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EFFECT OF IRRIGATION IMPROVEMENT ON CROP PATTERN AND CROP WATER REQUIREMENTS USING REMOTE SENSING AND GIS TECHNIQUES

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ABSTRACT

The cropping pattern and crop evapotranspiration (ETc) of a region are mainly affected by the efficiency of the irrigation system. The objectives of this study were to investigate the impact of irrigation projects in North Delta on crop pattern and water consumption. Remote sensing (RS) and GIS techniques were used to evaluate crop pattern and ETc on El Moheet Canal, North Delta. This canal was subject to irrigation improvement practices (Mesqas and Marwas). This study was carried out during two summer growing seasons (2011, before the improvement and 2013, after the improvement).

The obtained results showed that the pixels of the selected canal in both summer growing seasons were classified into 7 land uses (rice, cotton, seed melon, maize, open water, roads, and urban). Before the improvement, cotton was the dominant crop (42.7 %) followed by rice (33.3 %), seed melon (14.5%), and maize (9.5%). However, after the improvement, rice was the dominant crop (74.1%), followed by seed melon (10.7 %), cotton (9.2 %), and maize (6.0 %). The percentage of rice was strongly increased by about 113 % after the improvement. On the other hand, cotton, maize and seed melon were significantly decreased by about 79, 40 and 29 %, respectively, when compared with their areas before the improvement. It could be concluded from the Landsat data that the overall ETc was decreased after irrigation improvement in 2013 by about 4.3 %, whereas water requirement/ha was decreased by about 6.3 %.

The obtained images also showed that the cultivated area was decreased from 2011 to 2013 by about 4.3 % due to urbanization. However, the non-cultivated area was increased by about 25 %. Crop distribution and the equity in water distribution along the branch canal were improved due to irrigation improvement.

In conclusion, the improvement of the irrigation system saved irrigation water and raised the distribution equity of water.

Keywords: Remote Sensing, GIS, ET_c, crop water requirement, El Moheet Canal, North Nile Delta

INTRODUCTION

Water management has become a crucial issue particularly in arid and semi arid zones, which are characterized by scarce or limited water resources. Conserving water resources is a priority for the Egyptian Government through improving the irrigation systems. The World Vision of Water for Food and Rural Development (Hofwegen and Svendsen, 2000) showed that by 2025 the world population would increase by 2 billion inhabitants to a total of approximately 8 billion people. Water requirement critical to livelihood including food production is 1700 m^3/capita. This water is not available for everybody; nearly one-third of the world's population will live in regions that will experience severe water scarcity. Major irrigation projects viz. Irrigation Improvement Projects (IIP) and Irrigation Improvement and Integration Management Project (IIIMP) in the Northern parts of Nile Delta serve as an advantage to the farming community for enhancing the agricultural production and water saving. Introduction of irrigation results in major changes in cropping systems and water consumption.

The cropping pattern and crop evapotranspiration (ET_c) of a region are mainly affected by water availability and irrigation system efficiency. The cropping pattern of a region depends mainly upon the nature and quantum of irrigation water available. It is essential to study the local cropping patterns with respect to the soil suitability and water availability at micro scale. The estimation of crop pattern and ET_c in a wide area through the earth observation needs huge efforts, costs and time. Therefore, remote sensing and GIS techniques have to be used. It is necessary to estimate the ET for the entire selected area. Although, remote sensing techniques are considered for the entire area estimation of ET, the use of satellite imagery is investigated to establish such relationships between ET and crop pattern and the vegetation production.

Crop acreage is primary information needed for water allocation and irrigation scheduling (Bastiaanssen, 1998). Remote sensing could be used for estimation of crop type, crop yield, and soil survey mapping for agricultural research (Kurucu et al., 2000). Bos *et al.* (2001) reported that remote sensing can be used in monitoring irrigation and drainage systems across larger areas and identification of local crop classes. Öztekin (2012) monitored and determined the land use types using the low cost satellite images and GIS technique, where crop types and their coordinates were also determined and recorded during the field work. WaterWatch (2003) used remote sensing to study the distribution and ET_c of rice and cotton as affected by irrigation improvement in North Western Nile Delta. They observed an increase in rice at the expense of cotton as a result of irrigation improvement and the percentage of rice was slightly decreased from the head to the tail of canal, whereas cotton remained quite homogeneous over the entire area. Also, they observed a slight decrease in ET_c from head to tail of canals for rice and ET_c, although it was slightly increased for cotton and the head-tail differences in water availability were not showed up in the ET_c levels.

Denis (2013) reported that about ninety percent of annual precipitation is consumed in ET in semi-arid regions. Consequently, accurate estimates of ET are required for irrigation water management. Accurate estimation of ET is essential for hydrologic water balance, irrigation scheduling, and water resources planning and management. Therefore, Remote Sensing and GIS techniques with Hydrological Models are used to develop a friendly decision support system for estimating actual crop ETc. The indirect ET estimation methods are based on climatic data which vary from empirical relationships to complex methods. These different methods of ET estimation can be grouped into two types based on the techniques used. The first traditional methods based on GIS and the second is the remote sensing methods (Almhab and Busu, 2008). Ahmad *et al.* (2004) and Raju *et al.*

(2008) reported that remotely sensed estimates of ET_c can directly represent the crop growth conditions and is better than field measurements. Furthermore the integration of various space borne platforms for more precise information on estimation of ET_c is encouraged and is necessary in view of the actual image limitations (Anderson et al., 2012). Elhaddad *et al.* (2007) reported that the conventional methods estimate ET_o from meteorological data and apply crop coefficients to estimate ET_c, whereas the remote sensing models are able to directly estimate ET_c in a specific field due to factors such as water shortages or salinity impacts. Bleiweiss *et al.* (2010) used the spatial satellite remote sensing to estimate ET and then, biomass can be calculated to be linked with crop yield. This could provide an excellent opportunity to evaluate the impact of various parameters such as crop type, field size, soil, etc on the economic return from irrigated agriculture.

The objectives of this study were to investigate the impact of irrigation projects in Nile Delta on the crop pattern and water consumptive. I was also to monitor and determine the land use classification and crop water consumption based on satellite images.

MATERIALS AND METHODS:

Descriptions of the study area:

The study area of El-Moheet canal (640 ha) is located in North Nile Delta and was completely under improved surface irrigation. El-Moheet canal (3.500 Km length) lies between 31° 11’ 14” and 31° 13’ 06” N and 31° 00’ 48” and 31° 02’ 20” E as illustrated in Figure (1). Surface elevation is about 6 meters above the sea level. This area has a Mediterranean-type climate, typically hot-dry summer and mild-rainy winter. The mean annual temperature ranges between 5.7 and 34.2 °C. The average rainfall is about 150 mm/yr. Relative humidity ranges from 59.3% in May to 72.7% in January. The average daily sunshine hours ranges between 6.2 hours in January and 11.7 hours in June. Daily meteorological data were obtained from the meteorological station of the Rice Centre at Kafr El-Sheikh Research Station. These data include the minimum and maximum air temperature, minimum and maximum relative humidity, wind speed, sunshine hours, Pan Evaporation and rainfall.

Soils in the selected area are alluvial clayey and in general non-saline soils (EC values vary from 2 to 3 dSm^{-1}). Large part of the area is under subsurface drainage and water table is deeper than one meter below the ground surface.

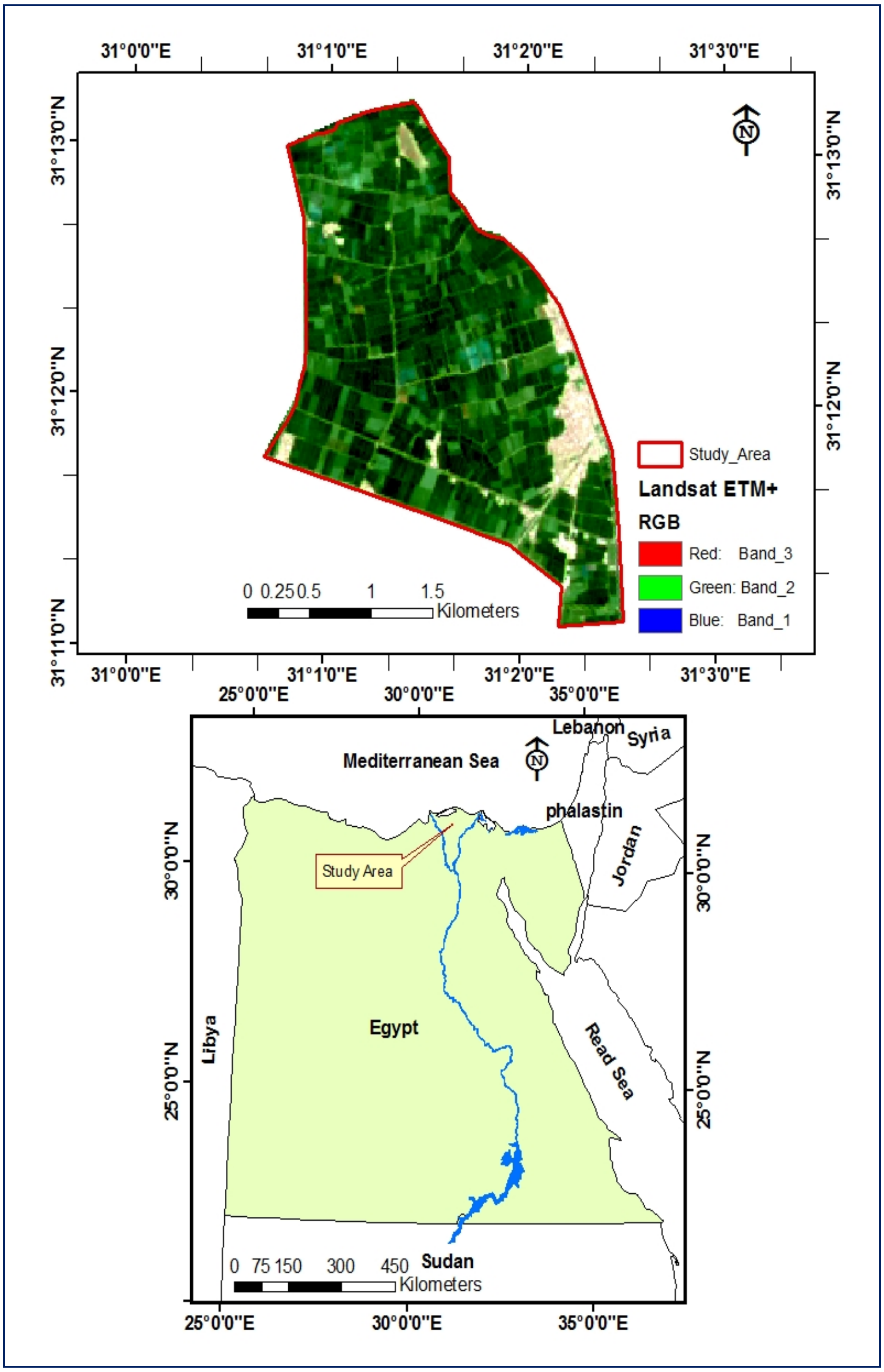

Fig (1): Location of the studied area (El-Moheet Branch Canal).

Remote Sensing Data Availability:

Remote sensing provides spatial coverage through the measurement of reflected and emitted electromagnetic radiations, across a wide range of wavelength from the earth's surface and the surrounding atmosphere. Remote sensing is the act of collecting data without physical contact with the studied object. Landsat imagery was used to calculate Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI) and ET_0.

Gap-Filling of Landsat 7 SLC-off Images:

Single scenes of Landsat 7 SLC-off images were filled using the Focal Analysis Screenshot module under ERDAS Imagine. This method was designed to modify neighboring pixels in a single Landsat 7 SLC-off scene, creating a final aesthetic image. No scientific analysis of accuracy is guaranteed using this method. This method was designed using ERDAS Imagine™*, along with ENVI™* or Adobe Photoshop™ * for final filled-image verification.

Remote Sensing Data:

Two Landsat 7 images (path 177, row 38) were used in this study. These images were acquired during the two summer seasons (2011 and 2013) before and after irrigation improvement.

Image Preprocessing:

Pre-processing of satellite data is necessary not only to remove the sensor errors during data acquisition but also display correction, band selection, reducing data dimensionality and to reduce the computational complexity. Radiometric, geometric, and atmospheric correction were carried out on the studied Landsat ETM+ image for better visualization enhancement.

Geometric Correction:

The studied images were geometrically corrected using image to image correction method. Images were projected using the UTM projection (WGS-1984 datum, zone 36 N). A subset of each image was used for spectral classification.

Atmospheric Correction using FLAASH Tool:

Atmospheric correction refers to the removal of atmospheric components from the image. This step is necessary for better reflectance. Atmospheric correction was done using FLAASH (Fast Line-of-sight Atmospheric Analysis of Spectral Hypecubes) tool based on MODTRAN algorithm in ENVI 5.1. From ENVI, the Landsat image could be read directly but for the atmospheric correction, the native file in BSQ format was used. This also has to be converted to either BIL or BIP format for the FLAASH tool.

Crop classification:

Initial unsupervised classification was applied, which is an automated cluster analysis technique that uses a minimum spectral distance cluster algorithm to assign a pixel to a cluster of pixels with similar attribute. Supervised classification was used for accurate and precise clustering of pixels into land use/land cover classes (Campbell, 1996).

In this study, Sub-pixel supervised image classification was used. Landsat ETM+ imagery, acquired in July 17th, 2011, and July 15th 2013 with

30 m ground resolution were used to record crop classification. Crop-classification of the two seasons was used to reflect crop situation before and after irrigation improvement. Head-tail analysis for the selected canal was performed. Field survey was carried out during July 2011 and 2013 to identify the locations of the grown summer crops. This selected period was suitable for spotting rice, cotton, maize and seed melon. About 80 fields for both summer seasons were visited and inspected. The coordinates of the four corners for each selected field were recorded using the GPS (Modil Gramin). Land use and crop classification were extracted and identified from the satellite images during one particular day (image acquisition date). Errors in land cover classification using remote sensing were resulted from differences in soil background, positional errors, land cover mixtures, or human errors. Therefore, accuracy assessment was done using 20 random points for each of the studied areas.

Calculation of ET_o:

FAO-Penman-Montieth Method:

ET_o was calculated from the meteorological data using the FAO-Penman-Montieth formula. This formula developed based on an empirical method to calculate the ET_o, which was adjusted by crop coefficient (k_c) to calculate ET_c (Hargreaves et al., 1985 and Popova et al., 2005). Meteorological parameters used in this equation were obtained from Sakha meteorological station.The following equation was used:

$$ET0 = \frac{0.408\,\Delta(R_n - G) + y\left[\frac{900}{T + 273}\right]U_2(e_s - e_a)}{\Delta + y(1 + 0.34\,u_2)}$$

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],

Hargreaves Method:

This method uses minimum amount of data (i.e., maximum, minimum and average temperature, number of the day, and latitude). ET_o was calculated from the meteorological data using Hargreaves formula.

This formula was also developed based on an empirical method to calculate ET_o, after that it was calibrated with FAO-Penman-Montieth under the same area with the same data. Calibrated Hargreaves was used also to calculate ET_o from predicted air temperature (T_{air}) derived from land surface temperature (LST). ET_o adjusted by crop coefficient to calculate ET_c.

The following equations were used:

$ET_0 = 0.0135(KT)\,R_a\,(TD)\,0.5\,(T + 17.8)$ (1)

$KT = 0.00185(TD)\,2 - 0.0433(TD) + 0.4023$ (2)

$TD = T_{max} - T_{min}$ (3)

Where,

ET_0 is the reference evapotranspiration (mm/day);

T is the monthly average temperature (^oC);

T_{max} and T_{min} are monthly maximum and minimum temperature (^oC), respectively.

R_a is the water equivalent of the extraterrestrial radiation (MJ/day), which was calculated based on the latitude and also the specific month in study area.

KT is an empirical constant that was calculated from the equation (2).

Relation between ET_o obtained from Hargreaves and FAO-Penman-Monteith methods was produced by El-Shirbeny (2012) as follow:

$y = 0.5826\,x - 0.1066$ (R2 = 0.7829)

A logarithmic relation between LST and T_{air} was established and R^2 was 0.74 according to El-Shirbeny (2012) as follow:

$y = 10.568Ln(x) - 8.5825$ (R2 = 0.7423)

The land surface temperature is calculated using equations (1-3)

$$T = T_{61} + [1.29 + 0.28(T_{61} - T_{62})](T_{61} - T_{62}) + 45(1 - \varepsilon_4) - 40\Delta\varepsilon$$
(1)

$$\varepsilon_4 = 0.9897 + 0.029\ln(NDVI)$$
(2)

$$\Delta\varepsilon = 0.01019 + 0.01344\ln(NDVI)$$
(3)

Where: T_{61}, T_{62} are the brightness temperature of the thermal bands (T_{61} and T_{62}) of remote sensing data, ε_4 the surface emissivity of T_{61} channel, and $\Delta\varepsilon$ is the differences in surface emissivity between the T_{61}, T_{62} channels.

2.4. Conveyance efficiency (E_{conv}):

E_{conv} was calculated using the following equation:

$$Econv(\%) = \frac{\text{Water discharge at tail of the watercourse } \left(\frac{L}{S}\right) \times 100}{\text{Water discharge at head of the watercourse } \left(\frac{L}{S}\right)}$$

Water discharge was measured by electromagnetic current meter (KENEK Corporation LP 30) in three unimproved field waterways. The E_{conv} values were found to be 81, 85 and 88% for the three waterways. This means that the The E_{conv} values ranged between 80 - 90%.

Water requirements:

Water requirements (m^3/ha) were calculated using the following equation:

Crop water requirements = ETc (m^3) / irrigation efficiency

Soil salinity:

Soil salinity (dSm^{-1}) was measured in the field using the TDR and by measuring the electrical conductivity (EC) in the soil paste extract at theses depths 0-30, 30-60 and 60-90 cm (Jackson, 1967).

RESULTS AND DISCUSSION

Land use classification:

Most of the Egyptian cropping systems produce two crops per year, one in the winter season and another in the summer. Few crops were adapted to the temperature regimes of both seasons and the irrigation system was designed to provide water to meet the needs of the cropping system.

Differences in irrigation facilities and economic situation contribute in changing the cropping pattern. Part of the farmers have the intention of developing a stable cropping pattern under a given agro-climatic setup and they do not shift much from this position except to the extent dictated by price factors in adjusting acreage allocations.

Data in Table (1) and Figures (2) show that pixels of the selected canal (El-Moheet) could be classified into seven land uses. The obtained acreage of each crop and land use during data acquisition date in both summer seasons (2011 and 2013) revealed that cotton was the dominant crop before the improvement (42.7%) followed by rice (33.3%), seed melon (14.5%) and maize (9.5%). However, an opposite trend was recorded after the improvement, where rice was the dominant summer crop (74.1%) followed by seed melon (10.7 %), cotton (9.2 %), and maize (6.0%). The overall accuracy for land use classification in summer 2011 and 2103 were 92 and 82%, respectively.

The percentage of rice was increased by about 113 % after irrigation improvement. In the contrary of rice, cotton, maize and seed melon were clearly decreased after improvement (-79.3 , -40.2 and -29.3 %, respectively), when compared with their areas before the improvement .The most obvious difference in cropping patterns in El-Moheet canal was the replacement of cotton, seed melon and maize by rice after the improvement. The significant increase in rice area after the improvement could be attributed to the improvement in the availability of irrigation water as a result of irrigation improvement processes .Consequently, the equity of the irrigation water along the improved branch canal was also improved, especially at the tail end area. The obtained images also show that the planted area was decreased from 2011 to 2013 by about 4.3% due to urbanization.

Table(1):Summer crop classification extracted from Landsat Images before and after irrigation improvement.

Crop	Crop area (2011)					Crop area (2013)					13/11 ratio +/-
	Total	**%**	**Head**	**Middle**	**Tail**	**Total**	**%**	**Head**	**Middle**	**Tail**	
Rice	182	33.3	76.6	55.2	49.7	387	74.1	132.5	131.7	122.4	113.0
Cotton	233	42.7	63.6	89.6	79.6	48	9.2	16.3	18.6	13.3	-79.3
Maize	52	9.5	18.4	17	16.6	31	6.0	8.6	12.6	9.8	-40.2
S.melon	79	14.5	30	29.8	19.3	56	10.7	23.2	17.7	15	-29.3
Planted Area	545	85.2	188.6	191.6	165.2	522	81.5	180.6	180.6	160.5	-4.3
Water	22	3.4	9.2	5.3	7.3	23	3.5	13.9	4.7	4.0	3.7
Rood	47	7.3	20.6	13.3	12.6	65	10.2	26.4	19.7	18.9	39.8
Urban	26	4.1	24	1.8	0.5	31	4.8	28.1	1.9	0.7	16.7
Unplanted Area	95	14.8	53.8	20.4	20.4	118	18.5	68.4	26.3	23.6	25.1
Total	640	100	242.4	212	185.6	640	100.0	249	206.9	184.1	0.0

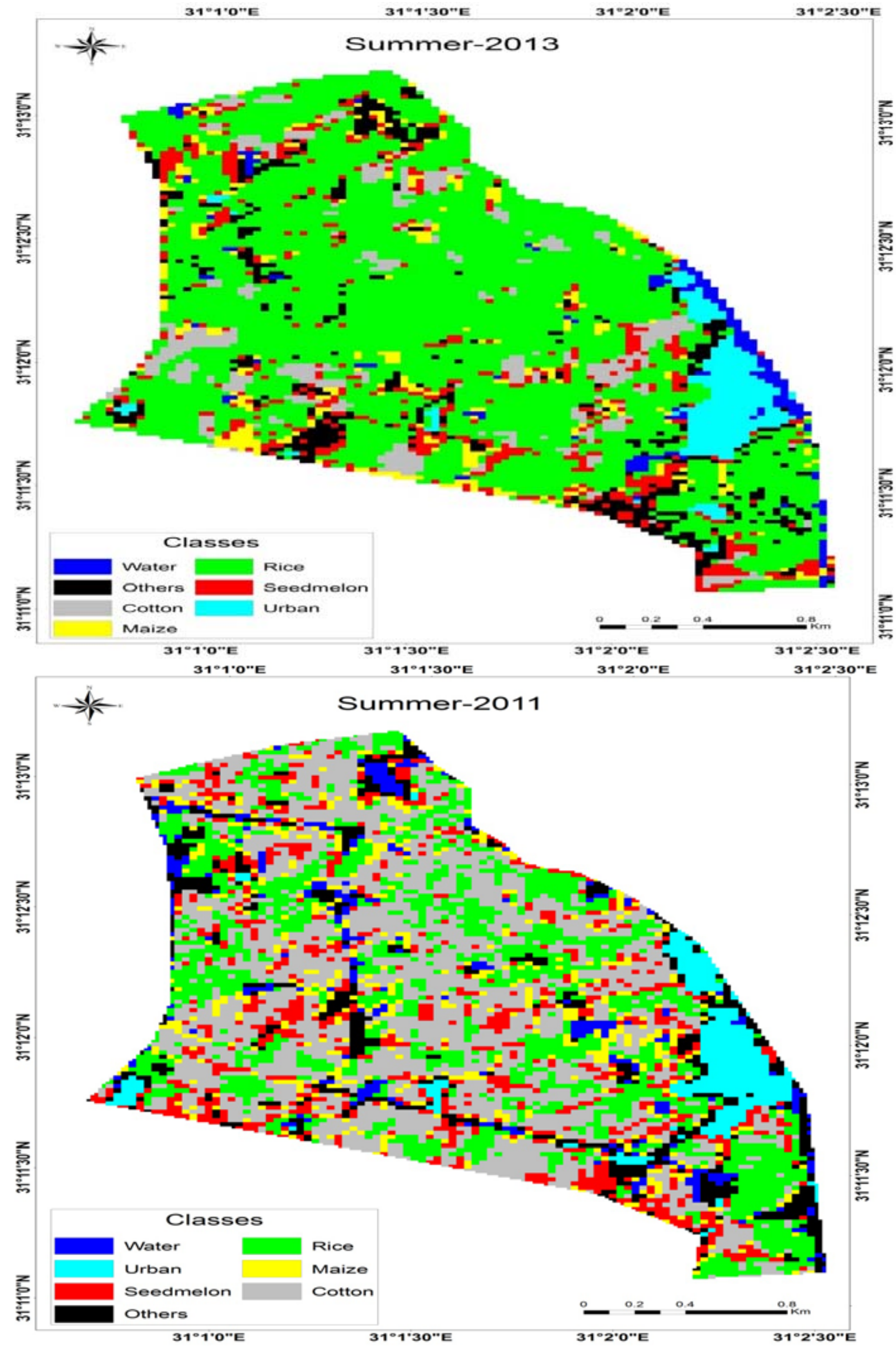

Fig. (2): Summer crop classification before the improvement (2011) and after the improvement (2013) extracted from Landsat Images.

It was observed that the non-cultivated areas (i.e., roads, open water and urban) along the investigated canal were increased from 2011 to 2013 by about 25 %. This could be attributed to the significant increase in roads (39.8 %) due to the conversion of the earthen courses into buried pipe lines. On the other hand, the urban area was also increased from 26 ha in 2011 to 31 ha in 2013(about 25 %).

To provide a more generic overview of the head-tail situations for the investigated canal, the difference in crop presence between the head and tail-end (divided into three equal area intervals from the inlet) was calculated and represented in Table (2). The most prominent head-tail pattern can be found with the main crops before and after irrigation improvement. In 2011 (before irrigation improvement) and 2013 (after irrigation improvement) the head-tail patterns for rice showed different patterns. The head/tail ratio for rice was decreased from 1.35 to 0.96 in 2011 and 2013, respectively. It means that rice was concentrated on the head reach before irrigation improvement, whereas after the improvement the rice area on the head third was approximately equal to that on the tail one (0.96). This trend could be attributed to the improvement the availability of irrigation water for the tail end as a result of irrigation improvement. On the contrary of rice, the head/tail ratio for cotton was increased from 0.7 to 1.08 in 2011 and 2013, respectively. Accordingly, within unimproved area, most of the rice area occupied the head reach, but most of the cotton area occupied the last reach. However, after the improvement of irrigation system, a reverse pattern was observed. The distribution of seed melon area along the investigated canal takes the same distribution tends before and after irrigation improvement (1.36 to 1.38). These results are in agreement with those obtained by WaterWatch (2003).

Consequently, with the completion of irrigation improvement in the selected canal, considerable changes are expected regarding to crop area and cropping system. Data collected during 2013 (Table 1) revealed an increase in area under production of rice by about 113 %. Cotton, which is another commercial crop, was decreased by about 79.3% in 2013. Simultaneous decrease was observed in the area of maize (about 40 %). The area under seed melon was slightly decreased after the improvement (about 29 %). The increase in rice area was observed after irrigation improvement (Table, 2), even though it needs relatively high water requirements. This change indicates that the irrigation improvement improves water equity along the branch canal especially in summer season. These results are in harmony with those obtained by WaterWatch (2003).

Table (2): Head-tail analysis for crops along the branch canal before and after improvement.

Crop	Crop % (2011)			Crop % (2013)			Head /Tail ratio	
	Head	Middle	Tail	Head	Middle	Tail	2011	2013
Rice	40.6	28.8	30.1	73.4	72.9	76.3	1.35	0.96
Cotton	33.7	46.8	48.2	9	10.3	8.3	0.7	1.08
Maize	9.8	8.9	10.1	4.8	7	6.1	0.97	0.79
S.melon	15.9	15.5	11.7	12.8	9.8	9.3	1.36	1.38
Planted area	77.8	90.4	89	69.4	87.2	87.6	0.87	0.79
Water	3.8	2.5	3.9	5.3	2.3	2.2	0.97	2.41
Rood	8.5	6.3	6.8	10.1	9.5	10.3	1.25	0.98
Urban	9.9	0.8	0.3	10.8	0.9	0.4	33.0	27.0
Unplanted area	22.2	9.6	11	30.6	12.8	12.4	2.02	2.47

Crop Evapotranspiration (ET_c):

Differences in weather conditions have to be known prior to comparing crop evapotranspiration and crop yield between the two summer seasons in both 2011 and 2013. The accumulated daily air temperature and the accumulated sunshine duration were calculated and represented in Table (3). Estimation of the ETc values for both the investigated summer seasons was done for only three cloudless months (July, August and September). Good quality and cloud free satellite images are also expected in these months. The total degree days in summer season (2011) before irrigation improvement are 2433 vs. 2470 for summer season (2013) after irrigation improvement (based on the Sakha Stations). The summer season year (2011) had 1014 hours of bright sunshine, whereas summer season (2013) had 1019 hours of sun shine. Therefore, summer of 2013 had about 0.5 % higher in sunshine hours and about 1.5 % higher temperature. Consequently, the ET values between the two investigated seasons were not significantly affected by these differences in meteorological conditions. The total actual evapotranspiration (ETc) and water requirements were calculated for rice, cotton, seed melon and maize in their respective growing calendar.

Table (3): The total degree days in summer seasons (2011 and 2013).

Climate information	Season	Summer months			Total
		July	August	Sept	
Degree days	2011	842	827.7	763.5	2433
	2013	832	832.4	805.5	2470
Total sunshine	2011	357	352.6	304.9	1014
	2013	358	351.9	308.6	1019

Data in Table (4) and Figures (3 - 5) represent the values of the actual evapotranspiration (ETc in mm/day) derived from Landsat images for the different crops along El-Moheet canal, their conversions into the seasonal values of ETc (m3/ha), and water requirements (m3 /ha or m3/area). The obtained data showed that the average daily ETc in summer 2011 for rice, cotton, seed melon and maize were 6.1, 5.17, 4.77 and 4.43 mm/day, respectively during the period from August first to the end of September. The total ETc for rice, cotton, seed melon and maize in the three months were

549, 465, 429 and 399 mm, respectively. The ETc in m3/ha for this period were 5490, 4653, 4293 and 3987 m3/ha, for the previous crops, respectively. Irrigation requirements were calculated by dividing ETc values by the irrigation efficiency at mesqa level. Irrigation efficiency at mesqa level before improvement was supposed to be 60 % with rice and about 70 % with the other crops. However, after the improvement the efficiency was raised to about 70 % with rice and about 80 % with the other crops due to raise in water efficiency by about 15 %. Therefore, water requirement (or water to be applied for irrigation) was 9150, 6647, 6133 and 5696 m3/ha with rice, cotton, seed melon and maize, respectively. The overall water requirements were calculated for the three months. This value was about 3989459 m3 /area. This means that each hectare needs about 81.3 m3/ day during that period.

Table (4): Water consumption and water requirements for summer crops (2011)

Crop	Area (ha)	ETac(mm/day)			Mean	ETc	W.requirement	
		July	Augst	Sept	mm	m^3/ha	m^3/ha	m^3/area
Rice	181.5	7.0	5.7	5.6	6.10	5490	9150	1660725
Cotton	232.8	5.9	5.1	4.5	5.17	4653	6647	1547422
S.Melon	79.1	5.7	4.5	4.1	4.77	4293	6133	485120
Maize	52	5.3	4.3	3.7	4.43	3987	5696	296192
Total	545.4	23.9	19.6	17.9	20.5	-	-	3989459
Mean	-	-	-	-	5.13	4606	7315	-

In case of summer season 2013 (after the improvement), data in Table (5) and Figs (6-8) show that the average daily ETc for rice, cotton, seed melon and maize were 6.13, 5.07,4.37 and 4.03 mm/day, respectively from August first to the end of September. The actual water consumption was higher with rice when compared with the other crops during the considered months. The total ETc for rice, cotton, seed melon and maize in that period, were 552, 456, 393 and 363 mm, respectively. The ETc in m3/ha for this period was 5517, 4563, 3933 and 3627 m3/ha, for these crops, respectively. Therefore, water requirement for different crops (according to ETc and the irrigation efficiency) were 7881, 5704, 4916 and 4534 m3/ha with rice, cotton, seed melon and maize, respectively. This means that each hectare needs about 79.6 m3/ day during that period.

Table (5): Water consumption and water requirements for summer crops (2013)

Crop	Area (ha)	ETc (mm/day)				ETc	W.requirement	
		July	August	Sept	mean	m3/ha	m3/ha	m3/area
Rice	386.6	6.7	6.1	5.6	6.13	5517	7881	3046795
Cotton	48.2	5.7	5.4	4.1	5.07	4563	5704	274932.8
S.Melon	55.9	5.2	4.7	3.2	4.37	3933	4916	274804.4
Maize	31.1	5.3	4.1	2.7	4.03	3627	4534	141007.4
Total	521.8	22.9	20.3	15.6	19.6	-	-	3737539
Mean	-	-	-	-	4.9	4410	7163	-

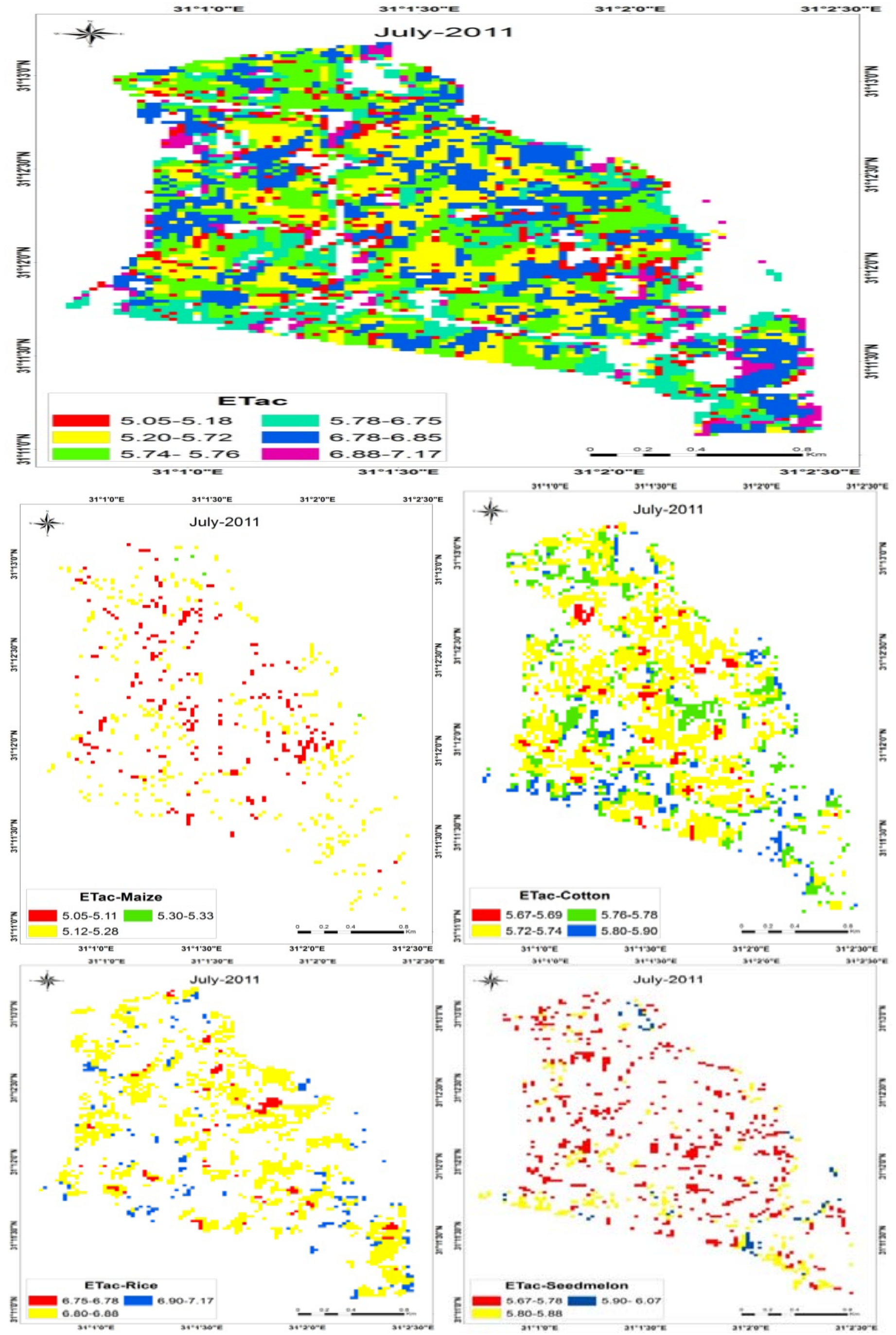

Fig (3): Estimated ET_c (mm) for summer crops in July (2011) extracted from Landsat data.

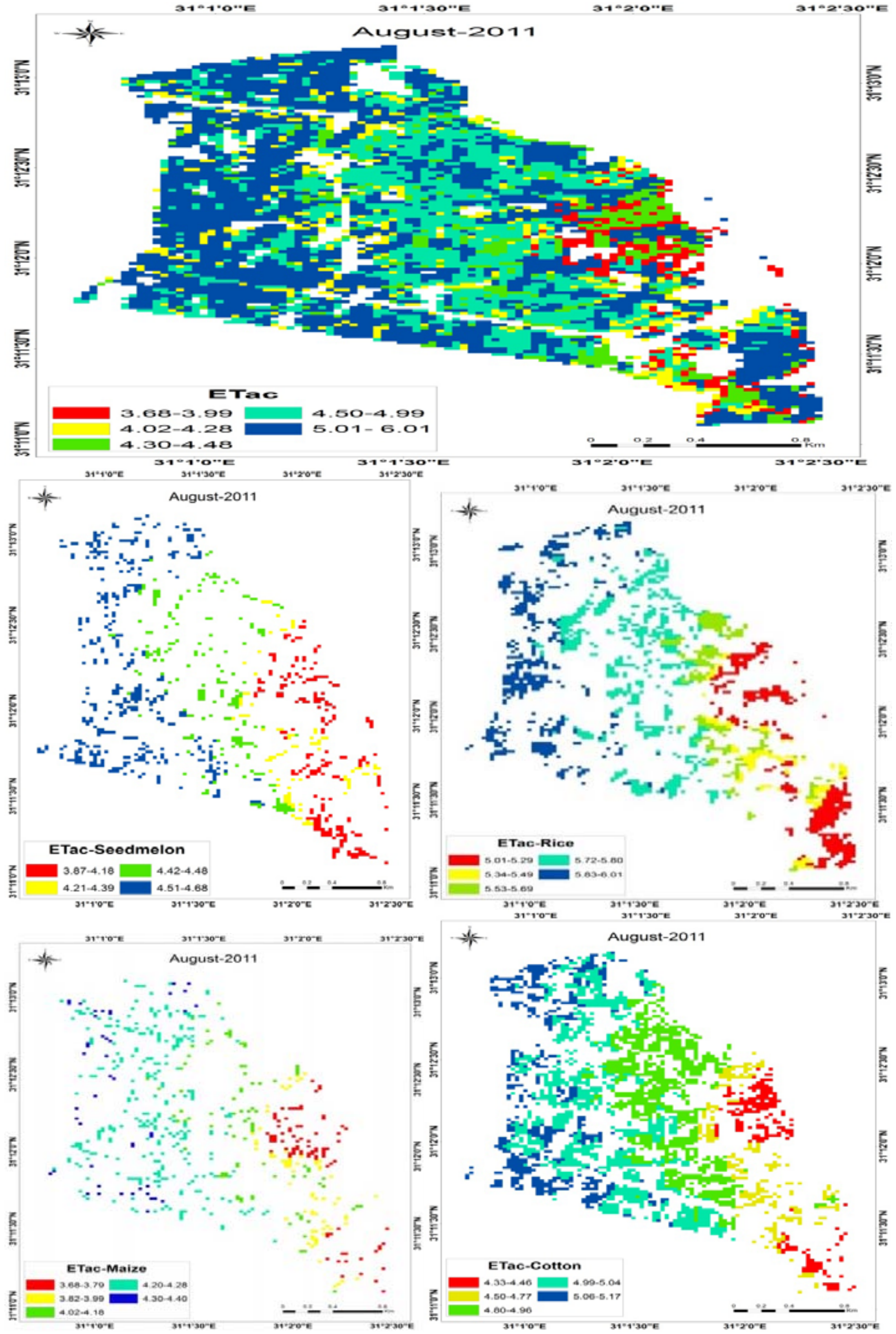

Fig (4): Estimated ET_c (mm) for summer crops in August (2011) extracted from Landsat data.

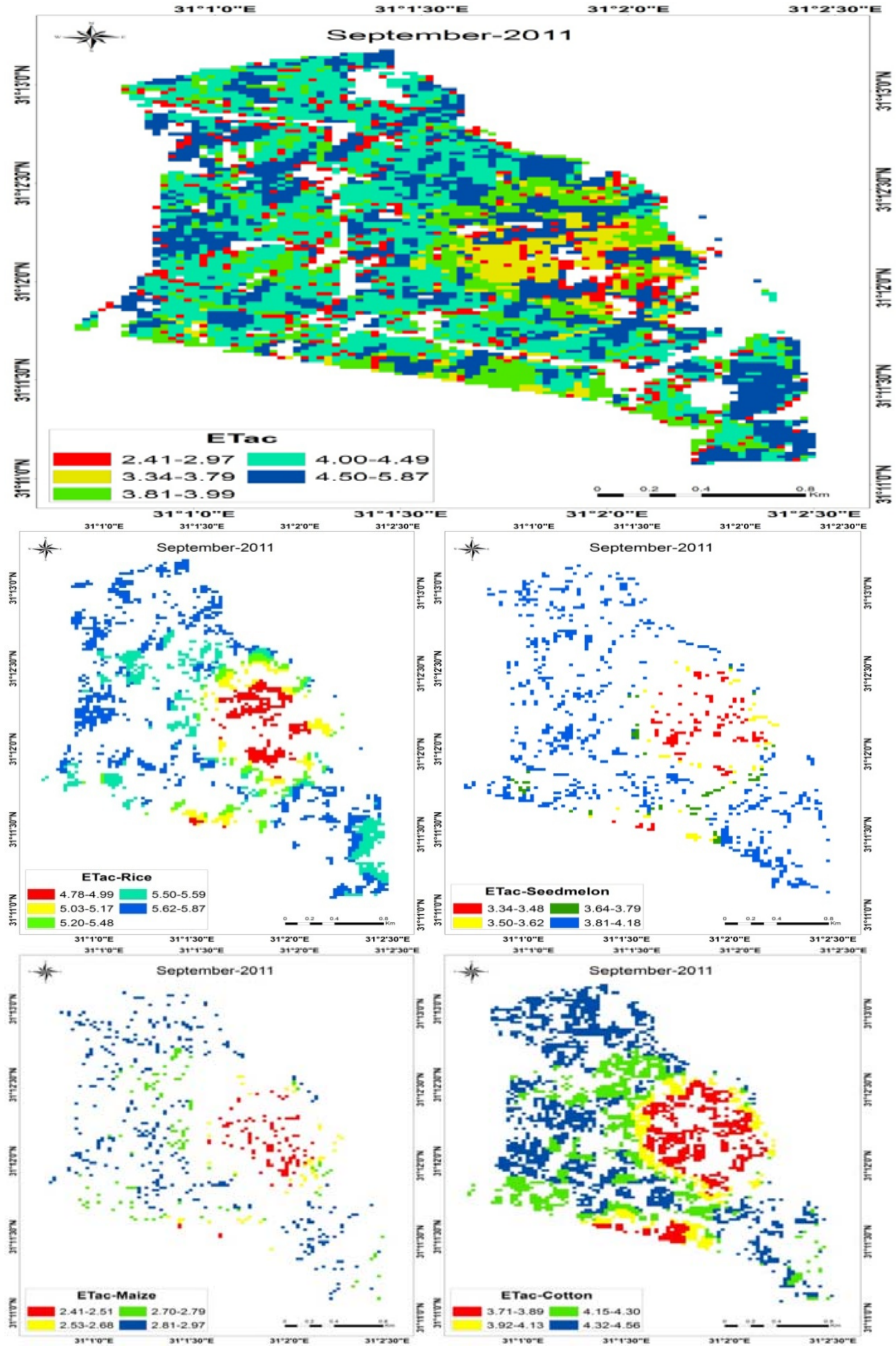

Fig (5): Estimated ET_c (mm) for summer crops in September (2011) extracted from Landsat data.

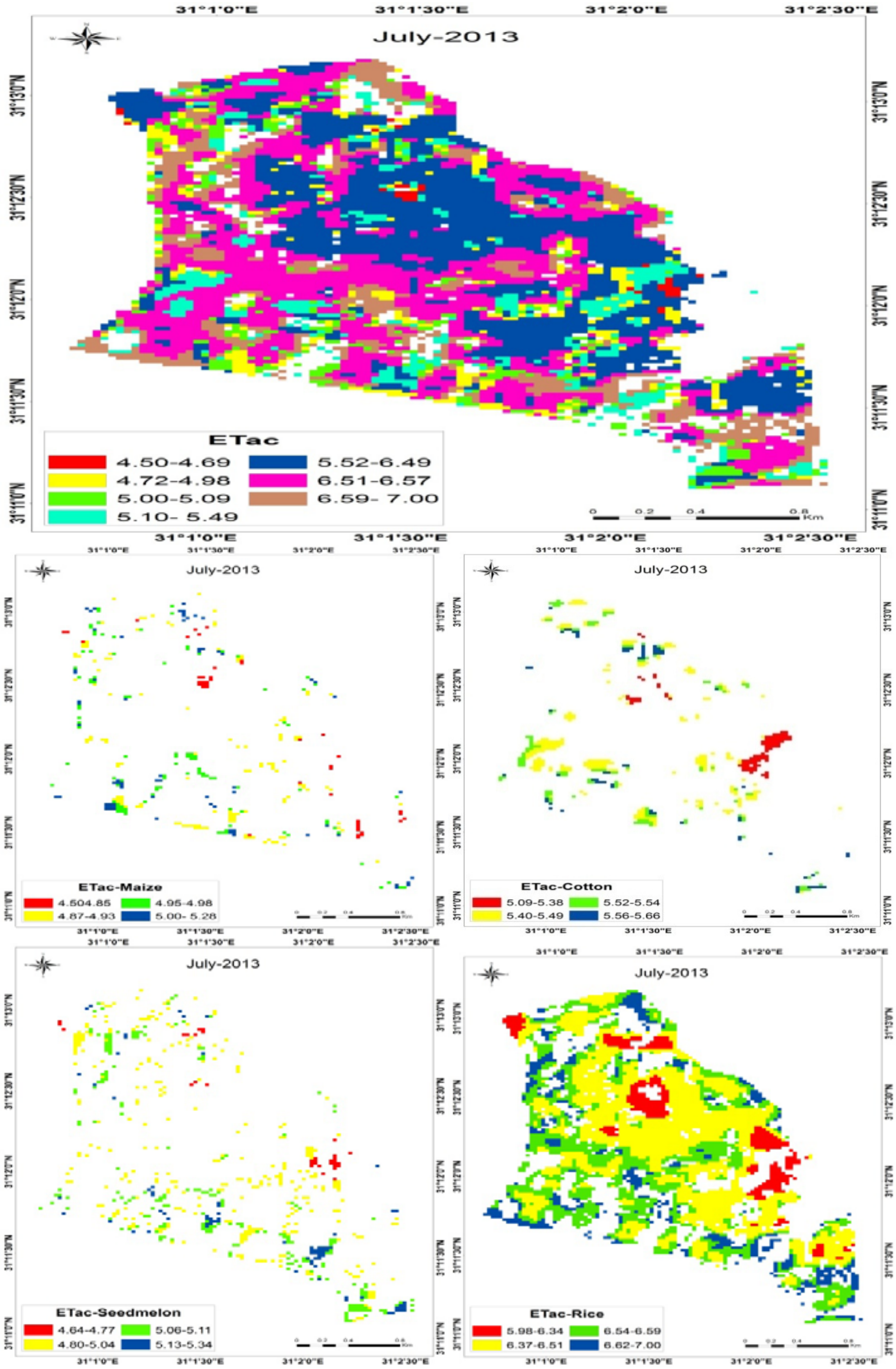

Fig (6): Estimated ET_c (mm) for summer crops in July (2013) extracted from Landsat data.

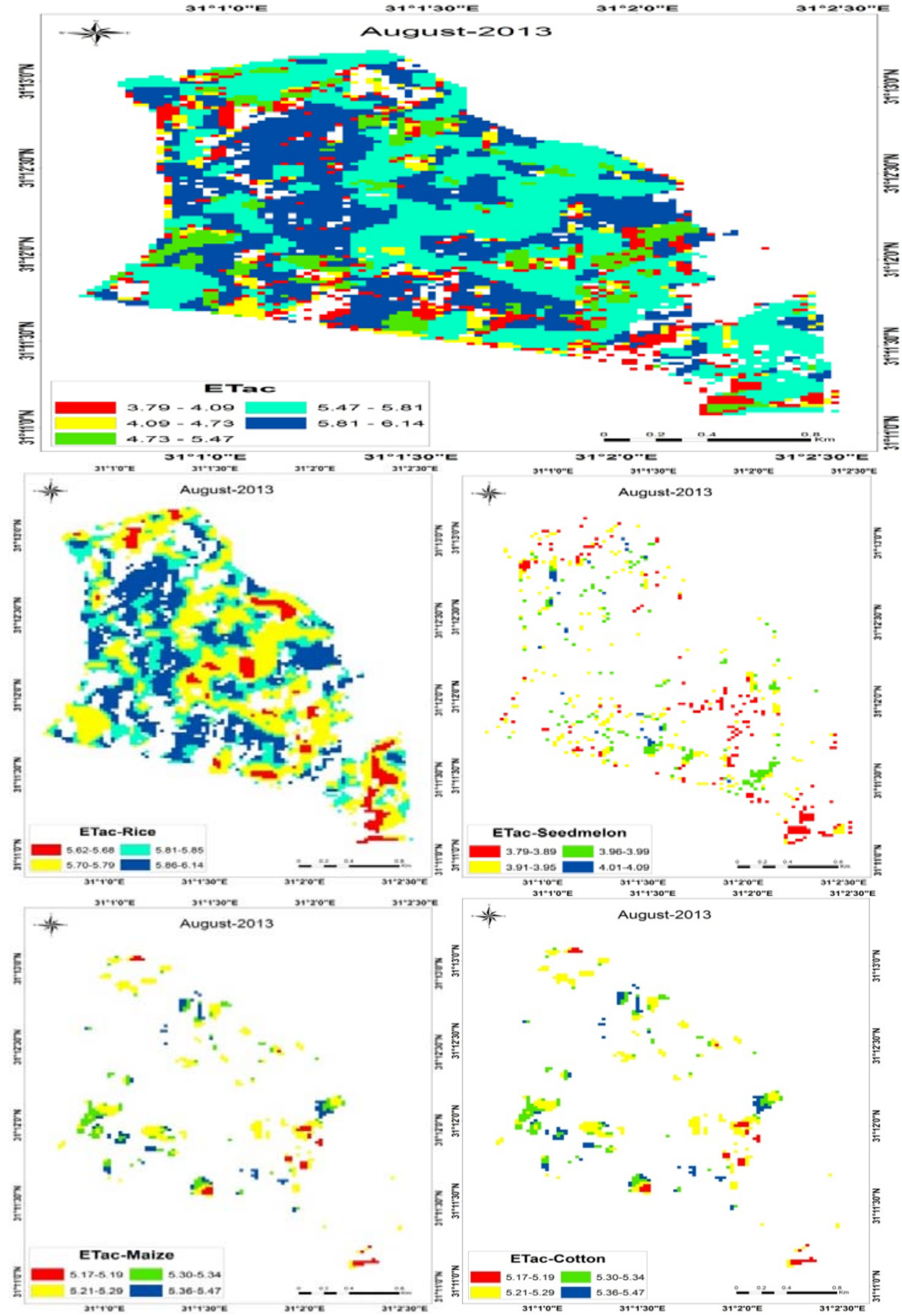

Fig (7): Estimated ET_c (mm) for summer crops in August (2013) extracted from Landsat data.

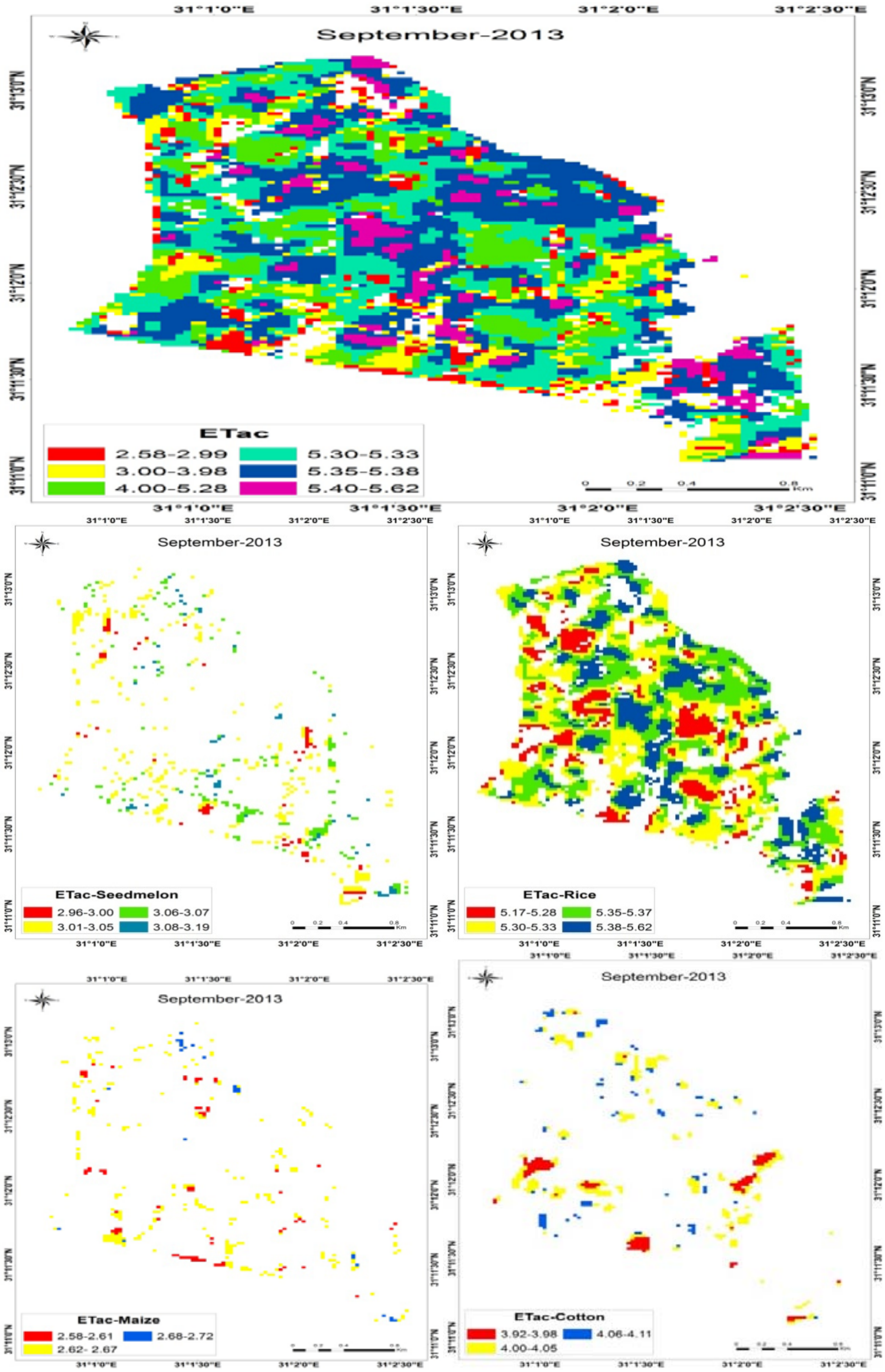

Fig (8):Estimated ET_c (mm) for summer crops in September (2013) extracted from Landsat data.

For comparing ETc values within the branch canal, head-tail analysis was carried out with respect to ETc and water requirements. For the branch canal, the mean ETc for the three equal-area distance intervals was calculated before irrigation improvements (2011) and represented in Table (6). The comparison within the branch canal (head /tail analysis) indicated that the ETc values and water requirement for all crops on the head-reach except for cotton were higher than those on the tail-reach. The ETc values for rice, seed melon and maize on the head-reach were higher than those in the tail-reach by about 54, 55 and 11%, respectively, whereas it was decreased by about 20 % for cotton. This trend reflects the crop pattern along the branch canal and indicates that water was more available in its head area before the improvement.

The comparison within the branch canal (head/tail analysis) after the improvement (2013) took an opposite trend to that found before the improvement, especially with cotton and maize, as shown in Table (6). Data indicate that the values of ETc and water requirements for all crops on the head-reach except for maize were higher than those for the tail-reach. The ETc values of rice, cotton and seed melon on the head reach were higher than those in the tail reach by about 8, 23 and 55 %, respectively, whereas it was decreased by about 12 % for maize. This trend may reflect the distribution of crops along the branch canal, which indicates that equity in water consumption, was improved for all branch canal reaches due to irrigation improvement. Finally, looking at the head-tail ratio, it could be concluded that the situation after improvement (2013) was better than that before improvement (2011) for all crops except maize.

Table (6): Head/Tail analysis for water requirements before and after irrigation improvement

Crop	Summer season (2011)					Summer season (2013)					Head/Tail Ratio	
	Area (ha)			ET_c (m^2/area)		Area (ha)			ET_c (m^2/area)			
	Head	Meddle	Tail	Head	Tail	Head	Meddle	Tail	Head	Tail	2011	2013
Rice	76.6	55.2	49.7	420534	272853	132.5	131.7	122.4	731003	675281	1.54	1.08
Cotton	63.6	89.6	79.6	295931	370379	16.3	18.6	13.3	74377	60688	0.80	1.23
S. melon	30.0	29.8	19.3	128790	82855	23.2	17.7	15.0	91246	58995	1.55	1.55
Maize	18.5	17.0	16.6	73760	66184	8.6	12.6	9.8	31192	35545	1.11	0.88
Total	188.7	191.6	165.2	919014	792271	180.6	180.6	160.5	927817	830508	1.16	1.12

Comparison between 2011(before the improvement) and 2013 (after the improvement) is represented in Table (7). It could be concluded from the Landsat data that the overall water consumption (ETc//ha) and water requirements were decreased between 2011 and 2013. The obtained data provide water consumption (m3/ha) in addition to the changes in water consumption for rice, cotton, seed melon and maize separately along El-Moheet canal command area during the three available months. The ETc values revealed that rice was slightly consuming more water in 2013 than in 2011 (+ 0.5 %), whereas its water requirements/ha were decreased after irrigation improvement in 2013 by about 13.9 %. Also, the total water requirements for the rice area were increased by about 83.5 % due to increase in its ETc and its area. However, water consumption (ETc, m3/ha) for cotton, seed melon and maize, was decreased in 2013 by about 1.9, 8.4 and 9.0 %, respectively, whereas the corresponding water requirements were decreased by about 14.2, 19.8 and 20.4%, respectively. Furthermore, data indicated that less water was consumed (ETc/ha) for El-Moheet by about 4.3 % in 2013 (after completion of Irrigation Improvement and Integrated Management Project , IIIMP) as compared to the baseline year 2011 (before IIIMP). However, water requirements for all area were decreased by about 6.3 % or by about 2.1 % for water requirements/ha. Since the meteorological differences were negligible, the increase in ETc could be attributed to the more availability of water resources, whereas the decrease in water requirements was related to water saving as a result of irrigation improvement. These results are in harmony with those obtained by WaterWatch (2002 and 2003).

Table (7): Comparison between the consumptive uses for improved vs unimproved area for different crops.

Crop	Summer 2011				Summer 2013				Differences %		
	Area	ETc	W.requirement		Area	Etc	W.requirement		ETc	W.requirement	
	(ha)	m3/ha	m3/ha	m3/area	(ha)	m3/ha	m3/ha	m3/area	ha	ha	area
Rice	181.5	5490	9150	1660725	386.6	5517	7881	3046795	0.5	-13.9	83.5
Cotton	232.8	4653	6647	1547422	48.2	4563	5704	274932.8	-1.9	-14.2	-82.2
Seed melon	79.1	4293	6133	485120	55.9	3933	4916	274804.4	-8.4	-19.8	-43.4
Maize	52	3987	5696	296192	31.1	3627	4534	141007.4	-9	-20.4	-52.4
Planted area	545.4	-	-	3989459	521.8	-	-	3737539	-	-	-6.3
Mean	-	4606	7315	-	-	4410	7163	-	-4.3	-2.1	-

Conclusion:

It could be concluded that the regular distribution of crops or crop pattern depends mainly on the situation of irrigation system and consequently on the distribution equity of water along the branch canal. In this work cotton was the dominant crop before irrigation improvement, whereas, rice became the dominant crop after improvement. Improving the irrigation system saves irrigation water and raises the distribution equity of water and consequently the crop distribution regularity improves along the improved irrigation canal. Crop distribution regularity should be achieved to maintain soil fertility.

Remote sensing techniques have the potential to provide the ability to detect and quantify the spatial differences in ETc information and crop growth stages. This technique could minimize the additional filed observations. Remote sensing based Kc estimation follow the similar pattern of seasonal variation of crop fraction. Since the meteorological differences were negligible, the changes in ETc could be attributed to the more availability of water resources. On the other hand, the decrease in water requirements was related to water saving as a result of irrigation improvement.

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تأثير تطويرالري على التركيب المحصولى والإحتياجات المائية للمحاصيل باستخدام تقنيات الاستشعار عن بعد ونظم المعلومات الجغرافية

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يتأثر التركيب المحصولى والبخر نتح (ET_C) للمحاصيل فى منطقة ما بصفة أساسية بكفاءة نظام الري. وكانت أهداف هذه الدراسة هى بحث تأثير مشاريع الري في شمال الدلتا على التركيب المحصولى والاستهلاك المائى للمحاصيل. واستخدم الاستشعار عن بعد (RS) و نظم المعلومات الجغرافية (GIS) لتقييم التركيب المحصولى والبخر نتح (ET_C) على ترعة المحيط فى شمال الدلتا . كانت هذه الترعة تخضع لعمليات تحسين الري (المساقي و المراوى) . وقد أجريت هذه الدراسة من خلال اثنين من مواسم الزراعة الصيفية (٢٠١١، قبل التحسين و ٢٠١٣ ، بعد التحسين) .

أظهرت النتائج أن وحدات البكسلات للترعة المختارة في كل من مواسم الزراعة الصيفية يمكن تصنيفها إلى ٧ إستخدامات الأراضي (الأرز والقطن وبطيخ البذر والذرة والمجارى المائية المفتوحة والطرق والمدن). وكان القطن هو المحصول السائد (٤٢.٧ ٪) قبل التحسين ، يليه الأرز (٣٣.٣ ٪) ، وبطيخ البذر (١٤.٥ ٪) ، والذرة (٩.٥ ٪) . بينما كان الأرز المحصول السائد (٧٤.١ ٪) بعد التحسين يليه بطيخ البذر (١٠.٧ ٪) ، والقطن (٩.٢٪) ، والذرة (٦.٠ ٪) . وقد ارتفعت نسبة الأرز بقوة بنحو ١١٣ ٪ بعد التحسين . بينما انخفضت محاصيل القطن والذرة و بطيخ البذر بشكل ملحوظ بنحو ٧٩ و ٤٠ و ٢٩ ٪ ، على التوالي، وذلك مقارنة مع مساحاتها قبل التحسين. ومن بيانات لاندسات يمكن استنتاج أن البخر نتح الكلى قد إنخفض بعد تحسين الري في عام ٢٠١٣ بنحو ٤.٣ ٪ ، في حين أن الاحتياجات المائية / هكتار انخفضت بنسبة حوالي ٦.٣ ٪.

وأظهرت الصور التي تم الحصول عليها أيضا أن المساحة المزروعة قد انخفضت من عام ٢٠١١ الى عام ٢٠١٣ بنحو ٤.٣ ٪ وذلك بسبب التوسع العمراني . ومع ذلك ، زادت المنطقة غير المزروعة بنحو ٢٥٪ كما تحسن توزيع المحاصيل والعدالة في توزيع المياه على طول الترعة نتيجة تطوير شبكة الري.

ويمكن إستنتاج ان تطوير نظام الري قد ساهم فى حفظ مياه الري وزيادة العدالة فى توزيع المياه على طول الترعة.

قام بتحكيم البحث

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