ATLAS

for

Water consumption (ETc) & amount of irrigation water used (IR) for Egyptian crops over three decades (1985-2015)

Part 1: North Nile Delta Region

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1- Introduction

The agricultural land in Egypt is nearly irrigated of about 98% due to the very dry conditions i.e. no rain fed agriculture from economic point of view is implemented.

Capita share per annum from water is less than the poverty edge of 1000 m^3 and it is continuously decreasing till the water scarcity level of less than 500 m^3 in the few coming decades. In addition, population growth, climate change and development projects all this will increase the pressure on already limited water resources. So, the water conservation procedures and rationalization of use has become imperative at all levels.

Ministry of agriculture and land reclamation in Egypt always seek to maximize the exploitation of natural resources. So it has set up a new strategy "sustainable agricultural development strategy 2030 ."

There are many important factors behind the decision to prepare a new Strategy for the Sustainable Agricultural Development towards 2030, some of these are:

- Accelerated scientific developments leading to wide possibilities for application of Information Technology (IT) in agricultural development.
- In spite of the fact that all previous agricultural development strategies have stressed the importance of maximizing returns on water use, efforts exerted so far in this field are not enough to direct farmers towards applying water-saving measures and improved cropping patterns. Areas planted to rice have greatly increased in spite of the sharp deterioration of water resources *per capita* below the water poverty level. (SADS, 2030)

Efficient water management of crops requires accurate irrigation scheduling which, in turn, requires the accurate measurement of crop water requirement. Irrigation is applied to replenish depleted moisture for optimum plant growth. Reference evapotranspiration plays an important role for the determination of water requirements for crops and irrigation scheduling. Various models/ approaches varying from empirical to physically base distributed are available for the estimation of reference evapotranspiration. Mathematical models are useful tools to estimate the evapotranspiration and water requirement of crops, which is essential information required to design or choose best water management practices.

In agricultural ecosystems the use of evapotranspiration (ET) to improve irrigation water management is generally widespread. Commonly, the crop ET (ETc) is estimated by multiplying the reference crop evapotranspiration (ETo) by a crop coefficient (Kc). Accurate estimation of ETo is critical because it is the main factor affecting the calculation of crop water use and water management. The ETo is generally estimated from recorded meteorological variables at reference weather stations.Knowledge of evapotranspiration (ET) is paramount within several fields such as hydrology, climate and water management, mainly applied to agriculture. ET is the combination of two separate processes: water losses by direct evaporation from soil or plant leaves or stems, and water evaporated through the crop transpiration. ET can be directly or indirectly measured by different methods: lysimetry, Bowen ratio–energy balance (BREB), eddy covariance, remote sensing energy balance, and scintillometry, among others **(Allen et al., 2011).** These methods are very expensive, time consuming, complex, and require work done by highly qualified people to obtain data of good quality. Published uncertainty of these methods is also variable – from 5 to 15% for lysimetry, up to 15 to 40% for remote sensing using vegetation indices (**Allen et al., 2011**). So, FAO Penman-Monteith method is now recommended as the sole standard method for the definition and calculation of the reference crop evapotranspiration. It has been found to be a method with a strong likelihood of correctly predicting ETo in a wide range of locations and climates. The method provides values that are more consistent with actual crop water use worldwide. In addition, the method has provisions for calculating ETo in cases where some of the climatic data are missing. The use of older FAO or other reference evapotranspiration calculation methods is no longer advisable.

The current study aims to estimate reference evapotranspiration and water consumption for crops grown in Nile Delta region through the last three decades (1985-2015). In addition, estimation of water needs at the farm level and Aswan High Dam.

2- Methodology

Study area

Nile Delta region

Nile Delta region was represented by Khafr El-Sheikh governorate.

Kafr El Sheikh is located in the delta region that encompasses Gharbia, Menofya, Dakahleyia, and Damietta governorates.

Kafr El Sheikh is an agricultural governorate, with total cultivated lands of 602.1 thousand feddans. It is famous for Industries include cotton-processing factories, the production of rice, beets, wheat, factory of poultry forage and fishing. The governorate contributes to the industrial activities by many major industries: dairy products, oil and soap, fodders, milling rice, cotton ginning and spinning, and beets sugar. There are several fish farms in the governorate as well. (**http://www.egypttravelsearch.net/Cities/Kafr_Ash-Shaykh.html**)

Climate of the study area

The average monthly maximum and minimum temperatures, relative humidity, sunshine hours and wind speed, in addition, total monthly rain fall through the study period (1985-2015) are presented in Table 1.

Table (1): Average monthly climatic data for Khfr El_Sheikh governorate through three decades (1985-2015).

Month	RF (mm)	Temp. °C		RH %	SS (hrs)	WS (m/ sec)
		Tmax.	Tmin.			
Jan.	19.8	18.8	6.7	69	7.0	1.0
Feb.	23.1	19.7	7.0	69	7.7	1.2
Mar.	8.2	21.7	8.6	65	8.6	1.4
Apr.	4.4	26.0	11.3	61	9.6	1.4
May	0.4	29.9	14.7	58	10.6	1.5
Jun.	0.0	32.3	18.5	61	11.9	1.5
Jul.	0.0	32.6	20.4	67	11.6	1.4
Aug.	0.0	33.3	20.4	69	11.3	1.1
Sep.	0.0	32.4	18.2	67	10.3	1.0
Oct.	3.2	29.0	15.6	63	9.3	1.0
Nov.	8.3	25.2	11.7	67	8.0	1.0
Dec.	15.1	20.5	8.0	70	6.6	0.9
Average	82.5	26.8	13.4	66	9.4	1.2

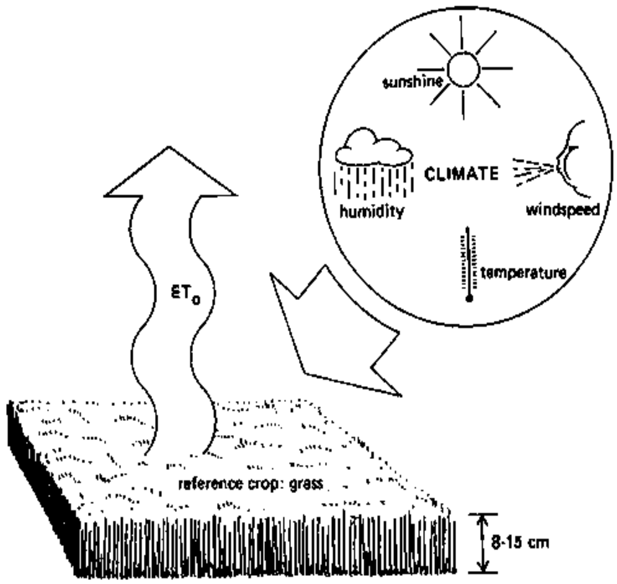
Where: RF = rain full (mm), T.max. T.min. =maximum and minimum temperatures °C; R.H. =relative humidity (%); SS = actual sunshine (hours) and W.S=wind speed (m/ sec);

Meteorological data were collected from the weather station in Agricultural research center- Sakha station – Kafr El Sheikh Governorate, and Egyptian Meteorological Authority (EMA).

Reference evapotranspiration (ETo)

Definition: According to FAO report (Chapter 3, crop water needs), ETo is the rate of evapotranspiration from a large area, covered by green grass, 8 to 15 cm tall, which grows actively, completely shades the ground and which is not short of water.

The reference evapotranspiration (ETo) are calculated by **FAO Penman-Monteith** method, using decision support software –**CROPWAT 8.0** developed by FAO, based on FAO Irrigation and Drainage Paper 56 (FAO 1998).



Reference evapotranspiration (ETo)

http://www.fao.org/docrep/s2022e/s2022e07.htm

CROPWAT is a decision support tool developed by the Land and Water Development Division of FAO. CROPWAT 8.0 for Windows is a computer program for the calculation of crop water requirements and irrigation requirements based on soil, climate and crop data. In addition, the program allows the development of irrigation schedules for different management conditions and the calculation of scheme water supply for varying crop patterns. CROPWAT 8.0 can also be used to evaluate farmers' irrigation practices and to estimate crop performance under both rainfed and irrigated conditions.

Calculating reference evapotranspiration by **FAO Penman-Monteith** equation is described as follows

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

Where

ET_o reference evapotranspiration [mm day^{-1}],

R_n net radiation at the crop surface [MJ m^{-2} day^{-1}],

G soil heat flux density [MJ m^{-2} day^{-1}],

T mean daily air temperature at 2 m height [°C],

u_2 wind speed at 2 m height [m s^{-1}],

e_s saturation vapour pressure [kPa],

e_a actual vapour pressure [kPa],

$e_s - e_a$ saturation vapour pressure deficit [kPa],

Δ slope vapour pressure curve [kPa °C^{-1}],

γ psychrometric constant [kPa °C^{-1}].

Crop water use (Crop evapotranspiration, ETc)

According to FAO report (Chapter 5 - Introduction to crop evapotranspiration, ET_c), water consumption or crop evapotranspiration (ETc) is calculated by multiplying the reference crop evapotranspiration, ET_o, by a crop coefficient, K_c:

$$\mathbf{ET_c = K_c\ ET_o}$$

where

ET_c crop evapotranspiration [mm d^{-1}],

K_c crop coefficient [dimensionless],

ET_o reference crop evapotranspiration [mm d^{-1}].

(http://www.fao.org/docrep/X0490E/x0490e0a.htm)

Amount of irrigation water used (IR)

For the determination of amount of irrigation water used or water needs, irrigation efficiency have been taken into consideration. The efficiency of irrigation water is the ratio between water consumption and irrigation water applied. According to Jensen (1980) irrigation efficiency for surface irrigation system is 60 %. However, for sub-merged crops, i.e. rice an irrigation efficiency of 50 % is used (Dastane, 1972 and Doorenbose and Pruitt, 1977). In this study, two irrigation efficiencies were used. The first, to calculate the amount of irrigation water at the farm level (80% was used for all crops except rice, 60% was used), and the second, to calculate the amount from the beginning of the irrigation source (High Dam) which was (50 % for rice and 60 % for the other crops).

3- Results and discussion

3-1- Reference evapotranspiration (ETo)

The results of ETo in Nile Delta region (represented by Khafr El-Sheikh governorate) through the period of 1985 – 2015 are given in Figs. 1- 31. Average monthly ETo through the study period (av. 31 years) is presented in Fig. 32.

Results indicated that there are inter and intera annual differences in ETo values through the study period. Regarding the inter annual differences (between months), the highest values of ETo was found for June followed by July, while December followed by January registered the lowest values.

As for Intra annual differences (between years), the highest value registered for 1986 (4.33 mm/ day) followed by 1987 (4.10 mm/ day) and 1994 (4.02 mm/ day). It is worth mentioning that the grand average (average 31 years) was 3.79 mm/ day.

On the other hand, the results showed that increasing ETo in 1986 due to increase maximum and minimum temperature, low relative humidity and increasing wind speed. In the same direction, ETo value in June in this year registered the highest one which recorded 7.21 mm/ day

In contrast, the 2007 has given less ETo value (3.57 mm/ day) due to low minimum temperature, increasing relative humidity and low wind speed.

According to F**AO** report (Chapter 3 - Meteorological data**), t**he evapotranspiration demand is high in 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 vapour can be stored in the air while wind may promote the transport of water allowing more water vapour 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. (http://www.fao.org/docrep/X0490E/x0490e07.htm)

Fig. 1: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1985)

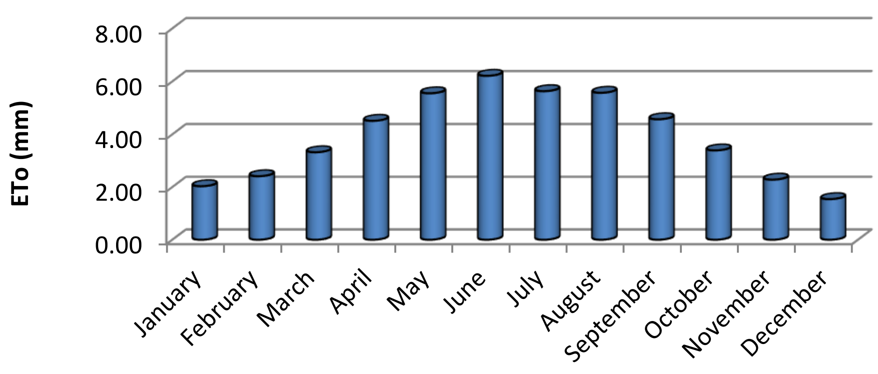


Fig. 2: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1986)

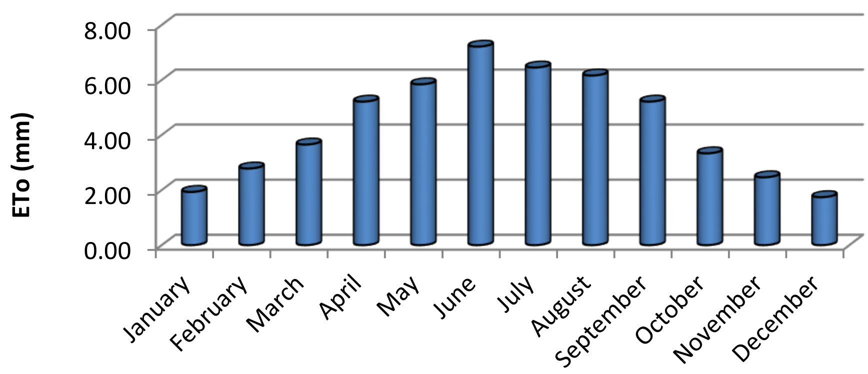


Fig. 3: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1987)

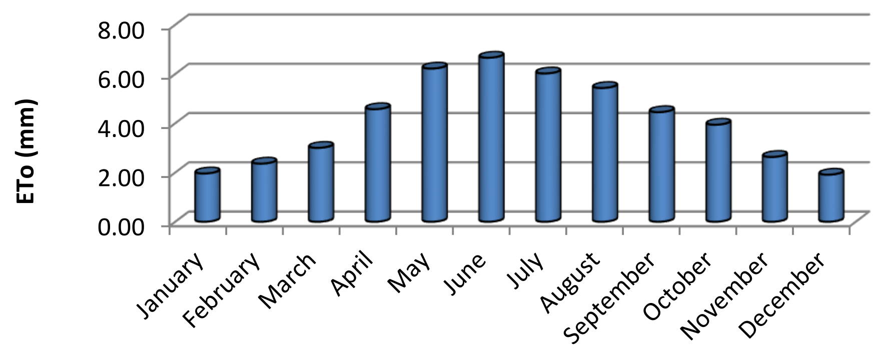


Fig. 4: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1988)

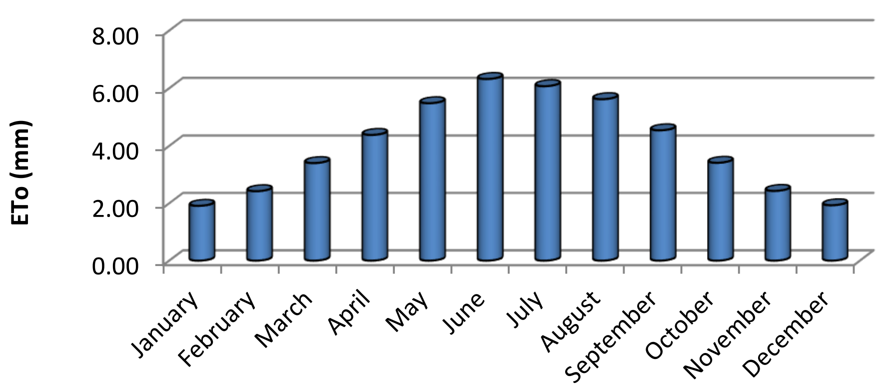


Fig. 5: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1989)

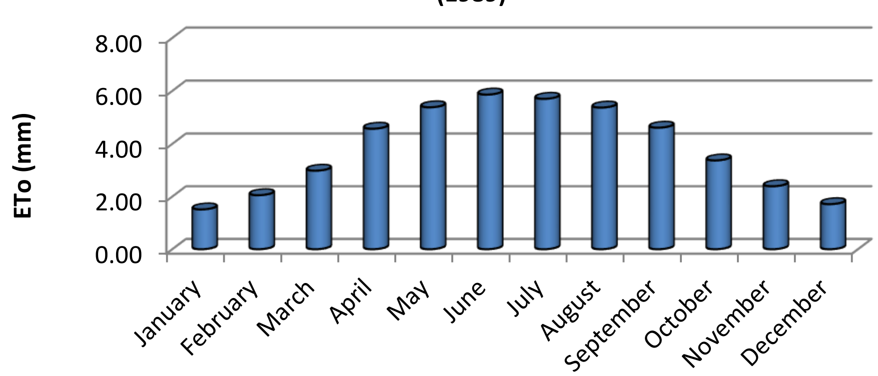


Fig. 6: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1990)

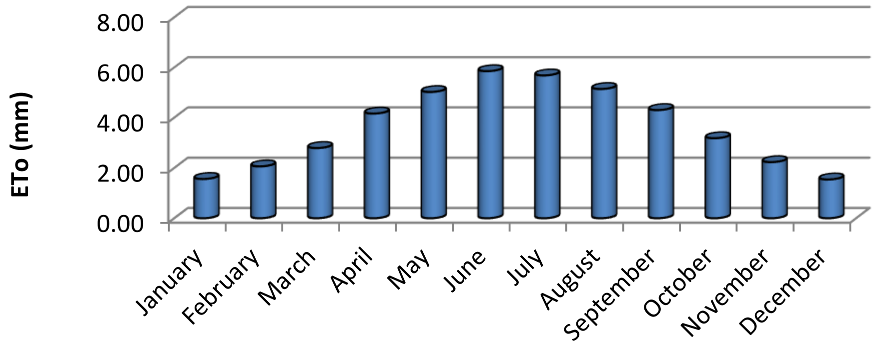


Fig. 7: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in

(1991)

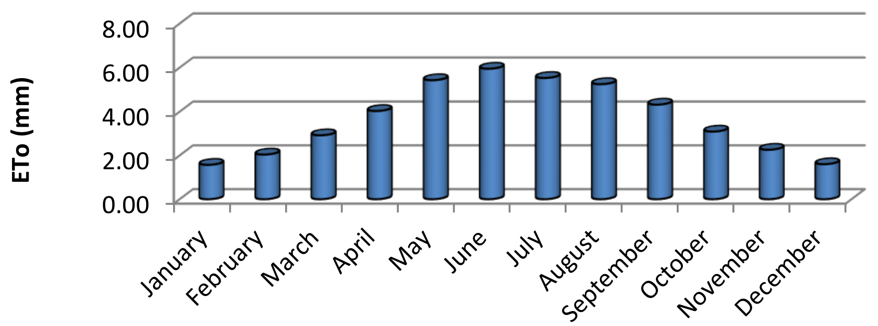


Fig. 8: Monthly reference evapotranspiration (ETo) in Khafr El-Sheikh governorate (1992)

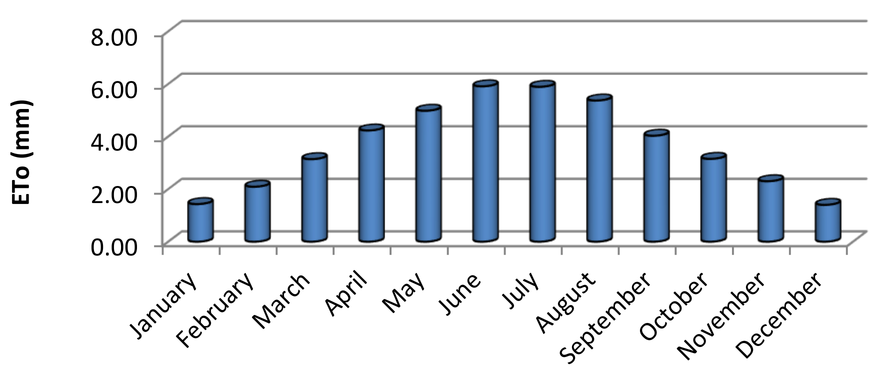


Fig. 9: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1993)

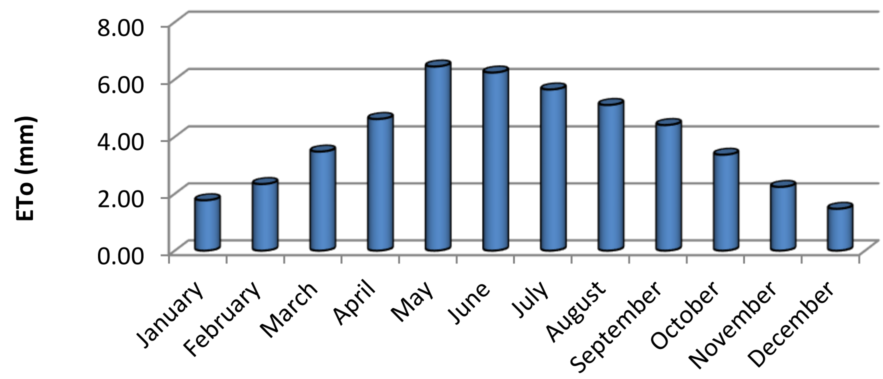


Fig. 10: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1994)

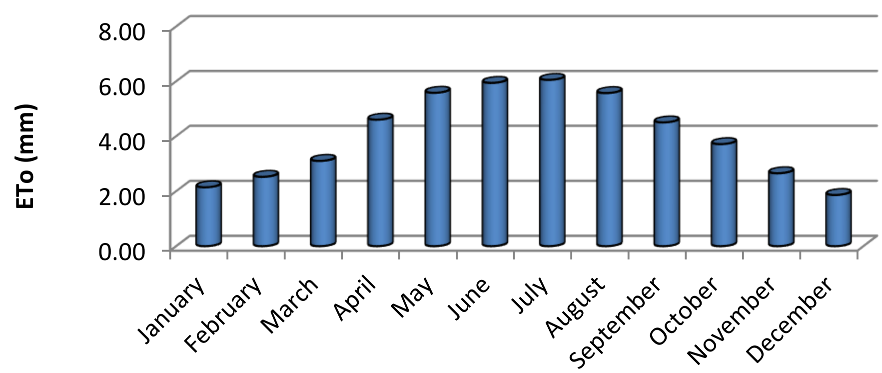
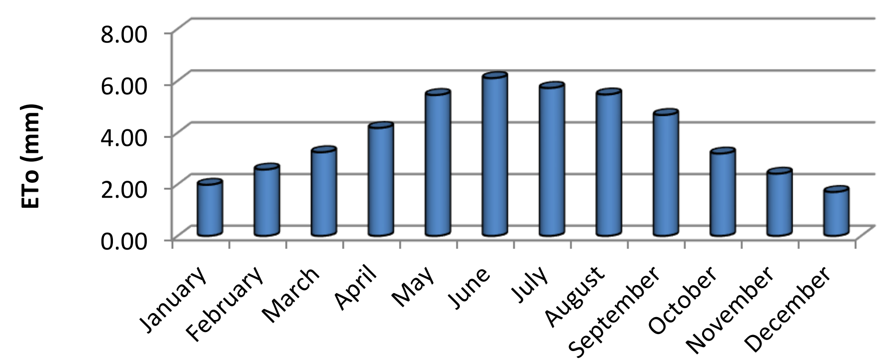


Fig. 11: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1995)



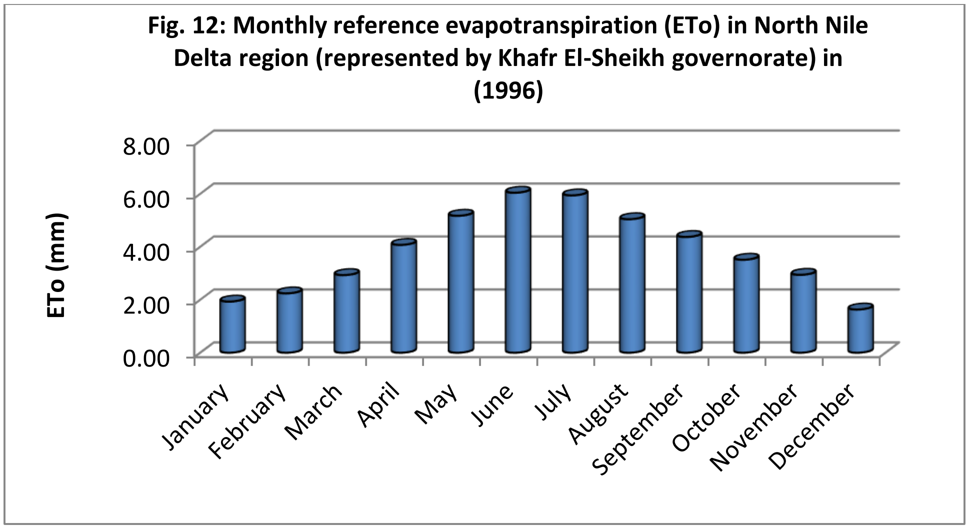


Fig. 12: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1996)
ETo (mm)
8.00
6.00
4.00
2.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December

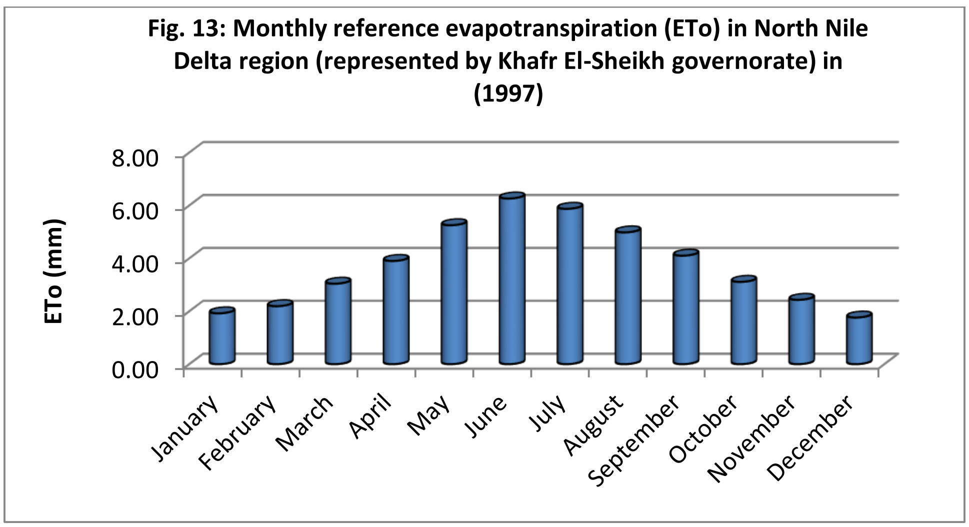


Fig. 13: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1997)
ETo (mm)
8.00
6.00
4.00
2.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December

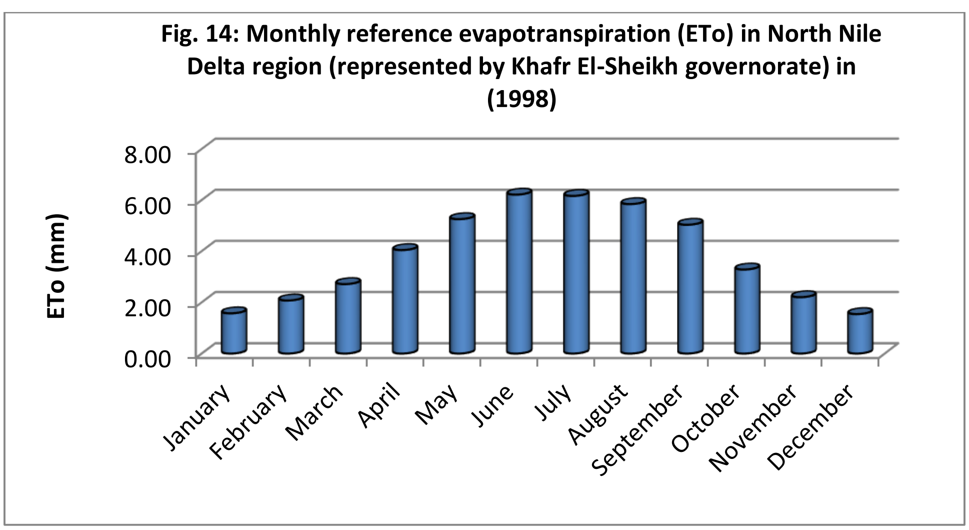


Fig. 14: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1998)
ETo (mm)
8.00
6.00
4.00
2.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 15: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (1999)

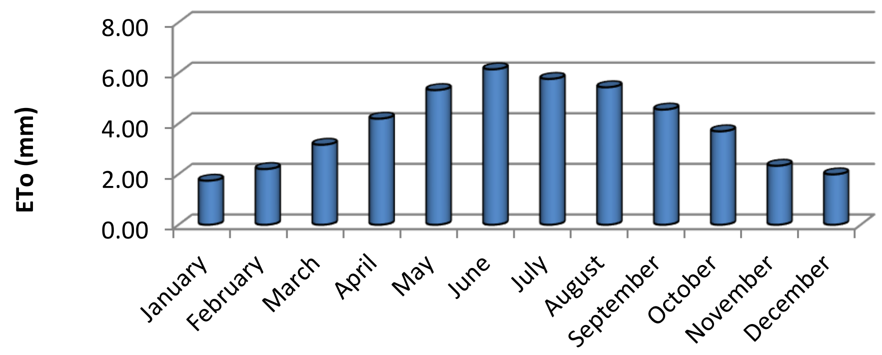


Fig. 16: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2000)

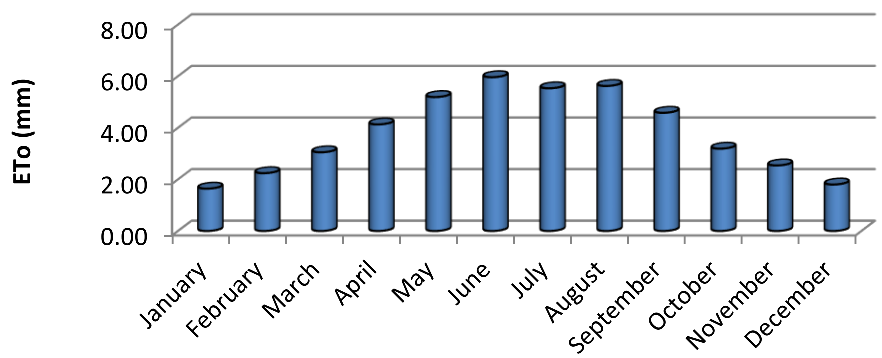


Fig. 17: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2001)

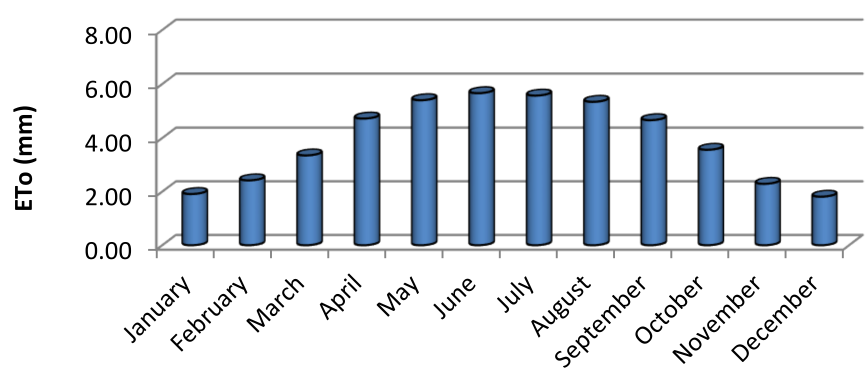


Fig. 18: Monthly reference evapotranspiration (ETo) North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2002)

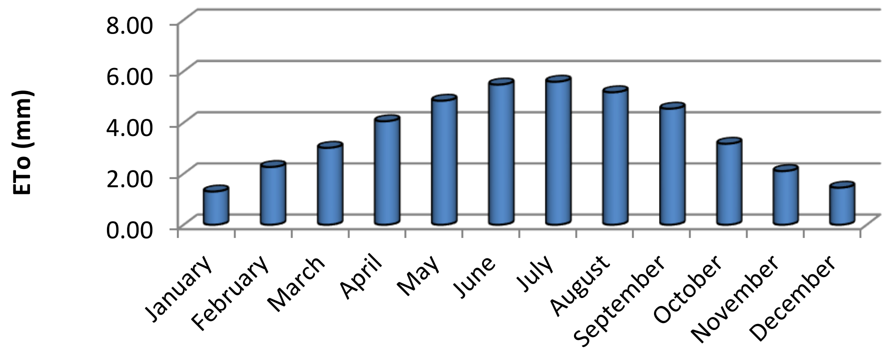


Fig. 19: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2003)

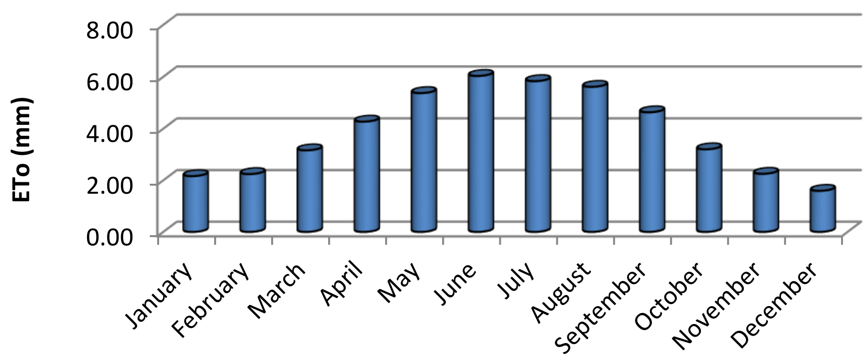
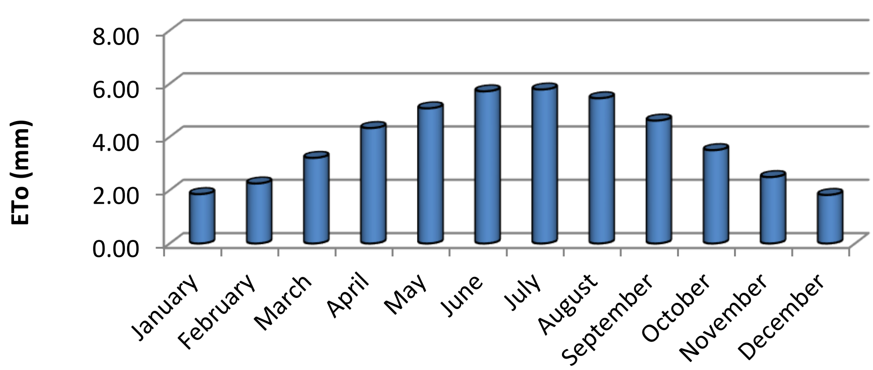


Fig. 20: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2004)



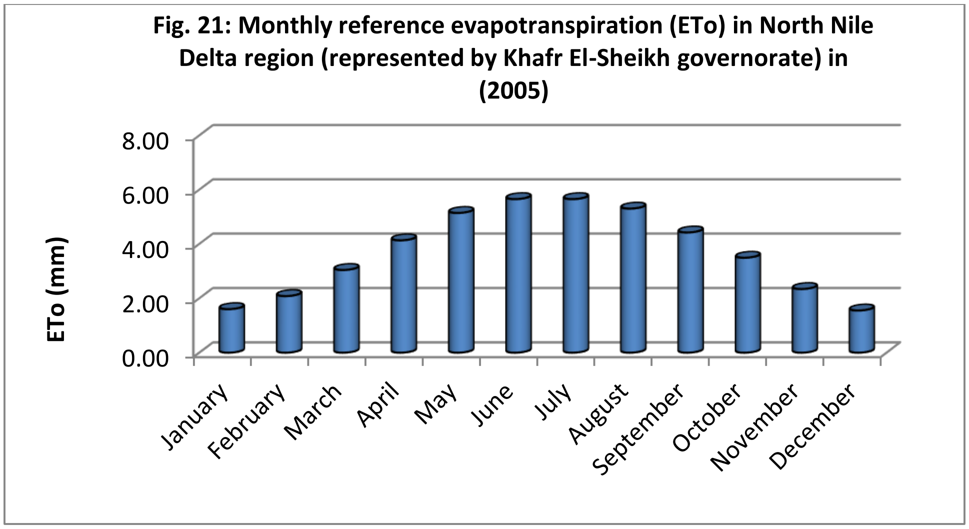


Fig. 21: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2005)
ETo (mm)
8.00
6.00
4.00
2.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December

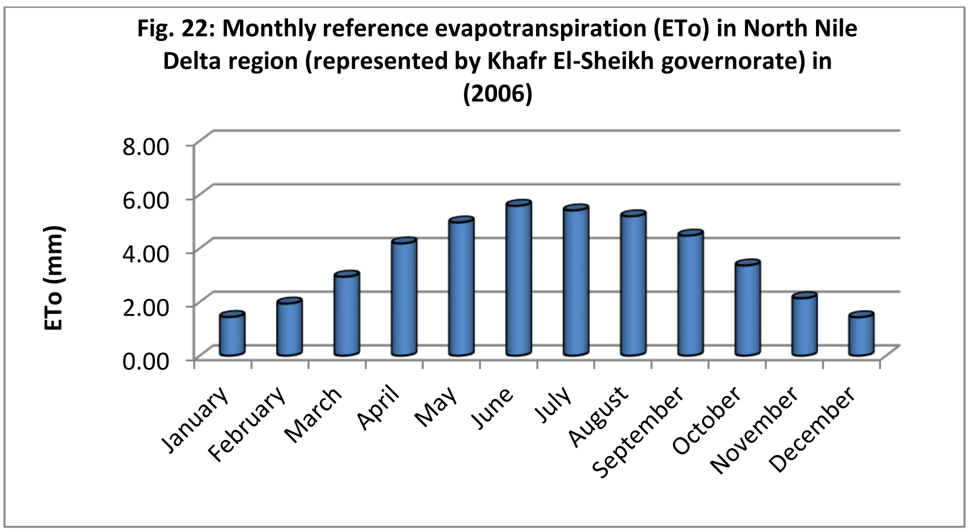


Fig. 22: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2006)
ETo (mm)
8.00
6.00
4.00
2.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December

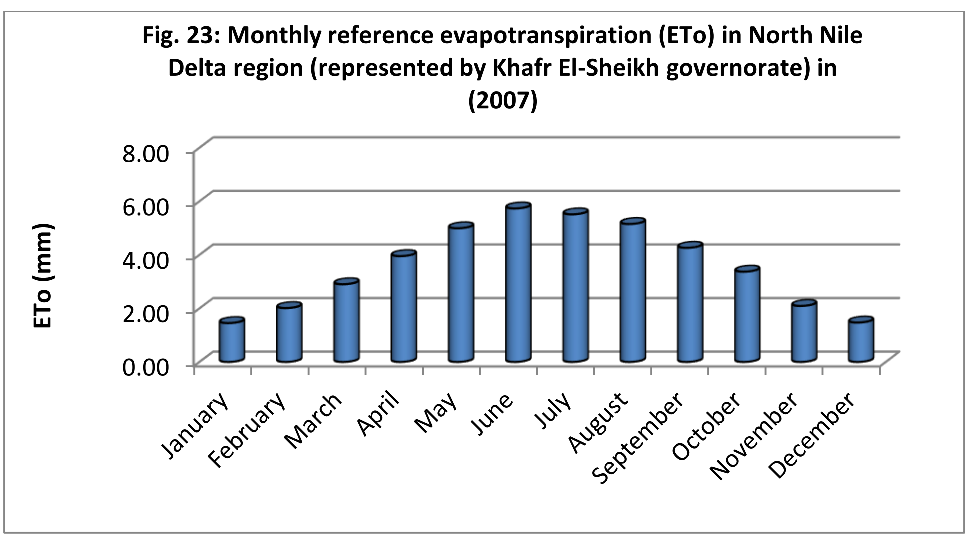


Fig. 23: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2007)
ETo (mm)
8.00
6.00
4.00
2.00
0.00
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 24: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2008)

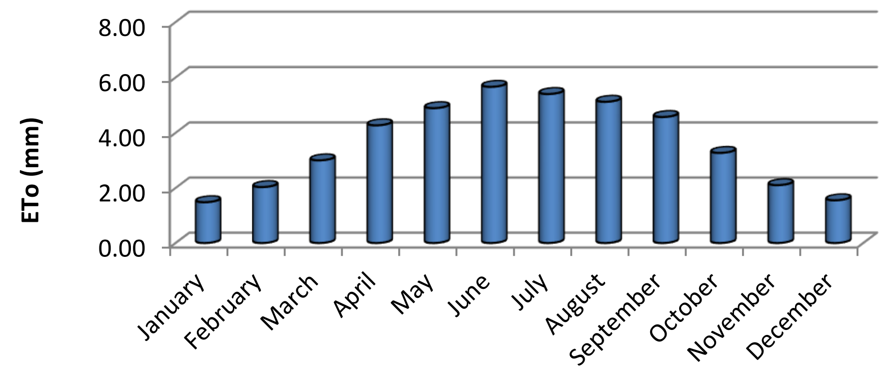


Fig. 25: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2009)

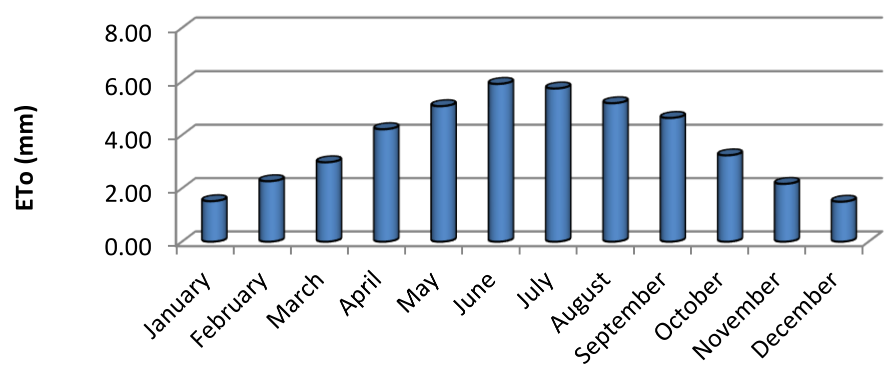


Fig. 26: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2010)

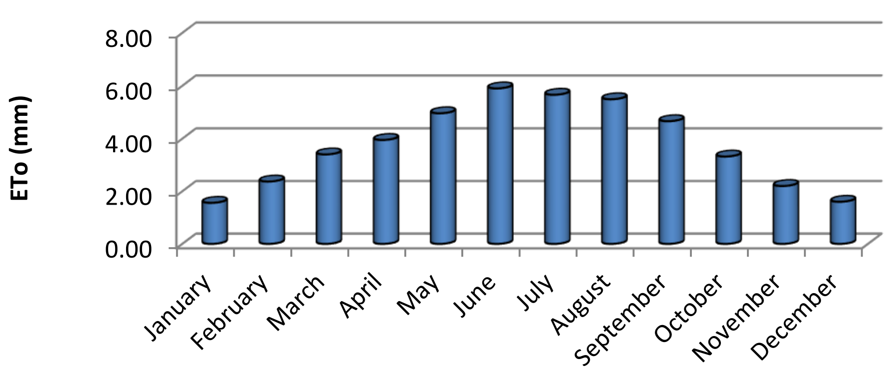


Fig. 27: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2011)

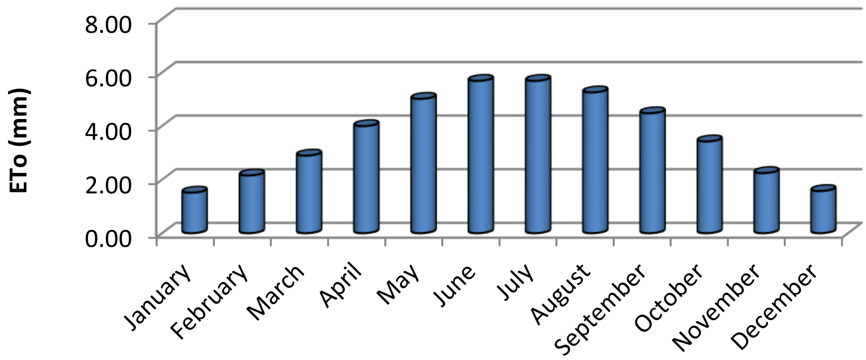


Fig. 28: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2012)

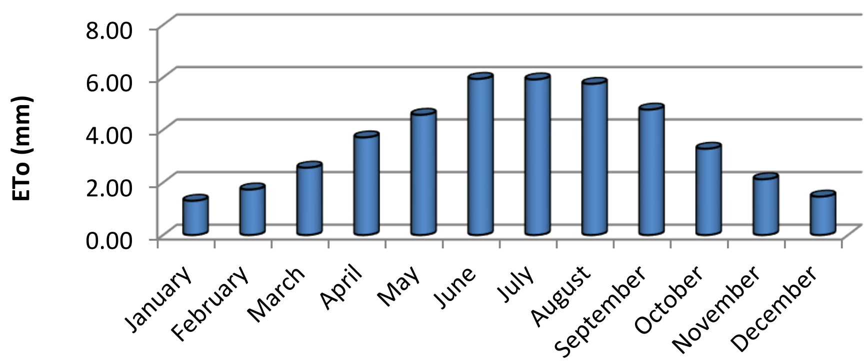


Fig. 29: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2013)

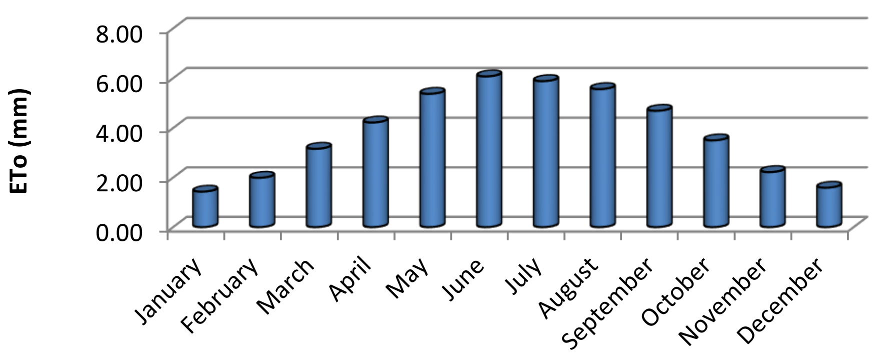


Fig. 30: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2014)

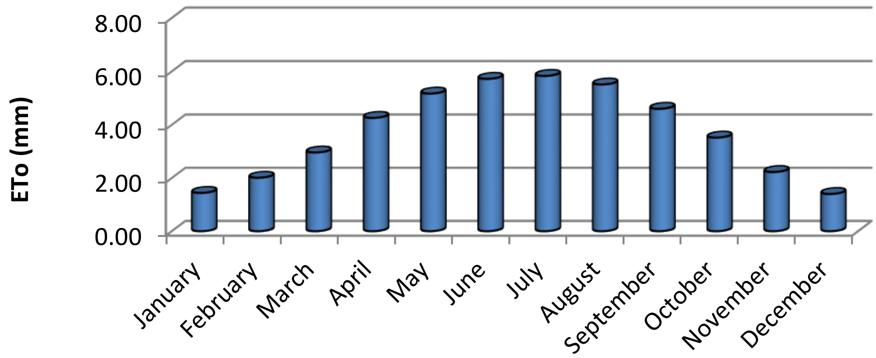
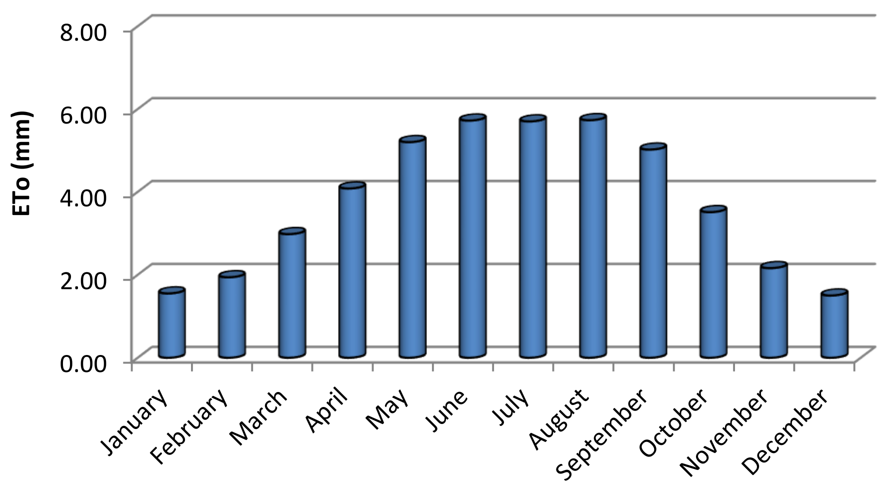
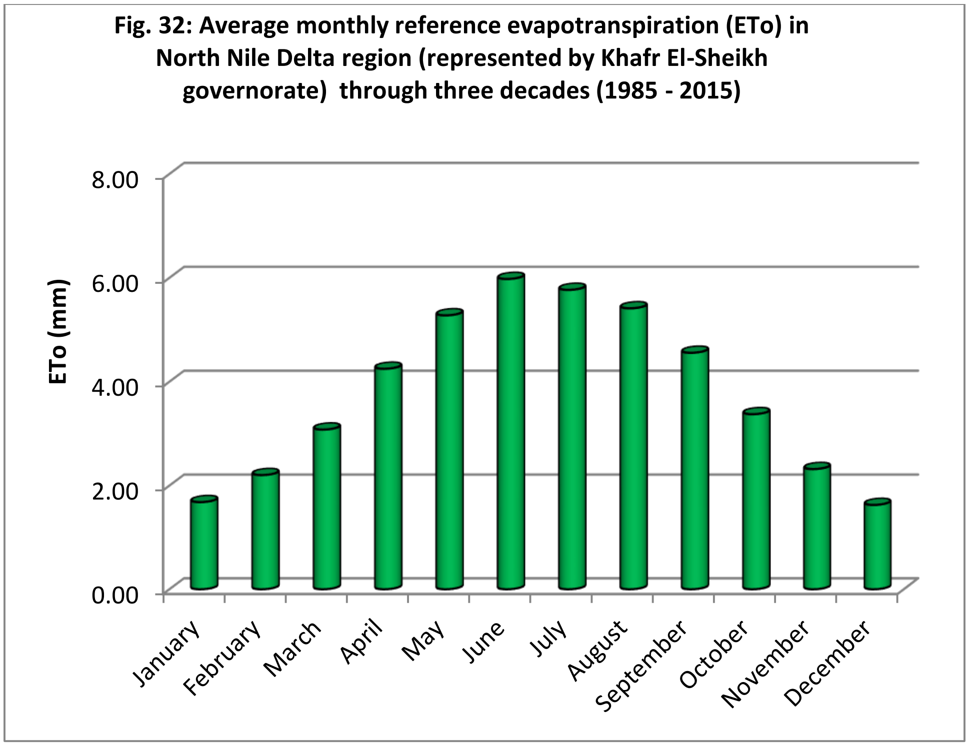


Fig. 31: Monthly reference evapotranspiration (ETo) in North Nile Delta region (represented by Khafr El-Sheikh governorate) in (2015)





3-2- Water consumption and amount of irrigation water used for crops

3-2-1- Winter field crops

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Barley: (Figs. 33-35)

Results show that ETc varied from 1713 m^3/ ha in 2012 to 2823 m^3/ ha in 1986. Average value through the study period recorded 2381 m^3/ ha.

Increasing ETc of barley in 1986 due to the increase in maximum and minimum temperature, low relative humidity and increasing wind speed during the growing season from November to March. Conversely, in 2012, where there was a decrease in maximum temperature especially during the months of January-February-March caused in decreasing ETc.

Regarding IR through the period of 1985-2015, it ranged from 2696 to 3529 m^3/ ha at the farm level and from 3595 to 4706 m^3/ ha at the High Dam level. Average IR at the respective two levels amounted to 2976 and 3968 m^3/ ha.

It is worth mentioning that, increasing amount of rainfall resulted in decreasing amount of irrigation water applied especially during the months of January-February-March. This result observed with all winter crops.

Generally, it could be mentioned that, weather variability that included a high temperature, low relative humidity and increasing wind speed caused in increasing water consumption and amount of irrigation water applied for barley about 19 % compared to their rates of this region (average 31 years).

Chick peas: (Figs. 36-38)

Values of ETc varied from 1456 to 2466 m^3/ ha, and the grand average (av. 31 years) registered 2084 m^3/ ha.

With respect to IR, The values ranged from 1819 to 3082 m^3/ ha at the farm level, and 2426 to 4109 m^3/ ha at the High Dam level. At the same direction, the grand average of IR through the last three decades reached 2605 and 3474 m^3/ ha for the two levels, respectively.

Faba bean (green): (Figs. 39-41)

The results show that, the lowest value of ETC was 1695 m^3/ ha found in 2012, however, the highest one was 2371 m^3/ ha found in 1994. The grand average of ETc was 2012 m^3/ ha. Increasing ETc in 1994 return to increasing maximum temperature and wind speed; and decreasing relative humidity specially through January and February.

Regarding IR values, the lowest and highest ones are 2119 and 2964 m^3/ ha, at the farm level; 2826 and 3951 m^3/ ha at the High Dam level. The grand average for the respective two levels were 2515 and 3353 m^3/ ha.

Faba bean (dry): (Figs. 42-44)

Values of ETc for dry faba bean take the same trend of green faba bean. The highest and lowest ones were 2944 and 2012 m^3/ ha recorded in 1994 and 2012, respectively. The grand average of ETc through the study period was 2532 m^3/ ha.
As for IR, the values varied from 2515 to 3680 m^3/ ha at the farm level, and 3353 to 4907 m^3/ ha at the High dam level. Average of IR at the two respective levels through 31 years were 3165 and 4220 m^3/ ha.

Flax : (Figs. 45-47)
Results as shown in the flax figures show that the highest values of ETc registered in 1986, 1994 and 1988 which obtained 2750, 2640 and 2610 m^3/ ha, respectively. While, the years recorded lowest values were 2012, 2014, 1998, 2006, which recorded ETc values of 1731, 2113, 2116, 2116 m^3/ ha, respectively. Average ETc during the study period amounted to 2323 m^3/ ha.
With respect to amount of irrigation water used (IR), it ranged between 2163 to 3437 m^3/ ha at the farm level; and 2885 to 4583 m^3/ ha at the High Dam level. The grand average of IR reached 2904 and 3872 m^3/ ha, for the two respective levels.

Garlic : (Figs. 48-50)
Values of ETc varied between 2268 to 3242 m^3/ ha. The grand average registered 2765 m^3/ ha.
Regarding IR, the highest value at the farm level was 4053 m^3/ ha registered in 1994, however, the lowest one was 2835 m^3/ ha found in 2012. The grand average was 3457 m^3/ ha. At the High Dam level, the highest and lowest values were 5405 and 3780 m^3/ ha, respectively. The grand average was 4706 m^3/ ha.

Lentil : (Figs. 51-53)
The results obtained from the 31 year climatic data indicate that, ETc varied from 1164 m^3/ ha in 2012 to 1959 m^3/ ha in 1994. Average ETc during 31 year recorded 1616 m^3/ ha.

As for IR, it varied between 1455 m^3/ ha to 2448 m^3/ ha at the farm level; and between 1940 to 3264 m^3/ ha at the High Dam level. The grand average for the respective two levels were 2020 and 2693 m^3/ ha.

Lupine : (Figs. 54-56)

Values of ETc for lupine ranged from 1665 m^3/ ha recorded in 2012 to 2847 m^3/ ha recorded in 1986. Average ETC for 31 year was 2389 m^3/ ha.

Concerning IR, the values varied between 2082 to 3558 m^3/ ha at the farm level; and 2775 to 4744 m^3/ ha at the High Dam level.

The grand average for IR at the farm level and the High Dam level were 2986 and 3981 m^3/ ha, respectively.

Onion : (Figs. 57-59)

Values of ETc varied between 2311 m^3/ ha registered in 2012 to 3245 m^3/ ha found in 1994. Average ETc for 31 year was 2778 m^3/ ha.

Vis-à-vis IR, the values varied between 2889 to 4056 m^3/ ha at the farm level; and 3852 to 5408 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 3472 and 4630 m^3/ ha.

Sugarbeet : (Figs. 60-62)

Results as shown in the sugarbeet figures indicate that the highest values of ETc found in the years 1986, 1994 and 2001 which registered 3838, 3832 and 3705 m^3/ ha, respectively. While, the lowest ETc found in 2012, 2002, and 2006 which recorded ETc values of 2636, 3051 and 3081 m^3/ ha, respectively. Average ETc for 31 year recorded 3366 m^3/ ha.

With reference to IR, the highest and lowest ones were 4798 and 3295 m^3/ ha, respectively, at the farm level. The respective values at the High Dam level were 6397 and 4393 m^3/ ha. The grand average for 31 year was 4208 and 5610 m^3/ ha for farm level and High Dam level, respectively.

Wheat : (Figs. 63-65)

Results as presented in wheat figures show that ETc varied from 2452 m^3/ ha in 2012 to 4108 m^3/ ha in 1986. Average ETc through the study period recorded 3360 m^3/ ha.
Regarding IR, it varied between 3066 to 5135 m3/ ha at farm level; and 4087 to 6846 m^3/ ha at the High Dam level. Average IR during the three decades registered 4200 and 5600 m^3/ ha, at the two levels, respectively.

3-2-2- Winter vegetable crops

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Cabbage: (Figs. 66-68)
Values of ETc varied from 2683 m^3/ ha in 1992 to 3389 m^3/ ha in 1986. Average ETc for 31 year was 2903 m^3/ ha.
Regarding IR, it varied between 3354 to 4236 m^3/ ha at the farm level; and 4472 to 5648 m^3/ ha at the High Dam. The grand averages for the respective two levels were 3629 and 4839 m^3/ ha.

Cucumber: (Figs. 69-71)
Values of ETc for winter cucumber ranged between 2698 m^3/ ha registered in 2001 to 3364 m^3/ ha found in 1986. The grand average of ETc for the study period was 2892 m^3/ ha.
As for IR, values ranged between 3373 to 4205 m^3/ ha at the farm level; and 4497 to 5606 m^3/ ha at the High Dam. The grand averages at the two levels were 3614 and 4819 m^3/ ha, respectively.
Eggplant: (Figs. 72-74)
The results show that ETc registered the lowest value during 2012 (2204 m^3/ ha) and 2002 (2391 m^3/ ha), while, the highest value found during 1994 (3128 m^3/ ha) followed by 1987 (3094 m^3/ ha). Average ETc during 31 year was 2675 m^3/ ha.
Concerning IR, the values varied between 2756 to 3910 m^3/ ha at the farm level; and 3674 to 5213 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 3344 and 4459 m^3/ ha.

Kidney bean (green): (Figs. 75-77)

Values of ETc varied from 2152 m^3/ ha in 2001 to 2645 m^3/ ha in 1986. The grand average of ETc recorded 2287 m3/ ha.

In addition, values of IR ranged between 2690 to 3306 m^3/ ha at the farm level; and 3587 to 4408 m^3/ ha at the High Dam. The averages of IR through the study period recorded 2859 and 3812 m^3/ ha, respectively.

Pepper: (Figs. 78-80)

Results of ETc for pepper show that the highest value found in 1986 (3571 m^3/ ha) and the lowest one registered in 1992 (2831 m^3/ ha). Average ETc through 31 year was 3052 m^3/ ha.

Vis-à-vis IR, the values varied between 3539 to 4464 m^3/ ha at the farm level; and 4719 to 5952 m^3/ ha at the High Dam. The respective grand averages for both levels were 3814 and 5086 m^3/ ha.

Potato (1): (Figs. 81-83)

Sowing date for potato (1) is the 1st of September, values of ETc ranged between 2747 to 3440 m^3/ ha registered in 2011 and 1986, respectively. Average ETc over three decades was 2956 m^3/ ha.

In addition, values of IR ranged between 3434 to 4300 m^3/ ha at the farm level; and 4578 to 5734 m^3/ ha at The High Dam. The grand averages for the two levels were 3695 and 4927 m^3/ ha, respectively.

Potato (2): (Figs. 84-86)

Sowing date for potato (2) is the 1st of November, results of ETc show that the minimum value of 1586 m^3/ ha registered in 2012, however, the maximum value of 2412 m^3/ ha found in 1994. Average ETc over the three decades was 2027 m^3/ ha.

Regarding IR, values varied between 1982 to 3015 m^3/ ha at the farm level; and 2643 to 4020 m^3/ ha at the High Dam. The grand averages were 2534 and 3378 m^3/ ha for both levels, respectively.

Squach: (Figs. 87-89)

Values of ETc varied between 2717 to 3388 m^3/ ha recorded in 2001 and 1986, respectively. The grand average of ETc was 2911 m^3/ ha.

In addition, values of IR ranged between 3396 to 4235 m^3/ ha at the farm level; and 4528 to 5646 m^3/ ha at the High Dam. Averages for the two respective levels over three decades were 3639 and 4852 m^3/ ha.

Strawberry: (Figs. 90-92)

The highest and lowest values of ETc were 4461 and 3452 m^3/ ha recorded in 1986 and 2012, respectively. Average ETc for 31 year was 3776 m^3/ ha.

Concerning IR, the highest and lowest ones were 5577 and 4316 m^3/ ha at the farm level; and 7436 and 5754 m^3/ ha at the High Dam. The grand average for 31 year recorded 4720 and 6293 m^3/ ha for both levels, respectively.

Tomato: (Figs. 93-95)

Results as shown in tomato figures indicate that ETc varied from 2900 m^3/ ha in 1992 to 3653 m^3/ ha in 1986. Average ETc value through the study period recorded 3123 m^3/ ha. With respect to IR, it varied between 3625 to 4566 m^3/ ha at the farm level; and 4833 to 6088 m^3/ ha at the High Dam. Averages IR over the three decades were 3904 and 5205 m^3/ ha for both levels, respectively.

3-2-3- Summer field crops

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Cotton: (Figs. 96-98)

Values of ETc ranged between 7270 m^3/ ha registered in 2002 to 9266 m^3/ ha found in 1986. Average ETc for 31 year was 7780 m^3/ ha.

In addition, results of IR show that the values varied between 9087 to 11582 m^3/ ha at the farm level; and 12116 to 15443 m^3/ ha at the High Dam. The grand averages of IR recorded 9724 and 12966 m^3/ ha for farm level and High Dam level, respectively.

Ground nut: (Figs. 99-101)

The highest values of ETc were 6697, 6177 and 6030 m^3/ ha registered in 1986, 1987 and 1998, respectively. However, the lowest value was 5321 m^3/ ha found in 2002. Average of ETc through 31 year registered 5688 m^3/ ha.

Concerning IR value, it ranged between 6652 to 8371 m^3/ ha at the farm level; and 8869 to 11162 m3/ ha at the High Dam. Averages of IR for 31 year were 7110 and 9480 m^3/ ha for the two levels, respectively.

Maize: (Figs. 102-104)

Values of ETc varied from 5280 m^3/ ha recorded in 2002 to 6625 m^3/ ha recorded in 1986. Average ETc over three decades was 5601 m^3/ ha.

Regarding IR, it ranged between 6600 to 8281 m^3/ ha at the farm level; and 8800 to 11041 m^3/ ha at the High Dam. The grand averages over three decades were 7008 and 9344 m^3/ ha for the two respective levels.

Onion: (Figs. 105-107)

Results of ETc as presented in onion figures indicate that the highest values of ETc found during the seasons 1986, 1987, 1998, which recorded 8685, 7969, 7812 m^3/ ha for the respective three seasons. While the 2002 season recorded the lowest ETc of 6940 m^3/ha. Average ETc for 31 year reached 7392 m^3/ ha.

As for IR, the values ranged between 8675 to 10856 m^3/ ha at the farm level; and 11567 to 14475 m^3/ ha at the High Dam. The respective averages over three decades for the two levels were 9239 and 12319 m^3/ ha.

Rice: (Figs. 108-110)

Water consumption (ETc) and irrigation water applied (IR) for rice crop was calculated as follows:

1. Old varieties of rice growing season length has 150 days (from 1985 to 2005)
2. New rice varieties growing season length has 120 days (from 2006 to 2015)

Results as recorded in rice figures indicate that values of ETc for old rice varieties ranging from 7307 m^3/ ha (found in 2002) to 9137 m^3/ ha (found in 1986). While, ETc values for new rice varieties ranged from 5618 m^3/ ha (found in 2006) to 5923 m^3/ ha (found in 2013). Average ETc of old and new varieties during the 31 years reached 7201 m^3/ ha.

Regarding the amount of IR at the farm level for old rice varieties, it varied from 10439 to 13052 m^3/ ha , however, values of IR for new rice varieties ranging from 8025 to 8461 m^3/ ha

Concerning values of IR at the High dam level, it varied from 14614 to 18273 m^3/ ha , however, values of IR for new rice varieties ranging from 11235 to 11846 m^3/ ha.

Averages of IR at the farm level and at the level of the High Dam during 31 years reached 10287 and 14402 m^3/ ha, respectively.

Soybean: (Figs. 111-113)

Values of ETc varied between 5352 m^3/ ha obtained in 2002 to 6752 m^3/ ha obtained in 1986. Average of ETc through 31 year registered 5728 m^3/ ha.

In addition, values of IR ranged between 6691 to 8439 m^3/ ha at the farm level; and 8921 to 11253 m^3/ ha at the High Dam. The respective averages for both levels through 31 year recorded 7160 and 9546 m^3/ ha.

Sugarcane: (Figs. 114-116)

The highest and lowest ETc values for sugarcane found in 1986 and 2012, which recorded 18158 and 13843 m^3/ ha, respectively. Average ETc over the three decades was 15247 m^3/ ha.

Concerning IR, the values varied between 17304 to 22698 m^3/ ha at the farm level; and 23071 to 30264 m^3/ ha at the High Dam. Average values of IR at the farm level and the High Dam level through the study period registered 19058 and 25411 m^3/ ha, respectively.

Sunflower: (Figs. 117-119)

Values of ETc varied between 3503 to 4612 m^3/ ha. Average value of ETc through 31 year was 3825 m^3/ ha.

As for IR, the values ranged between 4379 to 5765 m^3/ ha at the farm level; and 5838 to 7686 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 4781 and 6375 m^3/ ha.

3-2-4- Summer vegetable crops

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Cabbage: (Figs. 120-122)

Results of ETc as presented in cabbage figures show that the highest values of ETc found during the seasons 1986, 1987,1988 and 1998 compared to others ETc during the 31 seasons, which recorded 7608, 7014, 6785 and 6755 m^3/ ha for the respective four seasons. While the 2002 followed by 2006 season recorded the lowest ETc of 6047 and 6127 m^3/ha, respectively. Average ETc for 31 year reached 6454 m^3/ ha.

Regarding IR, the values ranged between 7559 to 9510 m^3/ ha at the farm level; and 10078 to 12681 m^3/ ha at the High Dam level. The respective averages over three decades for the two levels were 8068 and 10757 m^3/ ha.

Cucumber: (Figs. 123-125)

Values of ETc ranged between 3071 m^3/ ha found in 2012 to 4878 m^3/ ha found in 1986. Average value through three decades was 4046 m^3/ ha.

In addition, values of IR ranged between 3839 to 6097 m^3/ ha at the farm level; and 5119 to 8130 m^3/ ha at the High Dam. Average IR value for 31 year recorded 5058 and 6743 m^3/ ha, at the farm level and High Dam level, respectively.

Eggplant: (Figs. 126-128)

Results of ETc indicated that the highest and lowest values were 7838 and 5803 m^3/ ha recorded in 1986 and 2012, respectively. Average ETc for 31 year was 6559 m^3/ ha.

Concerning IR, the highest and lowest ones were 9798 and 7254 m^3/ ha at the farm level; and 13064 and 9672 m^3/ ha at the High Dam. The grand average for 31 year recorded 8199 and 10931m^3/ ha for both levels, respectively.

Kidney bean (green): (Figs. 129-131)

Values of ETc varied between 2624 m^3/ ha obtained in 2012 to 3952 m^3/ ha obtained in 1993. Average ETc over the three decades was 3290 m^3/ ha.

Vis-à-vis IR, the values varied between 3280 to 4940 m^3/ ha at the farm level; and 4373 to 6587 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 4112 and 5483 m^3/ ha.

Okra: (Figs. 132-134)

The highest and lowest values of ETc for okra were 4638 and 2950 m^3/ h registered in 1986 and 2012, respectively. Average ETc over the three decades was 3854 m^3/ ha.

Regarding IR, values varied between 3688 to 5797 m^3/ ha at the farm level; and 4917 to 7730 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 4818 and 6424 m^3/ ha.

Pepper: (Figs. 135-137)

Values of ETc varied between 5588 m^3/ ha obtained in 2012 to 7572 m^3/ ha obtained in 1986. Average ETc over the three decades was 6332 m^3/ ha.

With respect to IR, the values varied between 6985 to 9465 m^3/ ha at the farm level; and 9314 to 12620 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 7915 and 10553 m^3/ ha.

Potato: (Figs. 138-140)

Results of ETc for summer potato varied between 3240 m^3/ ha obtained in 2012 to 5096 m^3/ ha obtained in 1986. Average ETc during the study period was 4229 m^3/ ha.

Regarding IR, the values varied between 4050 to 6371 m^3/ ha at the farm level; and 5400 to 8494 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 5286 and 7048 m^3/ ha.

Squach: (Figs. 141-143)

Values of ETc for squach in summer season varied between 3131 m^3/ ha obtained in 2012 to 4953 m^3/ ha obtained in 1986. Average ETc during the study period was 4113 m^3/ ha.

Concerning IR, the values varied between 3914 to 6192 m^3/ ha at the farm level; and 5218 to 8256 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 5141 and 6854 m^3/ ha.

Tomato: (Figs. 144-146)

Results of ETc as presented in tomato figures (summer season) show that the highest values of ETc registered during the seasons 1986, 1987,1993, 1988 and 1994, which recorded 7986, 7569, 7480, 7084 and 7012 m^3/ ha for the respective five seasons. While the 2012 followed by 2002, 2006 and 2015 season recorded the lowest ETc of 5957, 6199, 6307 and 6319 m^3/ ha, respectively. Average ETc for 31 year reached 6695 m^3/ ha.

Regarding IR, the values ranged between 7447 to 9983 m^3/ ha at the farm level; and 9929 to 13311 m^3/ ha at the High Dam level. The respective averages over three decades for the two levels were 8369 and 11158 m^3/ ha.

Water melon: (Figs. 147-149)

Values of ETc varied between 4950 m^3/ ha recorded in 2002 to 6422 m^3/ ha recorded in 1986. Average value of ETc over three decades was 5384 m^3/ ha.

Concerning IR, the values varied between 6188 to 8027 m^3/ ha at the farm level; and 8250 to 10703 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 6731 and 8974 m^3/ ha.

3-2-5- Nili crops

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Maize: (Figs. 150-152)

The highest values of ETc recorded during the seasons 1986, 1998, 2003, 1994 and 2015, which recorded 5434, 5083, 4848, 4836 and 4830 m^3/ ha for the respective five seasons. While the 1997 followed by 1996, 1990 and 1992 season recorded the lowest ETc of 4360, 4434, 4475 and 4498 m^3/ ha, respectively. Average ETc for 31 year reached 4680 m^3/ ha.

Regarding IR, the values ranged between 5450 to 6793 m^3/ ha at the farm level; and 7266 to 9057 m^3/ ha at the High Dam level. The respective averages over three decades for the two levels were 5850 and 7801 m^3/ ha.

Sunflower: (Figs. 153-155)

Values of ETc varied between 3191 m^3/ ha recorded in 1997 to 3973 m^3/ ha recorded in 1986. Average ETc over the three decades was 3428 m^3/ ha.

As to IR, the values varied between 3989 to 4966 m^3/ ha at the farm level; and 5319 to 6621 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 4285 and 5713 m^3/ ha.

Tomato: (Figs. 156-158)

Results of ETc as presented in tomato figures (Nili season) indicate that values of ETc ranged between 4971 m^3/ ha recorded in 1997 to 6053 m^3/ ha recorded in 1986. Average ETc during the study period was 5249 m^3/ ha.

Concerning IR, the values varied between 6214 to 7566 m^3/ ha at the farm level; and 8286 to 10088 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 6561 and 8749 m^3/ ha.

3-2-6- Medical and aromatic crops

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Caraway: (Figs. 159-161)

Values of ETc varied between 2277 m^3/ ha obtained in 2012 to 3374 m^3/ ha obtained in 1986. Average ETc over the three decades was 2950 m^3/ ha.

Regarding IR, the values varied between 2846 to 4217 m^3/ ha at the farm level; and 3795 to 5623 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 3688 and 4917 m^3/ ha.

It is notable that , water consumption (ETc) and amount of irrigation water applied (IR) for the crops of **anise** and **coriander**, similar to those values of caraway.

Cumin: (Figs. 162-164)

Values of ETc for cumin varied between 1155 m^3/ ha found in 2012 to 1807 m^3/ ha found in 1994. Average ETc over the three decades was 1500 m^3/ ha.

As to IR, the values varied between 1444 to 2259 m^3/ ha at the farm level; and 1925 to 3012 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 1875 and 2500 m^3/ ha.

Jasmine: (Figs. 165-167)

The highest ETc values registered during the seasons 1986, 1998, 1993, 1987, 2003 and 1994. Values of ETc in the same order as the previous six years were as follows: 11786, 11009, 10539, 10524, 10449 and 10443 m^3/ ha. While the 2012 followed by 2002, 2013 and 2006 season recorded the lowest ETc of 9187, 9335, 9447 and 9479 m^3/ ha, respectively. Average ETc for 31 year reached 9943 m^3/ ha.

As to IR, the values ranged between 11484 to 14732 m^3/ ha at the farm level; and 15312 to 19643 m^3/ ha at the High Dam level. The respective averages over three decades for the two levels were 12429 and 16572 m^3/ ha.

Marjoram: (Figs. 168-170)

Values of ETc varied between 8665 m^3/ ha recorded in 2012 to 13206 m^3/ ha recorded in 1986. Average ETc over the three decades was 10939 m^3/ ha.

As regards IR, the values varied between 10831 to 16507 m^3/ ha at the farm level; and 14441 to 22010 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 13674 and 18231 m^3/ ha.

Spearmint: (Figs. 171-173)

Results of ETc as presented in spearmint figures show that the highest values of ETc registered during the seasons 1986, 1987, 1993, 1994 and 1988. Values of ETc in the same order as the previous five years was as follows: 13206, 12353, 12136, 11883 and 11645 m^3/ ha. While the 2012 followed by 2013, 2002, 2014 and 2015 season recorded the lowest ETc of 8665, 10068, 10109, 10165 and 10166 m^3/ ha, respectively. Average ETc for 31 year reached 10939 m^3/ ha.

Concerning IR, the values ranged between 10831 to 16507 m^3/ ha at the farm level; and 14441 to 22010 m^3/ ha at the High Dam level. The respective averages for both levels through the study period were 13674 and 18231 m^3/ ha.

3-2-7- Orchard trees

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Apple: (Figs. 174-176)

Values of ETc varied between 8207 m^3/ ha recorded in 1995 to 10516 m^3/ ha recorded in 1986. Average ETc over the three decades was 8909 m^3/ ha.

Regarding IR, the values varied between 10259 to 13146 m^3/ ha at the farm level; and 13679 to 17527 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 11136 and 14848 m^3/ ha.

Banana: (Figs. 177-179)

Results as presented in banana figures indicate that the highest values of ETc recorded during the seasons 1986, 1993, 1987, 1988, 1995, 1994, 2003 and 1985. Values of ETc in the same order as the previous seasons were as follows: 16969, 15515, 15430, 15119, 15105, 15016, 15009 and 15003 m^3/ ha. While, season 2012 recorded the lowest ETc of 13442 m^3/ ha. Average ETc for the study period reached 14435 m^3/ ha.

As to IR, the values ranged between 16802 to 21211 m^3/ ha at the farm level; and 22403 to 28281 m^3/ ha at the High Dam level. The respective averages for both levels through the study period were 18044 and 24059 m^3/ ha.

Date palm: (Figs. 180-182)

Values of ETc varied between 9647 m^3/ ha found in 2012 to 12113 m^3/ ha found in 1986. Average ETc over the three decades was 10316 m^3/ ha.

Regarding IR, the values varied between 12058 to 15141 m^3/ ha at the farm level; and 16078 to 20189 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 12895 and 17193 m^3/ ha.

Grapes: (Figs. 183-185)

Values of ETc varied between 6666 m^3/ ha found in 2002 to 8294 m^3/ ha found in 1986. Average ETc over the three decades was 7037 m^3/ ha.

Regarding IR, the values varied between 8332 to 10367 m^3/ ha at the farm level; and 11110 to 13823 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 8796 and 11728 m^3/ ha.

Mango: (Figs. 186-188)

Values of ETc ranged between 10620 m^3/ ha obtained in 2013 to 13948 m^3/ ha obtained in 1986. Average ETc over the study period was 11621 m^3/ ha.

concerning IR, the values varied between 13275 to 17435 m^3/ ha at the farm level; and 17700 to 23246 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 14526 and 19368 m^3/ ha.

Olive: (Figs. 189-191)

Values of ETc ranged between 6989 m^3/ ha obtained in 2002 to 8643 m^3/ ha obtained in 1986. Average ETc over the study period was 7552 m^3/ ha.

concerning IR, the values varied between 8737 to 10803 m^3/ ha at the farm level; and 11649 to 14404 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 9441 and 12587 m^3/ ha.

Orange: (Figs. 192-194)

Values of ETc varied between 9145 m^3/ ha recorded in 2012 to 11537 m^3/ ha recorded in 1986. Average ETc over the study period was 9797 m^3/ ha.

Regarding IR, the values varied between 11431 to 14421 m^3/ ha at the farm level; and 15241 to 19228 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 12247 and 16329 m^3/ ha.

Peach: (Figs. 195-197)

Values of ETc varied between 8197 m^3/ ha recorded in 2002 to 10187 m^3/ ha recorded in 1986. Average ETc over the study period was 8653 m^3/ ha.

Regarding IR, the values varied between 10246 to 12734 m^3/ ha at the farm level; and 13662 to 16978 m^3/ ha at the High Dam level. The respective averages for both levels through 31 year were 10816 and 14421 m^3/ ha.

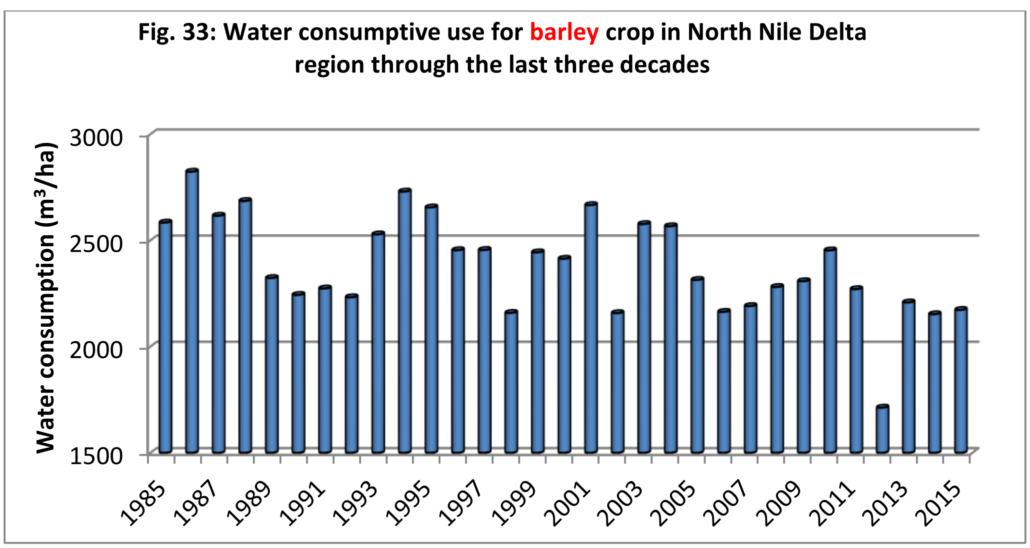


Fig. 34: Amount of irrigation water used (IR) at the farm level for barley in North Nile Delta region through the last three decades

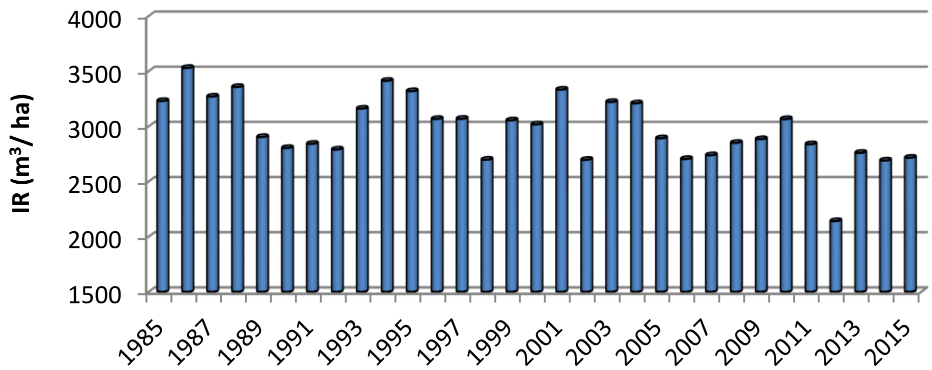


Fig. 35: Amount of irrigation water used (IR) at the high dam for barley in North Nile Delta region through the last three decades

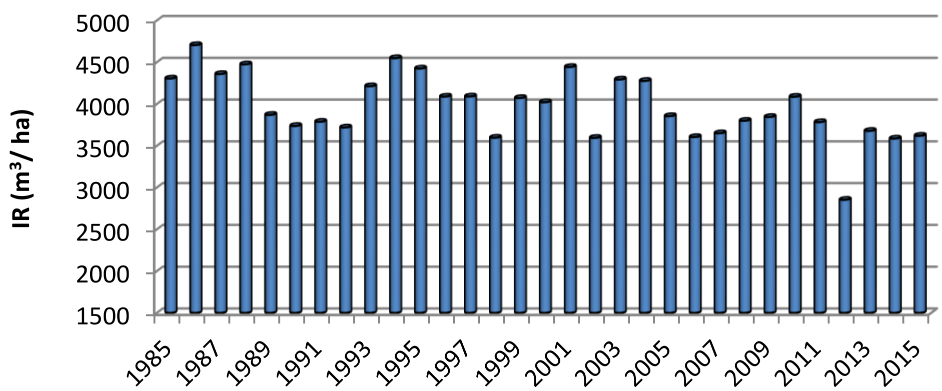


Fig. 36: Water consumptive use for chick peas in North Nile Delta region through the last three decades

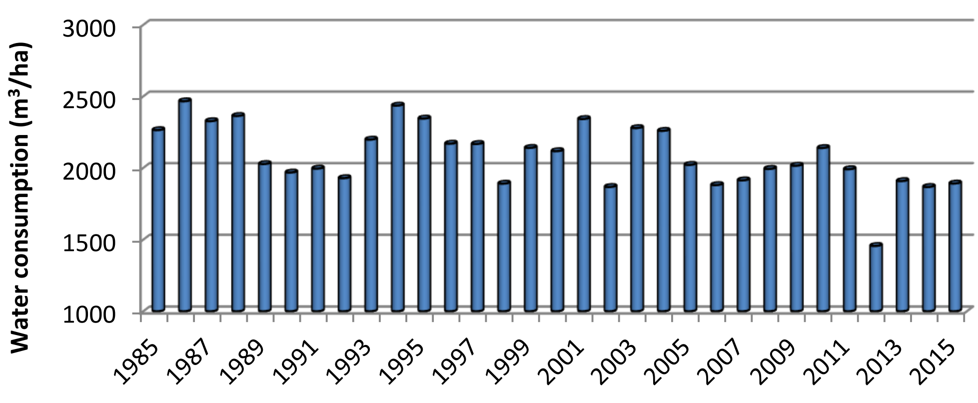


Fig. 37: Amount of irrigation water used (IR) at the farm level for chick peas in North Nile Delta region through the last three decades

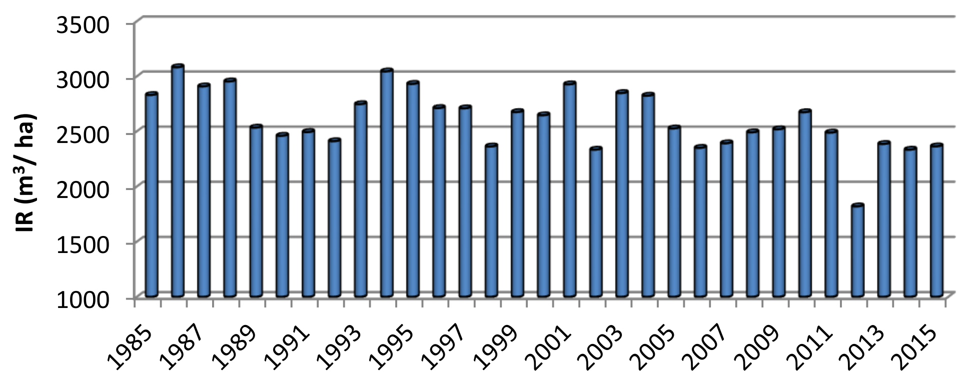


Fig. 38: Amount of irrigation water used (IR) at the high dam for chick peas in North Nile Delta region through the last three decades

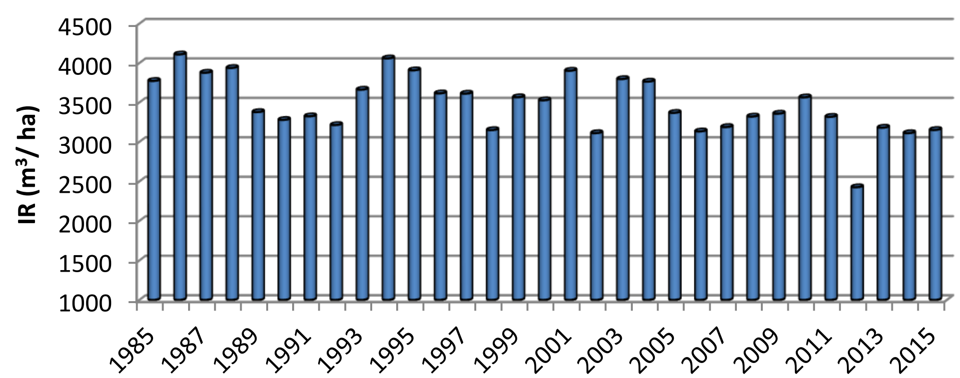


Fig. 39: Water consumptive use for faba bean (green) in North Nile Delta region through the last three decades

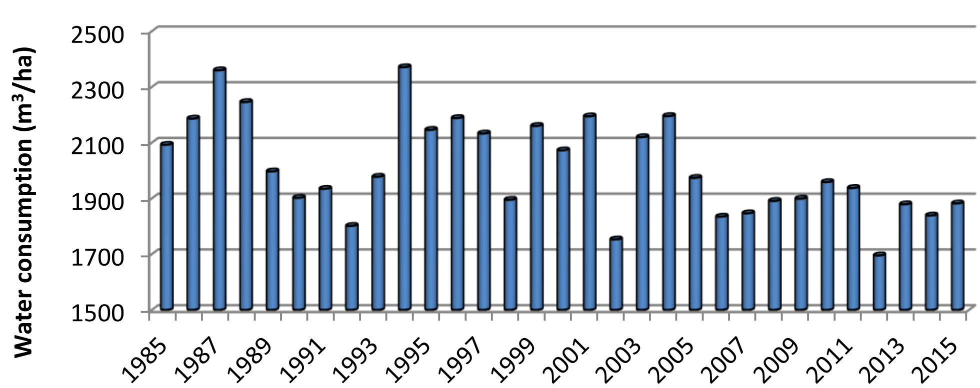


Fig. 40: Amount of irrigation water used (IR) at the farm level for faba bean (green) in North Nile Delta region through the last three decades

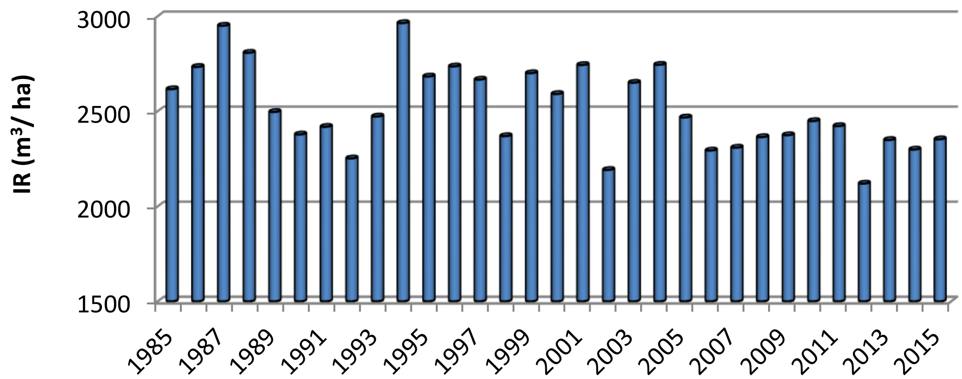


Fig. 41: Amount of irrigation water used (IR) at the high dam for faba bean (green) in North Nile Delta region through the last three decades

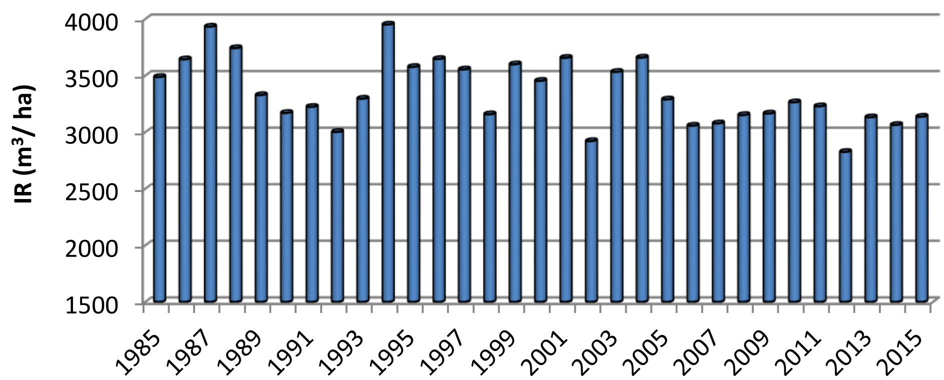


Fig. 42: Water consumptive use for faba bean (dry) in North Nile Delta region through the last three decades

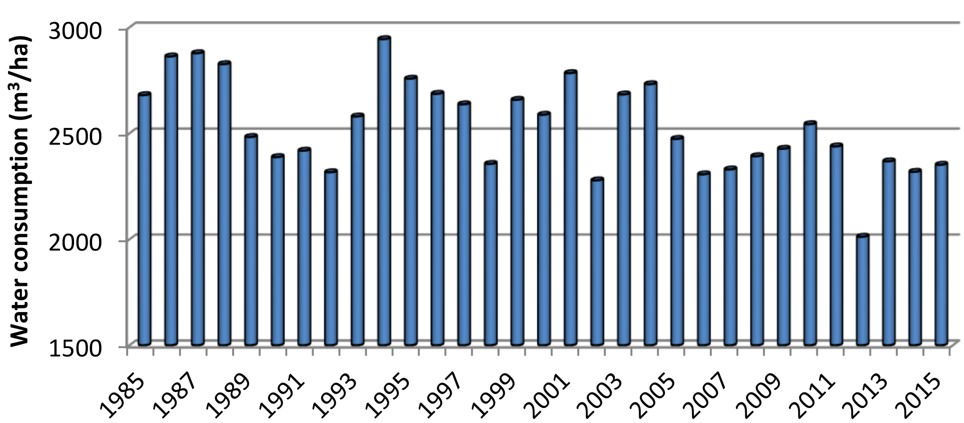


Fig. 43: Amount of irrigation water used (IR) at the farm level for faba bean (dry) in North Nile Delta region through the last three decades

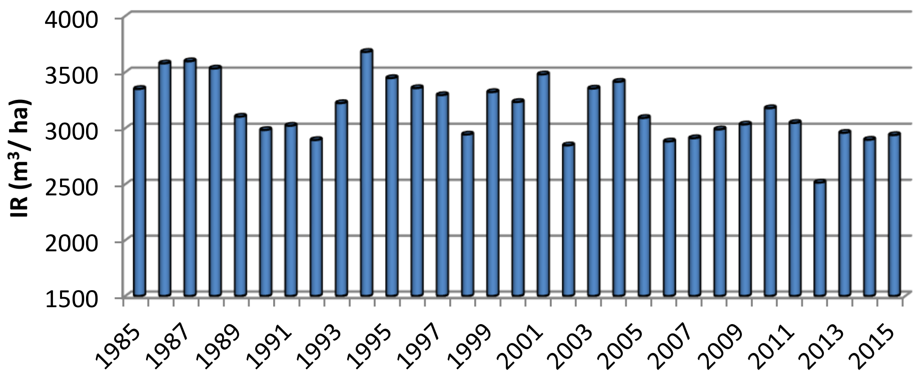


Fig. 44: Amount of irrigation water used (IR) at the high dam for faba bean (dry) in North Nile Delta region through the last three decades

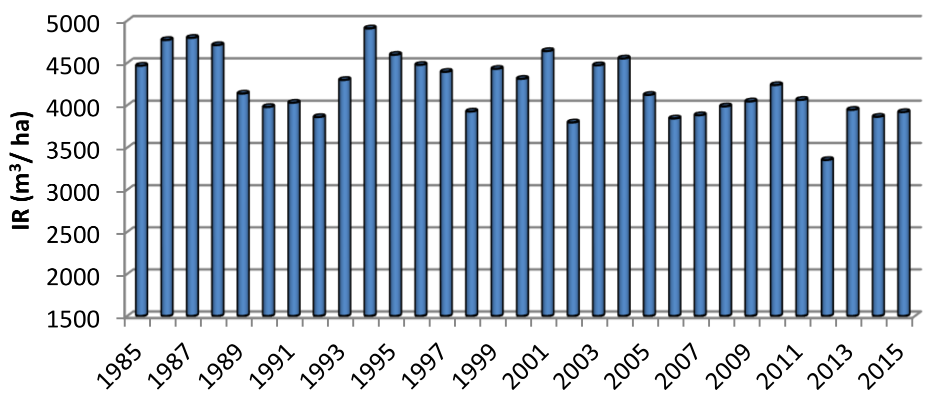
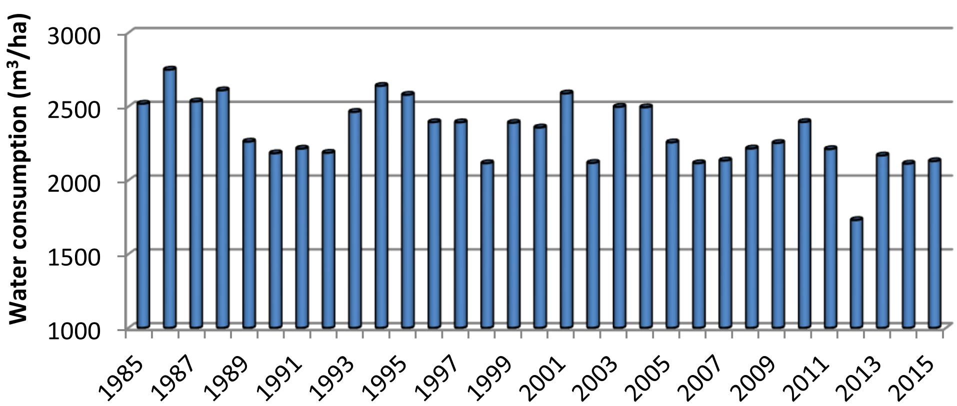


Fig. 45: Water consumptive use for flax in North Nile Delta region through the last three decades



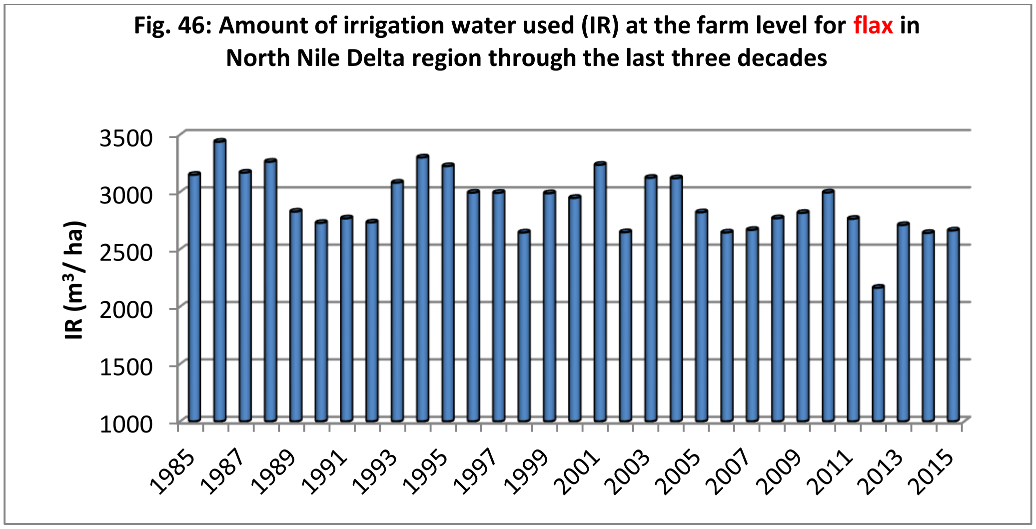


Fig. 46: Amount of irrigation water used (IR) at the farm level for flax in North Nile Delta region through the last three decades
IR (m3/ ha)
3500
3000
2500
2000
1500
1000
1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015

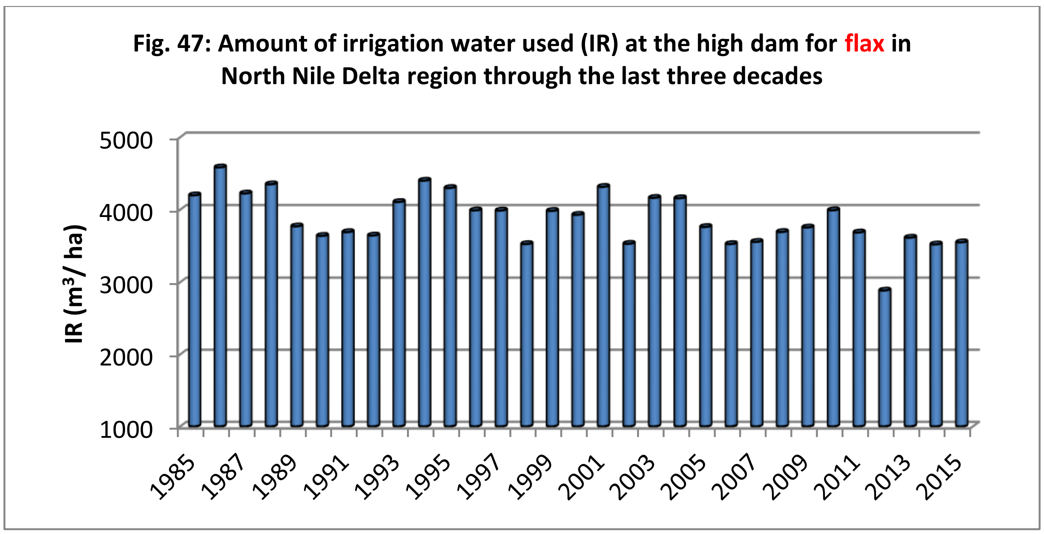


Fig. 47: Amount of irrigation water used (IR) at the high dam for flax in North Nile Delta region through the last three decades
IR (m3/ ha)
5000
4000
3000
2000
1000
1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015

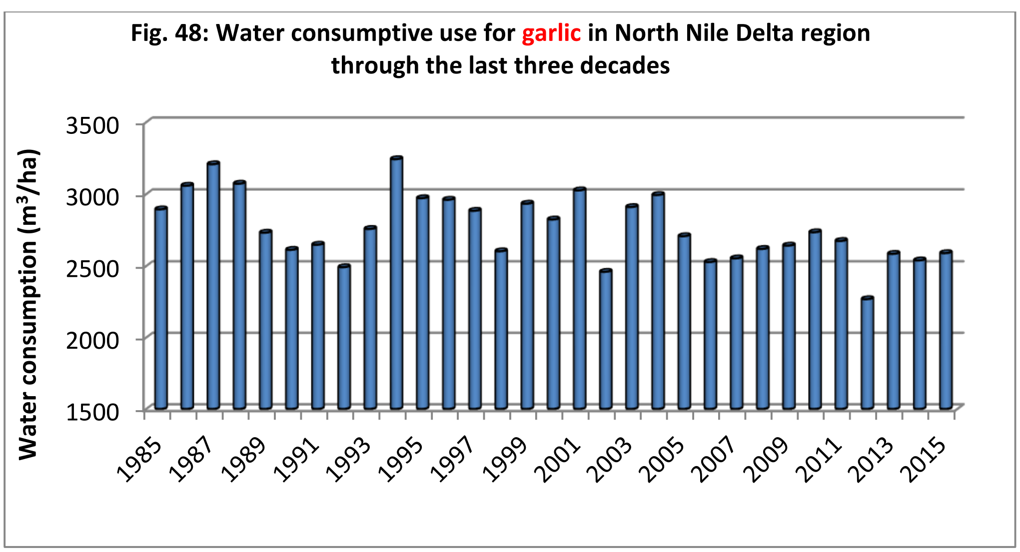


Fig. 48: Water consumptive use for garlic in North Nile Delta region through the last three decades
Water consumption (m3/ha)
3500
3000
2500
2000
1500
1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015

Fig. 49: Amount of irrigation water used (IR) at the farm level for garlic in North Nile Delta region through the last three decades

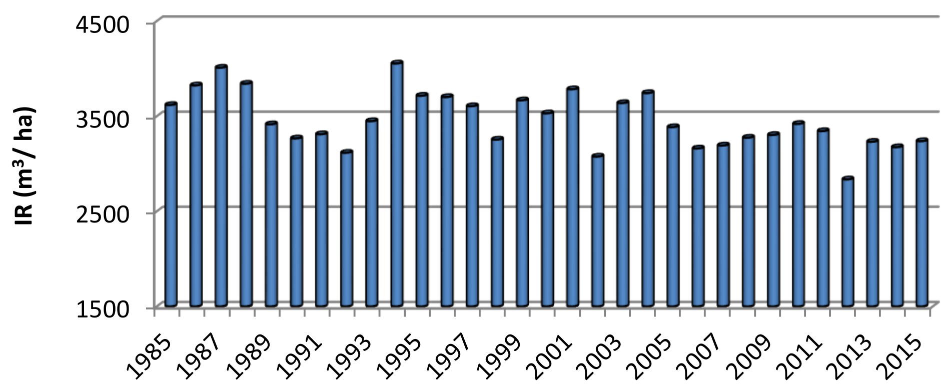


Fig. 50: Amount of irrigation water used (IR) at the high dam for garlic in North Nile Delta region through the last three decades

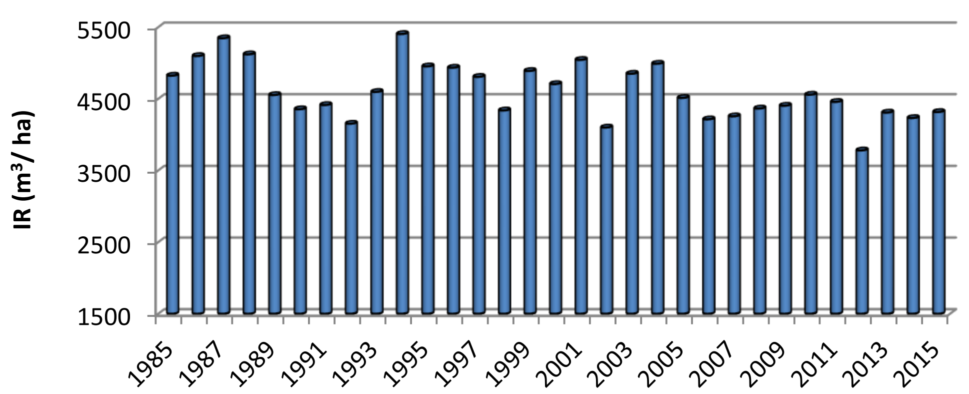


Fig. 51: Water consumptive use for lentils in North Nile Delta region through the last three decades

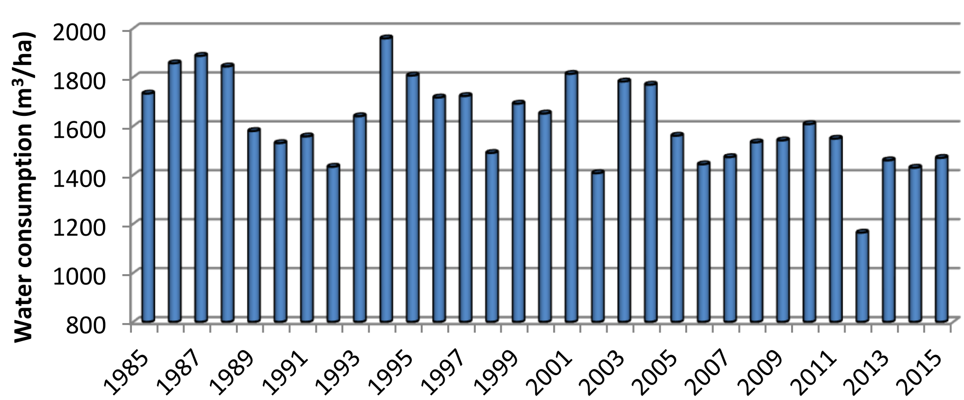


Fig. 52: Amount of irrigation water used (IR) at the farm level for lentils in North Nile Delta region through the last three decades

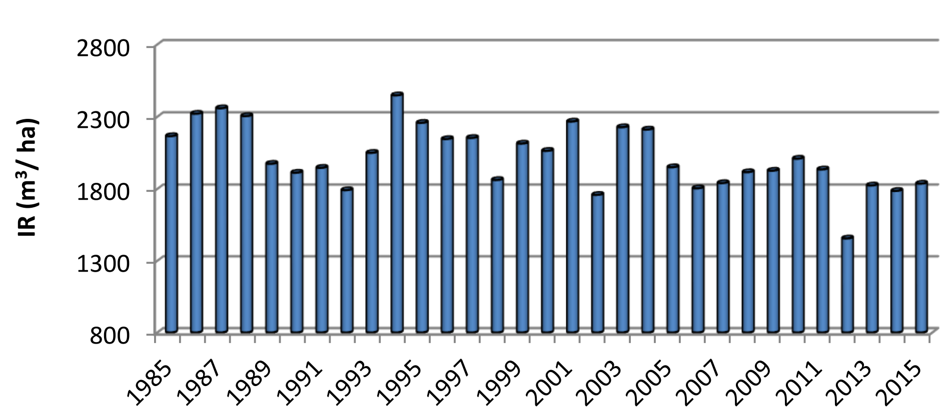


Fig. 53: Amount of irrigation water used (IR) at the high dam for lentils in North Nile Delta region through the last three decades

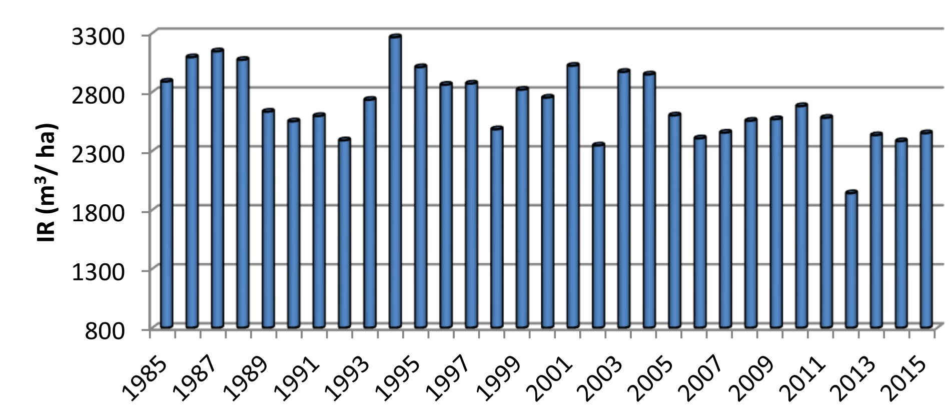


Fig. 54: Water consumptive use for lupine in North Nile Delta region through the last three decades

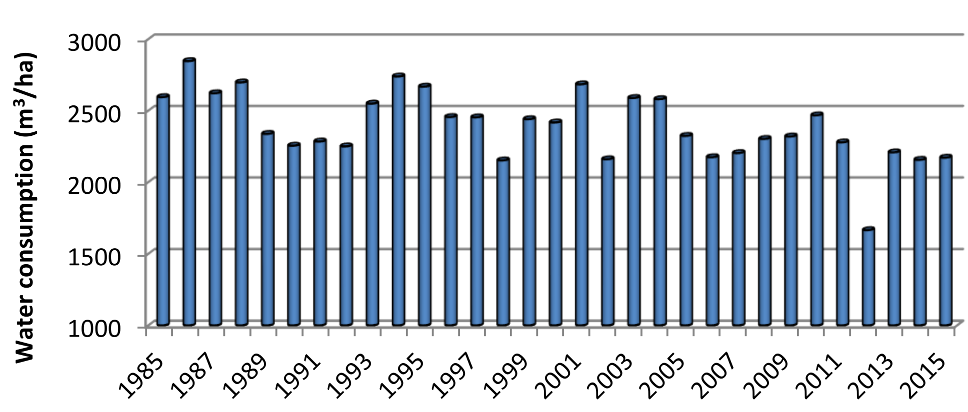


Fig. 55: Amount of irrigation water used (IR) at the farm level for lupine in North Nile Delta region through the last three decades

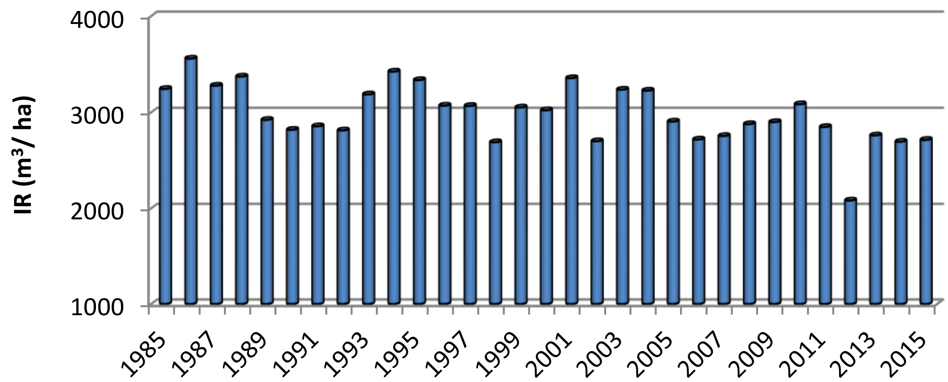


Fig. 56: Amount of irrigation water used (IR) at the high dam for lupine in North Nile Delta region through the last three decades

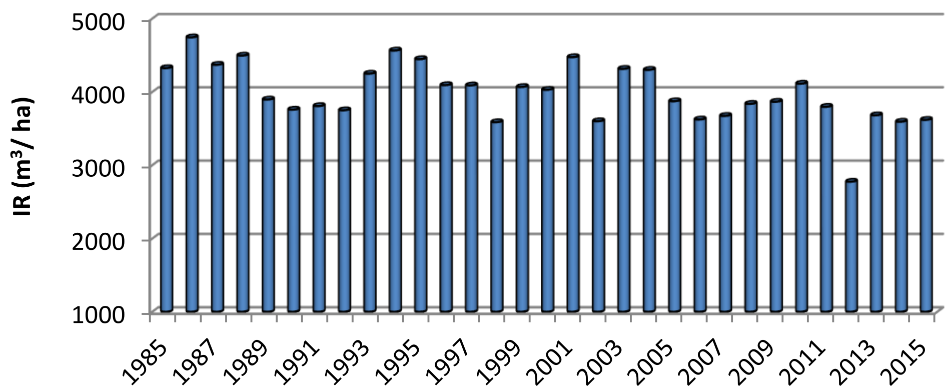


Fig. 57: Water consumptive use for onion (winter season) in North Nile Delta region through the last three decades

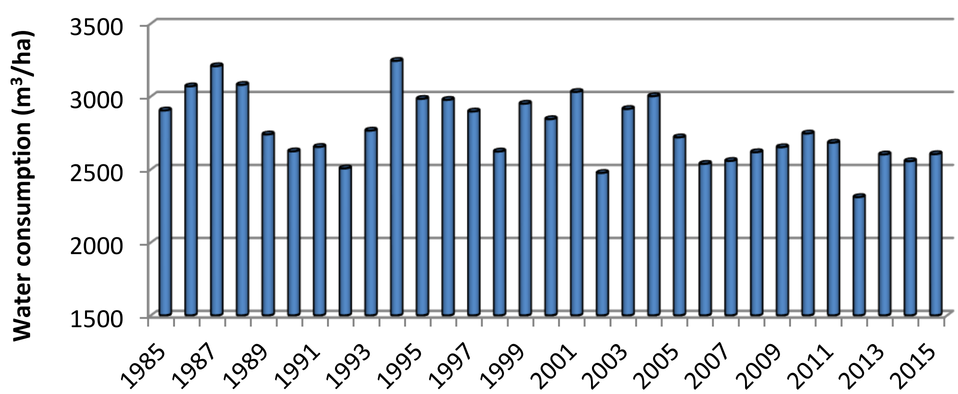


Fig. 58: Amount of irrigation water used (IR) at the farm level for onion (winter season) in North Nile Delta region through the last three decades

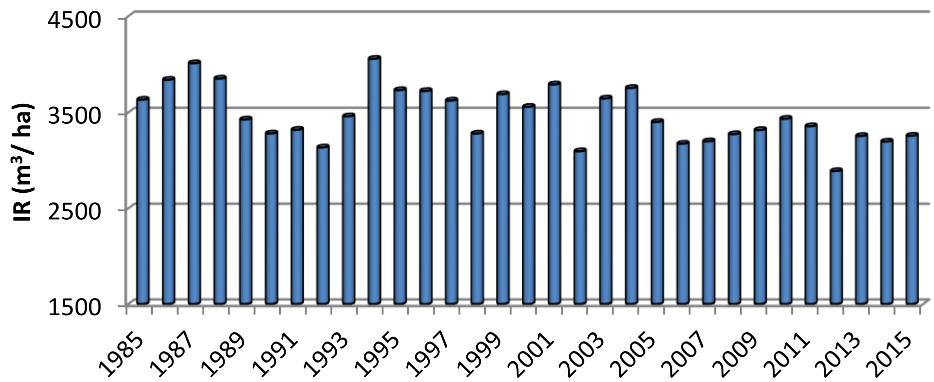


Fig. 59: Amount of irrigation water used (IR) at the high dam for onion (winter season) in North Nile Delta region through the last three decades

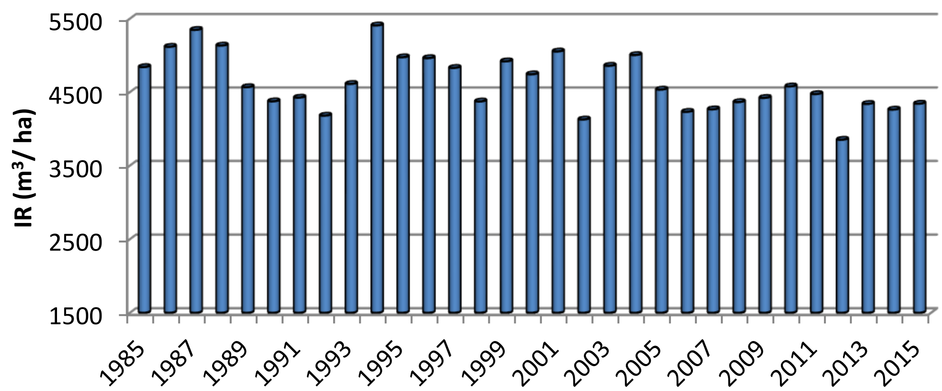


Fig. 60: Water consumptive use for sugarbeet in North Nile Delta region through the last three decades

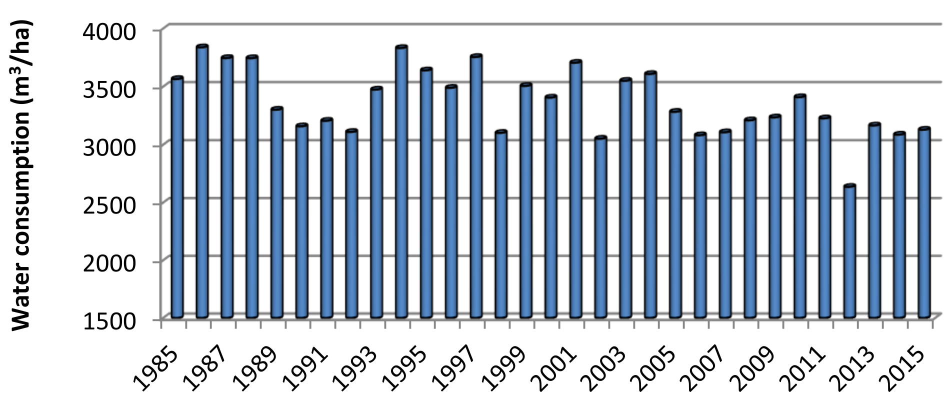


Fig. 61: Amount of irrigation water used (IR) at the farm level for sugarbeet in North Nile Delta region through the last three decades

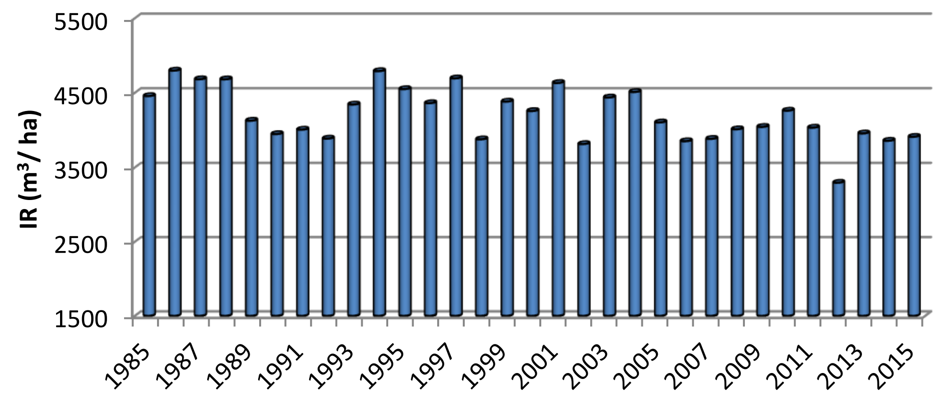


Fig. 62: Amount of irrigation water used (IR) at the high dam for sugarbeet in North Nile Delta region through the last three decades

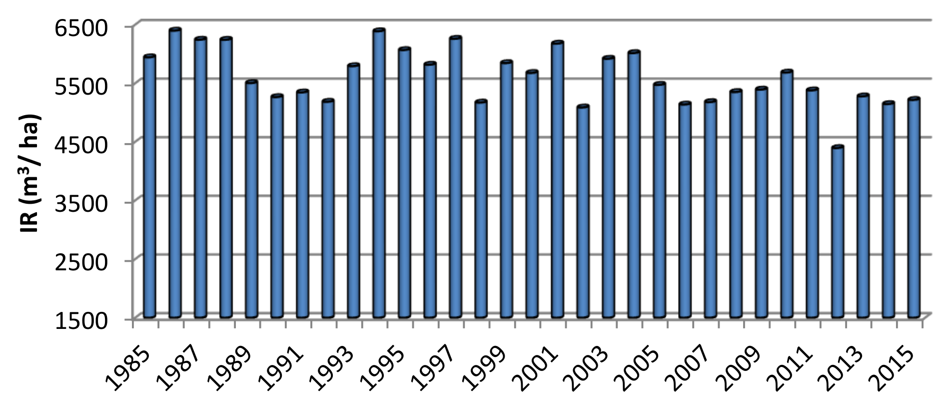


Fig. 63: Water consumptive use for wheat in North Nile Delta region through the last three decades

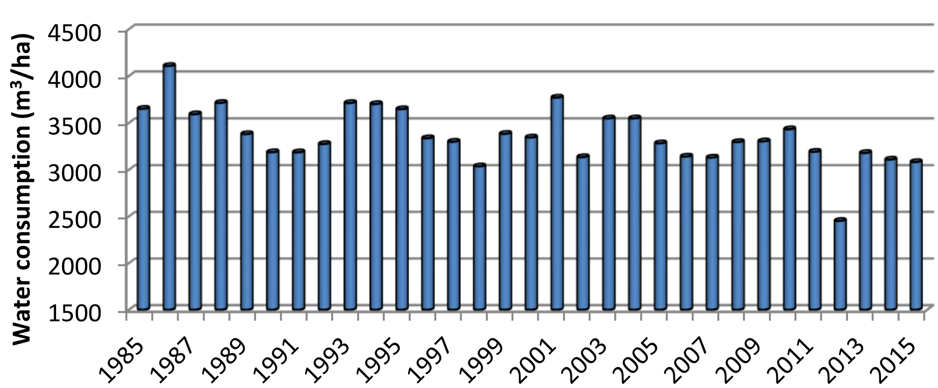


Fig. 64: Amount of irrigation water used (IR) at the farm level for wheat in North Nile Delta region through the last three decades

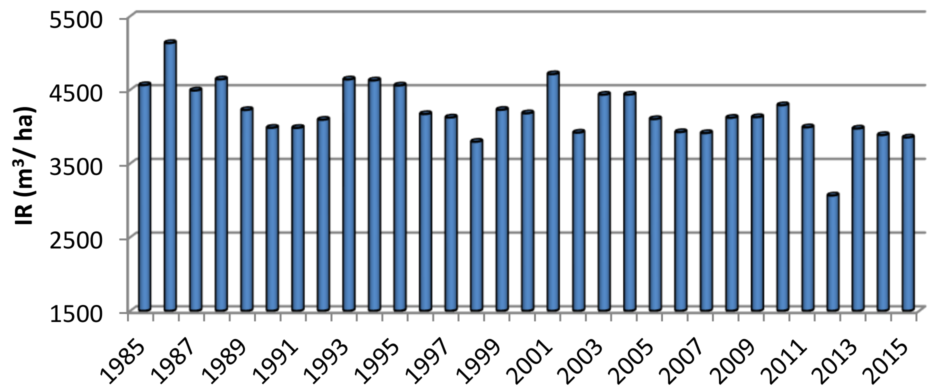


Fig. 65: Amount of irrigation water used (IR) at the high dam for wheat in North Nile Delta region through the last three decades

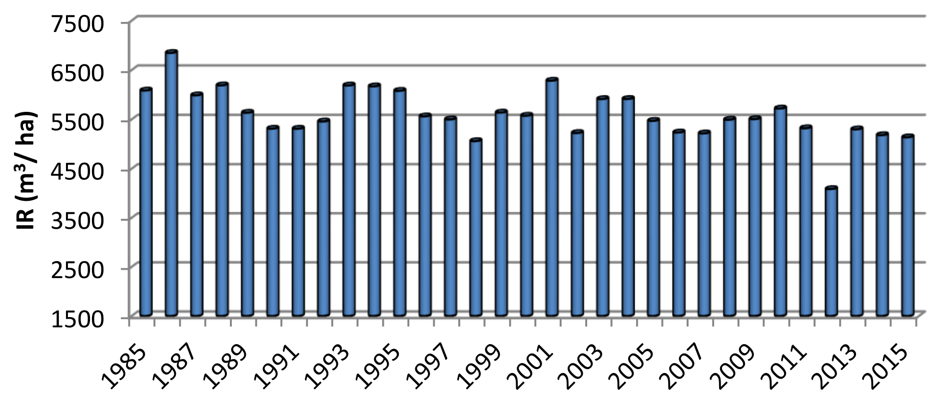


Fig. 66: Water consumptive use for cabbage (winter season) in North Nile Delta region through the last three decades

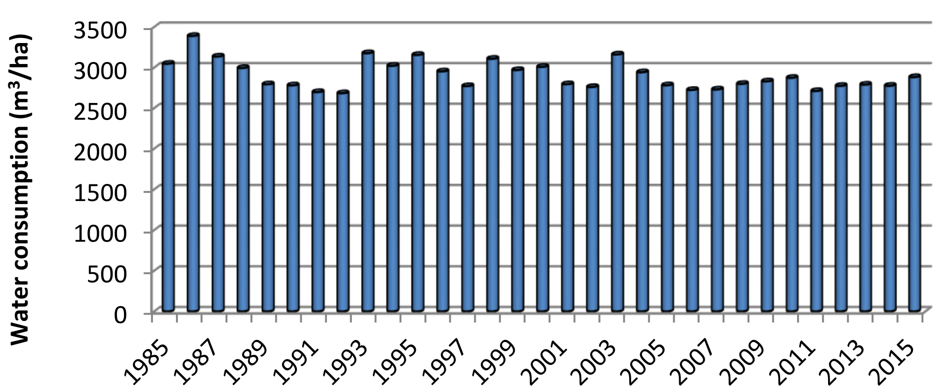


Fig. 67: Amount of irrigation water used (IR) at the farm level for cabbage (winter season) in North Nile Delta region through the last three decades

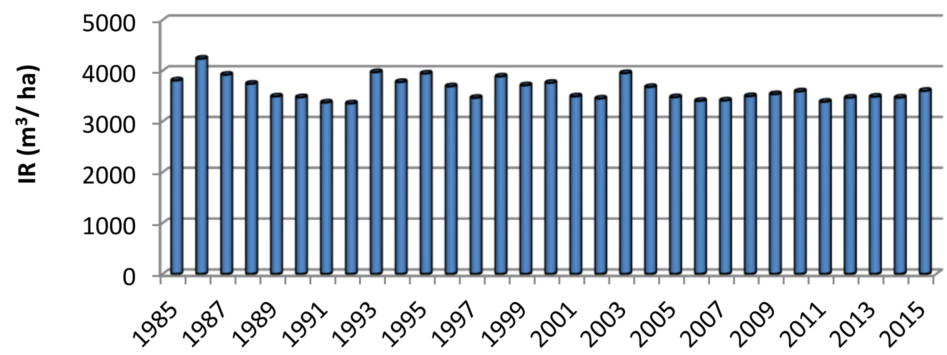


Fig. 68: Amount of irrigation water used (IR) at the high dam for cabbage (winter season) in North Nile Delta region through the last three decades

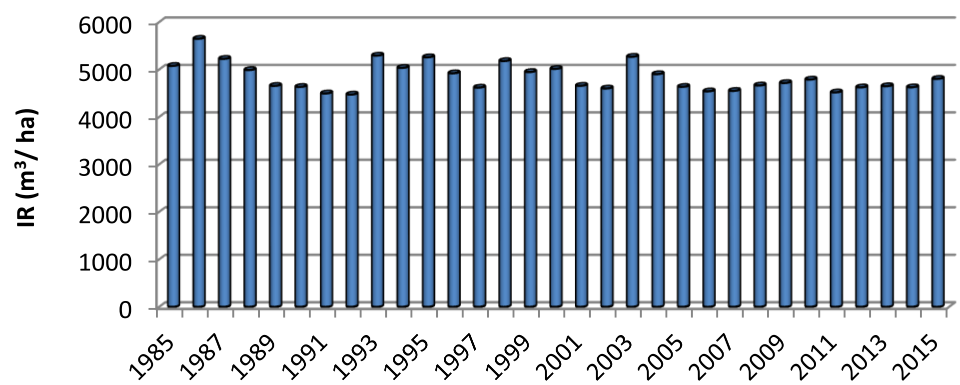


Fig. 69: Water consumptive use for cucumber (winter season) in North Nile Delta region through the last three decades

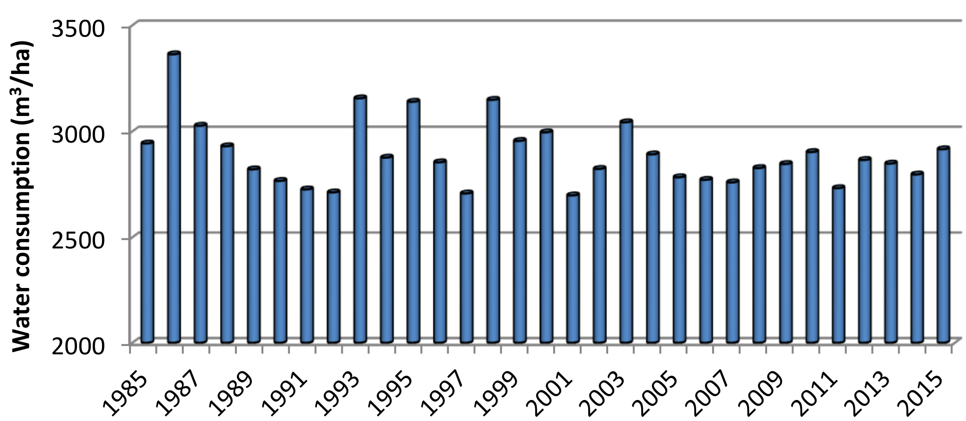


Fig. 70: Amount of irrigation water used (IR) at the farm level for cucumber (winter season) in North Nile Delta region through the last three decades

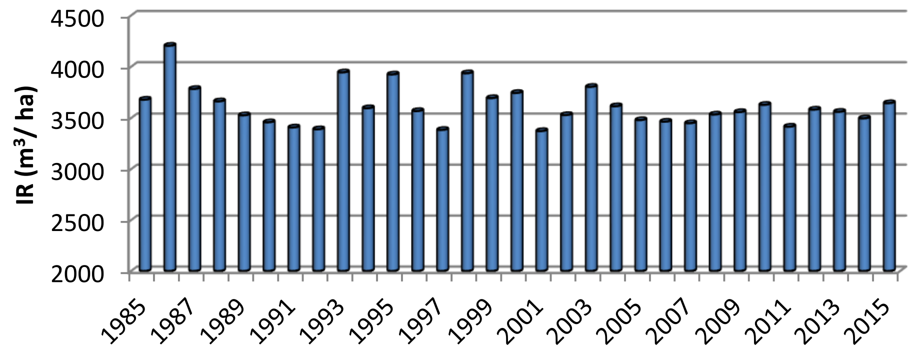


Fig. 71: Amount of irrigation water used (IR) at the high dam for cucumber (winter season) in North Nile Delta region through the last three decades

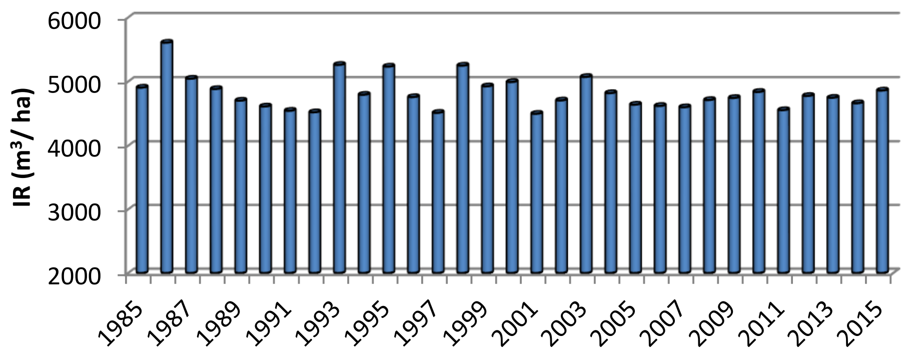


Fig. 72: Water consumptive use for eggplant (winter season) in North Nile Delta region through the last three decades

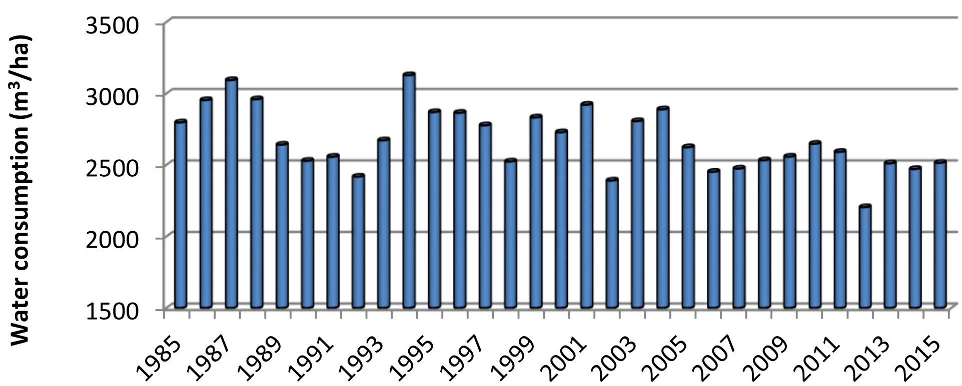


Fig. 73: Amount of irrigation water used (IR) at the farm level for eggplant (winter season) in North Nile Delta region through the last three decades

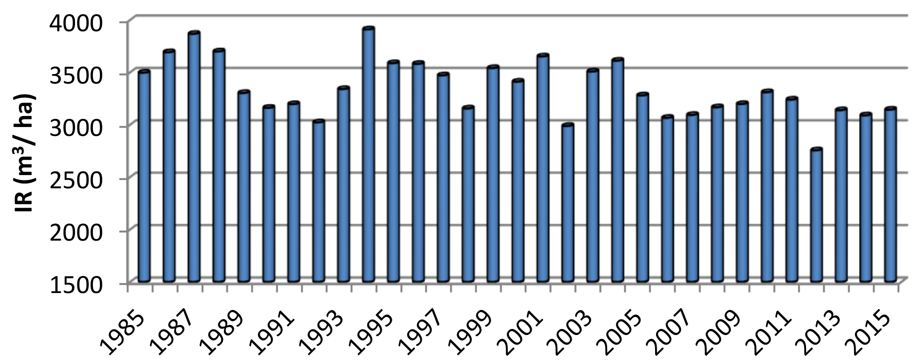


Fig. 74: Amount of irrigation water used (IR) at the high dam for eggplant (winter season) in North Nile Delta region through the last three decades

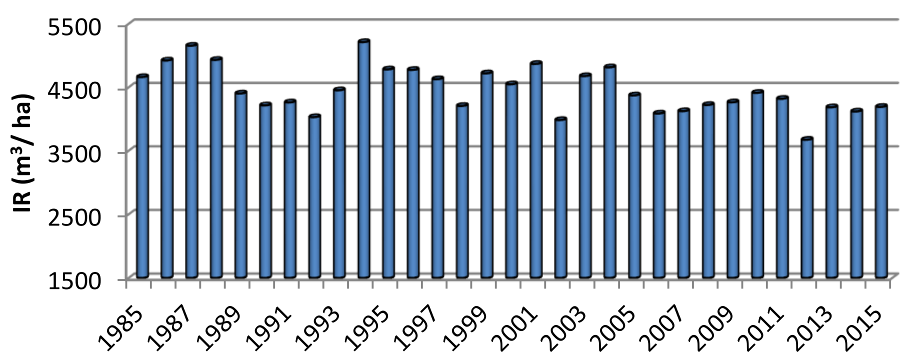


Fig. 75: Water consumptive use for green kidney bean (winter season) in North Nile Delta region through the last three decades

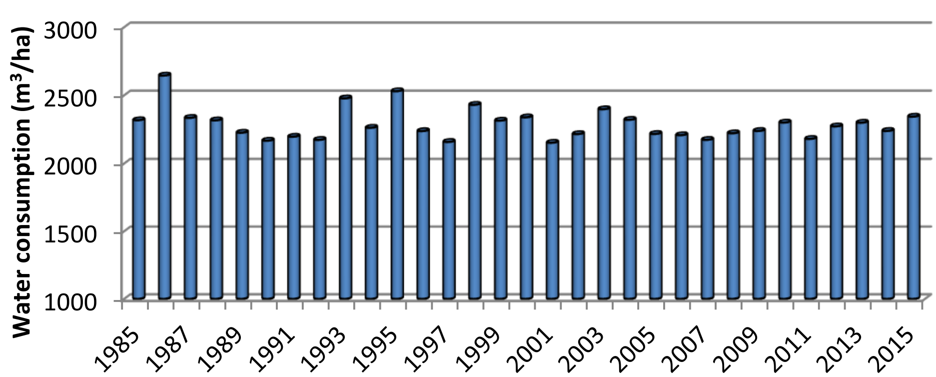


Fig. 76: Amount of irrigation water used (IR) at the farm level for green kidney bean (winter season) in North Nile Delta region through the last three decades

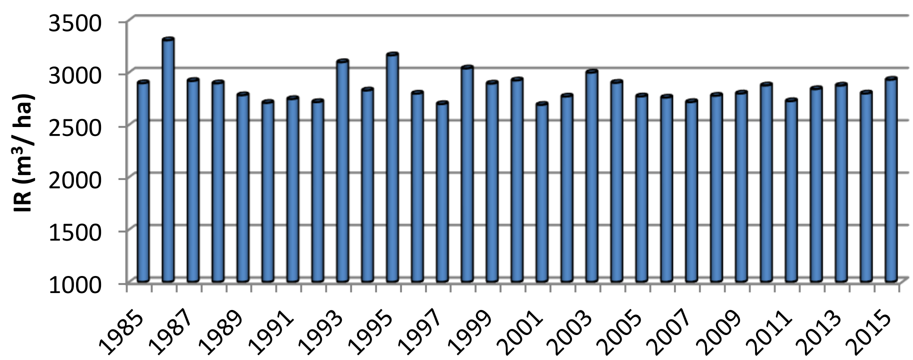


Fig. 77: Amount of irrigation water used (IR) at the high dam for green kidney bean (winter season) in North Nile Delta region through the last three decades

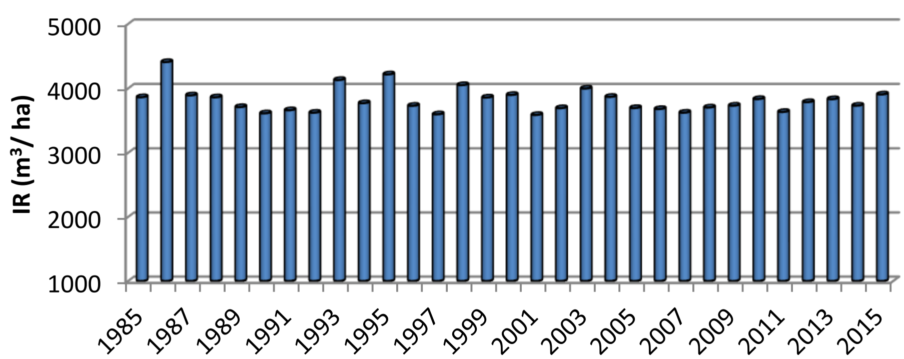


Fig. 78: Water consumptive use for pepper (winter season) in North Nile Delta region through the last three decades

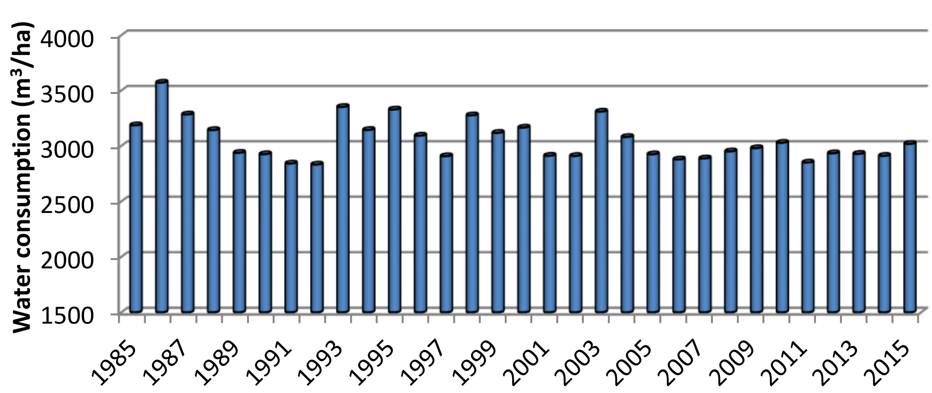


Fig. 79: Amount of irrigation water used (IR) at the farm level for pepper (winter season) in North Nile Delta region through the last three decades

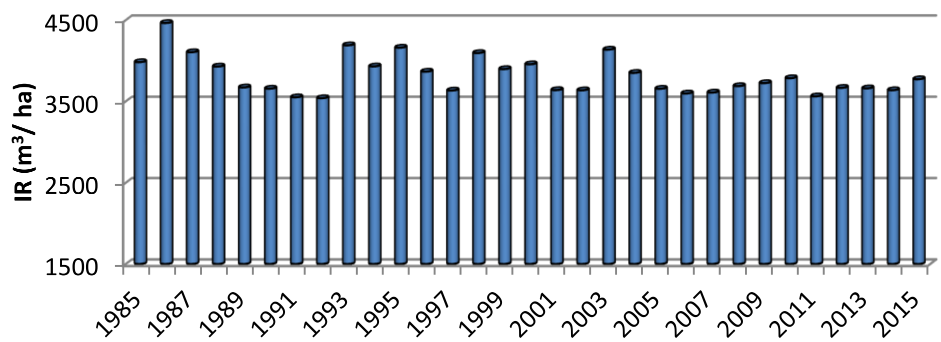


Fig. 80: Amount of irrigation water used (IR) at the high dam for pepper (winter season) in North Nile Delta region through the last three decades

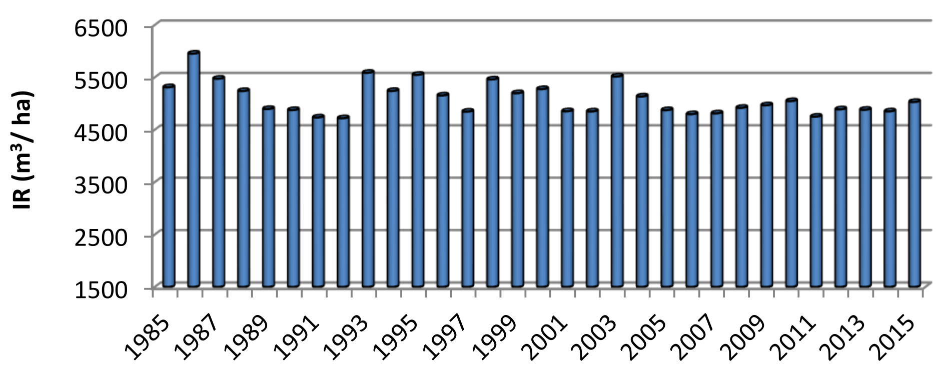


Fig. 81: Water consumptive use for potato (winter season 1) in North Nile Delta region through the last three decades

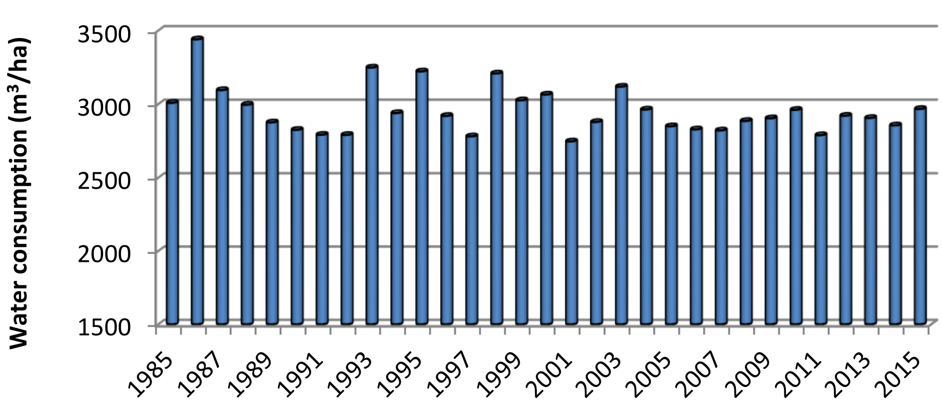


Fig. 82: Amount of irrigation water used (IR) at the farm level for potato (winter season 1) in North Nile Delta region through the last three decades

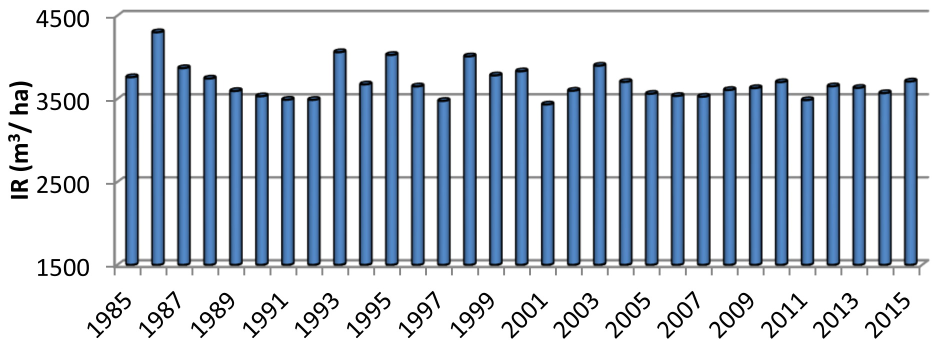


Fig. 83: Amount of irrigation water used (IR) at the high dam for potato (winter season 1) in North Nile Delta region through the last three decades

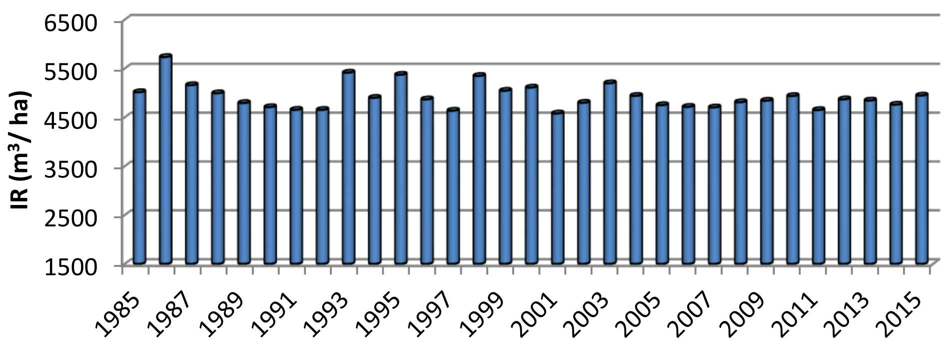


Fig. 84: Water consumptive use for potato (winter season 2) in North Nile Delta region through the last three decades

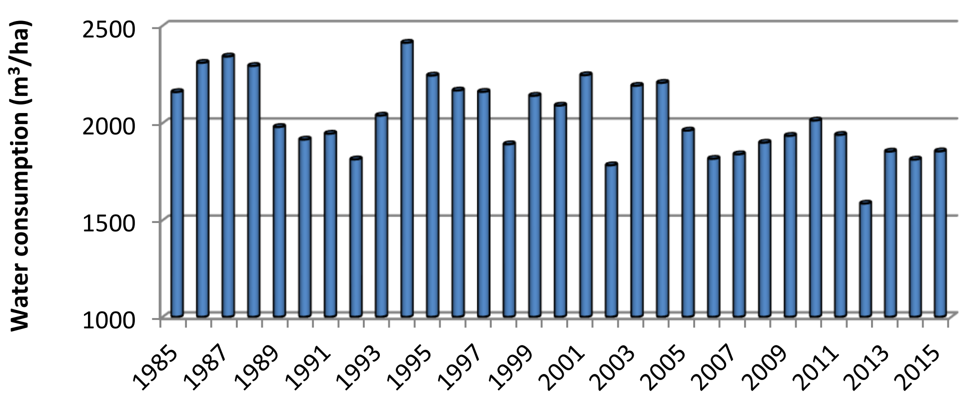


Fig. 85: Amount of irrigation water used (IR) at the farm level for potato (winter season 2) in North Nile Delta region through the last three decades

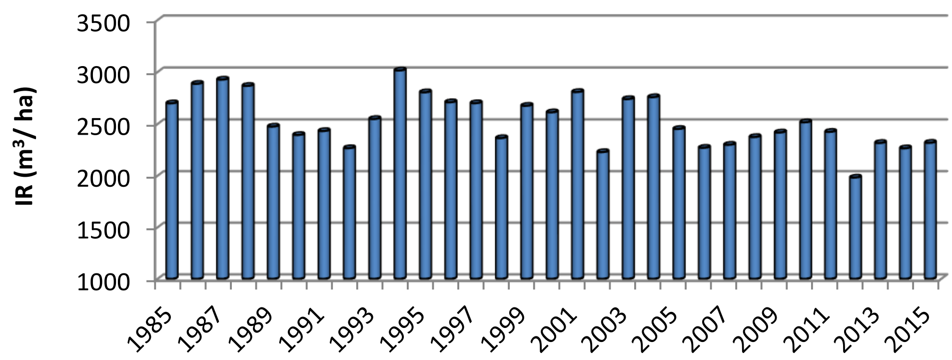


Fig. 86: Amount of irrigation water used (IR) at the high dam for potato (winter season 2) in North Nile Delta region through the last three decades

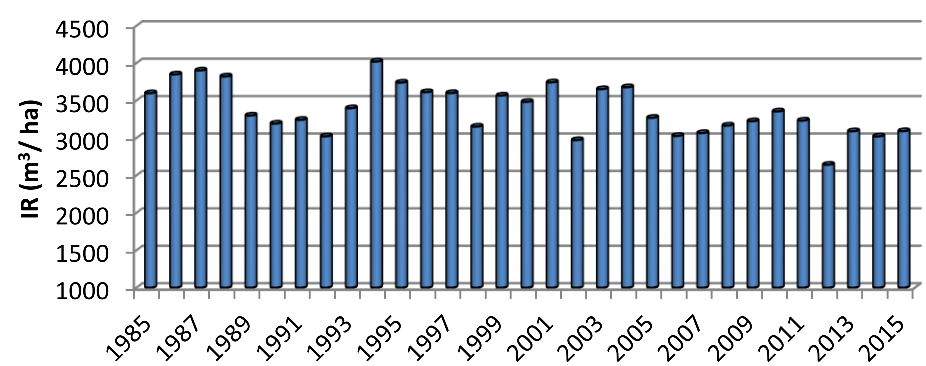


Fig. 87: Water consumptive use for squach (winter season) in North Nile Delta region through the last three decades

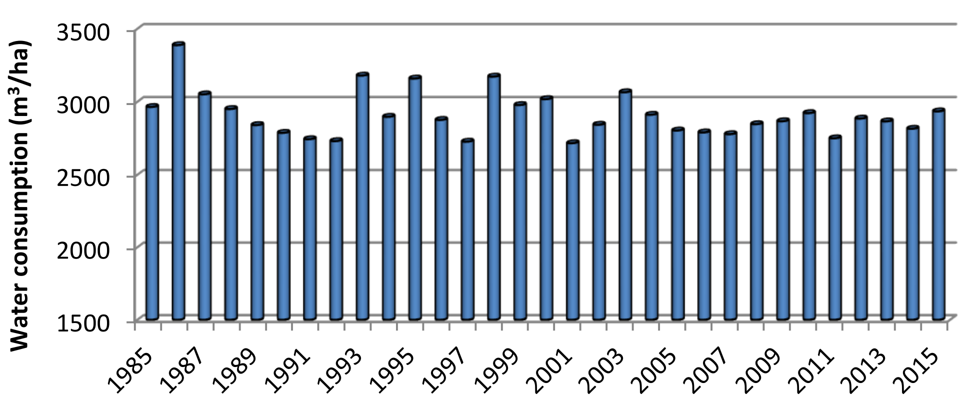


Fig. 88: Amount of irrigation water used (IR) at the farm level for squach (winter season) in North Nile Delta region through the last three decades

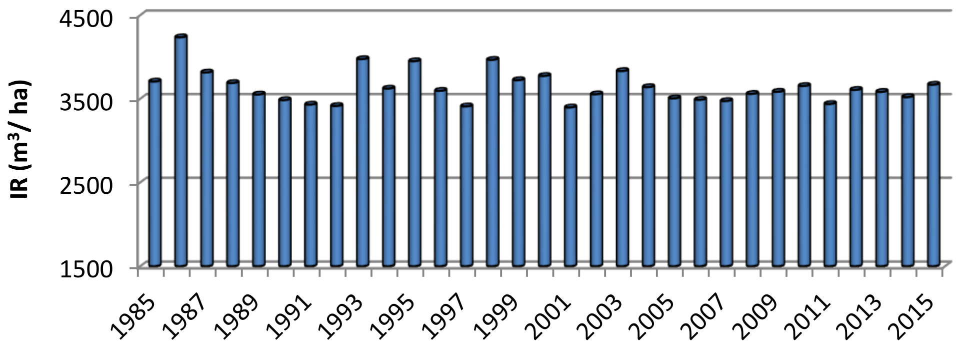


Fig. 89: Amount of irrigation water used (IR) at the high dam for squach (winter season) in North Nile Delta region through the last three decades

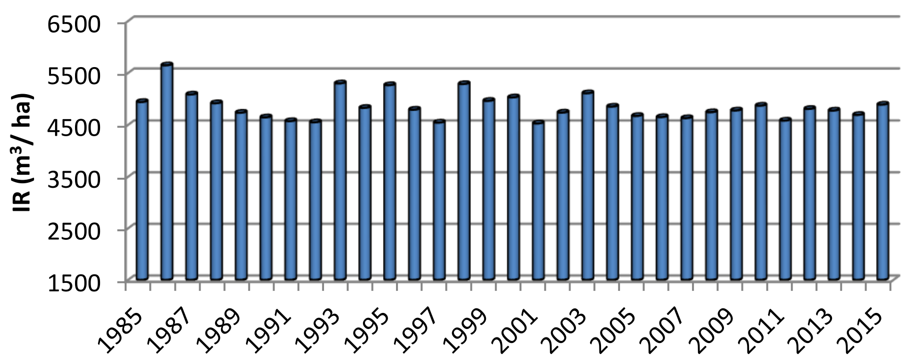
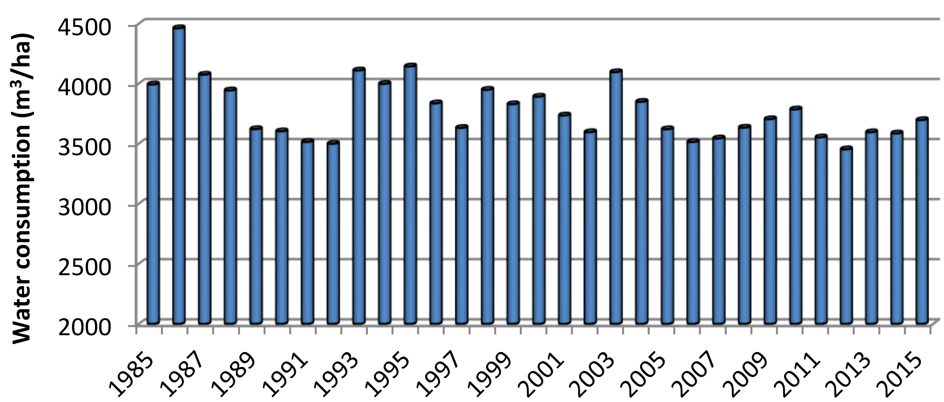


Fig. 90: Water consumptive use for strawberry in North Nile Delta region through the last three decades



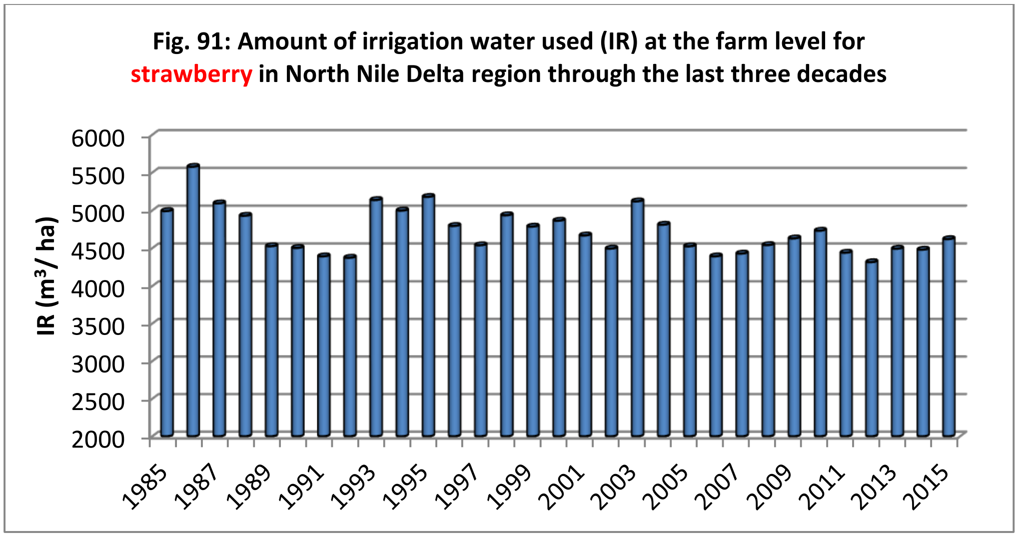


Fig. 91: Amount of irrigation water used (IR) at the farm level for strawberry in North Nile Delta region through the last three decades
IR (m³/ ha)
6000
5500
5000
4500
4000
3500
3000
2500
2000
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015

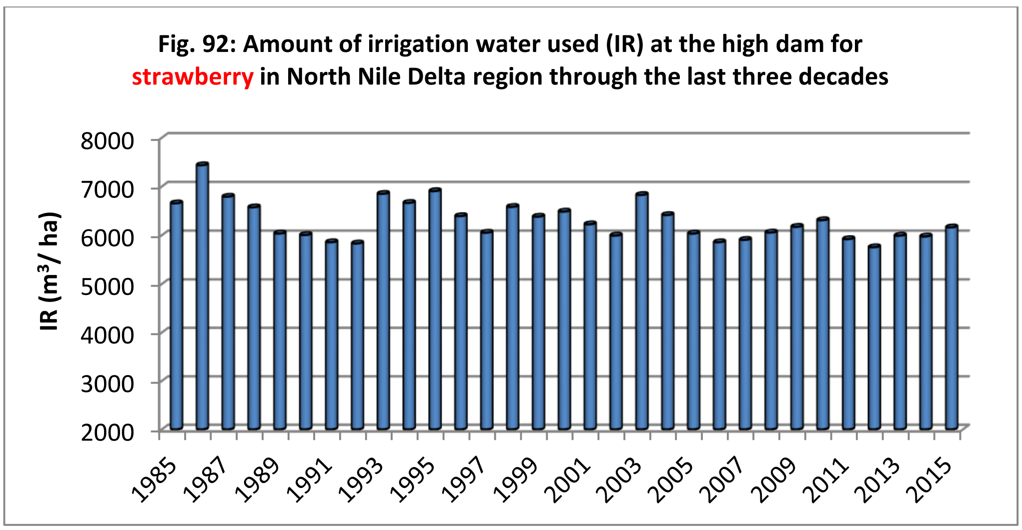


Fig. 92: Amount of irrigation water used (IR) at the high dam for strawberry in North Nile Delta region through the last three decades
IR (m³/ ha)
8000
7000
6000
5000
4000
3000
2000
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015

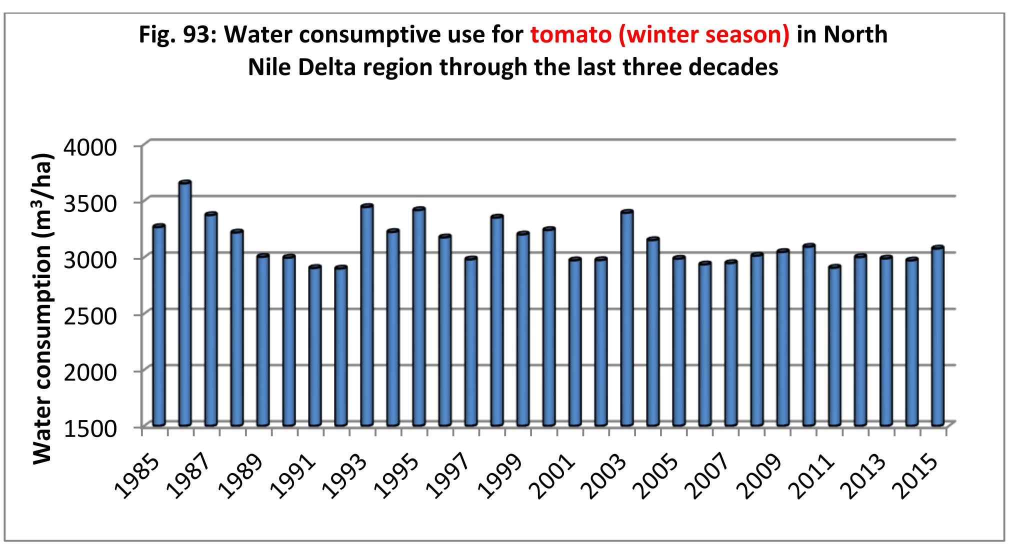


Fig. 93: Water consumptive use for tomato (winter season) in North Nile Delta region through the last three decades
Water consumption (m³/ha)
4000
3500
3000
2500
2000
1500
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015

Fig. 94: Amount of irrigation water used (IR) at the farm level for tomato (winter season) in North Nile Delta region through the last three decades

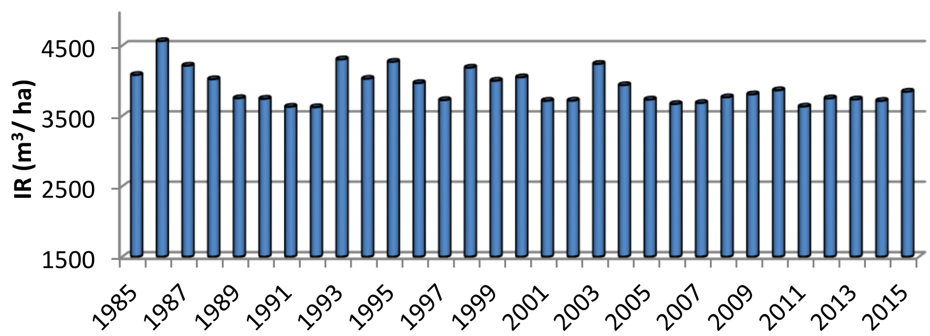


Fig. 95: Amount of irrigation water used (IR) at the high dam for tomato (winter season) in North Nile Delta region through the last three decades

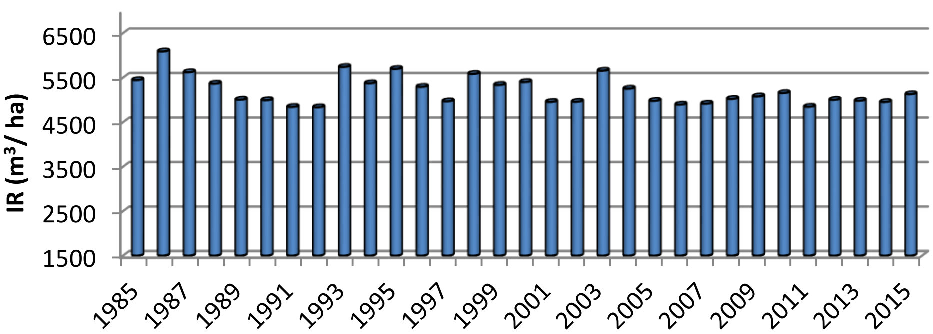


Fig. 96: Water consumptive use for cotton in North Nile Delta region through the last three decades

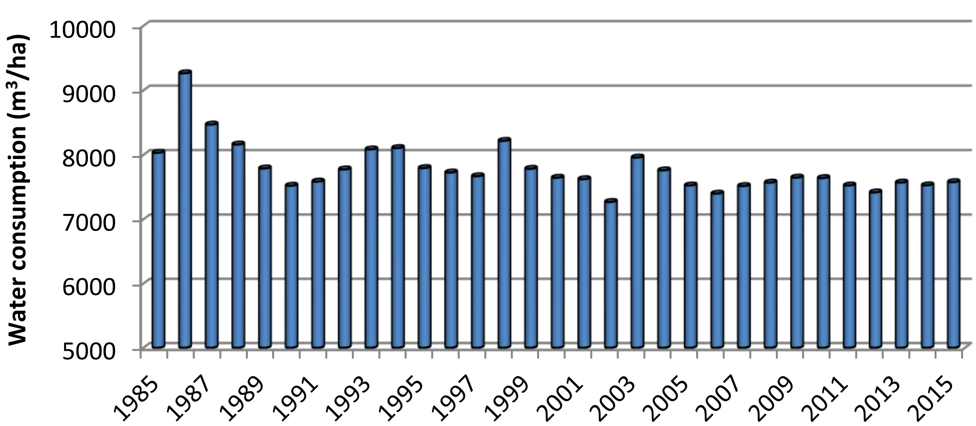


Fig. 97: Amount of irrigation water used (IR) at the farm level for cotton in North Nile Delta region through the last three decades

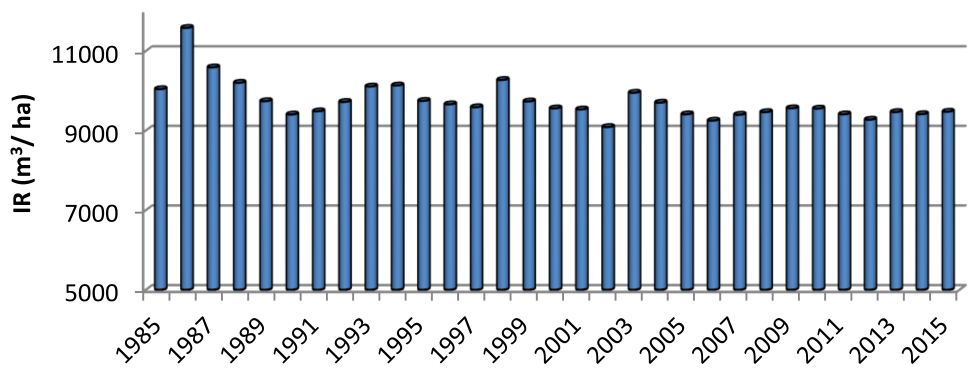


Fig. 98: Amount of irrigation water used (IR) at the high dam for cotton in North Nile Delta region through the last three decades

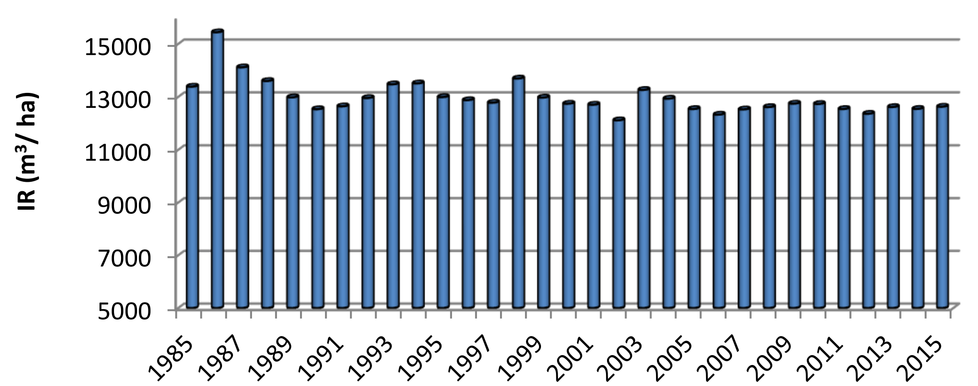


Fig. 99: Water consumptive use for ground nut in North Nile Delta region through the last three decades

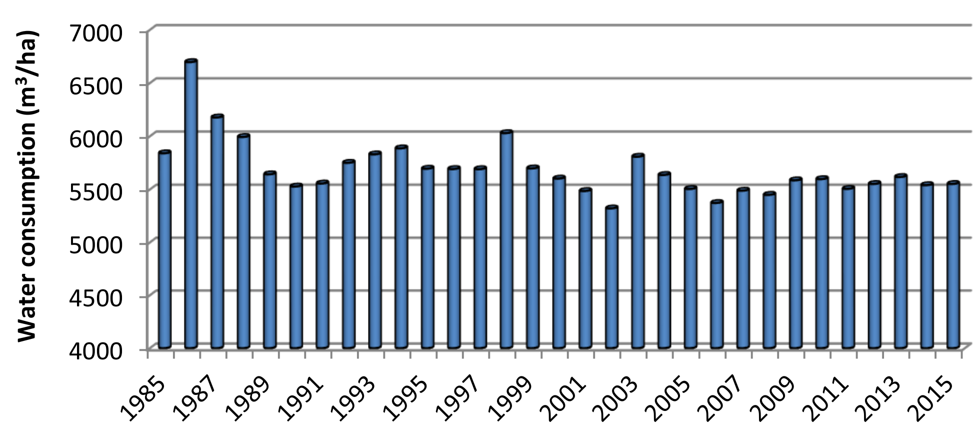


Fig. 100: Amount of irrigation water used (IR) at the farm level for ground nut in North Nile Delta region through the last three decades

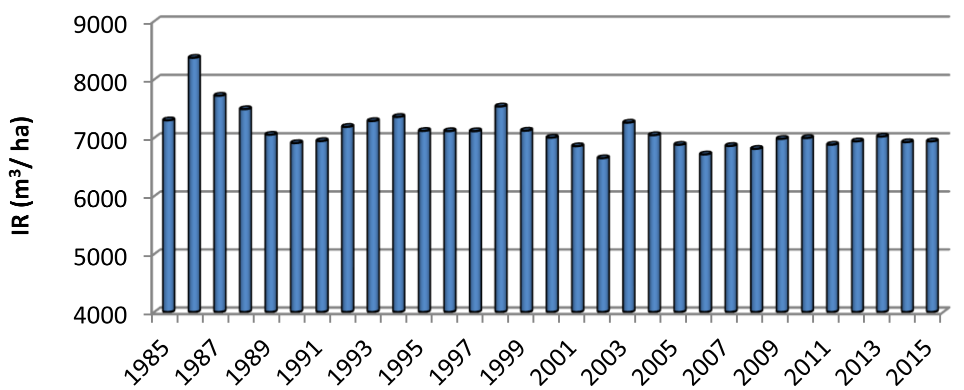


Fig. 101: Amount of irrigation water used (IR) at the high dam for ground nut in North Nile Delta region through the last three decades

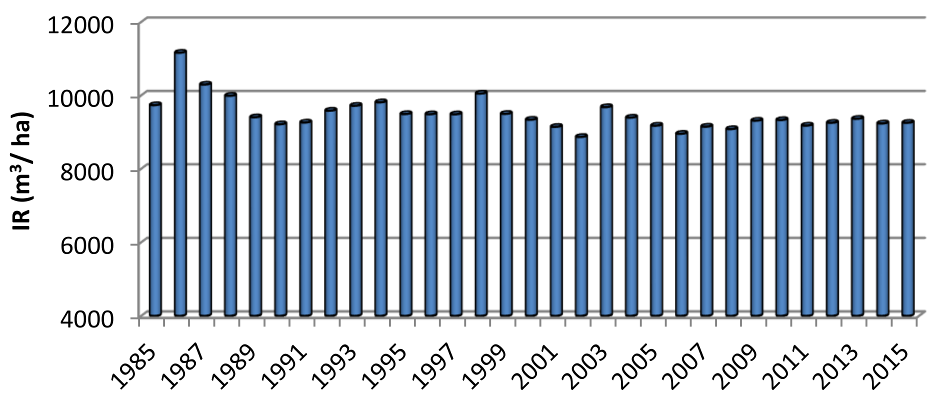


Fig. 102: Water consumptive use for maize (summer season) in North Nile Delta region through the last three decades

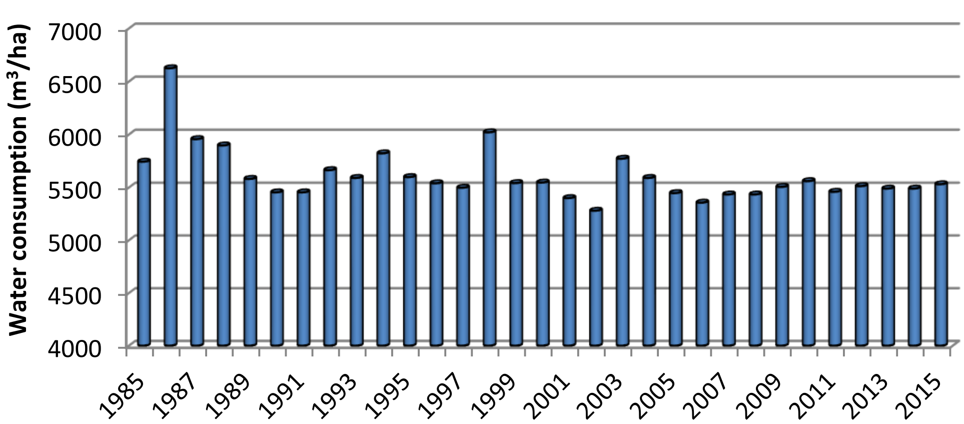


Fig. 103: Amount of irrigation water used (IR) at the farm level for maize (summer season) in North Nile Delta region through the last three decades

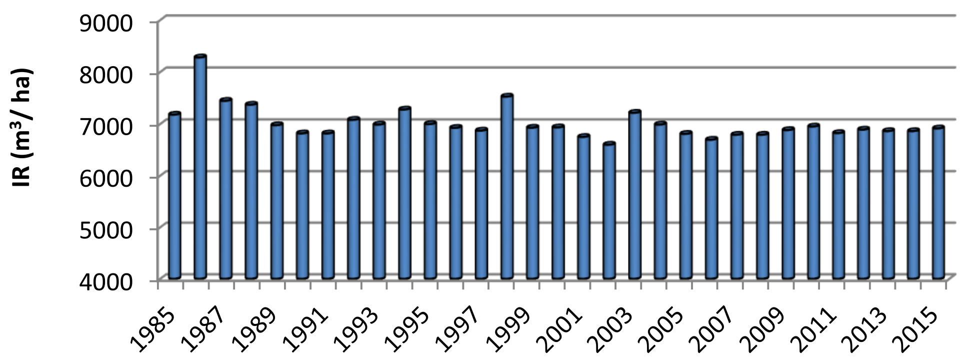


Fig. 104: Amount of irrigation water used (IR) at the high dam for maize (summer season) in North Nile Delta region through the last three decades

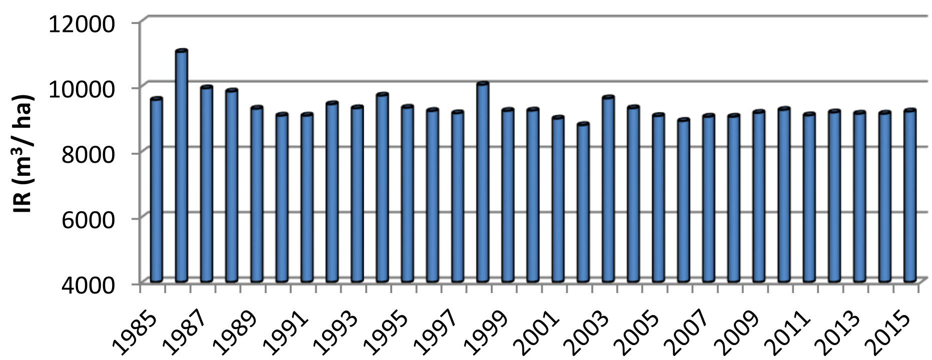
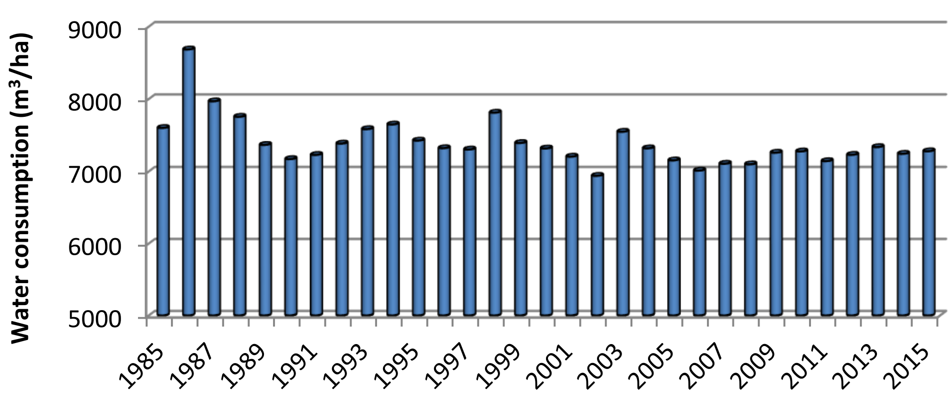


Fig. 105: Water consumptive use for onion (summer season) in North Nile Delta region through the last three decades



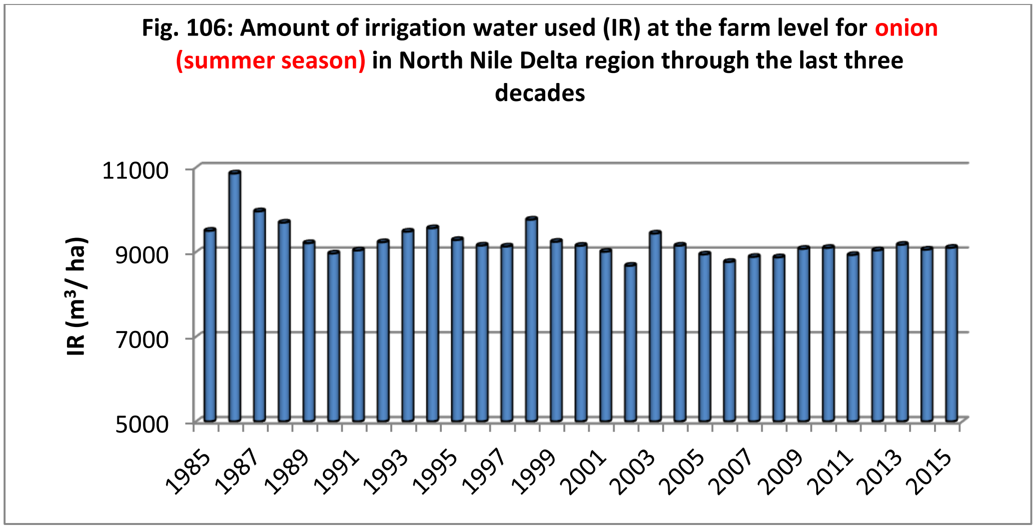


Fig. 106: Amount of irrigation water used (IR) at the farm level for onion (summer season) in North Nile Delta region through the last three decades
IR (m^3/ ha)
11000
9000
7000
5000
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015

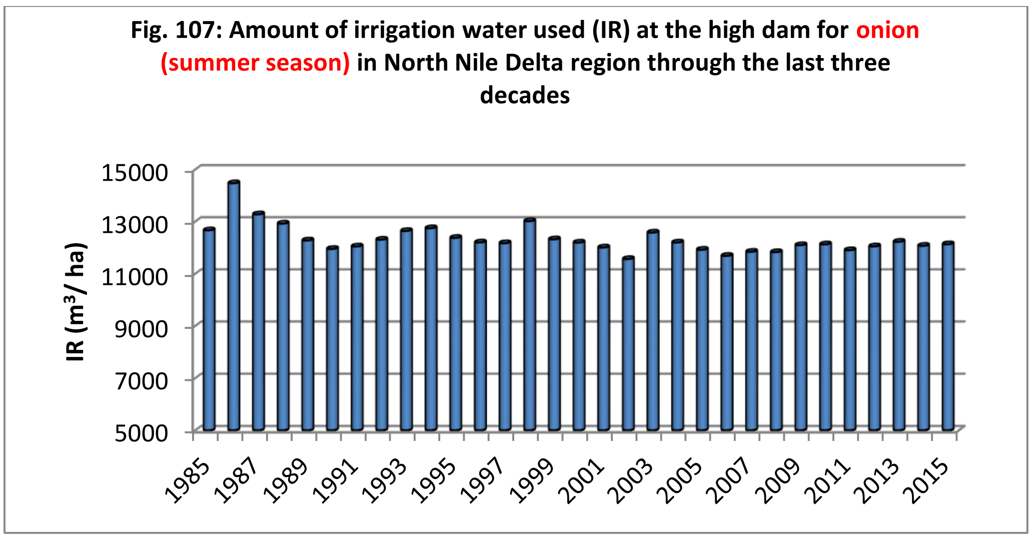


Fig. 107: Amount of irrigation water used (IR) at the high dam for onion (summer season) in North Nile Delta region through the last three decades
IR (m^3/ ha)
15000
13000
11000
9000
7000
5000
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015

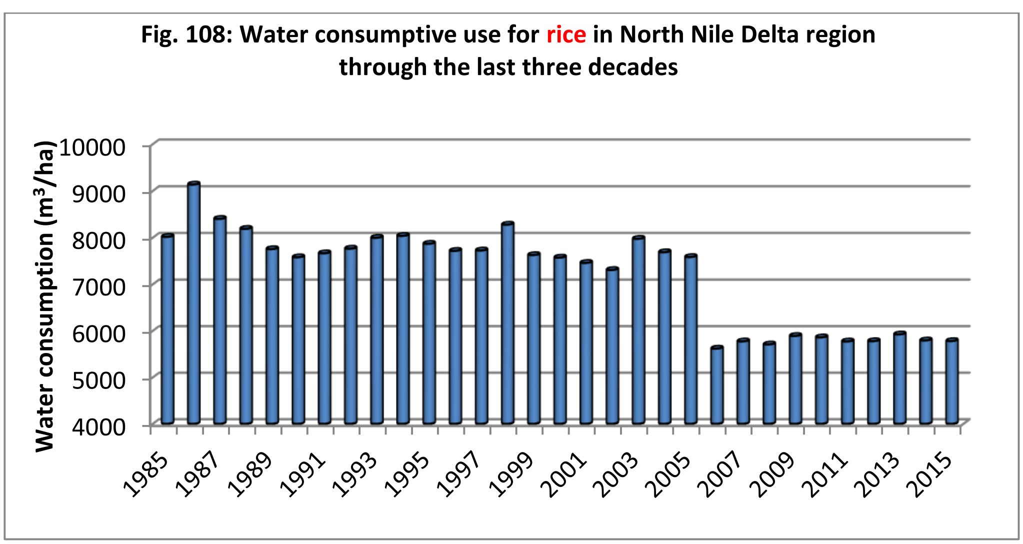


Fig. 108: Water consumptive use for rice in North Nile Delta region through the last three decades
Water consumption (m^3/ha)
10000
9000
8000
7000
6000
5000
4000
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015

Fig. 109: Amount of irrigation water used (IR) at the farm level for rice in North Nile Delta region through the last three decades

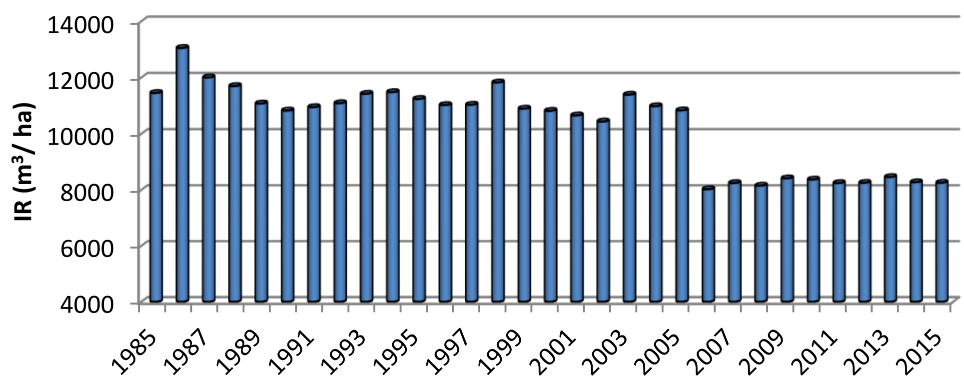


Fig. 110: Amount of irrigation water used (IR) at the high dam for rice in North Nile Delta region through the last three decades

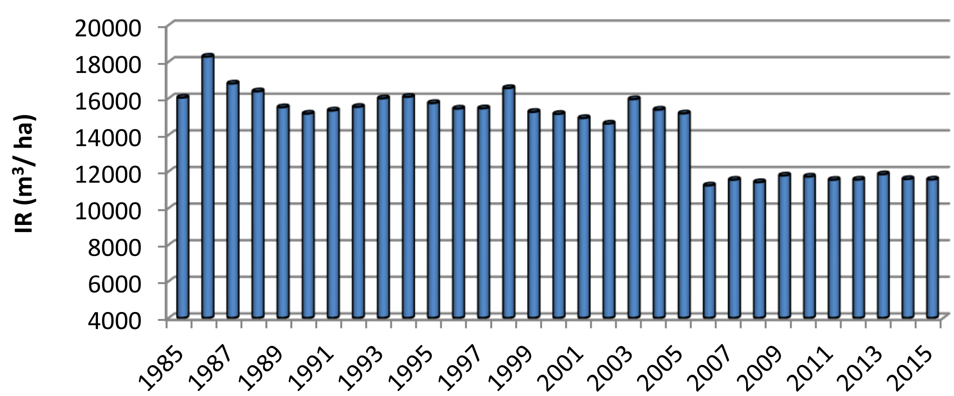


Fig. 111: Water consumptive use for soybean in North Nile Delta region through the last three decades

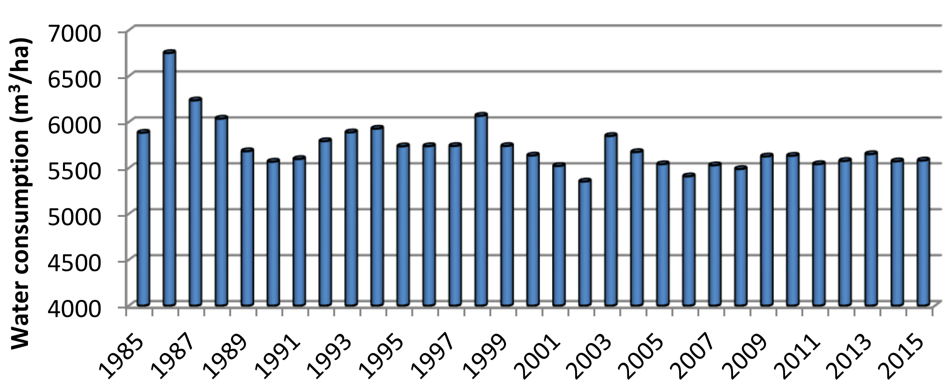


Fig. 112: Amount of irrigation water used (IR) at the farm level for soybean in North Nile Delta region through the last three decades

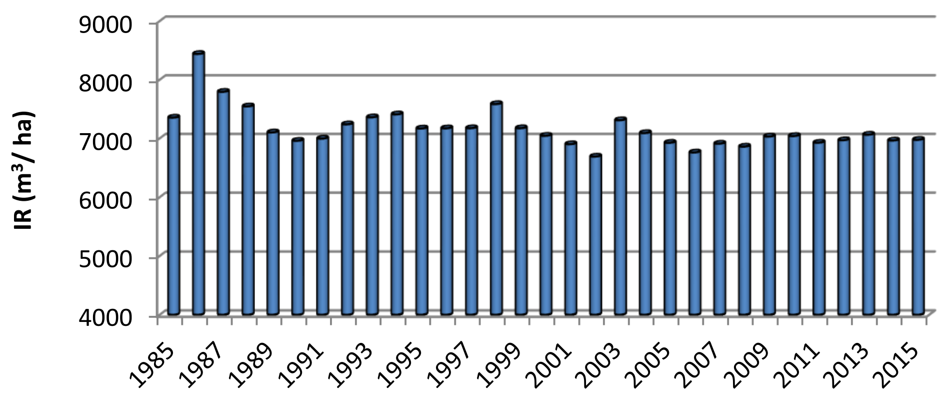


Fig. 113: Amount of irrigation water used (IR) at the high dam for soybean in North Nile Delta region through the last three decades

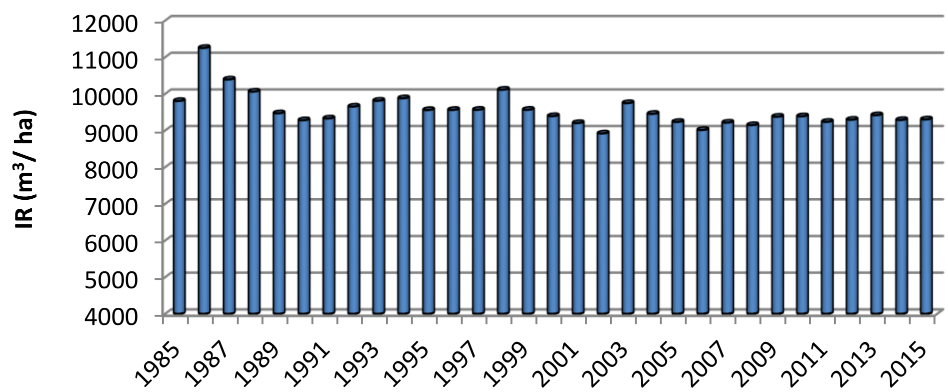


Fig. 114: Water consumptive use for sugarcane in North Nile Delta region through the last three decades

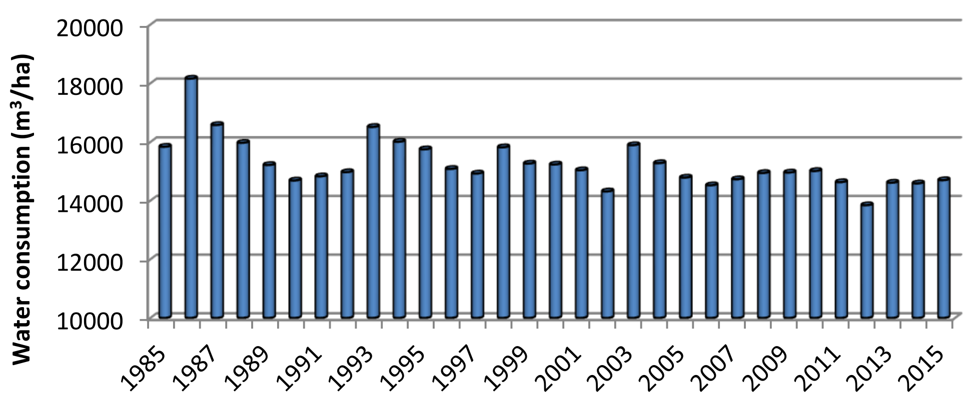


Fig. 115: Amount of irrigation water used (IR) at the farm level for sugarcane in North Nile Delta region through the last three decades

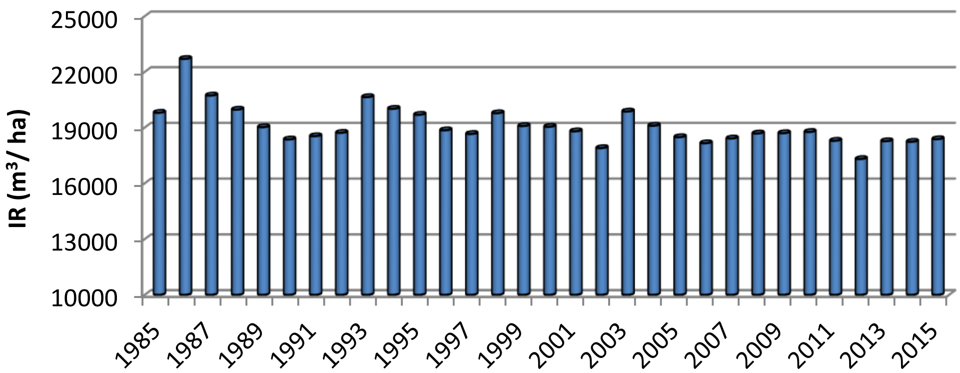


Fig. 116: Amount of irrigation water used (IR) at the high dam for sugarcane in North Nile Delta region through the last three decades

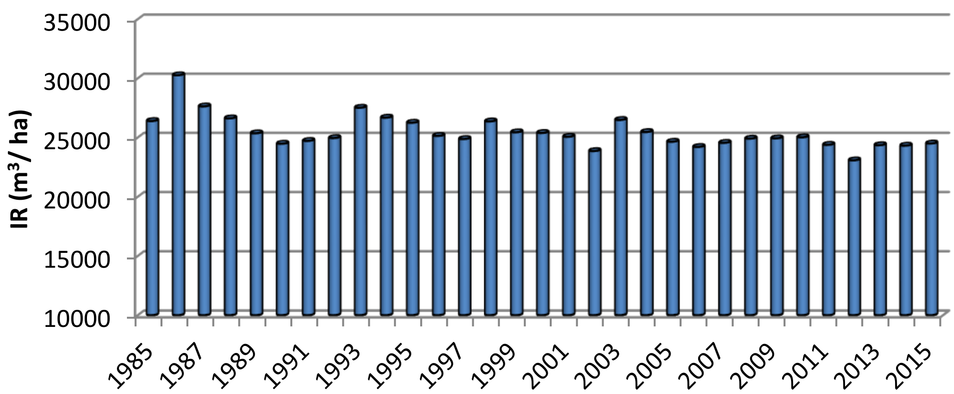


Fig. 117: Water consumptive use for sunflower (summer season) in North Nile Delta region through the last three decades

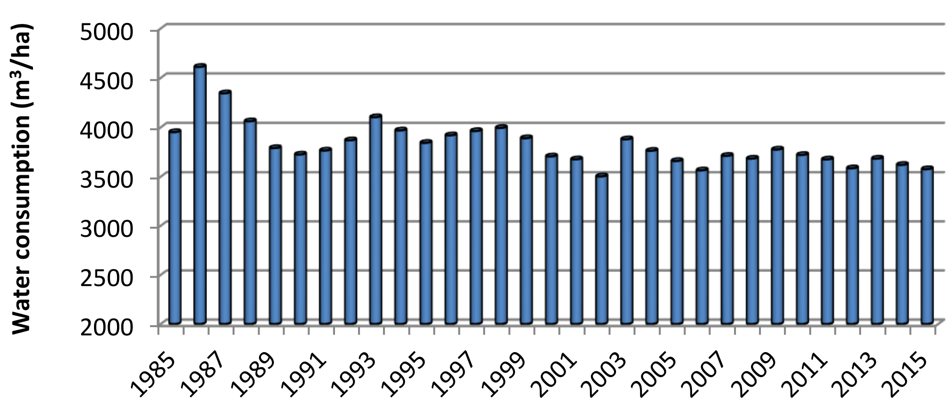


Fig. 118: Amount of irrigation water used (IR) at the farm level for sunflower (summer season) in North Nile Delta region through the last three decades

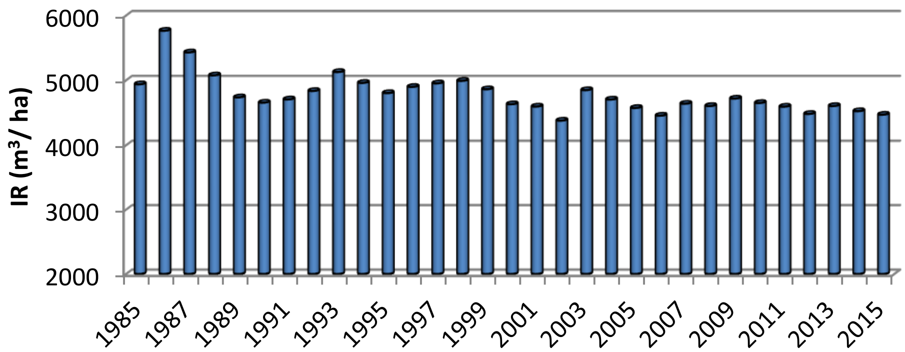


Fig. 119: Amount of irrigation water used (IR) at the high dam for sunflower (summer season) in North Nile Delta region through the last three decades

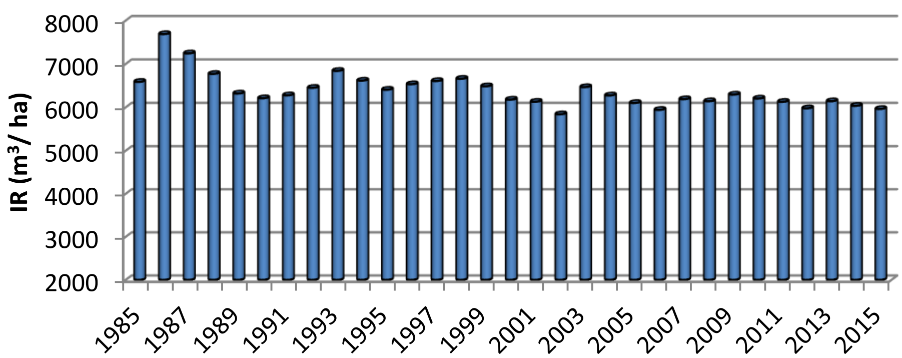


Fig. 120: Water consumptive use for cabbage (summer season) in North Nile Delta region through the last three decades

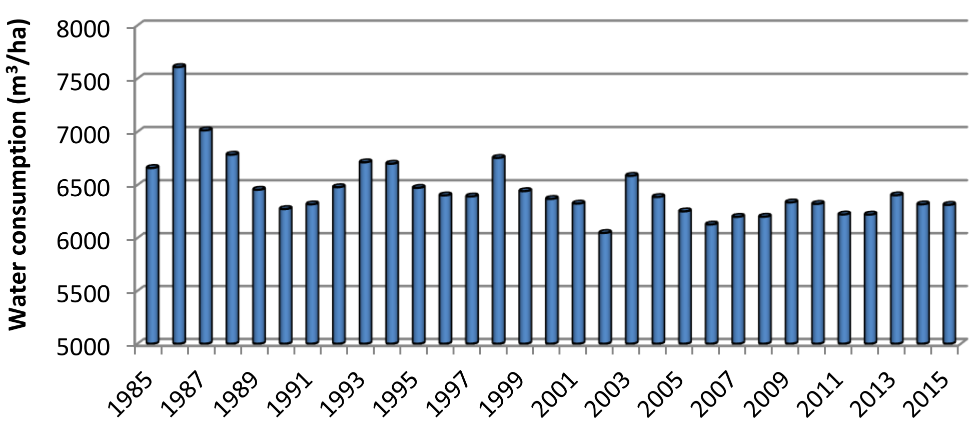


Fig. 121: Amount of irrigation water used (IR) at the farm level for cabbage (summer season) in North Nile Delta region through the last three decades

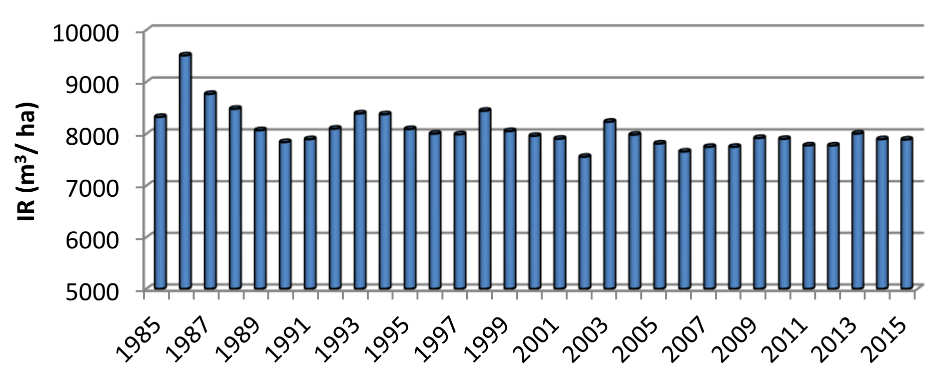


Fig. 122: Amount of irrigation water used (IR) at the high dam for cabbage (summer season) in North Nile Delta region through the last three decades

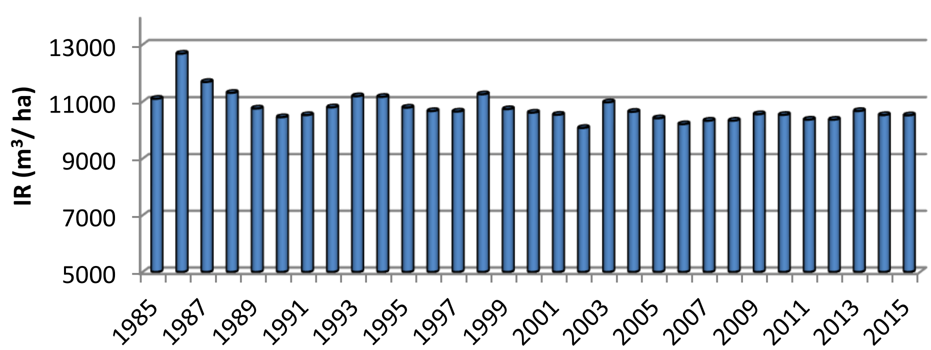


Fig. 123: Water consumptive use for cucumber (summer season) in North Nile Delta region through the last three decades

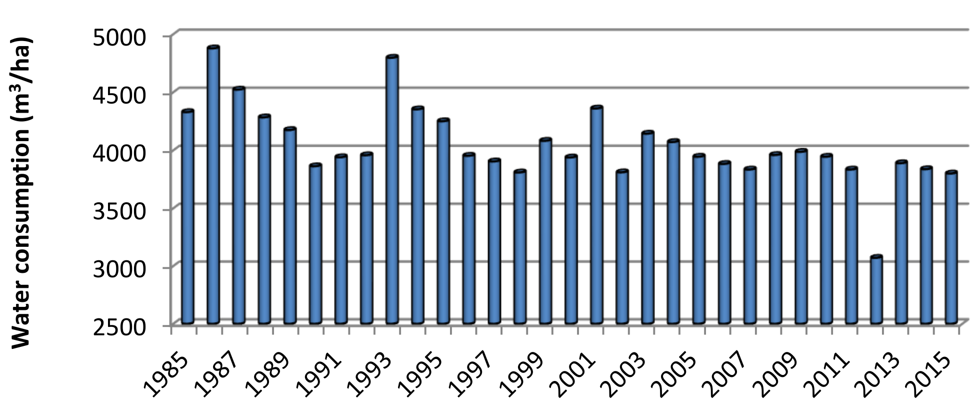


Fig. 124: Amount of irrigation water used (IR) at the farm level for cucumber (summer season) in North Nile Delta region through the last three decades

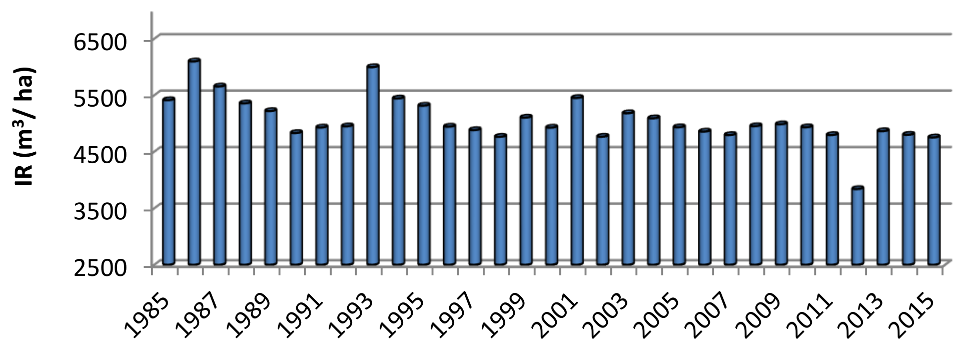


Fig. 125: Amount of irrigation water used (IR) at the high dam for cucumber (summer season) in North Nile Delta region through the last three decades

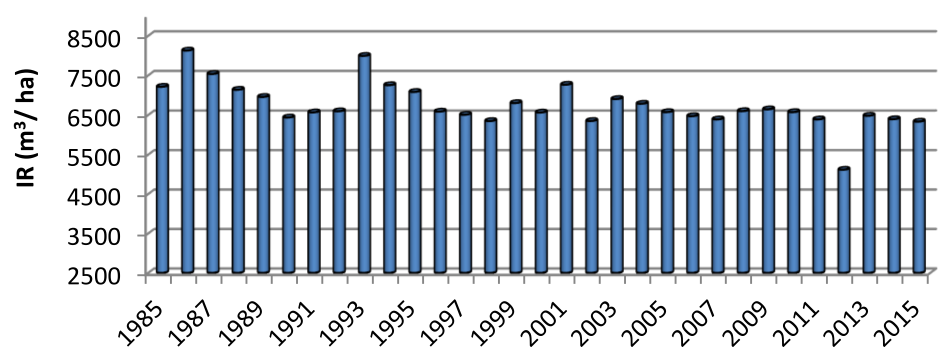


Fig. 126: Water consumptive use for eggplant (summer season) in North Nile Delta region through the last three decades

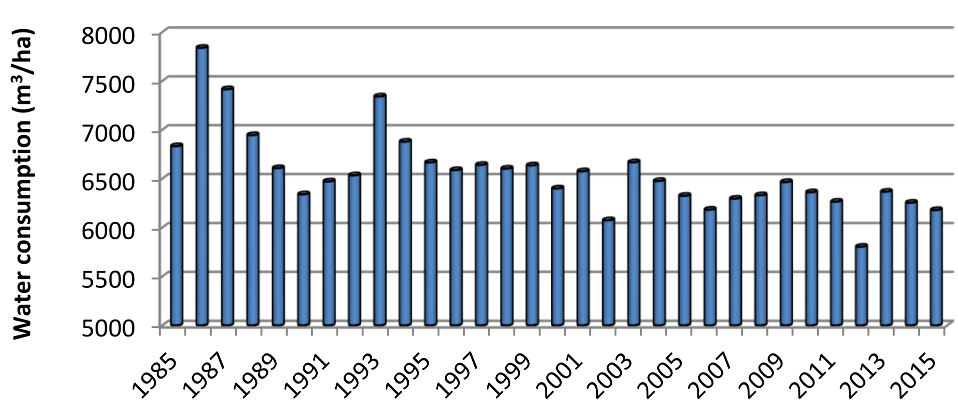


Fig. 127: Amount of irrigation water used (IR) at the farm level for eggplant (summer season) in North Nile Delta region through the last three decades

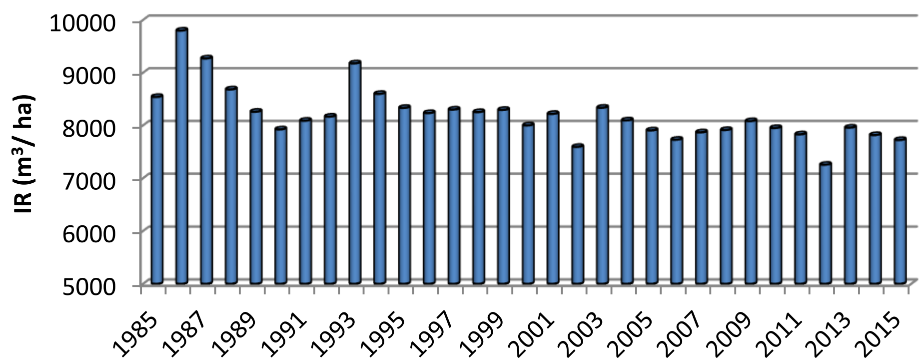


Fig. 128: Amount of irrigation water used (IR) at the high dame for eggplant (summer season) in North Nile Delta region through the last three decades

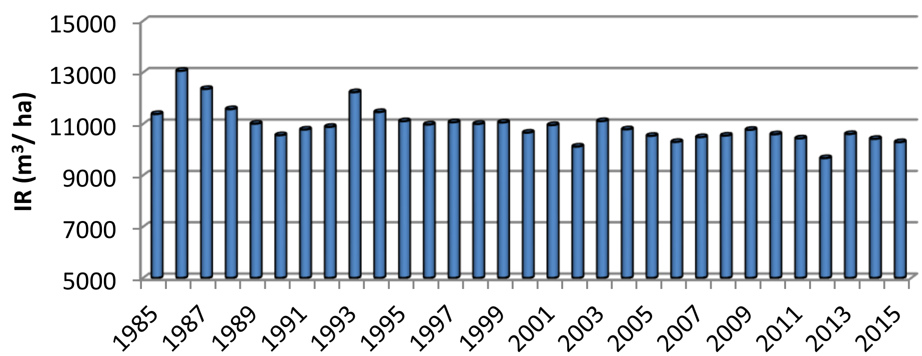


Fig. 129: Water consumptive use for green kidney bean (summer season) in North Nile Delta region through the last three decades

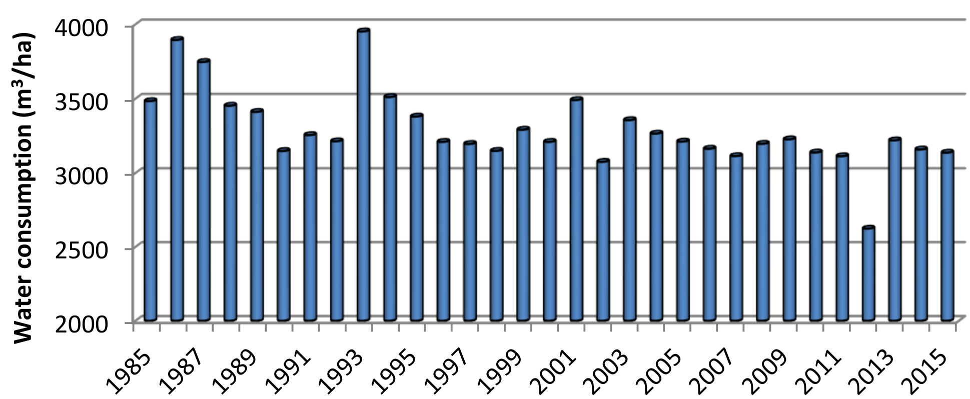


Fig. 130: Amount of irrigation water used (IR) at the farm level for green kidney bean (summer season) in North Nile Delta region through the last three decades

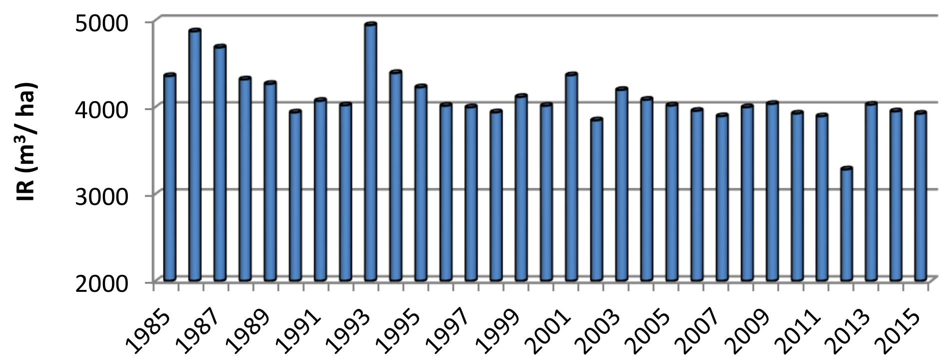


Fig. 131: Amount of irrigation water used (IR) at the high dam for green kidney bean (summer season) in North Nile Delta region through the last three decades

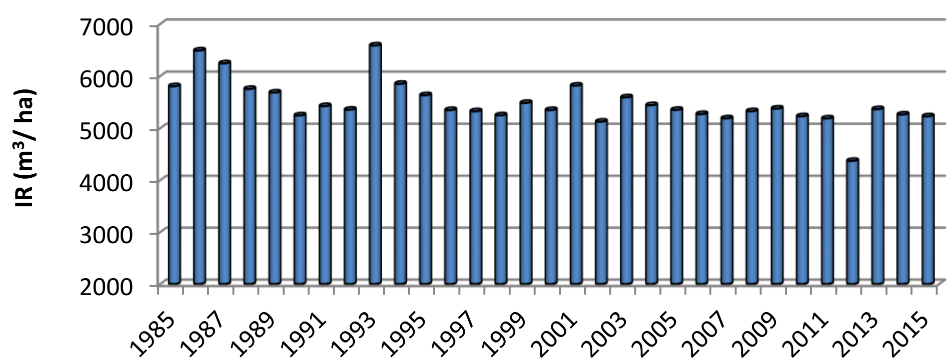


Fig. 132: Water consumptive use for okra in North Nile Delta region through the last three decades

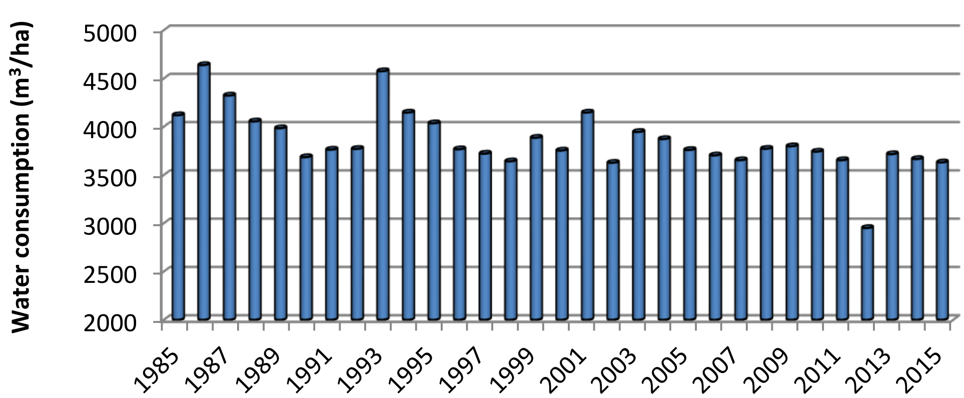


Fig. 133: Amount of irrigation water used (IR) at the farm level for okra in North Nile Delta region through the last three decades

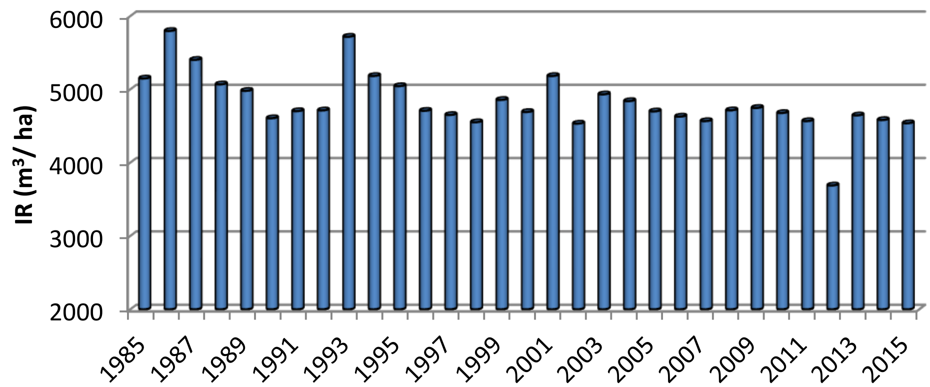


Fig. 134: Amount of irrigation water used (IR) at the high dam for okra in North Nile Delta region through the last three decades

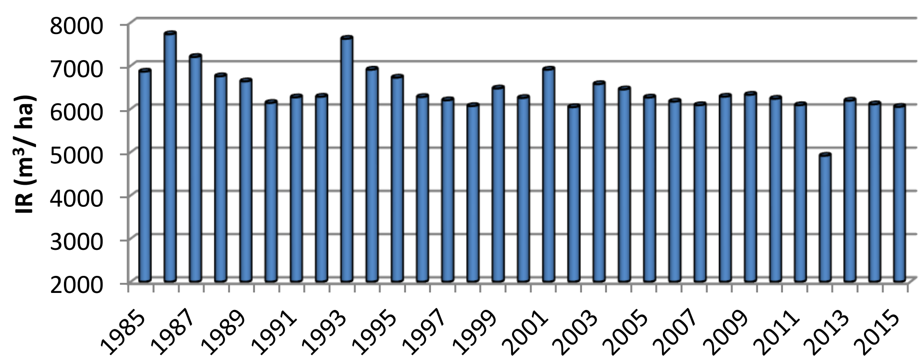


Fig. 135: Water consumptive use for pepper (summer season) in North Nile Delta region through the last three decades

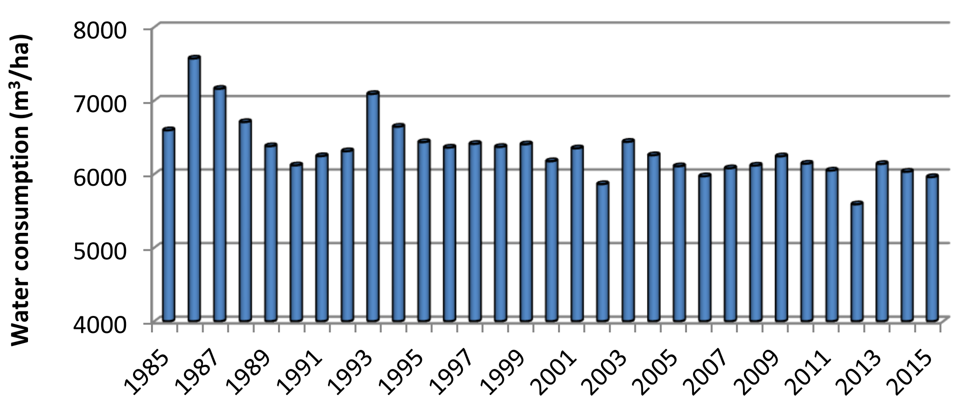


Fig. 136: Amount of irrigation water used (IR) at the farm level for pepper (summer season) in North Nile Delta region through the last three decades

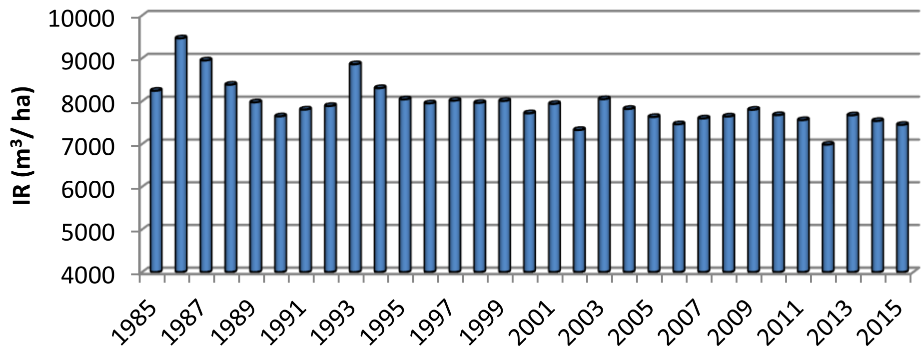


Fig. 137: Amount of irrigation water used (IR) at the high dam for pepper (summer season) in North Nile Delta region through the last three decades

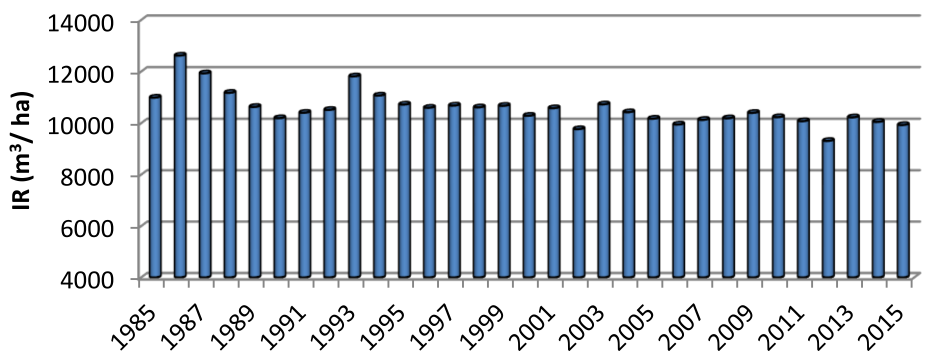


Fig. 138: Water consumptive use for potato (summer season) in North Nile Delta region through the last three decades

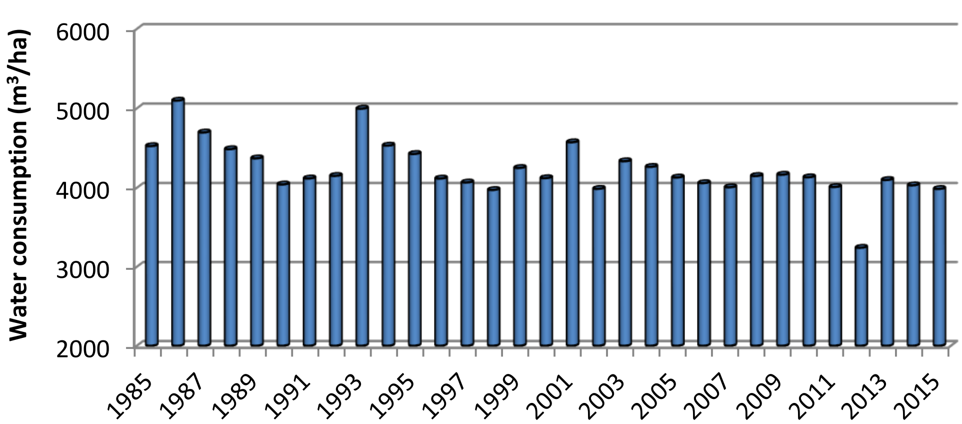


Fig. 139: Amount of irrigation water used (IR) at the farm level for potato (summer season) in North Nile Delta region through the last three decades

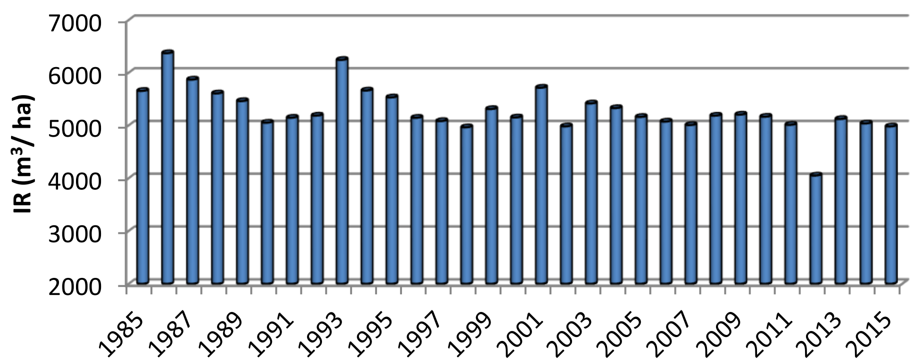


Fig. 140: Amount of irrigation water used (IR) at the high dam for potato (summer season) in North Nile Delta region through the last three decades

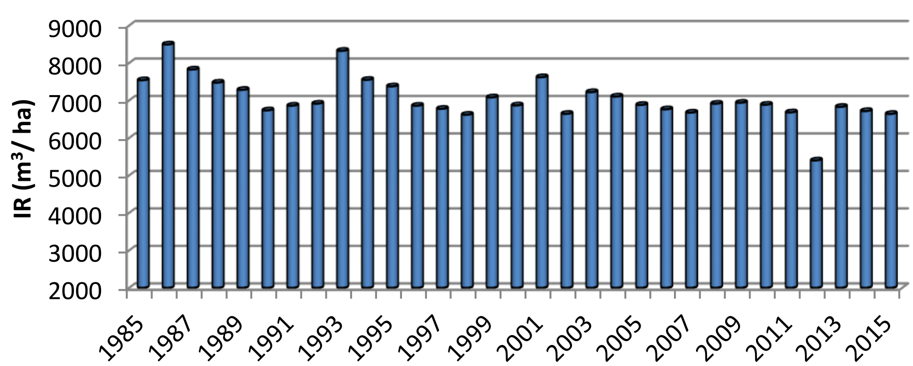


Fig. 141: Water consumptive use for squach (summer season) in North Nile Delta region through the last three decades

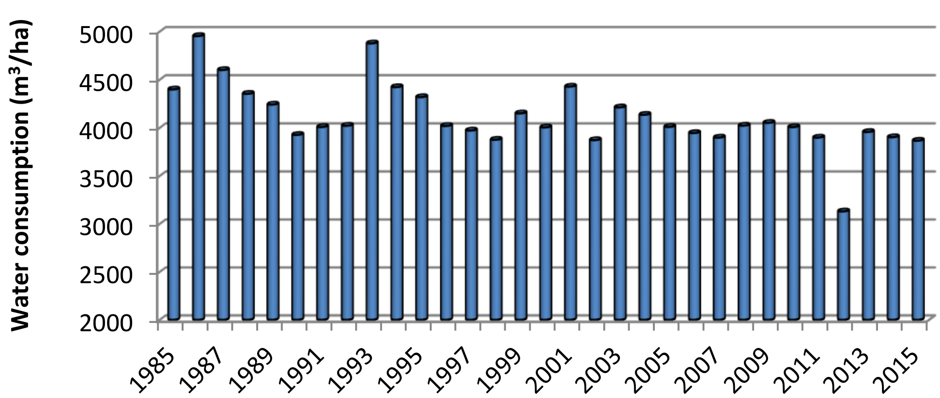


Fig. 142: Amount of irrigation water used (IR) at the farm level for squach (summer season) in North Nile Delta region through the last three decades

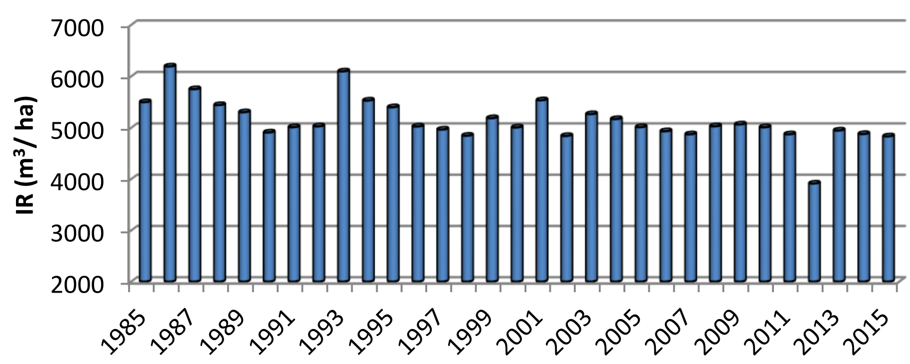


Fig. 143: Amount of irrigation water used (IR) at the high dam for squach (summer season) in North Nile Delta region through the last three decades

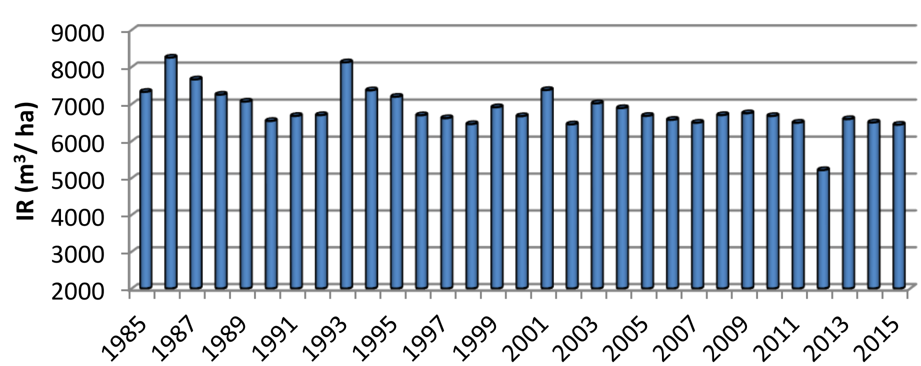


Fig. 144: Water consumptive use for tomato (summer season) in North Nile Delta region through the last three decades

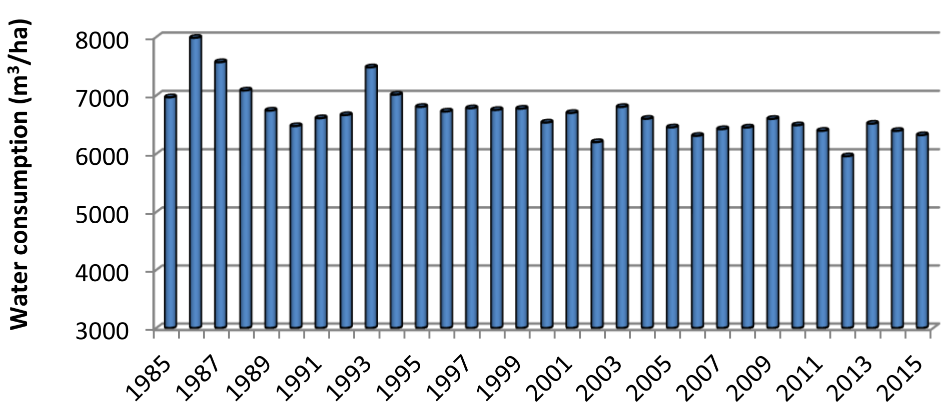


Fig. 145: Amount of irrigation water used (IR) at the farm level for tomato (summer season) in North Nile Delta region through the last three decades

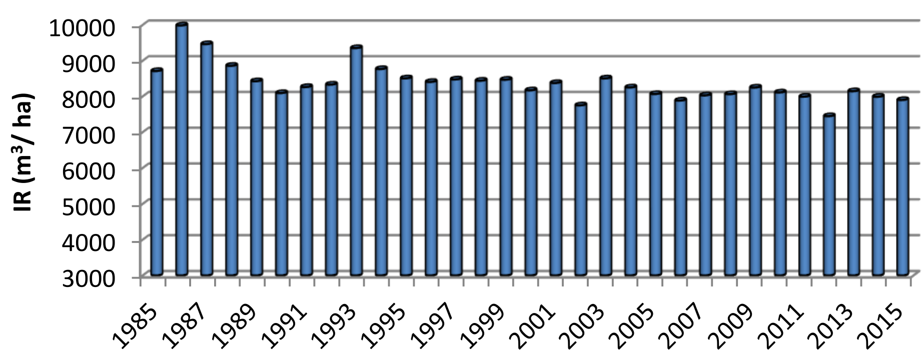


Fig. 146: Amount of irrigation water used (IR) at the high dam for tomato (summer season) in North Nile Delta region through the last three decades

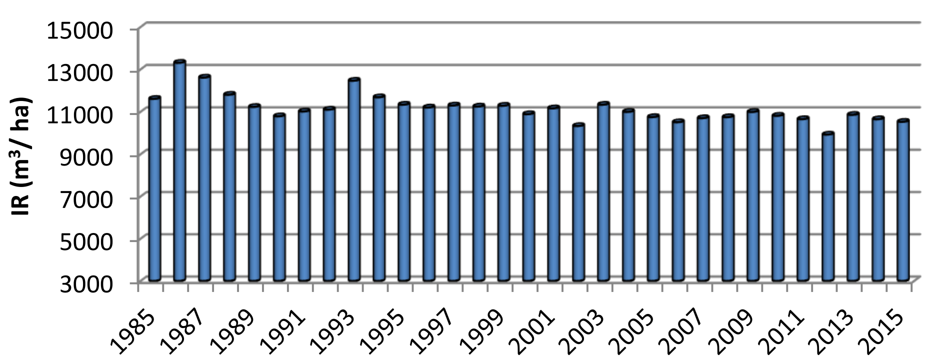


Fig. 147: Water consumptive use for water melon in North Nile Delta region through the last three decades

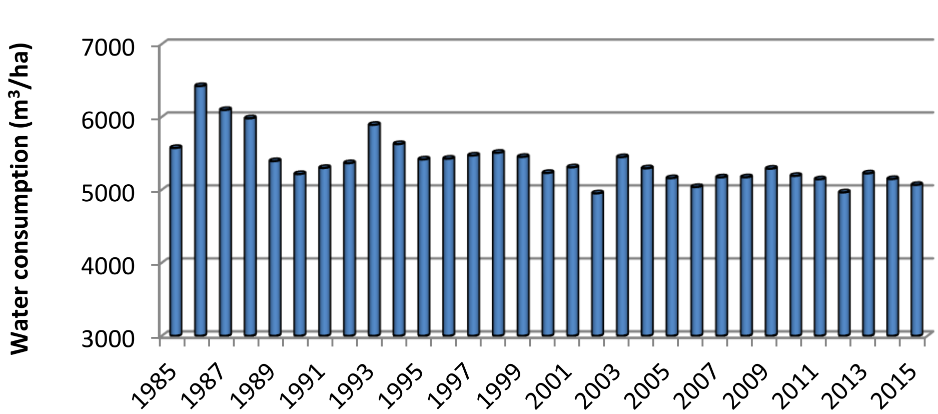


Fig. 148: Amount of irrigation water used (IR) at the farm level for water melon in North Nile Delta region through the last three decades

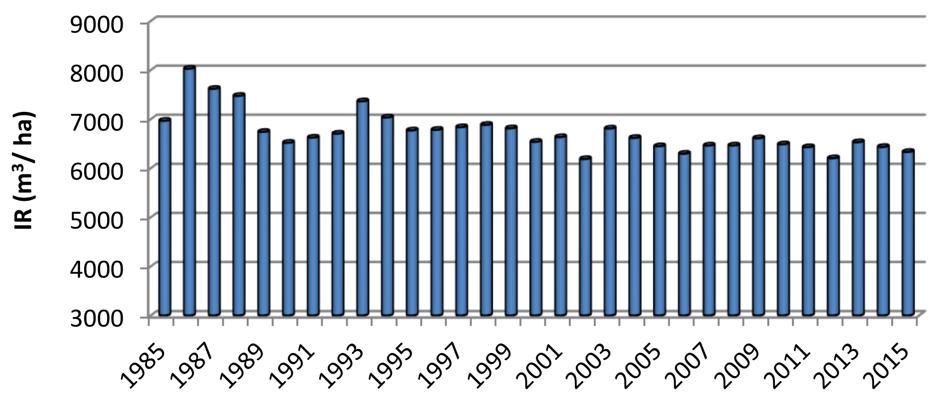


Fig. 149: Amount of irrigation water used (IR) at the high dam for water melon in North Nile Delta region through the last three decades

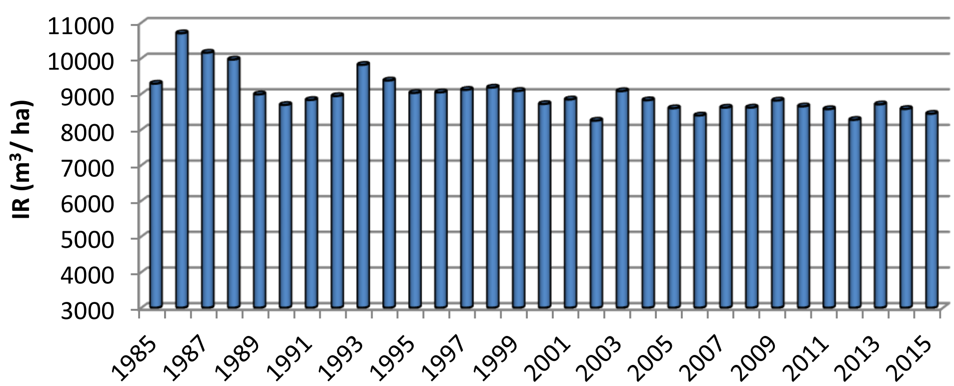


Fig. 150: Water consumptive use for maize (nili season) in North Nile Delta region through the last three decades

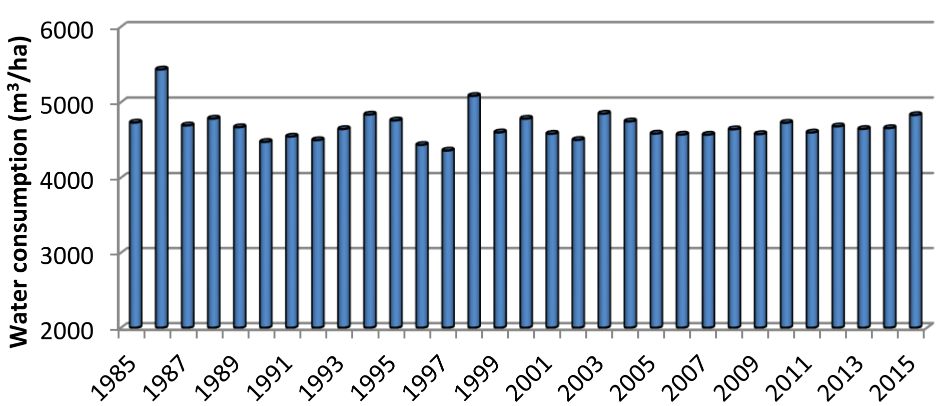


Fig. 151: Amount of irrigation water used (IR) at the farm level for maize (nili season) in North Nile Delta region through the last three decades

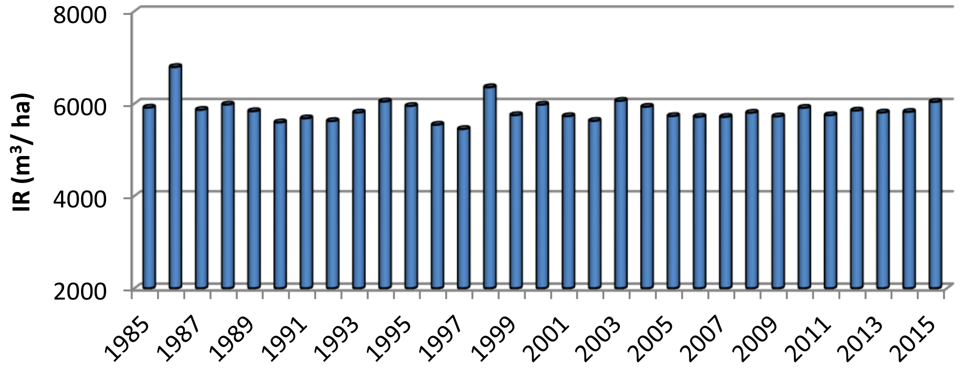


Fig. 152: Amount of irrigation water used (IR) at the high dam for maize (nili season) in North Nile Delta region through the last three decades

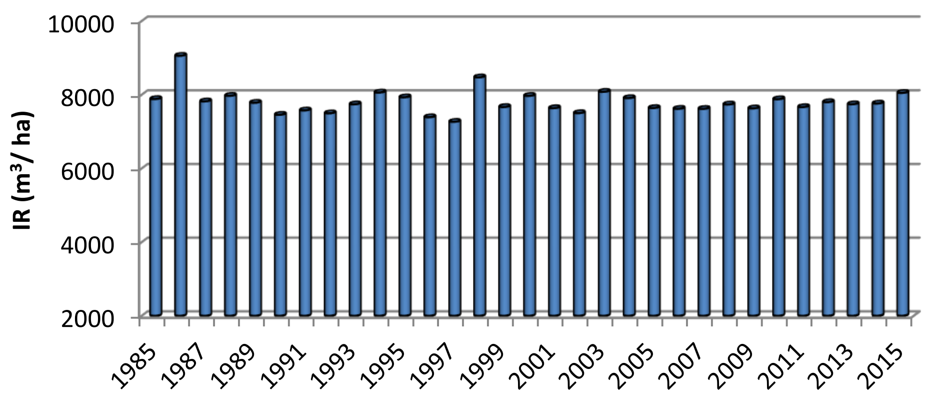


Fig. 153: Water consumptive use for sunflower (nili season) in North Nile Delta region through the last three decades

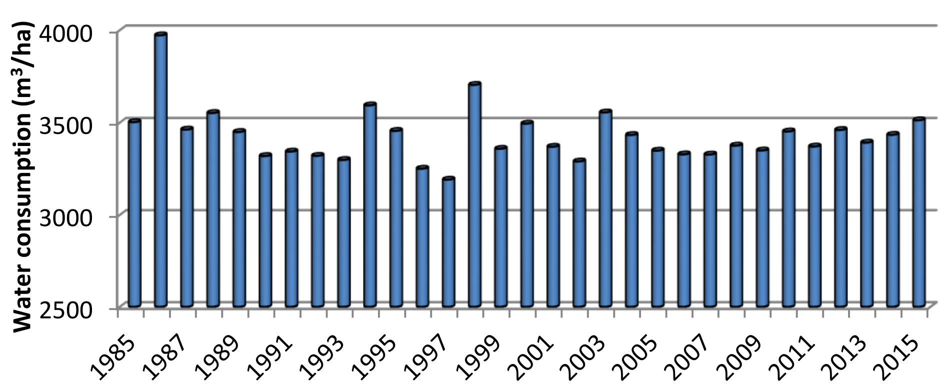


Fig. 154: Amount of irrigation water used (IR) at the farm level for sunflower (nili season) in North Nile Delta region through the last three decades

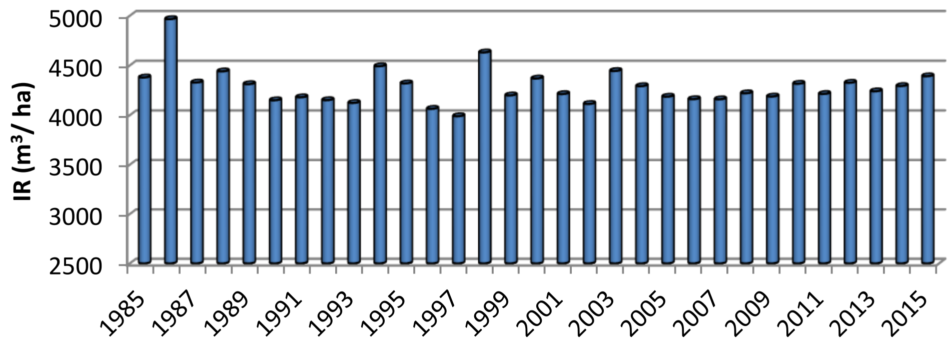


Fig. 155: Amount of irrigation water used (IR) at the high dam for sunflower (nili season) in North Nile Delta region through the last three decades

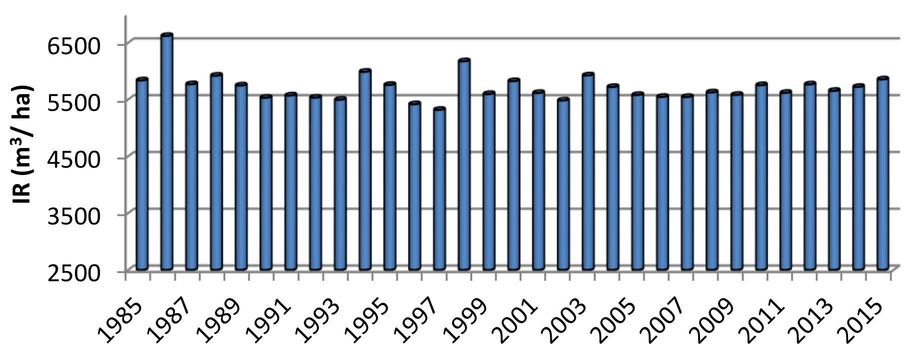


Fig. 156: Water consumptive use for tomato (nili season) in North Nile Delta region through the last three decades

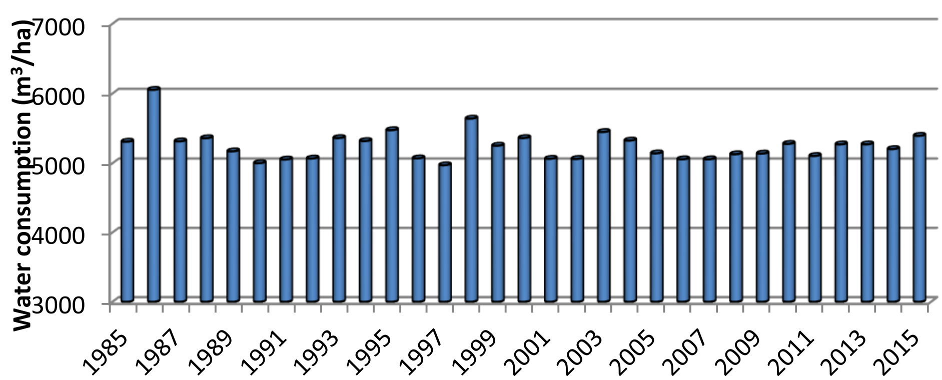


Fig. 157: Amount of irrigation water used (IR) at the farm level for tomato (nili season) in North Nile Delta region through the last three decades

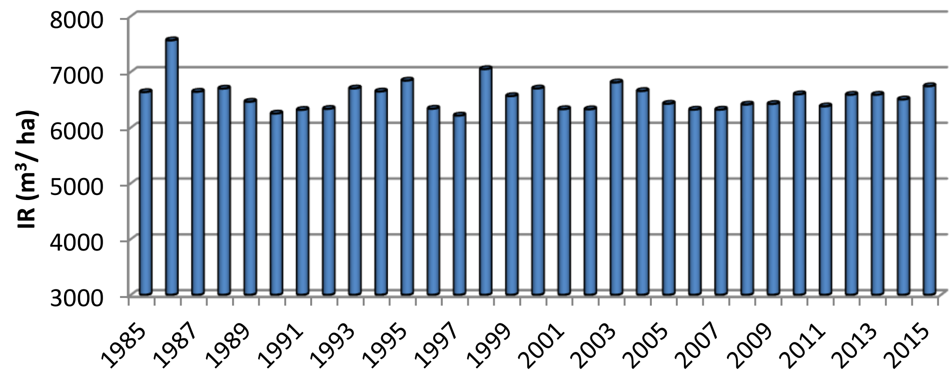


Fig. 158: Amount of irrigation water used (IR) at the high dam for tomato (nili season) in North Nile Delta region through the last three decades

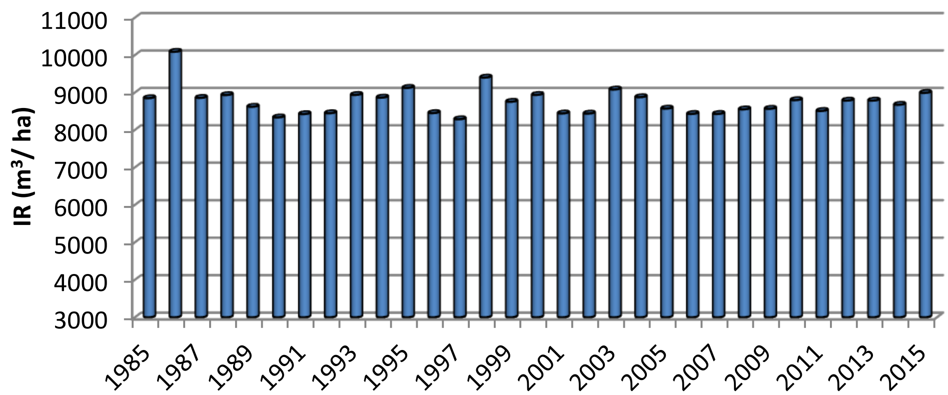


Fig. 159: Water consumptive use for caraway in North Nile Delta region through the last three decades

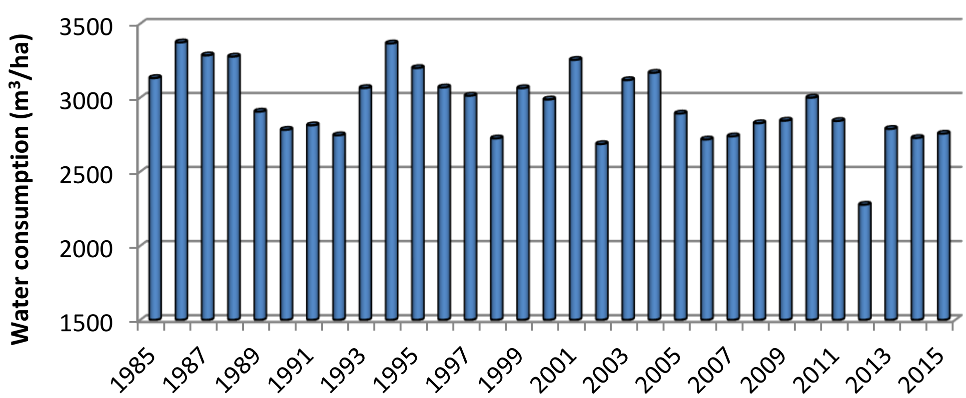


Fig. 160: Amount of irrigation water used (IR) at the farm level for caraway in North Nile Delta region through the last three decades

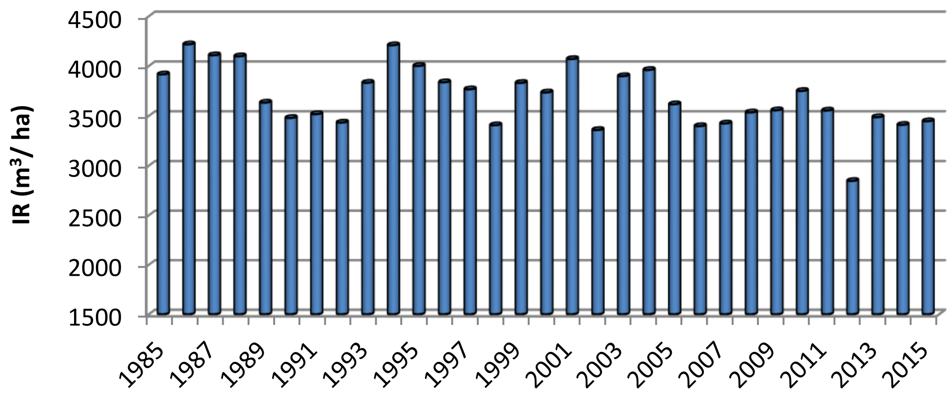


Fig. 161: Amount of irrigation water used (IR) at the high dam for caraway in North Nile Delta region through the last three decades

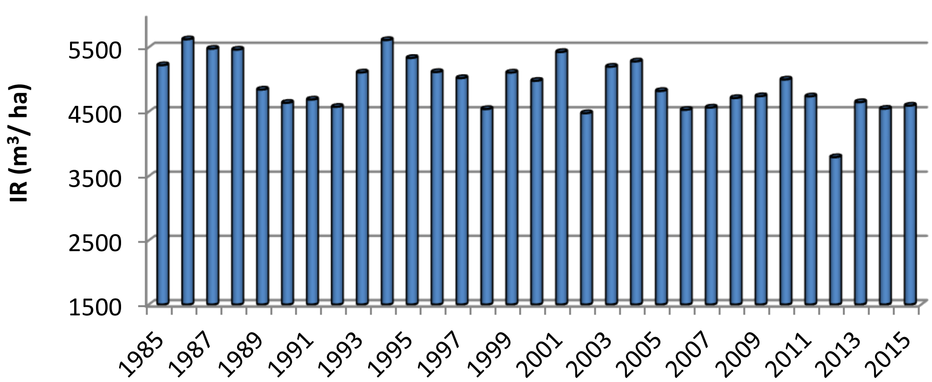


Fig. 162: Water consumptive use for cumin in North Nile Delta region through the last three decades

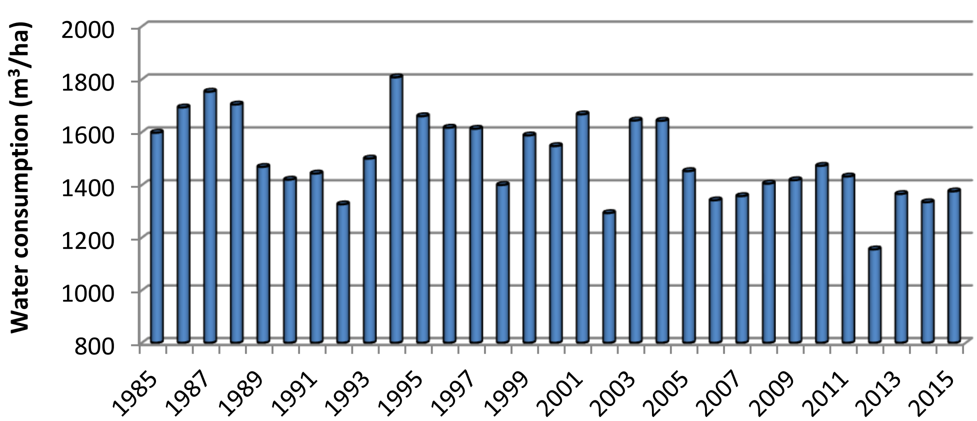


Fig. 163: Amount of irrigation water used (IR) at the farm level for cumin in North Nile Delta region through the last three decades

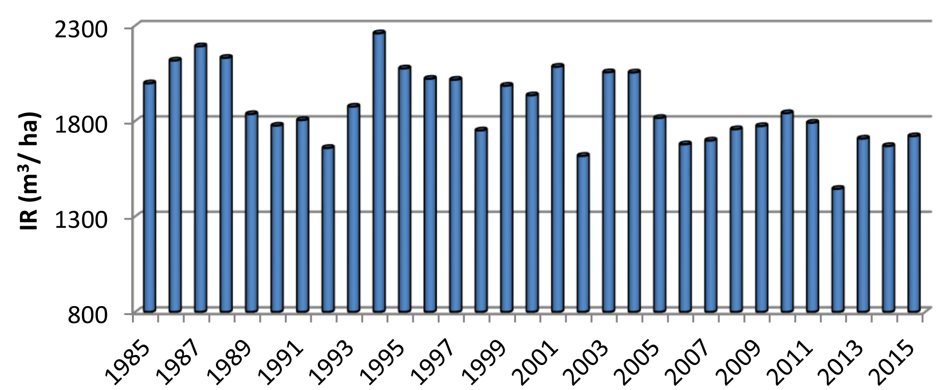


Fig. 164: Amount of irrigation water used (IR) at the high dam for cumin in North Nile Delta region through the last three decades

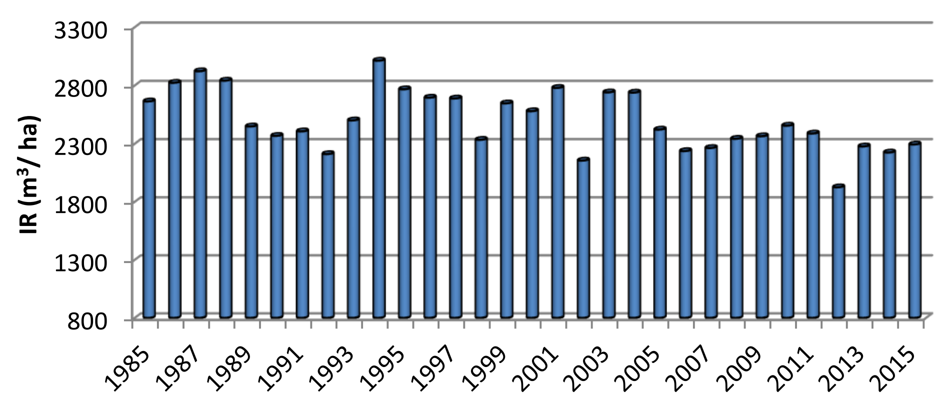


Fig. 165: Water consumptive use for jasmine in North Nile Delta region through the last three decades

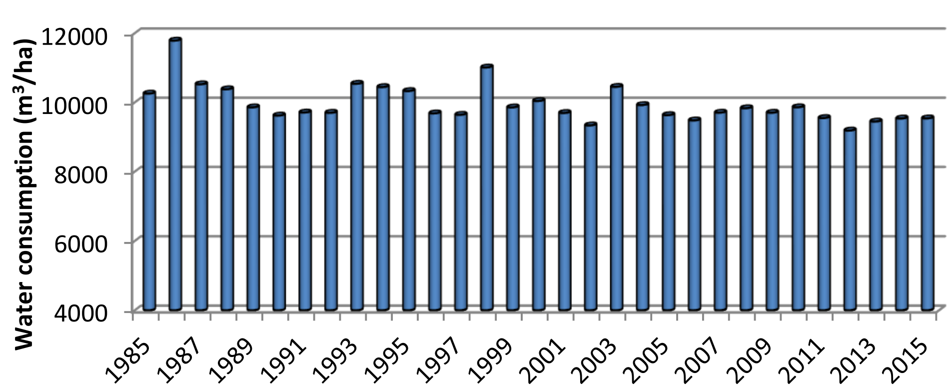


Fig. 166: Amount of irrigation water used (IR) at the farm level for jasmine in North Nile Delta region through the last three decades

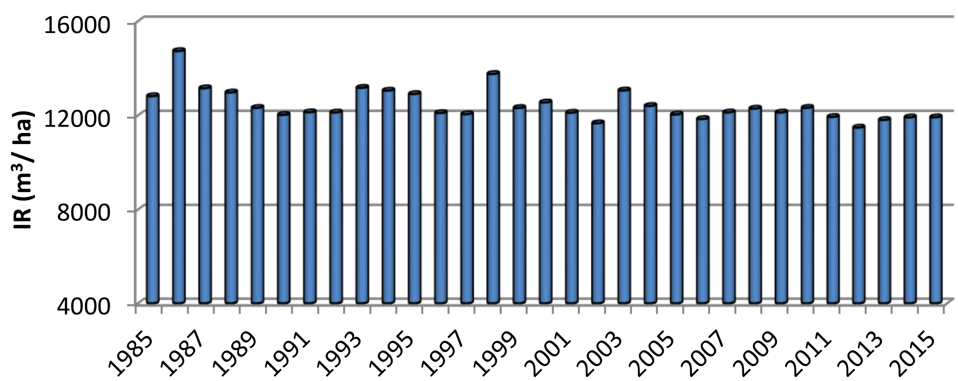


Fig. 167: Amount of irrigation water used (IR) at the high dam for jasmine in North Nile Delta region through the last three decades

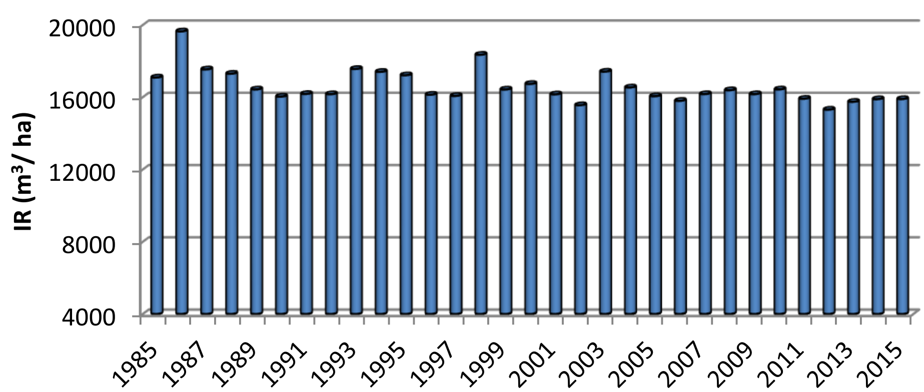


Fig. 168: Water consumptive use for marjoram in North Nile Delta region through the last three decades

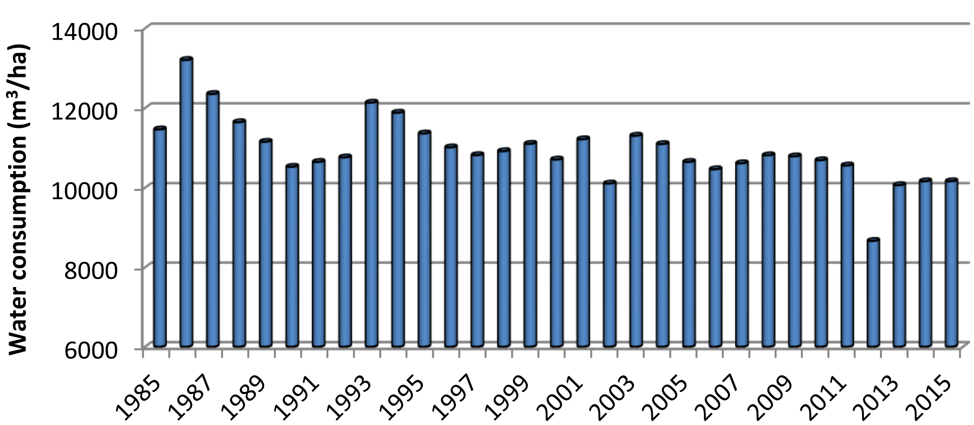


Fig. 169: Amount of irrigation water used (IR) at the farm level for marjoram in North Nile Delta region through the last three decades

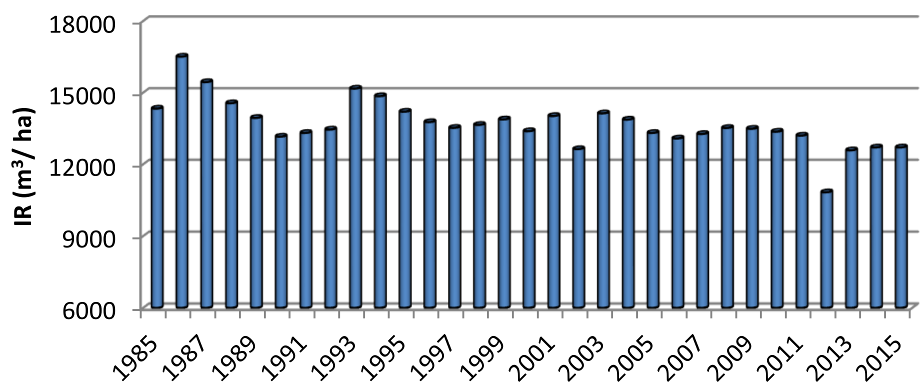


Fig. 170: Amount of irrigation water used (IR) at the high dam for marjoram in North Nile Delta region through the last three decades

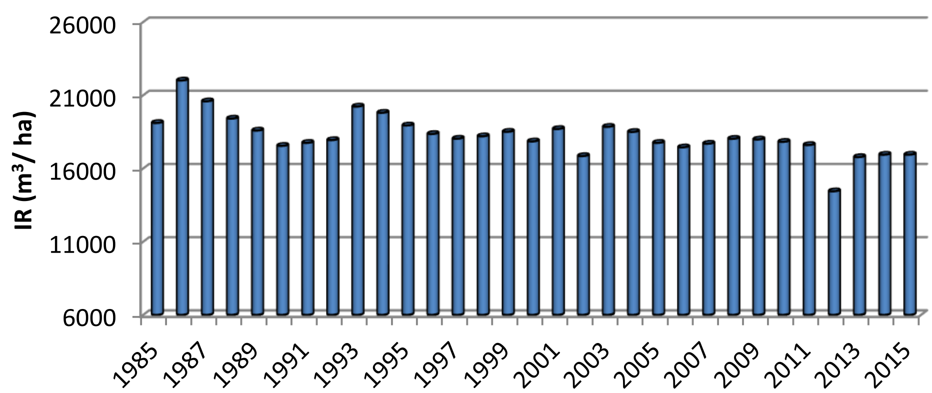


Fig. 171: Water consumptive use for spearmint in North Nile Delta region through the last three decades

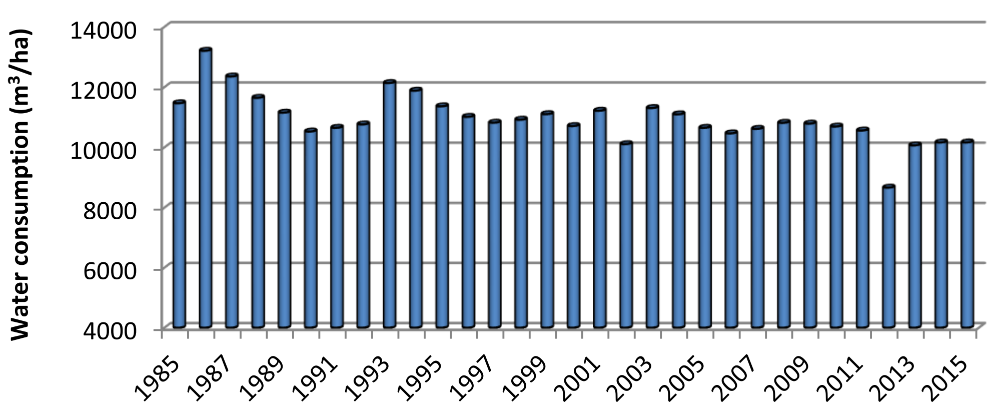


Fig. 172: Amount of irrigation water used (IR) at the farm level for spearmint in North Nile Delta region through the last three decades

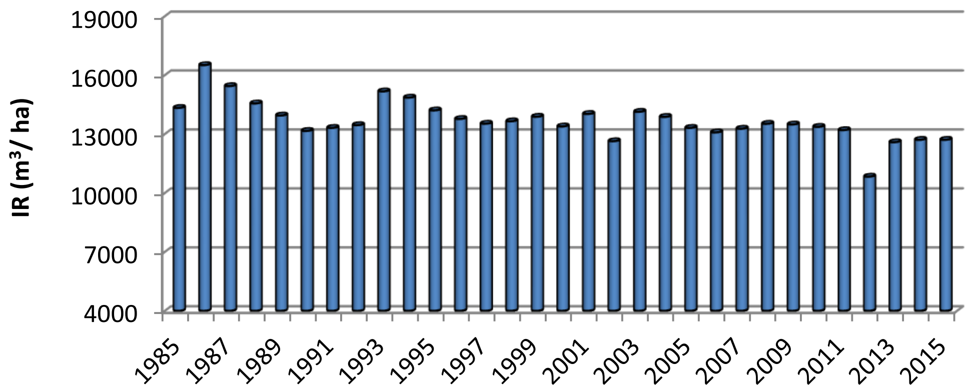


Fig. 173: Amount of irrigation water used (IR) at the high dam for spearmint in North Nile Delta region through the last three decades

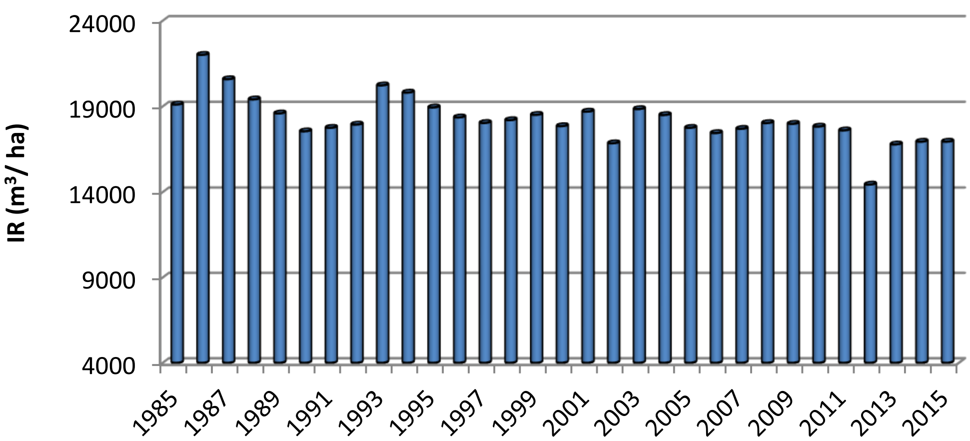


Fig. 174: Water consumptive use for apple in North Nile Delta region through the last three decades

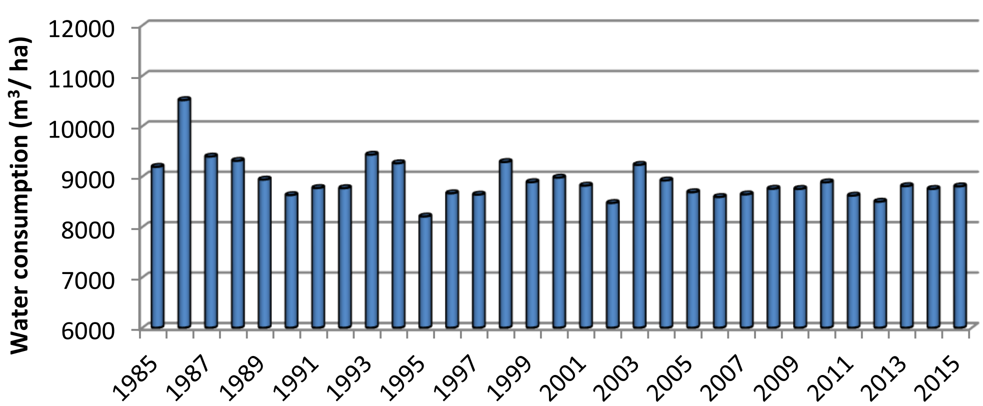


Fig. 175: Amount of irrigation water used (IR) at the farm level for apple in North Nile Delta region through the last three decades

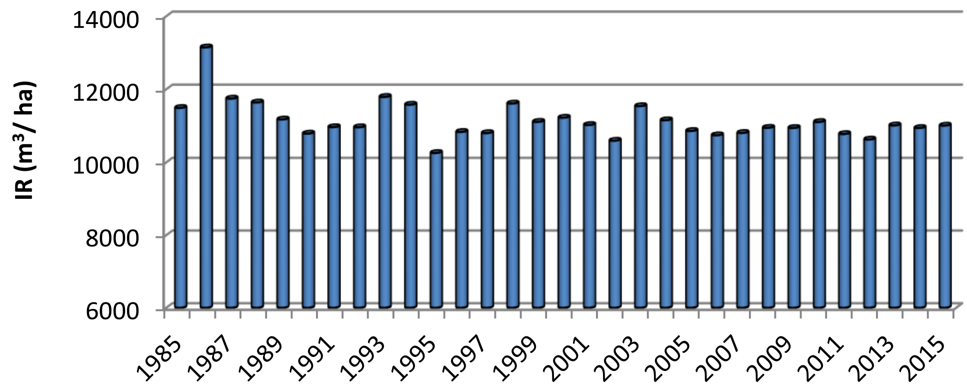


Fig. 176: Amount of irrigation water used (IR) at the high dam for apple in North Nile Delta region through the last three decades

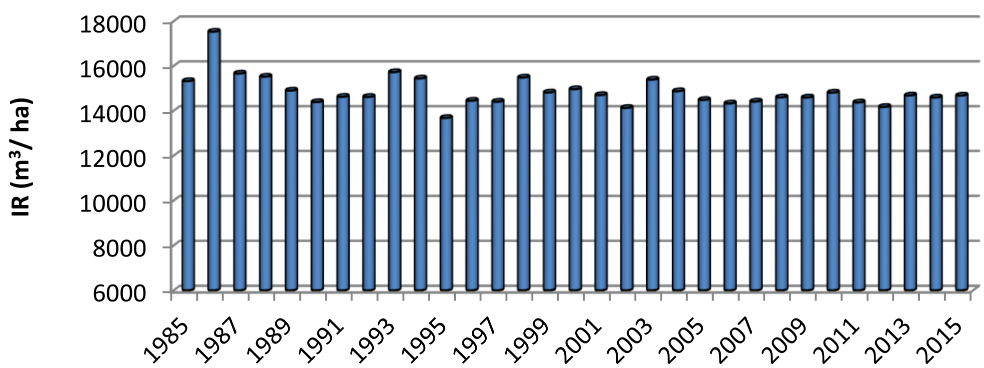


Fig. 177: Water consumptive use for banana in North Nile Delta region through the last three decades

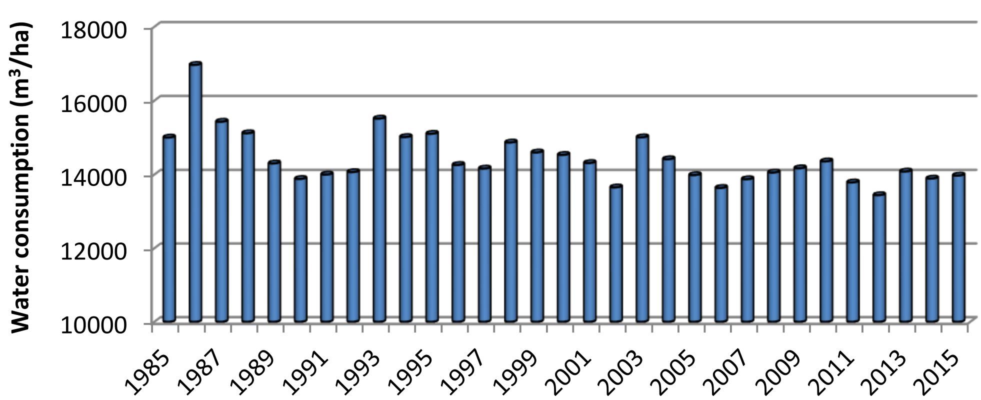


Fig. 178: Amount of irrigation water used (IR) at the farm level for banana in North Nile Delta region through the last three decades

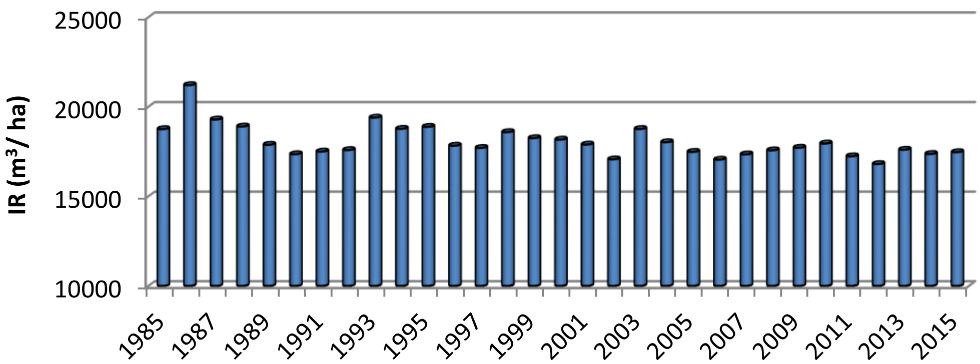


Fig. 179: Amount of irrigation water used (IR) at the high dam for banana in North Nile Delta region through the last three decades

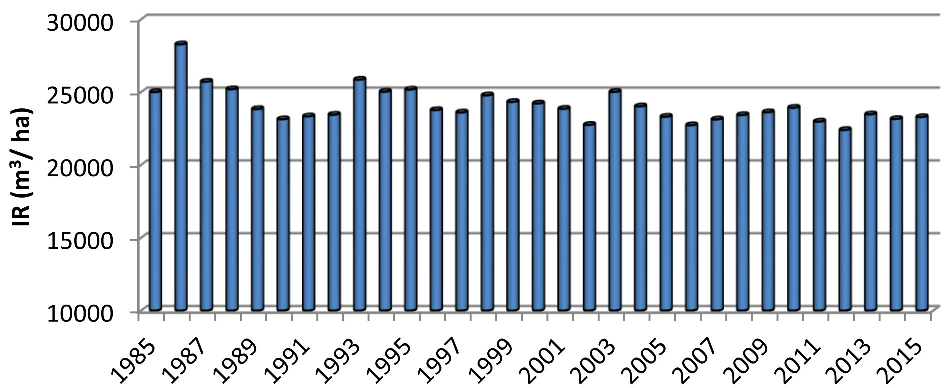


Fig. 180: Water consumptive use for date palm in North Nile Delta region through the last three decades

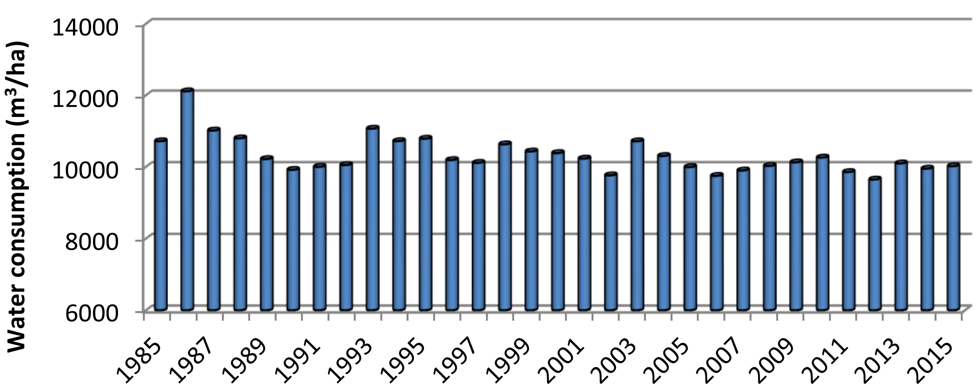


Fig. 181: Amount of irrigation water used (IR) at the farm level for date palm in North Nile Delta region through the last three decades

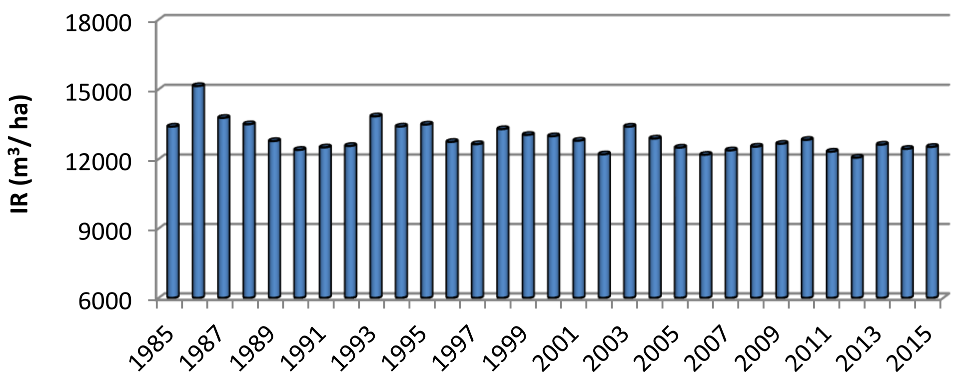


Fig. 182: Amount of irrigation water used (IR) at the high dam for date palm in North Nile Delta region through the last three decades

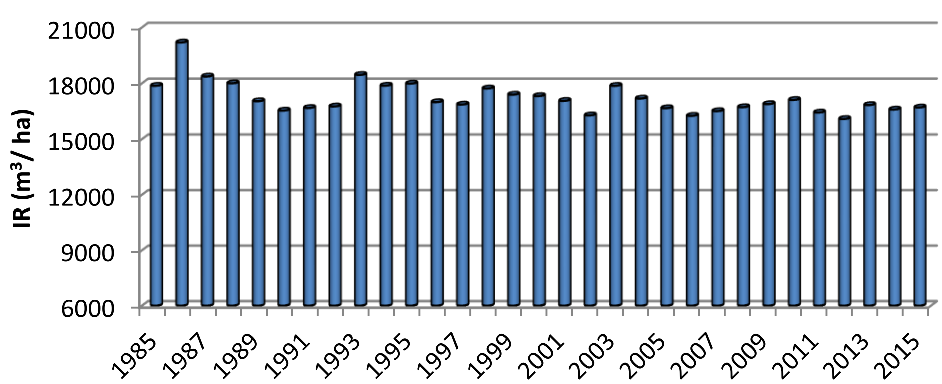


Fig. 183: Water consumptive use for grapes in North Nile Delta region through the last three decades

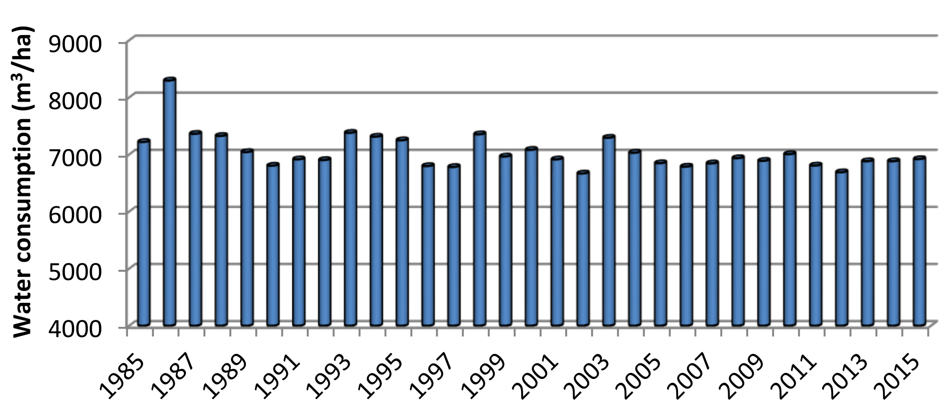


Fig. 184: Amount of irrigation water used (IR) at the farm level for grapes in North Nile Delta region through the last three decades

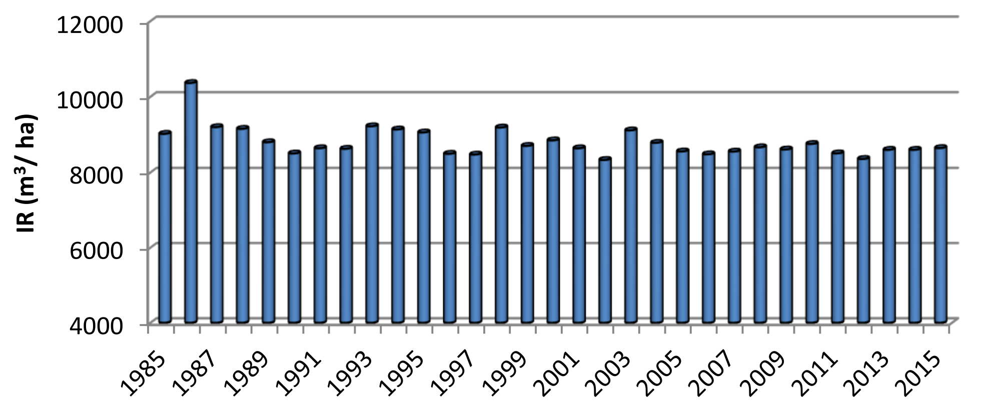


Fig. 185: Amount of irrigation water used (IR) at the high dam for grapes in North Nile Delta region through the last three decades

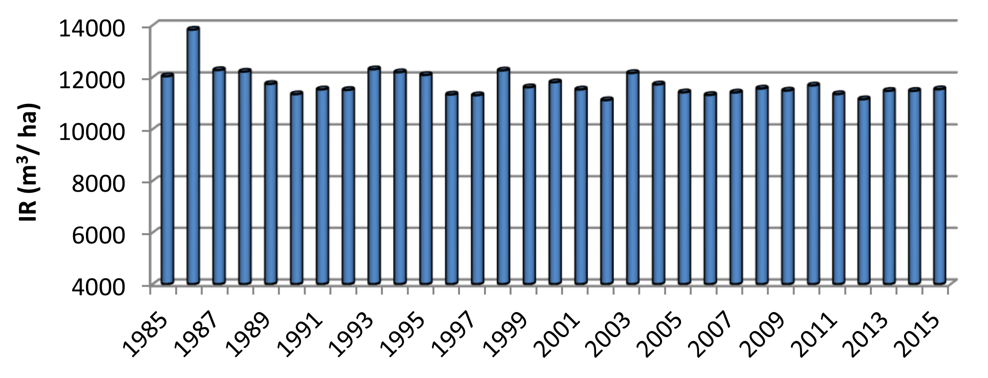


Fig. 186: Water consumptive use for mango in North Nile Delta region through the last three decades

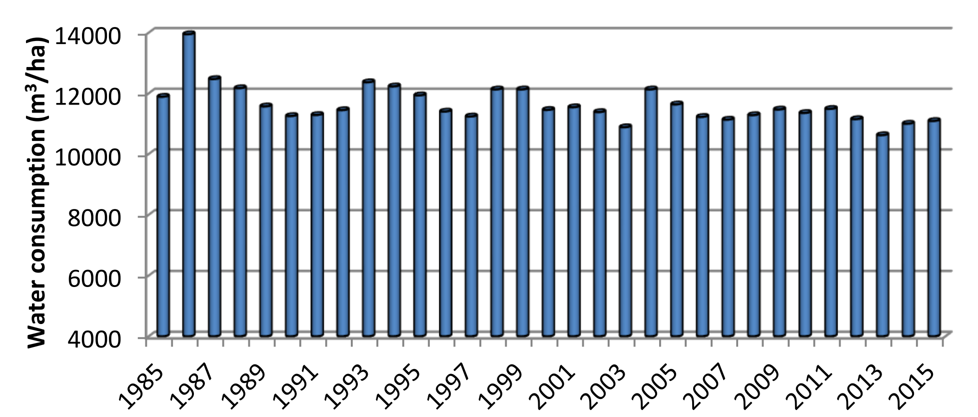


Fig. 187: Amount of irrigation water used (IR) at the farm level for mango in North Nile Delta region through the last three decades

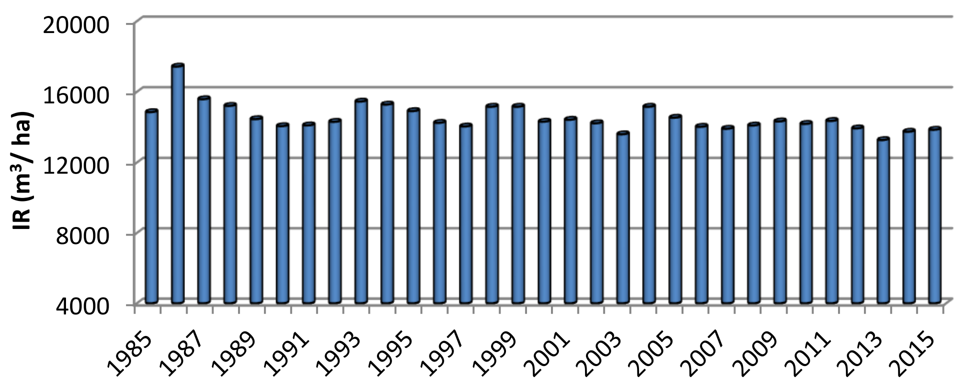


Fig. 188: Amount of irrigation water used (IR) at the high dam for mango in North Nile Delta region through the last three decades

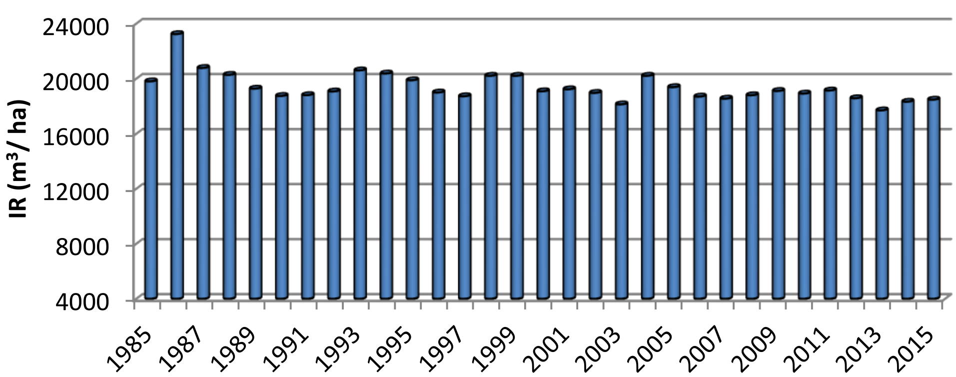


Fig. 189: Water consumptive use for olive in North Nile Delta region through the last three decades

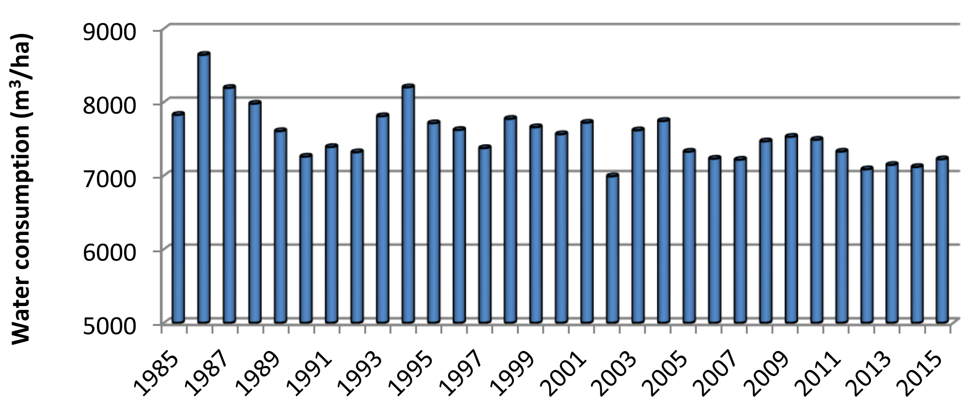


Fig. 190: Amount of irrigation water used (IR) at the farm level for olive in North Nile Delta region through the last three decades

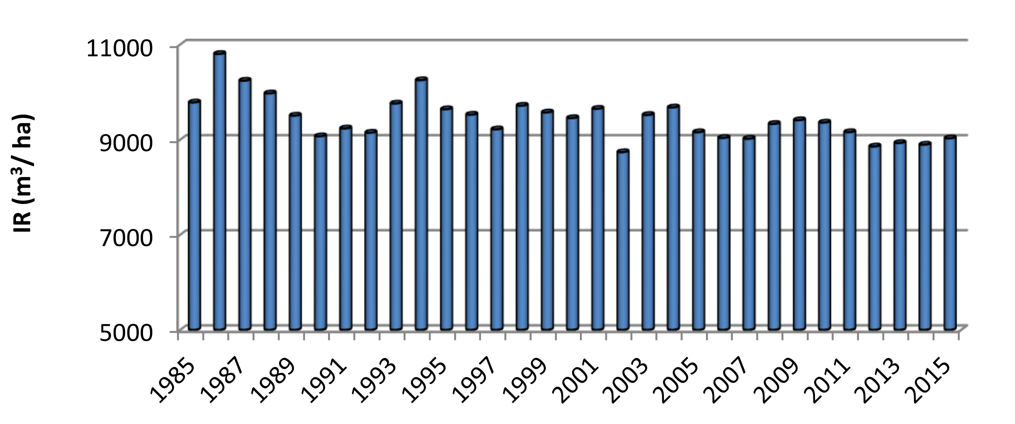


Fig. 191: Amount of irrigation water used (IR) at the high dam for olive in North Nile Delta region through the last three decades

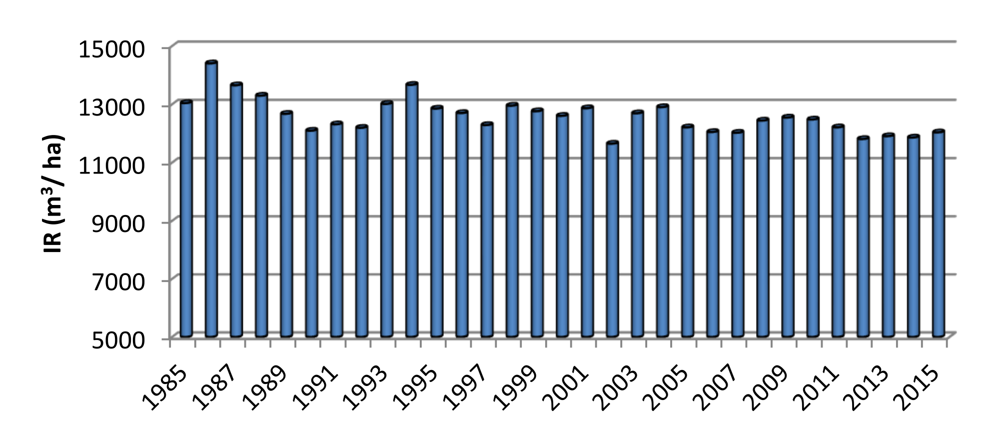


Fig. 192: Water consumptive use for orange in North Nile Delta region through the last three decades

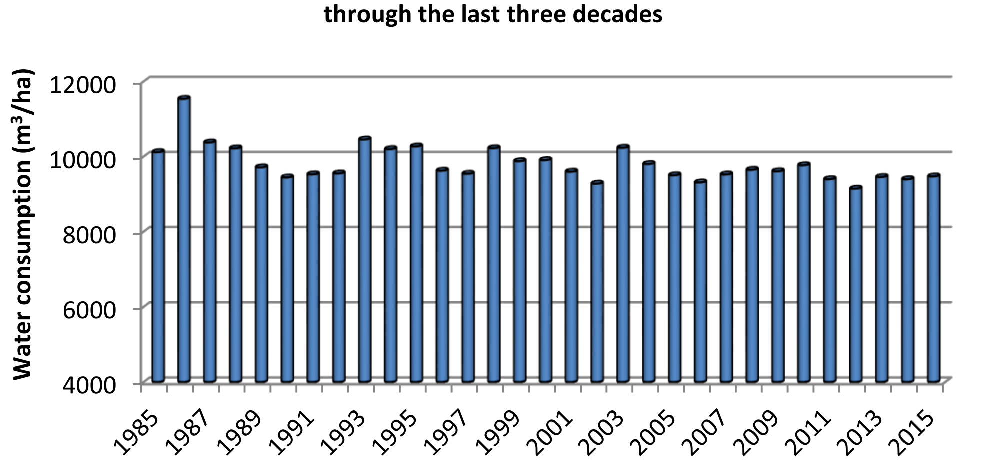


Fig. 193: Amount of irrigation water used (IR) at the farm level for orange in North Nile Delta region through the last three decades

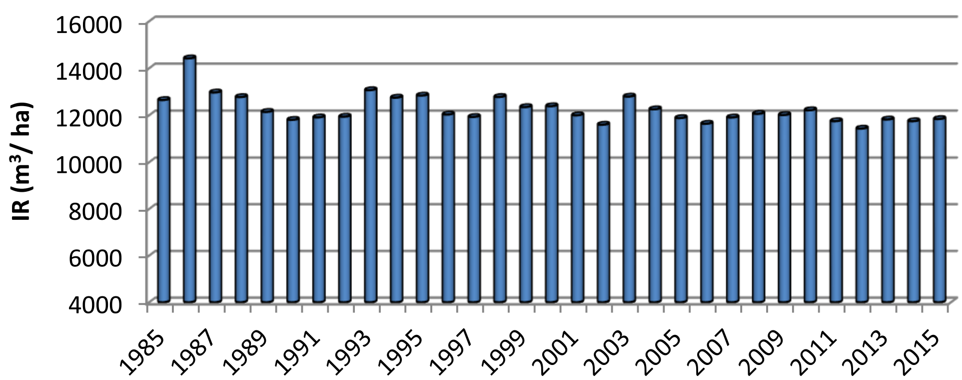


Fig. 194: Amount of irrigation water used (IR) at the high dam for orange in North Nile Delta region through the last three decades

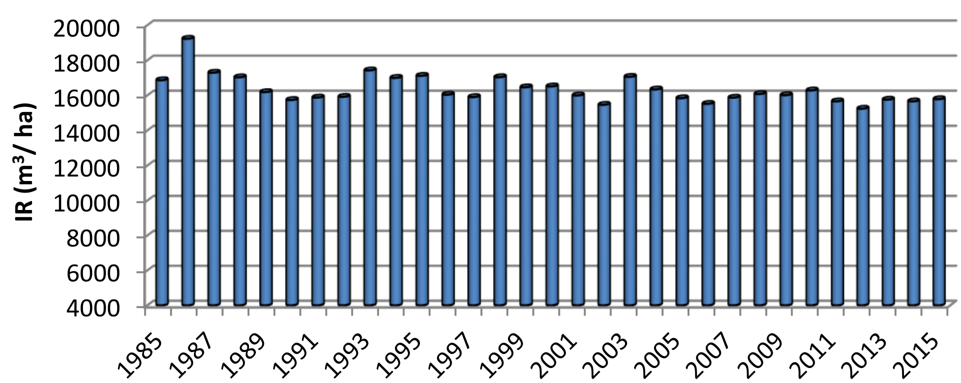
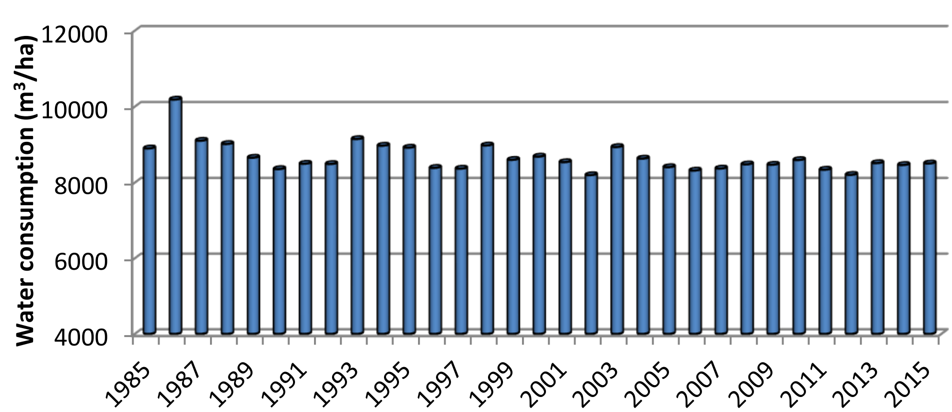
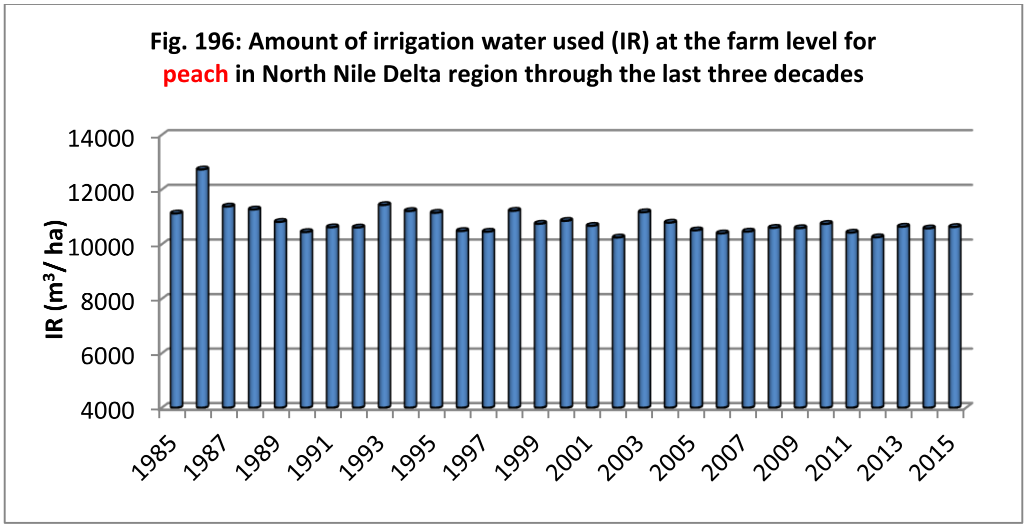
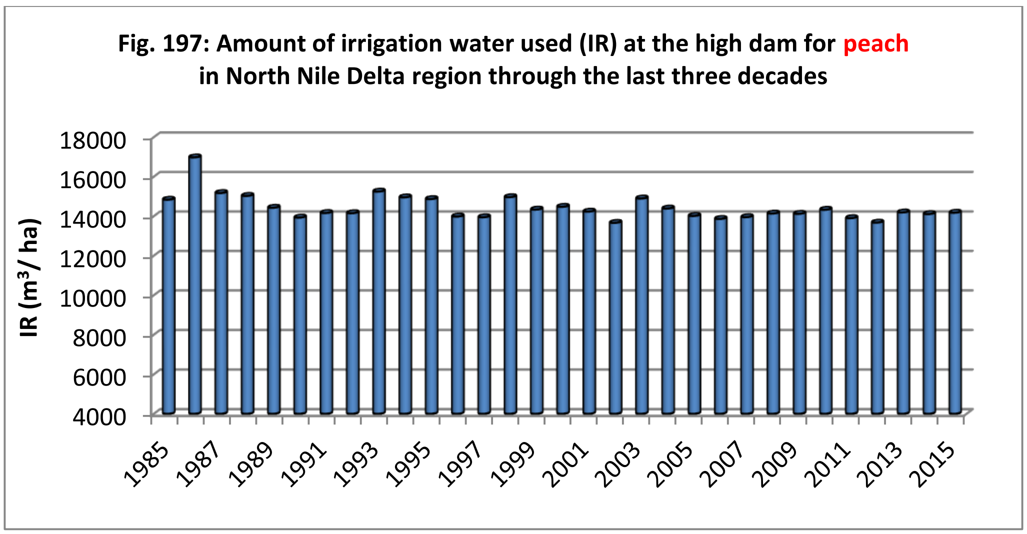


Fig. 195: Water consumptive use for peach in North Nile Delta region through the last three decades







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