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ADAPTATION OF SUGARCANE NATIONAL PRODUCTION IN EGYPT TO CLIMATE CHANGE

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ABSTRACT

Climate change is expected to increase water requirements for sugarcane and reduce its production in Egypt. In this paper, we quantified the effect of increase water requirements under climate change on cultivated areas of spring sugarcane in four governorates. Assessed the suitability of these governorates for sugarcane cultivation in 2040. We also investigated the effect of using gated pipes to reduce the applied irrigation water to sugarcane and the effect of intercropping oil crops with sugarcane on the applied water for sugarcane as adaptation strategies. Water requirements were calculated using BISm model. ECHAM5 climate model was used to develop A1B climate change scenario in 2040. The results showed that using gated pipes for irrigation saved an amount of irrigation water and it can be invested in cultivation of extra area of sugar beet and wheat. In 2040, water requirements for sugarcane will increase by an average 17% and the production will be reduced by average of 14% over the studied governorates. The results also indicated that the temperature in the studied governorates can sour up to 44°C during the period of May to August, which implied that sugarcane productivity will be reduced in 2040 in this region, however it will be still suitable to grow sugarcane. Using gated pipes for irrigation under climate change will maintain the old cultivated area and reduce the new cultivated area of sugarcane. Intercropping oil crops with spring sugarcane can reduce production-consumption gap of edible oil. Thus, these adaptation strategies can reduce climate change risk on sugarcane production in Egypt.

INTRODUCTION

Sugarcane is main source of sugar in Egypt. It is cultivated only in Upper Egypt in four governorates, where the prevailing weather conditions are suitable to its production. These governorates are El-Minia, Sohag, Qena and Aswan. The crop consumes large amounts of irrigation water as a result of inappropriate water management. Many industries are dependent on sugarcane cultivation in Upper Egypt. Thus, reduction in its cultivated area is not considered as a solution to better use of water resources, instead better water management is required.

As it is anticipated, climate change is expected to increase temperature. To date, global mean temperatures have increased by about 0.7°C since mid-1800s although the temperature increase is not uniform **(IPCC, 2007).** There were many published papers on the effect of climate change on several crops in Egypt. However, there was only one published paper on the effect of climate change on sugarcane in Egypt; but we could not obtain it. On the other hand, there are inconsistent results obtained internationally, where researchers concluded that sugarcane yield will be increased or decrease under climate change. **Singels et al., (2014)** indicated that sugarcane yield will increase under climate change in South Africa. Whereas, **Deressa et al., (2005)** reported that an increase by 2 ºC will negatively affect sugarcane yield in South Africa. Furthermore, **Chandiposha (2013)** concluded that sugarcane production will decrease in Zimbabwe under temperature increase. Furthermore, **Knox et al., (2010)** found a decreasing trend for future projections of sugarcane yield in Swaziland, unless irrigation was included in the simulations. On the other hand with temperature increase, in Brazil, **Singels et al., (2014)** indicated that its yield will be increase. Furthermore, **Marin et al., (2013)** reported that in South Brazil, the yield will increase as a result of rain increase of some climate change scenarios or CO_2 fertilization in other scenarios.

However, temperature increase is likely to have negative effect on physiological processes of sugarcane plant. Since sugarcane is a C4 plant species, whose photosynthetic pathway increases carbon dioxide assimilation with increase in temperature in the range of 8 to 34°C **(Sage and Kubien, 2007).** The temperature increase due to climate change is likely to improve sugarcane growth during winter since very low temperatures constrain leaf growth rate and photosynthesis, although it increases sucrose accumulation **(Gawander, 2007).** Furthermore, high temperatures is likely to negatively affect sprouting and emergence of sugarcane **(Rasheed et al., 2011)**. Poor emergence of sugarcane will result in significantly low plant population. In addition, temperatures above 32°C result in short internodes, increased number of nodes and lower sucrose **(Bonnett et al., 2006).** Thus, climate change is likely to reduce sugarcane and sucrose yields. Furthermore, **Clowes and Breakwell (1998)** revealed that high temperatures, especially at night, usually result in more flowering of sugarcane. Flowering in sugarcane ceases growth of leaves and internodes, this reduces sugarcane and sucrose yields. At tillering stage, the crop favored higher minimum temperature (about 26.2°C). Whereas, temperatures above 38°C make sugarcane growth seize (**Bonnett et al., 2006).**

Furthermore, high daily crop evapotranspiration due to high temperatures may cause water stress in sugarcane and that might require applying more frequent irrigation. Since water requirements for sugarcane in Egypt is between 34,255- 51,055 m^3/ha under surface irrigation with low application efficiency, i.e. 55%, it is very important to consider ways to reduce these large applied amounts, without any reduction in sugarcane productivity. It has been reported by **El-Khatib and Sherif (2007)** that irrigating sugarcane with gated pipes increased application efficiency by 10% and increase productivity by 12%.

Spring sugarcane (planted in February) offers a unique potential for intercropping because sugarcane planted in wide rows, and takes several months to develop its canopy, during which time the soil and solar energy goes to waste. The growth rate of sugarcane during its early growth stages is slow, with leaf canopy providing sufficient uncovered area for growing of another crop **(Nazir et al., 2002).** Furthermore, we can make use of the high amount of applied water to sugarcane by intercropping with summer crops, such as soybean, sesame and sunflower can be intercropped with it. Intercropping summer oil crops with spring sugarcane is very common practice done by Egyptian farmers. Intercropping soybean with sugarcane plays a considerable role in reduction of fertilizer costs. **El-Geddawy et al., (1988), Zohry (1994), Eweida et al., (1996) and Abou-Kreshe et al., (1997)** intercropped soybean with spring sugarcane and they concluded that sugarcane yield was increased, as well as land productivity. Intercropped sesame with spring sugarcane, is common practice where competition over solar radiation between sesame plants and sugarcane plants was low because sesame leaves are erect and does not cause any shading over the growing sugarcane plants **(El-Geddawy et al., 1995 and Abou-Kreshe et al., 1997). El-Gergawi et al., (2000)** indicated that land productivity was increased when sunflower was intercropped with spring sugarcane. However, **Abou-Kreshe et al., (1997)** indicated that competition over solar radiation between sunflower plants and sugarcane plants was high because sunflower plants are than sugarcane plants in that growth stage.

In this paper, we quantified the effect of increase water requirements under climate change on cultivated areas of spring sugarcane in four governorates. Furthermore, we assessed the suitability of these governorates for sugarcane cultivation in 2040. We also investigated the effect of using gated pipes to reduce the applied irrigation water to sugarcane and the effect of intercropping oil crops with sugarcane on the applied water for sugarcane as adaptation strategies to reduce climate change risk on sugarcane production in Egypt.

MATERIALS AND METHODS

Description of the studied area

The studied area is composed of four governorates located in the Upper Egypt. These governorates are: El-Minia (lat. 28.05º, long. 30.44, 40.0 masl), Sohag (lat. 26.36º, long. 31.38º, 68.70 masl), Qena (lat. 26.10º, long. 32.43º, 72.60 masl) and Aswan (lat. 24.02º, long. 32.53º, 108.30 masl).

The climate of the regions is very dry. The weather data indicate that the average monthly low temperature varied from 11.4, 14, 14.55 and 15.90 °C in January to 30.95, 31.15, 31.57 and 32.8 °C in August, for El-Minia, Sohag, Qena and Aswan respectively. Maximum temperatures varied from 20.4, 20.5, 21.0 and 22.3 °C in January to 37.6, 37.8, 38.9 and 39.6 °C during in August, respectively. While, relative humidity values ranged between (28-45.1%), (21.5-39.8%), (19.20-37.1%) and (17.2-39.9%) in January to August for El-Minia, Sohag, Qena and Aswan, respectively.

The soil of the studied area is clay in texture in the four governorates. Soil texture in El-Minia is composed of 15.7% sand, 31% silt, and 53.3 % clay, in Sohag is composed of 17.1% sand, 28.80% silt, and 54.1 % clay, in Qena is composed of 18.2% sand, 27.9% silt, and 53.53.9 % clay and in Aswan is composed of 53.2% sand, 28.3% silt, and 53.20 % clay. The average bulk density is 1.73, 1.78, 1.77 and 1.76 Mg m^3 for 0-90 cm depth, respectively and it is alkaline in reaction with pH values ranging from 7.95 to 8.42. Average soil salinity expressed as soil electrical conductivity (EC) in the saturated soil paste extract and organic matter content over 90 cm depth is about 0.60 dS/m and 1.52%, respectively. Field capacity, wilting point and available water values were 36.30, 17 and 16 in El-Minia, 36.83, 17.50 and 6.25 in Sohag, 36.70, 17.40 and 16 in Qena, and 36.92, 17.49 and 16.27 in Aswan, respectively. Total N and the available macronutrient values (P and K) were 0.38%, 7.40 ppm, and 268 ppm) in El-Minia, 0.40%, 7.51 ppm, and 272 ppm in Sohag, 0.39%, 7.47 ppm, and 266 ppm in Qena and 0.40%, 7.54 ppm, and 273 ppm in Aswan, respectively for El-Minia, Sohag, Qena, Aswan.

Cultivated area, productivity and production

Data for sugarcane cultivated area and productivity (ton/ha) and production, as well as soybean, sesame and sunflower cultivated area in 2013 were obtained from Central Administration for Agricultural Economics; Ministry of Agriculture and Land Reclamation in Egypt in 2012/13.

BISm model

The Basic Irrigation Scheduling model (BIS **Snyder et al., 2004**) is a model used in irrigation management of crops. It calculates evapotranspiration (ETo), crop factor (kc), water depletion from root zone and it schedules irrigation. The BISm application calculates ETo using the Penman-Monteith equation (as presented in **Allen et al. 1998**). Monthly

ETo values for each governorate, as an average over 10 years, from 2002 to 2011, were calculated. The used weather data were maximum and minimum temperature, relative humidity, wind speed and potential sun shine hours. For ETo calculations, the station latitude and elevation must be input. After calculating daily means per month, a cubic spline curve fitting subroutine was used to estimate daily ETo rates for the entire year. The model requires the input sowing and harvest dates to calculate crop kc; irrigation frequency to determine initial kc; water field capacity, and available water to calculate water depletion from root zone.

The BISm model was used to calculate water requirements for sugarcane using surface irrigation with 50% application efficiency under current climate and in 2040 for each of the four governorates. Sowing date for spring sugarcane was assumed to be 15th of February 2012, and harvested date was on 14 of February, which are the recommended dates. The same sowing date was assumed under climate change. Representative values for water holding capacity and available water in the soil of each governorate were used in the model. These values were obtained from our Department (unpublished results). Irrigation schedule for sugarcane was developed for each governorate and water requirements under surface irrigation were calculated.

CHAM5 climate change model

The climate change model ECHAM5 **(Roeckner et al., 2003)** was used. The model is an atmospheric oceanic general circulation model. The resolution of the model is 1.9 × 1.9 degrees. ECHAM5 model was used to develop A1B climate change scenario for each weather station in each governorate in 2040.

Temperature stress on sugarcane growing season

Because not found any research on the effect of climate change on sugarcane yield locally, investigated the effect of temperature increase above 38°C (cutoff temperature), where the deviation between maximum temperature and cutoff temperature will seize growth **(Bonnett et al., 2006)**. Thus, graphed cutoff temperature (for sugarcane growth in the growing season with measured temperature under current weather and projected temperature under climate change in each governorate.

Irrigation water management

The amount of water applied in each irrigation event, as well as the irrigation intervals were calculated by BISm model. Calculated the amount of water that can be saved as a result of using gated pipes for irrigation instead of surface irrigation. Suggested using these amounts of saved water to cultivate sugar beet and wheat. The water requirements of sugar beet and wheat were also calculated by BISm model. These calculations were done under current climate and in 2040 under climate change.

RESULTS AND DISCUSSION

Current situation of spring sugarcane production

Table (1) presented spring sugarcane cultivated area, productivity and total production in 2012/13 growing season. Sugarcane cultivated area was 105,879 hectare, which produced 12,438,550 ton. The total water requirements for its cultivated area were 4,576,445,141 m^3. This large water amounts is a result of low application efficiency under surface irrigation, i.e. 55%. Furthermore, high temperature in these four governorates increases evaporation demand and water requirements.

Table (1): Sugarcane cultivated area, productivity, total production, water requirements per hectare and total water requirements under surface irrigation in the studied governorates.

Governorates	Cultivated area (ha)	Productivity (ton/ha)	Total production (ton)	Water requirements (m^3/ha)	Total water requirements (m^3) ×10^6
El-Minia	16,456	114.0	1,875,965	34,255	563.7
Sohag	6,706	116.9	783,827	36,360	243.8
Qena	48,633	120.0	5,835,950	41,716	202.8
Aswan	34,084	115.7	3,942,808	51,055	1740.1
Total	105,879	116.6	12,438,550	40,846	4576.4

Potential sugarcane productivity under gates pipes

Irrigation of sugarcane with gated pipes can increase water application efficiency to 70%. This efficiency can be attributed to short irrigation period, which lead to low water percolation into the soil and low evaporation losses from soil surface **(El-Berry et al. 2006).** Thus, water requirements per hectare will be decrease, productivity and total production will increase. The total production was increased from 12,438,550 ton (Table 1) to 14,926,260 ton. In addition, an amount of irrigation water could be saved, i.e. 980,666,816 m^3 (Table 2).

Table (2): Water requirements (WR) and potential sugarcane production under gated pipes and amount of saved water under gates pipes in the studied governorates.

Governorates	WR under surface irrigation (m^3/ha)	WR (m^3/ha) under gates pipes	Productivity (ton/ha)	Total production (ton)	Amount of saved water (m^3)
El-Minia	34,255	26,914	136.80	2,251,158	120,790,091
Sohag	36,360	28,569	140.26	940,592	52,251,268
Qena	41,716	32,777	144.00	7,003,140	434,740,379
Aswan	51,055	40,114	138.82	4,731,370	372,885,078
Total	40,846			14,926,260	980,666,816

The amount of saved water in El-Minia and Sohag governorates could be invested in sugar beet cultivation to reduce sugar production-consumption gap. Regarding to Sohag, Qena and Aswan, sugar beet is not suitable for cultivation there. Therefore, we suggested using these amounts of water to cultivate wheat to reduce its production-consumption gap in these governorates. Table (3) indicated that under surface irrigation, sugar beet cultivated area could be increased by 17,806 hectare and larger area can be cultivated under drip system, i.e. 26,709 hectare over the two governorates. Regarding to wheat, 112,790 hectare can be cultivated under surface irrigation or 150,386 hectare can be cultivated under sprinkler irrigation system over the two governorates.

Table (3): Suggested crops to be cultivated in the studied governorates and its cultivated area.

Governorates	Suggested crop	Cultivated area under		
		Surface	Sprinkler	Drip
El-Minia	Sugar beet	12,751	--	19,126
Sohag	Sugar beet	5,055	--	7,583
Qena	Wheat	66,373	88,497	--
Aswan	Wheat	46,417	61,890	--

Effect of climate change on sugarcane grown under surface irrigation

Results in Table (4) indicated that water requirements for sugarcane grown under surface irrigation will be increased by about 17% averaged over all governorates in 2040 under climate change (Table 4). This finding can be attributed to temperature increase, which is likely to have an effect on physiological processes of sugarcane plants. Temperature increase above 34°C can pose as stress on these physiological processes **(Gawander, 2007; Sage and Kubien, 2007).** Accordingly, changing surface irrigation to gated pipes in sugarcane can be used as an adaptation strategy to reduce climate change risk on sugarcane production.

Table (4): Actual and predicted amount of water requirements and yield sugarcane under surface irrigation in the studied governorates in 2040.

Governorates	Actual WR (m^3/ha)	Predicted WR (m^3/ha) 2040	Increment Percentage of WR	Actual yield (ton/ha)	Predicted yield (ton/ha) 2040	Decrement Percentage of the yield (%) 2040
El-Minia	34,255	39735.8	16	1,616,216	1,389,945.76	14
Sohag	36,360	42177.6	16	677,324	582,498.64	14
Qena	41,716	48390.56	16	5,018,353	4,315,783.58	14
Aswan	51,055	59223.8	16	3,318,657	2,787,671.88	16
Total	40,846	189527.8	--	10,630,550	9,075,899.86	--

Effect of temperature stress on sugarcane growing season

In El-Minia and Sohag governorates, the measured temperature and the projected temperature in 2040 will be higher than the cutoff temperature for sugarcane growth (38°C) from May to September (Figure 1a and 1b). However, larger number of days where temperature was higher than 38°C in 2040 existed, compared to the measured temperature values. Similar trends were observed in Qena and Aswan, however number of days, where temperature was higher than 38°C prevailed to October in Aswan (Figure 1c and 1d). The results in all figures also indicated that the temperature in the studied governorates can sour up 44°C during the period of May to August in El-Minia and Sohag under climate change in 2040. High temperatures due to climate change may increase water requirements of sugarcane crop, as well as decreased sugarcane production. However, elevated temperatures due to climate change are likely to reduce natural ripening and quality of sugarcane **(Chandiposha 2013).**

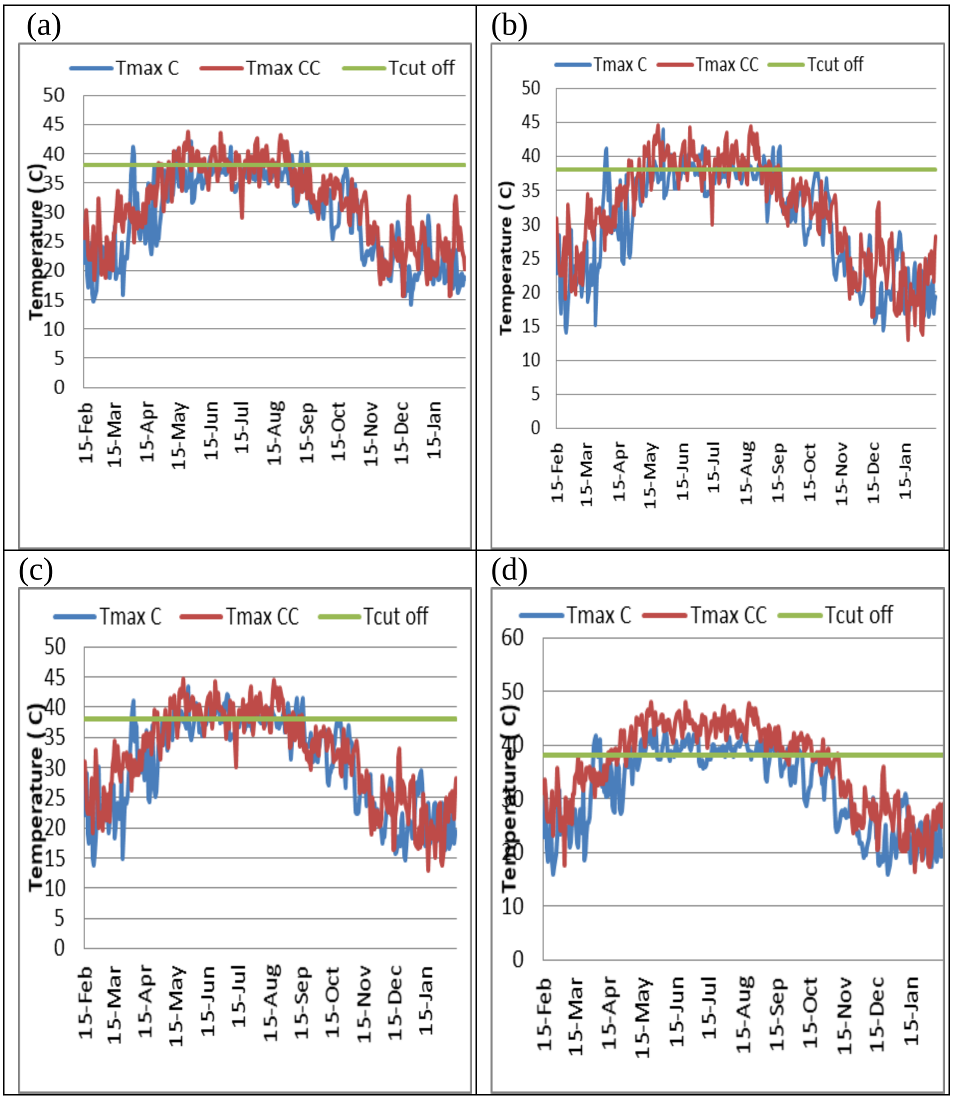

Figure (1): Effect of prevailing temperature (current and climate change) on sugarcane growing season in: (a) El-Minia, (b) Sohag, (c) Qena and (d) Aswan governorates.

Furthermore, temperature could reach 45 and 48°C in Qena and Aswan governorates, which will cause high temperature stress, causing increased water requirements of sugarcane especially in Aswan governorate under current climate and under climate change. Frequent irrigation cycles to meet high evaporation rates is likely to require more irrigation water from the storage reservoir, intensifying the competition for water between sugarcane production and other sectors.

These findings implied that sugarcane productivity will be reduced in 2040 in this region. However, it will be still suitable to grow sugarcane. Although study of sugarcane yield losses under climate change in Egypt was not yet done, this current study is considered the first to quantify the effect of climate change in sugarcane.

Potential sugarcane productivity irrigated with gated pipes in 2040

Using gated pipes for irrigation under climate change will be result in total production equal to 9,890,984 ton (Table 5). As a result of reduction in the applied water using gated pipes, the saved water amounts will be decrease to 530,869,7414 m^3. Gated pipes are a tool for development of surface irrigation. It is a new method to be used to distribute water into furrow irrigated fields as strategy based on water saving **(Goyal, 2014).**

Table (5): Applied water and potential sugarcane production under gated pipes and amount of saved water in the studied governorates in 2040.

Governorates	Applied water (m^3/ha)	Productivity (ton/ha)	Total production (ton)	Amount of saved water (m^3) $\times 10^6$
El-Minia	39,735.8	114.91	1,890,973	653.9
Sohag	42,177.6	117.82	790,097	282.84
Qena	48,390.56	120.96	5,882,638	235.33
Aswan	59,223.8	116.61	3,974,351	201.86
Total			9,890,984	530.87

Results in Table (6) revealed that under surface irrigation, sugar beet cultivated area could be increased by 7,378 hectare and larger area can be cultivated under drip system, i.e. 11,066 hectare over the two governorates. This based on the water requirement under surface, sprinkler and drip irrigation. **Arnaout (1999)** reported that the efficiency of any irrigation system depends deeply on water supply in the desired time. It was found that the average irrigation efficiency of drip system of 97.50% increased by 15.80% and 38.20% more than irrigation efficiency of sprinkler (81.70%) and furrow (59.30%) system, respectively. That is due to the absence of deep percolation of drip system and less evaporation. Distribution uniformity recorded 78.33 and 75.83% for sprinkler and furrow system, representing 5.87 and 8.37% less than average uniformity of the drip system (84.20%). **Abd EL- Hafez et al. (2001)** reported that by comparison with flooding method, sprinkler irrigation recorded lower percolation and higher water application efficiency to be 18.35 and 81.65%, respectively. In addition, field and crop water use efficiencies exceeded by 34.18 and 8.40%, respectively. The application of modern irrigation techniques, such as drip, bubbler and sprinkler to increase irrigation efficiency is one of the measures utilized for competent use of water **(NWRP, 2002)**. Efficient irrigation systems require the selection of an appropriate method for the crop growth, adequate monitoring of the irrigation system and of water delivery and appropriate application rates depending on the growth stage of the crop. Irrigation requirements differ depending on the locations, soil types and cultural practices **(Bilalis et al., 2009; Abd El-Halim et. al., 2016)**. The table (6) also showed that 41,131 hectare of wheat can be cultivated under surface irrigation or 54,841 hectare can be cultivated under sprinkler irrigation system over the two governorates.

Table (6): Suggested crops to be cultivated in the studied governorates and its cultivated area.

Governorates	Suggested crop	Cultivated area under		
		Surface	Sprinkler	Drip
El-Minia	Sugar beet	5,237	--	7,856
Sohag	Sugar beet	2,141	--	3,211
Qena	Wheat	26,723	35,631	--
Aswan	Wheat	14,408	19,210	--
Total	--	--	54,841	--

Intercropping oil crops with spring sugarcane to reduce production-consumption gap

The total cultivated area of soybean in Egypt was 9,405 hectare in 2013 growing season, and its total production was 29,576 ton. Results of (Table 7) growing seasons in that table indicated that in 2013 growing season, soybean was not planted in Qena and Aswan governorates. Thus, if we added the assigned sugarcane area to for intercropping soybean cultivated area, the cultivated soybean area will increase from 7,560 hectare in these four governorates to 42,853 hectare. This increase in the soybean cultivated area will increase its production and reduce edible oil gap in Egypt. The proper intercropping pattern increase light use efficiency **(Awal et al., 2006; Jiao et al., 2008)**, achieve water saving **(Feng et al., 2016; Metwally et al., 2017)**, with the advantage of high and stable yield than sole crop. Yield is taken as primary consideration in the assessment of the potential of intercropping practices.

Table (7): Potential soybean cultivated area under intercropping with sugarcane in the studied four governorates.

Governorates	Sugarcane cultivated area (ha)	Soybean cultivated area (ha)	Total area (sugarcane and soybean area) (ha)
El-Minia	5,485	7,543	13,028
Sohag	2,235	17	2,252
Qena	16,211	--	16,211
Aswan	11,361	--	11,361
Total	35,293	7,560	42,853

On other hand, the total cultivated area of sesame was 17,173 hectare in 2013 growing season, and its total production was 198,356 ton.

Intercropping sesame with sugarcane can increase its national production by 22,754 ton (Table 8).

Table (8): Potential sesame cultivated area under intercropping with sugarcane in the studied four governorates.

Governorates	Sesame cultivated area (ha)	Total area (sugarcane and sesame area) (ha)	Sesame production from sugarcane area (ton)
El-Minia	2,310	7,795	3,697
Sohag	484	2,719	1,419
Qena	473	16,684	10,651
Aswan	110	11,472	6,987
Total	3,377	38,670	22,754

The national production of sunflower was 14,387 ton resulted from 6,025 hectare in 2013 growing season. Table (9) revealed that cultivated area of sunflower in El-Minia and Sohag governorates was 800 hectare. This area can increase by including the assigned sugarcane area for intercropping in the four governorates to be 36,093 hectare. Intercropping of oil crops with subsistence crops has been encouraged by the farmers, however, planting these species must not compete with the food market occurring the minimum competition for natural resources **(Smeets, and Faaij 2010).**

Table (9): Potential sunflower cultivated area under intercropping with sugarcane in the studied four governorates.

Governorates	Sunflower cultivated area (ha)	Total area (sugarcane and sunflower area) (ha)
El-Minia	777	6,262
Sohag	23	2,258
Qena	0	16,211
Aswan	0	11,361
Total	800	36,093

CONCLUSION

Sugarcane is highly water consuming crop grown in south Egypt under surface irrigation with low application efficiency. There is a gap between sugarcane production and consumption compensated by importation. Changing surface irrigation to gated pipes could increase sugarcane yield. The total production of sugarcane will increase from 12,438,550 ton to 14,926,260 ton, if gated pipes will be used. In addition, an amount of irrigation water could be saved, i.e. 980,666,816 m^3. The saved amount of irrigation water can used in cultivation of new land in El-Minia and Sohag governorates with sugar beet and with wheat in Qena and Aswan.

Under climate change in 2040 and using surface irrigation, sugarcane water requirements will increase and its cultivated area will decrease. Furthermore, the sugarcane productivity per hectare will decrease, as well as its national production. Under this disappointing situation, irrigation with gated pipes can reduce yield losses under climate change. Consequently, it will help to maintain the same cultivated area and save an amount of irrigation water to expand in new areas with sugar beet. Thus, its cultivated area could be increased by 17,806 hectare and larger area can be cultivated under drip system, i.e. 26,709 hectare. Wheat cultivated area could be increased by 112,790 hectare under surface irrigation or 150,386 hectare can be cultivated under sprinkler irrigation system. To achieve this benefits the government of Egypt should take care of the costs involved in the constructions of gated pipes in sugarcane cultivated areas.

Furthermore, another solution could be used to increase water and land productivity of sugarcane cultivated area, namely intercropping summer oil crops with sugarcane. Soybean, sesame and sunflower can be intercropped with sugarcane under gated pipes irrigation. These crops will get its water requirements from the applied water to sugarcane. Thus, the cultivated areas of these crops will increase, as well as its national production. The cultivated area of soybean can be increase from 7,560 hectare to 42,853 hectare under intercropping system with sugarcane. This increase its cultivated area will increase its production. Similarly, the total cultivated area of sesame can be increase to be 198,356 ton under intercropping system with sugarcane. In addition, the cultivated area of sunflower can be increase to reach 36,093 hectares. This procedure can contribute in reduction of edible oil gap in Egypt. Thus, these adaptation strategies can reduce climate change risk on sugarcane production in Egypt.

REFERENCES

Abd EL- Hafez, S.A. ; A.A. EL Sabbagh ; A.Z. EL Baaly and Abou Ahmed (2001). Evaluating two methods of rice planting grown under sprinkler irrigation system at North Delta of Egypt. Minufia, J.Agric. Res., 26(2): 377- 386.

Abd El-Halim, A.K. ; A.M. Awad and M.E. Moursy (2016). Response of Peanut to some Kind of Organic Fertilizers under Drip and Sprinkler Irrigation by Stem. Alex. Sci. Exch. J., 37:703-713.

Abou-Kreshe, M. ; A.A. Zohray and B.S. Farghly (1997): Effect of intercropping some field crops with sugar cane third ratoon. J. Agric. Sci. Mansoure Univ., 22(12): 4163-4176.

Allen, R.G. ; L.S. Pereira ; D. Raes and M. Smith (1998) Crop evapotranspiration: guideline for computing crop water requirements. FAO, No56.

Arnaout, M.A. (1999). Comparative study between Fertigation and conventional methods of fertilizer application through different irrigation systems. Miser J. Ag. Eng., 16 (2): 209 – 217.

Awal, M.A. ; H. Kosh and T. Ikeda (2006). Radiation interception and use by maize/peanut intercrop canopy. Agric. and Forest Meteor., 13(1-2):74-83.

Bilalis, D.A. ; A. Karkanisa ; A. Efthimiadoua ; A. Konstantasa and V. Triantafyllidis (2009). Effects of irrigation system and green manure on yield and nicotine content of Virginia (flue-cured) Organic tobacco (Nicotianatabaccum), under Mediterranean conditions Industrial crops and products., 29: 388 - 394.

Bonnett GT, Hewitt ML, Glassop D (2006) Effects of high temperature on the growth and composition of sugarcane internodes. Aust J Agric Res., 5710:1087–1095.

Chandiposha, M. (2013) Review: potential impact of climate change in sugarcane and mitigation strategies in Zimbabwe. Afr J Agric Res., 8:2814–2818.

Clowes, M.J. and W.L. Breakwell (1998) Zimbabwe sugarcane production manual. Zimbabwe Sugar Association, Chiredzi, Zimbabwe.

Deressa, T. ; R. Hassan and D. Poonyth (2005) Measuring the economic impact of climate change on South Africa's sugarcane growing regions. Agrekon., 44(4):524–542.

El Berry, A.M. ; F.G. Ebaby ; S.S. Hassan and S.M. Fattouh (2006). Performance of locally developed surface irrigation in sugar cans production. Misr J. Agric. Eng., 23(1):169-19.

El-Geddawy, I.H. ; A.H. Nour ; T.M. Fayed and M. El-Said (1988) Possibility of intercropping wheat with sugarcane. Commun Sci Dev Res., 24(285):110–118.

El-Geddawy, A.S. ; M.S. Laila and T.M. Nour El-Hoda (1995). The relative benefit of intercropping maize with spring cane in Middle Egypt region. Egypt J Appl Sci., 10 (2) : 525- 632.

El-Gergawi, A.S.S. ; L.M. Saif and A.M. Abou-Salama (2000) Evaluation of sunflower intercropping in spring planted sugarcane fields in Egypt. Assuit J Agric Sci., 312:163–174.

El-Khatib, S.I. and S.A. Sherief (2007) Effect of surface irrigation systems on yield and yield components of autumn sugarcane and tomato intercropped. Technical conference, 9–11 Dec, San Diego,CA.

Eweida, M.H.T. ; M.S.A. Osman ; S.A.A. Shams and A.A. Zohry (1996) Effect of some intercropping treatments of soybean with sugar cane on growth, yield and quality of both components. Ann Agric Sci, Moshtohor, 24(2):473–486.

Feng, L. ; Z. Sun ; M. Zheng ; M. Muchoki ; J. Zheng ; N. Yang ; W. Bai ; C.H. Feng ; Z. Zhang ; Q. Cai and D. Zhang (2016). Productivity enhancement and water use efficiency of peanut-millet intercropping. Pak. J. Bot., 48(4): 1459-1466.

Gawander, J. (2007) Impact of climate change on sugar-cane production in Fiji. WMO Bull 56(1):34-39.

Goyal, Megh R. (2014). Management, Performance, and Applications of Micro Irrigation Systems. Research Advances in Sustainable Micro Irrigation. CRC Press, 19 Aug 2014 - Nature - 374 pages. 1771880694, 9781771880695.

Jiao, N.Y. ; C. Zhao ; T.Y. Ning ; L.T. Hou ; G.Z. Fu ; Z.J. Li and M.C. Chen (2008). Effects of maize-peanut intercropping on economic yield and light response of photosynthesis. Ying Yong Sheng Tai Xue, 19 (5):981-985.

IPCC Intergovernmental Panel on Climate Change (2007) Intergovernmental panel on climate change fourth assessment report: climate change 2007. Synthesis report. World Meteorological Organization, Geneva.

Knox, J.W. ; Díaz J.A. Rodríguez ; D.J. Nixon and M. Mkhwanazi (2010) A preliminary assessment of climate change impacts on sugarcane in Swaziland. Agric Syst., 1032:63–72.

Marin, F. ; R. James ; W. Jones ; A. Singels ; F. Royce ; E.D. Assad ; G.Q. Pellegrino and F. Justino (2013) Climate change impacts on sugarcane attainable yield in southern Brazil. Clim Changes., 117:227–239.

Metwally, A.A. ; S.A. Safina ; R. El-Killany and N. A. Saleh (2017). Productivity, land equivalent ratios and water use efficiency of intercropping corn with soybean in Egyp. RJPBCS, 8(4):328-344.

Nazir, M.S. ; A. Jabbar ; I. Ahmad ; S. Nawaz and I.H. Bhatti (2002) Production potential and economics of intercropping in autumn-planted sugarcane. Int J Agric Biol., 41:140–141.

NWRP. (2002). Facing the challenge. National Conference. Cairo, April 29, National water Resources plan project, planning sector, Ministry of Water Resources & irrigation.

Rasheed, R. ; A. Wahid ; M. Farooq ; I. Hussain and S.M.A. Basra (2011) Role of proline and glycine betaine pretreatments in improving heat tolerance of sprouting sugarcane Saccharum sp. bud. Plant Growth Regul., 65:35-45.

Roeckner, E.G. ; Bonaventura L Bäuml ; R. Brokopf ; M. Esch ; M. Giorgetta ; S. Hagemann ; I. Kirchner ; L. Kornblueh ; E. Manzini ; A. Rhodin ; U. Schlese ; U. Schulzweida and A. Tompkins (2003) The atmospheric general circulation model ECHAM5. Part I: model description. MPI report 349,Max Planck Institute for Meteorology, Hamburg, Germany, 127 pp.

Sage, R.F. and D.S. Kubien (2007) The temperature response of C3 and C4 photosynthesis. Plant Cell Environ., 30:1086–1106.

Singels, A. ; M. Jones ; F. Marin ; A.C. Ruane and P. Thorburn (2014) Predicting climate change impacts on sugarcane production at sites in Australia, Brazil and South Africa using the Canegro model. Sugar Tech., 164:347–355.

Smeets, E.M.W. and A.P.C. Faaij (2010). The Impact of Sustainability Criteria on the Costs and Potencials of BioenergyProduction— Applied for Case Studies in Brazil and Ukraine. Biomass and Bioenergy, 34: 319-333.

Snyder, R.L. ; M. Orang ; K Bali and S. Eching (2004) Basic irrigation scheduling. BIS. http://www.waterplan.water.ca.gov/landwateruse/wateruse/Ag/CUP/Californi/Climate_Data_010804.xls.

Zohry, A.A. (1994). Effect of intercropping soybean with sugarcane. PhD Thesis. Al-Azhar University.

تأقلم الإنتاج القومى لقصب السكر بمصر لتغير المناخ

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من المتوقع أن تغير المناخ يزيد من الاحتياجات المائية لقصب السكر ويقلل من إنتاجية في مصر. حيث تمت دراسة تأثير زيادة الاحتياجات المائية في ظل تغير المناخ على المناطق المزروعة من قصب السكر الربيعي في أربع محافظات، لتقييم مدى ملاءمة هذه المحافظات لزراعة قصب السكر في عام ٢٠٤٠، دراسة تأثير استخدام طريقة الرى السطحى المطور (الأنابيب المبوبة) لرفع كفاءة مياه الري المستخدمة في قصب السكر، وتأثير تحميل المحاصيل الزيتية مع قصب السكر على كميات مياه الرى المضافة والمستخدمة في ري قصب السكر كاستراتيجيات للتكيف مع التغيرات المناخية. وتم حساب جهد البخر– نتح باستخدام نموذج BISM. تم استخدام نموذج المناخ ECHAM5 لتطوير سيناريو تغير المناخ A1B في عام

٢٠٤٠. وقد أظهرت النتائج أن استخدام أنابيب الري المبوبة أدي الي توفير في كمية مياه الري المضافة مما يمكن استثمارها في زراعة مساحات إضافية من بنجر السكر والقمح في عام ٢٠٤٠ ، و يتوقع زيادة الاحتياجات المائية لقصب السكر بنسبة ١٧٪ ونقص فى الإنتاج بمعدل ١٤٪ بالمحافظات التي تمت دراستها. وأشارت النتائج أيضا إلى أن درجة الحرارة في المحافظات التي تمت دراستها يمكن أن تصل إلى ٤٤ درجة مئوية خلال الفترة من مايو إلى أغسطس ، مما يعني أن إنتاج قصب السكر سيقل في عام ٢٠٤٠ في هذه المنطقة وستظل المنطقة مناسبة لزراعة قصب السكرواستخدام أنابيب الري المبوبة في ظل تغير المناخ سيحافظ على المنطقة المزروعة القديمة ويقلل المساحة المزروعة الجديدة من قصب السكر. يمكن للمحاصيل الزيتية المحملة مع قصب السكر في الربيع أن تقلل من فجوة إنتاج واستهلاك زيوت الطعام. وبالتالي ، فإن استراتيجيات التكيف هذه يمكن أن تقلل من مخاطر تغير المناخ على إنتاج قصب السكر في مصر.