ISSN 1110-0419

Annals Of Agric. Sc., Moshtohor,
Vol. 44 (1): 367-392, (2006).

TRENDS OF CROP WATER PRODUCTIVITY UNDER EGYPTIAN CONDITIONS

BY

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ABSTRACT

Crop water productivity (CWP) is defined as Crop yield/Water consumptively used in evapotranspiration (ET). Crop water productivity can be quantified in terms of wet or dry, nutritional value or economic return.

The present study was carried out to estimate crop water productivity of winter, summer and perennial crops in the old lands at Delta, Middle and Upper Egypt regions. The crop productivity through three decades (1972-2002) was obtained from Agricultural Economic Research Institute Bulletins and used with the water consumptive use (ET) to calculate crop water productivity. ETcrop was estimated using CROPWAT4.3 model (Derek *et al.*, 1998).

Results indicate that crop water productivity (CWP) for winter and summer crops were increased in the second and third decades as compared with the first decade. The CWP for perennials was improved in the third decade as compared with the two others. Delta region is the most efficient in CWP as compared with Middle and Upper Egypt, which gave the highest CWP for most of the crops, followed by Middle Egypt region. Decreasing CWP in Upper Egypt may be related to increasing water consumptive use as a result of high temperature. Increasing CWP of any crop in any region encourage the increasing of the cultivated area in this region. This will help in maximizing the water use efficiency in the region.

INTRODUCTION

With increasing population and demand for food, sustainable production increases from irrigated agriculture must be achieved. With limited fresh water and land resources, and increasing competition for these resources, irrigated agriculture worldwide must improve its utilization of these resources (Molden *et al.*, 1998).

Water productivity is an efficiency term quantified as a ratio of product out put (goods and services) over water input. The output could be biological goods or products such as crop (grain, fodder) or livestock (meat, egg, fish) and can be expressed in terms of yield, nutritional value or economic return. The output could also be an environment services or functions. Water productivity can be quantified at different scales, and for a mixture of goods and services.

The overall aim of agricultural water management is to enable farm managers to achieve high levels of irrigation efficiencies, water use efficiencies and crop productivity that will maximize return on investments in rainfed and irrigated conditions under adequate or deficit water supply. This requires accurate predictions of crop water requirements and crop response to water for determining irrigation requirements and planning and implementation of irrigation schedules to achieve desired objectives (Smith, 2002).

The information regarding crop water productivity for Egyptian crops through long period is limited. Fiew researchers calculated water use efficiency or water utilization efficiency for some crops after carrying out field experiments for two years only.

For example, El- Marsafawy (1995) found that the highest water use efficiency (WUE) values for maize crop in Middle Egypt in 1992 and 1993 were 2.38 and 2.41 kg grains/ m^3 water consumption, respectively, obtained when plants irrigated at 0.6 accumulative pan evaporation. Emara, *et al.* (2000) concluded that the highest water utilization efficiency (W.Ut.E.) for sugar beet as expressed as root yield per m^3 of water was about 14 kg/ m^3 and it was accompanied with drought stress at middle of mid-season and middle and end of late-season. On the other hand, the lowest value was about 11 kg/ m^3 resulted from the non stressed treatment. Same trend was obvious regarding (W.Ut.E.) in relation to sugar yield. The average corresponding values of sugar yield were 2.52 and 2.00 kg/ m^3 respectively. Rayan *et al.* (2000) showed that average value of WUE (kg/ m^3) for cotton crop ranged between 0.288 to 0.666 at Shandaweel region (Upper Egypt). El- Samanody *et al.* (2004) found that average WUE value for sunflower crop ranged between 0.38 to 0.53 kg seeds/ m^3 water use at Giza region (Middle Egypt). El- Shenawy *et al.* (2005) stated that increasing the amounts of applied irrigation water for banana, under calcareous soils, and drip irrigation conditions at Nubaria area (North-West Nile Delta), led to an increase in water utilization efficiency (W.Ut.E) values. The highest WUtE value was 4.38 kg/ m^3 obtained from the I_2 (100% ETp) irrigation treatment during the 2003/ 2004 growing season.

Smith (2002) indicated that precise knowledge on crop response to water is essential in a range of applications for policies and investment strategies at national and regional level, as well as in practical management tools at basin, scheme and farm level, as follows:

- To assess the impact of drought, rainfall variability and climatic change on yield, production and environment;
- to evaluate water use efficiency and crop water productivity under prevailing rain patterns and traditional farm practices and define with farmers options for improvement and appropriate strategies to optimize yields and to reduce risks of crop failure related to crop choice, planting time, soil cultivation and

crop cultural practices (weeding, density, fertility) and to define options for water conservation and supplemental irrigation;

- to define under irrigate crop conditions water supply strategies for optimal crop production and economic returns under conditions of reduced water supply and to advise farmers to optimize timing and application rate of crop irrigation for optimal yields and income also under limited water supply;
- to define national and regional policies, plans and strategies to meet food requirements under conditions of drought and limited water supply in rainfed and irrigated agriculture;
- to identify research programmes in crop improvement and natural resources management for improved water productivity in both rainfed and irrigated crop production, including identifying opportunities for biotechnology.

The aim of this study is to evaluate the trends of crop water productivity for Egyptian crops through three decades. The results will reflect the status of crop water management in the Egyptian Agriculture Sector, and the effect of its performance on the crop water productivity.

MATERIALS AND METHODS

Crop Water Productivity

According to Smith (2002) Crop water productivity is defined as Crop yield/Water consumptively used in ET.

I- Crop Yield (Productivity)

Data of crop productivity for winter, summer and perennial crops at the three regions (Delta, Middle and Upper Egypt) was obtained from Agricultural Economic Research Institute Bulletins (Volumes No. 1972 to 2002). The unavailability of yield data for some crops reduced the number of representative years on some graphs.

II- Water Consumptive Use

Water consumptive use or Evapotranspiration (ET crop) was determined using a computer program named CROPWAT4.3 model.

Data needed for CROPWAT4.3 model:

The data needed are:

1. Climate Information.
2. Crop Informations.
3. Soil Information.

1. Climate Information

- Mean monthly temperature (minimum and maximum), humidity, sunshine, wind speed and rainfall data for 31 years (1972-2002) were collected for every region.
- Agrometeorological data for each region were obtained from one representative site within each region as follows:

The Delta region was represented by Sakha (Khafr El-Sheikh Governorate; Lat.: 31.07 N, Long.: 30.57 E, Elev.: 20 m); Middle Egypt was represented by Giza (Giza Governorate; Lat.: 30.03 N, Long.: 31.13 E, Elev.: 19 m) and Upper Egypt was represented by Shandaweel (Sohag Governorate Lat.: 26.26 N, Long.: 31.38 E, Elev.: 60 m).

Tables (1-3) indicate the average weather data (normals) of each governorate (average 31 years).

Table (1): Agroclimatological data for Khfr El-Sheikh (Sakha) region (av. 1972-2002).

Month	Tmax.	Tmin.	Average	RH (%)	SS (hrs)	WS (m/sec)	Rainfall (mm)
January	18.7	6.8	12.8	72	7.0	1.3	13.9
February	19.6	6.9	13.3	70	7.7	1.4	18.8
March	21.7	8.4	15.1	67	8.6	1.6	7.6
April	26.2	11.2	18.7	61	9.6	1.5	2.0
May	30.4	14.4	22.4	56	10.6	1.6	1.3
June	32.3	17.9	25.1	60	11.9	1.6	0.0
July	32.6	20.1	26.4	66	11.6	1.4	0.0
August	32.9	19.8	26.3	69	11.3	1.2	0.0
September	31.9	17.6	24.8	69	10.3	1.1	0.0
October	29.2	15.2	22.2	66	9.3	1.0	1.2
November	25.2	11.9	18.6	67	8.0	1.1	5.8
December	20.3	8.4	14.4	71	6.6	1.1	10.1
Year	26.8	13.2	20.0	66	9.4	1.3	60.7

where: T.max., T.min. = maximum and minimum temperatures °C; RH = relative humidity (%); SS = actual sun shine (hour) and WS = wind speed (m/ sec).

Table (2): Agroclimatological data for Giza region (av. 1972 - 2002).

Month	Tmax.	Tmin.	Average	RH (%)	SS (hrs)	WS (m/sec)	Rainfall (mm)
January	19.4	7.6	13.5	72	7.0	1.9	2.3
February	20.8	8.4	14.6	70	7.8	2.1	2.6
March	23.9	10.9	17.4	63	8.6	2.3	3.0
April	28.9	14.4	21.6	60	9.6	2.4	0.6
May	32.4	17.9	25.1	56	10.7	2.6	0.0
June	34.9	20.9	27.9	58	11.9	2.7	0.0
July	35.1	22.6	28.9	64	11.6	2.3	0.0
August	34.8	22.5	28.6	67	11.3	2.0	0.0
September	33.4	20.9	27.2	67	10.2	2.0	0.0
October	30.4	18.0	24.2	68	9.3	2.0	0.1
November	25.1	12.9	19.0	73	8.0	1.7	1.3
December	30.1	15.4	22.8	72	10.1	2.3	4.6
Year	29.1	16.0	22.6	66	9.7	2.2	14.4

Table (3): Agroclimatological data for Sohag (Shandaweel) region (av. 1972 -2002).

Month	Tmax.	Tmin.	Average	RH (%)	SS (hrs)	WS (m/sec)	Rainfall (mm)
January	20.8	6.5	13.7	64	8.9	1.3	0.0
February	23.4	8.1	15.8	63	9.8	1.6	0.0
March	27.3	11.4	19.4	52	9.9	1.9	0.0
April	32.1	15.3	23.7	39	10.3	1.9	0.0
May	36.3	19.6	27.9	30	11.3	2.2	0.0
June	38.1	22.3	30.2	36	12.3	2.2	0.0
July	37.8	22.8	30.3	46	12.2	1.9	0.0
August	36.5	22.3	29.4	48	11.9	1.9	0.0
September	35.4	20.4	27.9	48	10.8	2.3	0.0
October	32.8	17.9	25.4	48	10.0	1.9	0.0
November	27.2	13.2	20.2	58	9.3	1.6	0.0
December	22.4	8.1	15.3	62	9.0	1.4	0.0
Year	30.8	15.7	23.3	49	10.5	1.8	0.0

2. Crop Information

- Crop information including area and pattern % for different main crops in each site.
- Crop coefficient, growth stages, sowing and harvesting data for each crop. Crop information data for each crop are listed in Table (4).

3. Soil Information

3-1- Dominant soil types in the Governorates for farming system are considered. In this study, medium soil type was selected and used to estimate the soil moisture content of the major type of soil in Egypt. One of the irrigation scheduling criteria scenario with regard to the irrigation timing will be used for the study [User-Defined for application timing (days) or application depths (mm)].

3-2- Soil Description: Total available soil moisture (mm/m depth), maximum infiltration rate (mm/day), maximum rooting depth (m) and initial soil moisture depletion (% of total available moisture). Relevant soil characteristics for medium soil are descriped in Table (5).

- Until now CROPWAT (4.3) cannot calculate the crop water requirement for rice. In this paper ETcrop values for rice were calculated according to Doorenbos and Pruitt (1977) as follows:

$$ET_{crop} = ET0 * Kc$$

Where: ETcrop: Crop evapotranspiration
ET0: Reference crop evapotranspiration
Kc: Crop coefficient

Table (4): Crop Coefficient, growth stages, sowing and harvesting dates and season length for the main crops.

Crop	Crop Coefficient (Kc)			Growth Stages (day)				Sowing Date	Harvesting Date	Season Length (day)
	1	2	3	1	2	3	4			
Winter crops										
Barley	0.30	1.15	0.60	30	40	50	30	Nov.1	Apr. 1	150
Cabbage	0.40	1.05	0.75	25	45	45	35	Sep. 1	Feb. 1	150
Cucumber	0.45	1.20	0.75	20	30	25	15	Oct. 1	Jan. 1	90
Dry bean	0.45	1.20	0.60	20	40	40	35	Oct. 15	Mar. 1	135
Egg- Plant	0.45	1.20	0.75	30	40	50	30	Nov. 1	Apr. 1	150
Faba bean	0.40	1.15	0.60	30	45	45	30	Nov. 1	Apr. 1	150
Garlic	0.45	1.20	0.75	30	40	50	30	Oct. 1	Mar. 1	150
Green bean	0.45	1.20	0.75	20	35	30	20	Oct. 15	Feb. 1	105
Onion	0.45	1.20	0.75	30	40	50	30	Oct. 1	Mar. 1	150
Pepper	0.40	1.05	0.90	30	40	40	40	Oct. 1	Mar. 1	150
Potato	0.50	1.15	0.75	25	30	35	30	Oct. 1	Feb. 1	120
Squash	0.45	1.20	0.75	25	40	40	30	Nov. 1	Mar. 15	135
Sugar beet	0.35	1.20	0.70	35	45	50	50	Oct. 1	Apr. 1	180
Tomato	0.50	1.15	0.75	30	40	45	35	Sep. 1	Feb. 1	150
Wheat	0.30	1.15	0.50	30	65	40	30	Nov. 15	May-01	165
Summer crops										
Cabbage	0.40	1.05	0.75	25	45	45	35	May-01	Oct. 1	150
Cotton	0.35	1.15	0.60	30	50	60	50	Mar. 15	Sep. 20	190
Cucumber	0.45	1.20	0.75	20	30	25	15	Mar. 1	Jun. 1	90
Dry bean	0.45	1.20	0.60	20	30	40	30	Mar. 1	Jul. 1	120
Egg- Plant	0.45	1.20	0.75	30	40	50	30	Mar. 15	Aug. 12	150
Green bean	0.45	1.20	0.75	20	25	30	20	Mar. 1	Jun. 5	95
Groundnut	0.40	1.15	0.70	25	30	40	25	May-01	Aug. 29	120
Maize	0.30	1.20	0.75	25	40	35	20	May-15	Sep. 15	120
Onion	0.45	1.20	0.75	30	40	50	30	Apr. 15	Sep. 15	150
Pepper	0.40	1.05	0.90	30	40	40	40	Apr. 1	Sep. 1	150
Potato	0.50	1.15	0.75	25	30	35	30	Feb. 1	Jun. 1	120
Rice	1.00	1.20	1.00	30	30	30	30	Jun. 1	Oct. 1	120
Sorghum	0.35	1.10	0.65	20	35	40	25	May-15	Sep. 15	120
Soybean	0.40	1.15	0.60	20	35	40	25	May-01	Sep. 1	120
Squash	0.45	1.20	0.75	25	40	40	30	Apr. 1	Aug. 15	135
Sunflower	0.35	1.15	0.60	20	25	30	15	May-01	Aug. 1	90
Tomato	0.50	1.15	0.75	30	40	45	35	Mar.1	Aug. 1	150
Perennials										
Alfalfa	0.40	1.20	0.80	50	130	150	35	Jan. 1	Dec. 31	365
Banana	1.00	1.20	1.00	135	60	140	30	Jan. 1	Dec. 31	365
Date	0.70	0.80	0.60	140	30	150	45	Jan. 1	Dec. 31	365
Grapes	0.40	0.80	0.40	50	100	75	45	Mar. 1	Nov. 30	270
Mango	0.60	1.00	0.80	90	90	90	95	Jan. 1	Dec. 31	365
Orange	0.50	1.00	0.70	150	90	90	35	Jan. 1	Dec. 31	365
Sugarcane	0.40	1.25	0.75	30	60	180	95	Feb. 1	Jan. 31	365

Reference crop evapotranspiration (ET0) was calculated using CROPWAT4.3 model, and crop coefficient (Kc) was obtained from the FAO paper No. 33 (Doorenbos and Kassam, 1986), and modified for the crops under study..

Table (5): Relevant soil characteristics (soil retention capacity) for medium soil.

Soil Description	Medium
Total available soil moisture (mm/m depth)	110.0
Maximum infiltration rate (mm/day)	40.0
Maximum rooting depth (m)	2.0
Initial soil moisture depletion (%)	50

RESULTS AND DISCUSSION

I- Winter Crops

The crop water productivity (CWP) for barley, cabbage, cucumber, dry bean, egg plant, faba bean, garlic, green bean, onion, pepper, potato, squash, sugarbeet, tomato and wheat are shown in Table (6) and figs. (1-15).

Results indicated that CWP for winter crops were increased in the second and third decades as compared with the first decade. The fluctuation between results from year to year and from region to other may be due to the differences between weather conditions, genotypes and other factors. Average values of the three decades as recorded in Table (6) clearly show that Delta region was superior in CWP for barley, cucumber, faba bean, green bean, onion, squash, sugarbeet and wheat as compared with Middle and Upper Egypt. While, In Middle Egypt the superiority of this character was found for dry bean, egg plant, garlic, pepper and onion as compared with the two others. In Upper Egypt, it superior for Potato crop only. Decreasing number of superior crops in Upper Egypt in despite of increasing in productivity for some crops may be due to increasing temperature which caused increase in ETcrop and decrease in CWP.

The change percent of CWP between superior region and other two regions are presented in Table (7). Results indicated that increasing percentage of CWP in Delta compared to Middle and Upper Egypt ranged between (13.2-42.8) and (13.5-142.0)%, respectively. While, in Middle Egypt, the increasing percentage of CWP ranged between (4.5-21.2) and (12.2-73.9)% compared to Delta and Upper Egypt, respectively. In Upper Egypt CWP for potato crop increased by 3.1 and 13.1% compared to CWP in Delta and Middle Egypt, respectively. From the previous results it can be concluded that the high level of CWP (for some crops) in one region encourage to increase the cultivated area for these crops in this region.

In this connection, Doorenbos and Kassam (1986) found that the water utilization efficiency for harvested yield (Ey) for cabbage, faba bean, onion, pepper, potato, sugarbeet, tomato and wheat are (12-20), (0.3-0.6), (8-10), (1.5-3.0), (4-7), (6-9), (10-12), and (0.8-1.0) kg/ m^3, respectively. Rayan *et al.* (1999) indicated that water use efficiency (WUE) for wheat crop at Shandaweel region (Upper Egypt) ranged between 0.43 to 1.44 kg grains/ m^3 water consumptive use. El- Marsafawy (2000) showed that average values of WUE for wheat crop ranged between 0.83 to 1.70 kg grains/ m^3 water consumption at Giza region (Middle Egypt).

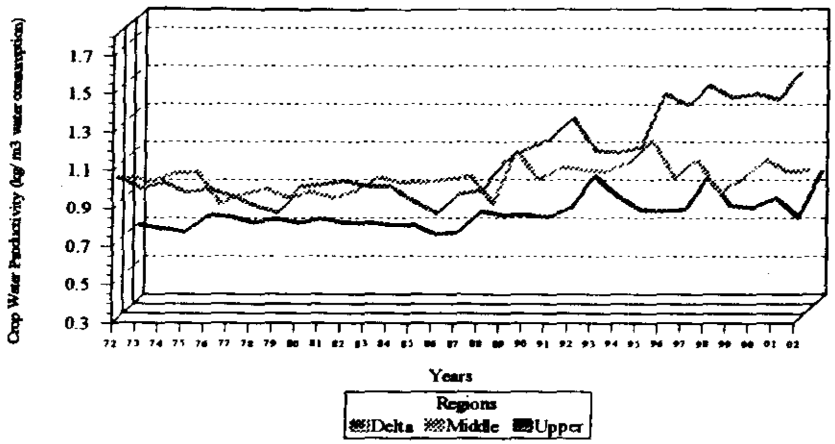

Fig. (1): Trends of crop water productivity for barley crop in Delta, Middle and Upper Egypt.

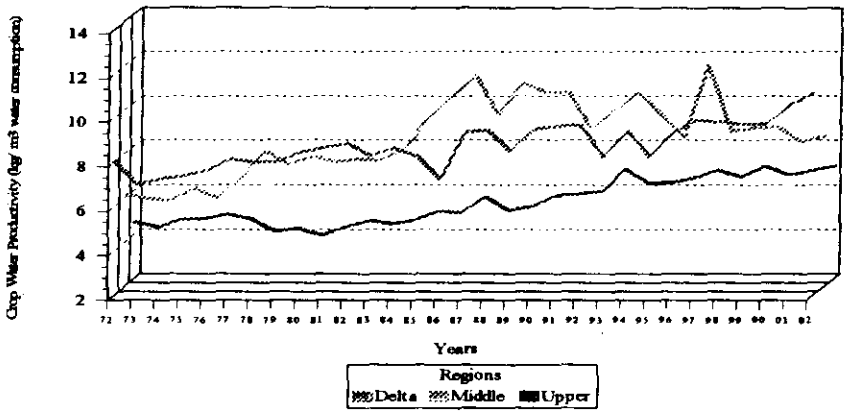

Fig. (2): Trends of crop water productivity for cabbage crop in Delta, Middle and Upper Egypt.

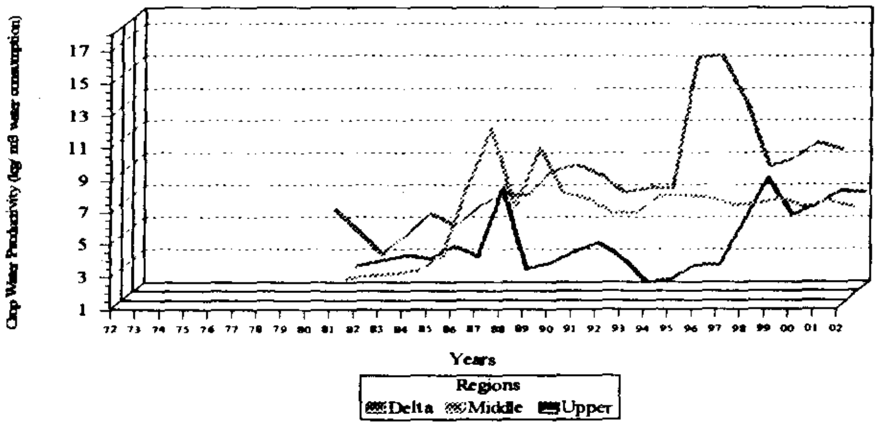

Fig. (3): Trends of crop water productivity for cucumber crop in Delta, Middle and Upper Egypt.

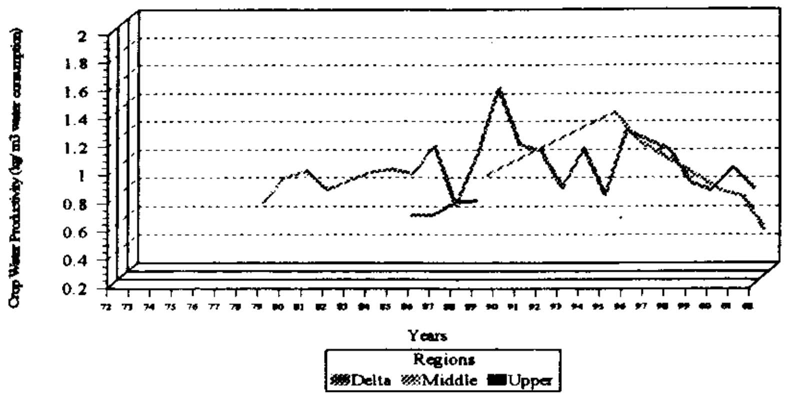

Fig. (4): Trends of crop water productivity for dry beans crop in Delta, Middle and Upper Egypt.

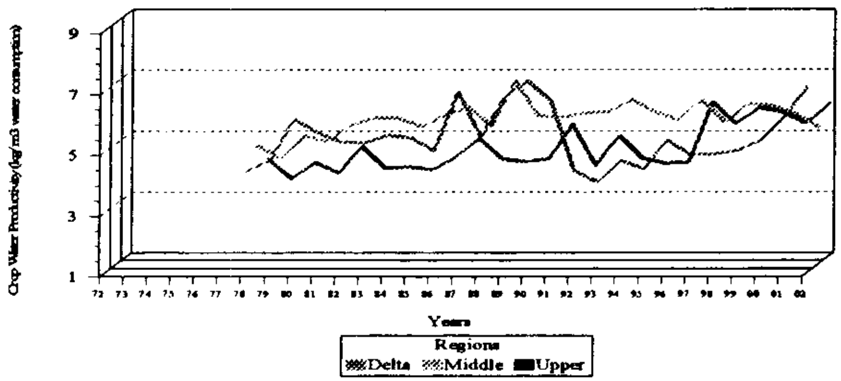

Fig. (5): Trends of crop water productivity for egg plant in Delta, Middle and UppeEgypt.

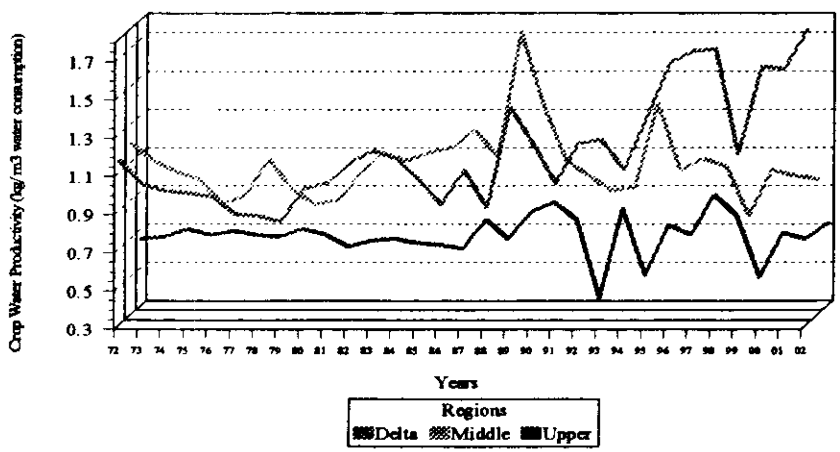

Fig. (6): Trends of crop water productivity for faba bean (dry) in Delta, Middle and Upper Egypt.

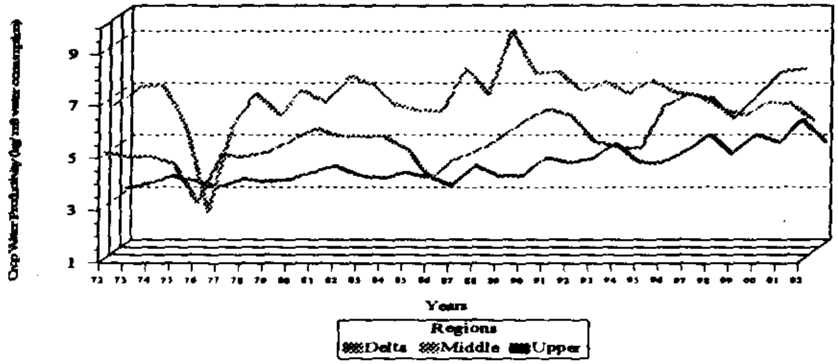

Fig. (7): Trends of crop water productivity for garlic crop in Delta, Middle and UppeEgypt.

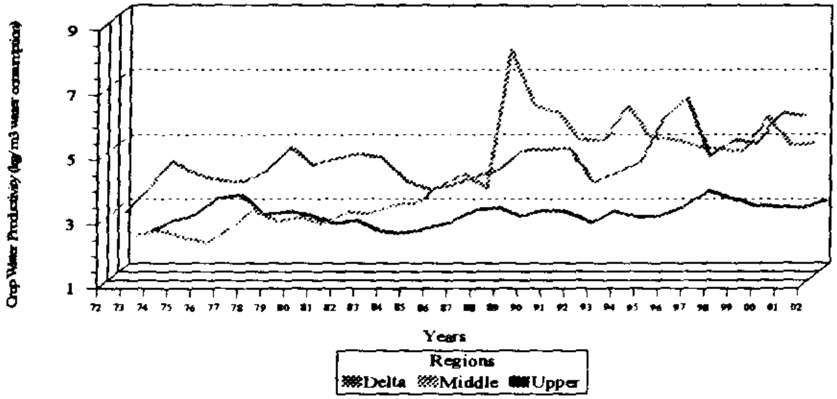

Fig. (8): Trends of crop water productivity for green beans crop in Delta, Middle and UpperEgypt.

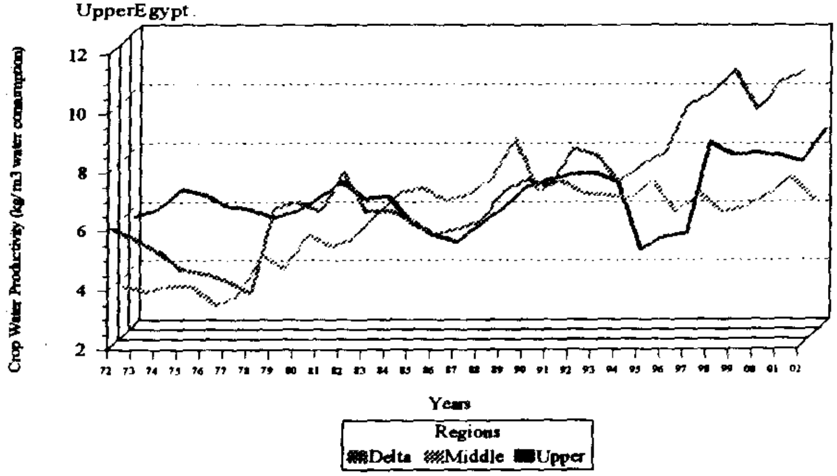

Fig. (9): Trends of crop water productivity for onion crop in Delta, Middle and Upper Egypt.

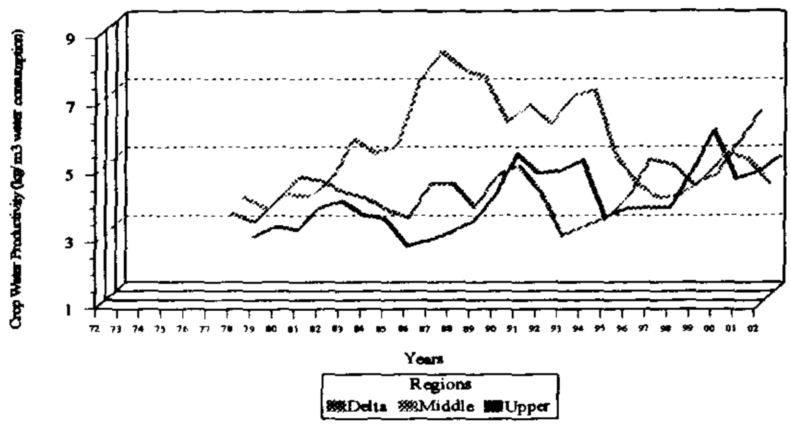

Fig. (10): Trends of crop water productivity for pepper crop in Delta, Middle and UpperEgypt.

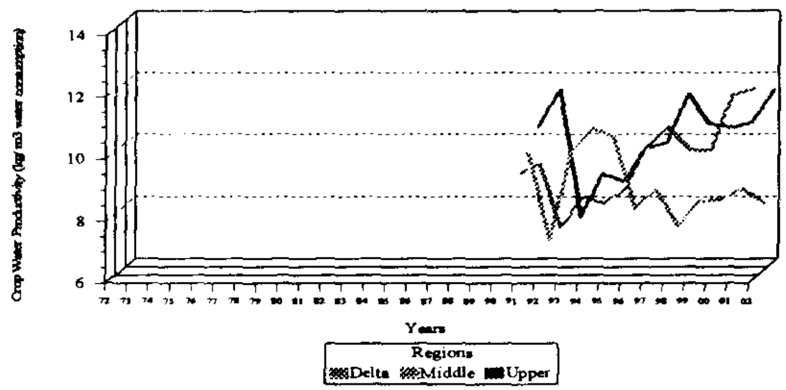

Fig. (11): Trends of crop water productivity for potato crop in Delta, Middle and Upper Egypt.

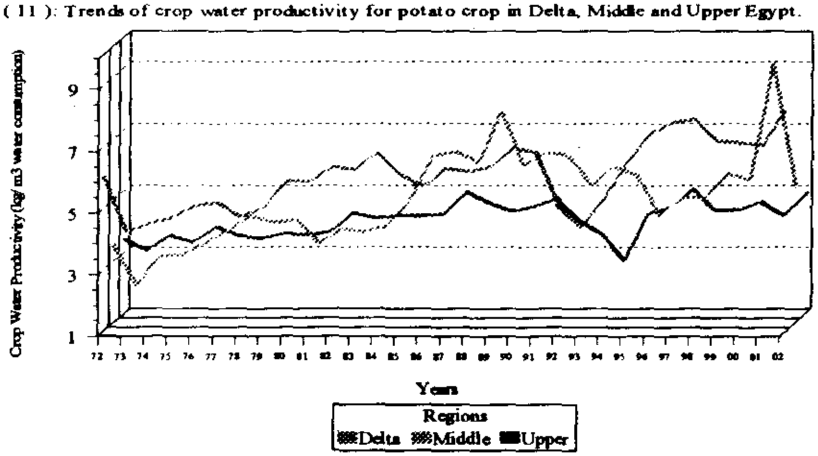

Fig. (12): Trends of crop water productivity for squash crop in Delta, Middle and Upper Egypt.

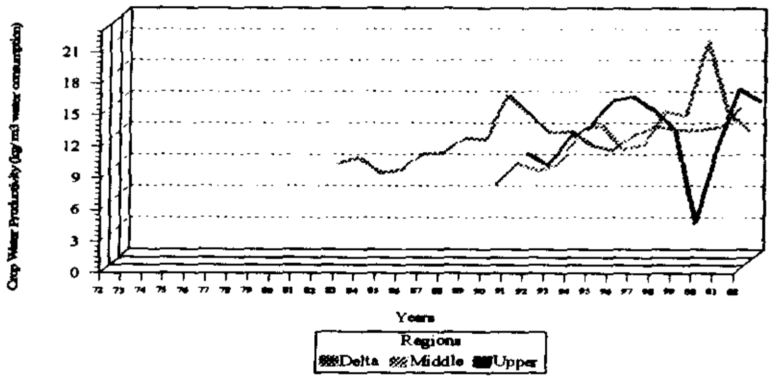

Fig. (13): Trends of crop water productivity for sugarbeet crop in Delta, Middle and Upper Egypt.

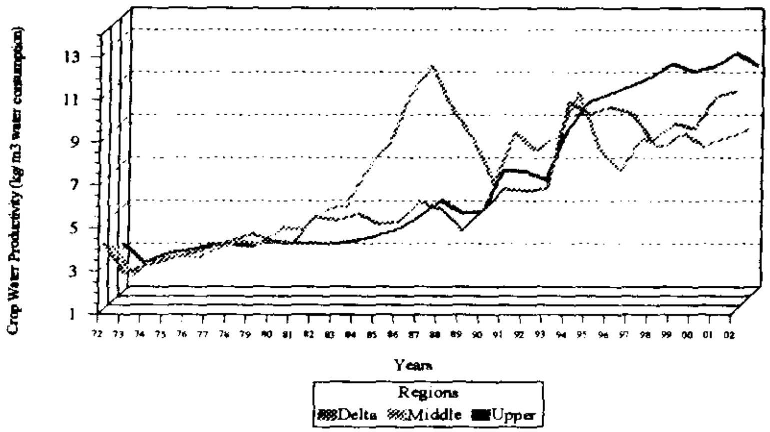

Fig. (14): Trends of crop water productivity for tomato crop in Delta, Middle and Upper Egypt.

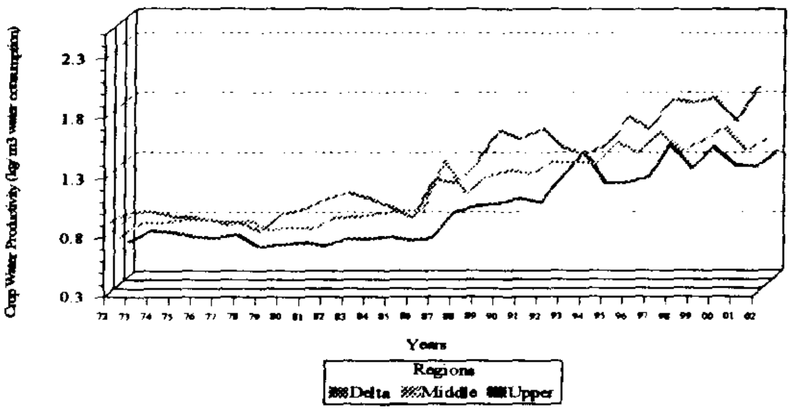

Fig. (15): Trends of crop water productivity for wheat crop in Delta, Middle and Upper Egypt.

II- Summer Crops

CWP for cabbage, cotton, cucumber, dry bean, egg plant, green bean, groundnut, maize onion, pepper, potato, rice, sorghum, soybean, squash, sunflower and tomato are presented in Table (6) and figs. (16-32).

Table (6):Trends of crop water productivity (CWP) for the main crops grown in Delta, Middle and Upper Egypt through three decades.

Crop	Delta				Middle Egypt				Upper Egypt			
	First decade (72-81)	Second decade (82-91)	Third decade (92-02)	Av.	First decade (72-81)	Second decade (82-91)	Third decade (92-02)	Av.	First decade (72-81)	Second decade (82-91)	Third decade (92-02)	Av.
Winter crops												
Barley	0.96	1.02	1.38	1.12	0.93	0.98	1.04	0.98	0.70	0.71	0.83	0.75
Cabbage	7.88	8.78	9.57	8.74	6.86	9.81	9.56	8.74	4.44	5.12	6.44	5.33
Cucumber	1.38	6.24	10.90	6. 17	0.42	5.84	6.71	4.32	0.45	3.04	4.17	2.55
Dry bean	0.55	1.06	1.03	0.88	...	0.95	0.98	0.97	...	0.62	...	0.62
Egg-Plant	4.15	5.98	5.07	5.07	3.95	5.92	6.02	5.30	3.13	4.35	5.01	4.16
Faba bean	0.98	1.13	1.48	1.20	1.00	1.23	0.95	1.06	0.67	0.69	0.65	0.67
Garlic	4.93	5.51	6.66	5.70	6.25	7.47	6.89	6.87	3.45	3.70	4.70	3.95
Green bean	3.95	4.65	5.42	4.67	2.27	4.46	5.33	4.02	2.39	2.51	2.84	2.58
Onion	5.32	6.69	9.47	7.16	4.00	6.85	6.67	5.84	6.11	5.99	6.84	6.31
Pepper	3.23	4.37	4.54	4.05	3.11	6.42	5.20	4.91	2.27	3.29	4.13	3.23
Potato	...	1.88	9.81	5.85	...	1.96	8.70	5.33	...	2.08	9.98	6.03
Squash	5.13	6.40	6.63	6.05	3.63	5.68	5.85	5.05	3.48	4.39	4.18	4.02
Sugar beet	...	10.27	13.20	11.74	...	4.18	12.58	8.38	...	4.74	11.77	8.26
Tomato	3.77	5.48	9.48	6.24	3.42	8.24	8.51	6.72	3.03	4.63	10.30	5.99
Wheat	0.94	1.25	1.73	1.31	0.80	1.06	1.44	1.10	0.61	0.76	1.23	0.87
Summer crops												
Cabbage	3.45	3.96	4.26	3.89	2.07	2.04	2.78	2.30	2.25	2.80	2.65	2.57
Cotton	0.25	0.26	0.27	0.26	0.18	0.19	0.24	0.20	0.19	0.16	0.26	0.20
Cucumber	4.36	4.74	4.83	4.64	3.62	3.88	4.27	3.92	2.29	3.53	4.91	3.58
Dry bean	0.37	0.40	0.45	0.41	0.23	0.34	0.34	0.30	0.21	0.29	0.33	0.28
Egg-Plant	3.07	3.13	3.38	3.19	2.64	2.52	2.62	2.59	2.12	1.96	2.25	2.11
Green bean	2.28	2.73	2.90	2.64	1.80	2.03	2.44	2.09	1.06	1.19	1.40	1.22
Groundnut	0.34	0.30	0.49	0.38	0.35	0.31	0.38	0.35	0.24	0.29	0.47	0.33
Maize	0.74	0.93	1.36	1.01	0.62	0.82	1.05	0.83	0.53	0.65	1.02	0.73
Onion	2.16	2.42	3.34	2.64	1.71	1.90	2.73	2.11	...	...	...	...
Pepper	2.26	2.26	2.20	2.24	2.56	2.76	2.26	2.53	1.57	1.67	1.79	1.68
Potato	4.07	4.68	5.37	4.71	3.21	3.89	4.09	3.73	3.19	4.08	3.95	3.74
Rice	0.75	0.84	1.18	0.92	0.57	0.63	0.85	0.68	...	...	...	...
Sorghum	...	...	...	...	0.61	0.64	0.71	0.65	0.54	0.60	0.76	0.63
Soybean	0.29	0.45	0.47	0.40	0.24	0.34	0.37	0.32	0.19	0.30	0.41	0.30
Squash	3.27	2.86	2.76	2.96	2.62	2.47	2.23	2.44	1.62	1.55	1.82	1.66
Sunflower		0.30	0.45	0.38	...	0.40	0.43	0.42	...	0.33	0.45	0.39
Tomato	2.54	3.54	4.57	3.55	2.08	4.02	4.73	3.61	1.49	1.92	3.58	2.33
Perennials												
Alfalfa	...	3.21	3.50	3.36	...	3.18	5.24	4.21	...	2.77	4.21	3.49
Banana	1.41	1.56	2.15	1.71	1.08	0.99	1.36	1.14	0.99	1.01	1.40	1.13
Date	1.14	1.24	1.74	1.32	1.02	1.06	1.27	1.12	0.67	0.54	0.80	0.67
Grapes	1.45	1.28	2.35	1.69	1.40	1.33	1.83	1.52	1.27	1.46	1.97	1.57
Mango	0.57	0.50	0.81	0.63	0.64	0.79	0.73	0.72	0.36	0.53	0.71	0.53
Orange	1.39	1.62	2.01	1.67	0.79	0.92	1.22	0.98	0.81	1.06	1.33	1.07
Sugarcane	4.63	5.34	5.57	5.18	4.66	4.70	5.55	4.97	3.89	4.23	5.34	4.49

Table (7): Change percent of CWP for winter crops between superior region and other two regions.

Crop	Superior region	Change % with the other two regions	
		Middle Egypt	Upper Egypt
Barley	Delta	14.3	49.3
Cucumber		42.8	142.0
Faba bean		13.2	79.1
Green bean		16.2	81.0
Onion		22.6	13.5
Squash		19.8	50.5
Sugarbeet		40.1	42.1
Wheat		19.1	50.6
		Delta	Upper Egypt
Dry bean	Middle Egypt	10.2	56.5
Egg plant		4.5	27.4
Garlic		20.5	73.9
Pepper		21.2	52.0
Tomato		7.7	12.2
		Delta	Middle Egypt
Potato	Upper Egypt	3.1	13.1

Results indicated that CWP for summer crops were improved in the second and third decades as compared with the first decade, except pepper (Delta), egg plant and squash (Middle Egypt), which were decreased in the third decade. Average values of the three decades as recorded in Table (6) indicated that Delta region was superior in CWP for most of summer crops (i.e. cabbage, cotton, cucumber, dry bean, egg plant, green bean, groundnut, maize, potato, soybean and squash) as compared with Middle and Upper Egypt. While, in Middle Egypt the superiority of CWP was found for pepper, sunflower and tomato as compared with the two other regions. Data in Table 6, also show that CWP of onion and rice were better improved in Delta than in Middle Egypt, and CWP of sorghum was better in Middle Egypt than in Upper Egypt.

The change percent of CWP values between superior region and other two regions are presented in Table (8). It can be concluded that increasing percentages of CWP in Delta region were ranged between (8.6 to 69.1) and (15.2 to 116.4)% compared to Middle and Upper Egypt, respectively. While, in Middle Egypt the increasing of CWP percentages as compared to that in Delta and Upper Egypt were ranged between (4.5-21.2) and (12.2-73.9)%, respectively.

According to Doorenbos and Kassam (1986) the water utilization efficiency for harvested yield (Ey) for cotton, groundnut, maize, rice, sorghum, soybean and sunflower were (0.4-0.6), (0.6-0.8), (0.8-1.6), (0.7-1.1), (0.6-1.0), (0.4-0.7) and (0.3-0.5) kg/ m^3, respectively. El- Marsafawy *et al.* (1998) reported that water use efficiency values for maize crop in 1996 were 1.30 and 1.09 kg grains/ m^3 water use for 70 and 140 cm row width, respectively. The same respective values in 1997 were 1.30 and 1.06 kg grains/ m^3 water consumption. Salib *et al.* (1998) found that the highest water use efficiency values by sunflower were 0.575 and 0.564 kg seeds/ m^3 water consumed in 1996 and 1997 seasons, respectively, obtained from applying 30 kg N/ fed. Mohamed *et al.* (2004) showed that water utilization efficiency (WUtE) for soybean crop ranged between 1.15 to 2.32 kg seeds/ mm applied water at Shandaweel region.

III- Perennial Crops

The CWP for alfalfa, banana, dates, grapes, mango, orange and sugarcane are recorded in Table (6) and figs. (33-39).

The results showed that CWP for perennial crops were improved in the third decade as compared with 1st and 2nd decades. Averages of the three decades as shown in Table (6) indicated that Delta region was higher in CWP for banana, date, grapes, orange and sugarcane than that in Middle and Upper Egypt. While, Middle Egypt gave the highest CWP for alfalfa and mango.

The change percent of CWP between superior region and other two regions are presented in Table (9). It can be concluded that increasing percentages of CWP in Delta region ranged between (4.2 to 70.4) and (11.2 to 104.5)% compared to Middle and Upper Egypt, respectively. While, in Middle Egypt the increasing of CWP percentages as compared to that in Delta and Upper Egypt were ranged between (14.3-25.3) and (20.6-35.8)%, respectively.

Table (8): Change percent of CWP for summer crops between superior region and other two regions.

Crop	Superior region	Change % with the other two regions	
	Delta	Middle Egypt	Upper Egypt
Cabbage		69.1	51.4
Cotton		30.0	30.0
Cucumber		18.4	29.6
Dry bean		36.7	46.4
Egg plant		23.2	51.2
Green bean		26.3	116.4
Groundnut		8.6	15.2
Maize		21.7	38.4
Onion		25.1	...
Potato		26.3	25.9
Rice		35.3	...
Soybean		25.0	33.3
Squash		21.3	78.3
	Middle Egypt	Delta	Upper Egypt
Pepper		12.9	50.6
Sorghum		...	3.2
Sunflower		10.5	7.7
Tomato		1.7	54.9

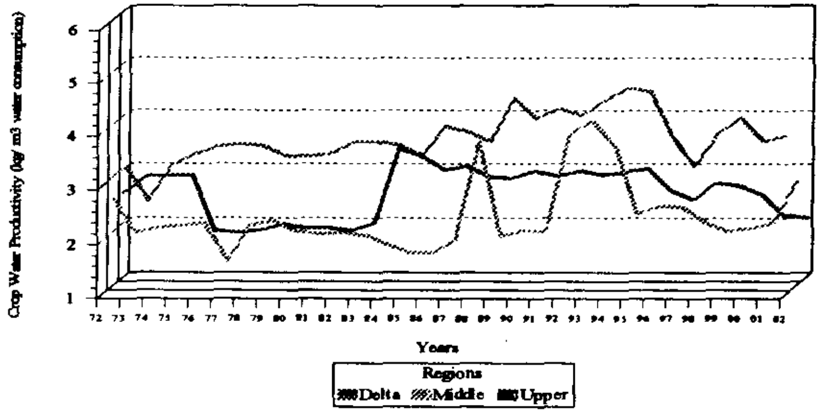

Fig. (16): Trends of crop water productivity for Cabbage crop in Delta, Middle and Upper Egypt.

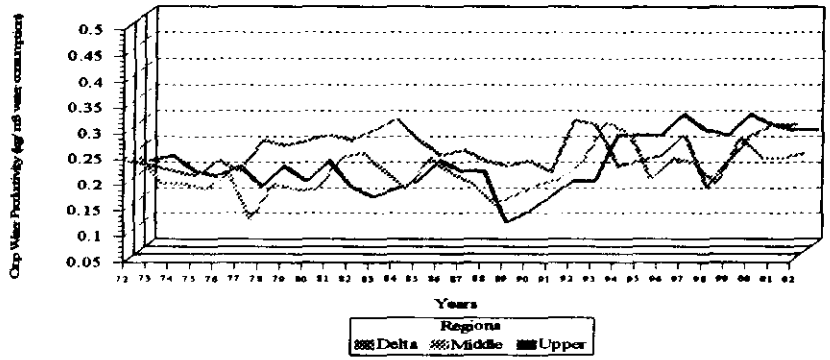

Fig. (17): Trends of crop water productivity for cotton crop in Delta, Middle and Upper Egypt.

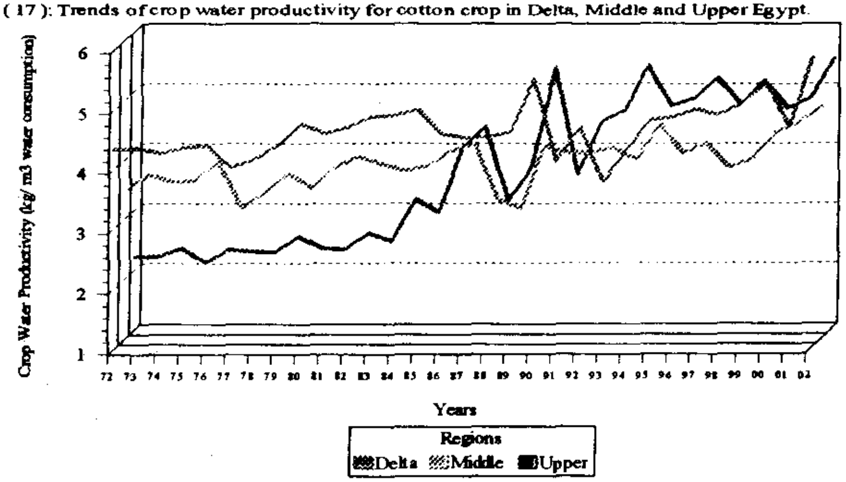

Fig. (18): Trends of crop water productivity for cucumber crop in Delta, Middle and Upper Egypt.

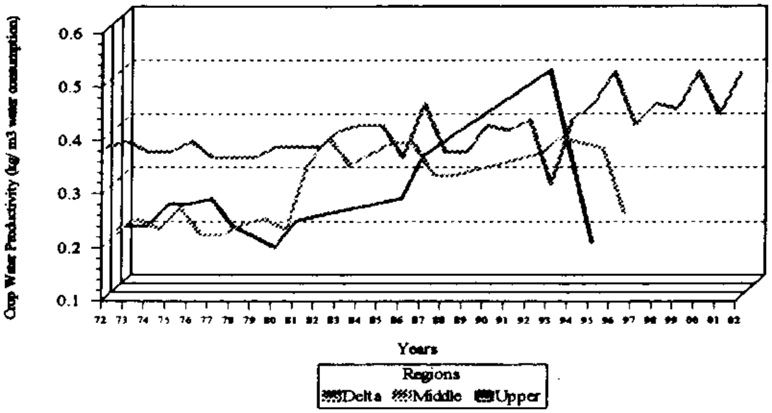

Fig. (19): Trends of crop water productivity for dry beans crop in Delta, Middle and Upper Egypt.

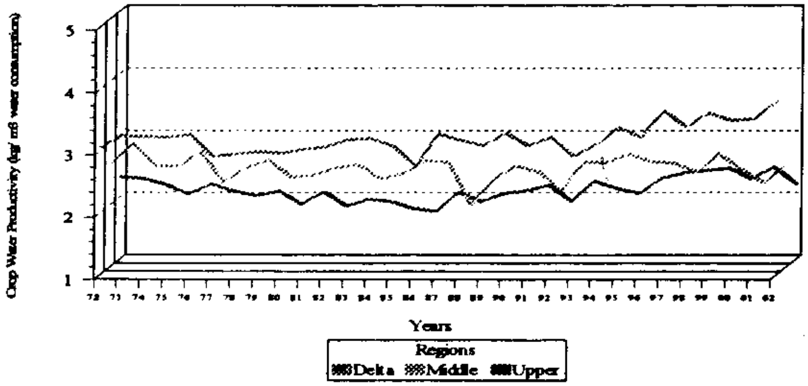

Fig. (20): trends of crop water productivity for egg plant crop in Delta, Middle and Upper Egypt.

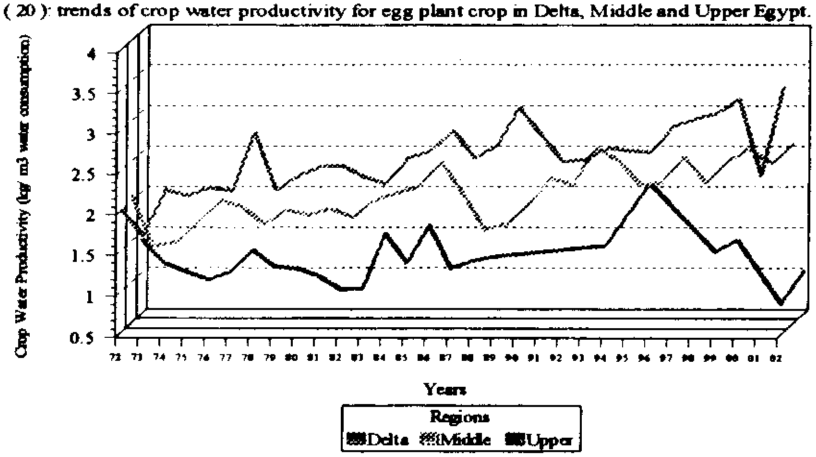

Fig. (21): trends of crop water productivity for green beans crop in Delta, Middle and Upper Egypt.

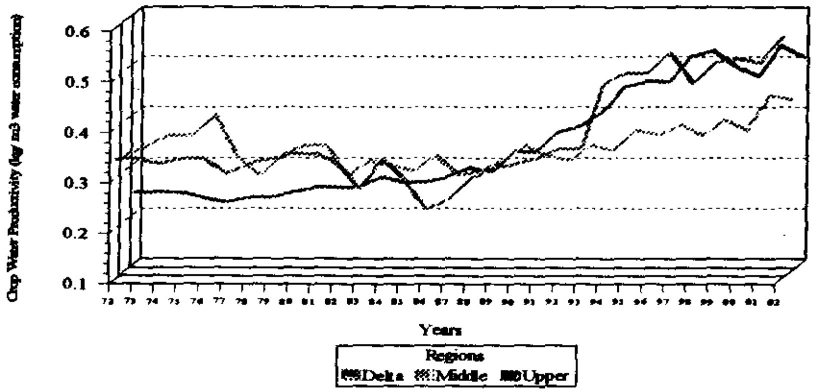

Fig. (22): Trends of crop water productivity for groundnut crop in Delta, Middle and Upper Egypt.

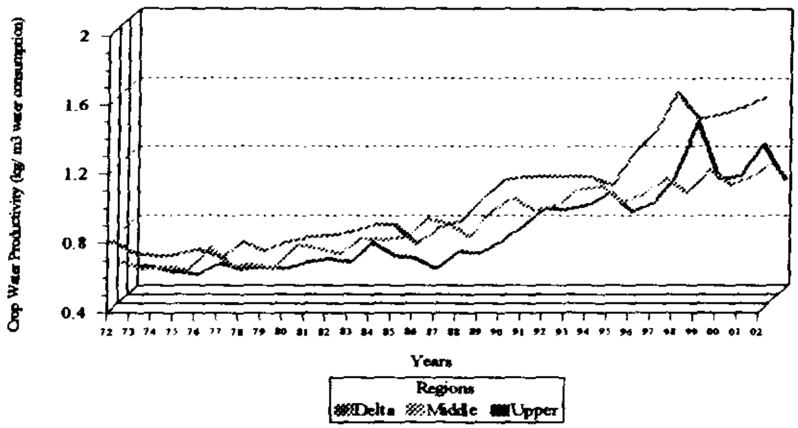

Fig. (23): Trends of crop water productivity for maize crop in Delta, Middle and Upper Egypt.

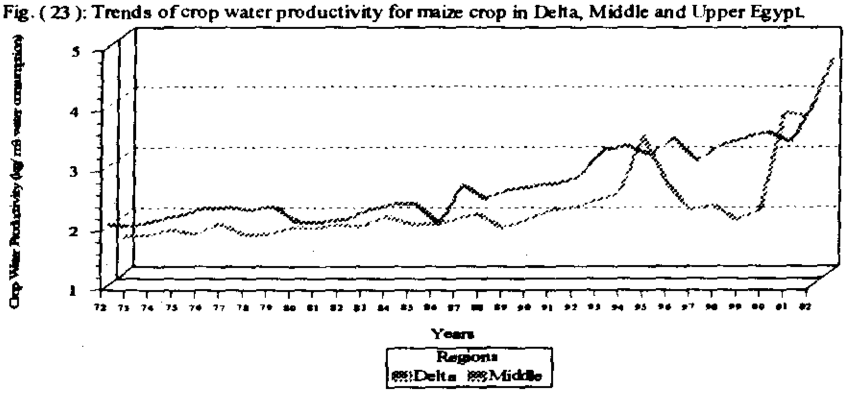

Fig. (24): Trends of crop water productivity for onion crop in Delta and Middle Egypt.

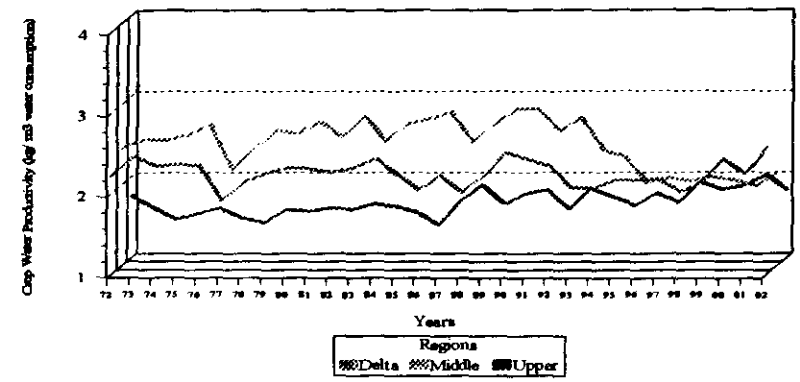

Fig. (25): Trends of crop water productivity for pepper crop in Delta, Middle and Upper Egypt.

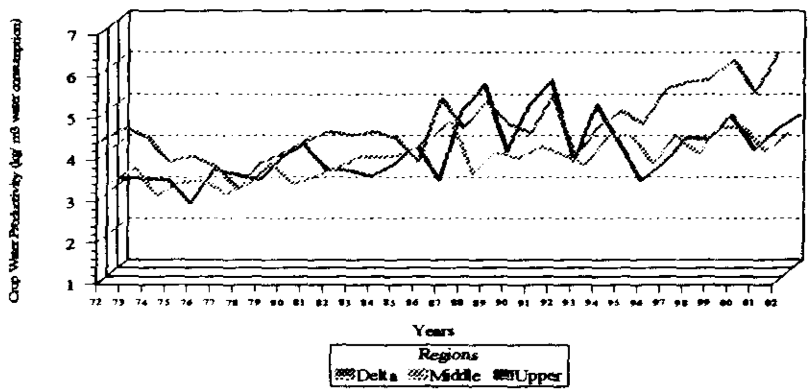

Fig. (26): Trends of crop water productivity for potato crop in Delta, Middle and Upper Egypt.

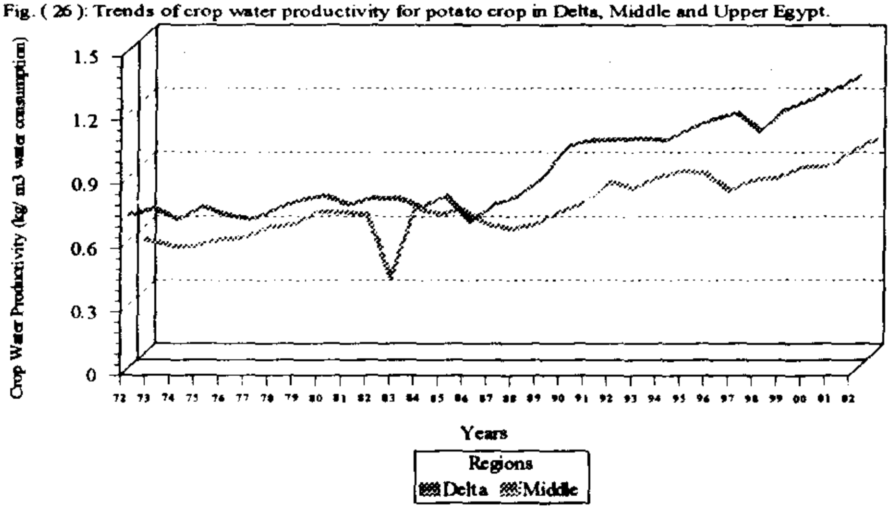

Fig. (27): Trends of crop water productivity for rice crop in Delta and Middle Egypt.

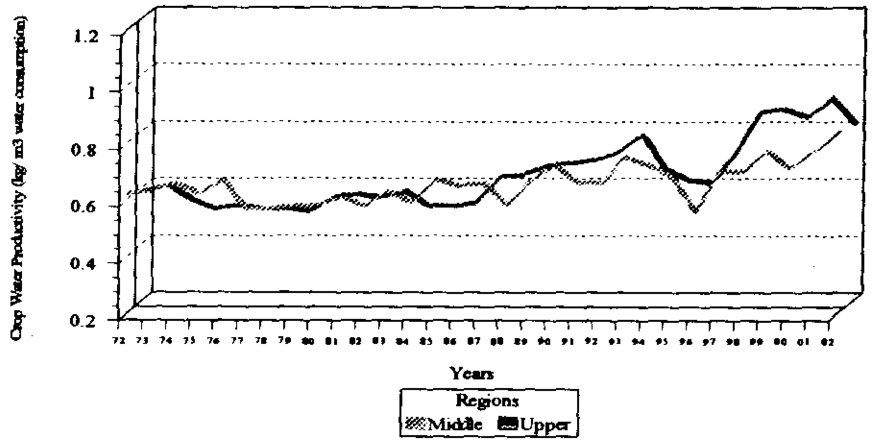

Fig. (28): Trends of crop water productivity for sorghum crop in Middle and Upper Egypt.

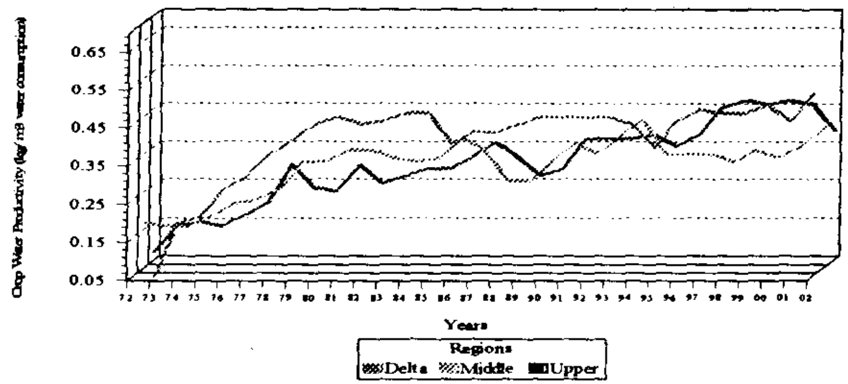

Fig. (29): Trends of crop water productivity for soybean crop in Delta, Middle and Upper Egypt.

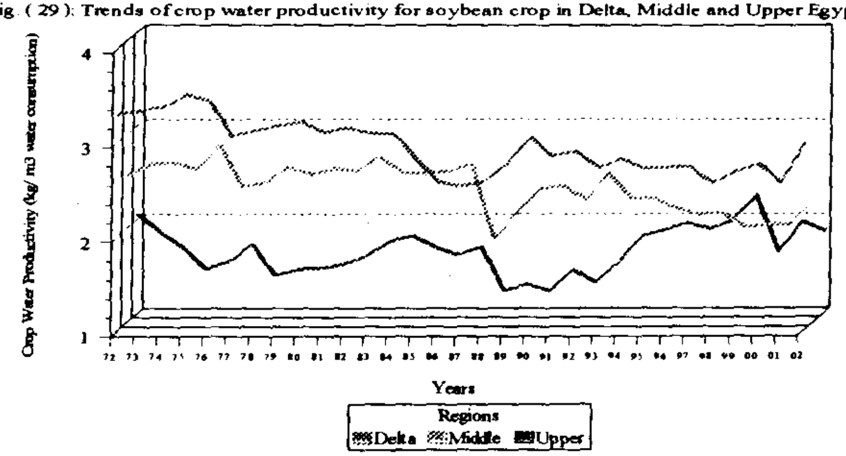

Fig. (30): Trends of crop water productivity for squash crop in Delta, Middle and Upper Egypt.

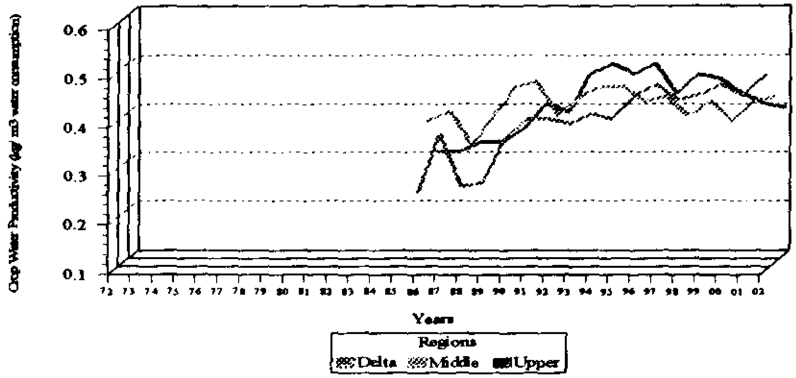

Fig. (31): Trends of crop water productivity for sunflower crop in Delta, Middle and Upper Egypt.

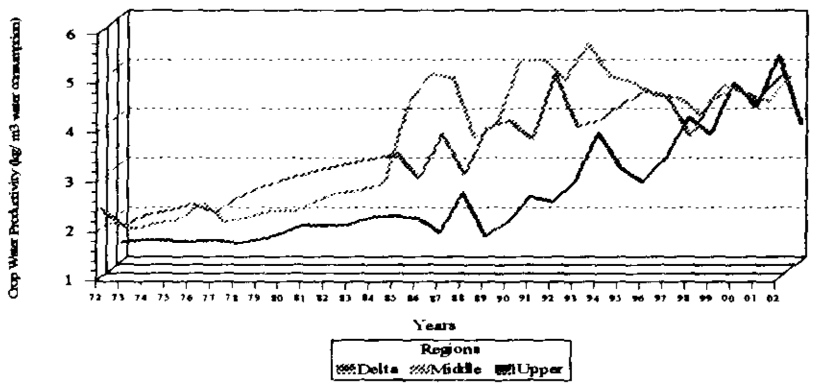

Fig. (32): Trends of crop water productivity for tomato crop in Delta, Middle and Upper Egypt.

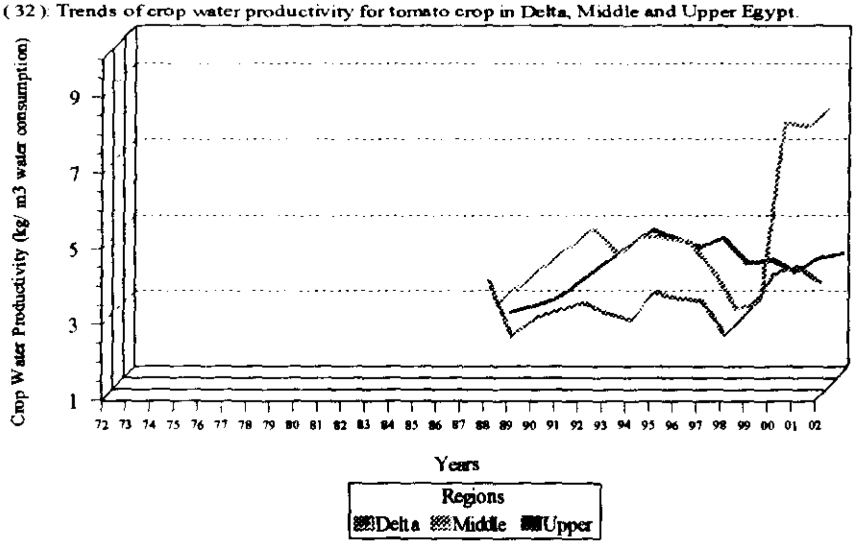

Fig. (33): Trends of crop water productivity for alfalfa crop in Delta, Middle and Upper Egypt.

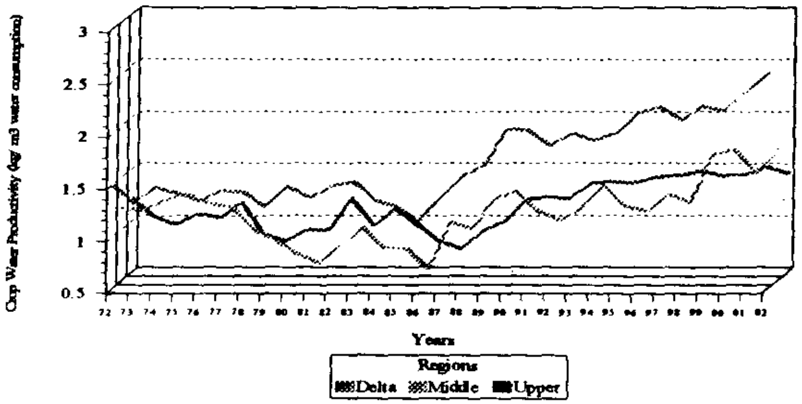

Fig. (34): Trends of crop water productivity for banana crop in Delta, Middle and Upper Egypt.

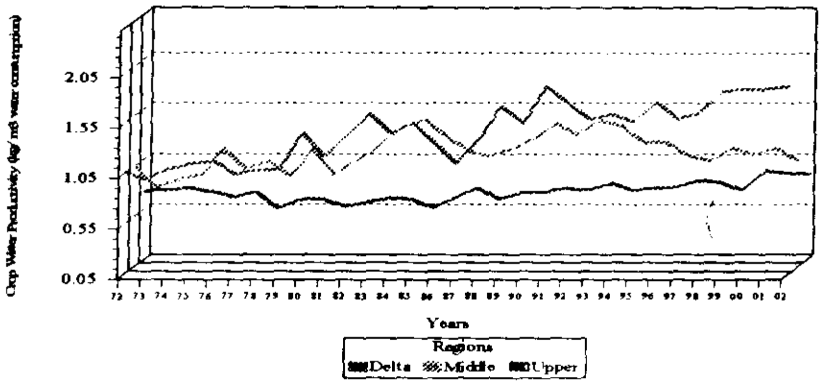

Fig. (35): Trends of crop water productivity for date crop in Delta, Middle and Upper Egypt.

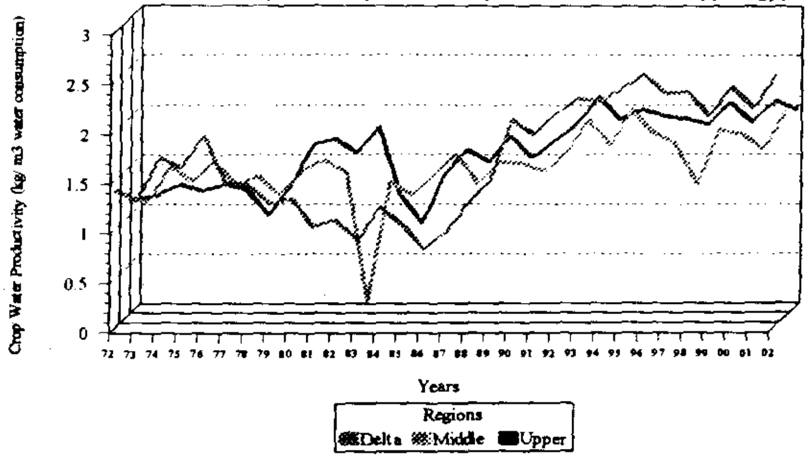

Fig. (36): Trends of crop water productivity for grapes crop in Delta, Middle and Upper Egypt.

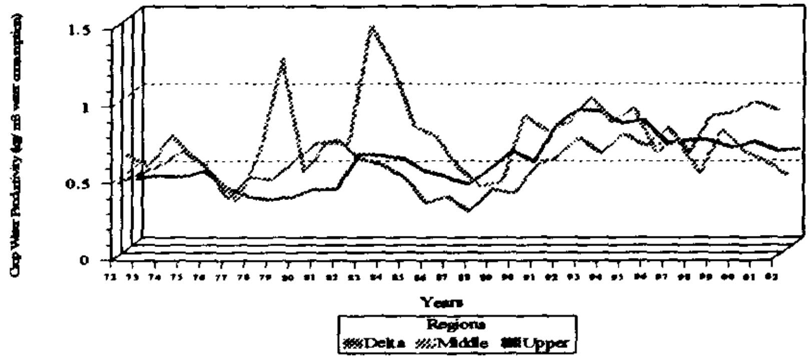

Fig. (37): Trends of crop water productivity for mango crop in Delta, Middle and Upper Egypt.

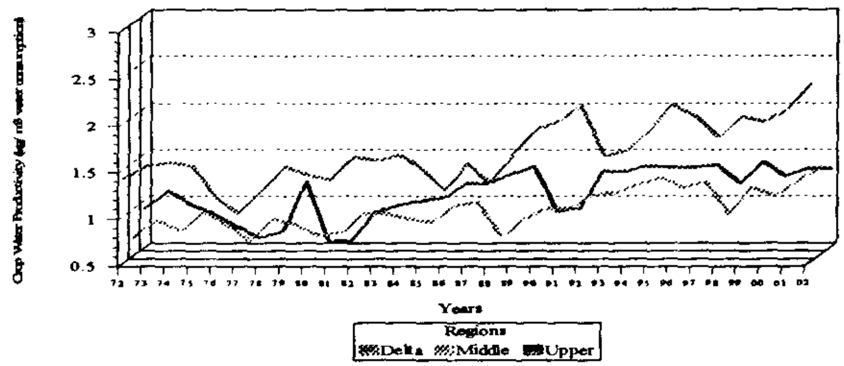

Fig. (38): Trends of crop water productivity for oranges crop in Delta, Middle and Upper Egypt.

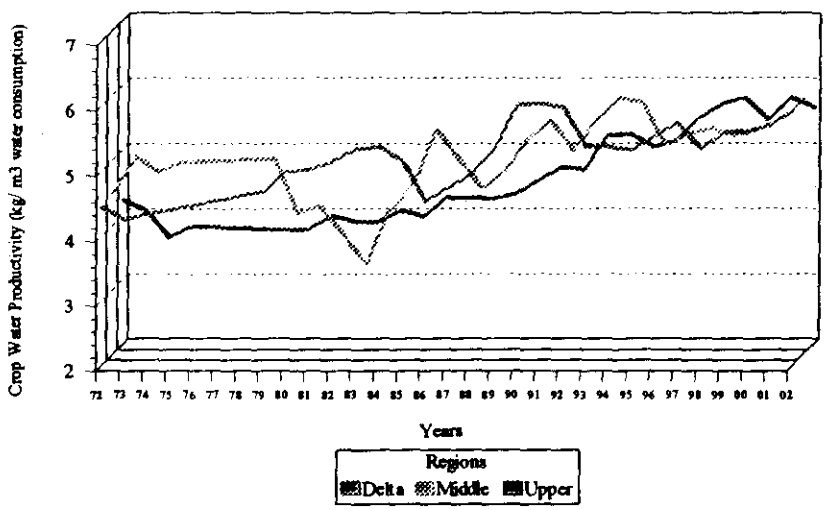

Fig. (39): Trends of crop water productivity for sugarcane crop in Delta, Middle and Upper Egypt.

Table (9): Change percent of CWP for perennial crops between superior region and other two regions.

Crop	Superior region	Change % with the other two regions	
	Delta	Middle Egypt	Upper Egypt
Banana		50.0	51.3
Date		22.3	104.5
Grapes		11.2	7.6
Orange		70.4	56.1
Sugarcane		4.2	15.4
	Middle Egypt	Delta	Upper Egypt
Alfalfa		25.3	20.6
Mango		14.3	35.8

Doorenbos and Kassam (1986) found that the water utilization efficiency for harvested yield (Ey) for alfalfa, banana, citrus, grapes and sugarcane are (1.5-2.0), (2.5-4.0), (2.0-5.0), (2.0-4.0) and (5.0-8.0) kg/ m^3, respectively.

Generally, it can be concluded that CWP for Egyptian crops were increased in the last 20 years for the winter and summer crops and in the last 10 years for perennials as compared with the previous years. These results emphasize on improvement in crop water management in the Egyptian Agriculture sector during the last two decades .

On the other hand, Delta region is the most efficient in CWP as compared with Middle and Upper Egypt, since it gave the highest CWP for most crops, followed by Middle Egypt region. Decreasing CWP in Upper Egypt for most crops may be due to increasing water consumptive use as a result of high temperature. Increasing CWP for some crops in a region encourage increasing the cultivated area of these crops in this region, to maximize the water use efficiency. In Upper Egypt, selecting crops of high yield as well as using efficient irrigation method may improve the CWP in this region.

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اتجاهات إنتاجية المحصول من وحدة المياه تحت الظروف المصرية

سامية محمود المرصفاوى
وحدة بحوث الأرصاد الجوية الزراعية والتغير فى المناخ _ قسم بحوث المقننات المائية والرى الحقلى معهد بحوث الاراضى والمياه والبيئة _ مركز البحوث الزراعية

إنتاجية المياه المحصولية تعرف على إنها نـاتج المحصـول/الاسـتهلاك المائى للمحصول، هذا ويمكن أن تقاس إنتاجية المياه للمحصول على أساس الوزن الجاف أو الرطب أو القيمة الغذائية أو العائد الاقتصادى للناتج المحصولى من وحدة المياه.

وقد أجرى هذا البحث لحساب إنتاجية المياه للمحاصيل المصرية الشتوية والصيفية والمعمرة في الدلتا ومصر الوسطي ومصر العليا ممثلة للاراضى القديمة (أراضى الوادى والدلتا) خلال ٣١ سنة. وقد تم اختيار محافظة كفر الشيخ (سخا) لتمثل منطقة الدلتا & محافظة الجيزة لتمثل منطقة مصر الوسـطى & ومحافظـة سوهاج (شندويل) لتمثل منطقة مصر العليا. بيانات إنتاجية المحاصـيل للمنـاطق الثلاث (الدلتا، مصر الوسطى، مصر العليا) تم الحصـول عليهـا مـن نشـرات الاقتصاد بمعهد الاقتصاد الزراعي خلال الفترة من ١٩٧٢ إلى ٢٠٠٢. بينما تـم حساب الاستهلاك المائى للمحاصيل باستخدام نموذج (CROPWAT4.3) .

ويهدف البحث إلى دراسة اتجاهات إنتاجية المحصول من وحـدة الميـاه خلال ٣١ سنة وذلك لتتبع كفاءة إدارة الرى والمحصـول فـى قطـاع الزراعـة المصرى خلال هذه الفترة ووضع الاستراتيجية الزراعية بنـاءا علـى الجـدارة الإنتاجية.

وقد أوضحت النتائج أن إنتاجية المحصول من وحدة الميـاه للمحاصـيل الشتوية والصيفية زادت فى العقدين الثانى والثالـث (١٩٨٢-٢٠٠٢) بالمقارنـة بالعقد الأول (١٩٧٢-١٩٨١). بينما تفوقت إنتاجية المحاصيل المعمرة فى العقـد الثالث بالمقارنة بالعقدين الأخرين.

ومن ناحية أخرى كانت منطقة الدلتا أكثر كفاءة فى الاستفادة بوحدة المياه مقارنة بمنطقة مصر الوسطى ومصر العليا حيث أعطت أعلى إنتاجية للمحصـول من وحدة المياه لمعظم المحاصيل تحت الدراسة مقارنة بإنتاجية المحصـول مـن وحدة المياه فى كل من مصر الوسطي ومصر العليا وهذا راجـع إلـى انخفـاض درجات الحرارة بها التى يكون لها أثر كبير فى انخفـاض الاحتياجـات المائيـة اللازمة للمحاصيل ومن ثم زيادة العائد من الوحدة الواحدة من الميـاه بهـا. وقـد احتلت مصر الوسطى المركز الثانى بعد منطقة الدلتا فى هذه الصفة.

مما تقدم يمكن استنتاج أن قطاع الزراعة المصرى يسير فى تقدم بما اتبعه من نقل للتكنولوجيا وإدارة جيدة للرى الحقلى خلال العقدين الآخرين بدليل ما حققه من تحسن فى زيادة العائد من وحدة المياه بتقدم السنين مما يكون له أفضل الأثـر فى تقليل الفجوة بين الإنتاج المحلى والاستهلاك من ناحية وخفض الاعتماد علـى الخارج والاستيراد من ناحية أخرى خاصة بالنسبة لمحاصيل الحبوب والمحاصيل الزيتية.

كذلك فان تفوق إنتاجية محصول معين من وحدة المياه فى منطقة مناخية معينة، مقارنة بالمناطق الأخرى، يجعلنا نفكر فى زيادة المساحة المنزرعـة بهـذا المحصول فى هذه المنطقة بدرجة أكبر من محاصيل أخرى قد تتفوق فى منطقـة مناخية أخرى وهذا يؤدى إلى زيادة العائد من وحدة المياه.