Approaches to increase the resiliency of Egyptian agriculture to climate change: An Overview

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Abstract

Climate change is expected to affect agricultural production in direct and indirect pathways. The increase in mean temperatures directly accelerates crop development, the change in seasonal precipitation amounts together with increasing evaporative demand can indirectly lead to more drought stress for crops. In Egypt, the agricultural sector is highly vulnerable to climate change due to its dependence on the Nile River for irrigation, increasing soil salinity by sea water intrusion and soil deterioration as a result of decomposition of its organic contents. In this article, previous research carried out in Egypt on climate change assessments on water resources (the Nile River and rainfall on the north coast of Egypt), crop evapotranspiration, crop water requirements, crop yield, agricultural soils and national cultivated area are reviewed. Furthermore, the implemented actions to increase crop resilience to climate change were discussed. Additionally, the procedures used to reduce greenhouse gases emission were also reviewed.

Keywords: Water resources, soil resources, climate-resilient crops, greenhouse gases emissions, carbon sequestration, biogas production

INTRODUCTION

Egypt is located on the Northeastern corner of Africa on the Mediterranean Sea between latitudes 22° and 32° N, and between longitudes 24° and 37° E. The total area of Egypt is 1,001,450 km^2, with a land area of 995,450 km^2. The Egyptian terrain consists of vast desert plateau interrupted by the Nile Delta and Valley, which occupy about 4% of the total area of Egypt. The Nile Delta and Valley divided the desert land of Egypt into the western desert (represents two third of Egypt territory) and the eastern desert. In addition, Sinai Peninsula located in the eastern part of Egypt represents 6% of the Egypt area and is located in Asia continent, which makes Egypt a transcontinental country. Water resources in Egypt are very limited, where more than 95% of it is received from outside of its international borders. It is consists of Egypt's water share from the Nile River, ground water, effective rainfalls on the northern strip of the Nile Delta, and recycled agricultural drainage water.

Climate change is expected to affect agricultural production in direct and indirect pathways. The increase in mean temperatures directly accelerates crop development, the change in seasonal precipitation amounts together with increasing evaporative demand can indirectly lead to more drought stress for crops (IPCC 2012). Martins *et al*., (2019) indicated that increased temperatures are likely to shorten the crop cycle as a result of acceleration in crop development and phenological stages (Eyshi Rezaei *et al*., 2018), thus reducing crop production (Asseng *et al*. 2013). On the other hand, alteration in precipitations will affect water resources and water availability for crops, so that crop yield will be severely affected and even crop failure could occur (Paymard *et al*., 2018). Reducing exposure to climate change and increasing the resilience of agricultural crops towards various biotic and abiotic stresses is a promising method for maximizing crop production under adverse conditions of drought, salinity and heat stress under climate change. Increasing the levels of biodiversity can help in improving the resiliency of agriculture to climatic shocks (Kozicka *et al*., 2020).

Emission of greenhouse gases (GHGs) from the soil results from the raise in air temperature that will lead to a raise in soil temperature, which will promote breakdown of soil organic matter and the release of CO_2 and CH_4 into the atmosphere (Kuzyakov *et al*., 2019).GHGs are also controlled by soil texture (Gaillard *et al*., 2016) and soil pH (Wang *et al*., 2010). Furthermore, rice cultivation is another sources of GHGs emissions including CH_4 and N_2O (Zheng *et al*., 2004), where under low oxygen content (waterlogged soils), anaerobic decomposition of organic carbon compounds results in the emission of CH_4 to the atmosphere (Magdoff and Van, 2010). Another source of greenhouse gases is the burning of crop residues, which contributes to greenhouse gases emissions in the atmosphere, where it increase the content of CO_2, CH_4 and N_2O and other trace gases (Smith *et al*., 2014).

In Egypt, the agricultural sector is highly vulnerable to climate change due to its dependence on the Nile River for irrigation, increasing soil salinity by sea water intrusion and soil deterioration as a result of decomposition of its organic contents. Therefore, in this paper, an overview of the previous researches done in Egypt on climate change assessments on water resources (the Nile River and rain fall on the north coast of Egypt), crops evapotranspiration, crops water requirements, crops yield, agricultural soils, and national cultivated area is presented. Furthermore, the implemented procedures used to increase crops resilience to climate change were discussed. Additionally, the procedures used to reduce the emission of greenhouse gases were also reviewed.

ASSESSMENT OF CLIMATE CHANGE EFFECTS ON AGRICULTURE IN EGYPT

Climate change and water resources

Egypt relays enormously on the Nile River as the main source of water, which contributes with about 95% of Egypt's water budget. Other water resources are precipitations and groundwater, which contribute with about 5% of the available supply. Sayed (2004) indicated that rainfall projection varies substantially in magnitude across the studied climate change models due to the highly non-linear relationship between precipitation and runoff. The uncertainty about the increase or decrease in precipitation near the sources of the Nile, as well as variations in temperature could have a larger than expected effect on Nile flows because these two factors are also interrelated which leads to moderate to extreme effects (Elsaeed, 2012). Furthermore, Nour El-Din (2013) reported that there is some uncertainty about the effect of future climate changes on Blue Nile (contributes more than 75% of the Nile flows), where roughly two-thirds of the studied general circulation models projected an increase in precipitation, whereas one-third of the studied models expected reduced precipitations.

It has also been suggested that Egypt's precipitations may decrease due to climate change, with an annual decline up to 5; 8 and 13% respectively by 2030, 2050 and 2100 (Barbi 2014). Ouda *et al*., (2016) projected that the amount of annual rainfall in northeastern coast of Egypt in 2030 will the lowest than its counterpart values from 1997 to 2014, except for 1999 (Figure 1a). The value of rainfall deviation in 2030 from the average of 18 years was −27%, which is considered deficit according to the classification of Kumar *et al*., (2009). Similarly, in the northwestern coast of Egypt, the projected annual rainfall value in 2030 will be the lowest compared to the recorded values from 1997 to 2014 (Figure 1b) (Ouda *et al*., 2016). The value of rainfall deviation in 2030 from the average of 18 years was −95%, which is considered scantly according to the classification of Kumar *et al*., (2009).

Projected values of climate elements under climate change

Table 1 shows the expected increase in the values of climate elements in 2030 using RCP6.0 scenario developed by CCSM4 model, in several governorates in Egypt from north to south. The table shows that it is expected that solar radiation will increase by an average of 1.1 MJ/m^2/day, temperature will increase an average of by 1.1 °C and wind speed will increase by an average of 0.9 m/sec in 2030, compared to 2014 (Ouda, 2017).

Crop evapotranspiration under climate change

The amount of crop evapotranspiration (ETc) is affected by reference evapotranspiration (ETo) and specific crop coefficients (Kc). Several studies showed an expected rise in the values of ETo under climate change in 2030 (Sayad *et al*., 2015; Ouda 2019b) (Figure 2).

Table 1: The expected increase in the values of climate elements in 2030, compared with its values in 2014

	Solar radiation (MJ/m/day)	Temperature (°C)	Wind Speed (m/sec)
Alexandria	0.5	0.5	1.5
Behira	0.4	1.0	0.9
Gharbia	0.8	1.9	0.2
Kafr El Sheikh	0.9	1.2	0.6
Dakahlia	0.5	1.9	0.9
Damietta	0.7	1.1	0.8
Sharkia	0.9	0.7	0.7
Menoufia	0.9	2.0	0.8
Qalyubia	0.9	2.1	0.8
Giza	0.8	2.6	0.5
BaniSweif	0.9	2.1	0.6
Fayoum	0.7	1.3	0.7
Minya	1.0	1.1	0.8
Assiut	1.0	1.7	1.3
Sohag	1.2	1.9	1.4
Qena	2.3	2.1	1.7
Aswan	3.3	2.2	1.3
New Valley	2.1	2.0	1.5
Average	1.1	1.6	0.9

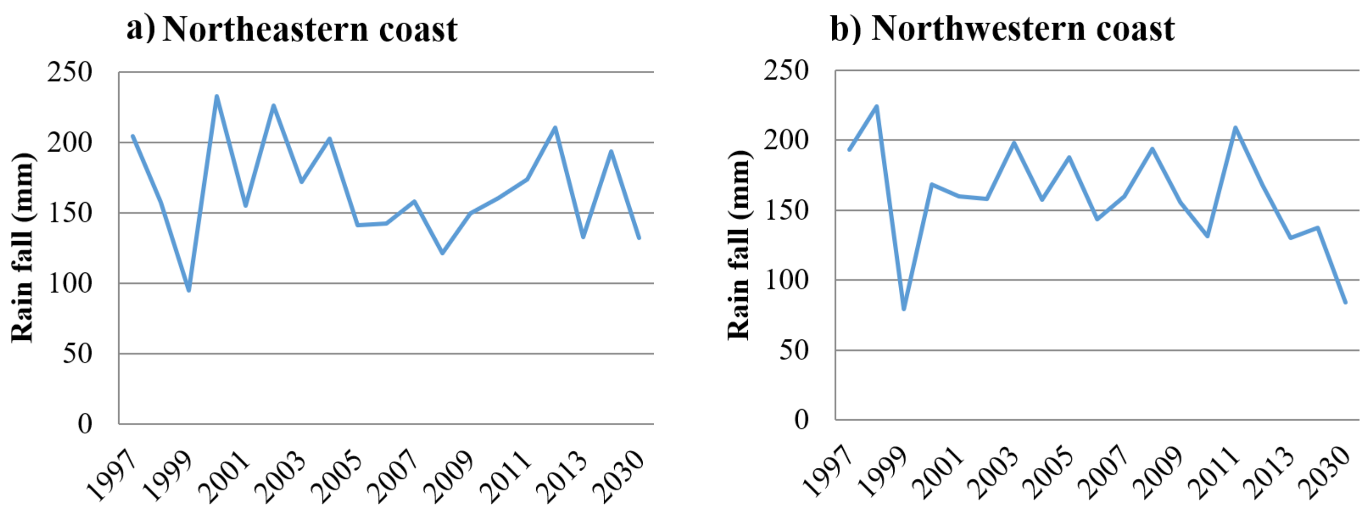

Figure 1: Comparison between annual amounts of rainfall from 1997 to 2014 and its projected value in 2030 in a) Northeastern coast and b) Northwestern coast

Additionally, Ouda (2019b) found that the values of Kc of several crops will increase under climate change in 2030 (Figure 3). Consequently, a noticeable increase in ETc values in 2030 will be expected under climate change (Ouda, 2019b) (Figure 4).

Crops water requirements under climate change

Several authors projected the values of water requirements for several crops and the percentages of increase in its values (Table 2).

Furthermore, Eid *et al.*, (1992) indicated that climate change could increase crops water demand for summer and winter crops by 16 and 2%, respectively in the year 2050. Whereas Attaher *et al.*, (2006) calculated national irrigation water demand in 2050 and 2100 and the percentage of increase could be up to +16% (Table 3).

Projection of climate change impacts on crops production

Assessment of climate change impact on crops production in Egypt started in the 1990s. Since that time, there was a large progress and improvement in the climate change scenarios developed by IPCC and the assessment analysis. These scenarios were used in a large number of studies in Egypt to assess its effects on crops yield. Examples of the IPCC scenarios and related studies were: IPCC (1990) used in Eid *et al.*, (1993) and Eid *et al.*, (1997a), IPCC (2001)used in Hassanein (2010) and Abou-Shleel and Saleh (2011), IPCC (2007) used in Khalil *et al.*, (2009) and Ouda *et al.*, (2013), and IPCC (2013) used in Sayad *et al.*, (2015) and Ouda *et al.*, (2016). All these studied concluded that the yield of the studied crops will be negatively affected by the stressful conditions of climate change.

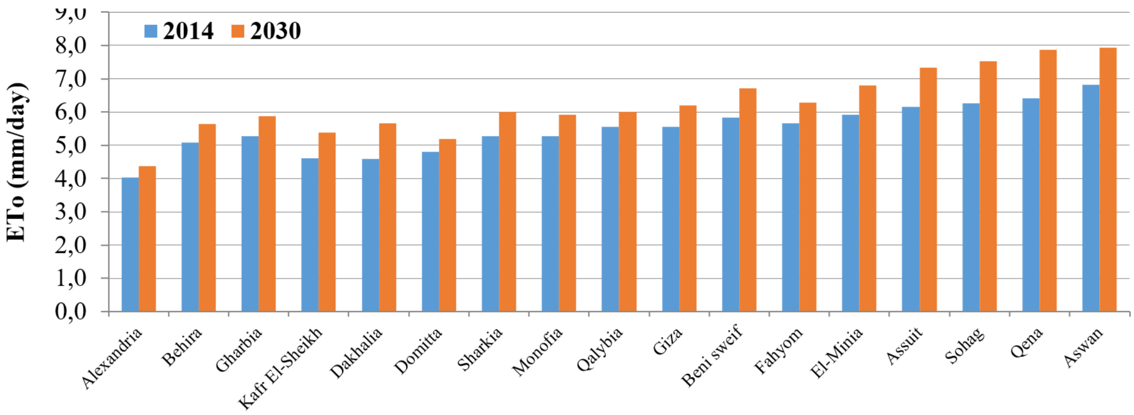

Figure 2: Comparison between ETo values in 2014 and the projected ETo values in 2030

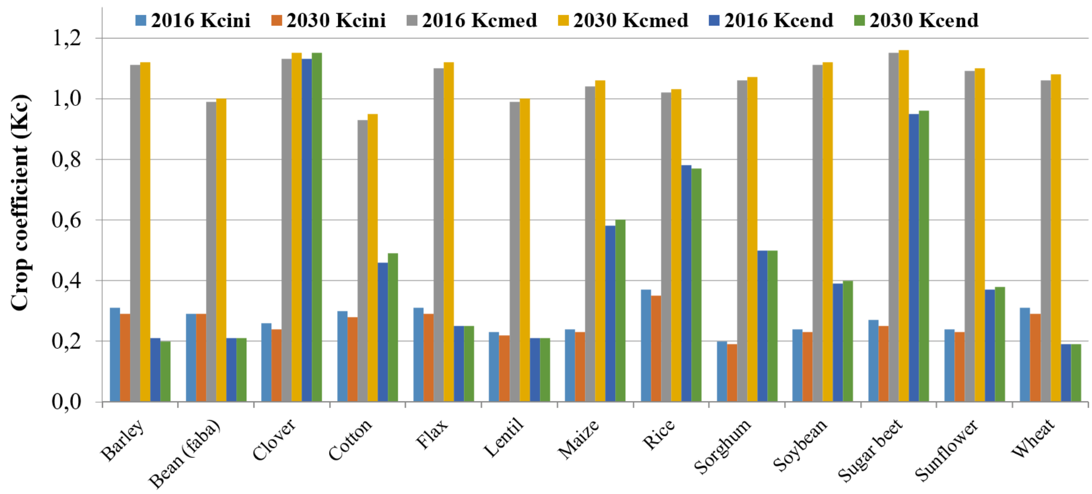

Figure 3: Comparison between Kc values in 2016 and 2030 for several field crops in Egypt

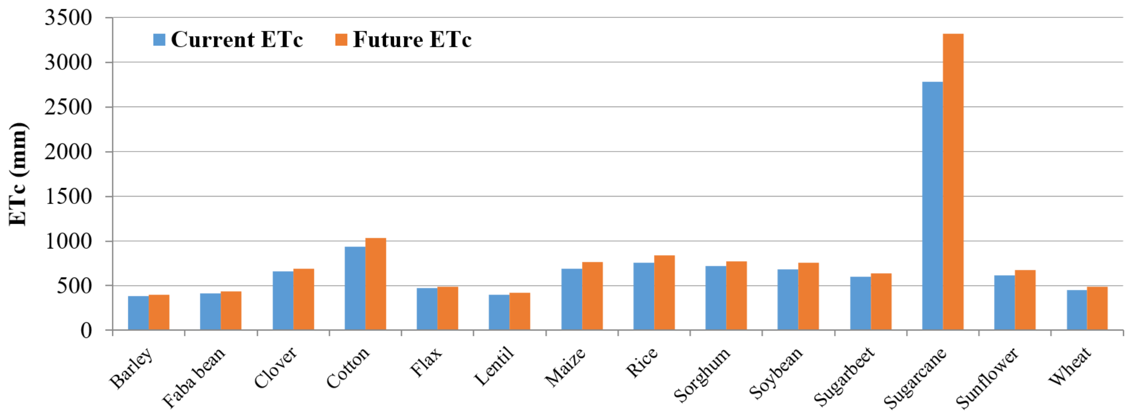

Figure 4: comparison between ETc values of different crops in 2016 and 2030

Climate change and cultivated lands in Egypt

Effect of climate change on agricultural soils

Only one study was done on the effect of climate change on the soil in Egypt. Muñoz-Rojas *et al*., (2017) applied the CarboSOIL model and global climate models to predict the effects of climate changes on soil organic carbon contents in 2030, 2050 and 2100 in Northern Egypt under different land use types. They projected an overall decreases of soil organic carbon contents in the topsoil soil layer and increases in the subsoil layers in the short, medium and long term. They also suggested that agricultural land relying on irrigation will be particularly vulnerable to losses of soil organic carbon stocks.

Effect of climate change on cultivated area

Fawaz and Soliman (2016) calculated that the loss in total cultivated area of Egypt in 2030 will be 8%, compared to the current cultivated area. Furthermore, Ouda and Zohry (2018) calculated the loss of the cultivated area of several winter and summer crops, as affected by the increase in its water requirements. The overall losses on the national level will reach 8 and 16% respectively for the winter and summer crops, compared to its counterpart value in 2015 (Table 4).

CLIMATE CHANGE AND CROPS RESILIENCY

Increasing the resiliency of cultivated crops to climate change was tackled in the context of reducing exposure, reducing sensitivity and increasing adaptive capacity.

Reducing exposure to climate change

Reducing exposure to climate change can be achieved by implementing resilient farming systems based on increased levels of biodiversity which can help improving its resiliency to shocks, as well as to promote soil health of the farm and nutritional output (Kozicka *et al*., 2020).

Integrated farms systems

To adopt diversity, farms should practice crops, and/or livestock production that lower reliance on external output (Lemaire *et al*., 2014). Eid *et al*., (2007) indicated that livestock and crops production is an excellent example of an integrated farm system, where feed crops and agricultural residues provide the feed for animals and, in turn, livestock manure is added to the soil to improve its fertility and reduce fertilizer use. It is a cheap way for society to conserve the environment and reduce pollution (El Sheikha, 2016).Ding *et al*., (2019) indicated that application of organic manure increased wheat yield grown in non-saline and saline soil under full irrigation by 18 and 11%, respectively.

Other integrated farm type is fish and crops farms, where fish effluents are used in irrigating the cultivated crops (van der Heijden, 2012). Integrated fish and crops farms attained similar sustainability as integrated livestock and crops farms. Irrigating crops with farm fish effluents improves soil quality due to organic matter that exists in fish water (Elnwishy *et al*., 2006). Isitekhale and Adamu (2016) reported that only 25% of N and 20% of P of fish feed is recovered in harvested fish and the rest is accumulated in farm effluent. Irrigation with fish farms

Table 4: Egypt cultivated area of winter and summer crops in 2015, the projected cultivated area in 2030 and percentage of reduction in the cultivated area

	Total cultivated area in 2015 (ha)	Total cultivated area in 2030 (ha)	Percentage of reduction (%)
Winter crops			
Wheat	1,354,844	1,260,005	7
Faba bean	34,418	32,353	6
Clover	624,741	568,514	9
Onion	148,173	128,910	13
Tomato	70,173	64,559	8
Potato	102,285	96,148	6
Sugar beet	231,193	212,697	8
		Average	8
Summer crops			
Cotton	100,349	84,665	16
Rice	506,249	445,499	12
Maize	938,329	760,046	19
Soybean	14,130	11,728	17
Sunflower	6,585	5,465	17
Potato	53,110	43,989	17
Tomato	89,825	71,860	20
Sugarcane	134,656	111,765	17
Fruit trees	524,763	455,565	13
		Average	16

Table 2: Projected percentage of increase in water requirements of several crops under climate change in 2050 using MAGICC/SCENGEN model

Crop	Percentage of increase in water requirements (%)	Reference
Wheat	+3 Not changed +1	Eid et al., (1993) Eid et al., (1994) Eid et al., (1997a)
Maize	+8	Eid et al., (1992)
Barley	+1	Eid et al., (1995)
Rice	+16	Eid et al., (1995)
Soybean	+3 +1	Eid and El-Sergany (1993) Eid et al., (1994)

effluents can substitute for 100% of fertilizer applied to winter crops (Zohry *et al*., 2020; Hefny *et al*., 2020) and for 50% of the applied fertilizer to summer crops (Zohry *et al*., 2020; Selim and Shams, 2019). AbdElMagid *et al.* (2018) reported that using fish farm effluent in irrigating onion and sugar beet increased yields by 16% for both crops without adding any chemical fertilizers.

Increasing crops diversification

Crop diversification strategies simultaneously increase net crop production and also improve soil health by imparting interspecific interactions among different crop species both above and below ground (Rakshit *et al*., 2018). Aboveground diversification increases canopy heat and light capture, whereas belowground diversification assists in better utilization of water and soil macro- and micro-nutrients (King and Hofmockel, 2017). Increasing crops diversification can be done by cultivating three crops per year (winter, fall then summer crops or winter, early summer then late summer crops) instead of two crops per year. This system has many beneficial effects on soil fertility, if legume crop was cultivated in between the winter crop and the summer crop. Zohry *et al*., (2017) compared between the effect of conventional crop sequence, namely wheat then maize and cultivation of three crops per year, namely maize, short-season clover, then wheat on wheat yield. Their results indicated that wheat productivity was increased by 16 and 47% in the first and second season, respectively when short-season clover followed maize, compared to maize fallowed by wheat sequence.

Furthermore, implementing intercropping systems can increase crop diversification and increase resilience to climate. Intercropping alters the microclimate of the soil by changing soil temperature and moisture: it changes the pattern of dispersal through wind, rain, or a vector that inclusively benefits the intercropped plants in one way or another. It increases nitrogen and carbon content in the rhizospheric soil, and therefore those resource pools can be further used by successive crops (Zang *et al*., 2015). Intercropping reduces water runoff and soil loss (Lithourgidis, 2011), increases nutrient availability and improves soil quality (Li *et al*., 2014). Furthermore, spatial arrangement and different pattern of roots exploit soil nutrients in this system minimize plants competition (Ijoyah and Fanen, 2012). Double benefits can be attained if these above mentioned were implemented in a crop rotation. Abou-Keriasha *et al*., (2012) implemented three crop rotations (prevailing, low intensive and high intensive rotations) and they reported that the yield of the cultivated crops, soil organic matter content were increased in the low intensive and high intensive rotations, compared to its counterpart values under the prevailing crop rotation.

Reducing sensitivity of crops to climate change

Reducing sensitivity of crops to climate change can be implemented by either management practices or cultivation of climate-resilient crops.

Using improved management practices on farm level

Several management practices were proven to be effective to reduce the sensitivity of the cultivated crops to water and salinity stress caused by climate change. El-Samnoudi *et al*., (2019) indicated that application of poultry manure and mulching to sorghum grown under deficit irrigation alleviated the effect of water stress and produced yield similar to the unstressed plants. Talaat *et al.* (2015) found that foliar application of 0.1 mg L^{-1} 24-epibrassinolide (EBL) and 25 mg L^{-1} spermine (Spm) to maize grown under drought stress conditions resulted in increasing in drought tolerance. Furthermore, Abdullah *et al.* (2015) found that the negative effects of late-season drought on growth and yield of wheat could be mitigated by application of an anti-transpirant, where it helped in increasing plants water use. Furthermore, Abd Allah *et al*., (2021) indicated that spraying faba been intercropping system with sugar beet with 200 ppm potassium silicate positively affected the yield of both crops and water equivalent ratio under deficit irrigation. Baddour *et al*., (2017) reported that spraying maize plants with ascorbic and proline, in addition to application of chicken manure, increased maize yield under saline conditions.

Cultivation of climate-resilient crops

Climate-resilient crops were defined by Dhankher and Foyer (2018) as "both crops and crop varieties with enhanced tolerance to biotic and abiotic stresses, which have the ability to maintain or increase crop yields under stress conditions such as drought, flooding, heat, chilling, freezing and salinity". Examples of climate-resilient crops are quinoa, pearl millet and sorghum.

The quinoa plants are reported to be tolerant to heat stress (Hinojosa *et al*., 2019), drought (Garcia *et al*., 2007) and salinity stress (Adolf *et al*., 2013). Quinoa has been selected by Food and Agriculture Organization of

Table 3: Percentage of increase in national irrigation water demand in 2050 and 2010

Climate change scenario	2050*	2100*
A1	8	16
A2	7	11
B1	6	7
B2	7	9
Average	7	11

**Calculated from Attaher et al., (2006).*

The United Nations (FAO, 2013a), as one of the crops destined to contribute to food security in this century. It has nutritional advantage over major cereals of the world. Quinoa seeds contained 16.5 g protein, 6.3 g fat, 3.8 g ash, 3.8 g crude fiber, 69.0 g carbohydrate, and energy amount of 399 Kcal/100 g. All these nutrients are higher than what found in wheat, maize, and rice (Hulse *et al*., 1980; United States National Research Council). Although quinoa grains do not contain gluten, it can be mixed with wheat flour in the preparation of bread with high nutritional value. Substituting wheat flour with 20% quinoa resulted in elevating protein, fat and fiber percentages than that of wheat flour (Soliman *et al*., 2019).

Millets are one of the world's six major cereal commodities, and it is consumed by one-third of the world's population. It can tolerate heat stress (Sage and Zhu, 2011), salinity stress (Yakubu *et al*., 2010) and water stress (Sher *et al*., 2019). It is nutritionally superior to other major cereals as they are rich in vitamin B, folic acid, phosphorus, iron and potassium. (Gupta *et al*., 2011). Pearl millet seeds contained 11.8 g protein, 4.8 g fat, 2.2 g ash, 2.3 g crude fiber, 67.0 g carbohydrate, and energy amount of 363 Kcal/100 g. In addition, it contained 42 mg Ca and 11 mg Fe (Hulse *et al*. 1980; United States National Research Council). Pearl millet has been cultivated in Egypt as a forage crop. Further research should be done on including it in bread making in Egypt.

Furthermore, sorghum is also considered as a climate-resilient crop. It was documented that sorghum resiliency is expressed in it being heat tolerant (Chiluwal *et al*., 2019), salinity tolerant (Shakeri and Emam, 2017) and water stress tolerant (Surwenshi *et al*., 2010). It is gluten-free and can substitute for wheat flour in bread making (Ismail and El-Nakhlawy, 2019). Sorghum seeds contain 10.4 g protein, 3.1 g fat, 1.6 g ash, 2.0 g crude fiber, 70.7 g carbohydrate and energy amount of 329 Kcal. In addition, it contained 25 mg Ca and 5.4 mg Fe (Hulse *et al*., 1980; United States National Research Council). Sorghum is more common in southern Egypt and is cultivated for its grain, used in bread making.

Increasing adaptive capacity

Increasing adaptive capacity to climate can be done using early warning systems. The concept of the early warning system is used as a tool for planning before extreme weather events (Basher, 2006). In Egypt, Young *et al*., (2021) presented a practical approach of incorporating critical rainfall thresholds, historical flood data and precipitation forecast for forecasting extreme rainfall and flooding in Alexandria, North Egypt, which could help in improving decision-making especially in data-scarce regions or cities for developing early warning system. Furthermore, Baldi *et al*., (2020) studied the spatio-temporal evolution of selected episodes of heavy rainfall trend over Sinai Peninsula, Egypt to improve early warning systems. The study was based on the analysis of meteorological data from ground stations in Sinai and rainfall estimates derived from satellite images with the aim to help the decision-makers to plan the construction of flood water harvesting structures and flash flood protection works.

REDUCTION OF THE EMISSION OF GREENHOUSE GASES

Accurate application of irrigation water to crops

The prevailing irrigation system in the old lands in Egypt is surface irrigation, which resulted in applying large amounts and that causes wasteful use of this valuable resource. Farmers used to pump water using diesel-powered pumps for irrigation, which have contributed in increasing greenhouse gases emission. Several practices were done to reduce the wasteful used of irrigation water:

• ***Application of the required irrigation*** amounts to crops, which will reduce the amount of fossil fuel used to pump water and consequently reduce the emission of GHGs.

• ***Land consolidation*** was done in several governorates of Egypt to unify irrigation dates, thus reduce the amount of fossil fuel used to pump the water (Ouda and Zohry, 2022).

• ***Implementing precise land leveling*** to reduce the applied water under surface irrigation, which improve crops productivity (Bahnas and Bondok, 2010), changing cultivation method from basins or furrows to raised beds proved to save applied irrigation water (Zohry *et al*., 2019). Farmers training on irrigation scheduling using simple scheduling technique was done in several governorates of Egypt to apply the required irrigation water to crops (Ouda and Zohry, 2022).

• Recently, the government of Egypt revealed a plan to ***change irrigation system from surface*** in the Nile Delta and Valley to sprinkler or drip, which will reduce the applied irrigation to the crops and consequently reduce the use of fossil fuel and reduce greenhouse gases emissions.

Using solar energy in irrigation systems

Lately, many farmers have switched to renewable solar energy in irrigation systems to pump water for irrigation, as an alternative to diesel or electric energy, which has lower operating cost, compared to using diesel or electricity (Taha, 2018 and 2019; Taha and Ghandour, 2021; Taha and Khalifa, 2022). the use of renewable solar energy in irrigation systems has also significant advantages, namely it requires minimal maintenance beyond cleaning the panels once a week. Furthermore, it eliminates any greenhouse gases emission as a result of using diesel pump.

The Farm-level Irrigation Modernization Project was implemented in Egypt to increased access to modern irrigation systems in the Mahmoudia, Manaifa and Meet Yazid canals in Egypt, primarily by phasing out diesel pumps and introducing electric ones, as well as by constructing an electricity grid to power the modernized pumping stations. A total of 197,633 water users (including landholders and tenants) benefited through improved irrigation and drainage services from this project (World Bank, 2020).

Soil carbon sequestration

Soil carbon sequestration can reduce the magnitude of CO_2 release to the atmosphere. It implies the removal of atmospheric CO_2 by plants and stored as soil organic matter (Lal, 2004). Application of organic manure and compost can potentially sequestrate more carbon to the soils and thus convert the soils to a net CO_2 sink (Gattinger *et al*., 2012).

Intercropping can increase soil carbon sequestration. Recent studies suggest greater input of carbon into the soil through root residues in intercropping systems, as compared to sole crops (Li *et al*., 2014). It was reported that cover crops increased soil organic carbon stock by 9-10% (Bolinder, 2020). In Egypt, Zohry *et al*. (2020) stated that an increase by 8% in soil organic matter was observed when pea was intercropped with sunflower and the increase was 9% when pea intercropped with wheat.

Reduction of GHGs emission from rice fields

Several field managements were documented to reduced emission of CH_4 and N_2O from rice fields. Hadi *et al*., (2010) indicated that intermittent drainage could reduce greenhouse gases emission by around 14.7 to 68.5%, compared to continuous flooding. Whereas, alternate wetting and drying could reduce the emissions by 33-39%, compared to continuous flooding with no yield differences (Setyanto *et al*., 2017). Intermittent irrigation and saturated soil have less CH_4 emission (around 53-67%), compared to continuous flooding (Husin *et al*., 1995).Water savings techniques applied to rice field can largely contribute to reduction of the emission of $CH_4$and N_2O (Djaman *et al*., 2018). Furthermore, conversion from paddy rice cultivars to upland cultivars can contribute in reduction of greenhouse gases (Nishimura *et al*., 2008).

In Egypt, rice belt is located in the Northern Nile Delta, where CH_4 emission is representing about 53.3% of the agricultural greenhouse gases emissions (Farag *et al*., 2013a). Recently, the total CH_4 emissions from rice cultivation in Egypt are steadily decreasing due to switching from long-season traditional rice cultivars to early-maturing short-duration cultivars (Farag *et al*., 2013b). Furthermore, the cultivation of new upland rice cultivars is now expanding in Egypt.

Elimination of burning of crops residues

In Egypt, it was estimated that about 3.1 Mt/year of rice straw are directly burned in open field (FAO, 2013b), as well as other crops residues (Abdelhady *et al*., 2014). These crop residues can be used in production of biogas (Zayat *et al*., 2015). Biogas is produced from anaerobic degradation of organic materials. Biogas units can be installed in the farmers households and use crop residues and animal manure, which will be fermented in biogas digesters and a significant amount of methane is produced that could be used in cooking, heating and generating electricity (Zayat *et al*., 2015). Furthermore, the potential utilization of the digestate as fertilizers can also reduce dependence on mineral fertilizers (Pöschl and Owende, 2010), which will also reduce emission of greenhouse gases. Thus, biogas generation serves three important functions: waste removal, environmental management and energy production (Ford, 2007).

CONCLUSION

Assessments of the effect of climate change on water and soil resources in Egypt, as well as crops production and its water requirements are essential measures to increase its resilience to face the harmful effects. The sustainable use of natural resources under climate change entails its rational use that allow to maintain these resources for the future generation. With respect to water and soil resources, several procedures were reviewed in this paper to conserveit without jeopardize the loss in crops production. Furthermore, methods to reduce the emission of greenhouse gases were also tackled. Thus, it could be concluded that these measures contribute in increasing food security.

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