiltration and infiltration rate (cm/hr) for intial, end of growing wheat and maize seasons.

Table (5): Effect of plowing depth on infiltration rate values.

Plowing depth (cm)	Final infiltration rate cm/hr		
	Begin	End of season	
		Wheat	Maize
0	0.87	0.87	0.80
20	2.53	3.06	2.37
40	2.11	2.33	1.70
60	2.39	3.08	2.06

6- Water Stable Aggregates (WSA):

Data in Table (6) showed that water stable aggregates in the end of wheat and maize seasons had different trends. The fine aggregates < 0.25 mm decreased with the increase of plowing depth in three soil layers under study. This decrease in fine aggregate had a corresponding increase in the coarse aggregate > 0.25 mm. This has resulted in that the structure coefficient (SC) increased with the increase of plowing depth in the three soil layer.

This behavior may be explained according to that the frequent wetting and drying soil under short irrigation interval causes differential expansion and shrinkage which promotes the formation and stabilization of soil aggregates (Sartori et al., 1985). Lal (1991) and Perfect and Blevins (1997) suggested that the optimum moisture content for structure formation is probably close to that of the sticky point where most pores are filled with water and close packing between particles can occur. Baver (1965) mentioned that tillage operations might have varied effects upon soil structure, depending on the nature of the implement, and the moisture content of manipulation. Degradation of soil structure resulting from tillage was believed to be due to excessive manipulation of the soil after plowing.

Table (6): Effect of plowing depth in water stable aggregates and structure coefficient.

Plowing depth (cm)	End of season					
	Wheat			Maize		
	< 0.25 mm	> 0.25 mm	S.C.	< 0.25 mm	> 0.25 mm	S.C.
Surface layer (0-20 cm)						
0	74.80	25.20	0.30	81.88	18.12	0.22
20	76.88	27.32	0.34	78.17	21.83	0.28
40	71.88	28.12	0.39	76.54	23.46	0.31
60	62.38	37.62	0.60	68.20	31.80	0.47
Subsurface layer (20-40 cm)						
0	81.20	18.80	0.23	86.33	13.67	0.16
20	75.58	24.42	0.32	82.70	17.30	0.21
40	63.69	36.31	0.57	71.64	28.36	0.40
60	60.14	39.86	0.66	66.58	33.42	0.50
Deep layer (40-60 cm)						
0	88.07	11.93	0.14	90.38	9.62	0.11
20	81.21	18.79	0.23	87.63	12.37	0.14
40	67.88	32.12	0.47	75.40	24.60	0.33
60	58.80	41.20	0.70	70.69	29.31	0.41

II- Effect of plowing depth on crop yields and crop components:

Data presented in Table (7) reveal that crop production of wheat and maize, expressed as grain yield has significantly increased from 2.71 and 7.90 ton/ha at no-till to 3.80 and 10.59 ton/h at 40 cm plowing depth in wheat and maize, respectively. Statistical analysis showed that insignificant increased between 40 cm and 60 cm plowing depth. Similar results were obtained for the weight of 100 kernels (Table 7) where, 40 cm and 60 cm plowing depth gave the highest value which was 4.88 and 4.96 gm/100 kernels in wheat and 39.84 and 38.20 gm/100 kernels in maize, while that of the no-till was 3.63 and 26.17 gm/100 kernels in wheat and maize. The same trend was nearly indicated with the average of plant height (Table 7), where the greatest value was reached with 40 cm plowing depth, which were 101.30 cm and 162.80 cm in wheat and maize, respectively. While that of the no-till were 81.68 cm and 134.6 cm in wheat and maize. The highest grain yield was obtained with 40cm and 60cm depth, while the lowest was obtained no-till. The increase in grain yield associated with increasing plowing depth from no-till to 20 and 40 cm were 18.08 & 40.22 % and 10.87 & 35.82 %, in wheat and maize, respectively.

Table (7): Effect of plowing depth on wheat and maize yield and its components.

Plowing depth (cm)	Wheat				Maize			
	Grain yield (Ton/h)	Relative yield (%)	Weight of 100 kernels (gm)	Plant height (cm)	Grain Yield (Ton/h)	Relative yield (%)	Weight of 100 kernels (gm)	Plant Height (cm)
0	2.71 c	-	3.63 c	81.68 c	7.90 c	-	26.17 c	1.34 c
20	3.20 b	18.08	4.46 b	93.40 b	8.76 b	10.87	32.54 b	154.35 b
40	3.80 a	40.22	4.88 a	101.30 a	10.59 a	34.05	39.84 a	162.80 a
60	3.72 a	37.27	4.96 a	99.80 a	10.73 a	35.82	38.20 a	158.42 a

III- Effect of plowing depth on spatial and temporal variability of soil bulk density and soil penetration resistance:

All plots were developed in the program, surfer, with kriging performed to smooth the data. The spatial continuity of kriged values for soil bulk density and soil penetration resistance value can be displayed visually with contour maps. Kriged values of soil bulk density and soil penetration resistance to show the spatial distribution and temporal variability. The spatial continuity increases from low to high with increasing plowing depth in different soil layer. Also, The spatial uniform increases with time (end of growing wheat and maize seasons), (Tsegaye and Hill 1998), (Figs 6 and 7).

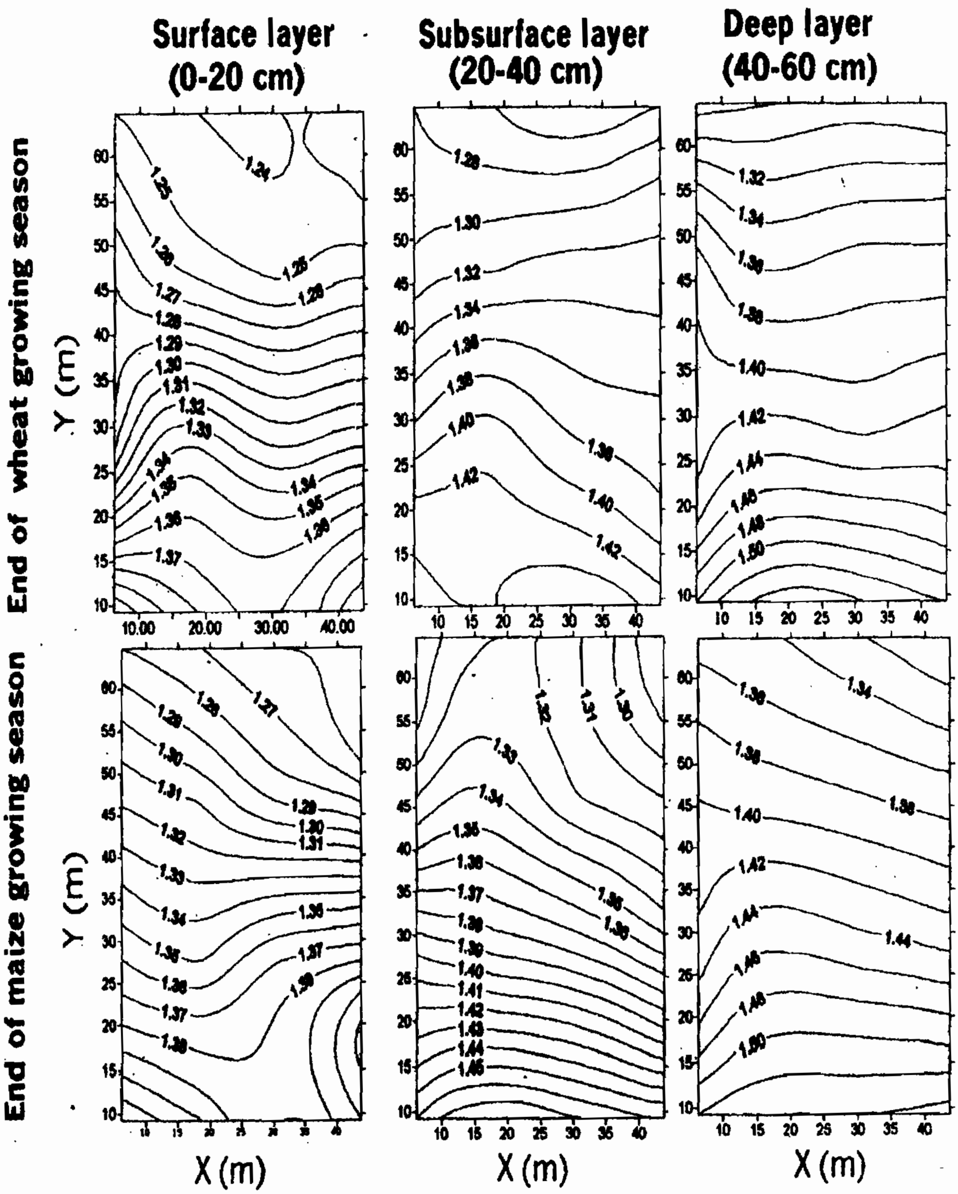


Fig (6): Kriging maps for spatial and temporal variability of soil bulk density at the end of wheat and maize growing seasons

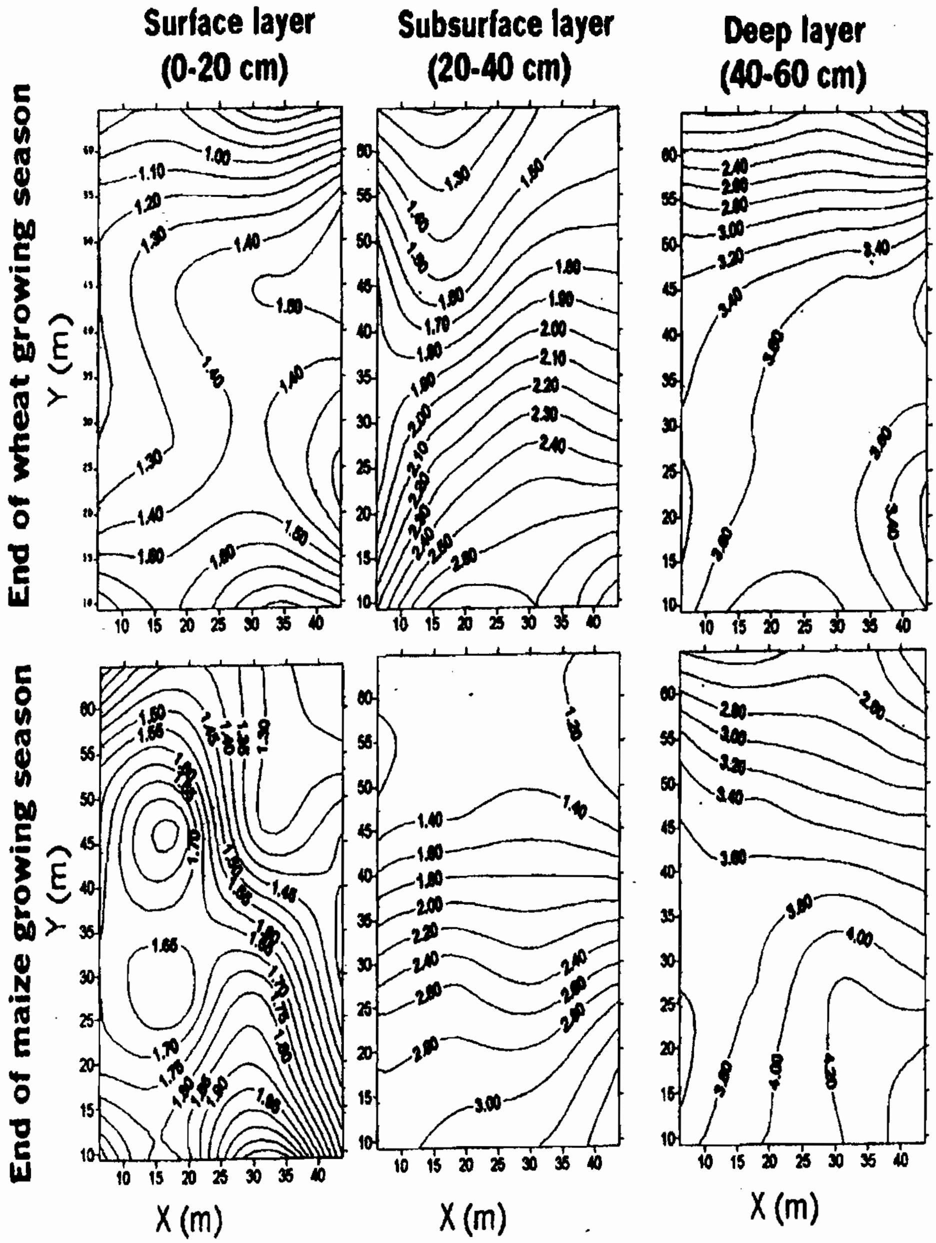


Fig (7): Kriging maps for spatial and temporal variability of penetration resistance values at the end of wheat and maize growing seasons

CONCLUSIONS

From obtained of this study, it can be concluded that:

1- Increasing plowing depth improves the hydro-physical properties for sustainable agriculture and soil quality of the calcareous soils.
2- The 40 cm plowing depth proved to be the most appropriate treatment for wheat and maize production under calcareous soil conditions.
3- The spatial continuity of soil compaction increases from low to high with increasing plowing depth in different soil layer.
4- The spatial uniformity of soil compaction increases with time.
5- The calcareous soils need to be plowed every two growing seasons at least to maximize the return from the unit of soil and water.

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تأثير الخدمة على الاختلافات الفراغية والزمنية للخواص الهيدروفيزيائية وإنتاجية محصولي القمح والذرة تحت ظروف الأراضي الجيرية – النوبارية

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الملخص العربي

نفذت تجربتان حقليتان بالمزرعة البحثية لمحطة البحوث الزراعية بالنوبارية خلال الموسم الشتوي ١٩٩٩/٢٠٠٠ لمحصول القمح والموسم الصيفي ٢٠٠٠ لمحصول الذرة الشامية بهدف دراسة تأثير ثلاثة أعماق للحرث (٢٠ سم ، ٤٠ سم ، ٦٠ سم) مقارنة بعدم الحرث وتم ذلك على محصول القمح والتأثير المتبقي على محصول الذرة الشامية وتم دراسة تنفيذ تأثير ذلك على الخواص الهيدروفيزيائية وإنتاجية محصول القمح والذرة الشامية والتغيرات الفراغية والزمنية على اندماج التربة (الكثافة الظاهرية ومقاومة الاختراق) . وأستخدم التصميم الإحصائي (القطاعات العشوائية الكاملة) في ثلاثة مكررات وتوصلت الدراسة إلى أهم النتائج التالية :-

١- <u>الخواص الهيدروفيزيائية .</u>

أ – انخفاض الكثافة الظاهرية ومقاومة الاختراق معنويا بينما زادت قيم التوصيل الهيدروليكى معنويا مع زيادة أعماق الحرث للطبقات السطحية وتحت السطحية والعميقة .ولوحظ زيادة قيم الكثافة الظاهرية ومقاومة الاختراق معنوياً بينما انخفضت قيم التوصيل الهيدرليكى معنويا مع الزمن كما يلي : نهاية موسم محصول الذرة الشامية > نهاية موسم محصول القمح > بعد الحرث مباشرة .

ب – التوزيع الحجمي للمسام : لوحظ زيادة في قيم المسامية الكلية معنوياً مع زيادة أعماق الحرث وكانت أعلى قيم عند العمق ٦٠سم للطبقة السطحية وتحت السطحية وزادت القيم إلى ٥٣,٥٨ % في الطبقة السطحية والى ٥٣,٢ % ، ٥٢,٨ % في الطبقة تحت السطحية والعميقة بمعدل زيادة يمثل ٥,٩%، ١١,٨٨%، ١٠,٤٣% على الترتيب انخفضت القيم مع الزمن من ٥٣,٥٨ % إلى ٥١,٧٦ % في الطبقة السطحية بمعدل يمثل ٣,٤ % للعمق ٦٠ سم . بينما

انخفضـــت القـــيم إلـــى ٥٠%، ٤٩,٨١ % بمعـــدل انخفاض يصل ٦% ، ٤% لكل من الطبقة السطحية وتحت السطحية .

زادت قيم المسام الهوائية والمسام الصرفية الكلية والمسام السريعة الصرف بينما انخفضت قيم المســـام المملوءة بالماء والمسام بطيئة الصرف مع زيادة أعماق الحرث والزمن وتمثلت أعلى قـــيم المســـام الهـوائـــية عند العمق ٦٠سم وزادت إلى ٢٨,١ % ، ٢٣,٦ % ، ٢٧,٢١ % في الطـبقة العمـــيقة وتحـــت السطحية والسطحية على الترتيب بمعدل زيـــادة يمثل ٤٤,٩ % ، ٥٠,٨ % ، ٤٠,٩ % وزادت قـــيم المســـــام الصـــرفية الكلية إلى ٤٦,٧٢ %، ٤٢,٦ % ، ٣٤,٦٨ % للطـــبقة الســـطحية وتحـــت السطحية والعميقة بزيادة أعماق الحرث بينما المسام سريعة الصرف زادت إلى ٣١,٥٨ % ، ٢٨,٥٧ %، ٢٤,٧ % لنفس الطبقات وأعماق الحرث.

جـــ - لوحظ زيادة معدل التسرب بزيادة أعماق الحرث وكانت أعلى القيم هي ٢,٣٩ ، ٣,٠٨ ، ٢,٠٦ ســـم/ســـاعة بعد الحرث مباشرة وفي نهاية موسم محصول القمح والذرة الشامية على الترتيب.

د- زيـــادة تكوين الحبيبات الثابتة مائيا ومعامل البناء بزيادة اعماق الحرث وكانت اعلى قيم لمعـــامل البناء عند عمق حرث ٦٠ سم وهي (٠,٦ ، ٠,٦٦ ، ٠,٧) في نهاية موسم محصول القمح بينما انخفضت في نهاية موسم محصول الذرة الشامية الى (٠,٤٧ ، ٠,٥ ، ٠,٤١) .

٢- <u>إنتاجية محصول القمح والذرة الشامية :</u>

لوحـــظ اتجاه معنوي لزيادة إنتاجية الحبوب لكـــــل من القمح والذرة الشامية من ٢,٧١ ، ٧,٩ طـــن/ هكتار إلى ٣,٨ ، ١٠,٥٩ طن/ هكتار حتى عمق ٤٠سم بزيادة تمثل ٤٠,٢٢ % ، ٣٥,٨٢ % على الترتيب .ولم يلاحظ أي فرق معنوي بين عمقي ٤٠سم ، ٦٠سم حرث .

٣- <u>التوزيع الفراغي والزمني لاندماج التربة (الكثافة الظاهرية ومقاومة الاختراق):</u>

أوضحت خرائط Krging والتي تم تحليلها باستخدام برنامج Surfer أن التوزيع الفراغي والزمنـــي لاندمـــاج الـــتربة (قـــيم الكثافة الظاهرية ومقاومة الاختراق) وذلك في نهاية موسم محصـــولي القمح والذرة الشامية إن اندماج التربة يقل مع زيادة أعماق الحرث ولكنة يزداد مع الزمن .