ANALYSIS

5(18), April - June, 2019

Climate Change

ISSN 2394–8558
EISSN 2394–8566

# Reduction of the vulnerability of the Egyptian cropping pattern to climate change stress

**Tahany Noreldin[1✉], Abd El-Hafeez Zohry[2]**

**The objective of this study was to quantify the effect of climate change in 2030 on the prevailing cropping pattern, with respect to its water requirements and cultivated areas. Furthermore, testing the effect of suggested procedures, namely using water saving techniques and implementing intercropping systems on reducing the negative effects of climate change on the cultivated area of the cropping pattern in 2030 was also done. Data on the area of 16 important crops cultivated in 2014/15 were collected. Water requirements of these crops were calculated. Climate scenario RCP6.0 resulted from MIROC5 climate model was used to calculate water requirements of the cropping pattern in 2030. The results indicated that using the suggested procedures could increase the cultivated area of the current cropping pattern by 28%. The results also showed that, in 2030, the cultivated area is expected to be reduced by 10%, as a result of increasing the water requirements of the crops. Furthermore, implementing the suggested procedures in 2030 could result in an increase in the cultivated area by 29%, compared to the area under traditional cultivation. Thus, it is recommended to use the suggested procedures to reduce the losses in the cultivated area in 2030.**

## INTRODUCTION

Cropping pattern is the yearly sequence and spatial arrangement of crops, or of crops and fallow on a given area. It indicates the proportion of area under different crops at a point of time (Madari & Shekadar, 2015). Cropping pattern is evolved based on climate, water availability and soil for efficient use of available natural resources (Valipour, 2014). The cropping pattern in Egypt depends on five main crops, namely wheat, maize, clover, cotton, and sugarcane. Wheat and maize for flour production, clover for feed; cotton for fiber and edible oil and sugarcane for sugar production. Other crops exist in the Egyptian cropping pattern, such as cereals, legumes, fibers, forages, vegetables and fruit crops. The current cropping pattern of Egypt is known to have food gaps as a result of the steady increase in the population, in addition to the lack of land and water resources (Hafez et al., 2011). As reported by Field Crops Research Institute; agricultural Research Center, Egypt have production-consumption gap in wheat and maize, where the gap is 49 and 47%, respectively (Ouda & Zohry, 2017; 2017a).There is a gap in legume crops, especially faba been, where expansion in sugar beet cultivated area was done using the cultivated area of faba bean resulted in 73% production-consumption gap (Zohry & Ouda 2017b). There is a gap in the production of oil crops, about 97%, where the cultivated area of sunflower and soybean became very low.

Two-crop sequence cultivation, a winter crop then a summer crop, is the common field practice by the Egyptian farmers. Within a cropping pattern, different crop systems could be implemented, such as intercropping systems (Rajesh Khavse and Chaudhary, 2019). An intercropping system is define as two or more crops share the same piece of land for a part, or for all, of their growing season (Eskandari et al., 2009). To ensure the optimum productivity in an intercropping system, the peak periods of growth of the two crops should not coincide, so that one quick maturing crop completes its life cycle before the main period of growth of the other crop starts (Parsons, 2003). In Egypt, several crops are good candidates to the main crop in an intercropping system. Sugar beet is one of them, where two intercropping systems were successfully implemented in Egypt: wheat intercropped with sugar beet (Abou-Elela, 2012) and faba bean intercropped with sugar beet (Abd El-Zaher & Gendy, 2014). Tomato, either winter or summer crop, is another good candidate for implementing intercropping system. The secondary crop in this systems modified the micro-climate for tomato, increase tomato yield (Fernandez-Munoz et al., 1995), increase water use efficiency (Pressman et al., 1997), reduced pests and diseases (Hao, 2013) and mitigating heat stress (Abdel, 2006). Additionally, sugarcane offers another unique potential for intercropping (Nazir et al., 2002), where, the secondary crop will not need extra irrigation water as it will use the applied water to sugarcane to fulfill its required irrigation water. Furthermore, implementing sugarcane intercropping systems provides extra income for farmers during the early growth stage of sugarcane (El-Gergawi et al., 2000). Fruit trees are also provide good environment for intercropping, especially young evergreen fruit tree (1-3 years old) or deciduous fruit trees. Both wheat and faba bean could be intercropped with sugarcane and under fruit trees (Zohry & Ouda, 2016). These intercropping systems, if implemented could increase food production and reduce food gaps.

[1]Water Requirements and Field Irrigation Research Department, Soils, Water and Environment Research Institute, Agricultural Research Center, Egypt; [2]Crop Intensification Research Department, Field Crops Research Institute, Agricultural Research Center, Egypt;
✉*Corresponding author:* Water Requirements and Field Irrigation Research Department, Soils, Water and Environment Research Institute, Agricultural Research Center, Egypt; Email: dr.tahany2013@gmail.com; Mobile: 202 0114074398

Additionally, in the old clay and new sandy soils of Egypt, irrigation application efficiency is low, which endure large water losses to the ground water. Using water saving techniques in the old clay soils and new sandy lands could be beneficial in many ways. Changing tradition method of cultivation in the old lands, from basins or on narrow furrows, to raised beds cultivation proved to reduce the applied water to crops under surface irrigation by 20-25% (Abou elenein et al., 2009, Karrou et al., 2012). Sing et al. (2010) found lower water consumption and higher wheat yield under raised beds planting than under conventional flatbeds planting due to decrease in the applied irrigation amounts. Moreover, raised beds cultivation showed reduction in seed mortality rates, and improve in soil quality (Limon-Ortega et al., 2002), which led to enhanced root growth, and higher yield (Dey et al., 2015).

In the new sandy lands, irrigation scheduling and fertigation could attain irrigation water saving. Irrigation scheduling helped in applying water in the exact time for the plant needs and result in irrigation water saving, compared to farmer practice (Taha, 2012; Mathukia et al. 2018). Furthermore, applying fertigation (application of fertilizer via irrigation water) resulted in increasing water and fertilizer use efficiency, compared to farmer practice (broadcast fertilizer on the soil then apply irrigation water) (Ibrahim et al., 2012). A saving by 23% in irrigation water was found in maize grown under drip irrigation, when irrigation scheduling and fertigation were implemented (Ouda et al, 2014). Irrigation scheduling and fertigation can attain irrigation water saving by 10% in wheat. Taha (2012) indicated that irrigation scheduling and fertigation attained irrigation water saving by 10% in wheat, compared to farmer practice. The obtained irrigation water as a result of using water saving techniques could be used in cultivating new areas under modern irrigation systems, namely sprinkler and drip systems to increase the cultivated area and food production (Emmanuel Mavhura et al. 2017; Siddartha Mandal and Binoy Chhetri, 2019).

Climate change is one of the overwhelming environmental threats that are defined as a long-term alteration in the global weather patterns, including temperature, precipitation, soil moisture, sea level, and storm activity (IPCC, 2007). The Intergovernmental Panel on Climate Change (IPCC, 2001) stated that 'water and its availability and quality, will be the main pressures on, and issues for, societies and the environment under climate change'. Accordingly, it is expected that climate change will induce disruption in food production systems in both irrigated areas and rain fed (IPCC 2013; Mandale et al. 2019). Climate change may significantly alter water availability as a result of changing temperatures and precipitation (IPCC, 2001; Ajay Kumar Singh and Pritee Sharma, 2018). Furthermore, climate change is expected to increase potential evapotranspiration due to higher temperature, solar radiation and wind speed (Abtew & Melesse, 2013), which will affect the hydrological system and water resources (Shahid, 2011; Gezu Tadesse and Moges Dereje, 2018). Ouda & Zohry (2017) indicated that, in 2030 and under climate change effect, water requirements for the cultivated crops will increase, which will result in reduction in the cultivated area and consequently in food production.

Modification in the management of the cropping pattern of Egypt should be done to face the negative effects of climate change. Water saving techniques and implementing intercropping systems could be used as adaptation strategies under climate change (Gichangi and Gatheru, 2018), where the increase in water productivity by the water saving techniques, as well as the increase in land productivity by implementing intercropping systems will compensate the loss in the productive lands under climate change. Thus, the objective of this study was to quantify the effect of climate change in 2030 on the prevailing cropping pattern, with respect to its water requirements and cultivated areas. Furthermore, testing the effect of using water saving techniques and implementing intercropping systems on reducing the negative effects of climate change on cultivated area of the cropping pattern in 2030 was also done.

## MATERIALS AND METHODS

### Current cropping pattern

Data on the total cultivated area of the most important winter and summer crops grown in the governorates of the Nile Delta and Valley were collected from the Central Administration for Agricultural Economics; Ministry of Agriculture and Land Reclamation in Egypt in 2014/15. The cultivated area included the old and new lands. The old lands are represented by the area surrounding the Nile River and its soil is clayey in texture. It is irrigated with surface irrigation with low application efficiency, namely 60%. The new lands are located on the edges of the old lands in most governorates. It is characterized by having sandy soil and it is under modern irrigation systems (sprinkler or drip system) with higher application efficiency, namely 70 and 80%.

### Calculation of water requirements for the current cropping pattern

The Basic Irrigation Scheduling model (BISm, Snyder et al., 2004) was used to calculate water requirements for the studied crops in the cropping pattern using weather data for the same studied year. The BISm model calculates evapotranspiration (ETo) using the Penman-Monteith equation (Monteith, 1965) as presented in the United Nations FAO Irrigation and Drainage Paper (FAO 56) by Allen et al., (1998). The model calculates crop coefficients and water consumptive use. The model schedule irrigation and calculate water requirements. Thus, the model was used to calculate water requirements for the studied crops in the current cropping pattern.

### Suggested management practicesin the current Egyptian cropping pattern

Two suggestions were quantified, namely using water saving techniques in both old and new lands and implementing intercropping systems. Changing cultivation method from basins or narrow farrows to raised bedsin the old lands, as well as using irrigation scheduling and fertigation in the new lands were suggested to be used tosave some of the applied irrigation water. Thus, these saved amounts of water could be used in cultivating new areas and increase the production of the cropping pattern.

Furthermore, implementing intercropping systems, where either wheat, maize, faba bean, soybean or sunflower could be intercropped with other crops in the old and new lands could increase its cultivated area through sharing the cultivated area of other crops. These intercropping systems are considered as tactics to increase the cultivated area of one crop (secondary crop) through sharing the cultivated area of the main crop. Furthermore, the two intercropped crops are using the applied water to the main crop. Under this situation, the cropped area of the secondary crop will increase by the area it will occupy from the cultivated area of the main crop (Ouda & Zohry, 2016).

### Calculation of water requirements of the projected cropping pattern in 2030

Climate change scenario RCP6.0 resulted from MIROC5 climate change model was used to calculate the projected water requirements for the studied crops in the cropping pattern in 2030. The MIROC5 climate change model is available from the following web site:

http://www.ccafs.cgiar.org/marksimgcm#.Ujh1gj-GfMY. The model is one of the CMIP5 Genral Circulation Models developed by Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology. The model has a horizontal resolution equal to 1.40º x 1.40º. BISm model was used to calulate the water requirements of the cropping pattern.

**Calculation procedure**

1. We assumed that changing the cultivation method for all the crops cultivated in the current cropping pattern in the old lands to raised beds cultivation will result in 15% saving in the applied irrigation water to them.
2. We assumed that sugarcane will be irrigated using gated pipes and fruit trees will be irrigated using drip system to attain 15% saving in the applied irrigation water to both sugarcane and fruit trees.
3. We assumed that implementing irrigation scheduling and fertigation in the new lands could result in water saving by15%.
4. We assumed that these amounts of water will be used in cultivating new lands. Thus, we calculated these areas and added it to the area of the current cropping pattern.
5. We suggested to implement intercropping systems to increase the cultivated area of wheat, maize, faba bean, soybean, and sunflower, without using extra irrigation water. The purpose of doing that is to create additional area to cultivate these crop through sharing other crops in their cultivated area.
6. To quantify the effect of implementing intercropping systems on the current cropping pattern, we used data previously published in the literature (Table 1).
7. We used the values of the potential added area of these five crops presented in Table (1) and added it to its area of the current cropping pattern.
8. We also assumed that, in 2030 under climate change, similar cropping pattern to the one existed in 2015 will be cultivated.
9. We assumed that the allocated water to the cropping pattern in 2030 will be the same as its counterpart value of the current cropping pattern, as a result of limited water resources in Egypt.
10. The increase in the water requirements of the studied crops were calculated, as well as the reduction in the cultivated area. Then, we calculated the cultivated area under climate change
11. We followed the above procedure in calculating the added area under climate change using water saving techniques and intercropping systems.

## RESULTS AND DISCUSSION

### Effect of using water saving techniques on the current cropping pattern

Table (2) presented the cultivated area of the current cropping pattern and its water requirements. The table showed that the total cultivated area of winter and summer crops in the studied year of 2014/15 was 6,296,944 hectares and it required 62,323,656,063 $m^3$ of irrigation water. The table also presented the potential cultivated area as a result of using water saving techniques in the old and the new lands. The results indicated that 9,348,548,409 $m^3$ of irrigation water could be saved. This amount of water was invested in irrigating new lands equal to 944,542 hectares, which could increase the total cultivated area to 7,241,488 hectares (Table 2).

Furthermore, implementing intercropping systems could be a good solution to reduce production-consumption gaps for wheat, faba bean, maize, soybean, and sunflower. Table (3) indicated that an increase by 23 and 9% in the cultivated area of wheat and maize respectively could be attained by implementing intercropping systems, compared to its values presented in Table (2) under current cropping pattern. A very high increase in the cultivated area of faba bean, soybean and sunflower equal to 611,878 and 1267%, respectively could occur, compared to its value in Table (2) under current cropping pattern. These high values resulted from the intercropping faba bean, soybean, and sunflower on crops cultivated in large areas, such as sugar beet, maize, and tomato, respectively. These huge increases can diminish the existed production-consumption gaps in these three crops.

Under this situation, the potential national cultivated area can be increase to reach 7,100,386 hectares. Table (3) also showed that the potential total cultivated area could be increased to reach 8,044,928 hectares, with 28% increase, if water saving techniques and intercropping systems were implemented compared to its value in Table (2) under current cropping pattern.

Similar results were obtained by Zohry & Ouda (2018), where they indicated that implementing intercropping systems, raised beds cultivation, and cultivation of three crops per year increase the total cultivated area by 35%.

### The projected cropping pattern under climate change

Table (4) showed that the lowest percentage of increase in the crop water requirements of winter crops could be found for faba bean and the highest percentage of increase could be found for onion. With respect to summer crops, percentage of increase in crop water requirements will be higher than its counterpart in winter crops, with the highest value will be exist for tomato. Similar results were obtained by Zohry & Ouda (2018), with respect to the expected increase in the water requirements of these crops under climate change. Furthermore, Morsy & Ouda (2018) indicated that an increase in water consumptive use for several crops in 2030 in Egypt will occur. An expected increase in the water requirements of crops was also found in Al-Jouf region in Saudi Arabia, where Chowdhury et al., (2016) concluded that water requirements for the cultivated crops are expected to increase in 2050. Therefore, these expected increases in water demand for agriculture should be met by implementing water conservation practices instead of flooding methods.

On the contrary, reduction in the cultivated area in Egypt is expected to occur under the effect of climate change due to the unavailability of extra water resources to fulfill the higher water demand for irrigation and fixed amount of allocated water to agriculture. Thus, it can be noticed from Table (4) that the highest reduction in the cultivated area can be occur for winter and summer tomato. Furthermore, the total cultivated area of winter and summer crops will be reduced by 10%, compared to its value in Table (2). Similar assessment was done by Ouda & Zohry (2018), which revealed that 16% decrease in the cultivated area of Egypt is expected under climate change.

### Reduction in the losses of productive lands under climate change

Although there is an expected losses in the cultivated area in 2030, using the suggested water saving techniques could still save a portion of the applied irrigation water to be used in cultivated new lands. Table (5) indicated that, in 2030, the potential added area will be lower than its counterpart values in 2015 by 11% (Table 2). Furthermore, implementing both water saving techniques and intercropping systems could result in an increase in the cultivated area by 29%, compared to traditional cultivation under climate change (Table 4). Furthermore, the cultivated area in 2030 will be lower by 10% (Table 5), compared to its

**Table 1** Potential increase in the cultivated area of five crops using different intercropping systems

| Intercropping system | Main crop | Reference | Potential added area (ha) | Reference |
|---|---|---|---|---|
| Wheat intercropped with | Tomato<br>Sugar beet<br>Cotton<br>Sugarcane<br>Fruit trees | Abd El-Zaher et al., (2013)<br>Abou-Elela (2012)<br>Zohry (2005)<br>Ahmed et al., (2013)<br>Ouda & Zohry (2016) | 305,735 | Ouda & Zohry (2016) |
| Maize intercropped with | Soybean<br>Cowpea<br>Tomato<br>Peanut<br>Potato | Sherif and Gendy (2012)<br>Hamd-Alla et al., (2014)<br>Mohamed et al., (2013)<br>Abd El-Zaher et al., (2007)<br>Ibrahim (2006) | 79,887 | Zohry & Ouda (2016a) |
| Faba bean intercropped with | Tomato<br>Sugar beet<br>Sugarcane<br>Fruit trees | Ibrahim et al., (2010)<br>Abd El-Zaher and Gendy (2014)<br>Farghly, (1997)<br>Zohry and Ouda (2016b) | 210,306 | Zohry & Ouda (2016b) |
| Soybean intercropped with | Sorghum<br>Sugarcane<br>Fruit trees | Abou-Keriasha et al (1997)<br>Eweida et al., (1996)<br>Zohry & Ouda (2019) | 124,068 | Zohry & Ouda (2019) |
| Sunflower intercropped with | Tomato<br>Sugarcane<br>Fruit trees | Abdel (2006)<br>El-Gergawi et al., (2000)<br>Zohry & Ouda (2019) | 83,444 | Zohry & Ouda (2019) |

**Table 2** The total cultivated area under the current cropping pattern in 2014/15 and its potential counterpart value under using water saving techniques

| | Current cropping pattern | | Potential cropping pattern under water saving techniques | | |
|---|---|---|---|---|---|
| | Cultivated area (ha) | Water requirements ($m^3$) | Saved water amount ($m^3$) | Add area (ha) | Total cultivated area (ha) |
| **Winter crops** | | | | | |
| Wheat | 1,354,844 | 8,825,826,373 | 1,323,873,956 | 203,227 | 1,558,071 |
| Faba bean | 34,418 | 178,997,045 | 26,849,557 | 5,163 | 39,581 |
| Clover | 624,741 | 5,948,296,442 | 892,244,466 | 93,711 | 718,452 |
| Onion | 148,173 | 1,244,936,988 | 186,740,548 | 22,226 | 170,399 |
| Tomato | 70,173 | 347,661,962 | 52,149,294 | 10,526 | 80,699 |
| Potato | 102,285 | 339,729,364 | 50,959,405 | 15,343 | 117,628 |
| Sugar beet | 231,193 | 1,955,202,088 | 293,280,313 | 34,679 | 265,872 |
| Others | 680,278 | 2,858,335,063 | 428,750,259 | 102,042 | 782,320 |
| Total | 3,246,104 | 21,698,985,326 | 3,254,847,799 | 486,916 | 3,733,021 |
| **Summer crops** | | | | | |
| Cotton | 100,349 | 1,264,924,487 | 189,738,673 | 15,052 | 115,401 |
| Rice | 506,249 | 5,896,134,782 | 884,420,217 | 75,937 | 582,186 |
| Maize | 938,329 | 9,259,942,383 | 1,388,991,357 | 140,749 | 1,079,078 |
| Soybean | 14,130 | 147,263,643 | 22,089,546 | 2,120 | 16,250 |
| Sunflower | 6,585 | 48,883,220 | 7,332,483 | 988 | 7,573 |
| Potato | 53,110 | 385,322,673 | 57,798,401 | 7,967 | 61,077 |
| Tomato | 89,825 | 824,943,808 | 123,741,571 | 13,474 | 103,299 |
| Cowpea | 516 | 1,032,000 | 154,800 | 77 | 593 |
| Sugarcane | 134,656 | 4,271,214,589 | 640,682,188 | 20,198 | 154,854 |
| Fruit trees | 524,763 | 9,789,068,856 | 1,468,360,328 | 78,714 | 603,477 |
| Others | 682,329 | 8,735,940,296 | 1,310,391,044 | 102,349 | 784,678 |
| Total | 3,050,840 | 40,624,670,737 | 6,093,700,611 | 457,626 | 3,508,467 |
| Grand total | 6,296,944 | 62,323,656,063 | 9,348,548,409 | 944,542 | 7,241,488 |

**Table 3** The potential total cultivated area of the current cropping pattern, using water saving techniques and implementing intercropping systems

| | Potential total area under surface irrigation and intercropping systems (ha) | Potential total area under water saving techniques and intercropping systems (ha) |
|---|---|---|
| **Winter crops** | | |
| Wheat | **1,660,579** | **1,863,806** |
| Faba bean | **244,724** | **249,887** |
| Clover | 624,741 | 718,452 |
| Onion | 148,173 | 170,399 |
| Tomato | 70,173 | 80,699 |
| Potato | 102,285 | 117,628 |
| Sugar beet | 231,193 | 265,872 |
| Others | 680,278 | 782,320 |
| Total | 3,762,146 | 4,249,062 |
| **Summer crops** | | |
| Cotton | 100,349 | 115,401 |
| Rice | 506,249 | 582,186 |
| Maize | **1,018,216** | **1,158,965** |
| Soybean | **138,198** | **140,318** |
| Sunflower | **90,029** | **91,017** |

| | | |
|---|---|---|
| Potato | 53,110 | 61,077 |
| Tomato | 89,825 | 103,299 |
| Cowpea | 516 | 593 |
| Sugarcane | 134,656 | 154,854 |
| Fruit trees | 524,763 | 603,477 |
| Others | 682,329 | 784,678 |
| Total | 3,338,240 | 3,795,866 |
| Grand total | 7,100,386 | 8,044,928 |

**Table 4** Expected percentage of increase in the water requirements of the current cropping pattern, expected percentage of reduction in its cultivated area and expected total cultivated area in 2030.

| | Expected increase in water requirements (%) | Expected reduction in the cultivated area (%) | Expected cultivated area (ha) |
|---|---|---|---|
| **Winter crops** | | | |
| Wheat | 7 | 5 | 1,260,005 |
| Faba bean | 4 | 6 | 33,041 |
| Clover | 9 | 8 | 568,514 |
| Onion | 13 | 9 | 128,911 |
| Tomato | 8 | 11 | 64,559 |
| Potato | 6 | 5 | 96,148 |
| Sugar beet | 8 | 6 | 212,698 |
| Others | 10 | 9 | 612,250 |
| Total | -- | -- | 2,976,126 |
| **Summer crops** | | | |
| Cotton | 17 | 12 | 83,290 |
| Rice | 12 | 16 | 445,499 |
| Maize | 19 | 15 | 760,046 |
| Soybean | 16 | 15 | 11,869 |
| Sunflower | 17 | 17 | 5,466 |
| Potato | 16 | 17 | 44,612 |
| Tomato | 20 | 18 | 71,860 |
| Cowpea | 17 | 14 | 428 |
| Sugarcane | 16 | 21 | 113,111 |
| Fruit trees | 11 | 12 | 467,039 |
| Others | 7 | 5 | 634,566 |
| Total | -- | -- | 2,637,787 |
| Grand total | -- | -- | 5,613,913 |

**Table 5** The potential total cultivated area for the projected cropping pattern, using water saving techniques and implementing intercropping systems in 2030.

| | Projected cropping pattern in 2030 | | | |
|---|---|---|---|---|
| | Under water saving techniques | | Under intercropping systems | Potential total cultivated area (actual + added) (ha) |
| | Potential add area (ha) | Potential total area (actual + added) (ha) | Potential cultivated area (actual + added) (ha) | |
| **Winter crops** | | | | |
| Wheat | 189,001 | 1,449,006 | 1,577,550 | 1,766,551 |
| Faba bean | 4,956 | 37,997 | 230,041 | 234,997 |
| Clover | 85,277 | 653,791 | 574,762 | 660,039 |
| Onion | 19,337 | 148,247 | 134,837 | 154,174 |
| Tomato | 9,684 | 74,243 | 62,454 | 72,138 |
| Potato | 14,422 | 110,570 | 97,171 | 111,593 |
| Sugar beet | 31,905 | 244,602 | 217,321 | 249,226 |
| Others | 91,838 | 704,088 | 619,053 | 710,891 |
| Total | 446,419 | 3,422,545 | 3,513,189 | 3,959,608 |
| **Summer crops** | | | | |
| Cotton | 12,493 | 95,783 | 88,307 | 100,801 |
| Rice | 66,825 | 512,324 | 425,249 | 492,074 |
| Maize | 114,007 | 874,053 | 865,484 | 979,491 |
| Soybean | 1,780 | 13,650 | 117,468 | 119,249 |
| Sunflower | 820 | 6,285 | 74,724 | 75,544 |
| Potato | 6,692 | 51,304 | 44,081 | 50,773 |
| Tomato | 10,779 | 82,639 | 73,657 | 84,436 |
| Cowpea | 64 | 493 | 444 | 508 |
| Sugarcane | 16,967 | 130,078 | 106,378 | 123,345 |
| Fruit trees | 70,056 | 537,095 | 461,791 | 531,847 |
| Others | 95,185 | 729,751 | 648,213 | 743,397 |
| Total | 395,668 | 3,033,455 | 2,905,796 | 3,301,464 |
| Grand total | 842,087 | 6,456,000 | 6,418,985 | 7,261,072 |

value of the current cropping pattern under implementing water saving techniques and intercropping systems (Table 3).

## CONCLUSION

This study quantified the effect of procedures to be done to increase the cultivated area of the current cropping pattern through implementing techniques to save some of the applied water to the cultivated crops and use these amounts of water to cultivate new areas. Furthermore, the effect of another technique on increasing the cropped area of the current cropping pattern, namely using intercropping systems was quantified. The results indicated that both water saving techniques and intercropping systems could increase the cultivated area of the cropping pattern. Our results also indicated that these procedures could be successful in increasing the area of the cultivated crops in the expected cropping pattern in 2030. Furthermore, these procedures could be helpful in reducing the losses in the cultivated area, as a result of increasing water requirements of the cultivated areas and limited water resources in 2030. Thus, it is recommended to use the suggested water saving techniques and intercropping systems to increase the cultivated area of the current cropping pattern and to reduce the losses in the cultivated area in 2030 under climate change.

## REFERENCES


1. Abd El-Zaher S, Mohamed W and Toaima S. Intercropping maize with peanut under plant spacing and three planting dates. 2007: 45(2):545-560.
2. Abd El-Zaher ShR and Gendy EK. Effect of plant density and mineral and bio-nitrogen fertilization on intercropping faba bean with sugar beet. Egyptian Journal of Applied Sciences, 2014: 29 (7): 352 – 366.
3. Abd El-Zaher SR, Shams AS and Mergheny MM. Effect of intercropping pattern and nitrogen fertilization on intercropping wheat with tomato. Egyptian Journal of Applied Sciences, 2013: 28(9): 474 – 489.
4. Abdel CG. Improvement of tomato fruit-set under natural high temperature: 1- Intercropping tomato with sunflower or corn. J. Dohuk Univ. 2006: (9)2:2-16.
5. Abou-Elela AM. Effect of intercropping system and sowing dates of wheat intercropping with sugar beet. Journal of Plant Production. 2012: 3(12):3101-3116.
6. Abouelenein R, Oweis T, El Sherif M, Awad H, Foaad F, Abd El Hafez S, Hammam A, Karajeh F, Karo M and Linda A. Improving wheat water productivity under different methods of irrigation management and nitrogen fertilizer rates. Egyptian Journal of Applied Science. 2009: 24 (12A):417-431.
7. Abou-Keriasha MA, Zohry AA and Farghly BS. 1997. Effect of intercropping some field crops with sugarcane on yield and its components of plant cane and third ratoon. J. Agric. Sci. Mansoura Univ., 1997: 2212: 4163 – 4176.
8. Abtew W and Melesse A. Climate Change and Evapotranspiration *In*: Evaporation and Evapotranspiration: Measurements and Estimations, Springer Science Business Media Dordrecht, 2003: DOI 10.1007/978-94-007-4737-113.
9. Ahmed AM, Ahmed NR and Khalil RA. Effect of intercropping wheat on productivity and quality of some promising sugarcane cultivars. Minia J Agric Research Devepol., 2013: 33 (4):557-583.
10. Ajay Kumar Singh, Pritee Sharma. Measuring the productivity of foodgrain crops in different climate change scenarios in India: An evidence from time series investigation. Climate Change, 2018, 4(16), 661-673
11. Allen RG, Pereira LS, Raes D, Smith M. Crop evapotranspiration: Guideline for computing crop water requirements. FAO N°56. 1998.
12. Chowdhury S, Al-Zahrani M, Abbas A. 2016. Implications of climate change on crop water requirements in arid region: An example of Al-Jouf, Saudi Arabia. J. King Saud Univ. 28(1):21-30.
13. Dey D, Nath D, Jamatia PB. Effect of raised bed planting method of maize under sandy loam soil of West Tripura. International Journal of Applied Research. 2015:1(7): 561-563.
14. El-Gergawi ASS, Saif LM, Abou-Salama AM. Evaluation of sunflower intercropping in spring planted sugarcane fields in Egypt. Assuit J. Agric. Sci. 2000: 312:163-174.
15. Emmanuel Mavhura, Desmond Manatsa, McDonald Matiashe. Adapting smallholder farming to climate change and variability: Household strategies and challenges in Chipinge district, Zimbabwe. Climate Change, 2017, 3(12), 903-913
16. Eskandari H, Ghanbari A and Javanmard A. Intercropping of cereals and legumes for forage production. Notulae Scientia Biologicae, 2009: 1: 07-13.
17. Eweida MHT, Osman MSA, Shams SAA, Zohry AA. Effect of some intercropping treatments of soybean with sugarcane on growth, yield and quality of both components. Annals of Agric. Sci., Moshtohor, 1996: 24 2: 473 – 486.
18. Farghly BS. Yield of sugar cane as affected by intercropping with faba bean. J. Agric. Sci. 1997: 22 12: 4177 – 4186.
19. Fernandez-Munoz R, Gonzalez-Fernandez JJ and Cuartero J. Variability of pollen tolerance to low temperatures in tomato and related with species. Journal of horticultural Science, 1995: 70:41-49.
20. Gezu Tadesse, Moges Dereje. Impact of Climate Change on Smallholder Dairy Production and Coping Mechanism in Sub-Saharan Africa-Review. Climate Change, 2018, 4(15), 299-313
21. Gichangi EM, Gatheru M. Farmers' awareness and perception of climate change and the various adaptation measures they employ in the semi-arid eastern Kenya. Climate Change, 2018, 4(14), 112-122
22. Hafez W, Abd El-Monsif H and Manaa M. Food security in Egypt in 2030: Future scenarios Available at: 2011. http://www.idsc.gov.eg /IDSC/publication/View.aspx?ID=352
23. Hamd-Alla WA, Shalaby EM, Dawood RA and Zohry AA. Effect of cowpea (Vigan sinensis L.) with maize (Zea mays L.) intercropping on yield and its components. International Scholarly and Scientific Research & Innovation, 2014: 8 (11): 1170 – 1176
24. Hao W. Control effect of tomato and maize intercropping against tomato powdery mildew. Plant Diseases and Pests. 2013: 4(2):22-24.
25. Ibrahim MM, Ouda SA, Taha A, El Afandi G and Eid SM. Water management for wheat grown in sandy soil under climate change conditions. Journal of Soil Science and Plant Nutrition, 2012: 12(2):195-210.
26. Ibrahim S, Shaaban M and Gendy EK. Intercropping faba bean with tomato. Egypt. J. Appl. Sci., 2010: 25(6A):167-181.
27. Ibrahim S. Intercropping potato with maize. Annals of Agricultural Science, 2006: 44(3): 799 – 817.
28. IPCC Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change fourth assessment report: Climate change 2007. Synthesis Report. World Meteorological Organization, Geneva, Switzerland.
29. IPCC. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Report of Working Group II of the Intergovernmental Panel on Climate Change (6$^{th}$Session, Geneva).2001.
30. IPCC. Summary for Policymakers. In: Climate Change. The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Stocker TF, Qin D, Plattner GK, Tignor M, Allen SK, Boschung J, Nauels A, Xia Y, Bex V and Midgley PM, Eds., Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2013.
31. Karrou M, Oweis T, Abou El Enein R, Sherif M. Yield and water productivity of maize and wheat under deficit and raised bed irrigation practices in Egypt. African Journal of Agricultural Research, 2012: 7 (11): 1755 – 1760.
32. Limon-Ortega A, Sayre KD, Drijber RA, Francis CA. Soil attributes in a furrow-irrigated bed planting system in northwest Mexico. Soil Till. Res. 2002: 63, 123–132.

33. Madari DM and Shekadar SI. Impact of irrigation on cropping pattern and production with special reference to Vijaour district. Golden Research Thoughts. 2015: 4(8):320-325.
34. Mandale VP, Jedhe SH, Khadtare MY. Spatio-temporal Trends of Rainfall and Rainy Days in the Marathwada Region of Maharashtra State. Climate Change, 2019, 5(17), 55-61
35. Mathukia RK, Gohil BS, Mathukia PR, Polara AM. Assessing Moisture Conservation and Water Saving Technology for Bt Cotton (*Gossypium hirsutum* L.) Production. Discovery Agriculture, 2018, 4, 14-21
36. Mohamed W, Ahmed NR and Abd El-Hakim WM. Effect of intercropping dates of sowing and N fertilizers on growth and yield of maize and tomato. Egyptian Journal of Applied Sciences, 2013: 28 (12B): 625 – 644.
37. Monteith JL. Evaporation and environment. In: G. E. Fogg (Ed.), Symposium of the Society for Experimental Biology: The State and Movement of Water in Living Organisms, Vol. 19 (pp. 205–234). Academic Press, Inc., NY. 1965.
38. Morsy M and Ouda S. Future Water Requirements for Prevailing Cropping Pattern. *In*: Cropping Pattern to Overcome Abiotic Stresses: Water, Salinity and Climate. Springer Publishing House. 2018. ISBN: 978-3-319-69879-3.
39. Nazir MS, Jabbar A, Ahmad I, Nawaz S and Bhatti IH. Production potential and economics of intercropping in autumn-planted sugarcane. Inter. J. Agric. and Biol. 2002: 41:140-141.
40. Ouda S and Zohry A A. Significance of Reduction of Applied Irrigation Water to Wheat Crop. *In:* Major Crops and Water Scarcity in Egypt. Springer Publishing House. 2016: pp 33-50.
41. Ouda S and Zohry A. Cropping Pattern to Face Water Scarcity. *In*: Cropping Pattern to Overcome Abiotic Stresses: Water, Salinity and Climate. Springer Publishing House. 2018.
42. Ouda S and Zohry AA. Crops Intensification to Reduce Wheat Gap in Egypt. *In*: Future of Food Gaps in Egypt: Obstacles and Opportunities. Springer Publishing House. 2017.
43. Ouda S, Taha A, and Ibrahim M. Increasing water productivity for maize grown in sandy soil under climate change conditions. Archives of Agronomy and Soil Science. 2014: 61(3):299–311.
44. Parsons MJ. Successful intercropping with sugarcane. Proc. S. Afr. Sug. Technol. Ass. 2003: 77: 77-98.
45. Pressman E, Bar-Tal A, Shaked R and Rosenfeld K. The development of tomato root system in relation to the carbohydrate status of the whole plant. Annals of Botany. 1997: 80: 533–538.
46. Rajesh Khavse, Chaudhary JL. Rainfall and drought characteristics for crop planning in Plain zone of Chhattisgarh. Climate Change, 2019, 5(17), 62-67
47. Shahid S. Impact of Climate Change on Irrigation Water Demand of Dry Season Boro Rice in Northwest Bangladesh. Climatic Change, 2011: 105,433-453.
48. Sherif S A and Gendy EK. Growing maize intercropped with soybean on beds. Egyptian Journal of Applied Sci. 2012: 27(9):409-423.
49. Siddartha Mandal, Binoy Chhetri. A study on sesame and blackgram intercropping system as influenced by moisture conservation practices under rainfed condition. Discovery, 2019, 55(277), 20-23
50. Sing VK, Dwivedi BS, Shukla AK, Mishra RP. Permanent raised bed planting of the pigeonpea-wheat system on a Typic Ustochrept: Effects on soil fertility, yield and water and nutrient use efficiencies. Field crops Research; 2010:116:127-39
51. Snyder RL, Orang M, Bali K and Eching S. Basic irrigation scheduling BIS. 2004. http://www.waterplan.water.ca.gov/landwateruse/wateruse/Ag/CUP/Californi/Climate_Data_010804.xls.
52. Taha A. Effect of climate change on maize and wheat grown under fertigation treatments in newly reclaimed soil. PhD Thesis, Tanta University, Egypt. 2012.
53. Valipour M. Analysis of potential evapotranspiration using limited weather data. Applied Water Science. 2014. doi:10.1007/s13201-014-0234-2
54. Zohry A A and Ouda S. Solution for Faba Bean Production-Consumption Gap. *In*: Future of Food Gaps in Egypt: Obstacles and Opportunities. Springer Publishing House. 2016b.
55. Zohry A and Ouda S. Crop Rotation can Lessen Production-Consumption Gap of Edible Oils in Egypt. *In:* Crop Rotation: An approach to Secure Future Food. Springer Publishing House. 2019. *Accepted for publication.*
56. Zohry A. and Ouda S. Cropping Pattern to Increase Food Security. *In*: Cropping Pattern to Overcome Abiotic Stresses: Water, Salinity and Climate. Springer Publishing House. 2018.
57. Zohry AA and Ouda S. Crops Intensification to Face Climate Induced Water Scarcity in Nile Delta region. *In*: Management of Climate Induced Drought and Water Scarcity in Egypt: Unconventional Solutions. Springer Publishing House. 2016.
58. Zohry AA and Ouda S. Increasing Land and Water Productivities to Reduce Maize Food Gap. *In*: Future of Food Gaps in Egypt: Obstacles and Opportunities. Springer Publishing House. 2016a.
59. Zohry AA. Effect of relaying cotton on some crops under bio-mineral N fertilization rates on yield and yield components. Annals of Agric. Sci. 2005: 431:89-103.



**Article Keywords**

Raised beds cultivation, irrigation scheduling, fertigation, intercropping systems, RCP6.0 climate scenario and MIROC5 climate model.

**Article History**

Received: 19 January 2019

Accepted: 04 March 2019

Published: April - June 2019

**Citation**

Tahany Noreldin, Abd El-Hafeez Zohry. Reduction of the vulnerability of the Egyptian cropping pattern to climate change stress. *Climate Change*, 2019, 5(18), 124-130




**General Note**

Article is recommended to print as color version in recycled paper. *Save Trees, Save Climate*.