**Water budget, crop water productivity and economic return of land and water units for Egyptian crops**

El-MarsafawySamia M. 1, A.I. Ibrahim2,F. A. Khalil1and Namait Allah Y. Mokhtar1

1 Soils, Water & Environment Research Institute, Agricultural Research Centre

2 Agricultural Economic Research Institute, Agricultural Research Centre

Samiaelmarsafawy797@hotmail.com

**Abstract:**Water is an important element of development and evolution. Egypt suffers from limited water resources because it is located within the arid and semi-arid zone. Agriculture is considered the largest consumer of water resources in Egypt. Update the data of water budget for agriculture at intervals is important to identify the total water budget for agricultural crops especially when adding new agricultural areas or using short duration varieties or spread modern irrigation systems in larger areas.

Current research aims to calculate the water budget (WB) for Egyptian crops in the 2016/2017 winter crops and the 2017 season for summer, Nili and perennial crops. CropWat8.0 model was used to calculate the irrigation water requirements for the crops under study. In addition, crop water productivity as well as the economic return of land and water units were calculated.

Results indicated that total cropped area was 6.7 million hectare and its water budget was 62.7 billion m3.The water budget of Egyptian crops represents 78.4% ofthetotal water resources in Egypt.The highest crop water productivity (CWP) registered for carrot, sugar beet, tomato, onion for winter crops; potato, cantaloupe, watermelon for summer crops. The CWP values for the previous crops exceeded 9 and 5 kg/m3 for winter and summer crops, respectively. Regarding Nili and perennial crops, the highest ones was found for tomato (5.05 kg/m3) and sugarcane (4.77 kg/m3). The highest economic return for the land and water units wererecorded for strawberry, peas (dry) and carrot. The economic return per land unit for the three respective crops were 157810, 86467 and 62429 LE/ha, while the economic return per irrigation water requirement (IWR) unit were 18.51, 14.25, 14.00 LE/m3IWRin the old lands; and 24.69, 19.00 and 18.66 LE/ m3IWR in the new lands.

[El-Marsafawy Samia M., A. I. Ibrahim, F. A. Khaliland Namait Allah Y. Mokhtar.**Water budget, crop water productivity and economic return of land and water units for Egyptian crops.** *N Y Sci J*2019;12(10):36-52]. ISSN 1554-0200 (print); ISSN 2375-723X (online). <http://www.sciencepub.net/newyork>. 5. doi:[10.7537/marsnys121019.05](http://www.dx.doi.org/10.7537/marsnys121019.05).

**Keywords:** water budget; crop water productivity, economics of the land and water units

**1. Introduction**

Water is an important element of development and evolution. Egypt suffers from limited water resources because they are located within the arid and semi-arid zone. The water resources sector in Egypt meets many challenges such as population growth, climate change and others that affect the self- sufficient from the main food crops and causing increased the gap between production and consumption. All this requires concerted efforts to make good use of this important resource and search for new resources can cover part of the increasing demand for water.

Water and agriculture are strongly interconnected. To grow food, you need water; but the agriculture sector remains highly susceptible to water-related disasters like floods, droughts and typhoons. In turn, water resources are also impacted by agricultural activities, as the largest water-consuming sector globally and a significant source of pollution. So producing food sustainably will require good water management in agriculture, and managing water sustainably will require taking into account the role of agriculture (Guillaume, 2019).

The 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs), and the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) provide both the framework and the targets that should guide global efforts towards more inclusive growth and sustainable livelihoods. Agriculture, through its links to food security, nutrition and health, rural development and growth, and the environment, is a major driver in the attainment of these targets. In the current environment of changing global agricultural markets, agriculture faces a triple challenge. First, it has to increase the production of safe and nutritious food to meet a growing demand driven by population increase. Second, agriculture has to generate jobs and incomes and contribute to poverty eradication and rural economic growth. Finally, agriculture has a major role to play in the sustainable management of natural resources and the adaptation to, and mitigation of climate change which is already affecting the livelihoods of many people, especially the most vulnerable (FAO, 2017). ET based irrigation scheduling is getting wider applications as a means to improve water productivity due to rising concern on water conservation. The environmental demand for water regulates the water requirement of the crops. The process is controlled by other factors like amount of ground coverage by the crops and its geometry, growth stage of the plant, nature and characteristics of the ground surface etc., apart from the meteorological parameters. The concept of reference ET gained importance in agricultural water requirement estimation. (Anjitha Krishna, 2019).

Owing to the difficulty of obtaining accurate field measurements, ET is commonly computed from weather data. A large number of empirical or semi-empirical equations have been developed for assessing crop or reference crop evapotranspiration from meteorological data. Some of the methods are only valid under specific climatic and agronomic conditions and cannot be applied under conditions different from those under which they were originally developed (FAO, No. 56).According to FAO report (Part A - Reference evapotranspiration, ETo), ETo can be computed from meteorological data. As a result of an Expert Consultation held in May 1990, the FAO Penman-Monteith method is now recommended as the sole standard method for the definition and computation of the reference evapotranspiration. The FAO Penman-Monteith method requires radiation, air temperature, air humidity and wind speed data.

Little studies on the water budget for Egyptian crops were carried out since the 1970s,

El-Gibali and Badawi (1978) found that total water requirements reached 44.0 B. m3/ year for whole cropped area considering an irrigation efficiency of 60 %. Aineret. al. (1999) indicated that the total irrigation requirements were 52.0, 43.9 and 39.0 B.m3/ year under surface, sprinkler and drip irrigation systems, respectively. Eid et al. (1999) found that the crop water need values of the new lands reached about 5686, 4521 and 3711 million m3/ year under surface, sprinkler and drip irrigation systems, respectively.

Regarding the total water resources in Egypt, Central Agency for Public Mobilization and Statistics issued a statement which indicated that, Egypt's total water resources in 2016/2017 reached 80.0 billion m3. This amount comes from 55.5 billion m3 of Nile River share & 24.5 billion m3 of agriculture drainage recycling, sewage recycling, rain and flash floods, and desalination.(<https://www.elwatannews.com>, <https://m.akhbarelyom.com/news>, <http://www.dotmsr.com/news>,<http://gate.ahram.org.eg/News/2133112.aspx>,<http://www.fedcoc.org.eg/Default.aspx>,).On the other hand, with regard to water efficiency and crop water productivity, FAO (2015) explained that, Water efficiency (WE) is defined as the proportion of water consumed through plant transpiration (and so contributing to plant growth) over the total water applied. It is a dimensionless ratio, often expressed in percentage.

Crop water productivity (CWP)is defined as the production per unit of water transpired or ‘crop perdrop’. The simplest measure is kg/m3 transpired (*physicalCWP*), but another meaningful measure is net incomeper unit of water transpired (USD/m3 or *economic CWP*).Moldenet. al. (2007) defined water productivity as the ratio of the net benefits from crop, forestry, fishery, livestock, and mixed agricultural systems to the amount of water required to produce those benefits. They added that, there are important reasons to improve agricultural water productivity:

* To meet the rising demand for food from a growing, wealthier, and increasingly urbanized population, in light of water scarcity.
* To respond to pressures to reallocate water from agriculture to cities and to ensure that water is available for environmental uses.
* To contribute to poverty reduction and economic growth. For the rural poor more productive use of water can mean better nutrition for families, more income, productive employment, and greater equity. Targeting high water productivity can reduce investment costs by reducing the amount of water that has to be withdrawn.

Perry et. al. (2009) indicated that to better understand how different crops, different agroclimatic environments, and different management practices may influence the relationship between crop production and water consumption, we define the water productivity of a crop (WP) as the ratio between the amount of crop produced and the amount of water consumed to obtain such production. Moreover, in defining water productivity, we need to be specific in indicating which product (biomass or yield) and which consumption (transpiration or evapotranspiration) we are referring to. Thus, we can express the water productivity of a crop (WP) as:

* Biomass WP(T) = (kg of biomass)/(m3 of water transpired).
* Biomass WP(ET) = (kg of biomass)/(m3 of water evapo-transpired).
* Yield WP(T) = (kg of usable yield)/(m3 of water transpired).
* Yield WP(ET) = (kg of usable yield)/(m3 of water evapo-transpired).

The aim of the present study is to find out the total water budget for Egyptian crops, and the percentages of water budget for winter, summer, Nili and perennial crops to the total water budget. In addition, crop water productivity and the economics of the land and water unitswere included in current study.This assessment can help redraw the agricultural map in different climatic regions according to the productive excellence and economic return of the land and water units.

**2. Materials and Methods**

**Study Area:**

Egypt has been divided into five geographical regions, taking into consideration the distinctive features of the agricultural regions (SADS, 2009). They are:

**Upper Egypt:**

 Including Asyut, Sohag, Qena, Aswan and the New Valley governorates;

**Middle Egypt**:

Including Giza, Bani-Sweif, Al-Fayoum, and Minya governorates;

**Middle Delta:**

Including Al-Qaliobeya, Al-Menoufeya, Al-Gharbeya, Al-Dakahleya, Kafr El-Sheikh and Dumyat governorates;

**Eastern Delta:**

Including Al-Sharkeya, Port Said, Ismailia, Suez, Northern Sinai and Southern Sinai governorates;

**Western Delta:**

Including Al-Beherah, Alexandria, Al-Nubareyah, and Matrouh governorates.

In this study, due to the lack of climate data for agricultural climatic regions, threegovernorateswithin these regions were selected to calculate the water budget in the old and newly reclaimed lands within the Nile Valley and Delta.These governoratesare: KafrEl-Sheikh, representing Eastern, Middle and WesternNileDelta (Lower Egypt); Giza and Asyut to represent Middle and Upper Egypt, respectively.Average climaticvalues of these governorates were used to calculate the water budget in the lands outside the Nile Valley and Delta.

**Meteorological data:**

Meteorological data were obtained from the weather station at Agricultural Research Center, Sakhastation,Kafr El-Sheikh Governorate, and from Egyptian Meteorological Authority (EMA). Average monthly minimum and maximum temperatures, relative humidity,wind speed and sunshine percent, in addition to total monthly rainfall through the study period (2016-2017) are presented in Table 1.

**Cultivated area:**

Data of cultivated areas during the 2016/17 winter season and 2017 summer, Nili and perennials for the selected areas of this study were obtained from the Agricultural Economic Research Institute Bulletins (AERI, Volumes 2016-2017).

Table (1): Average monthly weather data for Kafr El-Sheikh, Giza and Asyut in 2016and 2017.

|  |  |  |  |
| --- | --- | --- | --- |
|  Month | Kafr El-Sheikh, 2016  | Giza, 2016  | Asyut, 2016 |
| Min. | Max. | RH | WS | SS | RF | Min. | Max. | RH | WS | SS | RF | Min. | Max. | RH | WS | SS | RF |
| °C | °C | % | m/s | % | mm | °C | °C | % | m/s | % | mm | °C | °C | % | m/s | % | mm |
| January | 6.3 | 18.4 | 75 | 0.8 | 69 | 42.7 | 7.9 | 19.4 | 60 | 1.7 | 68 | 9.5 | 5.2 | 19.0 | 62 | 3.2 | 85 | 0.0 |
| February | 9.4 | 22.6 | 69 | 0.7 | 71 | 0.0 | 10.4 | 24.4 | 54 | 1.6 | 72 | 0.5 | 9.3 | 24.6 | 52 | 3.0 | 88 | 0.0 |
| March | 11.6 | 24.5 | 70 | 0.7 | 73 | 13.2 | 13.1 | 27.3 | 44 | 2.1 | 73 | 0.0 | 13.4 | 28.1 | 42 | 3.6 | 83 | 0.0 |
| April | 18.6 | 30.0 | 62 | 1.0 | 78 | 0.0 | 16.7 | 33.5 | 38 | 1.9 | 75 | 0.0 | 17.5 | 34.9 | 34 | 3.6 | 81 | 0.0 |
| May | 22.8 | 30.4 | 59 | 1.1 | 78 | 0.0 | 19.0 | 34.6 | 39 | 2.1 | 80 | 0.0 | 20.1 | 36.2 | 29 | 4.1 | 85 | 0.0 |
| June | 26.3 | 33.6 | 62 | 1.3 | 85 | 0.0 | 22.5 | 38.6 | 32 | 2.0 | 86 | 0.0 | 24.6 | 40.7 | 30 | 4.1 | 90 | 0.0 |
| July | 26.1 | 33.7 | 70 | 1.2 | 84 | 0.0 | 24.0 | 37.2 | 46 | 2.1 | 85 | 0.0 | 24.2 | 37.3 | 39 | 4.1 | 90 | 0.0 |
| August | 26.0 | 33.6 | 70 | 1.1 | 86 | 0.0 | 24.5 | 36.5 | 45 | 2.1 | 85 | 0.0 | 24.0 | 37.3 | 39 | 4.1 | 92 | 0.0 |
| September | 24.3 | 32.6 | 68 | 1.1 | 85 | 0.0 | 22.3 | 35.4 | 44 | 1.9 | 85 | 0.0 | 21.6 | 35.0 | 45 | 4.6 | 89 | 0.0 |
| October | 21.7 | 29.8 | 69 | 1.1 | 83 | 0.0 | 19.8 | 32.4 | 53 | 2.0 | 82 | 0.0 | 17.7 | 32.7 | 52 | 4.1 | 88 | 1.0 |
| November | 17.9 | 24.9 | 68 | 0.7 | 77 | 0.0 | 14.8 | 27.4 | 55 | 1.8 | 78 | 0.0 | 12.8 | 26.9 | 57 | 3.2 | 87 | 0.0 |
| December | 10.8 | 19.3 | 75 | 0.8 | 66 | 25.8 | 8.7 | 20.9 | 58 | 1.7 | 70 | 1.0 | 6.4 | 19.7 | 62 | 3.5 | 87 | 0.0 |
| Average | 18.5 | 27.8 | 68 | 1.0 | 78 | 81.7 | 17.0 | 30.6 | 47 | 1.9 | 78 | 11.0 | 16.4 | 31.0 | 45 | 3.8 | 87 | 1.0 |
|   | Kafr El-Sheikh, 2017 | Giza, 2017 | Asyut, 2017 |
| Month | Min. | Max. | RH | WS | SS | RF | Min. | Max. | RH | WS | SS | RF | Min. | Max. | RH | WS | SS | RF |
| °C | °C | % | m/s | % | mm | °C | °C | % | m/s | % | mm | °C | °C | % | m/s | % | mm |
| January | 5.7 | 18.2 | 75 | 0.6 | 69 | 9.6 | 6.9 | 19.4 | 60 | 1.7 | 68 | 0.0 | 5.4 | 19.2 | 57 | 3.1 | 85 | 0.0 |
| February | 10.2 | 19.7 | 73 | 0.7 | 71 | 25.2 | 8.0 | 21.5 | 60 | 1.7 | 72 | 0.8 | 6.6 | 20.9 | 53 | 3.2 | 88 | 0.0 |
| March | 17.9 | 21.7 | 73 | 1.0 | 73 | 0.0 | 12.0 | 24.4 | 48 | 1.7 | 73 | 0.0 | 11.0 | 25.2 | 44 | 3.6 | 83 | 0.0 |
| April | 21.6 | 26.5 | 65 | 1.0 | 78 | 10.6 | 15.0 | 29.2 | 41 | 2.0 | 75 | 1.6 | 15.4 | 31.3 | 38 | 3.5 | 81 | 0.0 |
| May | 25.8 | 30.6 | 62 | 1.2 | 78 | 0.0 | 19.4 | 34.6 | 35 | 2.0 | 80 | 0.0 | 20.1 | 36.3 | 33 | 3.3 | 85 | 0.0 |
| June | 28.1 | 32.5 | 66 | 1.2 | 85 | 0.0 | 22.3 | 36.7 | 36 | 2.1 | 86 | 0.0 | 23.5 | 37.4 | 36 | 4.3 | 90 | 0.0 |
| July | 29.0 | 34.2 | 71 | 0.9 | 84 | 0.0 | 24.5 | 38.2 | 42 | 2.0 | 85 | 0.0 | 25.4 | 39.3 | 33 | 3.4 | 90 | 0.0 |
| August | 28.3 | 33.9 | 71 | 0.8 | 86 | 0.0 | 24.6 | 37.1 | 46 | 2.0 | 85 | 0.0 | 24.6 | 37.9 | 41 | 3.7 | 92 | 0.0 |
| September | 25.9 | 32.5 | 68 | 1.0 | 85 | 0.0 | 22.2 | 34.9 | 46 | 1.9 | 85 | 0.0 | 20.9 | 35.2 | 47 | 4.4 | 89 | 0.0 |
| October | 24.0 | 28.7 | 68 | 0.9 | 83 | 0.0 | 18.5 | 31.0 | 47 | 1.9 | 82 | 0.0 | 16.7 | 30.3 | 48 | 3.6 | 88 | 0.0 |
| November | 19.9 | 23.7 | 72 | 0.6 | 77 | 9.3 | 13.7 | 25.5 | 54 | 1.7 | 78 | 0.0 | 10.9 | 25.0 | 56 | 3.1 | 87 | 0.0 |
| December | 8.4 | 21.5 | 77 | 0.5 | 66 | 5.6 | 12.4 | 23.9 | 64 | 1.5 | 70 | 0.0 | 9.0 | 23.1 | 60 | 3.0 | 87 | 0.0 |
| Average | 20.4 | 27.0 | 70 | 0.9 | 78 | 60.3 | 16.6 | 29.7 | 48 | 1.9 | 78 | 2.4 | 15.8 | 30.1 | 46 | 3.5 | 87 | 0.0 |

where: Min.and Max. = minimumandmaximum temperatures °C; RH =relative humidity (%); WS= wind speed (m/sec); SS = sunshine (%) and RF = rainfall (mm).

**Water budget for Egyptian crops:**

Crop water requirement is defined as the amount of water required to compensate the evapotranspiration loss from the cropped field. It refers to the amount of water that needs to be applied considering the efficiencies of the irrigation system, while crop evapotranspiration refers to the amount of water that is lost to the atmosphere through plant leaves (transpiration) and soil surface (evaporation). The irrigation water requirement also includes additional water for leaching of salts and to compensate for non-uniformity of water application (Allen et al., 1998).

**To calculate water budget for agricultural crops, four steps are followed:**

1. **Calculate reference crop evapotranspiration (ETo):**

The ETo was calculated by FAO Penman-Monteith method, using the decision support software CROPWAT 8.0 developed by FAO, based on Allen et al. (1998). The equation used for calculating ETois described as follows:



Where ETo is the reference crop evapotranspiration (mm day-1), Rn is the net radiation at the crop surface (MJ m-2 day-1), G is the soil heat flux density (MJ m-2 day-1), T is the mean daily air temperature at 2 m height (°C), u2 is the wind speed at 2 m height (m s-1), es is the saturation vapor pressure (kPa), eais the actual vapor pressure (kPa), es - ea is the vapor pressure deficit (kPa), is the slope of the pressure-temperature curve (kPa °C-1), andis the psychrometric constant (kPa °C-1).

1. **Calculate crop water use (crop evapotranspiration, ETc)**

According to Allen et al. (1998), crop evapotranspiration (ETc) is calculated by multiplying the reference crop evapotranspiration (ETo), by crop coefficient(Kc):

ETc = KcETo

WhereETc is the crop evapotranspiration (mm day-1), Kc is the crop coefficient (dimensionless), and ETo is the reference crop evapotranspiration (mm day-1).

The Kc values of the crops used in this study were obtained from FAO No. 56 and some values were adjusted according to the results of actual experiments in Egypt.

1. **Calculate irrigation water requirement (IWR):**

IWR = ETc/ IE

Where IE is the irrigation efficiency.

Irrigation efficiency can be defined in terms of: 1) the irrigation system performance, 2) the uniformity of the water application, and 3) the response of the crop to irrigation (Howell, 2003). In this study, the application efficiency that is related to the actual storage of water in the root zone to meet the crop water needs in relation to the water applied to the field was used. The irrigation efficiency values used in this study were:

- 60% for surface irrigation system (Jensen, 1980).

- 50% for submerged crops, i.e. rice (Dastane, 1972; and Doorenbos and Pruitt, 1977).

- 80% for the modern irrigation systems.

1. **Water budget (WB):**

The total water budget for the selected areas and crops was calculated according to the following equation:

$$WB=\sum\_{i=1}^{i=n}\left(IWR\right)i X \left(Area\right)i$$

where: (IWR)i: is the irrigation water requirement of crop i

(Area)i: is the cultivated area of crop i

**Selected crops:**

The water budget was calculated for the following crops:

**Winter season**:

Barley, chick peas, faba bean (green), faba bean (dry), fenugreek (green), fenugreek (dry), flax, garlic, lentil, lupine, onion, sugar beet, wheat, beans (green), beans (dry), cabbage, carrot, cucumber, eggplant, lettuce, peas (green), peas (dry), pepper, potato, squash, strawberry and tomato.

**Summer season**:

Cotton, ground nut, maize, onion, rice, soybean, sunflower, beans (green), beans (dry), cabbage, cantaloupe, cucumber, eggplant, jews mallow, okra, pepper, potato, squash, sweet melon, taro, tomato and water melon.

**Nili season**:

Beans (green), beans (dry), cabbage, cucumber, eggplant, maize, pepper, potato, squash, sunflower and tomato.

**Perennial crops**: apple, banana, date, grapes, mango, olive, orange, peach and sugar cane.

**Crop water productivity (CWP):**

According to Wichelns (2014), water productivity is,mostoften,defined as the average amount of output per unit of water applied on a field (Equation 1) or per unit of water evapo-transpired (Equation 2).

$$WP\left(AW\right)=\frac{Output\left(\frac{kg}{ha}\right)}{Appliedwater\left(\frac{m^{3}}{ha}\right)}………….\left(equation 1\right)$$

$$WP\left(ET\right)=\frac{Output\left(\frac{kg}{ha}\right)}{Evapo-transpiredwater\left(\frac{mm}{ha}\right)}……\left(equation 2\right)$$

the outputs refer to the actual yield of the crops under study, which were obtained from AERI(Volumes 2016-2017).

**Economics of the land and water units**

Data of the economic return per unit of land (farm net return) was obtained from AERI(Volumes 2016-2017). The productivity of the main and secondary crop products, average prices, the value of ~~the~~ main and secondary crop products, total revenue, cost of all agricultural operations, rent of the land unit, total costandfarmnet return were calculated. Regarding the economics of water unit, the following equations were used for the amounts of water consumed (ETC) and applied (IWR):

Economic return of water unitETc = $\frac{farmnetreturn}{cropevapotranspiration, ETc}$(LE/ m3)

Economic return of water unitIWR= $\frac{farmnetreturn}{irrigationwaterrequirements, IWR}$(LE/ m3)

**3. Results and Discussion**

**Cultivated and cropped areas and cropping intensity:**

Egyptian crops are grown in two to three seasons, winter (October through April), summer (May through September), and sometimes in the Nili season (June through October), in addition to the perennial crops that grow all over the year. The cultivated land of Egypt inside and outside the Nile Valley and Delta totals about 3.8 million hectares in 2016/ 2017 (Table 2). The largest cultivated area in Egypt is in Lower Egypt with a cultivated area of 1.9 million hectares and represents approximately 50% of the total cultivated area. While, the cultivated area in Middle and Upper Egypt registered about 0.6 and 0.5 million hectares, respectively, which represent about 16 and14% of the total cultivated area. Total newly cultivated area outside the Nile Valley and Delta amounted to 0.8 million hectares and represents 20% of the total cultivated area in Egypt. As a result of cultivating the land more than one time a year with a cropping intensity of 1.76, the cropped area inside the Nile Valley and Delta is estimated at 5.7 million hectares and 1.0 million hectares of the newly reclaimed lands outside the Nile Valley and Delta (Table 3).

Table 2: Cultivated areas (ha)inside and outside the NileValley and Delta in 2016/2017.

|  |  |  |  |
| --- | --- | --- | --- |
| Cultivated area | Inside the Nile Valley and Delta | Outside the Nile Valley and Delta (New Lands) | Grand Total |
| Lower Egypt | Middle Egypt | Upper Egypt | Total |
| Hectare | 1,906,172 | 595,939 | 542,433 | 3,044,544 | 760,985 | 3,805,528 |
| % | 50.1 | 15.7 | 14.3 | 80 | 20 | 100 |

Table 3: Total cropped area inside and outside the Nile Valley and Delta in 2016/2017 (ha).

|  |  |  |  |
| --- | --- | --- | --- |
| Cropped area | Inside the Nile Valley and Delta | Outside the Nile Valley and Delta (New Lands) | Grand Total |
| Lower Egypt | Middle Egypt | Upper Egypt | Total |
| Hectare | 3,619,753 | 1,112,776 | 925,374 | 5,657,903 | 1,024,681 | 6,682,584 |

Source of data: Agricultural Economic Research Institute Bulletins (AERI, Volumes 2016-2017).

**Reference evapotranspiration for the studied areas (ETo):**

The calculated monthly ETo values for Lower, Middle and Upper Egypt in 2016 and 2017 are presented in Figs. 1 and 2. It is clear from the results that Lower Egypt recorded the lowest ETo values as compared with Middle and Upper Egypt. Results showed that there are inter annual differences (between months) in ETo values through the study period. The highest ETovalues were recorded for June followed by July, while January followed by December registered the lowest ones.The obtained results agreed with what was mentioned in FAO report (<http://www.fao.org/docrep/X0490E/x0490e07.htm>),indicating that the evapotranspiration demand is high under hot-dry weather due to the dryness of the air and the amount of energy available as direct solar radiation and latent heat. Under these circumstances, much water vapor can be stored in the air, while wind may promote the transport of water allowing more water vapor to be taken up. On the other hand, under humid weather conditions, the high humidity of the air and the presence of clouds cause the evapotranspiration rate to be lower.

**Water consumption (crop evapotranspiration, ETc):**

The calculated ETc values for winter, summer, Nili and perennial crops under different agro-climatic areas are presented in Figs. 3 to 6. Results indicated, in general, that Upper Egypt registered higher crop water consumption as compared with Lower and Middle Egypt.Results indicated for winter season that, strawberry, sugar beet, onion and wheat consumed the highest amounts of water as compared with the other crops because their season length is longer than the other winter crops. In the same direction, taro (colocasus) and cotton in summer season; eggplant, pepper, cabbage, and tomato in Nili season. As for the perennials, bananas, sugarcane and mango were the highest water consuming crops. Average ETc values varied from 2149 to 5114 m3/ ha for winter crops; 4218 to 11022 m3/ ha for summer crops; 4544 to 8124 m3/ha for Nili crops; and 9641 to 19508 m3/ ha for perennials.

**Water Budget (WB):**

**Winter crops:**

Results presented in Table 4 indicated that, the WB for winter crops in the old and new lands within the Nile Valley and Delta reached about 11.9 and 1.5 billion m3, respectively. Whereas, the WB value outside the Nile Valley and Delta (the New lands) was around 2.0 billion m3. Accordingly, the total WB for winter crops reached about 15.4 billion m3.

**Summer crops:**

Thecalculated WB values for summer crops in the old and new lands inside the Nile Valley and Delta recorded 23.8 and 1.9 billion m3, respectively. However, the value outside the Nile Valley and Delta (New lands) amounted to 2.0 billion m3 (Table 5). The total WB for summer crops was 27.7 billion m3.

**Nili crops:**

Results of WB for Nili crops (Table 6) showed that values for the respective old and new lands inside the Nile Valley and Delta were 1.9 and 0.07 billion m3. Whereas, the value outside the Nile Valley and Delta (New lands) was 0.3 billion m3. Consequently, the total WB for Nili crops recorded about 2.2 billion m3.

**Perennial crops:**

Results tabulated in Table 7 indicated that, WB values for perennial crops in the old and new lands inside the Nile Valley and Delta were 8.8 and 3.0 billion m3, respectively. However, the water budget outside the Nile Valley and Delta (New lands) recorded 5.6 billion m3. Consequently, the total WB for the perennials recorded 17.4 billion m3.

**Total cropped area and WB for the Egyptian crops in the selected locations:**

Results presented in Table 8 show the total cropped area and WB for the selected agricultural crops. Total cropped area for winter, summer, Nili and perennial crops were 2.9, 2.7, 0.2 and 0.9 million hectares, respectively. According to the total cropped area, the total WB amounted to 15.4, 27.7, 2.2 and 17.4 billion m3 for the respective growing seasons.

**Table 4: Water budget (WB, m3) for winter crops inside and outside the Nile Valley and Delta in Egypt according to the cropped area in 2016/ 2017.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Crop | WB inside the Nile Valley and Delta | WB outside the Nile Valley and Delta | Grand Total | %from the total WB for all agricultural crops |
| Old lands | New lands | New lands |
| **Winter field crops** |   |   |   |   |  |
| Barley | 17,341,140 | 22,392,666 | 51,190,551 | 90,924,356 | 0.15 |
| Chick peas | 9,250,335 | 511,146 |   | 9,761,481 | 0.02 |
| Faba bean (Green) | 5,249,285 | 916,191 |   | 6,165,476 | 0.01 |
| Faba bean (Dry) | 129,968,657 | 21,694,099 | 57,554,190 | 209,216,946 | 0.33 |
| Fenugreek (dry) | 6,646,628 | 829,605 | 447,146 | 7,923,379 | 0.01 |
| Flax | 20,239,375 | 330,505 |   | 20,569,880 | 0.03 |
| Garlic | 60,268,042 | 4,098,414 | 10,073,233 | 74,439,689 | 0.12 |
| Lentil | 2,679,540 |   |   | 2,679,540 | 0.004 |
| Lupine | 450,592 |   |   | 450,592 | 0.001 |
| Onion | 274,330,260 | 63,007,440 | 26,774,290 | 364,111,990 | 0.58 |
| Sugar beet | 901,464,285 | 212,736,266 | 42,199,507 | 1,156,400,057 | 1.84 |
| Wheat | 6,153,779,210 | 568,483,527 | 613,032,708 | 7,335,295,446 | **11.70** |
| **Winter vegetables**  |   |   |   |   |  |
| Beans (green) | 14,436,069 | 1,627,178 | 35,749,052 | 51,812,298 | 0.08 |
| Beans (dry) | 61,636,781 | 139,219 | 9,481 | 61,785,481 | 0.10 |
| Cabbage | 54,897,003 | 5,453,442 | 169,199 | 60,519,644 | 0.10 |
| Carrot | 23,363,472 | 480,634 | 876,778 | 24,720,883 | 0.04 |
| Cucumber | 14,358,322 | 3,305,924 | 6,862,569 | 24,526,816 | 0.04 |
| Eggplant | 53,313,508 | 23,275,665 | 5,825,690 | 82,414,862 | 0.13 |
| Lettuce | 13,312,306 | 80,993 | 19,963 | 13,413,262 | 0.02 |
| Peas (green) | 61,838,963 | 3,283,094 | 15,553,518 | 80,675,575 | 0.13 |
| Peas (dry) | 510,469 | -  | 187,722 | 698,191 | 0.001 |
| Pepper | 38,968,599 | 17,949,634 | 12,765,399 | 69,683,631 | 0.11 |
| Potato | 318,980,735 | 11,042,856 | 148,943,170 | 478,966,761 | 0.76 |
| Squash | 28,812,900 | 12,083,563 | 11,554,474 | 52,450,937 | 0.08 |
| Strawberry | 26,460,020 | 92,666 | 23,198,296 | 49,750,983 | 0.08 |
| Tomato | 169,642,830 | 126,392,152 | 91,320,675 | 387,355,657 | 0.62 |
| **Other winter crops** | 3,474,857,845 | 419,259,600 | 836,589,177 | 4,730,706,622 | 7.54 |
| **Total winter crops** | 11,937,057,169 | 1,519,466,477 | 1,990,896,788 | 15,447,420,435 | 24.6 |

Note: In this table and other tables, the absence of some values reflects the absence of crop cultivation under the conditions of this type of land.

**Table 5: Water budget (WB, m3) for summer crops inside and outside the Valley and Nile Delta in Egypt according to cropped area in 2017.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Crop | WB inside the Nile Valley and Delta | WB outside the Nile Valley and Delta | Grand Total | %from the total WB for all agricultural crops |
| Old lands | New lands | New lands |
| **Summer field crops** |  |  |  |  |  |
| Cotton | 1,015,425,083 | 93,781,011 | 2,933,292 | 1,112,139,386 | 1.77 |
| Ground nut | 156,147,799 | 59,735,713 | 363,750,393 | 579,633,905 | 0.92 |
| Maize | 9,009,573,404 | 455,617,908 | 576,610,008 | 10,041,801,320 | **16.01** |
| Onion | 12,894,150 | 1,360,444 | 4,249,601 | 18,504,195 | 0.03 |
| Rice | 5,933,814,088 | 475,210,667 | 10,108,671 | 6,419,133,426 | **10.24** |
| Soybean | 152,751,289 | 884,969 | 2,703,740 | 156,339,997 | 0.25 |
| Sunflower | 26,177,802 | 1,872,804 | 17,466,573 | 45,517,179 | 0.07 |
| **Summer vegetables** |  |  |  |  |  |
| Beans (green) | 11,017,922 | 1,235,551 | 155,966 | 12,409,438 | 0.02 |
| Beans (dry) | 207,319,688 | 10,423,922 | 16,635,863 | 234,379,472 | 0.37 |
| Cabbage | 32,903,097 | 793,555 | 3,150,301 | 36,846,952 | 0.06 |
| Cantaloupe | 19,555,308 | 7,017,751 | 46,245,924 | 72,818,984 | 0.12 |
| Cucumber | 58,436,534 | 9,940,903 | 16,943,670 | 85,321,107 | 0.14 |
| Eggplant | 165,820,006 | 49,177,194 | 22,830,962 | 237,828,161 | 0.38 |
| Jews Mallow | 42,007,685 | 2,616,685 | 647,187 | 45,271,557 | 0.07 |
| Okra | 25,084,314 | 4,076,289 | 650,063 | 29,810,665 | 0.05 |
| Pepper | 124,537,471 | 66,626,441 | 22,450,500 | 213,614,411 | 0.34 |
| Potato | 319,608,358 | 14,763,219 | 25,984,050 | 360,355,626 | 0.57 |
| Squash | 36,245,856 | 12,284,947 | 20,014,126 | 68,544,929 | 0.11 |
| Sweet melon | 12,259,030 | 6,543,188 | 463,278 | 19,265,496 | 0.03 |
| Taro | 37,308,406 | 940,922 |  | 38,249,328 | 0.06 |
| Tomato | 386,511,065 | 201,736,949 | 267,249,610 | 855,497,624 | 1.36 |
| Watermelon | 76,846,153 | 18,653,320 | 142,447,697 | 237,947,169 | 0.38 |
| **Other summer crops** | 5,898,759,673 | 395,533,778 | 448,665,196 | 6,742,958,646 | 10.75 |
| **Total summer crops** | 23,761,004,179 | 1,890,828,126 | 2,012,356,669 | 27,664,188,973 | 44.1 |

**Table 6: Water budget (WB, m3) for Nili crops inside and outside the Valley and Nile Delta in Egypt according to cropped area in 2017.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Crop | WB inside the Nile Valley and Delta | WB outside the Nile Valley and Delta | Grand Total | %from the total WB for all agricultural crops |
| Old lands | New lands | New lands |
| Beans (green) | 22,552,708 | 592,647 | 4,668,893 | 27,814,248 | 0.04 |
| Beans (dry) | 53,957,597 |  |  | 53,957,597 | 0.09 |
| Cabbage | 14,496,081 | 2,030,923 | 50,910 | 16,577,914 | 0.03 |
| Cucumber | 6,516,526 | 873,651 | 366,458 | 7,756,636 | 0.01 |
| Eggplant | 17,410,983 | 9,970,656 | 36,367,594 | 63,749,233 | 0.10 |
| Maize | 1,280,691,653 | 10,760,209 | 86,961,444 | 1,378,413,307 | 2.20 |
| Pepper | 10,896,001 | 6,103,529 | 14,992,256 | 31,991,785 | 0.05 |
| Potato | 243,838,136 |  |  | 243,838,136 | 0.39 |
| Squash | 10,526,352 | 3,211,261 | 17,889 | 13,755,502 | 0.02 |
| Sunflower | 253,406 |  | 539,640 | 793,046 | 0.001 |
| Tomato | 47,207,861 | 18,735,510 | 47,893,165 | 113,836,536 | 0.18 |
| **Other Nili crops** | 199,954,937 | 18,602,328 | 61,280,101 | 279,837,366 | 0.45 |
| **Total Nili crops** | 1,908,302,242 | 70,880,714 | 253,138,349 | 2,232,321,306 | 3.56 |

**Table 7: Water budget (WB, m3) for perennial crops in the old and new lands in Egypt according to cropped area in 2017.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Crop | WB inside the Nile Valley and Delta | WB outside the Nile Valley and Delta | Grand Total | %from the total WB for all agricultural crops |
| Old lands | New lands | New lands |
| Apple | 22,880,262 | 10,842,341 | 390,560,796 | 424,283,399 | 0.68 |
| Banana | 563,358,209 | 79,405,827 | 204,522,522 | 847,286,557 | 1.35 |
| Date | 337,077,583 | 302,826,041 | 320,482,660 | 960,386,283 | 1.53 |
| Grapes | 337,518,968 | 100,058,682 | 513,732,046 | 951,309,696 | 1.52 |
| Mango | 1,025,814,522 | 548,905,143 | 420,383,467 | 1,995,103,132 | 3.18 |
| Olive | 74,718,833 | 321,896,871 | 674,618,833 | 1,071,234,538 | 1.71 |
| Orange | 1,049,737,302 | 393,550,144 | 479,250,535 | 1,922,537,982 | 3.07 |
| Peach | 7,059,653 | 19,811,442 | 347,656,246 | 374,527,341 | 0.60 |
| Sugarcane | 4,092,886,440 | 514,730,164 | 798,938 | 4,608,415,541 | **7.35** |
| **Other perennials** | 1,266,719,465 | 700,097,557 | 2,236,983,603 | 4,203,800,625 | 6.70 |
| **Total perennials** | 8,777,771,237 | 2,992,124,210 | 5,588,989,647 | 17,358,885,094 | 27.68 |

**Table 8: Irrigation water budget for Egyptian crops according to cropped area in 2016/2017**

|  |  |  |
| --- | --- | --- |
| **Groups** | **Cropped area (ha)** | **Water budget ( m3)** |
| **Winter crops** | **2,887,853** | **15,447,420,435** |
| **Summer crops** | **2,665,702** | **27,664,188,973** |
| **Nili crops** | **211,353** | **2,232,321,306** |
| **Perennials** | **917,676** | **17,358,885,094** |
| **Grand Total** | **6,682,584** | **62,702,815,807** |

**Crops that consumed the largest proportion of the total water budget:**

Results of this study indicated that, maize, wheat, rice and sugarcane nearly consumed half of the water budget (47.5%) allocated to agricultural cropsand occupied 44.7% of the total cropped area (Table 9). The agricultural area of these four respected crops were about 1.09, 1.22, 0.54 and 0.14 million ha. The total water budget for each crop, respectively, were about 11.4, 7.3, 6.4 and 4.6 billion m3.

**Table 9: Crops that consumed the largest proportion of the total water budget.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **crop** | Area(ha) | % of grand total cropped area | Total WB(m3) | % of total water budget |
| Maize (summer and Nili seasons) | 1,087,541 | 16.3 | 11,420,214,627 | 18.2 |
| Wheat | 1,217,381 | 18.2 | 7,335,295,446 | 11.7 |
| Rice | 544,623 | 8.1 | 6,419,133,426 | 10.2 |
| Sugarcane | 135,932 | 2.0 | 4,608,415,541 | 7.3 |
| Total (four crops) | 2,985,477 | 44.7 | 29,783,059,040 | 47.5 |
| Grand total of cropped area and water budget | 6,682,584 |   | 62,702,815,807 |   |

**Crop water productivity (CWP, kg/m3 water consumed):**

Resultspresentedin Tables (10 - 13)indicated that,crops with the highest CWP values were sugar beet, onion, and garlic for winter field crops; carrot, tomato, lettuce, eggplant, strawberry, potato, and cabbage for winter vegetables; onion for summer field crop; potato, cantaloupe, watermelon, tomato, and cucumber for summer vegetables.Eggplants recorded the highest CWP for Nili crops and sugarcane for perennials. The results indicated that, some crops were superior in CWP under new lands conditions as compared with old lands.These cropsare: barley, faba bean (dry), beans (dry), lettuce, potato, strawberry, maize, sunflower, apple, banana, mango and orange.

Generally, CWP values varied from 0.52 to 10.61 kg/m3 for winter field crops; 0.66 to 11.84 kg/m3 for winter vegetables; 0.29 to 2.64 kg/m3 for summer field crops; 0.55 to 5.82 kg/m3 for summer vegetables; 0.34 to 5.05 kg/m3 for Nili crops; and 0.66 to 4.77 kg/m3 for perennials.

**Table 10: Crop water productivity (CWP, kg/ m3 water consumed) for winter crops inside and outside the Nile Valley and Delta in 2016/ 2017.**

|  |  |  |  |
| --- | --- | --- | --- |
| Crop | CWP inside the Nile Valley and Delta | CWP outside the Nile Valley and Delta | Average CWP  |
| Old lands | New lands | New lands |
| **Winter Field crops** |   |   |   |   |
| Barley | 1.11 | 1.07 | 1.51 | 1.23 |
| Chick peas | 0.83 | 0.53 |   | 0.68 |
| Faba bean (Green) | 5.02 | 3.36 |   | 4.19 |
| Faba bean (Dry) | 0.96 | 0.85 | 1.15 | 0.99 |
| Fenugreek (dry) | 0.66 | 0.44 | 0.44 | 0.52 |
| Flax | 3.96 | 4.09 |   | 4.02 |
| Garlic | 6.06 | 4.56 | 5.54 | 5.39 |
| Lentil | 1.05 |   |   | 1.05 |
| Lupine | 0.69 |   |   | 0.69 |
| Onion | 9.73 | 10.04 | 9.26 | 9.68 |
| Sugar beet | 11.33 | 10.79 | 9.71 | 10.61 |
| Wheat | 1.66 | 1.48 | 1.49 | 1.55 |
| **Winter vegetables**  |   |   |   |   |
| Beans (green) | 3.83 | 2.73 | 2.40 | 2.98 |
| Beans (dry) | 0.56 | 0.52 | 1.05 | 0.71 |
| Cabbage | 7.54 | 8.22 | 6.17 | 7.31 |
| Carrot | 11.67 | 15.28 | 8.56 | 11.84 |
| Cucumber | 5.99 | 5.02 | 5.15 | 5.39 |
| Eggplant | 9.22 | 10.37 | 5.14 | 8.24 |
| Lettuce | 7.05 | 7.89 | 10.50 | 8.48 |
| Peas (green) | 3.17 | 2.67 | 2.65 | 2.83 |
| Peas (dry) | 0.99 |   | 0.33 | 0.66 |
| Pepper | 4.16 | 4.22 | 4.10 | 4.16 |
| Potato | 6.33 | 8.56 | 7.69 | 7.53 |
| Squash | 5.90 | 4.10 | 4.04 | 4.68 |
| Strawberry | 7.55 | 7.80 | 7.92 | 7.76 |
| Tomato | 10.98 | 11.11 | 7.59 | 9.89 |

**Table 11: Crop water productivity (CWP, kg/ m3 water consumed) for summer crops inside and outside the Nile Valley and Delta in 2017.**

|  |  |  |  |
| --- | --- | --- | --- |
| Crop | CWP inside the Nile Valley and Delta | CWP outside the Nile Valley and Delta | Average CWP  |
| Old lands | New lands | New lands |
| **Summer field crops** |   |   |   |   |
| Cotton | 0.32 | 0.28 | 0.27 | 0.29 |
| Ground nut | 0.54 | 0.48 | 0.52 | 0.52 |
| Maize | 1.14 | 0.93 | 1.22 | 1.09 |
| Onion | 3.49 | 2.44 | 1.98 | 2.64 |
| Rice | 1.34 | 1.12 | 1.18 | 1.22 |
| Soybean | 0.39 | 0.34 | 0.31 | 0.35 |
| Sunflower | 0.49 | 0.58 | 0.71 | 0.59 |
| **Summer vegetables**  |   |   |   |   |
| Beans (green) | 2.69 | 2.64 | 1.26 | 2.20 |
| Beans (dry) | 0.48 | 0.50 | 0.67 | 0.55 |
| Cabbage | 3.91 | 2.92 | 2.52 | 3.12 |
| Cantaloupe | 4.90 | 6.30 | 5.57 | 5.59 |
| Cucumber | 4.43 | 3.35 | 5.27 | 4.35 |
| Eggplant | 3.58 | 2.57 | 3.43 | 3.19 |
| Jews Mallow | 2.69 | 1.17 | 1.29 | 1.72 |
| Okra | 2.69 | 2.34 | 2.25 | 2.43 |
| Pepper | 2.58 | 1.71 | 2.89 | 2.39 |
| Potato | 6.07 | 5.20 | 6.21 | 5.82 |
| Squash | 4.23 | 3.10 | 4.08 | 3.80 |
| Sweet melon | 4.53 | 3.59 | 3.28 | 3.80 |
| Taro  | 3.29 | 2.96 |   | 3.13 |
| Tomato | 4.98 | 5.21 | 4.04 | 4.74 |
| Watermelon | 5.93 | 4.43 | 4.71 | 5.02 |

**Table 12: Crop water productivity (CWP, kg/ m3 water consumed) for Nili crops inside and outside the Nile Valley and Delta in 2017.**

|  |  |  |  |
| --- | --- | --- | --- |
| Crop | CWP inside the Nile Valley and Delta | CWP outside the Nile Valley and Delta | Average CWP  |
| Old lands | New lands | New lands |
| Beans (green) | 2.38 | 2.30 | 1.19 | 1.96 |
| Beans (dry) | 0.34 |   |   | 0.34 |
| Cabbage | 3.72 | 3.59 | 2.07 | 3.13 |
| Cucumber | 2.35 | 2.35 | 1.56 | 2.09 |
| Eggplant | 3.16 | 3.07 | 2.88 | 3.04 |
| Maize | 1.08 | 0.72 | 1.29 | 1.03 |
| Pepper | 1.95 | 2.15 | 2.22 | 2.11 |
| Potato | 3.44 |   |   | 3.44 |
| Squash | 2.31 | 2.86 | 1.18 | 2.11 |
| Sunflower | 0.52 |   | 0.73 | 0.63 |
| Tomato | 5.71 | 5.78 | 3.66 | 5.05 |

**Table 13: Crop water productivity (CWP, kg/ m3 water consumed) for perennial crops inside and outside the Nile Valley and Delta in 2017.**

|  |  |  |  |
| --- | --- | --- | --- |
| Crop | CWP inside the Nile Valley and Delta | CWP outside the Nile Valley and Delta | Average CWP  |
| Old lands | New lands | New lands |
| Apple | 1.44 | 1.12 | 2.15 | 1.57 |
| Banana | 2.19 | 2.51 | 2.46 | 2.39 |
| Date | 4.73 | 0.96 | 0.94 | 2.21 |
| Grapes | 2.24 | 2.29 | 2.34 | 2.29 |
| Mango | 0.53 | 0.49 | 0.98 | 0.66 |
| Olive | 1.06 | 1.38 | 1.01 | 1.15 |
| Orange | 1.89 | 1.56 | 1.97 | 1.81 |
| Peach | 1.63 | 1.39 | 1.37 | 1.46 |
| Sugarcane | 6.62 | 6.37 | 1.31 | 4.77 |

**Economic evaluation of land and water units:**

Results of the economic evaluation of the land unit (farm net return, LE/ha), water consumption unit (LE/ m3ETc), and irrigation water requirements unit (LE/ m3IWR) for the studied area are presented in Tables (14 - 17). The results could be summarized in the following points:

1. **Farm net return:**

The superiority in the farm net return was found for onion, faba bean (green), garlic, chick peas of the winter field crops; strawberry, peas (dry), carrot, tomato, beans (dry), lettuce, eggplant, cucumber, squash, peas (green), potato of the winter vegetables; groundnut, cotton of the summer field crops; beans (dry), jews mallow, tomato, okra, watermelon, sweet melon, eggplant, beans (green) of summer vegetables; beans (dry), tomato, eggplant, beans (green) of Nili crops; and all perennial crops. Each of the previous crops earned a net farm return of more than 20,000 LE/ha.

Values of farm net return ranged between 126 and 48621 LE/ha for winter field crops; 14386 and 157810 LE/ha for winter vegetables; 1190 and 37298 LE/ha for summer field crops; 8750 and 83095 LE/ha for summer vegetables; 2793 and 66476 LE/ha for Nili crops; and 46136 and 131219 LE/ha for perennials.

1. **Economics of the water consumption unit (LE/ m3ETc)**

Values of the economics of water consumption unit ranged from 0.04 to 16.05 LE/m3ETc for winter field crops; 3.68 to 30.86 LE/m3ETcfor winter vegetables; 0.16 to 4.03 LE/m3ETcfor summer field crops; 1.07 to 14.45 LE/m3ETcfor summer vegetables; 0.61 to 9.91 LE/m3ETcfor Nili crops; and 2.71 to 8.41 LE/m3ETc for perennial crops. Results showed that, the crops that achieved an economic return from the water consumption unit exceed 8 LE/m3ETcwere: Faba bean (green), onion, garlic, chick peas for winter field crops; strawberry, peas (dry), carrot, lettuce, beans (dry), tomato, eggplant, cucumber for winter vegetables; beans (dry), okra, sweet melon for summer vegetables; beans (dry) for Nili crops; and date for perennial crops. Regarding summer field crops, the highest economic return from unit of water consumption reached about 4 LE/m3ETc.

1. **Economics of the irrigation water requirements unit in the old lands (LE/ m3IWR)**

Economics of the water unit for irrigation water requirements in the old lands varied between 0.02 and 9.63 LE/m3IWR for winter field crops; 2.21 and 18.51 LE/m3IWR for winter vegetables; 0.10 and 2.42 LE/m3IWR for summer field crops; 0.64 and 8.67 LE/m3IWR for summer vegetables; 0.35 and 5.94 LE/m3IWR for Nili crops; and 1.62 and 5.05 LE/m3IWR for perennial crops.

1. **Economics of the irrigation water requirements unit in the new lands (LE/ m3IWR)**

Values of the economics of the irrigation water requirements unit in the new lands varied from 0.31 to 12.84 LE/m3IWR for winter field crops; 2.94to24.69 LE/m3IWR for winter vegetables; 0.13to3.22 LE/m3IWR for summer field crops; 1.13to11.56 LE/m3IWR for summer vegetables; 0.47to3.64 LE/m3IWR for Nili crops; and 2.17to6.73 LE/m3IWRfor perennial crops.

**Table 14: Economic return of land and water units for winter crops in 2016/ 2017.**

|  |  |  |
| --- | --- | --- |
| **Crop** | \*Farm net return  | Economics of water unit |
| (LE/ha) | (LE/m3ETc) | Old lands | New lands |
| (LE/m3IWR) | (LE/m3IWR) |
| **Winter Field crops** |   |   |   |   |
| Barley | 1,183 | 0.39 | 0.23 | 0.31 |
| Chick peas | 29,150 | 10.80 | 6.48 | 8.64 |
| Faba bean (Green) | 42,736 | 16.05 | 9.63 | 12.84 |
| Faba bean (Dry) | 8,564 | 2.56 | 1.53 | 2.04 |
| Fenugreek (dry) | 3,245 | 0.98 | 0.59 | 0.79 |
| Flax | 6,898 | 2.32 | 1.39 | 1.86 |
| Garlic | 41,114 | 10.95 | 6.57 | 8.76 |
| Lentil | 7,555 | 3.52 | 2.11 |   |
| Lupine | 126 | 0.04 | 0.02 |   |
| Onion | 48,621 | 12.96 | 7.78 | 10.37 |
| Sugar beet | 11,421 | 2.58 | 1.55 | 2.06 |
| Wheat | 9,105 | 2.16 | 1.30 | 1.73 |
| **Winter vegetables**  |   |   |   |   |
| Beans (green) | 19,567 | 5.89 | 3.54 | 4.71 |
| Beans (dry) | 59,552 | 16.36 | 9.81 | 13.09 |
| Cabbage | 14,386 | 3.68 | 2.21 | 2.94 |
| Carrot | 62,429 | 23.33 | 14.00 | 18.66 |
| Cucumber | 43,333 | 11.18 | 6.71 | 8.95 |
| Eggplant | 47,374 | 13.13 | 7.88 | 10.50 |
| Lettuce | 52,024 | 17.65 | 10.59 | 14.12 |
| Peas (green) | 21,543 | 6.49 | 3.89 | 5.19 |
| Peas (dry) | 86,467 | 23.75 | 14.25 | 19.00 |
| Pepper | 17,826 | 4.26 | 2.56 | 3.41 |
| Potato  | 20,636 | 5.19 | 3.11 | 4.15 |
| Squash | 24,455 | 6.18 | 3.71 | 4.94 |
| Strawberry | 157,810 | 30.86 | 18.51 | 24.69 |
| Tomato | 60,717 | 14.21 | 8.53 | 11.37 |

Currency equivalents (as of September 2019): US $1.00 = 16.55 LE

\*Data were obtained from AERI (Volumes 2016-2017).

**Table 15: Economic return for land and water units for summer crops in Egypt in 2017.**

|  |  |  |
| --- | --- | --- |
| **Crop** | Farm net return  | Economics of the water unit |
| (LE/ha) | (LE/m3ETc) | Old lands | New lands |
| (LE/m3IWR) | (LE/m3IWR) |
| **Summer field crops** |   |   |   |   |
| Cotton | 21,824 | 2.41 | 1.45 | 1.93 |
| Ground nut | 23,855 | 3.36 | 2.02 | 2.69 |
| Maize | 4,248 | 0.61 | 0.36 | 0.49 |
| Onion | 37,298 | 4.03 | 2.42 | 3.22 |
| Rice | 12,431 | 1.82 | 0.91 | 0.91 |
| Soybean | 1,190 | 0.16 | 0.10 | 0.13 |
| Sunflower | 2,640 | 0.54 | 0.32 | 0.43 |
| **Summer vegetables**  |   |   |   |   |
| Beans (green) | 23,926 | 5.67 | 3.40 | 4.54 |
| Beans (dry) | 83,095 | 14.45 | 8.67 | 11.56 |
| Cabbage | 14,286 | 1.77 | 1.06 | 1.41 |
| Cantaloupe | 8,750 | 1.78 | 1.07 | 1.42 |
| Cucumber | 17,117 | 3.52 | 2.11 | 2.81 |
| Eggplant | 27,810 | 3.49 | 2.09 | 2.79 |
| Jews Mallow | 51,238 | 7.96 | 4.77 | 6.37 |
| Okra | 49,760 | 10.76 | 6.46 | 8.61 |
| Pepper | 10,962 | 1.42 | 0.85 | 1.13 |
| Potato | 17,145 | 3.42 | 2.05 | 2.74 |
| Squash | 12,650 | 2.56 | 1.54 | 2.05 |
| Sweet melon | 40,667 | 8.28 | 4.97 | 6.62 |
| Taro  | 11,762 | 1.07 | 0.64 |   |
| Tomato | 50,110 | 6.13 | 3.68 | 4.90 |
| Watermelon | 43,533 | 6.52 | 3.91 | 5.22 |

**Table 16: Economic return for land and water units for Nili crops in Egypt in 2017**

|  |  |  |
| --- | --- | --- |
| **Crop** | Farm net return  | Economics of the water unit |
| (LE/ha) | (LE/m3ETc) | Old lands | New lands |
| (LE/m3IWR) | (LE/m3IWR) |
| Beans (green) | 25,345 | 4.55 | 2.73 | 3.64 |
| Beans (dry) | 66,476 | 9.91 | 5.94 |   |
| Cabbage | 13,095 | 1.74 | 1.04 | 1.39 |
| Cucumber | 12,852 | 1.83 | 1.10 | 1.46 |
| Eggplant | 25,431 | 3.13 | 1.88 | 2.50 |
| Maize | 3,621 | 0.59 | 0.35 | 0.47 |
| Pepper | 9,329 | 1.21 | 0.72 | 0.97 |
| Potato | 18,321 | 2.61 | 1.57 |   |
| Squash | 11,038 | 1.61 | 0.96 | 1.29 |
| Sunflower | 2,793 | 0.61 | 0.37 | 0.49 |
| Tomato | 31,150 | 4.41 | 2.65 | 3.53 |

**Table 17: Economic return for land and water units for perennial crops in Egypt in 2017**

|  |  |  |
| --- | --- | --- |
| **Crop** | Farm net return  | Economics of the water unit |
| (LE/ha) | (LE/ m3ETc) | Old lands | New lands |
| (LE/m3IWR) | (LE/m3IWR) |
| Apple | 81,802 | 6.84 | 4.10 | 5.47 |
| Banana | 131,219 | 6.73 | 4.04 | 5.38 |
| Date | 117,176 | 8.41 | 5.05 | 6.73 |
| Grapes | 64,821 | 6.72 | 4.03 | 5.38 |
| Mango | 65,964 | 4.13 | 2.48 | 3.30 |
| Olive | 73,250 | 7.08 | 4.25 | 5.66 |
| Orange | 72,855 | 5.43 | 3.26 | 4.35 |
| Peach | 81,798 | 6.94 | 4.16 | 5.55 |
| Sugarcane | 46,136 | 2.71 | 1.62 | 2.17 |

**Conclusions:**

From the obtained results it could be concluded that:

* Total cultivated and cropped areas in Egypt during 2016/17 were about 3.8 and 6.7 million ha, respectively,withcropping intensity of 176%.
* The cropped area for winter, summer, Nili and perennial crops were 43.2, 39.9, 3.2 and 13.7%, respectively, of the total cropped area.
* Total water budget (WB) for crops inside and outside the Nile Valley and Delta amounted to 62.7 billion m3 which represents 78.4% of the total water resources in Egypt.
* The WB of seasonal crops was 24.6% for winter crops, 44.1% for summer crops, 3.6% for Nili crops and 27.7% for perennial crops of the grand total WB.
* Crop water productivity (CWP)varied from 0.52 to 10.61 kg/m3 for winter field crops; 0.66 to 11.84 kg/m3 for winter vegetables; 0.29 to 2.64 kg/m3 for summer field crops; 0.55 to 5.82 kg/m3 for summer vegetables; 0.34 to 5.05 kg/m3 for Nili crops; and 0.66 to 4.77 kg/m3 for perennials.
* Values of farm net return ranged between 126 and 48621 LE/ha for winter field crops; 14386 and 157810 LE/ha for winter vegetables; 1190 and 37298 LE/ha for summer field crops; 8750 and 83095 LE/ha for summer vegetables; 2793 and 66476 LE/ha for Nili crops; and 46136 and 131219 LE/ha for perennials.

**References**

AERI2016-2017.Agricultural Economic Research Institute Bulletins. Volumes No. 2016-2017. Ministry of Agriculture and Land Reclamation – Economic Affairs sector, Bulletin of Important indicators of the Agricultural Statistics.

Ainer, N. G.; W. I. Miseha; F. A. Abbas and H. M. Eid (1999).A new concept of rationalization of irrigation water use in Egypt. Third Conference of On-Farm Irrigation and Agroclimatology, January 25-27, 1999

Allen, R.G.; L.S. Pereira; D. Raes; and M. Smith. (1998). Crop evapotranspiration: Guide-lines for computing crop water requirements. In FAO Irrigation and Drainage Paper No. 56; FAO: Rome, Italy, 1998; 300p.

Anjitha Krishna, P.R. (2019). Evapotranspiration and agriculture-A review. Agricultural Reviews.2019.(40):1-11 . DOI: [10.18805/ag.R-1848](https://arccjournals.com/journal/agricultural-reviews/R-1848)

Dastane, N. G. (1972). A practical manual for water use research in agriculture. 2nd Published at Poona by NarabharatPrakashanPeth. Poona-2 India.

Doorenbose, J. and W. O. Pruitt (1977).Crop water requirements.Irri.& Drainage Paper No. 24, FAO, Rome.

Eid, H. M.; N. G. Ainer; S. M. El- Marsafawy and A. N. Khater (1999). Crop water needs under different irrigation systems in the new lands. The Third Conference of On- Farm Irrigation and Agroclimatology, Jan. 25-27, Egypt.

El-Gibali, A.A. and A. Y. Badawi (1978). Estimation of irrigation needs in Egypt. Egypt J. Soil Sci., 18 No. (2): 159-179.

FAO (2015).Towards a Regional Collaborative Strategy on Sustainable Agricultural Water Management and Food Security in the Near East and North Africa Region.Main Report, Second Edition, 2015, FAO RNE.

FAO (2017). Water for Sustainable Food and Agriculture: A report produced for the G20 Presidency of Germany. Food and Agriculture Organization of the United Nations, Rome, 2017.ISBN 978-92-5-109977-3.[www.fao.org/publications](http://www.fao.org/publications)

Guillaume Gruère (2019). Never let a good water crisis go to waste. Organisation for Economic Co-operation and Development (OECD).*21 March 2019,*<https://www.oecd.org/agriculture/never-waste-a-good-water-crisis/>

Howell, T.R. (2003). Irrigation efficiency.Encyclopedia of Soil Science, 2002 Marcel Dekker, Inc.

Jensen, M. E. (1980). Design and operation of farm irrigation system. An ASAE Monograph, No. 3 in a series published by Amer. Sec. of Agric. Eng. 2950 Nile Road. P.O. Box 410.

Molden, D., T. Oweis, S. Pasquale, J.W. Kijne, M.A. Hanjra, P.S. Bindraban, B.A.M. Bouman, et al. (2007). “Pathways for Increasing Agricultural Water Productivity.” In Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture, edited by D. Molden, 279–310. London/Colombo: Earthscan/IWMI. <https://www.researchgate.net/publication/266382480>

Perry C., P. Steduto, R. G. Allen, C. M. Burt (2009). Increasing productivity in irrigated agriculture: Agronomic constraints and hydrological realities. Agricultural Water Management 96 (2009) 1517–1524. [www.elsevier.com/locate/agwat](http://www.elsevier.com/locate/agwat)

SADS (2009).Sustainable Agricultural Development Strategy towards 2030.Ministry of agriculture and land reclamation, 2009.

Wichelns D. (2014). Water productivity: Not a helpful indicator of farm-level optimization. Global Water Forum [www.globalwaterforum.org](http://www.globalwaterforum.org).[http://www.globalwaterforum.org/ 2014/11/11/water-productivity-not-a-helpful-indicator-of-farm-level-optimization/](http://www.globalwaterforum.org/%202014/11/11/water-productivity-not-a-helpful-indicator-of-farm-level-optimization/)

# <http://www.fao.org/3/X0490E/x0490e05.htm>. Part A-Reference evapotranspiration (ETo)

10/15/2019