Crop pattern and crop water requirements of winter crops as affected by irrigation improvement using remote sensing and GIS techniques

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Abstract

The cropping pattern and crop evapotranspiration (ET_{c}) 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 ET_c on El Moheet Canal, North Delta. This canal was subject to irrigation improvement practices (Mesqas and Marwas). This study was carried out during two winter growing seasons (2010/2011, before the improvement and 2012/2013, after the improvement). Three types of winter crops were identified in the studied area, which are wheat, sugar beet, and clover. This was in addition to urban, open water and roads. Data indicated that the cultivated area was decreased from 2010/2011 to 2012/2013 by about 5 %, whereas the non-cultivated area was increased by about 26 %. This could be due to changes in land uses from agricultural to non-agricultural activities. Data also, revealed that sugarbeet was the dominant winter crop in the studied area before irrigation improvement (66.7 %), followed by clover (20.7 %) and wheat (12.6 %). After irrigation improvement the cultivated area was almost equally divided among the three winter crops. The wheat area was increased after irrigation improvement and represent about 35.5 % of the cultivated area, followed by sugarbeet (32.6 %) and clover (31.9 %). So, it could be concluded that irrigation improvement had a positive effect on wheat and clover areas, and a negative effect on the sugar beet area. This could be attributed not only to the irrigation improvement, but also to the economic and marketing conditions. The average daily ETc after irrigation improvement was lower than that before irrigation improvement by about 29.2 % , whereas water requirement/ha was decreased by about 38.1 % .

In conclusion : a- the ET_c values for the studied winter crops along the branch canal weren't significantly affected by irrigation improvement, but mainly affected by the meteorological conditions and the crop pattern in the area that is affected by the situation of the irrigation system. b-crop distribution and the equity in water distribution along the branch canal were improved due to irrigation improvement. c- 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.

1. 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. 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 in addition to the climate have to be used data 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. WaterWatch (2004) reported that berseem and wheat are the main crops grown in the winter in Egypt, accountable for approximately 70 % of the cropped area. The remote sensing analysis focusing on the whole IIP-area in North-Western Delta showed that the berseem area stayed constant from 1998 before improvement to 2003 after improvement. The wheat area increased with 17 % in the non-improved areas, and with 12 % in the improved areas. The sugar beet area increased with 9 % in the non- improved areas, and decreased with 7 % in the improved areas. After improvement, the tail-head trend within the improved and non-improved branch canals became more similar as compared to that before improvement. Within the improved branch canals the tail-head ratio for berseem went from 0.88 to 1.00, while for wheat the ratio decreased from 0.90 to 0.81 due to more head-end cultivation of wheat. Within the non-improved branch canals the tail-head ratio for berseem went from 1.03 to 1.01, while for wheat the ratio increased from 0.78 to 0.82. 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.

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). Using the remote sensing analysis ,WaterWatch (2004) observed that the total consumptive use in IIP area Northwestern Delta area from October till May was 608 mm in 1998 (before IIP) and 534 mm after IIP in 2003 (12.1% decrease). The decrease in consumptive use could be attributed to meteorological conditions. The reference evapotranspiration for the same period was 719 mm in before IIP and 628 mm after IIP (12.6% decrease). Improved areas consumed 1% less water than non-improved areas in 2003. Almost no tail-head differences are apparent in the branch canals, leading to the conclusion that consumptive use is very uniform within the Northwestern Delta area.

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 of winter crops. The land use classification and crop water consumptions were also determined based on satellite images.

2. Materials and Methods:

2.1. Descriptions of the study area: The study area of El-Moheet canal (640 ha) is located in North Nile Delta and 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 Fig (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. Soils in the selected area are alluvial clayey and in general non-saline soils (EC values vary from 2 to 3 dSm^{-1}). The selected area is under subsurface drainage and water table is deeper than one meter below the ground surface.

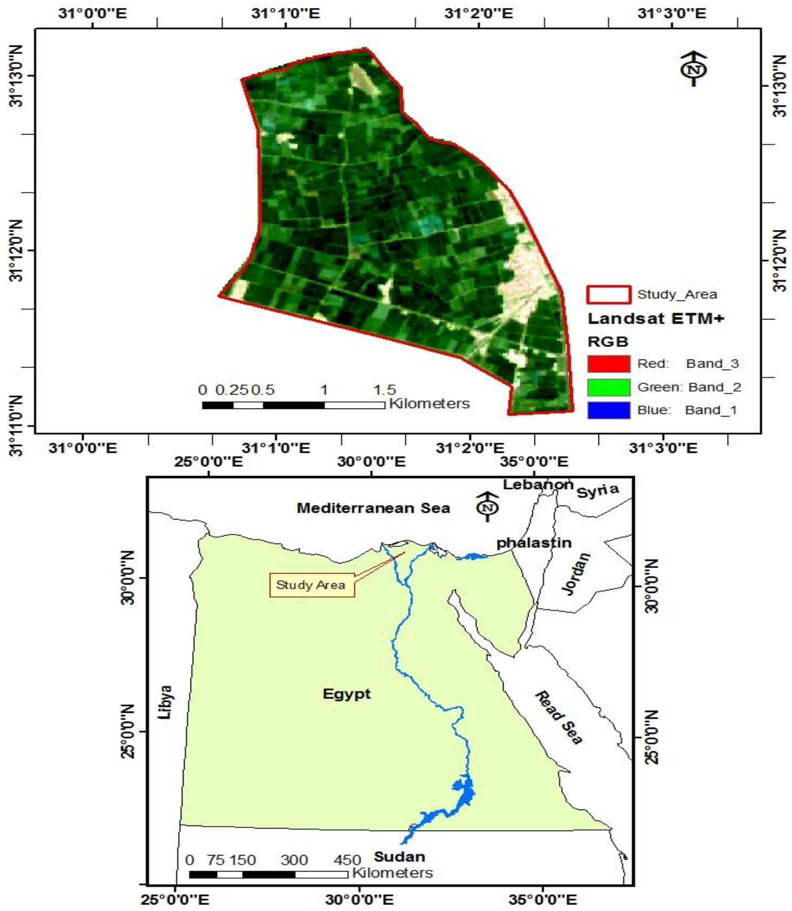


Fig (1): Location of the studied area.

2.2. 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.

2.2.1. 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.

2.2.2. 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.

2.2.3. 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.

2.2.3.1. 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. **2.2.3.2. 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.

2.2.4. 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 February 12th, 2010/2011, and February 15th 2012/2013 with 30 m ground resolution were used to record winter crop classification. Crop-classification of the two winter 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 February 2011 and 2013 to identify the locations of the grown winter crops before and after irrigation improvement ,respectively. This selected period was suitable for spotting wheat, clover and sugarbeet. About 80 fields for both winter 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. 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.

2.3. Calculation of ET_o and ET_c :

2.3.1. 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 and Samani, 1985 and Popova et al., 2005).** Meteorological parameters used in this equation were obtained from Sakha Rice Centre ,Kafr el-sheikh. The following equation was used:

$$ET_o = 0.408\,\Delta(R_n - G) + y\,[900 / (T+273)]\,U_2\,(e_s - e_a) / \Delta + y\,(1+0.34\,u_2)$$

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],

2.3.2. 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:

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

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

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

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 extra-terrestrial 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 :

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

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

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

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

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

$$\varepsilon_4 = 0.9897 + 0.029\,In(NDVI) \qquad (2)$$

$$\Delta\varepsilon = 0.01019 + 0.01344\,In\,(NDVI) \qquad (3)$$

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:

$$Econv\,(\%) = \frac{\text{Water discharge at water way tail(L/S)} * 100}{\text{Water discharge at water way head (L/S)}}$$

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 E_{conv} values ranged between 80 - 90%.

2.5. Water requirements:

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

$$\textit{Crop water requirements} = ETc\ (m^3) / \textit{irrigation efficiency}$$

2.6. 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).**

3. Results and Discussion

3.1. 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.

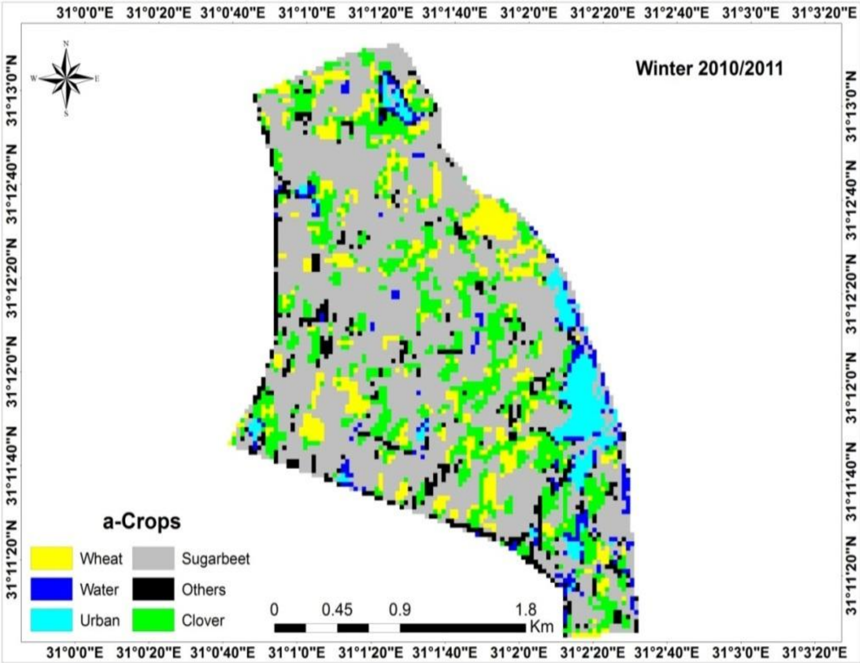
Differences in irrigation facilities and economic situation contribute in changing the cropping pattern. Part of the farmers have the intention of developing a stable cropping pattern under a given agro-climatic setup and they do not shift much from this position except to the extent dictated by price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

Winter crop classification was derived from the Landsat Images before and after irrigation improvement. Three types of crops were identified in the studied area, which are wheat, sugar beet, and clover. This is in addition to urban, open water and roads are illustrated in Fig (2). The acreage of each crop and land use during one particular day in winter seasons before and after irrigation improvement is represented in Table (1). Data indicated that the cultivated area was decreased from 2010/2011 to 2012/2013 by about 5 %, whereas the non-cultivated area was increased by about 26 %. This could be due to changes in land uses from agricultural to non-agricultural activities, which mostly are represented in urbanization. Data also, revealed that sugar beet was the dominant winter crop in the studied area before improvement (66.7 %), followed by clover (20.7%) and wheat (12.6%),where, the wheat occupied about 35.5 % of the cultivated area, followed by sugarbeet (32.6 %) and clover (31.9 %). The overall accuracy of land use classification during the two winter seasons was about 92 and 94 %, respectively.

Table (1): Acreage of winter crops and other land uses extracted from Landsat Images before and after irrigation improvement.

Crop	Crop pattern (ha) at 2010/2011					Crop pattern(ha) at 2012/2013					012/013 / 010/011
	Total	%	Head	Middle	Tail	Total	%	Head	Middle	Tail	Ratio
Sugerbeet	363.8	66.7	113.4	130.6	119.8	169.5	32.6	42.5	60.7	66.3	0.47
Wheat	68.7	12.6	28.2	18.0	22.5	184.7	35.5	85.2	55.8	43.7	2.69
Clover	113.0	20.7	48	30.4	34.5	166.2	31.9	51.5	61.1	53.6	1.47
Planted area	545.5	85.2	189.7	179.0	176.8	520.4	81.3	179.2	177.6	163.7	0.95
Water	21.7	3.4	14.2	3.2	4.3	22.5	3.5	14.9	3.5	4.1	1.04
Others	46.4	7.3	18.0	19.0	9.4	67.0	10.5	25.0	21.0	21.0	1.44
Urban	26.4	4.1	22.0	1.9	2.5	30.1	4.7	24.6	2.6	2.9	1.14
Unplanted area	94.5	14.8	54.2	24.1	16.2	119.6	18.7	64.5	27.1	28.0	1.26
Total	640	100	243.9	203.1	193	640	100	243.7	204.7	191.7	1.00

The relative changes in crop pattern and land uses were calculated as ratios for the two winter seasons before and after irrigation improvement and the results were sorted based on the ratio for each crop and land use as represented in Table (1). A value greater than one, indicates a decrease in area after the improvement, whereas a lower value than one indicates an increase in the area after the improvement. It is observed that the wheat area had the largest increase after irrigation improvement(ratio 2.69), followed by clover (ratio 1.47). This increase in the area of both wheat and clover could be attributed to the large decline in sugarbeet area (ratio 0.47). So, it could be concluded that irrigation improvement had a positive effect on wheat and clover, and a negative effect on the sugar beet area. These changes in crop pattern may be related not only to the irrigation improvement, but also to the economic and marketing conditions. There were also an obvious increase in the road and other urban areas after improvement.



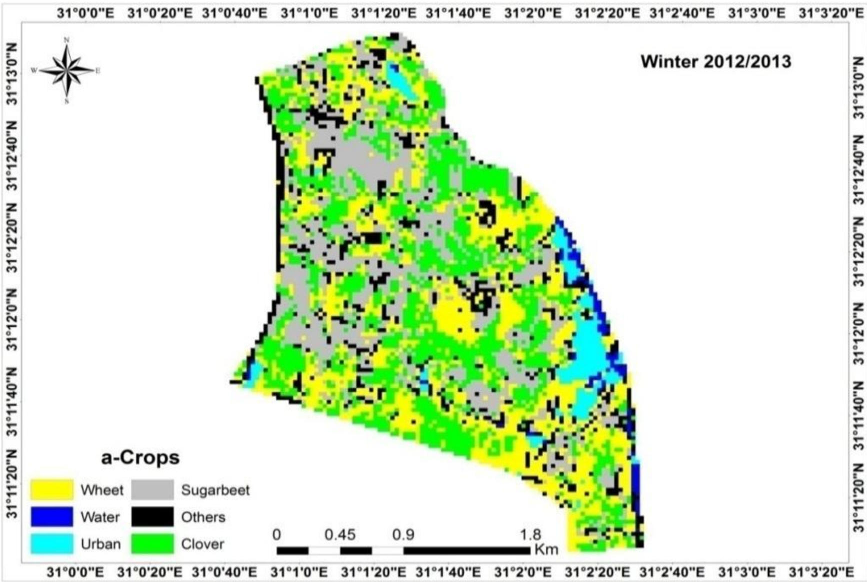


Fig (2): Winter crop classification extracted from Landsat Images along El-Moheet canal before the improvement (2010/2011) and after the improvement (2012/2013).

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. The head/tail analysis of the differences between winter crops along El-Moheet branch was carried out for both 2010/2011 season (before improvement) and 2012/2013 season (after improvement) .The most prominent irregular head/tail pattern was found for the wheat before and after irrigation improvement. The head/tail ratio for wheat was greater than that with for sugarbeet and clover in both seasons. This ratio was higher than one for wheat in both growing seasons. It was increased from 1.2 before the improvement to 1.8 after the improvement, which means that most of wheat areas were concentrated on the head-reach after irrigation improvement. An opposite trend was found for both clover and sugarbeet. The head/tail ratio for clover was decreased from 1.3 before the improvement to 0.9 after the improvement. This indicates that most of clover area occupied the head-reach area of the investigated canal before irrigation improvement, but after improvement clover was concentrated in the tail-end.

Table (2): Head/tail analysis for winter crops along El-Moheet branch canal before and after improvement.

Crop	Area % (2010/2011)			Area % (2012/2013)			Head/Tail ratio	
	Head	Middle	Tail	Head	Middle	Tail	010/011	012/013
Sugarbeet	59.8	73	67.8	23.7	34.2	40.5	0.9	0.6
Wheat	14.9	10.1	12.7	47.5	31.4	26.7	1.2	1.8
Clover	25.3	17.0	19.5	28.7	34.4	32.8	1.3	0.9
Planted area	77.8	88.1	91.6	73.5	86.7	85.4	0.8	0.9
Water	5.8	1.6	2.2	6.1	1.7	2.1	2.6	2.9
Others	7.4	9.4	4.9	10.3	10.3	11	1.5	0.9
Urban	9.0	0.9	1.3	10.1	1.3	1.5	7.0	6.7
Unplanted area	22.2	11.9	8.4	26.5	13.2	14.6	2.6	1.8

For sugarbeet, the head/tail ratio was also decreased from 0.9 before the improvement to 0.6 after the improvement. This means that sugarbeet was dominant in the tail-end than that in the head-reach area after irrigation improvement. The tail-reach areas are slightly higher in their salinity than the head-reach areas , which is favored for sugarbeet. It is interesting to note that the decrease in sugarbeet at the head-reach in both cropping seasons was replaced by wheat which already took the converse trend. Farmers in the tail-end prefer to invest in growing more wheat due to the better reliability of water resources as well as its usage in both human and animal feeding. These results are in agreement with those obtained by **WaterWatch (2004).**

3.2. Crop Evapotranspiration (ET_c):

The consumptive use dependents not only on water management but the meteorological conditions also play an important role. The meteorological conditions of the two winter seasons (2010/2011 and 2012/2013) are represented in Table (3). The total degree days in the winter season (2010/2011) before irrigation improvement were 1332.0 vs. 1482.4 for winter season after irrigation improvement (2012/2013). The total hours of sunshine for 2010/2011 and 2012/2013 for three months (December, February and March) were 741.8 and 744.9 hours of bright sunshine, respectively. Hence, the 2012/2013 season has 0.42 % higher sunshine hours and 11.3 % higher temperature than the 2010/2011 season. These differences are relatively low; therefore, the ET values among the two investigated seasons may be slightly affected by the meteorological conditions.

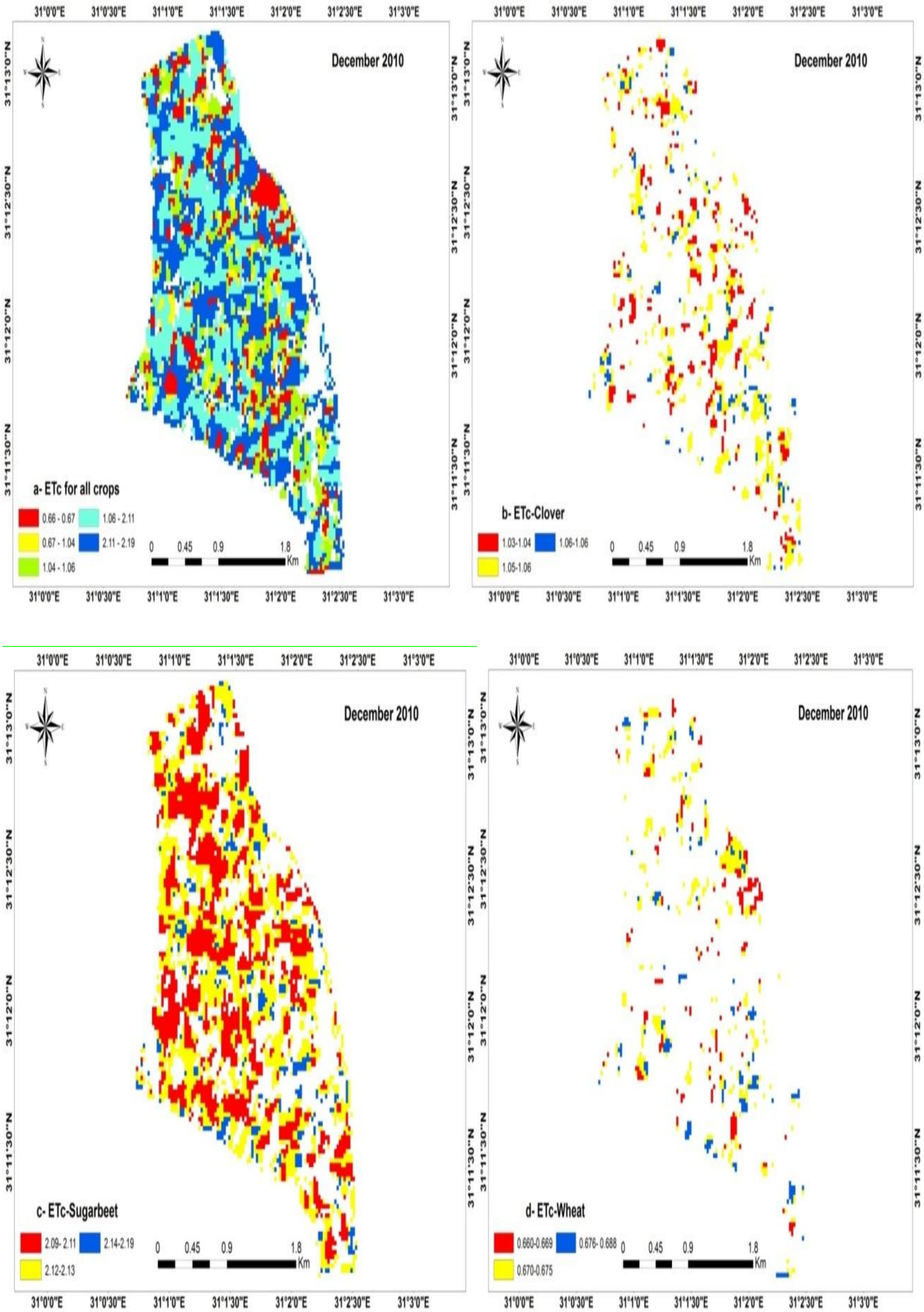
Table (3): The total degree days and sunshine in winter seasons (010/011) and (012/013).

Climate information	Winter seasons	Winter months			Total	Change %
		Dec.	Feb.	March		
Temperature degree days	2010/2011	480.5	400.4	451.1	1332.0	11.3
	2012/2013	494.5	414.4	573.5	1482.4	
Total sunshine	2010/2011	237.9	230.3	273.6	741.8	0.42
	2012/2013	237.9	230.3	276.7	744.9	

Data in Table (4) and Figures (3 to 5) show that the average daily actual (ETc) for sugarbeet, wheat and clover before the improvement (2010/2011) were 3.5, 3.0 and 1.7 mm/day, respectively. The total ETc for these crops in three month (December, February and March) were 315, 270 and 153 mm, respectively (3150, 2700 and 1530 m^3/ha, respectively). The irrigation requirement was calculated by dividing ETc values by the irrigation efficiency at mesqa level (70 %). Therefore, water requirement or irrigation water to be applied to sugar beet, wheat and clover was 4500, 3857 and 2186 m^3/ha, respectively.

Table (4): Water consumption and water requirements for winter crops (2010/2011).

Crop	Area (ha)	ETc(mm/day)			Mean	ETc	W. Requirements	
		Dec	Feb	March	mm	m^3/ha	m^3/ha	m^3/area
Sugarbeet	363.8	2.2	4.3	3.9	3.5	3150	4500	1637100
Wheat	68.7	0.7	3.9	4.4	3.0	2700	3857	264986
Clover	113.0	1.1	1.9	2.0	1.7	1530	2186	246986
Planted area	545.5	4.0	10.1	10.3	8.2	-	-	2149072
Mean	-	-	-	-	-	2460	3940	-



Figure(3): Estimated ET_c (mm) for a) all winter crops , b) clover, c) sugarbeet and d) wheat in December (2010) extracted from Landsat data.

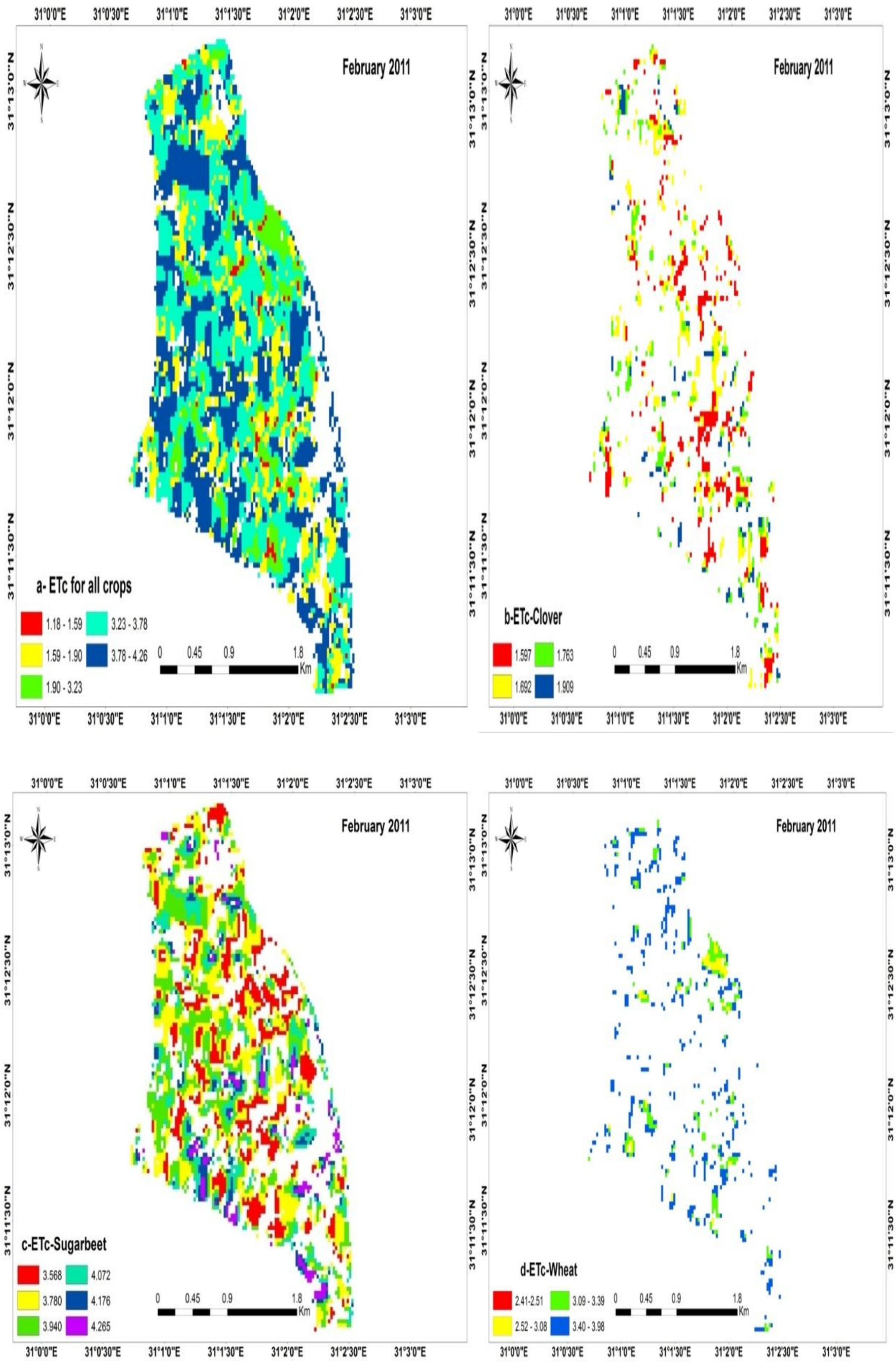


Fig (4): Estimated ET_c (mm) for a) all winter crops , b) clover for , c) sugarbeet and d) wheat in February (2011) extracted from Landsat data.

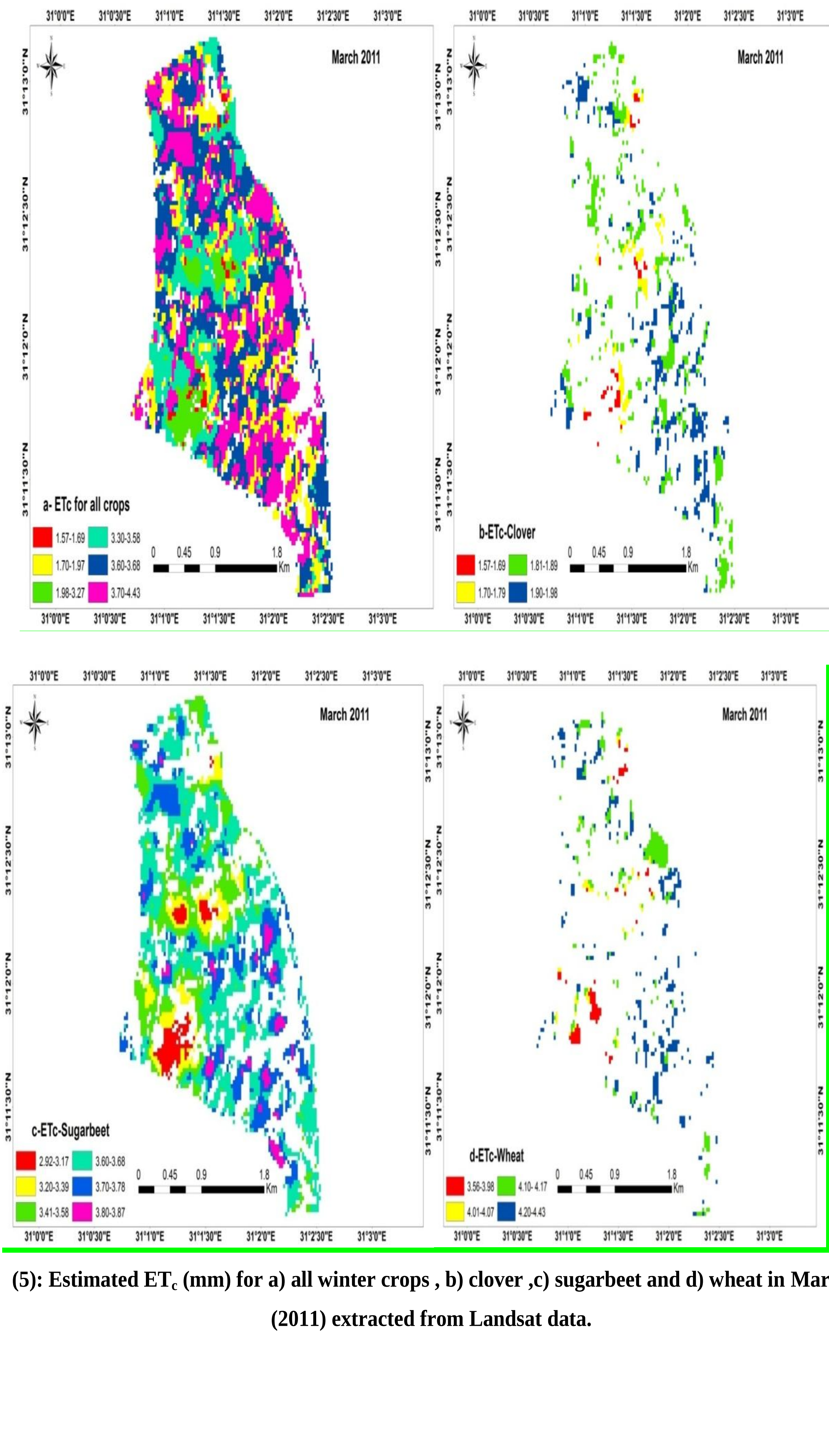


Fig (5): Estimated ET_c (mm) for a) all winter crops , b) clover ,c) sugarbeet and d) wheat in March (2011) extracted from Landsat data.

Concerning the evaluation of water consumptive use for the three studied crops after irrigation improvement (2012/2013), data in Table (5) and Figs (6 to 8) represent the average daily ETc (mm or m^3/ha) and water requirements (m^3/ha or m^3/crop area) in the three cloudless months. Data revealed that the average daily ETc after improvement was lower than that before irrigation improvement by about 22 %, although it had 0.42 % higher sunshine hours and 11.3 % higher total temperature. The average of ETc values in the three studied months for sugar beet, wheat and clover were 2.70, 2.43 and 1.30 mm/day, respectively. The total ETc for these crops in these 90 days was 243, 219 and 117 mm, respectively (2430, 2190 and 1170 m^3/ha, respectively). Irrigation requirements (ETc/ 0.7) were calculated for each of the studied three crops in El-Moheet canal branch. Consequently, water requirements for sugar beet, wheat and clover were 3038, 2738 and 1463 m^3/ha, respectively.

Table (5): Water consumption and water requirements for winter crops (2012/2013).

Crop	Area	Etc (mm/day)			Mean	ETc	W. Requirements	
	(ha)	Dec	Feb	March	mm	m^3/ha	m^3/ha	m^3/area
S.beet	169.5	1.9	2.8	3.3	2.7	2430	3038	514856
Wheat	184.7	0.6	2.8	3.9	2.4	2190	2738	505616
Clover	166.2	0.9	1.3	1.7	1.3	1170	1463	243068
Total	520.4	3.4	6.9	8.9	6.4	-	-	1263540
Mean	-	-	-	-	-	1930	2428	-

Data in Table (6) indicate that the overall water consumption was decreased after irrigation improvement, although the sunshine hours and the total temperature were higher in 2012/2013 than in 2010/2011. Data also revealed that sugarbeet consumed relatively less water in 2012/2013 than 2010/2011 (-22.9 %) and its water requirements/ha were decreased after the improvement by about 32 %. Also, the total water requirements for the sugarbeet area were decreased by about 68 % due to the decrease in ET_c and its area. On the other hand, water consumption (ETc, m^3/ha) for clover and wheat were decreased in 2012/2013 by about 23.5 and 18.9%, respectively, whereas their water requirements/ha were decreased by 33.1 and 29 %, respectively.

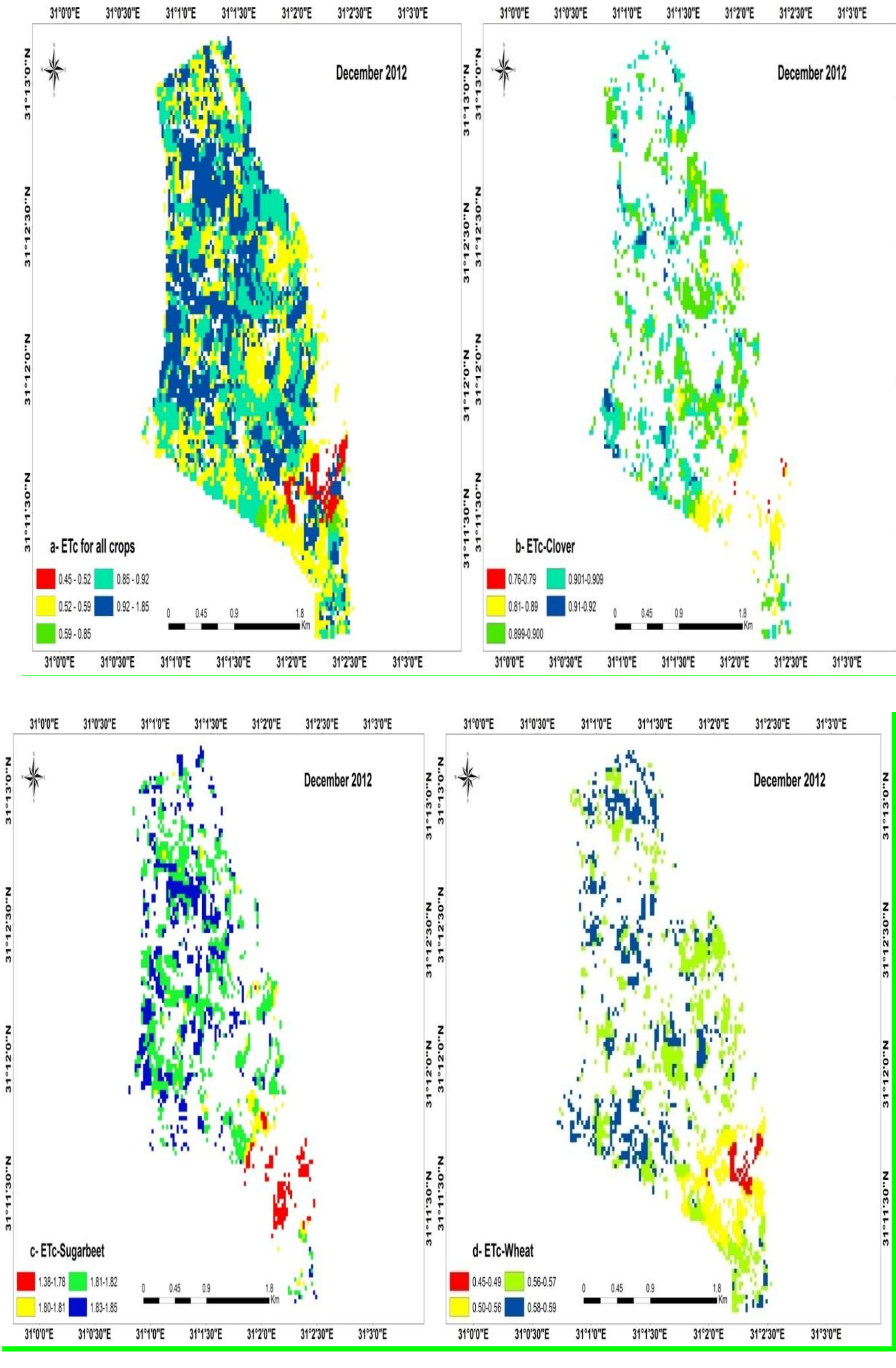


Fig (6): Estimated ET_c (mm) for a) three winter crops , b) clover ,c) sugarbeet and d) wheat in December (2012) extracted from Landsat data.

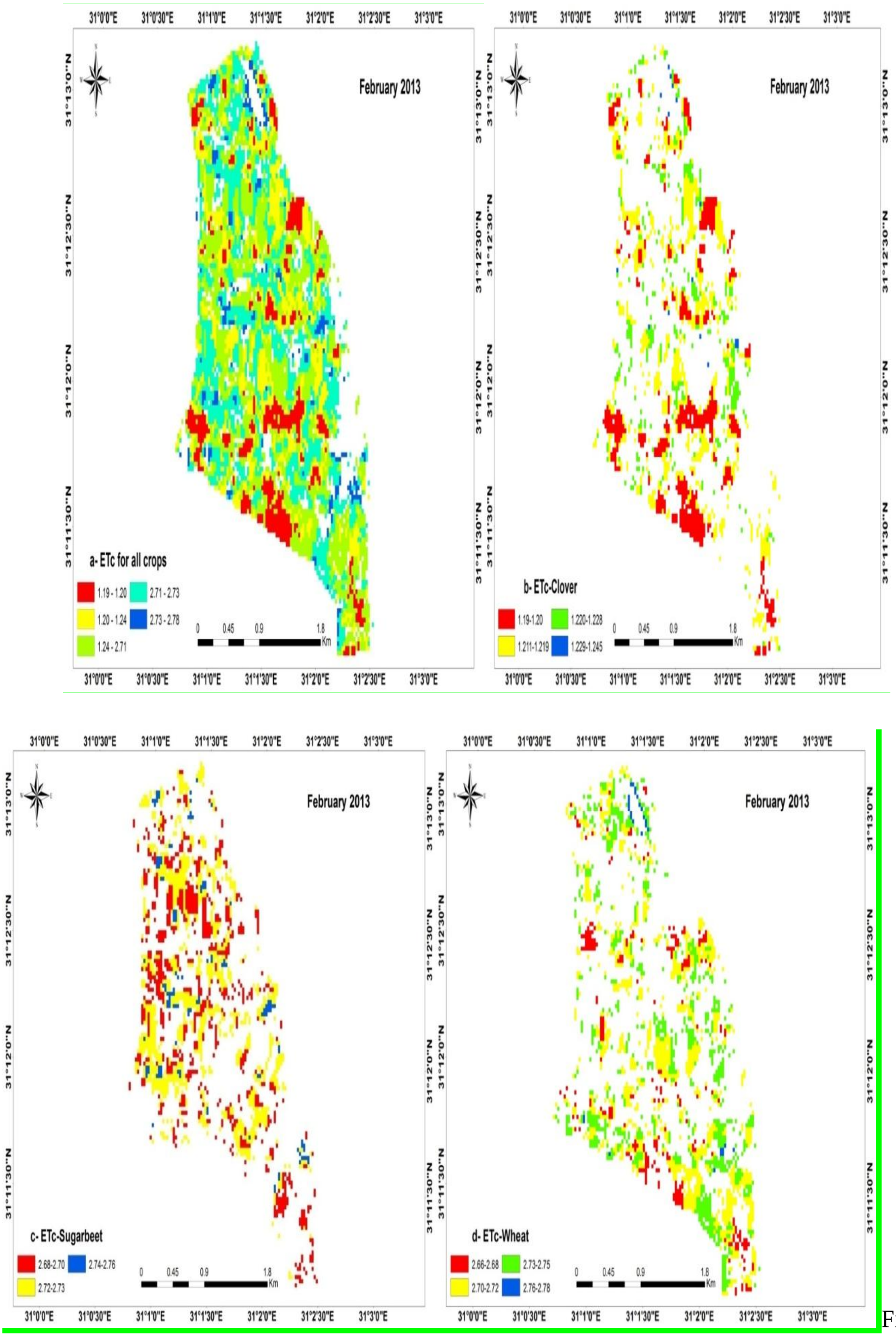


Fig (7): Estimated ET_c (mm) for a) three winter crops , b) clover , c) sugarbeet and d) wheat in February (2013) extracted from Landsat data.

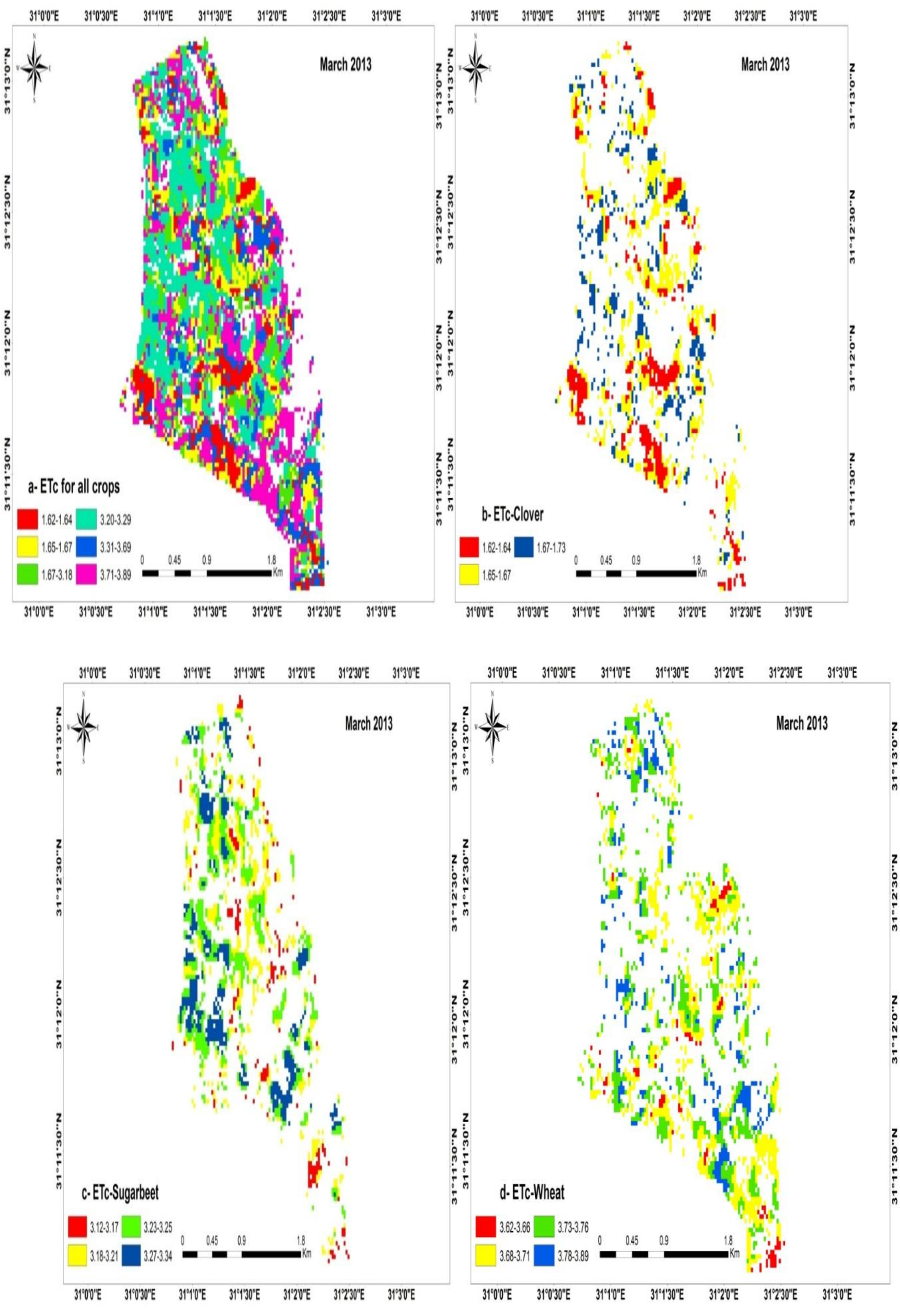


Fig (8): Estimated ET_c (mm) for a) three winter crops , b) clover ,c) sugarbeet and d) wheat in March (2013) extracted from Landsat data.

It is worthy to mention that the obtained data indicated that the ETc for El-Moheet area after IIIMP was decreased by about 29.2 % as compared to the baseline year 2010/2011, whereas water requirements for all areas were decreased by about 41 % due to the decrease in ET_c and the planted area. These results are in harmony with those obtained by **WaterWatch (2002 and 2004).**

Table (6): Consumptive use for improved vs unimproved area for different crops in 2010/2011 and 2012/2013.

Crop	Winter (2010/2011)				Winter (2012/2013)				Differences %		
	Area	ETc	W. Requirement		Area	Etc	W. Requirement		ETc	W. Requirement	
	(ha)	m^3/ha	m^3/ha	m^3/area	(ha)	m^3/ha	m^3/ha	m^3/area	m^3/ha	m^3/ha	m^3/Area
S.beet	363.8	3150	4500	1637100	169.5	2430	3038	514856	-22.9	-32.5	-68.6
Wheat	68.7	2700	3857	264986	184.7	2190	2738	505616	-18.9	-29.0	90.8
Clover	113.0	1530	2186	246986	166.2	1170	1463	243068	-23.5	-33.1	-1.6
Total	545.5	2732	3902	2128637	520.4	1933	2416	1257184	-29.2	-38.1	-40.9

The ET_c values (mm or m^3/ha) of winter crops along the branch canal weren't significantly affected by irrigation improvement, but they were mainly affected by the meteorological conditions and the crop pattern in the area that affected by the situation of the irrigation system. For comparing the ET_c within the branch canal, the head/tail analysis was carried out before and after irrigation improvement with respect to ET_c and water requirements (Tables 7 & 8). The head /tail analysis before the improvement (2010/2011) indicated that the values of ETc and water requirement (in m^3/area) for wheat and clover on the head-reach were higher than those for the tail-reach by about 25 and 39 %, respectively. However, these values for sugarbeet took an opposite trend (-5 %). The obtained results reflected the crop pattern along the branch canal and revealed that the distributions of wheat and clover within the three reaches, was less homogeneous, whereas it was homogeneous for sugarbeet.

Table (7): Head/Tail analysis of water requirements of winter season (2010/2011).

Crop	Area (ha)			ETc (m^3/area)		W.Req (m^3/area)		Head/Tail Ratio
	Head	Middle	Tail	Head	Tail	Head	Tail	
S.beet	113.4	130.6	119.8	357210	377370	510300	539100	0.95
Wheat	28.2	18.0	22.5	76140	60750	108767	86783	1.25
Clover	48.0	30.4	34.5	73440	52785	104928	75417	1.39
Total	189.6	179.0	179.8	506790	490905	723995	701300	1.03

After irrigation improvement, the ET_c values for wheat on the head- reach were higher than that in the tail-reach by about 95 %, whereas they decreased for sugarbeet and clover by about 36

% and 4 %, respectively. This trend indicates that wheat and sugar beet areas had a less homogeneous distribution, whereas clover had homogeneous distributions ,where the head/tail ratio close to one. Also, after improvement the head/tail analysis proves that sugar beet occupied a larger area in tail reach although it needs more water requirements. This could be attributed to the equity of water distribution along the water courses due to the irrigation improvement. It could be also attributed to the relatively high soil salinity in these areas, which is favored for sugarbeet.

Table (8): Head/Tail analysis of water requirements of winter season (2012/2013)

Crop	Area (ha)			ET_c (m^3/area)		W. Req (m^3/area)		Head/Tail Ratio
	Head	Middle	Tail	Head	Tail	Head	Tail	
S.beet	42.5	60.7	66.3	103275	161109	127500	198900	0.64
Wheat	85.2	55.8	43.7	186588	95703	233278	119651	1.95
Clover	51.5	61.1	53.6	60255	62712	75345	78417	0.96
Total	179.2	178.0	163.6	350118	319524	436122	396967	1.10

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 sugarbeet was the dominant crop before irrigation improvement, whereas, wheat 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 ET_c information and crop growth stages. This technique could minimize the additional filed observations. Remote sensing based K_c estimation follow the similar pattern of seasonal variation of crop fraction. Since the meteorological difference was relatively small, the changes in ET_c could be attributed mainly 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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