

Soil Carbon Dioxide Flux Following Tillage Systems in Arid and Semi-arid Agro-ecosystems

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Abstract:

A field experiment was conducted at the experimental farm, Faculty of Agriculture, Al-Azhar University, Assuit, Egypt which is located at 27° 12' 16.67" N latitude and 31° 09' 36.86" E longitude for two successive sunflower growing seasons of 2011 and 2012. This study aims to assess the effect of soil management practices (conventional, reduced and no tillage) at different soil moisture content (65 and 85 % of field capacity, F.C.) with two fertilizer types (urea and urea-form) on soil carbon dioxide flux in order to mitigate its effect on global climate changes as well as sunflower growth.

The results indicated that the emitted soil CO₂ ranged from 12.49 to 22.65, 14.49 to 25.06 and 14.14 to 25.95 g/ 100 m² for no tillage (NT), reduced tillage (RT) and conventional tillage (CT), respectively at 65 % of F.C., with using urea fertilizer. The lowest emitted CO₂ values were observed in the second week while the highest ones were noticed in the 5th week for NT treatment and in the 7th week for RT or CT treatment. The trend line of CO₂ emission was less inclined under NT than under RT or CT tillage. The trend line of the emitted soil CO₂ under RT and CT treatments subsequently became approximately equal.

The young growing plants at 85% of F.C. using urea fertilizer showed more CO₂ uptake than it at 65% of F.C. using ureaform fertilizer. The no tillage treatment (NT) had higher CO₂ flux than RT treatment at the beginning of the evaluation period (till 4th week) and lower flux at the end. The trend line of emitted soil CO₂ from CT treatment showed almost a steady flux through the growing season (10 week), and the CO₂ flux values ranged between 17.71 and 25.40 g/ 100 m².

Sunflower grain yield was significantly affected by soil moisture content and fertilizer type as well as it was highly significantly affected by tillage manner. Sunflower grain yield was higher in the plots treated with ureaform at 65 % of F.C. than in those treated with urea at 85 % of F.C. It was superior under the conventional tillage followed by the reduced tillage then no tillage. On the average basis, sunflower grain yield was 1.97, 2.01 and 2.22 ton/ fed for NT, RT and CT, respectively at 65% of F.C. However, it was 1.05, 1.76 and 2.22 ton/ fed for the respective treatments at 85 % of F.C.

Keywords: Carbon dioxide flux, Tillage system, Soil moisture content, Nitrogen fertilizers, Sunflower crop.

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Introduction:

Tillage operations strongly control the soil environment by altering the soil geometry. Soil tillage management can affect factors controlling soil respiration, including substrate availability, soil temperature, water content, pH, oxidation-reduction potential, kind and number of microorganisms, and the soil ecology (Acquaah, 2002).

Alvarez and Alvarez (2000) found that active microbial biomass and carbon mineralization were higher under no tillage (NT) than under conventional tillage in the top 5 cm of the soil profile. A widespread adoption of conservation tillage could result in net increases in carbon sequestration in agricultural lands, reversing its decline caused by intensive tillage practices used for decades (Campbell *et al.* 2001). Carbon sequestration rates can be expected to peak in 5 to 10 years with increasing soil organic carbon (SOC) reaching a new equilibrium in 15 to 20 years. Increased carbon storage has been frequently observed in soils under conservation tillage, particularly with no till (Zibilske *et al.*, 2002). Yang *et al.* (2003) indicated that the conversion from conventional tillage to conservation tillage at an annual rate of 2%, particularly no till, could reverse the loss of SOC in Chinese Mollisols within 20 years. Soil plowing is a principal cause of CO₂ emission from croplands leading to a depletion of soil organic matter content (Lal, 2004). Valzano *et al.* (2005) stated that, in most instances, increased tillage levels or increased tillage periods resulted in reductions in soil carbon. There are confounding factors, however, that moderate the extent to which low or no tillage and stubble retention improve soil carbon levels.

La Scala *et al.* (2006) reported that conventional tillage caused the highest CO₂ emission during almost the whole study period of 4 weeks. Tillage also stimulates soil organic matter decomposition, releases more CO₂ into the atmosphere, and contributes to global warming (Baker *et al.*, 2007). Chatskikh and Olesen (2007) observed a reduction in carbon dioxide emissions with a reduction in tillage. Carbon dioxide emissions following conventional tillage of 40 kg C/day were 25 % higher than carbon dioxide emissions measured for the direct drill treatment. Usually, short-term CO₂-C flux after tillage is higher in the conventional tillage plots or in some cases similar to the ones registered in the no-tillage plots (Costa *et al.*, 2008). Recent estimation showed that conversion of cropland practice from conventional tillage to no-tillage will potentially sequester 4.60 Tg C/yr (Lu *et al.*, 2009). The conversion from conventional till to no till restored some of the depleted SOC and N pools in a long-term tillage experiments in different soils of Ohio, USA (Mishra *et al.*, 2010). Mousadek *et al.* (2011) found that immediately after fall tillage, the conventional tillage showed the highest CO₂ flux of 4.9 g m²/h; reduced tillage exhibited an intermediate value of 2.1 g m²/h whereas the lowest flux of 0.7 g m²/h was reported under no tillage. The aim of the current study is to assess the effect of soil management practices (conventional, reduced and no tillage) at different soil moisture content (65 and 85 %) with two fertilizer types (urea and ureaform) on soil carbon dioxide flux in order to mitigate its effect on global climate changes. The study also tends to obtain the most cropping productivity that can sequester CO₂ in soil and re-

duce its emissions by trying different management practices to assess the optimum ones.

Materials and Methods:

The experiment was conducted at the experimental farm, Faculty of Agriculture, Al-Azhar University, Assiut, Egypt (27° 12- 16.67= N latitude and 31° 09- 36.86= E longitude).

The site is characterized by a flat relief and is dominated by well drained Torrifluvents (Soil Survey Staff, 1996) that are clay loam in texture, slightly alkaline and have low organic matter but adequate potassium level in the top layers of 60 cm soil depth (Table 1).

Table 1: Some chemical (a) and physical (b) properties of soil at the experimental site.

a- Chemical properties

Depth (cm)	O.M. (%)	CaCO ₃ (%)	pH	EC _e (dS/m)	Soluble ions (meq/L) in the soil paste							Available nutrients (ppm)		
					CO ₃ ⁻² , HCO ₃ ⁻¹	Cl ⁻¹	SO ₄ ⁻²	Ca ⁺²	Mg ⁺²	Na ⁺¹	K ⁺¹	N	P	K
0-25	2.13	3.41	7.66	0.95	2.25	1.20	6.0	2.50	1.30	5.24	0.13	70.0	9.63	367
25-50	2.01	3.11	7.75	1.09	2.04	1.10	6.89	2.80	1.48	5.57	0.20	56.5	9.55	343

O.M. = organic matter EC_e = electrical conductivity of soil past extract

b- Physical properties

Depth (cm)	Particle-sized distribution %			Texture class	Moisture content %		A.W. (%)
	Sand	Silt	Clay		F.C.	W.P.	
0-25	26.50	40.00	33.50	Clay Loam	41.0	20.3	20.7
25-50	25.11	39.14	35.75	Clay Loam	40.8	20.0	20.8

F.C. = field capacity W.P. = wilting point A.W. = available water

The study included two levels of soil moisture content, with three tillage manner and two nitrogen fertilizers at the recommended level. The experiment was laid out in split split plots design with 12 treatments and three replications. The main plots were assigned for irrigation regimes (65 and 85% of F.C.) and they were bounded with a buffer zone of 3 m width to avoid the horizontal seepage of irrigation water. The split plots were assigned for three tillage manner as follows: a) No tillage (NT) where flat discs were used to create an opening in the soil which is followed by a tine to deliver the seed

and fertilizer into the slot and a press wheel to close the slot, b) Reduced tillage (RT), where the residues of the previous crop were left on the soil surface, as mulch, and a minimum vertical tillage (chiseling, 15 cm depth) and disc harrowing (5 cm depth) were carried out immediately before sowing and c) Conventional tillage (CT), after burning the residues of the preceding crop, the soil was ploughed to a 30 cm depth by chisel plough (consisted of 7 rigid shanks of 18 cm width and spaced 28 cm apart). The split split plots were assigned for two nitrogen fertilizers at the recommended level (Urea 46.5%

N as a fast nitrogen fertilizer and ureaform 40% N as a slow nitrogen fertilizer). In addition to the previous treatments, a control uncultivated soil treatment was used as a base line for emitted carbon dioxide and to assess the changes in the ecosystem. The plot area was almost 100 m² (10 x 10 m², 1/40 fed.) and the previous crop was alfalfa.

In the summer season of 2011 and 2012, sunflower seeds (cultivar *sakha 130*) were planted in the 14th of June of both years in hills 20 cm apart from each other and 60 cm distance between rows. All cultural management practices for growing sunflower were conducted in the same way as they were carried out in the neighboring fields following the recommendation of the Egyptian Ministry of Agriculture. Phosphorus fertilizer in the form of superphosphate (15.5% P₂O₅) was broadcasted during soil preparation processes at a level of 100 kg superphosphate / fed. Ureaform slow release nitrogen fertilizer (75 kg N/ fed) was added to the soil before sowing. While urea fertilizer was added to plants in three doses: the 1st dose (22kg N/fed) was after 15 days, the 2nd one (22kg N/fed) was after 60 days and the 3rd one (22kg N/fed) after 75 days from planting. Potassium was added as K₂SO₄ in two doses, the 1st dose (25kg K₂O/fed) was after 15 days and the 2nd one (25kg K₂O/fed) was after 75 days from plantation. In both seasons, the sunflower plants were harvested after 93 days from planting. Plant samples of sunflower were collected for growth and yield measurements from square meters of each plot.

Classical chamber method was used for CO₂ measurement by trapping it in alkali solution, which al-

lows CO₂ fluxes from the soil to be measured directly (Davidson *et al.*, 2002). Each measurement chamber (38 cm in length x 23 cm in width x 22 cm in height) covered a soil surface of 0.0874 m² and had transparent PVC walls. To prevent CO₂ leakage to atmosphere, the chamber was inserted 5 cm deep into the soil. The soil surface CO₂ flux (Fs) measurements were taken in the daytime between 9 and 11 o'clock every week using a glass jar filled with 100 ml of 1 N sodium hydroxide. The jars were removed from the chambers, quickly capped, and sent to the laboratory for analysis according to Stevenson (1986). Carbon evolved as CO₂ was estimated by the formula outlined by Stotzky (1965). At the same times and locations when CO₂ emission was measured, soil samples were collected from surface layer (0–15 cm) to determine soil water content.

Soil samples before and after each growing season were taken at depths of 0-25 and 25-50 cm using a spiral auger. In the laboratory, the samples were air dried, ground and sieved (particle size < 2mm) and prepared for physical and chemical analysis according to Klute (1986) and Page *et al.* (1982). Also, undisturbed soil samples were taken using the core method technique.

Sunflower plants were sampled at harvesting time and ten guarded sunflower plants were chosen randomly from each treatment to estimate plant height (cm), head diameter (cm), seed index (g) and grain yield (ton/ fed). The seed oil content of sunflower plants was determined as outlined by Bedov (1985). The collected data were subjected to a statistical analysis using the MSTAT micro computer program.

Results and Discussion:

The emission of carbon dioxide from soils depends on many factors such as tillage, fertilization, soil moisture regime, soil temperature and land use type. It is important to improve our understanding of soil processes in order to gain more confidence in projections about future changes in the global atmospheric CO₂ concentration.

Figure (1) shows the effect of tillage manner on soil CO₂ flux after week from planting and the 10 subsequent weeks through the summer sunflower growing season of 2011 and 2012 (average values) at 65% of the field capacity (F.C.) when the soil was fertilized by urea. Diurnal CO₂ patterns were evident in all weeks during the growing season as the emitted soil CO₂ increased with the

time for all tillage manners. During this period (10 weeks) the emitted soil CO₂ ranged from 12.49 to 22.65, 14.49 to 25.06 and 14.14 to 25.95 g/100 m² for no tillage (NT), reduced tillage (RT) and conventional tillage (CT), respectively. The lowest CO₂ flux values were observed in the second week while the highest ones were noticed in the 5th week for NT treatment and in the 7th week for RT or CT treatments. The trend line was less inclined under NT than under RT or CT tillage. The trend line of the emitted soil CO₂ under RT and CT treatments subsequently became approximately equal. This might be related first to the temperature dependence of soil respiration, and then later related to the light dependence of photosynthesis (Rolston *et al.*, 2010).

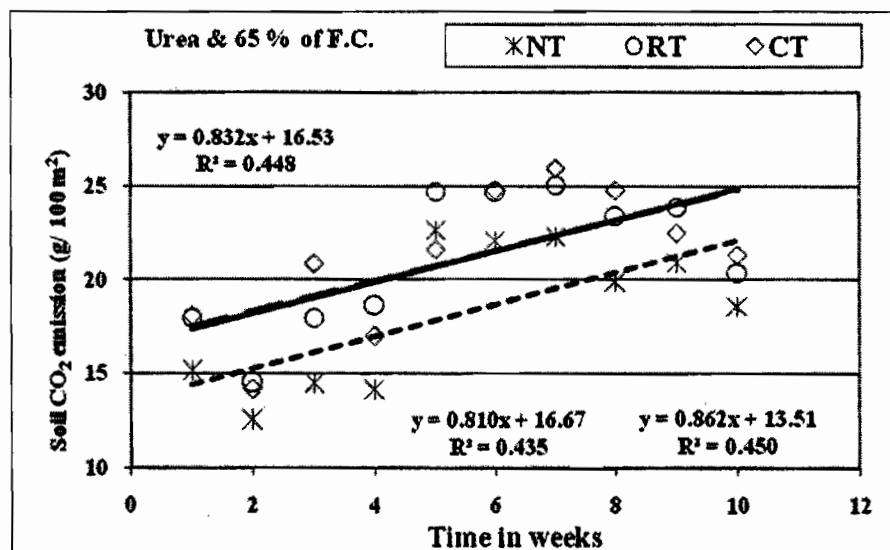


Fig. (1). Soil carbon dioxide emission (average values) in relation to time and tillage manner when soil was fertilized by urea at 65% of F.C. for sunflower.

A slight difference persisted in the emitted soil CO₂ as a result of tillage manner at 85 % of F.C. when the soil was fertilized by urea (Fig. 2). The trend lines of tillage manner are much closer and they increased as the time proceed. In the 2nd week of

both years following the planting of sunflower years, strong diurnal photosynthetic patterns (negative net ecosystem exchange) were observed by the young growing plants with 85% of F.C. showing more CO₂ uptake than with 65% of F.C. In gen-

eral, the trend lines of emitted soil CO₂ were confined between 15 and 25 g/ 100 m² for 65 % of F.C. and between 15 and 27 g/ 100 m² for 85 % of F.C. Buchner *et al.* (2008) pointed out that surface CO₂ fluxes showed a significant dependence on soil hydraulic properties.

Figure (3) shows the effect of tillage manner on soil CO₂ flux through the summer sunflower growing season of 2011 and 2012 (average values) at 65% of F.C. when the soil was fertilized by ureaform. In general, the results indicated that the emitted soil CO₂ from NT treatment was less than from RT or CT. The no tillage treatment (NT) had higher CO₂ flux than RT treatment at the beginning of the evaluation period (till 4th week), but a lower flux at the end. The trend line of emitted soil CO₂ from CT treatment shows almost a steady flux through the growing season (10 weeks) and CO₂ flux values between 17.71 and 25.40 g/ 100 m².

Futhermore, almost similar results were recognized when the soil was irrigated at 85 % of F.C. (Fig. 4).

The weekly soil CO₂ flux recorded in the NT plots ranged from 13.59 to 24.37 g/ 100 m², while it varied from 13.11 to 26.09 g/ 100 m² in the RT or CT ones. Generally, CT treatment showed the highest amount of emitted soil CO₂ during the entire growing season.

A number of possible mechanisms were reported to be involved in tillage-induced reductions in soil carbon. These mechanisms include:

- The physical disruption of soil carbon may result in a higher rate of microbial breakdown. Such a decline was due to increases in the decomposition rate by the shattering of macro-aggregates, mixing of surface soil and increases in the intensity and number of wetting and drying cycles. The repeated cultivation of soils combined with limited carbon inputs eventually results in major aggregate breakdown leaving the soil vulnerable to erosion and compaction (Anderson, 2009). Also, the movement and incorporation of soil carbon deeper into a profile, moisture conditions facilitate microbial breakdown.

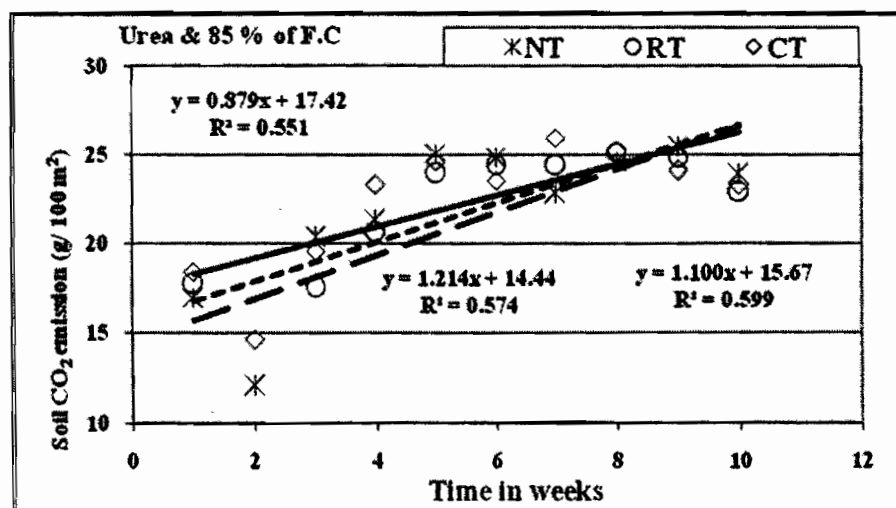


Fig. (2). Soil carbon dioxide emission (average values) in relation to time and tillage manner when soil was fertilized by urea at 85% of F.C. for sunflower.

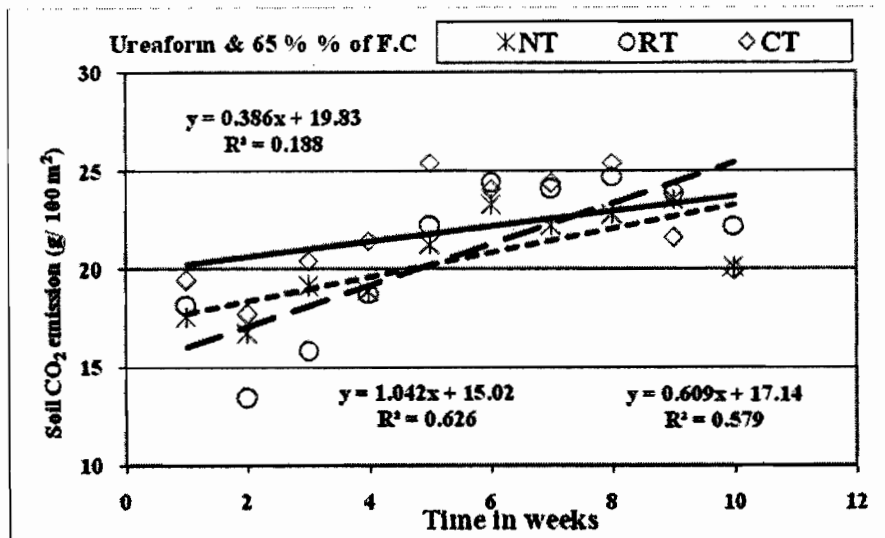


Fig. (3). Soil carbon dioxide emission (average values) in relation to time and tillage manner when soil was fertilized by ureaform at 65% of F.C. for sunflower.

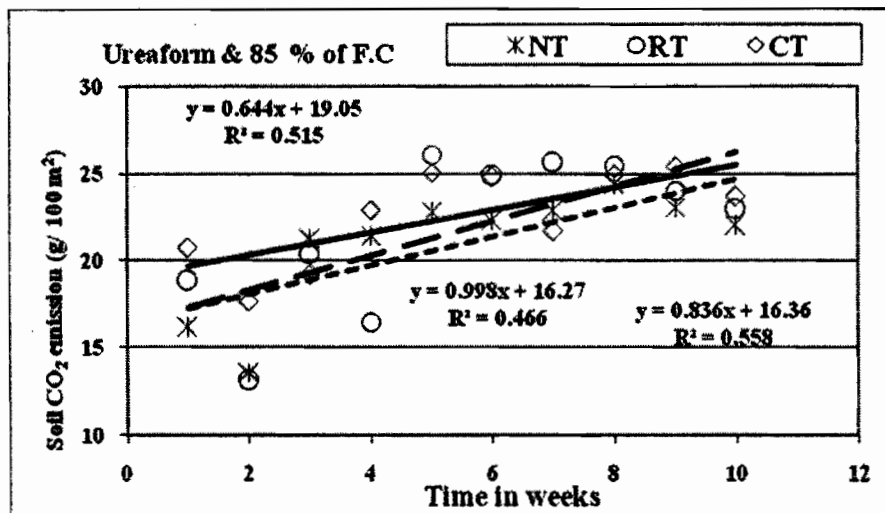


Fig. (4). Soil carbon dioxide emission (average values) in relation to time and tillage manner when soil was fertilized by ureaform at 85% of F.C. for sunflower.

Each tillage system should adapt to the local characteristics of soil, climate and crop. These variables determine the management required in each specific situation. Conservation tillage usually has positive re-percussions on soil quality and crop yield mainly due to the improvements achieved in soil water storage, especially in regions where this parameter is often limiting under conditions of drought (Murillo *et al.*, 2001). West and Marland (2002) found that compared to conventional tillage systems, a no-tillage system

was found to sequester 337 ± 108 kg C/ha/yr more C to a sampling depth of 30 cm. In contrast, the difference between the ability of reduced tillage and no tillage systems to sequester carbon was insignificant.

Tillage also could disrupt soil aggregate and transfer labile or fresh organic matter once protected by aggregates to unprotected readily decomposable organic matter, thus exposing them to microbial attack (De Gryze *et al.*, 2006; Grandy and Robertson, 2007 ; La Scala *et al.*, 2008). Chavez *et al.* (2009) revealed

that at a low soil temperature and soil water content conditions, soil tillage caused a limited increase in soil CO₂-C flux. The lower soil CO₂ efflux (SCE) before the tillage might be due to slower decomposition of crop residues placed on the soil surface than when they were incorporated into mineral soils after the tillage (Curtin *et al.*, 2000).

The tillage-induced increase in SCE might partially be attributed to the increases in temperature and moisture sensitivity of SCE. The SCE significantly increased after the tillage, especially immediately after irrigation. The mean SCE increased from $2.56 \pm 0.66 \mu\text{mol}/\text{m}^2/\text{sec}$ before the tillage to $6.73 \pm 3.61 \mu\text{mol}/\text{m}^2/\text{sec}$ after the tillage, with an increment of 2.6 times. By comparing SCE measured before and after the tillage in the same ranges of soil temperature and moisture, the CO₂ efflux increased by 1.2 to 2.2 times.

Also, tillage could change soil physical factors, such as soil temperature, soil moisture, O₂ concentration, the contact of soil microbes with substrate, and substrate distribution. The reason may be that the tillage-loosed soil was favorable to heat exchange and irrigation water infiltration (Zhang *et al.*, 2011).

Activities used to sequester carbon in cropland soils have the potential to alter land use and land cover indirectly through their effect on crop yields. In general, the results obtained in this investigation show that sunflower grain yield was significantly affected by soil moisture content and fertilizer type as well as it was highly significantly affected by tillage manner (Table 2). In both seasons sunflower grain yield was superior under the conventional tillage followed by the reduced tillage and then the no

tillage. Under the CT tillage, sunflower showed highest plant height head diameter, grain yield and seed index, either when irrigated at 65% F.C. or 85% F.C. Mean sunflower grain yield was 1.97, 2.01 and 2.22 ton/ fed for NT, RT and CT, respectively at 65% of F.C. It was 1.05, 1.76 and 2.22 ton/ fed for the respective treatments at 85 % of F.C. The yield component of sunflower (head diameter, plant height, seed index and seed oil) followed the same trend of sunflower yield.

The ureaform fertilizer at the used recommended rate gave significantly higher grain yield and seed index than those obtained with the urea fertilizer in both seasons. Also, the application of irrigation regime of 65% F.C. was superior for sunflower growth and yield in both seasons than of 85% F.C. regime. This means that frequent irrigation of sunflower plants (at 85% F.C.), even though at the high temperature in summer season, may suppress vegetative plant growth and could result in reduction in grain yield and seed index, especially under the NT treatment. The interaction of soil moisture content (irrigation at different % F.C.) and tillage manner, showed significant (year 2011) and highly significant (year 2012) effects on sunflower yield and yield components (table 2).

It is thus evident that tillage practices have major effects on soil properties and amount of emitted CO₂ from soil. The adoption of conservation tillage for reversing the decline of SOC in agricultural lands is possible in the clay soil of Egypt, as it has been in many other countries. But, cultivation and crop type, high temperature during summer season and a semiarid climate accelerate organic carbon loss and weaken soil structure.

Also, tillage and residue incorporation enhance C mineralization and atmospheric fluxes, suggesting that tillage intensity should be decreased to reduce C loss. Continuous monitoring of long-term changes in the soil organic carbon and soil quality under conservation tillage in different agro-ecological zones is essential. There is also a need to obtain more

data on long-term effects of different tillage systems on carbon and nitrogen mineralization and immobilization in field situations. It is worthy to mention that tillage is still a farming practice widely used in Egypt and overlaps with hot and dry summer. From this point of view, the conventional tillage practice should be re-evaluated.

Table 2. Effect of tillage manner, fertilizer type and irrigation at different moisture content of field capacity on sunflower yield and its component.

summer 2011									
parameter	fertilizer type	65% of F.C.				85% of F.C.			
		NT	RT	CT	mean	NT	RT	CT	mean
Grain yield(ton/fe d)	U	1.96	1.85	2.13	1.98	1.33	1.74	2.13	1.73
	UF	2.03	2.11	2.23	2.12	1.39	1.83	2.16	1.79
	mean	2.00	1.98	2.18	2.05	1.36	1.79	2.14	1.76
	LSD	A*=0.142	B*=0.10	C**=0.01	AC*=0.31				
Head diamter (cm)	U	21.80	22.17	23.07	22.34	17.67	20.40	22.67	20.24
	UF	21.53	23.00	24.47	23.00	17.20	21.60	23.10	20.63
	mean	21.67	22.58	23.77	22.67	17.43	21.00	22.88	20.44
	LSD	A*=2.07	C**=0.43	AC*=1.75					
Plant height(cm)	U	179.7	197.0	212.7	196.44	166.7	199.0	231.0	198.89
	UF	202.7	222.3	224.3	216.44	171.0	235.0	222.0	209.33
	mean	191.2	209.7	218.5	206.44	168.8	217.0	226.5	204.11
	LSD	B**=6.99	C**=8.13	BC**=11.5	AC**=11.5				
Seed index(g)	U	6.45	6.13	7.05	6.54	5.71	6.44	7.06	6.40
	UF	6.74	6.80	8.08	7.20	5.67	6.55	7.95	6.72
	mean	6.59	6.47	7.56	6.87	5.69	6.50	7.50	6.56
	LSD	B**=1.29	C**=0.30	AC**=0.46	BC*=0.46				
Seed oil %	U	45.84	37.10	42.15	41.70	38.05	39.28	42.44	39.93
	UF	46.29	40.38	47.37	44.68	41.95	39.60	43.03	41.53
	mean	46.07	38.74	44.76	43.19	40.00	39.44	42.74	40.73
	LSD	A*=2.01	C**=2.68						
summer 2012									
Grain yield(ton/fe d)	U	1.77	1.83	2.42	2.01	0.74	1.67	2.40	1.60
	UF	2.11	2.23	2.09	2.14	0.76	1.81	2.19	1.59
	mean	1.94	2.03	2.26	2.08	0.75	1.74	2.30	1.59
	LSD	A*=0.31	C**=0.05	AC**0.26	BC*26				
Head diamter (cm)	U	21.00	22.00	23.67	22.22	16.00	19.67	24.67	20.11
	UF	21.00	22.33	23.67	22.33	15.67	21.00	23.33	20.00
	mean	21.00	22.17	23.67	22.28	15.83	20.33	24.00	20.06
	LSD	A*=1.04	C**=1.00	AC**=1.42					
Plant height(cm)	U	165.0	198.7	213.7	192.44	153.3	186.0	238.3	192.56
	UF	195.7	206.7	203.3	201.89	163.7	221.7	223.3	202.89
	mean	180.3	202.7	208.5	197.17	158.5	203.8	230.8	197.72
	LSD	B*=5.76	C**=4.53	AC**=6.41	BC**=6.41	ABC**=9.06			
Seed index(g)	U	8.41	6.74	8.22	7.79	4.85	6.44	7.59	6.30
	UF	6.78	6.19	7.04	6.67	4.69	7.57	6.69	6.32
	mean	7.59	6.47	7.63	7.23	4.77	7.01	7.14	6.31
	LSD	A**=0.39	B**=0.27	AB**=0.38	B**=0.21	C**=0.29	AC**=0.29	ABC**=0.41	
Seed oil %	U	44.84	37.52	42.95	41.77	38.97	40.103	42.503	40.53
	UF	46.79	40.15	48.04	44.99	41.91	41.70	42.26	41.96
	mean	45.81	38.83	45.50	43.38	40.44	40.90	42.38	41.24
	LSD	A*=5.96	C**=2.87	AC*=4.06					
		A= Irrigation at F.C.			B= Fertilizer type			C= Tillage manner	

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انبعاث ثاني أكسيد كربون التربة نتيجة أساليب الحرث في نظم البيئة الزراعية

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أجريت تجربة حقلية بمزرعة كلية الزراعة جامعة الأزهر أسيوط- مصر (خط عرض $27^{\circ} 12' 16.67''$ شمالاً وخط طول $36.86^{\circ} 09' 31''$ جنوباً) خلال موسمين متتاليين لمحصول عباد الشمس (٢٠١١، ٢٠١٢) بهدف تقييم تأثير أساليب الحرث (حرث عادي و شبه حرث وبدون حرث) والمحتوي الرطوبي (٦٥%، ٨٥% من السعة الحقلية) ونوع السماد (اليوريا، اليوريا فورم) علي انبعاث ثاني أكسيد كربون التربة وكذلك علي النمو والمحصول لعباد الشمس بهدف تقليل أثره علي التغيرات المناخية.

أوضحت النتائج ان كمية ثاني أكسيد الكربون المنبعث من التربة تراوحت ما بين ١٢,٤٩ الي ٢٢,٦٥ ، ١٤,٤٩ الي ٢٥,٠٦ ، ١٤,١٤ الي ٢٥,٩٥ جم/م^٢ مع معاملات بدون حرث و شبه الحرث والحرث علي التوالي عند محتوى رطوبي ٦٥% من السعة الحقلية والتسميد باليوريا. وقد تم تسجيل أقل قيم لثاني أكسيد الكربون المنبعث في الأسبوع الثاني بينما كانت أعلى القيم في الأسبوع الخامس للمعاملة بدون حرث وفي الأسبوع السابع مع معاملات الحرث الأخرى. وكان اتجاه خط الانبعاث أقل انحداراً مع معاملة بدون حرث عنه في باقي معاملات الحرث ثم كان اتجاه خط الانبعاث تقريبا متساوي لمعاملات الحرث العادي وشبه الحرث. وكما أظهرت النباتات حديثة النمو عند محتوى رطوبي ٨٥% من السعة الحقلية مع سماد اليوريا تثبتت أكثر لثاني أكسيد الكربون عنه عند محتوى رطوبي ٦٥% من السعة الحقلية. وقد كان انبعاث ثاني أكسيد الكربون أعلى في المعاملة بدون حرث عنها في معاملة شبه الحرث وذلك في بداية فترة التقييم (٤ أسابيع) ثم انخفض عند نهاية الموسم وذلك مع استخدام سماد اليوريا فورم. وكان اتجاه خط انبعاث ثاني أكسيد كربون للتربة المعاملة بالحرث العادي تقريبا ثابت خلال موسم النمو (١٠ أسابيع) حيث تراوحت قيم الانبعاث بين ١٧,٧١ الي ٢٥,٤٠ جم/م^٢.

تأثر محصول حبوب عباد الشمس معنوياً بالمحتوي الرطوبي للتربة ونوع السماد وكان تأثيره معنوياً جداً بأسلوب الحرث. وكان محصول حبوب عباد الشمس أعلى في الأحواض المعاملة باليوريا فورم عند محتوى الرطوبي ٦٥% من السعة الحقلية عنه في الأحواض المعاملة باليوريا عند محتوى رطوبي ٨٥% من السعة الحقلية. كما كان محصول الحبوب الأكبر تحت معاملة الحرث يليها معاملة شبه الحرث ثم معاملة بدون حرث. حيث كان ١,٩٦ ، ٢,٠١ ، ٢,٢٢ طن/فدان في المعاملة بدون حرث و شبه الحرث والحرث العادي علي التوالي عند محتوى الرطوبي ٦٥% من السعة الحقلية بينما كان ١,٠٥ ، ١,٦٧ ، ٢,٢٢ طن/فدان مع المعاملات السابقة علي نفس الترتيب عند محتوى رطوبي ٨٥% من السعة الحقلية.