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Original Research Article

Impact of Conservation Agriculture System on Combating Water Erosion Hazards at Wadi El-Raml, Northwestern Coast of Egypt

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Abstract

Conservation agriculture practices (CA) is a management for available organic matter resources and considered important measures to enable farming in accordance with the principles of sustainable agriculture. The two-years experiment were performed on the soil under wheat crop. CA practices can help to decrease the area and duration for exposed soil to water erosion by increased soil aggregate size distribution, soil porosity, soil moisture and soil organic matter. Soil organic matter (SOM) is an important indicator of soil fertility and productivity because of its crucial role in soil chemical, physical and biological properties. CA leaves a soil organic mulch at the soil surface, which decreases runoff and soil loss. On other hand, soil mulch with plant residue as a component of CA is increased soil content of SOM. The least total cost for cultivation wheat crops under rainfed agriculture of Egypt achieved at conservation agriculture with No-tillage treatment (CANT) while the highest cost achieved at traditional agriculture (TA) treatment. The best results of decreased soil loss, increased SOM and wheat crop yield obtained when continue to apply conservation practices for more than one season. Indeed, our results showed the soil loss decreased about (56%) while wheat grain yield and SOM increased about (7% and 45%) respectively when using CA at the second season compared to TA. Conservation agriculture signifies environmentally friendly technologies reduce of climate related risks.

Keywords: Rainfed agriculture, traditional agriculture, conservation agriculture, organic matter, soil mulch.

INTRODUCTION

Erosion was a result of climate variability and change; it is worldwide phenomenon that caused of billions of tons topsoils removed every year (Vach *et al*., 2018). The major land degradation features in Northwest Coastal Zone (NWCZ) of Egypt is soil erosion. In the Northwestern Coast Zone of Egypt (NWCZ) most yield production depends on rainfed agricultural productivity for achieve to food security (Wassif and Meselhy 2022). Water erosion hazards is threats rainfed agriculture in the region which occupies 70.1% of rainfed agriculture (Wassif *et al*., 2020). According to Vach *et al*., (2018) and Xuan Du *et al*., (2021) soil water erosion is a cause of soil degradation by excess surface runoff. The key to soil degradation is remove topsoil along with the organic matter and other nutrients held within it (Amini and Asoodar 2015 and (CSA), 2020). Soil organic matter content play a critical role in the biological productivity of agricultural soil reported by Amini and Asoodar (2015). Xuan Du *et al*., (2021) was reported that the croplands worldwide experience higher erosion rates than other land uses. Globally, to combat water erosion hazards is solved primarily by improving the size and shape of the fields, crop rotation and using soil protection technologies via reduction of the intensity of soil cultivation. Also, it can be by keeping the residues of the preceding crops at the field (Vach *et al*., 2018). Conservation agricultural practices have been developed to reduce water erosion and optimizing cropland production Mensik *et al*., 2020). Mostly soil conventional tillage practices, which invert the soil using heavy machinery, sequent high ground pressure and neglect to protect soil surface otherwise by using conservation agriculture (Nurbekov *et al*., 2016 and Wassif *et al*., 2020). Conservation agriculture (CA) is defined by USDA-NRCS as a system that leaves enough crop residues from cover crops on the soil surface after planting to provide at least 30% soil cover (USDA NIFA 2012). It is considered of existing strategies, can help producers minimize the risks associated with climate variability and change as well as improve resource – use efficiency

(USDA NIFA 2012 and Mensik et al 2020). CA has better to adaptability to climate change. So, it considered to be climate smart (Nurbekov *et al*., 2016). On this context, it has association with three principles: a) no or minimum mechanical soil disturbance b) keep of permanent soil mulch cover c) crop rotation (USDA NIFA 2012, Amini and Asoodar 2015, Nurbekov *et al*., 2016 and Mensik *et al*., 2020).

The aim of this research is to study the effect of conservation agriculture system and traditional agriculture system with continue of applying these systems through two seasons, on water runoff, soil losses, soil content of organic matter, wheat crop yield and input costs in wadi El Raml area, NWCZ, Egypt.

MATERIAL AND METHOD

The field was performed in Wadi El Raml area located at west Matrouh city about 13 km and extended from southwest to northeast of the city. In the Fig 1 showed the Wadi lie within the latitudes of 31° 09´ 00", 31° 21´ 00" North and within the longitudes of 27° 06´ 00", 27° 12´ 00" East. The total area of this Wadi is about 194 km^2 about (18476 ha). It was conducted in two seasons, 2019-2020 and 2020-2021. It is occupied about 1 ha. Three replicates. The main plots involved 3 agriculture systems i.e. traditional agriculture (TA), conservation agriculture with min-tillage (CAMT) and conservation agriculture with no-tillage (CANT). This experiment was continued for two consecutive seasons to perform six treatments as the following: TA_{FS}, TA_{SS}, $CAMT_{FS}$, $CAMT_{SS}$, $CANT_{FS}$ and $CANT_{SS}$. The wheat crop was cultivated in (first December 2019 and 2020 for first and second seasons respectively) in all plots using conservation tillage machine and harvested in (April 2020 and 2021 for first and second seasons respectively). The specifications of machine used in this experiment were hanging behind the tractor with three hitch points. The machine consisted of two units with about 2 m working width the first unit for tillage consists of seven shanks with chisel blade arranged in two rows and the second unit for sowing crop seeds in rows with 16 cm between them, as shown in Fig 2.

The machine carried out the study treatments as follows: conservation agriculture with Min-tillage (CAMT) treatment using all units of machine where, tillage unit used at 10 cm tillage depth and sowing wheat crop seeds by planting unit in one pass. conservation agriculture with No-tillage (CANT) treatment used planting unit only without tillage unit. Traditional agriculture (TA) using traditional chisel plow seven blades at 20 cm tillage depth to make two perpendicular passes after that in another pass using planting unit only in machine without tillage unit for sowing wheat seeds. The forward speed of tractor was fixed about 4.5 km/h for all treatments.

Each treatment with its 3 replicates was carried out in a rectangular plot (50×12 m) for oriented in NW to SE direction. The distance between treatments kept at 2 m, which created a buffer zone area between treatments. At harvesting, three randomized samples were taken from each plot using a square wooden frame (1 m^2) to determine the yield. Finally, the wheat crop harvested for conservation agriculture system (CAMT and CANT) by cutting by sickle at 5 cm above the soil surface. While the traditional agriculture (TA) harvested by pulling by hand.

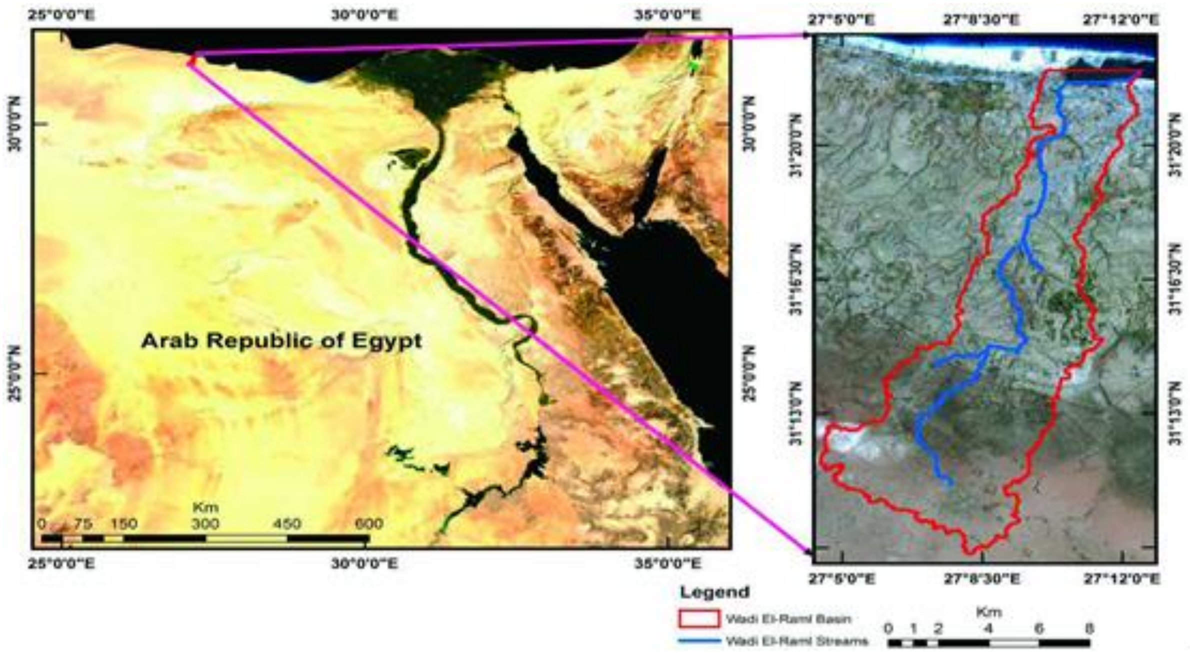

Fig 1: Location map of at Wadi El-Raml area, NWCZ of Egypt

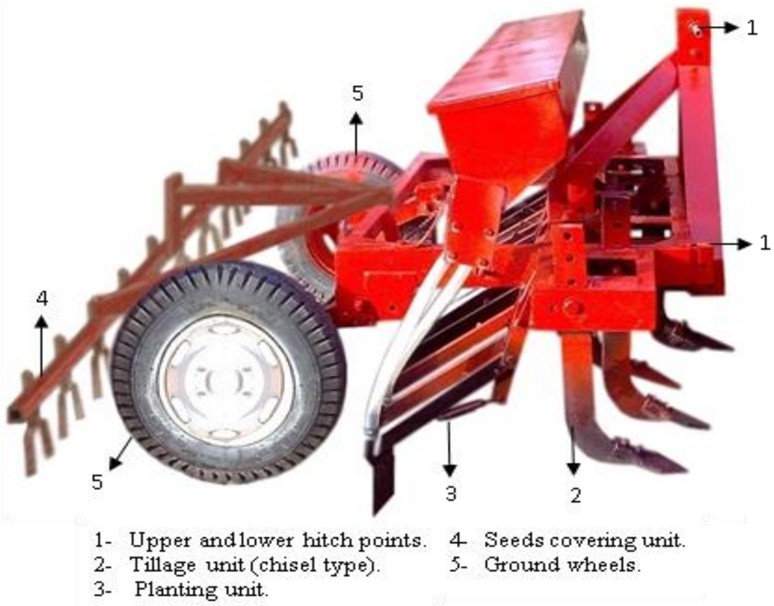

Fig 2: Combination machine for conservation agriculture

Soil samples were collected at triplicate of surface soil layer (0-20 cm) The particle size distribution using the pipette method, was 68.43% sand, 17.37% silt and 14.2 % clay. The field slope degree 7% South-North direction. Table 1 shows some physical and chemical properties of the initial soil before cultivated. Such properties were measured according to methods described by Klute 1986 and Page 1986.

Table 1: Some soil properties surface layer (0-20 cm) for the initial soil at Wadi El-Raml, NWCZ, Egypt

Treatment	pH	EC (ds/m)	$CaCo^3$ (%)	Particle Size Distribution (%)				Texture class	BD	Soil erodibility ($t.ha.mj^{-1}.mm^{-1}$)
				C.S*	F.S*	S*	C*		$Mg.m^{-3}$	
Initial	**7.5**	**1.08**	**10.5**	**56.7**	**11.73**	**17.37**	**14.2**	**S. L***	**1.67**	**0.63**

C.S*= Coarse Sand, F.S*= Fine Sand, S* = Silt, C*=Clay, S. L*= Sandy Loam, BD*= Bulk density.

Soil erodibility was measured according to Morgan 2005. This area is suffering from water erosion as cleared in Table 1 because the soil erodibility (K) was > 0.50 as according to Vopravil 2007. Soils most susceptible to water erosion which is a serious problem for agricultural productivity. Soil loss plots (5×10m) were used to measure soil loss and runoff using Gerlesh trough FAO (1993), which existed at the end of slope Fig 3 & 4. Runoff and associated soil loss for every effective rainstorm were determined according to FAO (1993). The Enrichment Ratio (ER) was calculated as the following equation: ER= Ce/Co Where, Ce is the concentration of nutrient in the sediment, and Co is the concentration of soil nutrients in the bare soil according to Are et al (2011). Theoretical and actual field capacity and field efficiency of machines were calculated by using equations mentioned by Kepner et al (1978). Soil bulk density was measured using a core method as described by Black (1986). Total hourly cost was determined according to El-Awady 1978 as follows:

$$\mathbf{C=\left(\frac{p}{h}\right)*\left(\frac{1}{L}+\frac{i}{2}+t+r\right)+(1.2*RFC*f)+\left(\frac{m}{144}\right)+\left(\frac{P_1}{h_1}\right)*\left(\frac{1}{L_1}+\frac{i}{2}+t+r_1\right)}$$

Where: C = Hourly cost, (L.E./h), P = Initial price of the tractor, (L.E), h = Yearly working hours of tractor. (h/year), L = Life expectancy of the tractor, (year), T = Annual taxes and overhead ratio, (%), f = Fuel price, (L.E./L), m = The monthly average wage,(L.E./month), 1.2 = Factor accounting for lubrications, RFC = Actual rate of fuel consumption, (L/h), I = Annual interest rate,(%), r = Annual repairs and maintenance ratio for tractor, (%),P_1 = Initial price of machine, (L.E), h_1 = Yearly working hours of machine, (h/year), r_1 = Annual repairs and maintenance ratio for machine, (%), 144 = Operator monthly average working hours, (h) and L_1: Life expectancy of machine. Total cost per unit area was determined as follows: $\boldsymbol{TCA = C/AFC}$ ***Where:*** **TCA** = Total cost per unit area, (L.E./ha), **AFC** = Actual field capacity, (ha/h) and **C** = Hourly cost, (L.E./h). Net profit estimated as follows: **NP = P – TCA** ***Where:*** **NP** = Net profit, (L.E./ha), **P** = Profit, (L.E./ha) and **TCA** = Total cost per unit area, (L.E./ha).

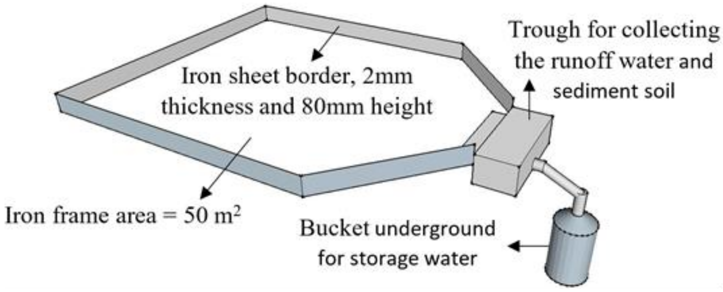

Fig 3: Schematic diagram showing iron sheet border installed around the study treatment and trough to collect runoff water and sediment soil

Fig 4: Gerlesh trough to collect runoff water and sediment soil

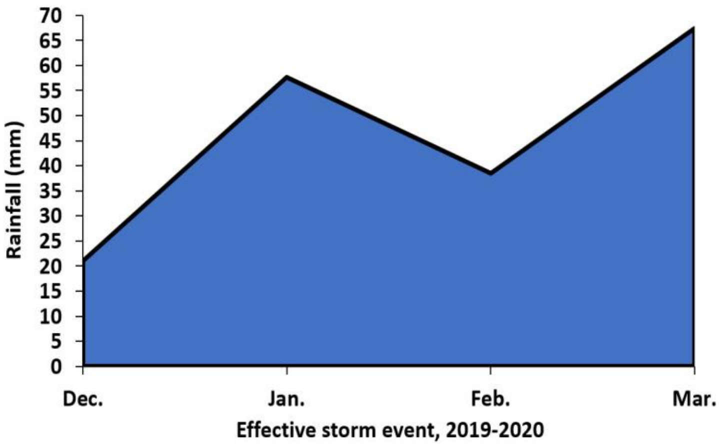

Fig 5: Effective storm events and precipitation depth of rainfall (mm) at the study area through duration (2019-2020)

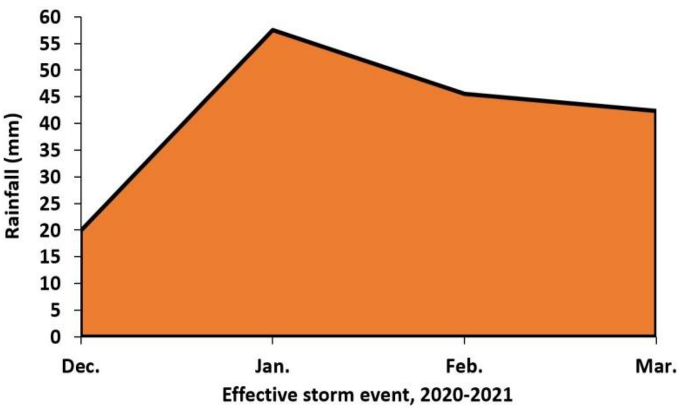

Fig 6: Effective storm events and precipitation depth of rainfall (mm) at the study area through duration (2020-2021)

RESULT AND DISSCUSSION

Combating water erosion with CA

The results of runoff (%) and soil loss (Mg/ha/yr) were decrease in treatments as follow $CANT_{SS} < CANT_{FS} < CAMT_{SS} < CAMT_{FS} < TA_{SS} < TA_{FS}$, respectively as in Fig. (7 and 8) and Table 2. Generally, the results showed that surface runoff less by 49% of $CANT_{SS}$ than $CANT_{FS}$, 38% $CAMT_{SS}$ than $CAMT_{FS}$ and 3% TA_{SS} than TA_{FS}. On other hand, the $CANT_{FS}$ runoff ratio less than $CAMT_{FS}$ and TA_{FS} about 12% and 40% respectively. In addition, $CANT_{SS}$ runoff ratio less than $CAMT_{SS}$ and TA_{SS} about 28% and 68% respectively. Among different practices the $CANT_{SS}$ was the greatest reduction in both surface runoff and soil loss, and it is agreed with Nurbekov *et al*., (2016) and Mensik *et al*., (2020). These results can explain by several mechanism associated with CA. such as CA practices can help to decrease the area and duration for exposed soil to water erosion by increased soil aggregate size distribution, soil porosity, surface roughness, soil moisture and soil organic matter Mensik *et al*., (2020) and Boruta *et al*., (2021).

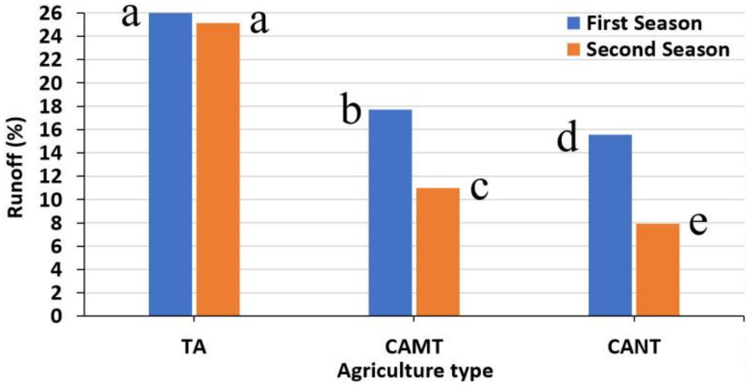

Fig 7: Effect of traditional agriculture (TA), conservation agriculture with Min-tillage (CAMT) and conservation agriculture with No-tillage (CANT) on runoff (%) through two seasons. Values followed by different letters are significantly at $p < 0.05$ and LSD = 1.6015

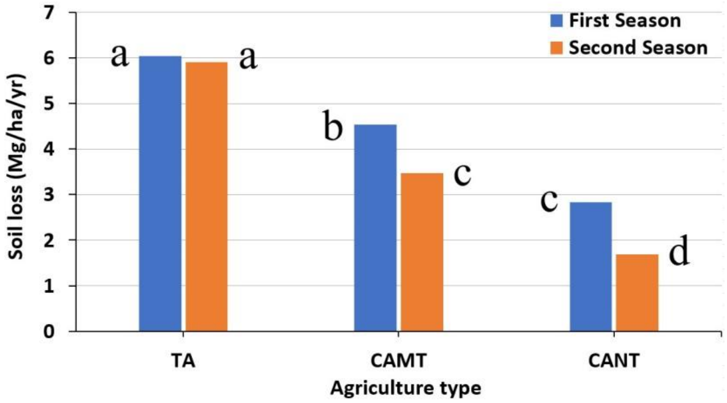

Fig 8: Effect of traditional agriculture (TA), conservation agriculture with Min-tillage (CAMT) and conservation agriculture with No-tillage (CANT) on soil loss (Mg/ha/yr) through two seasons. Values followed by different letters are significantly at $p < 0.05$ and LSD = 0.7518

Table 2: The effect of study treatments on soil organic matter, runoff (%) and soil loss (Mg/h/year) under different effective rainfall storm events

Treatment		Plant residue cover (%)	SOM (%)	Effective storm event	Rainfall (mm)	Runoff (%)	Soil loss (Mg/ha/yr)
Agriculture type	**Seasons number**						
Traditional agriculture	**First**	**4**	**0.22**	**Dec**	21	5.07	1.47
				Jan.	57.68	6.61	1.54
				Feb.	38.51	5.19	1.42
				Mar.	67.44	9.1	1.64
				Total annual	**184.63**	**25.97**	**6.04**
	Second	**5**	**0.21**	**Dec**	19.89	4.51	1.35
				Jan.	57.47	8.43	1.59
				Feb.	45.53	6.89	1.52
				Mar.	42.32	5.31	1.44
				Total annual	**169.21**	**25.14**	**5.9**

Treatment		Plant residue cover (%)	SOM (%)	Effective storm event	Rainfall (mm)	Runoff (%)	Soil loss (Mg/ha/yr)
Agriculture type	**Seasons number**						
Conservation agriculture with Min-tillage	**First**	**30**	**0.25**	**Dec**	21	2.78	1
				Jan.	57.68	5.1	1.24
				Feb.	38.51	3.22	1.02
				Mar.	67.44	6.61	1.27
				Total annual	**184.63**	**17.71**	**4.54**
	Second	**40**	**0.30**	**Dec**	19.89	1.22	0.68
				Jan.	57.47	4.46	0.97
				Feb.	45.53	3.17	0.93
				Mar.	42.32	2.13	0.89
				Total annual	**169.21**	**10.98**	**3.47**
Conservation agriculture with No-tillage	**First**	**30**	**0.27**	**Dec**	21	2.11	0.64
				Jan.	57.68	4.98	0.73
				Feb.	38.51	3.4	0.7
				Mar.	67.44	5.09	0.76
				Total annual	**184.63**	**15.58**	**2.83**
	Second	**70**	**0.35**	**Dec**	19.89	1.3	0.38
				Jan.	57.47	2.7	0.46
				Feb.	45.53	2.03	0.43
				Mar.	42.32	1.91	0.41
				Total annual	**169.21**	**7.94**	**1.68**

Soil organic matter (SOM) and Enrichment ratio

There was a negative relationship between SOM (%) content in soil and runoff (%). Also, negative relationship with soil loss (Mg/ha/yr). SOM is an important indicator of soil fertility and productivity because of its crucial role in soil chemical, physical and biological properties Amini and Asoodar (2015) and Wassif *et al*., (2020). The results in Fig 9 obtained the highest value of SOM with $CANT_{SS}$ < $CAMT_{SS}$ < $CANT_{FS}$ < $CAMT_{FS}$ < TA_{FS} < TA_{SS}; 0.35% > 0.30% >0.27% >0.25% >0.22% > 0.21%, respectively. The quantity of SOM% was increased about 51% by conservation agriculture practices than traditional agriculture. These results due to decrease of loss SOM and decomposition and it is agreement with Amini and Asoodar (2015) and Wassif and Meselhy (2022).

The enrichment ratio (ER) meaning ratio of concentration of nutrients in sediments or eroded materials to that of the treatment soil. It is essential estimate of soil degradation by soil water erosion. Fig. (10) shows that lower ER of SOM of $CANT_{FS+SS}$ < $CAMT_{FS+SS}$ < TA_{FS+SS} 1.05% < 1.96% < 4.36% respectively. These results declare that CA leaves a soil organic mulch at the soil surface, which decrease runoff and soil loss. on other hand, it is decreased decomposition of SOM. The latest was promote greater aggregate stability which restrict soil water erosion. The same results were by Amini and Asoodar (2015), Wassif *et al*., (2020) and Wassif and Meselhy (2022).

The results in the Figure 11 showed that the soil cover percentage increased in the two treatments of conservation agriculture (CAMT and CANT), about of (40% and 70%) respectively compared to the coverage ratio of about (5%) for traditional agriculture. Increasing the proportion of the soil cover from plant residues had the greatest effect in increasing the soil content of organic matter and reducing the chances of losing it from the soil with the eroded soil.

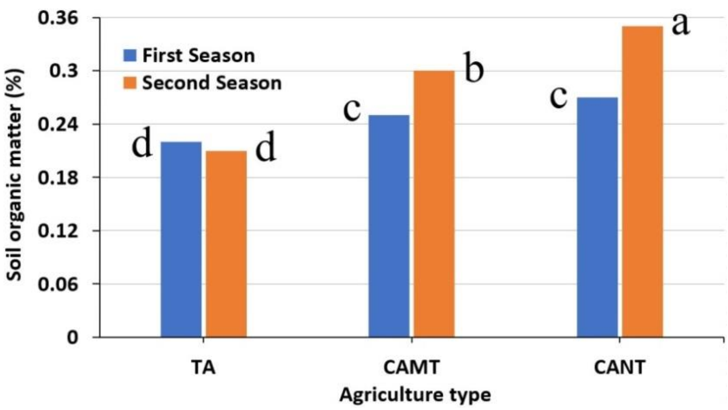

Fig 9: Effect of traditional agriculture (TA), conservation agriculture with Min-tillage (CAMT) and conservation agriculture with No-tillage (CANT) on soil organic matter through two seasons. Values followed by different letters are significantly at p < 0.05 and LSD = 0.0244

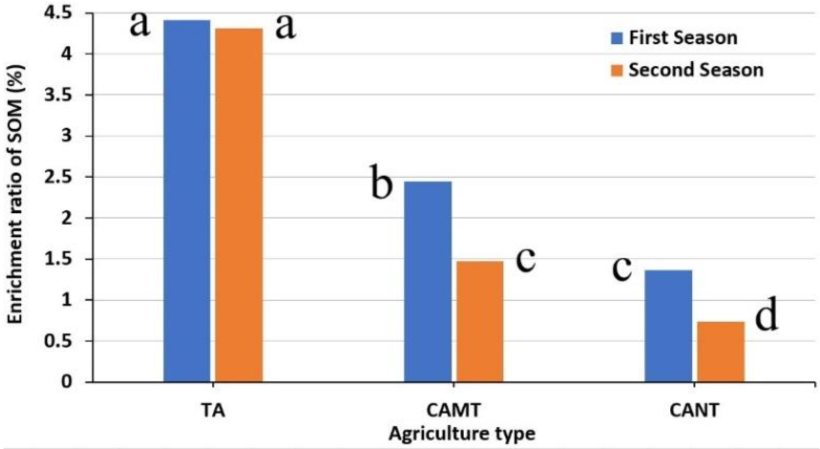

Fig 10: Effect of traditional agriculture (TA), conservation agriculture with Min-tillage (CAMT) and conservation agriculture with No-tillage (CANT) on Enrichment ratio of SOM through two seasons. Values followed by different letters are significantly at $p < 0.05$ and LSD = 0.2063

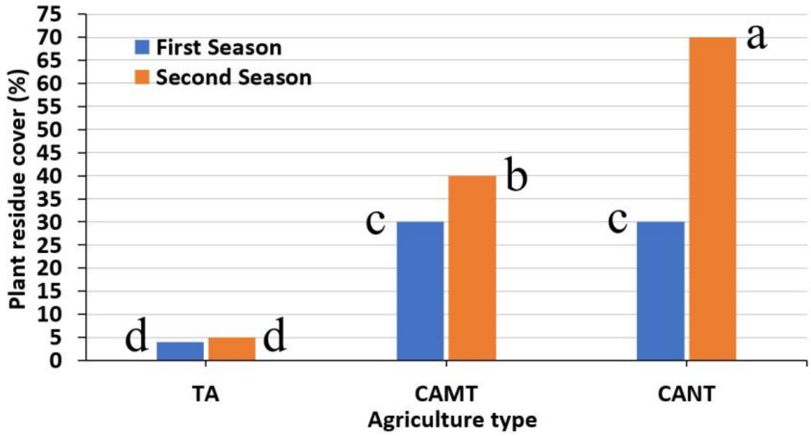

Fig 11: Effect of traditional agriculture (TA), conservation agriculture with Min-tillage (CAMT) and conservation agriculture with No-tillage (CANT) on plant. Residue cover through two seasons. Values followed by different letters are significantly at $p < 0.05$ and LSD = 2.1515

Yield and Economic Return

The results showed that the productivity of wheat for conservation agriculture was lower compared to traditional agriculture during the first season, but the productivity of wheat for conservation agriculture increased compared to traditional agriculture during the second season, this is agreement with USDA NIFA (2012), Du X *et al*., (2020), Nurbekov *et al*., (2016), Wassif *et al.*, (2020) and Mensik *et al.*, (2020). This is due to the fact that during the first season the time was not enough for microorganisms to grow in the soil and play their role in improving the soil physical and chemical properties, which leads to an increase in soil fertility and moisture content, which is reflected in an increase in wheat productivity. However, the continuation of application the conservation agriculture system for the second season led to an increase in wheat productivity, unlike what happened in traditional agriculture, as the exposure of the soil surface, absence of organic residues in it and increase in fragmentation of the soil structure led to the rapid drying of the soil, loss its content of organic matter and decrease in the activity of microorganisms, which led to lower productivity. The yield enhancing by conservation practices compared with traditional practices as cleared in Fig 12. Which is 80% of the total area sown to wheat and the crop yield was healthier compared with the crop yield under traditional practices.

Otherwise, yield results as shown in Fig 13 and 14 cleared that increased in grain and straw yield under traditional practices in first season about of (8% and 9%) compared with conservation practices. But in the second season the wheat yield of grain and straw under conservation agriculture increased about of (5% and 4%) compared with traditional agriculture.

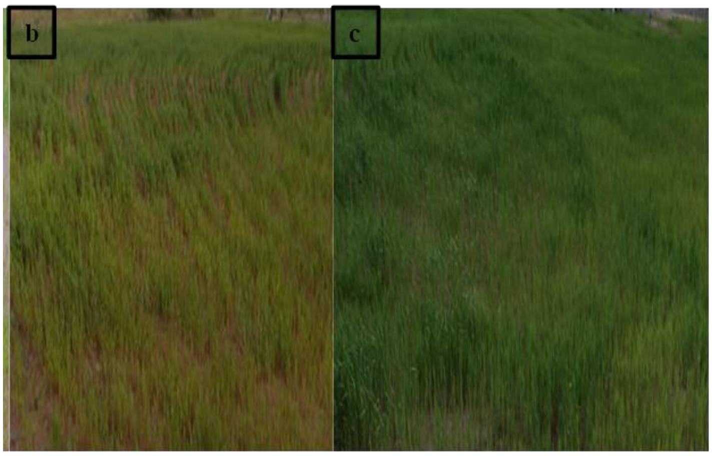

Fig 12: Rainfed wheat crop in (b) the traditional agriculture, (c) conservation agriculture

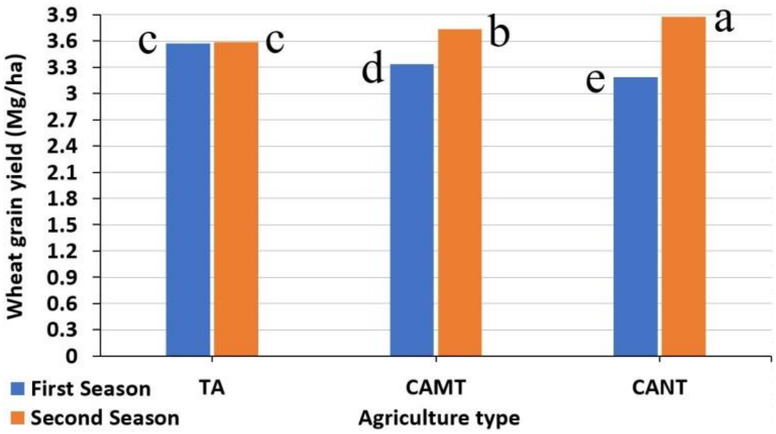

Fig 13: Effect of traditional agriculture (TA), conservation agriculture with Min-tillage (CAMT) and conservation agriculture with No-tillage (CANT) on wheat grain yield through two seasons. Values followed by different letters are significantly at $p <$ 0.05 and LSD = 0.1368

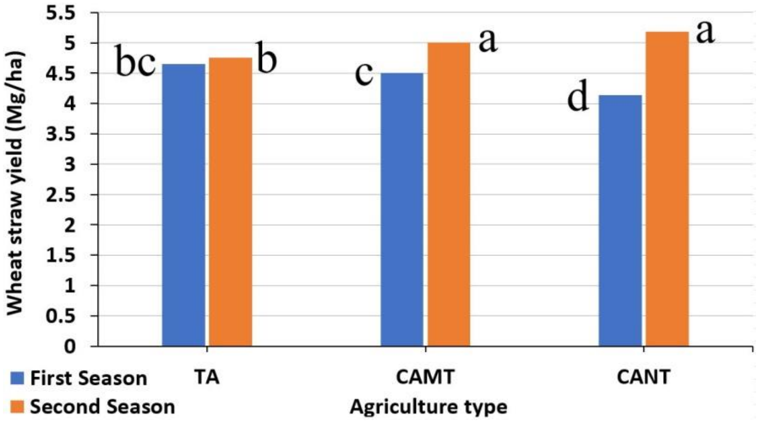

Fig 14: Effect of traditional agriculture (TA), conservation agriculture with Min-tillage (CAMT) and conservation agriculture with No-tillage (CANT) on wheat straw yield through two seasons. Values followed by different letters are significantly at $p <$ 0.05 and LSD = 0.2187

Economic Return

The costs of wheat production in this study were divided into fixed costs for all treatments, namely the price of planting seeds, and variable costs according to the level of soil preparation and the requirements of covering the soil from plant residues, where, the costs of covering soil for traditional agriculture were absent, while the soil was covered with rice straw at 30% in the two conservation agriculture treatments (CAMT and CANT) during the first season only. The results showed that the highest production costs were achieved with traditional agriculture, which was about 2750 LE, and the lowest cost at conservation agriculture treatment with no tillage (CANT) about 1522 LE. In general, conservation agriculture is characterized by lower production costs compared to traditional agriculture, and with the continuation of conservation agriculture system for several consecutive seasons, it led to an increase in crop productivity and achieving the highest profit. Where the order of the study's treatments in achieving the highest profit was as follows ($CANT_{SS}$ > $CAMT_{SS}$ > TA_{SS} > TA_{FS} > $CAMT_{FS}$ > $CANT_{FS}$). As shown in the Fig 15 and Table 3 these results agreement with Wassif *et al*., (2020), Mensik *et al*., 2020 and Boruta *et al*., (2021).

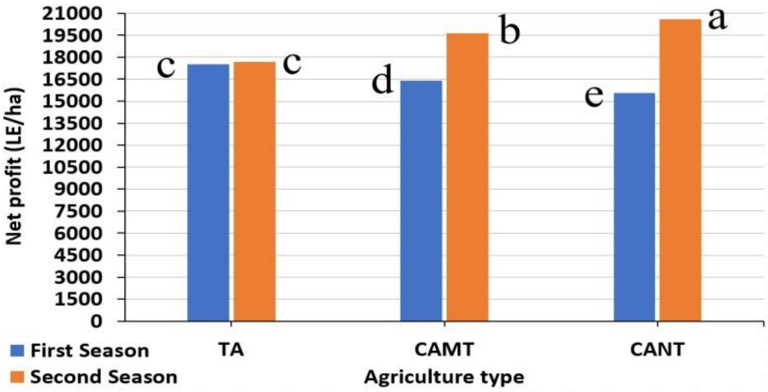

Fig 15: Effect of traditional agriculture (TA), conservation agriculture with Min-tillage (CAMT) and conservation agriculture with No-tillage (CANT) on net profit through two seasons. Values followed by different letters are significantly at $p < 0.05$ and LSD = 151

Table 3: Economic return for productivity of wheat yield under different agriculture systems

Treatments		Cost						Profit			Net profit (LE/ha)
Agriculture type	Seasons number	Machine cost (LE/ha)	Seeds cost (LE/ha)	Rice straw cost (LE/ha)	Wheat grain yield (Mg/ha)	Wheat straw yield (Mg/ha)	Total cost (LE/ha)	Wheat grain profit (LE/ha)	Wheat straw profit (LE/ha)	Total profit (LE/ha)	
TA	First	1450	1300	0	3.574	4.655	2750	16083	4190	20273	17523
	Second	1450		0	3.586	4.753	2750	16137	4278	20415	17665
CA_{MT}	First	380		1000	3.335	4.508	2680	15008	4057	19065	16385
	Second	380		0	3.735	5.011	1680	16808	4510	21318	19638
CA_{NT}	First	222		1000	3.186	4.141	2522	14337	3727	18064	15542
	Second	222		0	3.877	5.186	1522	17447	4667	22114	20592

TA = Traditional agriculture.
TA_{MT} = Conservation agriculture with Min-tillage.
TA_{NT} = Conservation agriculture with No-tillage.
Seeds cost = 120 kg/ha seeds x10.83 LE/kg = 1300 LE/ha.
Rice straw cost to cover 30% of soil surface = 1000 LE/ha.
Price of wheat grain = 4500 LE/Mg.
Price of wheat straw = 900 LE/Mg.

Environmental benefits

Conservation agriculture signifies environmentally friendly technologies. Since it uses resources more competently than conventional agriculture making resources available for other uses, as well as conserving them for coming generations. The substantial decrease in fossil fuel usage under no tillage agriculture marks in smaller amount greenhouse gases release into atmosphere and cleaner air. Conservation agriculture reduced the air and soil pollution.

From the abovementioned discussion, the continues or long-term application of conservation practice on soil quality, potential annual water soil loss, productivity of cereal crops under rainfed conditions of Egypt be more benefit.

CONCLUSION

According to the results obtained, we can confirm that conservation practices is the best to combat the water erosion hazards. At the same time, soil conservation practice provided soil protection against damage by surface runoff of rainwater in eroded area under rainfed condition. This is because of, reduced crop water stress, increased SOM by decreased decomposition and improve soil quality. Also, positively influencing on soil environment and the yield of crops after long time use. On the other hand, it is also cheaper in the case of mechanization than traditional agriculture. When choosing a method of conservation agriculture with less soil cultivation should be reduce costs and simplify workload and decrease erosion. Finally, this study highlights the importance of conservation management in improving soil health properties in croplands and reduce of climate related risks. Also, we recommended to apply it for a long period of time to achieve high productivity in addition to benefiting from its benefits as previously mentioned and promising to the farmers.

REFERENCES

- Amini, S., & Asoodar, M. A. (2015). Investigation on the effect of conservation tillage on soil organic matter (SOM) and soil organic carbon (SOC): the review. *New York Science Journal*, 8(3), 16-24.
- Are, K. S., Babalola, O., Oke, A. O., Oluwatosin, G. A., Adelana, A. O., Ojo, O. A., & Adeyolanu, O. D. (2011). Conservation strategies for effective management of eroded landform: soil structural quality, nutrient enrichment ratio, and runoff water quality. *Soil science*, *176*(5), 252-263.
- Black, G. R. (1986). Bulk density. P. 374-390. In Page, (eds.). Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods, Am. Soc. Agron. Inc. Medison. Wis. USA.
- Breza-Boruta, B., Kotwica, K., & Bauza-Kaszewska, J. (2021). Effect of Tillage System and Organic Matter Management Interactions on Soil Chemical Properties and Biological Activity in a Spring Wheat Short-Time Cultivation. *Energies*, *14*(21), 7451. https://doi.org/10.3390/en14217451.
- Climate Smart Agriculture (CSA). (2020). Brief No. 7 for Agricultural Field Officers https://climatefinance.gov.gd/embedded-pdf/building-an-a-frame-csa-brief-no7-for-agricultural-field-officers/ The Programme is implemented by the Government of Grenada, the German Development Cooperation (GIZ) and UNDP and funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) under the International Climate Initiative (IKI).
- Du, X., Jian, J., Du, C., & Stewart, R. D. (2020). Conservation management decreases surface runoff and soil erosion International Research and Training Center on Erosion and Sedimentation, China Water & Power Press. Publishing services by Elsevier B.V. on behalf of KeAi Communications Co. Ltd. https://doi.org/10.1016/j.iswcr.2021.08.001.
- El-Awady, M. N. (1978). Engineering of Tractor and Agricultural Machinery. Text Book, (in Arabic), Fac. of Agric. Ain Shams Univ., Cairo, Egypt.
- FAO. (1993). Field measurement of soil erosion and runoff, Soil Bull. No. 68, Rom, Italy.
- Kepner, R. A., Bainer, R., & Barger, E. L. (1978). Principles of Farm Machinery. Ch 5, the AVI Publishing Company.
- Klute, A. (1986). Methods of Soil Analysis. Part (1): Physical and Mineralogical Methods. No. 9 in the Agronomy Series. American Society of Agronomy - Soil Science Society of America (publisher), Second Edition. Madison, Wisconsin, USA.
- Menšík, L., Kincl, D., Nerušil, P., Srbek, J., Hlisnikovský, L., & Smutný, V. (2020). Water erosion reduction using different soil tillage approaches for maize (Zea mays L.) in the Czech Republic. *Land*, *9*(10), 358. doi:10.3390/land9100358.
- Morgan, R. P. C. (2005). Soil Erosion and Conservation. 3rd edition. Publishing, Oxford. ISBN 1-4051-1781-8.
- Nurbekov, A., Akramkhanov, A., Kassam, A., Sydyk, D., Ziyadaullaev, Z., & Lamers, J. P. A. (2016). Conservation Agriculture for combating land degradation in Central Asia: a synthesis. *AIMS Agriculture and Food*, *1*(2), 144-156. DOI: 10.3934/agrfood.2016.2.144.
- Page, A. L., Millar, R. H., & Keeney, D. R. (1982). Methods of Soil Analysis, Part 2. ASA and SSSA, Madison, WI, USA. pp. 149-157.
- USDA NIFA. (2012). Conservation tillage .out research publication of the USDANIFA funded project: climate variability to climate change: extension challenges and opportunities in the Southeast USA.
- Vach, M., Hlisnikovský, L., & Javůrek, M. (2018). The effect of different tillage methods on erosion. *Agriculture*, *64*(1), 28-34. DOI: 10.2478/agri-2018-0003.
- Vopravil, J., Janeček, M. I. L. O. S. L. A. V., & Tippl, M. A. R. T. I. N. (2007). Revised soil erodibility K-factor for soils in the Czech Republic. *Soil and Water Research*, *2*(1), 1-9.
- Wassif, O. M., Meselhy, A. A., Sharkawy, S. F., & Ali, A. A. (2020). Quantify impact of wind erosion on organic matter content under management practices, Wadi El Raml, NWCZ, Egypt. *Egyptian Journal of Desert Research*, *70*(1), 83-102.
- Wassif, O. M., & Meselhy, A. A. (2022). Effect of contour tillage system and water harvesting method on mitigation of soil water erosion hazards Xi'an ShiyouDaxueXuebao (ZiranKexue Ban)/Journal of Xi'an Shiyou University, Natural Sciences Edition, 65(4). DOI 10.17605/OSF.IO/Y3KRF.