

EXHIBIT 5

Research Article

Estimation of water losses through evapotranspiration of aquatic weeds in the Nile River (Case study: Rosetta Branch)

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Abstract

Aquatic weeds management and estimation of water losses from evapotranspiration must be taken into consideration in order to reduce water losses. The objective of this research is estimating the water losses through evapotranspiration of aquatic weeds in the Rosetta Branch in order to identify the quantities of water that could be saved when applying appropriate maintenance programs for aquatic weeds. To achieve the objective of this research, the research team identify areas of infection of the aquatic weeds using field visits, determine its coordinates using GPS and Satellite imagery (Landsat-8) and estimate of water losses through evapotranspiration of aquatic weeds by using the following evapotranspiration equation: $ET_c = ET_o \times K_c$. The result for estimation of the average annual water losses through evapotranspiration of aquatic weeds in the Rosetta Branch during one year (from December 2015 to November 2016) were 21.3 million m^3 /year, 0.7 million m^3 /year and 1.1 million m^3 /year for water hyacinth, Common Reed and Torpedo grass, respectively.

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Keywords: Water losses; Evapotranspiration; Aquatic weeds; Nile River

1. 1 Introduction

After constructing Aswan High Dam, a series of barrages have been built across the river and its Branches; regulate the water level in the Nile River to meet Egyptian demands for cultivation, industrial, navigation, hydroelectric power and domestic water supply. This regulation allows a gradual rise and drop down in the water level creating a favorable habitat for many aquatic weeds to spread in huge amount. [Khattab and El-Gharably \(1984\)](#) mentioned that there are three aquatic weeds forms which are floating weeds, emergent and ditch bank weeds and submerged weeds. The

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high aquatic weed infestations caused a lot of problems by causing water losses, retardation of flow, obstruction of gates and intakes, interference with navigation, health hazards and alteration in the physico-chemical characteristics of both water and hydro soil (El-Samman and Abou EL-Ella, 2009). Also, the Nile River system has been subjected to several ecological changes: silt free water running downstream and the consequent excessive use of fertilization, permanent presence of water throughout the year, low current velocity in the Nile and decrease the water flow to the Mediterranean. These factors have encouraged fast growth of aquatic weeds such as water hyacinth (*Eichhornia crassipes*) within the Egyptian Nile River even at the end of the growing season, which extends from the end of March to October (El-Shinnawy et al., 2000). *Eichhornia crassipes* is the most notorious aquatic weed; it is listed as one of the top ten world's worst weeds. Peninah et al. (2013) stated that Lake Victoria, Kenya, which is the largest freshwater body in the tropics, has undergone serious ecological changes including invasion by the water hyacinth, *Eichhornia crassipes*, the presence of the weeds in the lake has led to many problems including blockage of water pumps, reduced fishing activities and increase in water borne diseases such as schistosomiasis. The need for improving monitoring and reporting of aquatic weeds problems is stressed. Advances in the technology of remote sensing, coupled with the increasingly widespread availability of cheap computer databases can provide the means for such improvements (Murphy, 1988).

Water losses increase through evapotranspiration and considered as one of the most important weed problems in water bodies, which require tools to reduce water losses. Thus, estimating water losses through evapotranspiration of aquatic weeds is very important for preparation of both canals maintenance and weeds removal programs in order to reduce water losses. Florentina et al. (2016) results indicated that in 2014, the open water evaporation was in average of 4.3 mm/day and the aquatic plants evapotranspiration was in average of 7.8 mm/day on the Căldărușani Lake. The two processes generated a water loss of 34% of lake's volume. In lack of vegetation, the water volume lost by evaporation would have been lower, than the aquatic plants transpiration (i.e., reed associations). Angela et al. (2014) stated that the average annual water loss of Common Reed of six seasons between 2005 and 2011 ranged from 566 to 1008 mm but depended on the weather, especially on net radiation. The average evapotranspiration (ET) of Common Reed was 779 mm for the entire study period while the average Kc value was 1.23. Seasonal mean Kc values for Common Reed ranged from 0.73 to 1.37. In cool weather (seasonal mean air temperatures <17 °C), annual mean crop coefficient (Kc) and ET were 0.73 and 385 mm respectively, while in hot weather (seasonal mean temperatures above 18 °C), Kc and ET were 1.37 and 875.4 mm respectively. Brezny et al. (1973) stated that evapotranspiration of water hyacinth (*Eichhornia crassipes* Mart Solms.) was 30–40% higher, that of narrow leaf cattail (*Typha angustifolia* L.) was 60–70% higher, and that of purple nutsedge (*Cyperus rotundus* L.) was 130–150% higher than evaporation from a free water surface under equivalent conditions. Rosa et al. (2009) proved that the colonization of the aquatic weeds increased the water losses in the mesocosms, with the highest losses being observed in those colonized by *Typha latifolia*, between 3.54 to 4.71 times the water surface without aquatic weeds. The losses in the mesocosms colonized by *Myriophyllum aquaticum*, *Brachiaria subquadripata*, *Echinochloa polystachya*, and *Pontederia lanceolata* were statistically similar and promoted increases between 1.54 to 2.21 times the free surface. The results showed that aquatic weeds control is important to prevent water losses in reservoirs used for water storage. Timmer and Weldon (1966) proved that water loss through evapotranspiration from water hyacinth was 3.7 times that from open water. El-Shinnawy et al. (2000) stated that comparing water lost by tubes of water covered by *Eichhornia crassipes* with similar tubes of open water for a period of five weeks showed that the ratio of evapotranspiration to evaporation varied from 1.5:1 to 3.2:1 in winter and summer respectively. Also, it was reported that phreatophytes (excluding beneficial species) cover about 6.5 million ha in the seventeen western states of the United States of America losing annually 30.65 km³ of water. Victor et al. (1987) stated that evapotranspiration of water hyacinth, water lettuce, *Salvinia* and water fern, should represent 196,000; 84,000; 87,000 and 71,000 l/ha/day, respectively. Wherefore, this research objective to estimating the water losses through evapotranspiration of aquatic weeds in the Rosetta Branch, in order to identify the quantities of water could be saved when applying appropriate maintenance programs for the different types of aquatic weeds.

2. Materials and methods

2.1. Rosetta Branch study area

The southern beginning of the Delta head is at the intersection of latitude 30°10'26.57" North with longitude 31°8'19.56" East is the starting point of Rosetta Branch, which runs northeast to 239,035 km to pour in the Mediter-

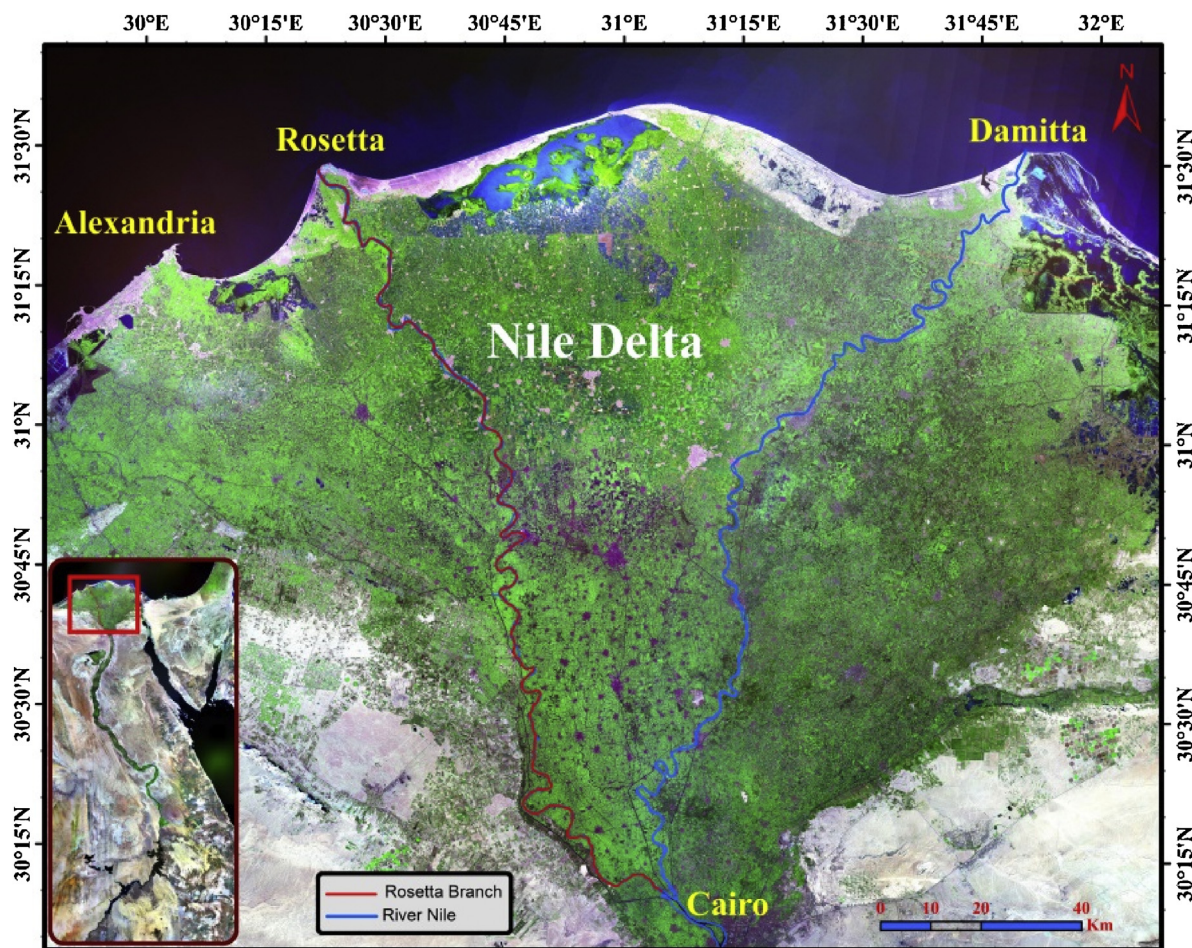


Fig. 1. Nile Delta showing Rosetta Branch (study area).

reanean Sea at Rashid city at intersection of latitude $31^{\circ}28'15.39''$ North with longitude $30^{\circ}21'53.19''$ East, as shown in Fig. 1. The average width of Rosetta Branch ranged between 132 to 485 m. Rosetta Branch has 44 islands that could be classified between permanent and seasonal islands, with a combined area of 1872.6 feddan (feddan = 4200 m^2), including eight permanent islands with extensive land use in agriculture. The total sum of the water area without islands in the Rosetta Branch during research period ranged between 13,943–15,239 feddan, depending on rise and drop down in the water level.

2.2. Determination of the areas and infestation percentages for the aquatic weeds types

Rosetta Branch was divided into three reaches (reach 1: from km. 0.0 to km. 79.0, reach 2: from km. 79.0 to km. 162.5 and reach 3: from km. 162.5 to km. 235.6) to facilitate the inventory and classification of aquatic weeds with determination of the areas and infestation rates of the aquatic weeds (water hyacinth especially). Also, there are three meteorological stations covers those three reaches on Rosetta Branch, which facilitate the estimation of water losses through evapotranspiration of aquatic weeds in Rosetta Branch.

Determination of the areas and infestation percentages for aquatic weed types during the period from December 2015 to November 2016 were done by using two complementary ways to each other. The first way depend on field visits for five days during each season of the four seasons to inventory and classify of the aquatic weeds types in Rosetta Branch by using GPS to determine the coordinates of the area infested by different types of aquatic weeds. The second way was done by analysis of satellite images available to the Rosetta Branch for the same period. Satellite imagery

analysis has been intensified during the aquatic weeds boom in the spring and summer (from March to October). 10 satellite images were used, including 2 images dated 06 Dec. 2015 and 07 Jan. 2016 represent winter season, 2 images dated 11 Mar. 2016 and 14 May 2016 represent spring season, 4 images dated 15 Jun. 2016, 01 Jul. 2016, 17 Jul. 2016 and 19 Sep. 2016 represent summer season (two of them were taken before the intensification of the mechanical control and the other two were taken during and after the intensification of the mechanical control which implemented by the Ministry of Water Resources and Irrigation) and 2 image dated 15 Oct. 2016 and 16 Nov. 2016 represent the autumn season.

2.3. Satellite imagery analysis

Methodology of satellite imagery analysis relied on the following:

- Download the satellite imagery (Landsat-8) from the website (<https://lv.eosda.com>), for two Scenes (Path & Row: 039/177 and 038/138), during dates starting from December 2015 to November 2016, and used layer stack tools from ERDAS IMAGINE Software for band combination, and Mosaic the images for each date.
- Applied Enhancements tools on the images such as Contrast and Stretching Histogram.
- Digitizing the water body and the outline bank border for Rosetta Branch, and used it for subset the river boundary.
- Using the NDVI index for highlighting the plants (weeds), on each date by below equation:

$$\text{Normalized Difference Vegetation Index (NDVI)} = \frac{(NIR - RED)}{(NIR + RED)} = \frac{(Band\ 5 - Band\ 4)}{(Band\ 5 + Band\ 4)} \quad (1)$$

- Used the Unsupervised Classification for classifying the output of NDVI to three classes (Water, Land and Plants) based on the histogram curve.
- Use the river boundary for creating buffer zone based on distance 10 m towards the inside (it is the estimate distance for ditch weeds growing), that aims to detect and select the aquatic weeds on the near shoreline (–10 m) and classified it as a ditch weeds class.
- Convert the thematic layer from the raster to vector format in shape file extension (Shp) to classify the weeds based on the buffer zone (–10 m) to ditch and floating or submerged weeds.
- Field checking for five days during each season of the four seasons, which aimed to recognize the types of aquatic weeds on Rosetta Branch, and saved GPS points for accuracy assessment.
- Extraction of coordinates table, for 15th random points to calculate the accuracy assessment by the field truth, that aim to accepted the results of satellite imagery classification.
- Extraction the areas table, for each type of image classes (Water, Weeds and Lands), and another table for areas of each type of weeds (Ditch or Floating), and create the layouts.

Also, data collection for the infection percentages of the floating aquatic weeds in the Nile River and its branches through reports issued by Channel Maintenance Research Institute (CMRI), National Water Research Center (NWRC), during the period from 1985/1986 to 2013/2014, were considered in the present research.

2.4. Meteorological data and reference evapotranspiration, (ET_0)

The collected meteorological data which cover the entire Rosetta Branch was obtained from 3 stations, Rashid 1 (Latitude: 30.25 N, Longitude: 30.75 E), Rashid 2 (Latitude: 30.75 N, Longitude: 30.75 E) and Rashid 3 (Latitude: 31.25 N, Longitude: 30.50 E). Meteorological data collected from 3 stations were used in the program Cropwat 8 for calculating the reference evapotranspiration (ET_0) from average monthly weather stations variables.

2.5. Crop coefficient (K_c)

Values of crop coefficient (K_c) of aquatic weeds which were used in this research derived from research papers for each Meleha (2005) and Rashed (2014) that conducted on almost similar areas in the climatic conditions of the Rosetta Branch. The monthly average value was used of water hyacinth coefficient (K_c) which has been calculated by

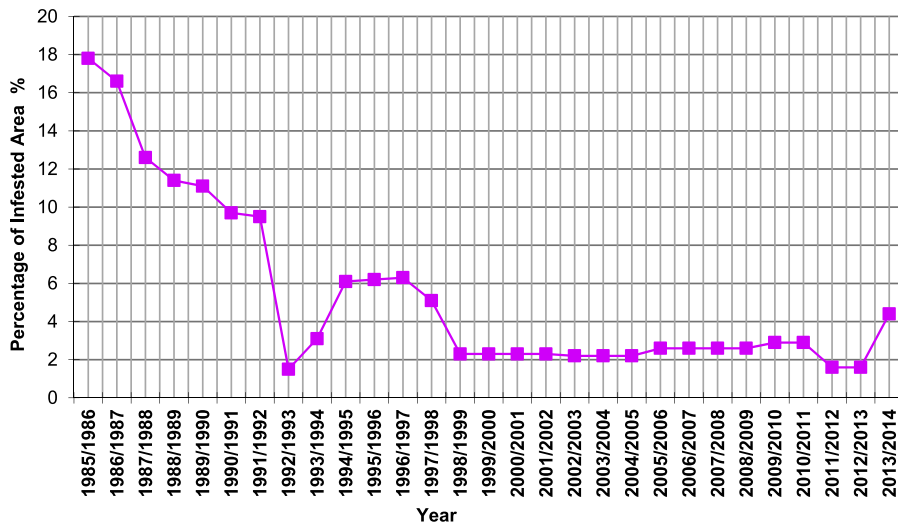


Fig. 2. Percentage of infested areas by floating weeds (water hyacinth) in the Nile River.

Meleha (2005) who estimated the monthly average of crop coefficient (K_c) for water hyacinth of the average value by many empirical formulas were 1.48, 1.54, 1.38, 1.42, 1.96, 2.27, 2.41, 2.31, 2.20, 1.97, 1.62, 1.34 and 1.30 in the months from Nov., 2004 till Nov., 2005 respectively. While, the monthly average was used of Common Reed and Torpedo Grass coefficient which has been calculated by (Rashed, 2014) who estimated the monthly average of crop coefficient (K_c) for each of the Common Reed and Torpedo grass to open water evaporation, values ranged between 1.19–1.33 and 1.25–1.35 mm/d respectively, during months from Nov. 2008 till Aug. 2009. It has been using Common Reed coefficient values that was recorded 1.08, 0.69, 0.60, 1.24, 1.27, 1.28, 1.98, 1.63 and 1.55, while Torpedo grass coefficient values was recorded 1.21, 0.80, 0.56, 1.28, 1.32, 1.32, 1.82, 1.71 and 1.65 for the months same of satellite images were used in this research.

2.6. Calculation of evapotranspiration (ET_c) of aquatic weeds in Rosetta Branch

Average daily of water losses of evapotranspiration (ET_c) for each of water hyacinth, Common Reed and Torpedo Grass is calculated by equation as follows:

$$ET_c = ET_o \times K_c \quad (2)$$

where: ET_c : evapotranspiration, ET_o : reference evapotranspiration, K_c : crop coefficient.

3. Results and discussion

In Nile River and its branches, water hyacinth is the most common type of floating weeds. It represents more than 90% of the floating weeds in the river. Thus, it is considered representative for all types of floating weeds in the Nile River. Data were collected for the infestation percentages of the floating weeds (water hyacinth) in the Nile River and its branches from eleven public Nile protection directorates that covered the entire length of Nile River from High Aswan Dam to Mediterranean Sea through reports issued by CMRI (Channel Maintenance Research Institute), 2014, this monitoring of infestation was carried out for 29 consecutive years during the period from 1985/1986 to 2013/2014 as shown in Fig. 2. The total percentage of infested area by floating weeds (water hyacinth) in Nile reached 17.8% in season 1985/1986 (the maximum rate of infestation), after this year, the infestation decreased gradually with increasing time and reached the minimum level in season 1992/1993 which was 1.5%, then, increased to reach about 6.3% in season 1996/1997, then, decreased to range between 2.1–4.4% during the period from 1998/1999 to 2013/2014 as shown in Fig. 2. The infestation percentages of the floating weeds (water hyacinth) in the Nile River during the inventory years concentrated in Rosetta and Damietta branches.

3.1. The infestation of aquatic weeds

Rosetta Branch was divided into three reaches in order to facilitate the inventory and classification of aquatic weeds with determination of the areas and infestation percentages of the aquatic weeds during the period from December 2015 to November 2016 using two methods. The first method by depends on the field visits to observe the aquatic weeds types for inventory of the types aquatic weeds and using GPS to determine the coordinates of infestation sites from them to use it in determining the extracted infestation areas from satellite imagery for each type accurately. The second method depends on the analysis of 10 satellite imagery available to calculate the areas and infestation percentages for the aquatic weeds types that have been monitored for the same period.

3.2. Inventory and classification of aquatic weeds through field visits

The results of the inventory and classification of aquatic weeds for five days during each season of the four seasons in December 2015, May 2016, July 2016 and October 2016, showed four main life forms of aquatic weeds which related to the plants position in the Rosetta Branch. These four forms are floating weeds represented in water hyacinth "*Eichornia crassipes*", ditch-bank weeds represented in Common Reed "*Phragmites australis*" emergent weeds represented in Torpedo grass "*Echinochloa stagninum*", submerged weeds represented in Eurasian Water-Milfoil "*Myriophyllum spicatum*" and Curlyleaf Pondweed "*Potamogeton crispus*". Water hyacinth is the most common type in the three reaches, it is the main problem of aquatic weeds in Rosetta Branch, followed by Common Reed and Torpedo grass, while, submerged weeds are the least common and monitored in the first reach only. Infestation area does not exceed 2–10 feddan during four seasons. The areas and infestation percentages of the aquatic weeds has been determined on Rosetta Branch in three reaches. These weeds are water hyacinth "*Eichornia crassipes*", Common Reed "*Phragmites australis*" and Torpedo grass "*Echinochloa stagninum*".

Through field observations, it has been monitored that the increase in the spread of aquatic weeds during the summer season from the rest of seasons and the spread of aquatic weeds during the seasons could be arranged in the following order: summer > spring > autumn > winter. This arrangement corresponds to the period of weed boom that starts from March to October each year.

3.3. Areas and infestation percentages of aquatic weeds using satellite imagery

The results of analysis 10 satellite imagery available for the areas and infestation percentages for the aquatic weeds in Rosetta Branch during the period from December 2015 to November 2016 are shown in [Tables 1 and 2](#). The following could be shown:

- Total infestation areas of aquatic weeds ranged between 679.30–3179.37 feddan of the total water surface area in Rosetta Branch (three reaches) which is equivalent to injury percentage ranged between 5.07–20.86%. The highest infestation of aquatic weeds recorded in 01 Jul. 2016 and lowest infestation in 07 Jan. 2016.
- Infestation areas of water hyacinth ranged between 542.15–2935.55 feddan of the total water surface area which is equivalent to infestation percentage 4.04–19.26%. The infestation areas existed in the highest value in summer season "01-Jul-2016" and the lowest value was accompanied with winter season "07 Jan. 2016".
- Infestation areas of Common Reed ranged between 36.98–103.29 feddan of the total water surface area which is equivalent to infestation percentage 0.24–0.74%. The infestation areas were existed in the highest value in spring season "14 May 2016" and the lowest value was accompanied with autumn season "19 Sep. 2016".
- Infestation areas of Torpedo grass ranged between 66.07–168.65 feddan of the total water surface area which is equivalent to infestation percentage 0.44–1.20%. The infestation areas were existed in the highest value in summer season "17 Jul. 2016" and the lowest value was accompanied with autumn season "19 Sep. 2016".

[Figs. 3–6](#) show the spread of aquatic weeds in the distance from South of Desouq city at kilometer 170.900 to Fawah city at kilometer 185.800, as an example of some areas of aquatic weeds infection during the four seasons.

The previous results in tables and figures, show the highest infestation of aquatic weeds during summer season (May and July 2016) due to the availability of weed growth factors which help aquatic weeds boom in this period. Also, drains that flow untreated drainage on Rosetta Branch (such as Al-Rahawi drain, Sibal drains and others), this

Table 1

Infestation areas of aquatic weeds in the Rosetta Branch.

No.	Reaches		Total Water surface area (feddan = 4200 m ²)	Infested areas of water hyacinth	Infested areas of Common Reed	Infested areas of Torpedo grass	Total infested area of aquatic weeds	Date
	From (km)	To (km)						
1	0.000	79.000	2649.30	280.38	44.80	74.37	399.55	06 Dec. 2015
2	79.000	162.500	4705.41	483.75	16.64	26.88	527.27	
3	162.500	235.600	6919.91	190.92	30.15	19.32	240.39	
	Total infestation		14,274.62	955.05	91.59	120.57	1167.21	
1	0.000	79.000	2610.35	112.55	21.32	54.14	188.01	07 Jan. 2016
2	79.000	162.500	4618.22	294.15	13.81	19.15	327.11	
3	162.500	235.600	6180.36	135.45	16.62	12.11	164.18	
	Total infestation		13,408.93	542.15	51.75	85.40	679.30	
1	0.000	79.000	2646.73	277.53	50.93	73.66	402.12	11 Mar. 2016
2	79.000	162.500	5515.51	430.13	20.86	36.08	487.07	
3	162.500	235.600	6966.56	158.64	10.85	15.09	184.58	
	Total infestation		15,184.28	866.3	82.64	124.83	1073.77	
1	0.000	79.000	2753.68	328.99	42.09	56.51	427.6	14 May 2016
2	79.000	162.500	4777.69	974.50	33.99	49.32	1057.81	
3	162.500	235.600	6412.27	577.54	27.2	31.87	636.61	
	Total infestation		13,943.64	1881.03	103.29	137.69	2122.02	
1	0.000	79.000	2732.54	312.44	33.49	70.38	416.31	15 Jun. 2016
2	79.000	162.500	5244.4	911.92	30.55	57.28	999.76	
3	162.500	235.600	6232.32	830.17	19.69	28.98	878.84	
	Total infestation		14,209.26	2054.53	83.73	156.64	2294.91	
1	0.000	79.000	2755.74	331.95	28.81	53.76	414.53	01 Jul. 2016
2	79.000	162.500	5395.6	962.97	35.98	57.54	1056.49	
3	162.500	235.600	7088.36	1640.63	29.33	38.39	1708.35	
	Total infestation		15,239.70	2935.55	94.13	149.68	3179.37	
1	0.000	79.000	2843.3	210.19	31.29	53.48	294.96	17 Jul. 2016
2	79.000	162.500	5341.12	606.38	37.75	62.43	706.56	
3	162.500	235.600	5876.05	1148.7	26.73	52.75	1228.18	
	Total infestation		14,060.47	1965.27	95.77	168.65	2229.69	
1	0.000	79.000	2983.39	130.61	11.44	23.4	165.45	19 Sep. 2016
2	79.000	162.500	5338.53	459.43	14.18	26.7	500.31	
3	162.500	235.600	6805.29	452.75	11.36	15.97	480.08	
	Total infestation		15,127.21	1042.79	36.98	66.07	1145.84	
1	0.000	79.000	2870.31	169.53	43.12	57.16	269.81	15 Oct. 2016
2	79.000	162.500	5100.34	314.93	38.26	43.61	396.8	
3	162.500	235.600	6868.97	184.78	14.82	15.26	214.86	
	Total infestation		14,839.62	669.24	96.2	116.03	881.47	
1	0.000	79.000	2855.85	135.22	34.85	46.52	216.59	16 Nov. 2016
2	79.000	162.500	5043.28	278.35	29.65	35.55	343.55	
3	162.500	235.600	6741.35	155.53	15.74	16.32	187.59	
	Total infestation		14,640.48	569.10	80.24	98.39	747.73	

Table 2
Infestation percentages of aquatic weeds in the Rosetta Branch.

No.	Reaches		Total Water surface percent (%)	Infestation percent of water hyacinth	Infestation percent of Common Reed	Infestation percent of Torpedo grass	Total infestation percent of aquatic weeds	Date
	From (km)	To (km)						
1	0.000	79.000	100	10.58	1.69	2.81	15.08	06 Dec. 2015
2	79.000	162.500	100	10.28	0.35	0.57	11.20	
3	162.500	235.600	100	2.75	0.44	0.28	3.47	
	Total infestation		100	6.69	0.64	0.84	8.17	
1	0.000	79.000	100	4.31	0.82	2.07	7.20	07 Jan. 2016
2	79.000	162.500	100	6.37	0.30	0.41	7.08	
3	162.500	235.600	100	2.19	0.27	0.20	2.66	
	Total infestation		100	4.04	0.39	0.64	5.07	
1	0.000	79.000	100	10.48	1.92	2.78	15.18	11 Mar. 2016
2	79.000	162.500	100	7.80	0.38	0.65	8.83	
3	162.500	235.600	100	2.28	0.15	0.22	2.65	
	Total infestation		100	5.71	0.54	0.82	7.07	
1	0.000	79.000	100	11.95	1.53	2.05	15.53	14 May 2016
2	79.000	162.500	100	20.40	0.71	1.03	22.14	
3	162.500	235.600	100	9.01	0.42	0.50	9.93	
	Total infestation		100	13.49	0.74	0.99	15.22	
1	0.000	79.000	100	11.43	1.23	2.58	15.24	15 Jun. 2016
2	79.000	162.500	100	17.39	0.58	1.09	19.06	
3	162.500	235.600	100	13.32	0.32	0.46	14.10	
	Total infestation		100	14.46	0.59	1.10	16.15	
1	0.000	79.000	100	12.05	1.04	1.95	15.04	01 Jul. 2016
2	79.000	162.500	100	17.85	0.67	1.06	19.58	
3	162.500	235.600	100	23.15	0.41	0.54	24.10	
	Total infestation		100	19.26	0.62	0.98	20.86	
1	0.000	79.000	100	7.39	1.10	1.88	10.37	17 Jul. 2016
2	79.000	162.500	100	11.35	0.71	1.17	13.23	
3	162.500	235.600	100	19.55	0.45	0.90	20.90	
	Total infestation		100	13.98	0.68	1.20	15.86	
1	0.000	79.000	100	4.38	0.38	0.78	5.54	19 Sep. 2016
2	79.000	162.500	100	8.61	0.26	0.50	9.37	
3	162.500	235.600	100	6.65	0.17	0.23	7.05	
	Total infestation		100	6.89	0.24	0.44	7.57	
1	0.000	79.000	100	5.91	1.50	1.99	9.40	15 Oct. 2016
2	79.000	162.500	100	6.17	0.75	0.86	7.78	
3	162.500	235.600	100	2.69	0.22	0.22	3.13	
	Total infestation		100	4.51	0.65	0.78	5.94	
1	0.000	79.000	100	4.73	1.22	1.63	7.58	16 Nov. 2016
2	79.000	162.500	100	5.52	0.59	0.70	6.81	
3	162.500	235.600	100	2.31	0.23	0.24	2.78	
	Total infestation		100	3.88	0.56	0.67	5.11	

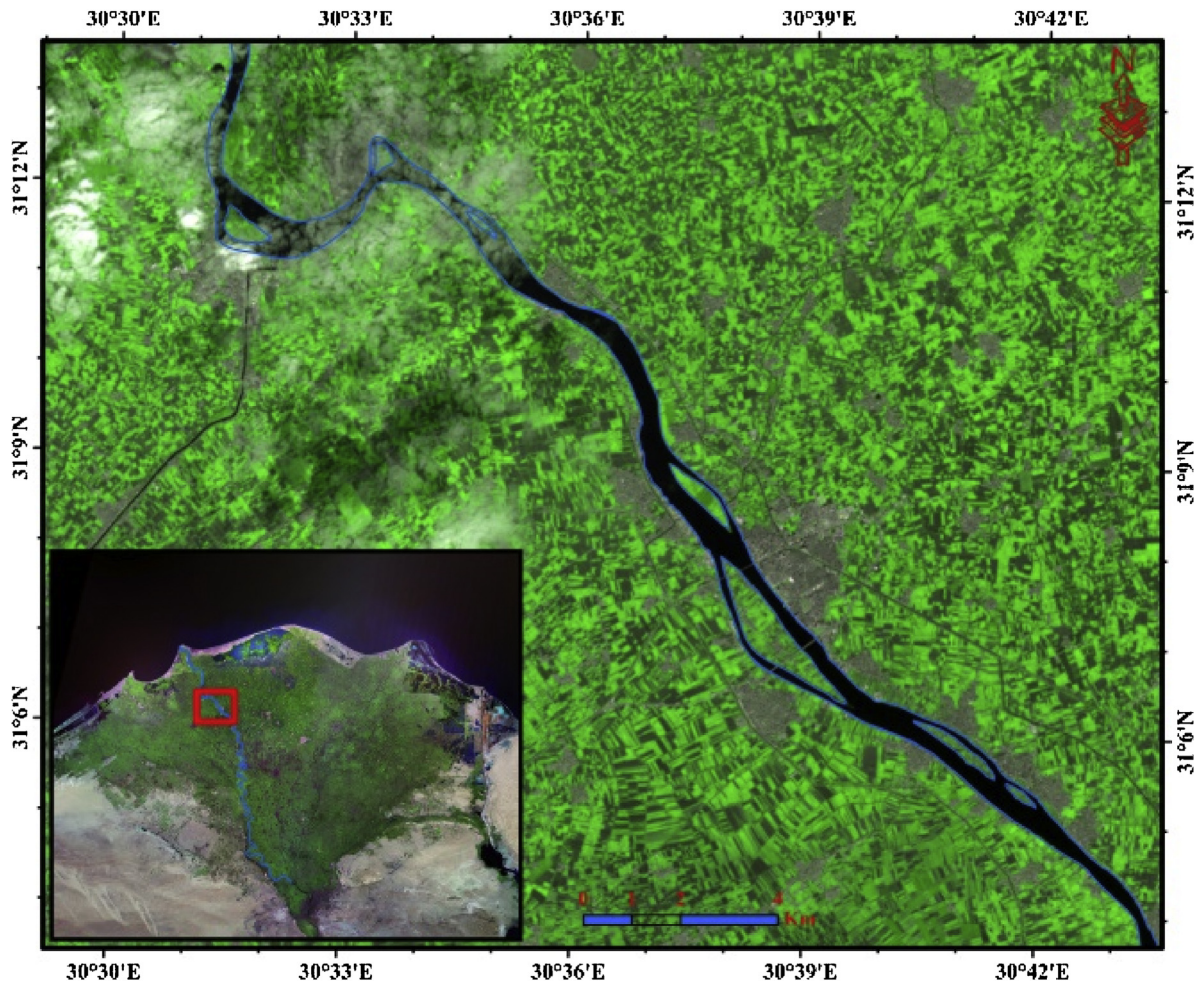


Fig. 3. Aquatic weeds from Desouq city to Fuwah city in 06 Dec. 2015.

drainage carries with it nutrients that help the aquatic weeds growth and expansion (water hyacinth especially) and very weak method to manage and control aquatic weeds mechanical control. While, infestation decreased of aquatic weeds during autumn season (September and October 2016) as a result of the intensive maintenance work to control the weeds with increased equipment used in weed control and prepare a good maintenance plan during July and August 2016. Whereas, the lowest infection of aquatic weeds was during winter season especially in Jan. 2016 because the factors that help to grow weeds were weak.

Table 3 presents average monthly weather stations variables which have been calculated from meteorological data that were collected from the three meteorological stations “Rashid 1, Rashid 2 and Rashid 3”. This data included maximum and minimum temperature, relative humidity (%), wind speed (km/d) and sun shine (hours). Reference evapotranspiration (ET_o) was calculated from average monthly weather stations variables by entering the data on program Cropwat 8. The highest values of reference evapotranspiration were recorded during summer season (Jun. 2016 and Jul. 2016), while, the lowest values of reference evapotranspiration were recorded during winter season (Dec. 2015 and Jan. 2016).

Water losses that calculated by evapotranspiration from aquatic weeds on Rosetta Branch were depended on meteorological station Rashid 1 covers the distance from principle to km. 79,000. While, Rashid 2 covers a reach from km. 79,000 to km. 162,500, whereas, Rashid 3 covers a reach from km. 162,500 to km. 235,600 on Rosetta Branch.

Table 4 presents average water losses through evapotranspiration that was calculated for water hyacinth compared to evaporation of free surface for the same infested area from Rosetta Branch during the period from December 2015

Table 3
Average monthly weather stations variables and evapotranspiration reference (ET_o) on Rosetta Branch.

Date	Station	Temperature		Humidity	Wind	Sun Shin	ET _o
		Min. (°C)	Max. (°C)	%	km d ¹	Hours	mm d ¹
Dec. 2015	Rashid 1	11.2	20.5	64.0	85.44	8.2	1.88
	Rashid 2	12.0	19.4	75.0	96.12	8.0	1.73
	Rashid 3	13.3	19.9	66.7	92.88	8.4	1.86
Jan. 2016	Rashid 1	9.8	18.2	58.4	109.92	7.2	1.93
	Rashid 2	8.3	17.5	67.0	100.2	8.4	1.81
	Rashid 3	9.6	17.6	67.9	105.36	7.8	1.72
Mar. 2016	Rashid 1	15.9	26.6	43.9	117.84	8.7	3.96
	Rashid 2	11.6	22.2	66.3	111.84	8.2	3.09
	Rashid 3	13.2	22.8	60.2	113.04	8.8	3.32
May 2016	Rashid 1	20.8	33.2	40.5	121.44	11	6.05
	Rashid 2	16.9	28.3	58.5	111.36	10.6	5.03
	Rashid 3	18.7	28.8	54.7	110.64	11.2	5.30
	Rashid 1	24.2	37.1	43.2	113.04	11.5	6.64
Jun. 2016	Rashid 2	21.4	31.9	64	112.08	11.8	5.83
	Rashid 3	22.5	31.9	57.6	108.24	12.2	6.03
	Rashid 1	25	35.5	54.4	106.08	11.1	6.26
Jul. 2016	Rashid 2	22.9	30.7	70.8	111.12	11.6	5.65
	Rashid 3	24.4	31.3	61.7	118.32	11.6	5.94
	Rashid 1	23.7	33.8	54.4	108.96	10.1	5.14
Sep. 2016	Rashid 2	22.0	29.2	70.3	91.44	9.8	4.31
	Rashid 3	22.9	30.8	56.9	102.96	10.1	4.72
	Rashid 1	21.3	30.7	62.2	104.16	9.2	3.87
Oct. 2016	Rashid 2	20.2	27.8	70.8	86.16	8.7	3.29
	Rashid 3	21.1	28.1	59.4	96.24	8.9	3.53
	Rashid 1	16.5	25.6	55.9	93.84	8.3	2.73
Nov. 2016	Rashid 2	16.2	23.4	73	104.76	8.8	2.41
	Rashid 3	16.3	24.8	57.2	97.44	8.5	2.63

Table 4

Average water losses through evapotranspiration of water hyacinth and evaporation of water surface for the same infected area in the Rosetta Branch from December 2015 to November 2016.

Date	Reach		ET _o	Kc average	Et=ET _o × Kc	Infection areas	Water losses of water hyacinth	Water losses of water surface
	From (km)	To (km)					mm/d	mm/d
06 Dec. 2015	0.000–79.000		1.88	1.54	2.89	280.38	3403	2213
	79.000–162.500		1.73	1.54	2.66	483.75	5404	3514
	162.500–235.600		1.86	1.54	2.86	190.92	2293	1491
Water losses of evapotranspiration and evaporation in 6 Dec. 2015						955.05	11101	7220
07 Jan. 2016	0.000–79.000		1.93	1.38	2.66	112.55	1259	912
	79.000–162.500		1.81	1.38	2.49	294.15	3085	2236
	162.500–235.600		1.72	1.38	2.37	135.45	1350	978
Water losses of evapotranspiration and evaporation in 07 Jan. 2016						542.15	5695	4126
11 Mar. 2016	0.000–79.000		3.96	1.96	7.76	277.53	9045	4615
	79.000–162.500		3.09	1.96	6.06	430.13	10947	5582
	162.500–235.600		3.32	1.96	6.51	158.64	4337	2212
Water losses of evapotranspiration and evaporation in 11 Mar. 2016						866.30	24330	12410
14 May 2016	0.000–79.000		6.05	2.41	14.58	328.99	20146	8359
	79.000–162.500		5.03	2.41	12.12	974.50	49605	20587
	162.500–235.600		5.3	2.41	12.77	577.54	30975	12856
Water losses of evapotranspiration and evaporation in 14 May 2016						1881.03	100727	41802
15 Jun. 2016	0.000–79.000		6.64	2.31	15.34	312.44	20129	8713
	79.000–162.500		5.83	2.31	13.47	911.92	51590	22329
	162.500–235.600		6.03	2.31	13.93	830.17	48570	21024
Water losses of evapotranspiration and evaporation in 15 Jun. 2016						2054.53	120290	52067
01 Jul. 2016	0.000–79.000		6.26	2.2	13.77	331.95	19198	8727
	79.000–162.500		5.65	2.2	12.43	962.97	50272	22851
	162.500–235.600		5.94	2.2	13.07	1640.63	90060	40930
Water losses of evapotranspiration and evaporation in 01 Jul. 2016						2935.55	159531	72509
17 Jul. 2016	0.000–79.000		6.26	2.2	13.77	210.19	12156	5526
	79.000–162.500		5.65	2.2	12.43	606.38	31656	14389
	162.500–235.600		5.94	2.2	13.07	1148.7	63056	28657
Water losses of evapotranspiration and evaporation in 17 Jul. 2016						1965.27	106869	48573
19 Sep. 2016	0.000–79.000		5.14	1.62	8.33	130.61	4569	2819
	79.000–162.500		4.31	1.62	6.98	459.43	13468	8316
	162.500–235.600		4.72	1.62	7.65	452.75	14546	8975
Water losses of evapotranspiration and evaporation in 19 Sep. 2016						1042.79	32585	20111
15 Oct. 2016	0.000–79.000		3.87	1.34	5.19	169.53	3695	2755
	79.000–162.500		3.29	1.34	4.41	314.93	5833	4351
	162.500–235.600		3.53	1.34	4.73	184.78	3670	2739
Water losses of evapotranspiration and evaporation in 15 Oct. 2016						669.24	13199	9846
16 Nov. 2016	0.000–79.000		2.73	1.39	3.79	135.22	2155	1550
	79.000–162.500		2.41	1.39	3.35	278.35	3916	2817
	162.500–235.600		2.63	1.39	3.66	155.53	2388	1717
Water losses of evapotranspiration and evaporation in 16 Nov. 2016						569.10	8459	6085
Average water losses through evapotranspiration of water hyacinth and evaporation of water surface (m ³ /day)							58279	27475
Average water losses through evapotranspiration of water hyacinth and evaporation of water surface (million m ³ /year)							21.3	10.0

Kc average: calculated by Meleha (2005).

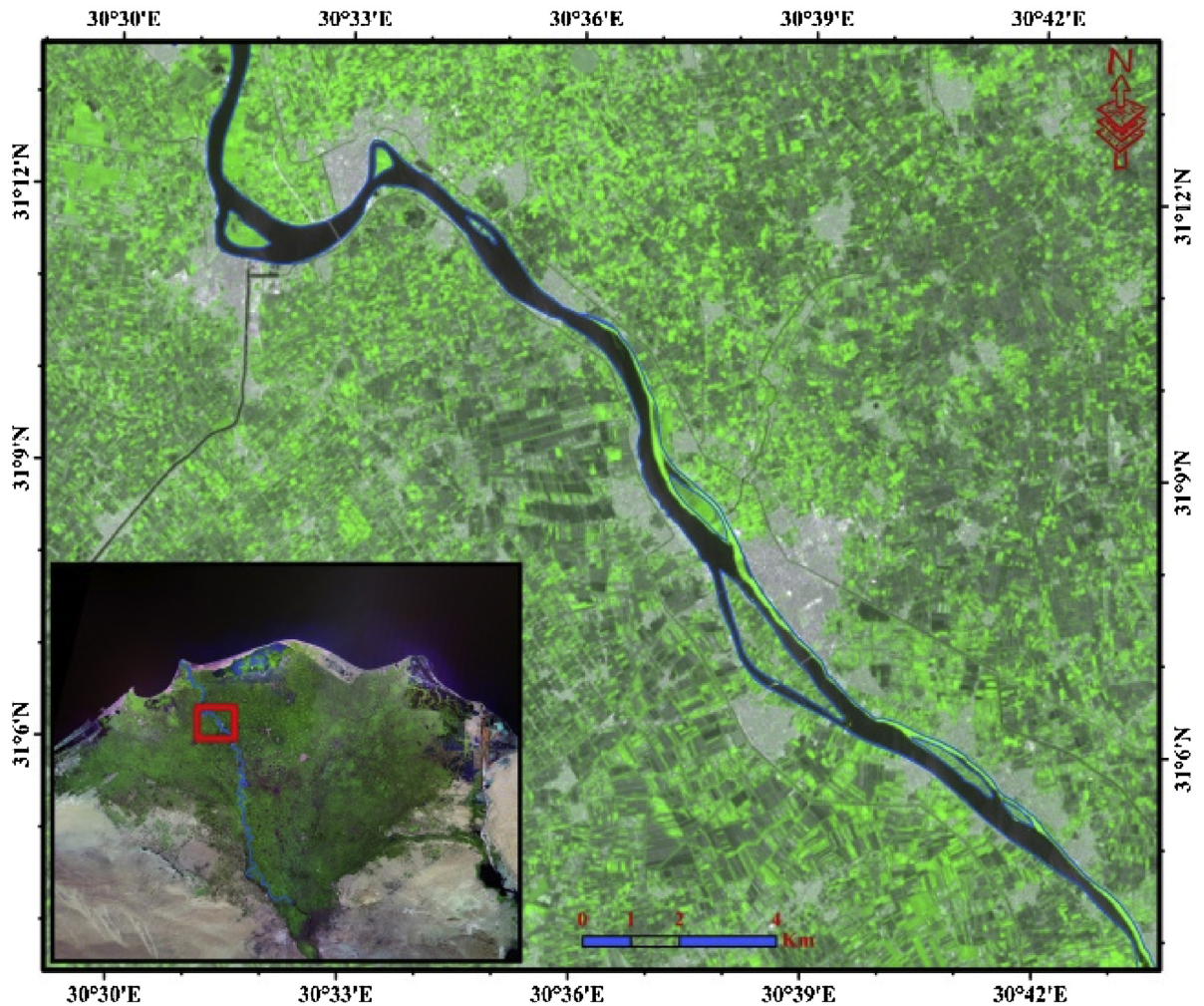


Fig. 4. Aquatic weeds from Desouq city to Fuwah city in 14 May. 2016.

to November 2016. Average daily evapotranspiration rate of water hyacinth was $58,279 \text{ m}^3/\text{d}$, while, evaporation of free surface for the same infested area was $27,475 \text{ m}^3/\text{d}$. Average annual of water losses of evapotranspiration of water hyacinth was 21.3 million m^3/y and evaporation of free surface for the same infested area was 10.0 million m^3/y . Evapotranspiration of water hyacinth reached 2.13 fold that found in evaporation of free surface for the same infested area, these results agree with both [El-Shinnawy et al. \(2000\)](#) and [Brezny et al. \(1973\)](#), while, disagree with the results obtained by [Victor et al. \(1987\)](#) which was recorded values of evapotranspiration of water hyacinth higher than the values obtained in this research. The highest values of water losses from water hyacinth reached $159,531 \text{ m}^3/\text{d}$ which recorded in 01 Jul. 2016, while, the lowest values of water losses reached $5695 \text{ m}^3/\text{d}$ which recorded in 07 Jan. 2016.

[Tables 5 and 6](#) present average water losses through evapotranspiration that were calculated for both of Common Reed and Torpedo grass compared to evaporation of water surface for the same infested area from Rosetta Branch during the period of this research. The results show average daily evapotranspiration rate for both of Common Reed and Torpedo grass was 1875 and $2938 \text{ m}^3/\text{d}$, while, evaporation of water surface for the same infested area was 1473 and $2251 \text{ m}^3/\text{d}$, respectively. Average annual of water losses of evapotranspiration for both of Common Reed and Torpedo grass was 0.68 million and 1.07 million m^3/y respectively, while, evaporation of water surface for the same infested area was 0.54 million and 0.82 million m^3/y , respectively. Evapotranspiration for both of Common Reed and Torpedo grass reached 1.27 and 1.30 fold that found in evaporation of free surface for the same infested area respectively. These results agree with [Angela et al. \(2014\)](#), while, the results obtained in this research recorded values of evapotranspiration

Table 5

Average water losses through evapotranspiration of Common Reed and evaporation of water surface for the same infected area in the Rosetta Branch from December 2015 to November 2016.

Date	Reach		ETo mm/d	Kc average	Et = Et _o × Kc mm/d	Infection areas feddan	Water losses of Common Reed	Water losses of water surface
	From (km)	To (km)					m ³ /d	m ³ /d
06 Dec. 2015	0.000–79.000		1.88	1.08	2.03	44.80	382	354
	79.000–162.500		1.73	1.08	1.87	16.64	131	121
	162.500–235.600		1.86	1.08	2.01	30.15	254	235
Water losses of evapotranspiration and evaporation in 6 Dec. 2015						91.59	767	710
07 Jan. 2016	0.000–79.000		1.93	0.69	1.33	21.32	119	173
	79.000–162.500		1.81	0.69	1.25	13.81	73	105
	162.500–235.600		1.72	0.69	1.19	16.62	82	120
Water losses of evapotranspiration and evaporation in 07 Jan. 2016						51.75	274	398
11 Mar. 2016	0.000–79.000		3.96	0.60	2.37	50.93	508	847
	79.000–162.500		3.09	0.60	1.85	20.86	162	271
	162.500–235.600		3.32	0.60	1.99	10.85	91	151
Water losses of evapotranspiration and evaporation in 11 Mar. 2016						82.64	761	1269
14 May 2016	0.000–79.000		6.05	1.24	7.50	42.09	1326	1070
	79.000–162.500		5.03	1.24	6.24	33.99	891	718
	162.500–235.600		5.3	1.24	6.57	27.2	750	605
Water losses of evapotranspiration and evaporation in 14 May 2016						103.29	2967	2393
15 Jun. 2016	0.000–79.000		6.64	1.27	8.43	33.49	1186	934
	79.000–162.500		5.83	1.27	7.40	30.55	950	748
	162.500–235.600		6.03	1.27	7.66	19.69	633	498
Water losses of evapotranspiration and evaporation in 15 Jun. 2016						83.73	2769	2180
01 Jul. 2016	0.000–79.000		6.26	1.28	8.01	28.81	971	757
	79.000–162.500		5.65	1.28	7.23	35.98	1092	854
	162.500–235.600		5.94	1.28	7.60	29.33	936	732
Water losses of evapotranspiration and evaporation in 01 Jul. 2016						94.13	2999	2343
17 Jul. 2016	0.000–79.000		6.26	1.28	8.01	31.29	1053	823
	79.000–162.500		5.65	1.28	7.23	37.75	1146	896
	162.500–235.600		5.94	1.28	7.60	26.73	854	666
Water losses of evapotranspiration and evaporation in 17 Jul. 2016						95.77	3053	2385
19 Sep. 2016	0.000–79.000		5.14	1.98	10.17	11.44	489	247
	79.000–162.500		4.31	1.98	8.53	14.18	508	257
	162.500–235.600		4.72	1.98	9.35	11.36	446	225
Water losses of evapotranspiration and evaporation in 19 Sep. 2016						36.98	1443	729
15 Oct. 2016	0.000–79.000		3.87	1.63	6.31	43.12	1142	701
	79.000–162.500		3.29	1.63	5.36	38.26	862	529
	162.500–235.600		3.53	1.63	5.75	14.82	358	220
Water losses of evapotranspiration and evaporation in 15 Oct 2016						96.20	2362	1450
16 Nov. 2016	0.000–79.000		2.73	1.55	4.23	34.85	619	399
	79.000–162.500		2.41	1.55	3.74	29.65	466	300
	162.500–235.600		2.63	1.55	4.08	15.74	269	174
Water losses of evapotranspiration and evaporation in 16 Nov. 2016						80.24	1354	873
Average water losses through evapotranspiration of Common Reed and evaporation of water surface (m ³ /day)							1875	1473
Average water losses through evapotranspiration of Common Reed and evaporation of water surface (million m ³ /year)							0.68	0.54

Kc average: calculated by [Rashed, 2014](#).

Table 6

Average water losses through evapotranspiration of Torpedo grass and evaporation of water surface for the same infected area in the Rosetta Branch from December 2015 to November 2016.

Month	Reach		ETo	Kc average	Et = Eto × Kc	Infection areas	Water losses of Torpedo grass	Water losses of water surface
	From (km)	To (km)						
06 Dec. 2015	0.000–79.000		1.88	1.21	2.27	74.37	710	587
	79.000–162.500		1.73	1.21	2.09	26.88	236	195
	162.500–235.600		1.86	1.21	2.25	19.32	183	151
Water losses of evapotranspiration and evaporation in 06 Dec. 2015						120.57	1129	933
07 Jan. 2016	0.000–79.000		1.93	0.8	1.54	54.14	351	439
	79.000–162.500		1.81	0.8	1.45	19.15	116	145
	162.500–235.600		1.72	0.8	1.38	12.11	70	87
Water losses of evapotranspiration and evaporation in 07 Jan. 2016						85.40	537	671
11 Mar. 2016	0.000–79.000		3.96	0.56	2.22	73.66	686	1225
	79.000–162.500		3.21	0.56	1.80	36.08	272	486
	162.500–235.600		3.32	0.56	1.86	15.09	118	210
Water losses of evapotranspiration and evaporation in 11 Mar. 2016						124.83	1076	1921
14 May 2016	0.000–79.000		6.05	1.28	7.74	56.51	1838	1436
	79.000–162.500		3.21	1.28	4.11	49.32	851	665
	162.500–235.600		5.3	1.28	6.78	31.87	908	709
Water losses of evapotranspiration and evaporation in 14 May 2016						137.69	3597	2810
15 Jun. 2016	0.000–79.000		6.64	1.32	8.76	70.38	2591	1963
	79.000–162.500		5.83	1.32	7.69	57.28	1851	1402
	162.500–235.600		6.03	1.32	7.96	28.98	969	734
Water losses of evapotranspiration and evaporation in 15 Jun. 2016						156.64	5411	4099
01 Jul. 2016	0.000–79.000		6.26	1.32	8.26	53.76	1866	1413
	79.000–162.500		5.65	1.32	7.46	57.54	1802	1365
	162.500–235.600		5.94	1.32	7.84	38.39	1264	958
Water losses of evapotranspiration and evaporation in 01 Jul. 2016						149.68	4932	3736
17 Jul. 2016	0.000–79.000		6.26	1.32	8.26	53.48	1856	1406
	79.000–162.500		5.65	1.32	7.46	62.43	1955	1481
	162.500–235.600		5.94	1.32	7.84	52.75	1737	1316
Water losses of evapotranspiration and evaporation in 17 Jul. 2016						168.65	5548	4203
19 Sep. 2016	0.000–79.000		5.14	1.82	9.35	23.4	919	505
	79.000–162.500		4.31	1.82	7.84	26.7	880	483
	162.500–235.600		4.72	1.82	8.59	15.97	576	317
Water losses of evapotranspiration and evaporation in 19 Sep. 2016						66.07	2375	1305
15 Oct 2016	0.000–79.000		3.87	1.71	6.62	57.16	1589	929
	79.000–162.500		3.29	1.71	5.63	43.61	1030	603
	162.500–235.600		3.53	1.71	6.04	15.26	387	226
Water losses of evapotranspiration and evaporation in 15 Oct. 2016						116.03	3006	1758
16 Nov. 2016	0.000–79.000		2.73	1.65	4.50	46.52	880	533
	79.000–162.500		2.41	1.65	3.98	35.55	594	360
	162.500–235.600		2.63	1.65	4.34	16.32	297	180
Water losses of evapotranspiration and evaporation in 16 Nov. 2016						98.39	1771	1073
Average water losses through evapotranspiration of Torpedo grass and evaporation of water surface (m³/day)							2938	2251
Average water losses through evapotranspiration of Torpedo grass and evaporation of water surface (million m³/year)							1.07	0.82

Kc average: calculated by [Rashed \(2014\)](#).

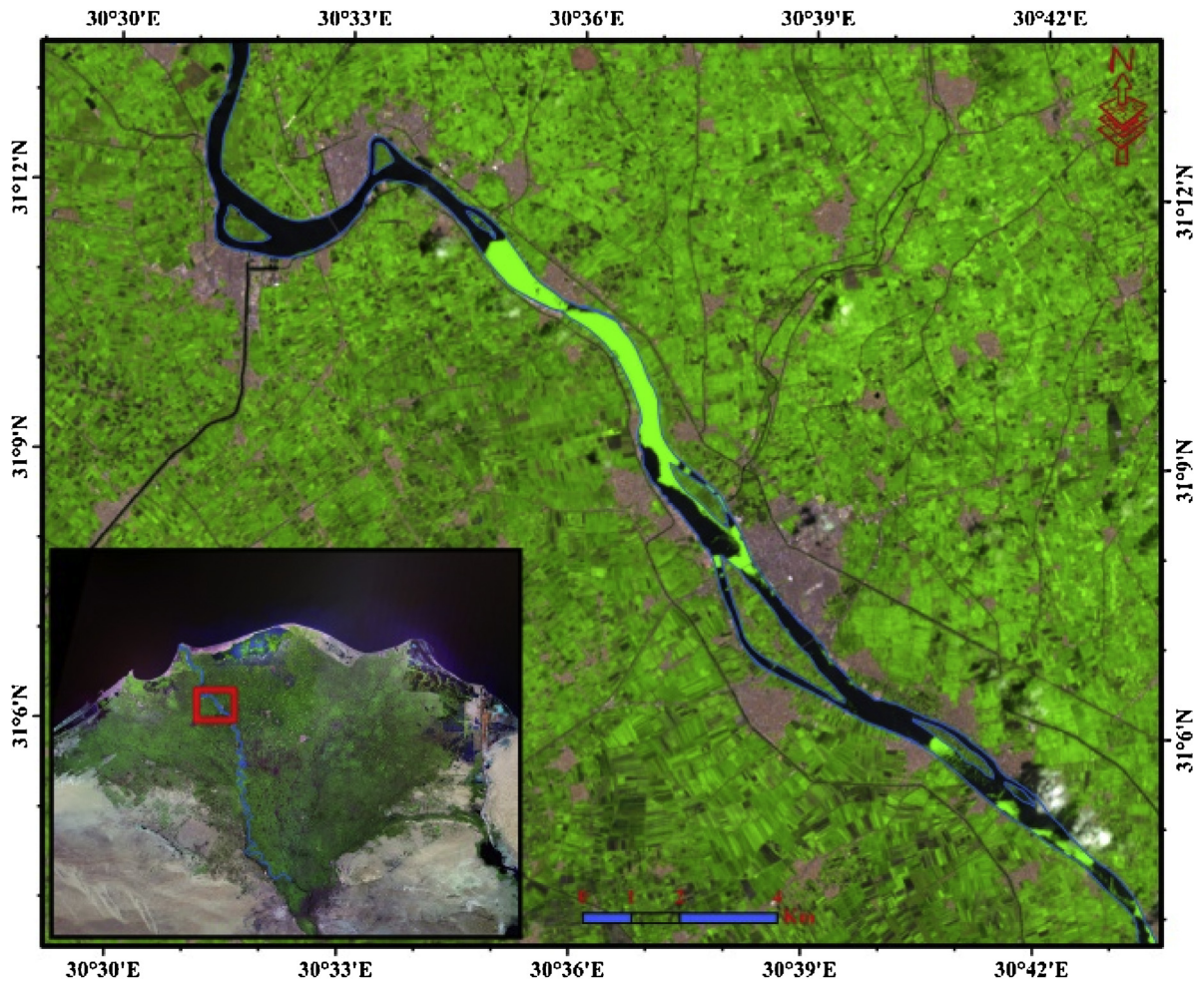


Fig. 5. Aquatic weeds from Desouq city to Fuwah city in 17 Jul. 2016.

for both Common Reed and Torpedo grass less than the values obtained by Florentina et al. (2016) and Rosa et al. (2009) for plants similar to the same species. The highest value of water losses for both of Common Reed and Torpedo grass reached 3053 and 3006 m³/d respectively which recorded in 17 Jul. 2016 and 15 Oct. 2016, while, the lowest value of water losses reached 274 and 537 m³/d which recorded in 07 Jan. 2016 for both of them, respectively.

4. Conclusions

Growth of aquatic weeds (water hyacinth especially) in Rosetta Branch causes many serious problems. Wherefore, it must be managed and controlled to a minimum infestation level. Field visits to Rosetta Branch for inventory and classification of various types of aquatic weeds and using of satellite imagery to identify areas and percentages of infestation by the aquatic weeds has been done. Meteorological data collected from meteorological stations located in the Rosetta Branch were analyzed using the program Cropwat 8. The water losses through evapotranspiration of aquatic weeds in the Rosetta Branch during the study period were estimated. It can be concluded that:

- The monitoring of aquatic weeds in Rosetta Branch during the period from December 2015 to November 2016 showed that the infestation areas by different types of weeds, ranged between 679.30–3179.37 feddan of water surface area which is equivalent to infestation percentage ranged between 5.07–20.86%. Infestation areas of water hyacinth, Common Reed and Torpedo grass ranged between 542.15–2935.55, 36.98–103.29 and 66.07–168.85 feddan which

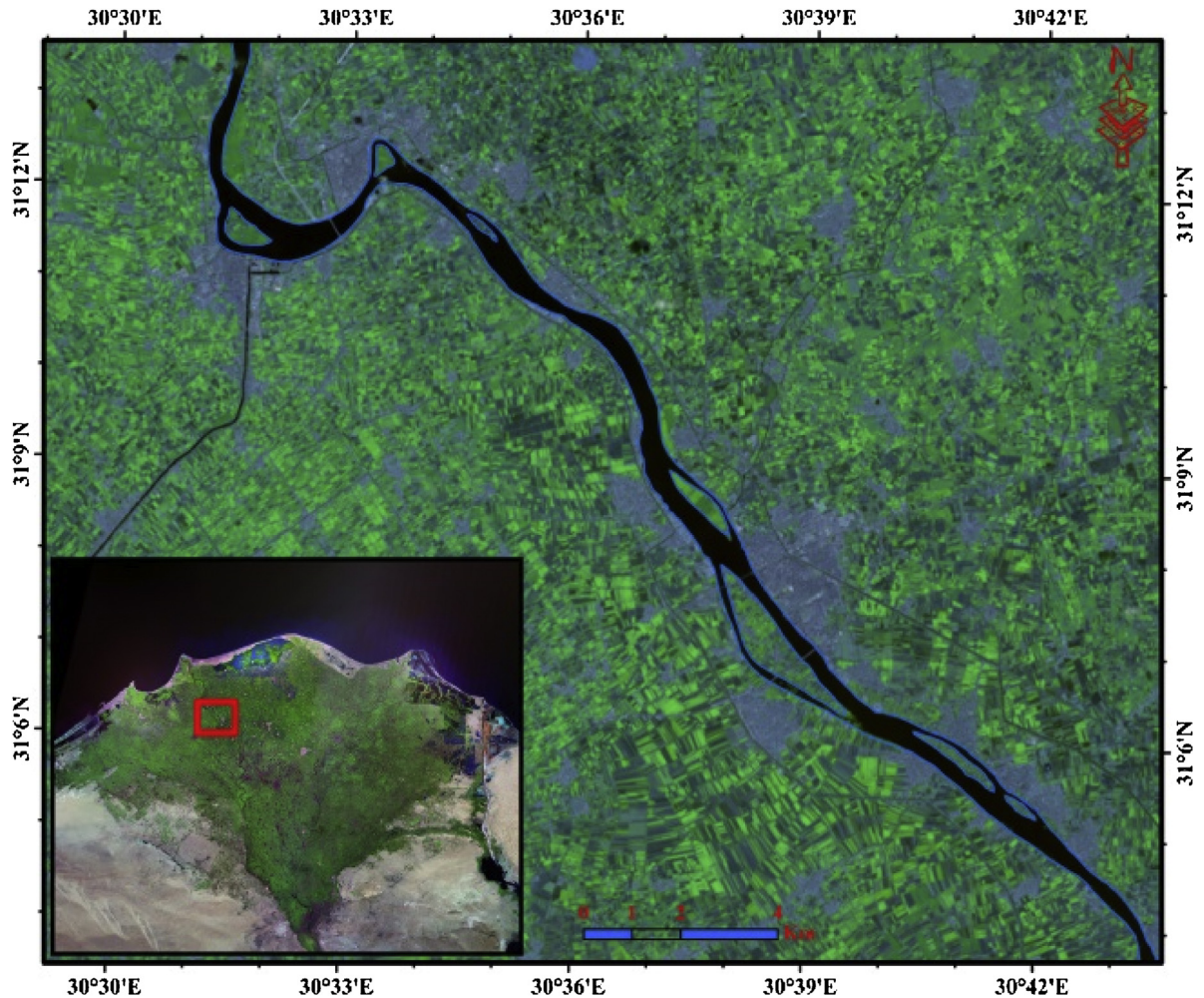


Fig. 6. Aquatic weeds from Desouq city to Fuwah city in 15 Oct. 2016.

is equivalent to infestation percentage ranged between 4.04–19.26, 0.24–0.74 and 0.44–1.20% respectively of the total water surface area of Rosetta Branch.

- In Rosetta Branch, average annual evapotranspiration rate of water hyacinth, Common Reed and Torpedo grass was 21.3 million m^3/y , 0.7 million m^3/y and 1.1 million m^3/y , which represent about 92%, 3%, 5% of evapotranspiration from those weeds respectively. While, evapotranspiration of water hyacinth, Common Reed and Torpedo grass reached 2.12, 1.27 and 1.30 fold that found in evaporation of free surface for the same infected area, respectively.

Thus, it could be concluded that the main problem of water losses through evapotranspiration of aquatic weeds in the Nile River (Rosetta Branch) represented in water hyacinth, according to the present study more than 90% of water losses were from water hyacinth.

5. Recommendations

From the result of this paper, it can be recommended that:-

- Monitoring of aquatic weeds by using geographic information system and remote sensing to estimate the aquatic weeds infestation in irrigation and drainage networks and Nile River (Rosetta Branch especially) is strongly recommended, in order to prepare the maintenance programs for different types of aquatic weeds.

- Identify a management strategy to reduce the excessive growth of aquatic weeds in Rosetta Branch in order to control the weeds as well as prepare a good maintenance plan and raise the technical capacity of the working teams who are responsible for the maintenance work.
- Removal of aquatic weeds, especially water hyacinth accumulated upstream the barriers with appropriate mechanical equipment for this.
- Do not leave the aquatic weeds, especially water hyacinth on the edges of the waterway to prevent renewed infection as a result of re-falling in the waterway and growth and spread of these weeds.
- Provision of trained technical employment for the operation and maintenance of mechanical equipment used in weed removal.

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