P-ISSN: 3009 – 7487
E-ISSN: 3009 – 7886

JOURNAL OF PLANT AND FOOD SCIENCES June 2025

Total water allocation for Egyptian clover and alfalfa, and their water economics

Ibrahim, M. A.[1], Khalil, M.[2 *], El-Marsafawy, Samia M.[3], and Ibrahim, K. M. A.[4]

1- Agricultural Economic Research Institute, Agricultural Research Centre, Giza, Egypt. dr.ali_66@yahoo.com
2- Animal Production Research Institute, Agricultural Research Centre, Giza, Egypt khalilmostafa22@yahoo.com
3- Soil, Water & Environment Research Institute, Agricultural Research Centre, Giza, Egypt. samiaelmarsafawy797@hotmail.com
4- Faculty of Agriculture "Sadat branch", Al-Azhar University
*** Corresponding author:** Khalil, M.
E-mail: khalilmostafa22@yahoo.com

Received: 19th February 2025; in revised form: 19th February 2025/ Accepted: 1st May 2025/ Published: 26th June 2025
DOI: 10.21608/jpfs.2025.362056.1026

ABSTRACT

The current study focuses on Egyptian clover and alfalfa crops in old and new lands as well as inside and outside the Nile Valley and the Delta. The weather data were obtained from the Agricultural Research Center and the Egyptian Meteorological Authority during the three study periods (2017/18-2019/20). The data on cultivated areas of Egyptian clover and alfalfa, as well as their productivity during the study periods, were obtained from the Economic Affairs Sector, Ministry of Agriculture and Land Reclamation. The main objectives are: identify the total water budget acquired by both crops; crop water productivity, and the economic return of land and water units. The results showed that the average amount of irrigation water applied under different climatic regions (inside and outside the Nile Valley and Delta) amounted to 4435, 4311, 4439 m^3 / feddan for Egyptian clover and 8788, 8671, 8743 m^3 / feddan for alfalfa through 2017/18, 2018/19, and 2019/20 seasons, respectively. The overall average of total water budget for the total cultivated area amounted to 6.570 billion m^3 for Egyptian clover and 614.462 million m^3 for alfalfa. The net return per land unit for Egyptian clover crop was 15263 LE/ feddan, and it was 56739 LE/ feddan for alfalfa crop, while the net return per water unit were 3.55 and 7.49 LE/ m^3 for the corresponding crops.

Keywords: *Egyptian clover and Alfalfa crops, irrigation water requirement, economic return of land and water units*

.

INTRODUCTION

Due to the high population and semi-arid conditions, the Mediterranean countries face severe water scarcity for irrigation (Mekonnen and Hoekstra, 2016) and (United Nations, 2017).

Egypt is located in a semi-arid region. The demand for freshwater has risen in recent years, not only due to population growth and increased food and animal feed needs but also as a result of the cumulative impact of climate change. The overall irrigation requirements are projected to increase between 4 and 18% if irrigated agriculture does not adapt to these changing circumstances (Fader *et. al.*, 2016). Water resources management in a semi-arid region is essential to regulate the existing water amount and to achieve a suitable development level, food security, and stability (El-Marsafawy and Mohamed, 2021). Livestock and dairy production sectors face numerous challenges due to intensified water usage (Khwlil *et. al.*, 2012). There are few publications available that deal with the relationship between green forage production and dairy production in semi-arid ecosystems, mainly from the perspective of water use and productivity. It is important to address these interactions to assess the impact of the activities on existing water resources such as rainfall, surface water, and groundwater. Approximating water usage at different stages of animal production and combining these estimates will help producers and stakeholders to identify areas of high water usage and implement strategies to improve water use efficiency. In North Africa, increased pressure on groundwater is already putting the sustainability of many farming systems at risk (Kuper *et. al.,* 2015).

Egyptian clover is the primary winter forage crop grown in the Nile Valley and Delta that playing a crucial role in Egyptian agriculture sustainability. It plays a vital role in maintaining the agricultural ecosystem by enriching the soil through atmospheric nitrogen fixation. Clover is environmentally friendly as its growth does not rely on pesticides (Khalifa and Badawy, 2024).

According to (FAO, 2014), Egyptian clover is an important crop used for fodder and to maintain soil fertility. It was first cultivated in Egypt; it is now widely grown in irrigated cropping systems in West and South Asia. It is also utilized in commercial farming in many countries with mild winters for over 6000 years; India is the largest producer.

The main objectives of this study are: to determine the irrigation water needs, crop water productivity, and economic returns for the land and water units used for two primary green forage crops (Egyptian clover and alfalfa) in old and newly developed areas inside and outside the Nile valley and Delta.

MATERIALS AND METHODS

The current study focuses on Egyptian clover and alfalfa crops in old and new lands (inside and outside the Nile Valley and the Delta). According to the Sustainable Agricultural Development Strategy 2030, Egypt has been divided into five geographical regions, taking into consideration the characteristics and configurations of the agricultural regions (SADS, 2009). These regions are: Middle Delta (Qaliobeya, Menofeya, Gharbeya, Kafr El-Sheikh, Dakahleya, and Demyatta Governorates); East Delta (Sharkya, Ismailia, Port Said, Suez, North and South Sinai Governorates); West Delta (Alexandria, Nubareyah, Beherah, and Matrouh Governorates); Middle Egypt (Giza, Fayoum, Bani-Sweif, and Minya Governorates); and Upper Egypt (Sohag, Qena, Asyout, Aswan, and the New Valley Governorates). Due to the shortage of climatic data, three governorates were selected to calculate irrigation water requirements in the old and new lands within the Nile Valley and Delta. These governorates are: Kafr El-Sheikh, representing the Middle Nile Delta (Lower Egypt); Giza, representing Middle Egypt; and Asyut, representing Upper Egypt. Average climatic data for three years from these governorates were used to calculate the irrigation water requirements in the lands outside the Nile Valley and Delta.

1. Data collection:

- Weather data:

Weather data were obtained from the Agricultural Research Center and the Egyptian Meteorological Authority. Average monthly minimum and maximum temperatures, relative humidity, wind speed, and sunshine per cent, in addition to total monthly rainfall through the study periods (2017/18-2019/20) are existed in Table 1.

- Cultivated area and crop productivity:

Data on the cultivated areas of Egyptian clover and alfalfa crops and their productivity during the study period were obtained from the Economic Affairs Sector, Ministry of Agriculture and Land Reclamation (EAS-MALR), Volumes 2017/2018 - 2019/2020.

The selected crops:

1. Egyptian clover, which is a winter fodder crop, is planted on the 1*st* of October. It can be cut up into 4 to 6 cuts, with an extended season of about 220 days.
2. Alfalfa, a perennial fodder crop that can last 3-5 years. The study was conducted over three years, with a planting date of 1*st* October. It can be cut up 6 to 10 cuts.

2. Calculation and equations:

The CROPWAT8.0 model established by the Food and Agriculture Organization and the United Nations was used to estimate reference evapotranspiration (ETo), which is based on the method described by *(*Allen *et. al.,*1998*).*

- Crop water use (evapotranspiration, ETc)

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

Crop evapotranspiration (ETc) = ETo × Kc (1)

The Kc values of the crop were obtained from FAO No. 56, and it adjusted according to the results of actual field trials in Egypt.

- Crop water productivity (CWP) and irrigation water requirements (IWR)

According to (Kassam *et. al.*, 2001), CWP is defined as crop yield divided by water consumed.

$$\text{CWP} = \frac{Crop\ yield\ (kg)}{Crop\ evapotranspiration\ (ETc,\ \ m3)} \quad (2)$$

$$\text{IWR} = \frac{Crop\ evapotranspiration\ (ETc)}{Irrigation\ Efficiency\ (IE)} \quad (3)$$

Where: The irrigation efficiency values used in this study were:

60% for flood irrigation system (Jensen, 1980); (old lands)

75% for sprinkler irrigation system (new lands).

- Total water budget (TWB)

The total water budget of the Egyptian clover and alfalfa crops was calculated by multiplying the irrigation water requirements by the total area of the crop. This step has been carried out over the study period(season-by-season), and then the average overall results were taken to obtain the average total water budget.

TWB = IWR × total area (4)

- Economic return of water unit (LE/ m^3)

Economic return of water unit or net return from irrigation water unit was done through net return from land unit (LE/ feddan) for Egyptian clover and alfalfa (data were obtained from (EAS-MALR, EAS-MALR, Volumes 2017/2018-2019/2020), divided by irrigation water requirements (m^3/ feddan)

$$\text{Net return from the water unit} = \frac{Net\ return\ from\ land\ unit}{Irrigation\ water\ requirements} \quad (5)$$

Table (1): Average monthly weather data and total rainfall during the period of 2017/18- 2019/20

Month.	Min.	Max.	RH	WS	SS	RF	Min.	Max.	RH	WS	SS	RF	Min.	Max.	RH	WS	SS	RF
	Kafr El-Sheikh, 2017/2018						**Giza, 2017/2018**						**Asyut, 2017/2018**					
October	24.0	28.7	68	0.85	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	0.62	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	0.50	66	5.6	12.4	23.9	64	1.5	70	0.0	9.0	23.1	60	3.0	87	0.0
January	13.9	19.3	76	0.57	69	36.4	9.0	20.4	58	1.8	68	0.0	6.6	19.9	58	3.2	85	0.0
February	14.6	21.6	76	0.40	71	16.6	12.5	24.7	53	1.4	72	3.0	11.5	26.1	46	2.9	88	0.0
March	16.6	25.4	65	0.54	73	0.0	14.4	28.8	44	1.5	73	0.0	14.2	30.5	38	3.5	83	0.0
April	20.0	27.8	63	0.86	78	0.0	15.9	29.9	43	1.6	75	0.0	16.6	32.5	37	3.8	81	0.0
May	23.8	31.2	60	1.11	78	0.0	21.1	35.1	42	1.9	80	0.0	21.6	38.0	30	3.7	85	0.0
June	25.3	32.6	62	1.14	85	0.0	23.1	36.5	42	2.1	86	0.0	23.2	38.5	34	4.1	90	0.0
July	25.4	34.2	67	1.04	84	0.0	24.4	37.9	46	1.9	85	0.0	24.8	37.9	42	3.9	90	0.0
August	25.2	33.9	67	0.88	86	0.0	25.1	37.1	47	2.0	85	0.0	24.4	37.5	42	4.1	92	0.0
September	23.5	32.8	66	0.80	85	0.0	24.1	35.6	48	1.9	85	0.0	21.9	35.4	49	4.2	89	0.0
	Kafr El-Sheikh, 2018/2019						**Giza, 2018/2019**						**Asyut, 2018/2019**					
October	20.6	29.5	67	0.67	83	3.5	20.2	31.1	49	1.8	82	0.0	18.9	32.7	48	3.8	88	0.0
November	17.4	25.0	71	0.28	77	11.9	15.5	26.9	58	1.8	78	0.0	12.7	26.5	55	3.0	87	0.0
December	13.9	19.5	76	0.28	66	22.2	11.2	22.0	61	1.5	70	2.0	8.0	20.7	63	3.4	87	0.0
January	12.3	18.9	68	0.38	69	14.9	7.0	19.6	52	1.6	68	0.0	5.8	19.1	54	2.9	85	0.0
February	14.3	19.7	86	0.33	71	15.3	8.1	21.8	53	1.6	72	2.0	7.6	22.2	52	3.5	88	0.0
March	17.6	21.7	72	0.53	73	17.3	12.0	23.7	50	2.0	73	4.0	9.9	24.9	45	3.9	83	0.0
April	21.3	25.1	65	0.52	78	3.9	14.5	28.5	46	2.1	75	0.1	14.1	29.6	38	4.3	81	0.0
May	25.4	31.9	57	0.79	78	0.0	19.0	35.5	34	2.3	80	0.0	22.0	37.9	29	3.8	85	0.0
June	28.0	33.0	66	1.19	85	0.0	23.2	37.1	41	2.4	86	0.0	25.0	39.0	35	4.2	90	0.0
July	28.4	33.5	70	0.97	84	0.0	24.3	38.2	43	2.2	85	0.0	25.2	38.9	36	3.5	90	0.0
August	28.9	34.2	71	0.80	86	0.0	24.5	37.7	46	2.3	85	0.0	25.0	39.0	36	2.9	92	0.0
September	27.9	32.4	68	0.89	85	0.0	22.5	34.8	53	2.3	85	0.0	22.3	35.2	47	3.8	89	0.0
	Kafr El-Sheikh, 2019/2020						**Giza, 2019/2020**						**Asyut, 2019/2020**					
October	26.7	30.3	71	0.66	83	57.3	20.2	32.7	54	1.9	82	0.4	19.2	33.7	49	3.5	88	0.0
November	25.1	27.4	66	0.42	77	0.0	15.6	29.1	50	1.6	78	0.0	13.6	28.6	53	3.0	87	0.0
December	13.4	21.4	73	0.45	66	60.7	11.1	22.6	56	2.1	70	0.0	8.1	21.5	58	3.2	87	0.0
January	11.8	18.4	75	0.35	69	67.5	8.1	19.3	58	1.9	68	0.0	5.4	18.5	60	3.5	85	0.0
February	13.7	20.4	71	0.59	71	14.3	9.4	21.2	59	1.9	72	4.8	7.5	21.5	56	3.3	88	0.0
March	15.6	22.6	68	0.93	73	60.8	12.3	24.9	53	2.5	73	17.0	11.2	26.2	46	4.0	83	0.0
April	18.9	26.0	63	1.14	78	0.0	14.3	29.1	44	2.0	75	0.0	14.8	30.3	40	4.0	81	0.0
May	23.8	31.9	51	1.32	78	0.0	19.1	34.6	38	2.4	80	0.0	19.5	35.7	37	3.7	85	0.0
June	25.8	31.1	61	1.29	85	0.0	21.3	36.7	40	2.1	86	0.0	22.6	38.7	35	3.9	90	0.0
July	27.3	33.7	68	1.18	84	0.0	23.5	37.3	51	2.2	85	0.0	23.6	38.7	36	3.9	90	0.0
August	28.8	34.6	68	1.07	86	0.0	24.5	37.1	49	2.3	85	0.0	24.1	38.6	39	3.6	92	0.0
September	27.1	34.6	68	1.08	85	0.0	24.7	36.8	51	2.1	85	0.0	23.2	38.0	42	3.6	89	0.0

where: Min. and Max. = minimum and maximum temperatures °C; RH = relative humidity (%); WS = the height of wind speed from soil surfaces (m/sec); SS= sunshine (%) and RF = total rainfall (mm).

RESULTS AND DISCUSSION

Egyptian clover crop (EC):

Water consumption:

The Water Consumption of Egyptian Clover crop (WCEC) for each cutting under Different Agro-Climatic Regions (DACR) of the North Nile Delta (NND), Middle Egypt (ME), and Upper Egypt (UE) expressed Inside the Nile Valley and Delta (INVD) is shown in Figure 1. The highest WCEC values in INVD were recorded for the first cut: 534, 712, and 919 m^3/ fed in the 1*st* season; 505, 709, and 990 m^3/ fed in the 2*nd* season; and 557, 737, and 1005 m^3/ fed in the 3*rd* season for the respective areas of NND, ME, and UE. Meanwhile, the lowest values were found for the second cut at 206, 321, and 455 m^3/ fed; 198, 321, and 437 m^3/ fed; and 231, 384, and 470 m^3/ fed for the same respective seasons and areas.

Water consumptive use per feddan in UE was the highest in the three seasons due to higher temperatures compared to the other two areas. Crop consumptive use was calculated directly based on water extracted by the growing plants from the effective root zone during irrigation intervals, plus that withdrawn from the last watering till harvesting. The positive relationship between temperature and water evapotranspiration might be the main reason for high crop water consumption. It's possible that seed type, cultivation methods, or soil structure also contributed to the high-water consumption.

The results in Figure 2 show the average water consumptive use per cutting outside the Nile Valley and the Delta (ONVD) during the three seasons of 2017/18 - 2019/20. The highest values of 722, 735, and 766 m^3/ feddan were recorded in the 1st cut for the respective three seasons. The low values were noticed for the second and third cuts. The results obtained from the WCEC in ONVD are consistent with those obtained in INVD. The reason for the high-water consumption values in the first cut is that, at the beginning of the cultivated season (October), during the autumn, most regions of Egypt experience high temperatures, so the soil requires to irrigate ever more to compensate for the evapotranspiration. In contrast, during the second and third cuts in December, January, and February, which is the winter season, the temperature decreases, resulting in lower water requirements. For the fourth, fifth, and sixth cuts, the irrigation water requirement increases as the temperature rises. It can be concluded that the positive relationship between temperature and irrigation water is the main reason for the increased irrigation water requirements of Egyptian clover.

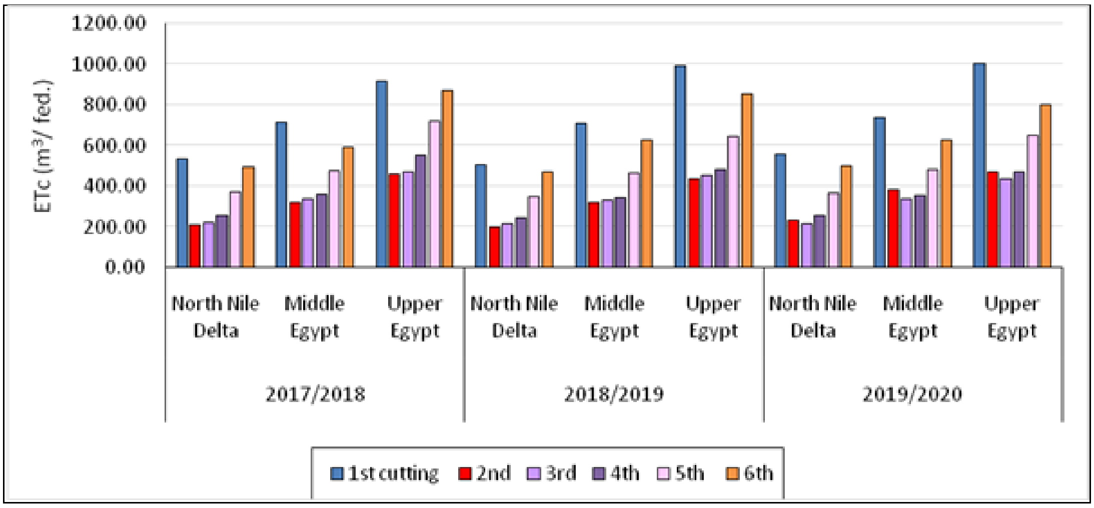

Figure 1: Water consumption (ETc) of Egyptian clover per cutting under the conditions of agro-climatic regions inside the Nile Valley and Delta during three seasons (2017/18-2019/20).

Note: 1feddan = 0.42 hectare

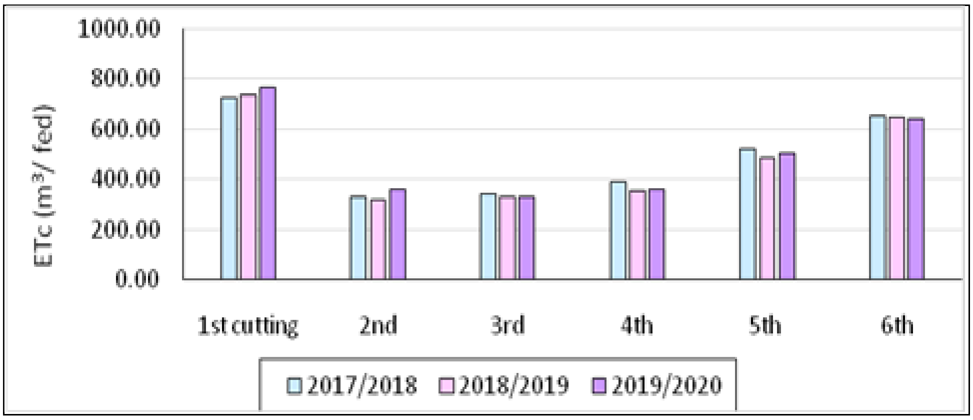

Figure 2: Water consumptive use (ETc) of Egyptian clover crop per cutting outside for three regions, the Nile Valley and Delta, during three seasons (2017/2018-2019-2020).

Crop water productivity (CWP):

It's important to note that water is a crucial input for crop production. Maximizing irrigation water productivity is a key issue in agriculture, as it can increase crop production and help close the food gap. Water not only directly affects crop growth, but also indirectly influences nutrient availability and the timing of cultural operations *(*Darwesh, 2018*)*.

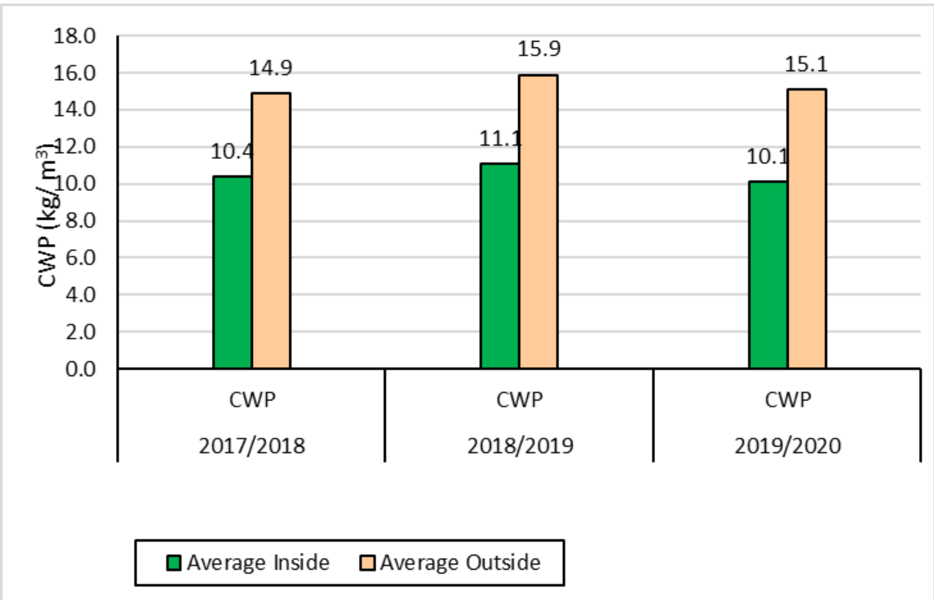

Figure 3: Average crop water productivity (CWP) of Egyptian clover inside and outside the Nile Valley and Delta during the period of 2017/18 - 2019/20.

Figure 3 presents the average Crop Water Productivity (CWP) for Egyptian clover from 2017/18 to 2019/20. The results show that average CWP under the conditions of INVD and ONVD were 10.4 and 14.9; 11.1 and 15.9; 10.1 and 15.1 kg/ m^3 for the respective three seasons.

CWP for Egyptian clover was higher under ONVD than INVD, likely due to high irrigation efficiency. The percentage reduction in total fresh yield in INVD compared to ONVD was 35.0%, 34.6%, and 37.9%, possibly due to dry cultivation dominating in INVD. Moreover, the use of modern irrigation systems, such as sprinkler irrigation, in ONVD could contribute to the higher CWP, as it raises irrigation and fertilization efficiency and maintains soil fertility. The overall average CWP during the three seasons was 10.5 kg/ m^3 for INVD and 15.3 kg/ m^3 for ONVD.

Alfalfa crop (AL):

Water consumption:

Alfalfa is a perennial fodder crop that can carry on for about 3-5 years. In the first year of cultivation, about 6 cuttings were taken. The first cut took about 3 months to grow, while it took less time in the following years (8 cuts/ year).

The Water Consumption of Alfalfa (WCAL) per cut under DACR in INVD during the three seasons is depicted in Figure 4. The results show that WCAL gradually increased, and it was more pronounced from the fourth cut. This is because the first cuts were taken in winter months with low temperature and high relative humidity. In successive cuts during the spring and summer seasons, water consumption increased as a result of high temperature and low relative humidity. Also, it was observed that the values of WCAL of different cuts in the first year were higher than those in the second and third years. Additionally, the results indicated that the values of WCAL in INVD increased under the climate conditions of the Upper Egypt region compared to the Northern Delta and Middle Egypt due to high temperatures in Upper Egypt. The increasing percentage in total WCAL per feddan in Upper Egypt was around 75%, and 35% compared to the total WCAL under the conditions of the North Nile Delta and Middle Egypt, respectively.

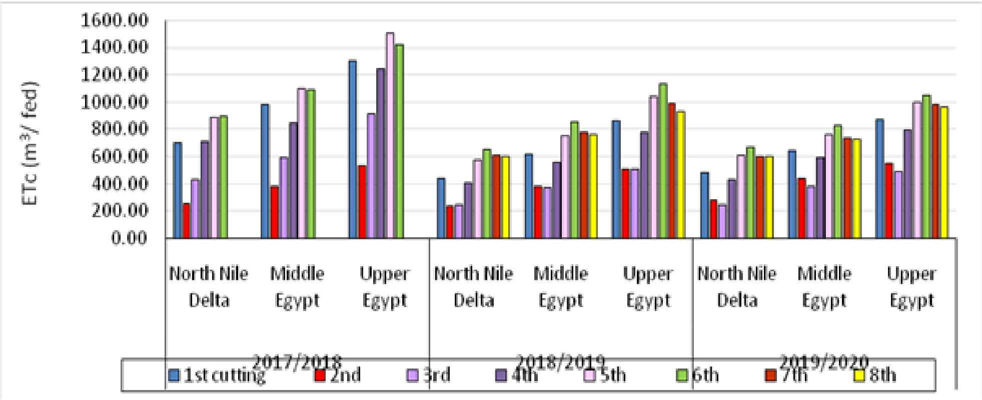

Figure 4: Water consumptive use of alfalfa per cutting under different agro-climatic regions inside the Nile Valley and Delta during three seasons (2017/ 18-2019/ 20).

Figure 5 displays water consumptive use values (WCAL) in the ONVD region. The results indicate that the fifth and sixth cuts realized the highest WCAL values over the three years, ranging from 850 to 1164 m^3. In contrast, the second and third cuts got the lowest values, ranging from 373 to 390 m^3. The trend of WCAL values in ONVD is similar to that in INVD, with low water consumptive use during winter, which increases in spring to reach a peak in summer, despite the short growth period between cuttings.

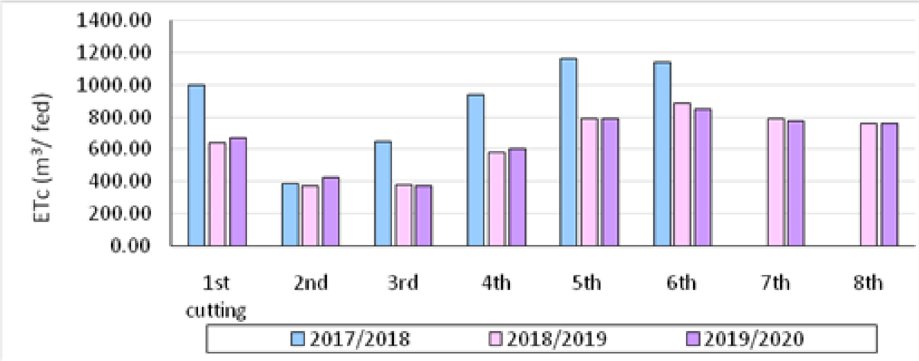

Figure 5: Water consumptive use of alfalfa crop per cutting outside for three regions, the Nile Valley and Delta, during three seasons.

(Gharsiram *et al.*, 2023) found that the actual water use for the alfalfa crop during its growth period was 544.2 mm, while the total net irrigation applied was 507.9 mm, and the gross irrigation amounted to 725.6 mm. The study highlighted that the use of CROPWAT allowed for precise management of irrigation water, ensuring that the alfalfa crop received the appropriate amount of water based on its specific growth stage requirements. The data from the CROPWAT model indicated that there was no reduction in yield, even with 100% critical depletion of available soil moisture. Additionally, the seasonal yield response factor was calculated to be 0.80. These findings underscore the effectiveness of the irrigation strategy employed, which resulted in suitable crop yields without any loss due to critical soil moisture depletion. The decrease in irrigation water was due to the significant rainfall during the two growing seasons under review. The study found that the average amount of effective rainfall throughout the year in 2021-22 and 2022-23 was 651.7 mm. Rainfall was particularly high from July to September, indicating a significant rainy season during these months. However, from November to May, the rainfall was minimal, indicating a dry period during this time. Understanding this climate information is crucial for assessing water availability and the growing needs of the alfalfa crop in the region.

Crop water productivity (CWP):

Figure 6 indicates the average CWP of the AL crop in INVD and ONVD during the three seasons. The results in the two respective regions of INVD and ONVD were 6.1 and 5.4; 6.8 and 9.8; 5.9 and 6.1 kg/ m^3, in the 1st, 2nd and 3rd years, respectively. The average CWP in ONVD was higher than that in INVD for the 2nd and 3rd years, while in the 1st year, it was higher in INVD. This difference may be due to the high values of fresh yield obtained in ONVD in the 2nd and 3rd years.

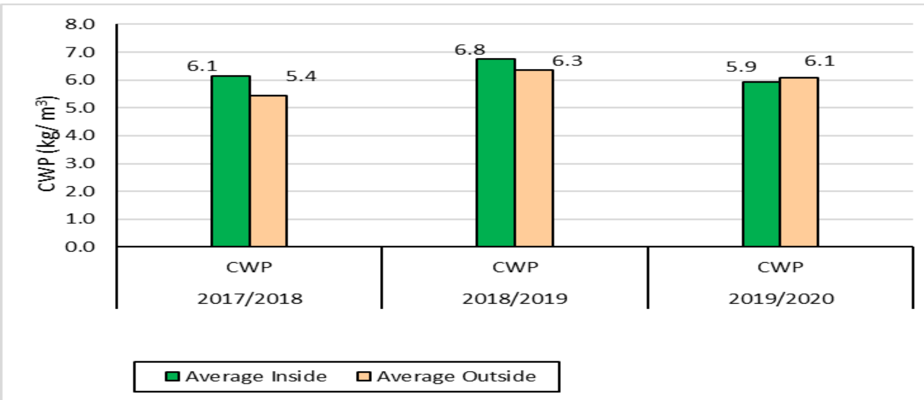

Figure (6): Average crop water productivity (CWP) of alfalfa inside and outside the Nile Valley and Delta during the period of 2017/18 - 2019/20.

Analysis of results:

The cultivation of the Egyptian clover crop is concentrated in INVD and fewer areas in ONVD, while alfalfa took an opposite trend. This is due to a law that prohibits the irrigation of clover or alfalfa in INVD after May 10 because of the cultivation of cotton, to prevent them from becoming a host for the cotton leaf worm. Additionally, there is a law that criminalizes flood irrigation in new lands (in ONVD), so the irrigation water needs in ONVD were calculated using sprinkler irrigation (with an irrigation efficiency of 75%), whereas, in INVD, calculations were made based on the flood irrigation system (with an irrigation efficiency of 60%).

Irrigation water requirement (IWR):

The calculation of Irrigation Water Requirement (IWR) was based on the flood irrigation system in INVD and sprinkler irrigation in ONVD for Egyptian clover or alfalfa. It's important to note that the growing season of Egyptian clover is about 7 months, while alfalfa is a full year, as it is a perennial plant. Figure 7 illustrates the average IWR for Egyptian clover and alfalfa crops in both INVD and ONVD (averaged over three seasons).

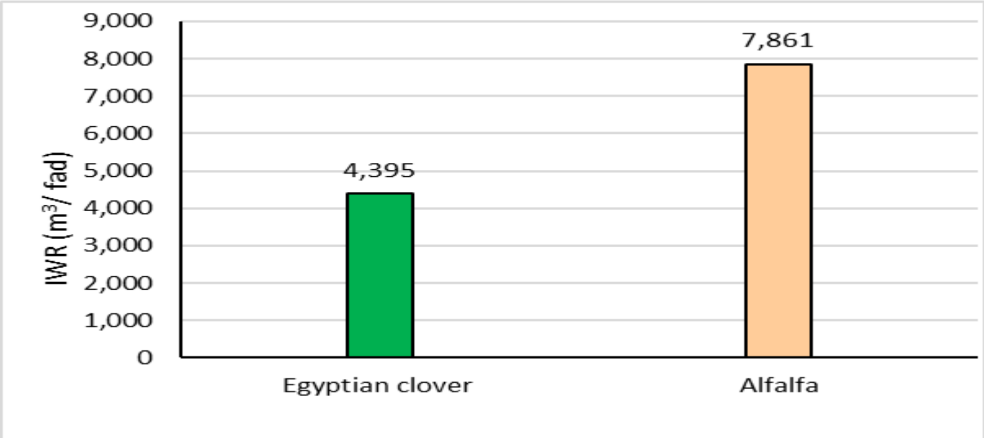

Figure 7: Overall average of irrigation water requirements (IWR) for Egyptian clover and alfalfa crops over three years.

The results indicated that the average IWR for Egyptian clover and alfalfa crops was 4395 and 7861 m^3/ feddan, respectively. The IWR for the alfalfa crop was higher by 3466 m^3/ feddan compared to Egyptian clover due to alfalfa's longer growing season compared to Egyptian clover.

Fresh crop productivity:

The productivity of the Egyptian clover crop exceeded that of alfalfa crop as average value of three years across all climatic regions in INVD and ONVD. The average green crop yield was 36762 and 33442 kg/ feddan for Egyptian clover and alfalfa crops, respectively. This represents a 10% increase (see Figure 8).

Egyptian clover (*Trifolium alexandrinum* L.) is considered one of the most important leguminous forages in the Mediterranean region and the Middle East. It is known for its rapid growth rate, high-quality forage, and very low potential for causing bloating. When grown with grass, these legumes enhance the nutritional value and overall quality of the forage mixture in comparison to grass alone (Zemenchik *et al.*, 2002).

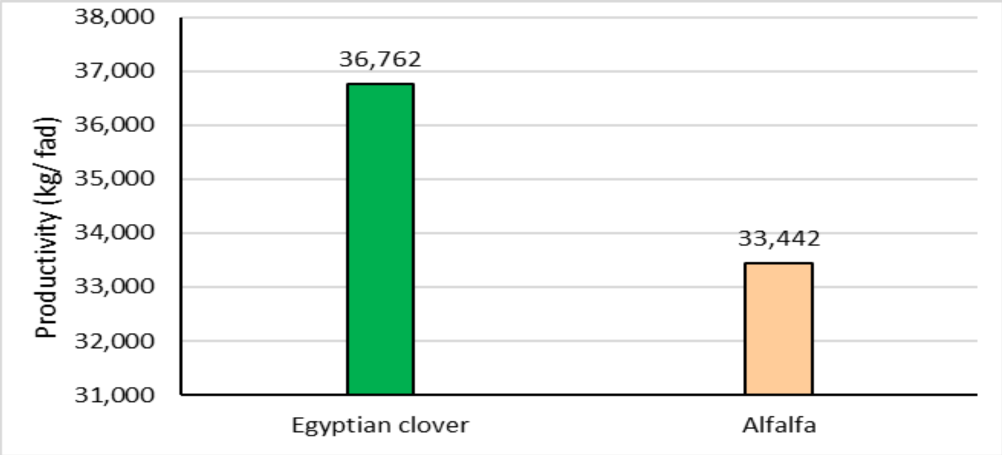

Figure 8: Overall average of crop productivity for Egyptian clover and alfalfa crops over three years. Source of data: EAS-MALR, Volumes 2017/2018-2019/2020.

Crop water productivity (CWP):

The average CWP in INVD and ONVD during the three years is shown in Figure 9. The results showed great superiority of CWP for Egyptian clover compared to the alfalfa crop. This is due to the increase in the productivity of Egyptian clover and its low water consumptive use compared to the alfalfa crop. The recorded values of CWP were 12.6, 13.5 and 12.6 kg/ m^3 for Egyptian clover crop during 2017/18, 2018/19 and 2019/20, respectively. The respective values for alfalfa were 5.8, 8.3 and 6.0 kg/ m^3.

The overall averages of CWP for the two crops during the three years were 12.9 and 6.7 kg/ m^3. In the same direction, the higher values of Berseem yield per unit applied water (WUtE), as well as consumed water (WUE), were 15.52, 15.68 kg/ m^3 and 20.06, 19.74 kg/ m^3 for dry and semi-dry cultivation, respectively compared to 15.07 kg/ m^3 applied and 18.47 kg/ m^3 consumed, respectively under the wet or the common cultivation method (irrigation till the water level reaches 5.0 cm above soil surface) (Kassab, 2012). (Darwesh, 2018) stated that irrigation water management could be achieved via a great determination of the amount and timing of applied irrigation water in a planned and efficient manner. With good irrigation management, the Berseem hay crop can have a high yield and quality potential. Berseem is a high water use forage crop because it generates a substantial amount of above-ground biomass, and has a longer growing season compared to other irrigated crops. Also, he revealed that decreasing the amount of irrigation water from the traditional method (irrigation till 5 cm above the soil surface) to 2.5 cm above the soil surface reduced fresh yield. The highest values of water consumptive use and consumptive use efficiency were recorded for irrigation without any stress during the growing season (irrigation till 5 cm above the soil surface). *(Barzegar et al. 2016)* found that water use efficiencies for Egyptian clover were 0.32 and 0.20 g l^{-1} for 100 and 60% field capacity, respectively. As the water supply increased, the root and shoot dry weight and water use efficiency increased. Treatment of 100% field capacity resulted in the highest accumulation of N, P, and K. The study suggested that a sufficient water supply can moderate the adverse effects of soil compaction on clover performance.

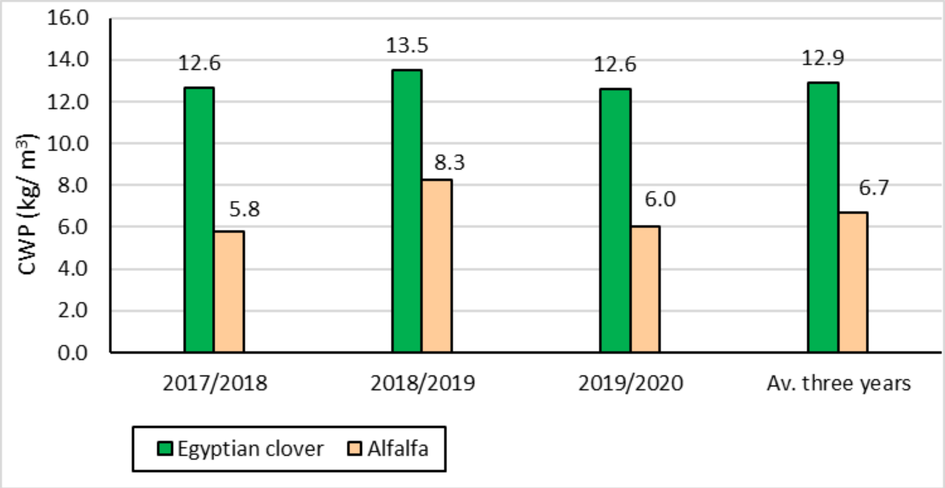

Figure 9: Average crop water productivity (CWP) of Egyptian clover and alfalfa crops during the period of 2017/18-2019/20.

Economic return from land and water units:

Economics of land unit:

The data presented in Table 2 display the economic return per unit of land for Egyptian clover and alfalfa crops in different climatic regions of Egypt in INVD and ONVD. The results indicate that the average net return for the three years in INVD ranged from 11195 to 16839 LE / feddan for the Egyptian clover crop, and 40457 to 72735 LE / feddan for the alfalfa crop. In ONVD, both crops recorded an economic return of 19376 and 68409 LE / feddan, respectively. The overall average economic return in INVD and ONVD was 15263 and 56739 LE / feddan, respectively.

The reason for the higher economic return on alfalfa compared to Egyptian clover is due to alfalfa being exported at higher prices, while Egyptian clover is mainly marketed locally. Additionally, alfalfa is easier to dry, handle, and store, and is available throughout the year. On the other hand, Egyptian clover is primarily used for feeding as a fresh part and is sometimes dried during the last two cuttings, especially in hot weather.

Despite the lower net income of Egyptian clover compared to alfalfa, Egyptian clover has many advantages since its growing season is shorter than that of alfalfa, it requires less water, and it has a higher productivity per unit of water. Berseem can fix large amounts of atmospheric nitrogen, supporting animal feeding values and improving soil fertility for future crops. When used as a green manure on newly reclaimed or depleted soils, Berseem is extremely beneficial to farmers. Egypt's traditional cultivation methods were well-suited to the environment and farming systems. With the development of new varieties, herbage and seed production have improved, leading Egypt to become the largest exporter of berseem seed. Extensive research on its cultivation and enhancement has been undertaken.

Table (2): Average net return from land unit for Egyptian clover and alfalfa crops inside and outside the Nile Valley and Delta over three years (2017/18-2019/ 20).

Region		Net return from land unit (LE/ fed)	
		Egyptian clover	Alfalfa
Inside the Nile Valley and Delta (INVD)	Lower Egypt	13,643	72,735
	Middle Egypt	16,839	40,457
	Upper Egypt	11,195	45,353
Outside the Nile Valley and Delta (ONVD)		19,376	68,409
G. average		15,263	56,739

Economics of irrigation water unit:

The economic return of adding irrigation water to Egyptian clover and alfalfa crops in INVD and ONVD is summarized in Table 3. The net return per unit of water in Lower Egypt, Middle Egypt, and Upper Egypt in INVD was 3.97, 3.56, and 1.73 LE / m^3 for the Egyptian clover crop, and 11.36, 4.78, and 4.01 LE / m^3 for the alfalfa crop, respectively. In the ONVD region, the net return per unit of water was 4.96 and 9.79 LE / m^3 for Egyptian clover and alfalfa crops, respectively. Across all climatic regions over three years, the average net return was 3.55 LE/ m^3 for Egyptian clover and 7.49 LE / m^3 for alfalfa.

Table (3): Average net return from irrigation water unit for Egyptian clover and alfalfa crops inside and outside the Nile Valley and Delta over three years (2017/18-2019/ 20).

Region		Net return from irrigation water unit (LE/ m^3)	
		Egyptian clover	Alfalfa
Inside the Nile Valley and Delta (INVD)	Lower Egypt	3.97	11.36
	Middle Egypt	3.56	4.78
	Upper Egypt	1.73	4.01
Outside the Nile Valley and Delta (ONVD)		4.96	9.79
G. average		3.55	7.49

Total water budget for Egyptian clover and alfalfa crops:

The cultivated area of Egyptian clover in INVD and ONVD was 1.686, 1.633, and 1.568 million feddan for 2017/18, 2018/19, and 2019/20 respectively. The total water budget for these areas for the three seasons was about 6.853, 6.350, and 6.508 billion m^3 per season, respectively (Figure 10). The cultivated area of alfalfa during the three years was approximately 73.321, 73.469, and 73.632 thousand feddan for 2017/18, 2018/19, and 2019/20, respectively. The total water budget for these areas was around 589.810, 588.732, and 644.844 million m^3 per year, respectively (Figure 11). The average total cultivated area during the three years was 1.629 million feddan for Egyptian clover and 73.474 thousand feddan for alfalfa. The average total water budget for both crops was about 6.570 and 614.462 million m^3, respectively.

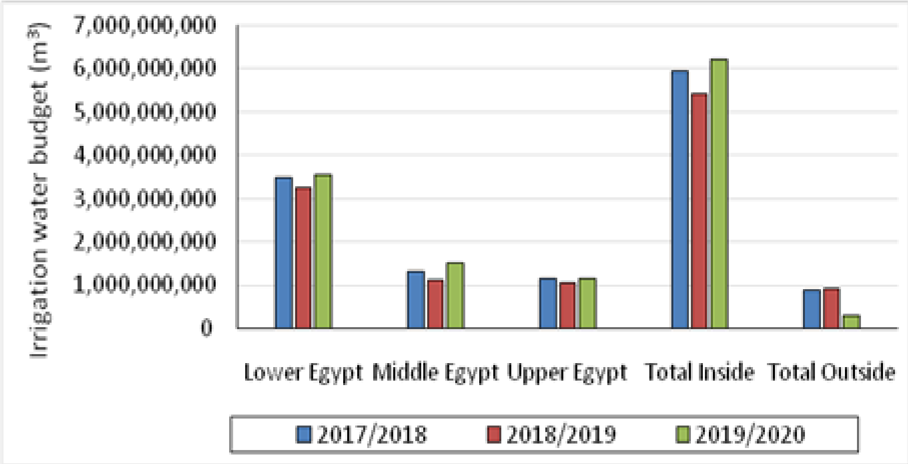

Figure 10: Total irrigation water budget for Egyptian clover crop inside and outside the Nile Valley and Delta during the period of 2017/18 – 2019/20.

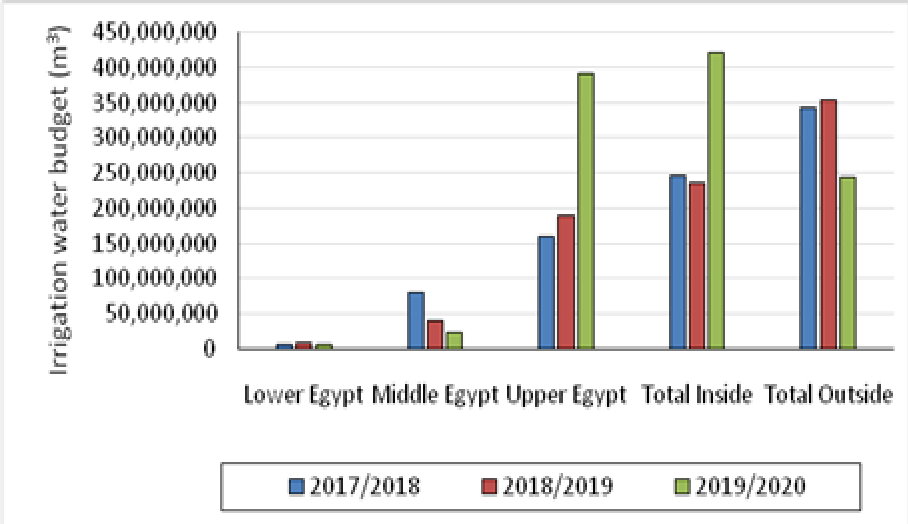

Figure 11: Total irrigation water budget for alfalfa crop inside and outside the Nile Valley and Delta during the period of 2017/18 – 2019/20.

Conclusion

It can be concluded that both Egyptian clover and alfalfa crops are important for crop rotation in different climatic regions (inside and outside the Nile Valley and Delta). In terms of crop water productivity, the Egyptian clover crop is better than the alfalfa. Nonetheless, in terms of the economics of land and water units, alfalfa is the best. In addition, crop rotation in INVD is mainly based on Egyptian clover as one of the important winter crops, as green forage. Alfalfa is mainly grown in ONVD and newly reclaimed areas, mainly for export to other countries as a straw to achieve a high net return.

REFERENCES

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

Barzegar, A., Yousefi, A., Zargoosh, N. (2016). Water stress and soil compaction impacts on clover growth and nutrient concentration. Eurasian J Soil Sci 2016, 5 (2) 139 - 145

Darwesh, R.K. (2018). Water Productivity for Egyptian Clover as Affected by Different Irrigation Regimes and Cultivation Methods in The North Middle Nile Delta Region.

Journal of Environmental, Biodiversity & soil security vol. 2, issue 2018 pp. 193 to 203.

EAS-MALR, Volumes 2017/2018-2019/2020. Economic Affairs Sector-Ministry of Agriculture and Land Reclamation. Bulletin of Important indicators of the Agricultural Statistics.

El-Marsafawy, S.M., Mohamed, A.I. (2021). The water footprint of Egyptian crops and its economics. Alexandria Engineering Journal 60, 4711–4721.

Fader, M., Shi, S., Von Bloh, W., Bonea, U.A., Cramer, W. (2016). Mediterranean irrigation under climate change: More efficient irrigation is needed to compensate for increases in irrigation water requirements. Hydrology and Earth System Sciences 20, 2, 953–973. https://doi.org/10.5194/hess-20-953-2016.

FAO (2014). Egyptian Clover *(Trifolium alexandrinum).* [By: Muhammad, D. B. Misri, M. El-Nahrawy, S. Khan and A. Serkan]. Food and Agriculture Organization of the United Nations Regional Office for the Near East and North Africa, Cairo, 2014.

Gharsiram, R., Solanki, M., Suchitra, Kumawat, L., Jaryal, R.D. (2023). Assessment of Crop-Water Requirement of Alfalfa Using FAO-CROPWAT Model-8.0. Int. J. Environ. Clim. Change, vol. 13, no. 10, pp. 3896-3905, 2023; Article no. IJECC.105856

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.

Kassam, A., Smith, M. (2001). FAO methodologies on crop water use and crop water productivity. In Proceedings of the Expert Meeting on CropWater Productivity, Rome, Italy, 3–5 December 2001.

Kassab, M.M., Ibrahim, M.A.M., Talha, N.I. (2012). Effect of cultivation method and irrigation rate on productivity and water efficiency of berseem crop-grown in North Nile Delta. *Minufiya J. Agric. Res.* Vol. 37 No 4(2): 1019-1033.

Khalifa, A.A., Badawy, A.S.M. (2024). Suitability of Egyptian Clover and Alfalfa as Safe Habitats Tonatural Enemies in The Egyptian Agrosystem. Journal of the Advances in Agricultural Researches (JAAR) Volume: 29 (1)

Khwlil, A.H., Boudon, A., Maxin, G., Faverdin, P. (2012). Prediction of water intake and excretion flow in Holstein dairy cows under thermo-neutral conditions. Anime Consortium. http://dx.doi.org/10.1017/S175173111200047x.

Kuper, M., Faysse, N., Hammani, A., Hartant, T., Hamamouche, M., Ameur, F. (2015). Liberation or anarchy? The Janus nature of groundwater use on North Africa’s new irrigation frontiers. In Integrated groundwater management (ed.Jakeman T, Barreteau O, Hunt R, Rinaudo J-D and Ross A), Chapter 19. Springer Publishers, Dordrecht, The Netherlands (in press).

Mekonnen, M.M., Hoekstra, A.Y. (2016). Four billion people facing severe water scarcity. Science Advances, 2(2):e1500323. doi:10.1126/sciadv.1500323.

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

United Nations (2017). The United Nations world water development report 2017: wastewater: the untapped resource; facts and figures; 2017. Retrieved from http://unesdoc.unesco.org/images/0024/ 002475/247553e.pdf. Accessed 12 March 2018.

Zemenchik, R.A., Albrecht, K.A., Shaver, R.D. (2002). Improved nutritive value of kura clover-and birdsfoot trefoil-grass mixtures compared with grass ultures. *Agron. J.* 94 (5), 1131–1138.