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EVAPOTRANSPIRATION ESTIMATION USING REMOTE SENSING DATAAND SOME CLIMATIC MODELS

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ABSTRACT

This study aims to assess the estimated values of evapotranspiration using the surface energy balance system (SEBS model) and four climatic models widely used including Penman-Monteith (FAO 56-PM), Penman (FAO 24-P), radiation (R) and Hargreaves-Samani (HS). Remote sensing model (SEBS) was used to estimate daily actual evapotranspiration values for wheat, Sugar beet and green onions crops using nine Landsat ETM+7 satellite images representing the 2012 / 2013season. The selected site represents a private farm (6^{th} October agricultural company) located in Ismailia governorate (between 31.92 and 32.62 E longitudes and 30.38 and 30.52 N latitudes).

Results indicated that there were clear differences between the estimated Et_a values using any of the tested climatic or remote sensing models. The Et_a values estimated by SEBS, P, R, and HS methods were lower than those estimated by PM method. Estimated Et_a values using SEBS model were generally low compared with those estimated by the tested climatic models. The actual evapotranspiration values (Et_a) for the studied crops using SEBS, PM, P, R, and HS methods are 384, 574, 382, 450, and 329 for wheat, 491, 533, 331, 409 and 264 for sugar beet and 279, 614, 414, 508 and 360 mm/season for green onion crop respectively. Data suggested that, more studies and verification are needed to evaluate all the factors that might affect the quality of data affecting the surface energy balance under arid lands condition. Results concluded also that more verification through several consecutive seasons for various crops is recommended for estimating the actual evapotranspiration at the field level.

Keywords: Reference & actual crop evapotranspiration, FAO-56 Penman-Monteith method, (PM), Penman method (FAO 24 P), Radiation method (FAO R), Hargreaves-Samani method (HS), Remote sensing model (SEBS) model.

INTRODUCTION

Water scarcity in Egypt and the other countries in the arid zone was the major factor that limits the ambitious hopes to expand the agricultural area and increase its productivity to meet the present gap between food production and consumption. The pressure of population growth and increasing domestic demand and other sectors for water as well as the negative impact of climate change represent additional challenges for the agricultural sector. To meet these challenges, good water governance which aims to reduce losses and increase benefits per unit of water should be adopted. For this reason, accurate estimation of crop water requirement was very important. The problem of over irrigation or under irrigation will be minimized if we were able to accurately estimate crop water requirement or crop evapotranspiration (Sallam, 2014; Subedi & Chávez, 2015).

One of the most efficient ways to improve water use efficiency and optimize plant production is to provide crops only with the water they need based on the climate-plant-soil relationship. Therefore, the concept of evapotranspiration is the base for estimating the right amount of irrigation water that should be applied. As the measurement of ET from a crop surface is a very difficult and time consuming task, a large number of empirical methods have been developed over the last 50 years by numerous scientists and specialists worldwide to estimate evapotranspiration from different climatic variables like Thornthwaite method, Hargreaves method, Turc method, Blaney-Criddle method, Penman method, Penman-Monteith method etc. On the other hand, the scientific community has been interested in estimating evapotranspiration by remote sensing, since it is the unique way to retrieve ET at several temporal and spatial scales. For this reason, different methods have been developed to derive surface fluxes from remote sensing observations, such as: Surface Energy Balance Algorithm for Land (SEBAL), Bastiaanssen, 2000; Bastiaanssen *et al.*, 1998a,b; Jacob *et al.*, 2002), S-SEBI (Simplified Surface Energy Balance Index, Roerink *et al.* 2000), and SEBS (Surface Energy Balance System, Jia *et al.* 2003; Su, 2002).

Wahaj *et al.* (2007) studied crop water requirement as affected by climate change in some countries in Africa. They indicated that the reference crop evapotranspiration (Et_o) values of maize and dry bean crops were 678 and 189 mm, respectively for Kafr El-Shiekh governorate. They added that the Et_o values for maize, dry bean, groundnut, and sorghum crops were 825, 310, 835, and 825 mm respectively for Giza governorate. In Egypt. Khalifa *et al.* (2011) used the CROPWAT model to assess the effects of different deficit irrigation scenarios on the yields of crops planted in field trials. They found that crop evapotranspiration values of wheat, peanut, and maize crops were 282, 543, and 524 mm $seasons^{-1}$ respectively. George *et al.* (2002) found that certain models, such as Hargreaves-Samani, perform best in situations where only maximum and minimum air temperature data were available. They concluded that the Hargreaves-Samani model fell within 1 percent of PM- FAO 56 method.

The Surface Energy Balance System (SEBS) model, developed by Su (2002), can be used to determine turbulent heat fluxes by employing satellite and meteorological data. It consists of: (1) an estimation of a series of land surface physical parameters, such as emissivity, albedo, vegetation coverage *etc.* based on spectral reflectance and radiance; (2) an extended model of roughness length estimation for heat transfer; and (3) an evaporative fraction estimation at limiting cases by energy balance. Weiqiang *et al.* (2013) used Surface Energy Balance System (SEBS) model based on ASTER images and field observations data for deriving Et_a over the NamCo area in the southwest of China. They showed that the derived ET in different months over the study area was close to the field measurement; it is therefore concluded that the SEBS methodology is successful for the retrieval of Et_a using the ASTER and in-situ data over the study area. Matinfar and Soorghali (2014) used SEBS model, spectral data and Landsat 5 (TM) thermal band to estimate actual evapotranspiration rates. Results of the model were compared with the Penman Montieth method. Statistical analysis showed significant differences between the results of the two methods. They concluded that, the SEBS model can be a valuable alternative to traditional methods of estimating actual evapotranspiration.

Bansouleh *et al.* (2015) conducted a study to assess the accuracy of estimated Et_a based on SEBS algorithm using LANDSAT TM images in Iran. The Et_a of maize was calculated using four images of LANDSAT during the maize growing season in year 2010. At the same time, the actual ET of maize was measured in a Lysimeter in the same region. They observed a reasonable match between measured and calculated crop evapotranspiration by SEBS algorithm. The maximum difference between the calculated evapotranspiration by SEBS algorithm with measured values by Lysimeter was about 4.56% of measured ET.

In Egypt, few studies have applied remote sensing data at farmers' field level to estimate evapotranspiration. However, Elhag *et al.* (2011) used SEBS model to estimate daily evapotranspiration and evaporative fraction over the Nile Delta along with data acquired by the Advance along Track Scanning Radiometer (AATSR) and the Medium Spectral Resolution Imaging Spectrometer (MERIS), and six in situ meteorological stations. The simulated daily evapotranspiration values were compared against actual ground-truth data taken from 92 points uniformly distributed all over the study area. The derived maps and the correlation analysis showed strong agreement, demonstrating SEBS' applicability and accuracy in the estimation of daily evapotranspiration over agricultural areas.

The main objective of this study was to investigate the possibility of using the remote sensing model (SEBS) for in the estimation of actual evapotranspiration (Et_a) directly in the presence of three selected crops (wheat, Sugar beet, green onion) in comparison with four climatic models (Penman-Monteith (PM-FAO 56), Penman (P-FAO-24), Radiation method (R), and Hargreaves-Samani (HS) for used in estimating reference evapotranspiration indirectly or in absence of crop under Egyptian conditions.

MATERIALS AND METHODS

Location and general description of the site:

The selected site represents a 6^{th} October farm that was located in Ismailia governorate between 31.92 and 32.62 E longitudes and 30.38 and 30.52 N latitudes (Figure 1).

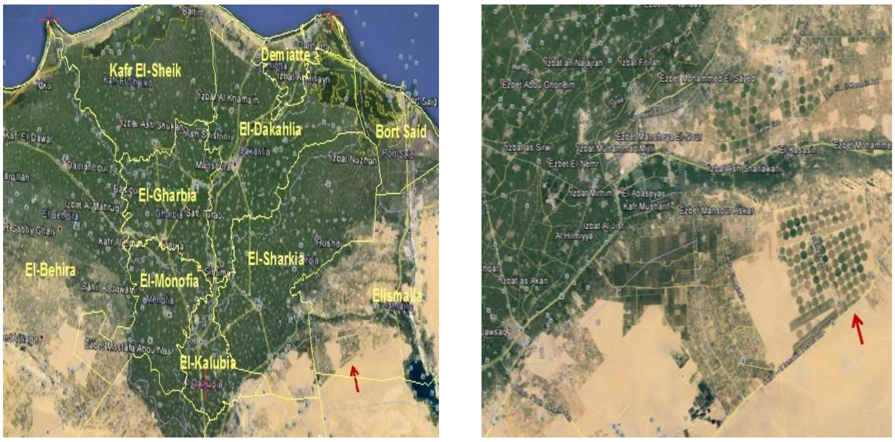


Fig. 1: Site location as illustrated on the administrative map and on satellite image.

Data availability:

Satellite Data:

Nine Landsat ETM+7 images (Table 1) acquired in October, November, and December 2012, Jan., February, March., April, May, and June 2013. Remote sensing and Meteorological data were used to estimate evapotranspiration at the day of images captured using the SEBS model. It is worthy to mention that the Landsat images were atmospherically and radiometricaly corrected before using in the SEBS model.

Table.1. Landsat ETM+7 satellite images specifications.

Scene coverage area	**185 x 185 km**
Spatial Resolution	30 m Multispectral
	15 m Panchromatic
Blue-green	450 - 515 nm
Green	525 - 605 nm
Red	630 - 690 nm
Near-infrared	750 - 900 nm
Mid-infrared	1550 - 1750 nm
Far-infrared	10400 - 12500 nm
Mid-infrared	2090 - 2350 nm
Pan	520- 900 nm

Meteorological data

Meteorological data includes the maximum, minimum, and mean air temperatures and dew point temperatures (C^o), wind speed (ms^{-1}), relative humidity (%), and solar radiation (MJm^{-2}) for Ismailia governorate during the period from Oct to Dec 2012 and from Jan to Dec 2013 were presented in Table 2. These data were required for calculating reference evapotranspiration values (Et_o) using Penman-Monieth (PM), Penman (P), radiation (R), and Hargreaves-Samani (HS) methods as well as actual evapotranspiration values at the day of image captured by the SEBS model.

Table.2. Monthly average meteorological data for Ismailia governorate during the period from Oct 2012 to Dec 2013.

Date	T_{max} (°C)	T_{min} (°C)	T_{mean} (°C)	T_{dew} (°C)	U_2 (ms^{-1})	RH (%)	R_s (MJm^{-2})
Oct. 2012	32.6	20.3	26.5	14.6	3.3	51.5	18.1
Nov.	26.7	16.7	21.7	11.9	3.1	57.6	14.3
Dec.	21.1	11.6	16.4	6.8	3.1	56.7	12.5
Jan. 2013	19.1	8.1	13.6	4.1	3.9	55.6	13.1
Feb.	21.4	9.3	15.4	4.5	3.5	49.0	16.5
Mar.	26.6	11.7	19.1	4.7	4.5	41.0	21.2
Apr.	27.6	13.2	20.4	6.8	4.4	43.0	24.1
May	33.6	18.2	25.9	9.1	4.1	36.1	27.9
Jun.	35.2	20.3	27.8	11.5	4.0	38.3	30.0
Jul.	35.1	20.7	27.9	14.0	4.1	44.2	29.1
Aug.	36.2	21.6	28.9	14.8	3.5	44.0	27.0
Sep.	33.4	20.4	26.9	14.7	4.1	49.6	23.2
Oct.	28.8	16.4	22.6	11.5	4.4	52.7	19.0
Nov.	26.4	15.2	20.8	10.6	3.5	55.7	14.1
Dec.	19.5	9.3	14.4	4.4	3.8	53.5	11.5

Crop Data:

Three crops representing the major farming activity in the study area were selected to estimate the evapotranspiration using the selected four climatic models in addition to a remote sensing model (SEBS). The following is a brief description of each of these crops.

1. Wheat crop:

Wheat crop is one of the main cultivated winter crops in the study area under center pivot irrigation system. The variety was Misr-1, sowing dates ranged from 25th to 27th of November 2012 and the harvesting dates ranged from 23th to 30th of April 2013, The wheat crop was fertilized in this farm during growth season by 94, 13, 47, 11, and 10 kg/Fadden of N, P_2O_5, K_2O, CaO and MgO, respectively, in addition to micronutrients injected through irrigation water using the fertigation system.

2. Sugar beet crop:

Few center pivots were cultivated with Sugar beet crop in winter season 2012/2013. The variety was *Giza*, sowing dates ranged from 10th to 12th of December 2012 and harvested from 10th to 15th of June 2013. The Sugar beet crop was fertilized in this farm during growth season by 72, 11, 67, 13, and 8 kg/Fadden of N, P_2O_5, K_2O, CaO and MgO, respectively. in addition to micronutrients injected through irrigation water.

3. Green onion crop:

Green onion crop is one of the main winter vegetable crop cultivated in the study area under center pivot irrigation system mainly for export to UK. The variety was *Baja*, sowing dates ranged from 15st to 18st of September 2012 and the harvesting dates ranged from 6th to 13th of April 2013. The green onion crop was fertilized in this farm during growth season by 79, 12, 29, 9, and 9 kg/Fadden of N, P_2O_5, K_2O, CaO and MgO, respectively, in addition to micronutrients injected through irrigation water.

Irrigation system:

The center pivot is the main irrigation system in the farm particularly for field and vegetable crops. The application efficiency of the system was about 75%. The pump station produces pressure of about 6 bars to maintain water flow of about 80 $Lsec^{-1}$ through nuzzle of a large center pivot. The pivot takes 12 hours to complete one cycle to apply 20 m^3/Faddan of irrigation water.

Evapotranspiration estimation models:

The ET techniques were selected by considering the availability of meteorological data required by those models. In this study, the selected methods can be divided into two broad groups: I) climatic models, e.g. Penman-Montieth (PM-FAO 56), Penman, (P-FAO 24), Radiation-based method (R-FAO 24), temperature-based method (Hargreaves-Samani, HS), and II) remote sensing model based on surface energy balance method (SEBS). Ibrahim (2013) described a simple method using the Microsoft Excel to be a helpful tool in computation of evapotranspiration parameters using the different climatic models.

The performance efficiencies of these methods were determined using the appropriate statistical analysis such as the regression analysis and correlation coefficients.

I. Climatic models:

1. Penman–Monteith method (Allen *et al.*, 1998):

This version PM model was recommended by FAO as a main method for estimating reference evapotranspiration (Et_o) if the required data are available (Allen *et al.*, 1998). The FAO 56 PM method is given as follows:

$$Et_o = \frac{0.409 \cdot \Delta \cdot (R_n - G_d) + \left(\gamma \cdot U2_{mean} \cdot (e_s - e_a) \cdot \frac{900}{T_{mean} + 273}\right)}{\Delta + \gamma \cdot (1 + 0.34 \cdot U2_{mean})} \quad \text{mm/day}$$

where Δ is the slope of the saturation vapor pressure/temperature relationship (kPa^oC^{-1}), R_n is net radiation $_{(MJm-2\ d-1)}$, G_d is soil heat flux ($MJm^{-2}\ d^{-1}$), γ is the psychrometric constant ($kPa\ ^oC^{-1}$), T is mean daily air temperature at 2 m height (^oC), U_{2mean} is wind speed at 2 m height ($m\ s^{-1}$), and (e_s - e_a) is the saturation vapor pressure deficit (kPa).

2. Penman's method (Doorenbos and Pruitt, 1977):

$$Et_o = C \times ((W \times R_n) + (1 - W) \times f(U) \times (e_a - e_d)) \quad mmday^{-1}$$

where W is temperature-related weighting factor, Rn is the net solar radiation, f(U) is wind-related function, (e_a - e_d) is the difference between saturation vapor pressure at mean air temperature and mean actual vapor pressure of the air, and C is the adjustment factor to compensate for the effect of day and night weather conditions.

3. Radiation method (Doorenbos and Pruitt, 1977):

$$ET_o = C \times W \times R_s \qquad \text{mmday}^{-1}$$

where R_s is the solar radiation, W is weighting factor which depends on temperature and altitude, and c is the adjustment factor which depends on mean humidity and daytime wind conditions.

4. Hargreaves-Samani method:

The Hargreaves and Samani (198 and 1985) equation is a temperature-based equation expressed as follows:

$$ET_o = 0.0135 \times KT \times R_a \times (TD)^{0.5} \times (T_{mean} + 17.8) \qquad \text{mmday}^{-1}$$

where Et_o is the reference evapotranspiration (mm/day), $KT=0.00185\times(TD)^2-0.0433\times TD+0.4023$, Tmean is the mean air temperature (°C), TD is $(T_{max}-T_{min})$ (°C), and Ra is the daily extraterrestrial radiation (mm/day).

Actual evapotranspiration (Et_a):

Actual evapotranspiration values of the tested crops (Et_a) were estimated simply by multiplying Et_o by the corrected crop coefficient (KC) according to the minimum relative humidity and wind speed as described by Ibrahim (2013) for different growth stages.

II. Surface energy balance system model (SEBS):

The surface energy balance system (SEBS) model derived by Su (2001) for the estimation of atmospheric turbulent fluxes using satellite earth observation data in combination with meteorological information as inputs to retrieve a set of geo-physical parameters, evaporative fraction, net radiation, and soil heat flux parameters etc. The equations used in the SEBS model were:

$$\lambda Et = R_n - G - H$$

where R_n is the net solar radiation, G is the soil heat flux, H is the turbulent sensible heat flux, and λEt is the turbulent latent heat flux (λ is the latent heat of vaporization and Et is the evapotranspiration).

$$R_n = (1-\alpha)(R_{s,sun}+R_{s,sky})+R_{L,sky}-R_{L,out}$$

where α is the albedo, R_s is the incoming and outgoing solar radiation, R_L is the incoming and outgoing longwave radiation.

$$G = R_n(\tau_c+(1-f_c)(\tau_s-\tau_c))$$

where $\tau_c = 0.05$ for full vegetation canopy, $\tau_s = 0.315$ for bare soil, and f_c is fractional canopy cover.

$$H = (\rho\, C_p\, (T_s - T_a)/r_{ah})$$

where ρ is air density, C_p is air specific heat (1004 J $kg^{-1}\, K^{-1}$), T_s is surface temperature, T_a is air temperature, and r_{ah} is the aerodynamic resistance to heat transport.

$$\lambda = (\lambda E/(R_n-G)) = (\lambda_r\, \lambda E_{wet}/(R_n-G))$$

where λ is the evaporative fraction, λ_r is the relative evaporation, and λE_{wet} is the evaporation at potential rate under wet conditions.

$$E_{daily} = 8.64 * 10^7 * \lambda_0^{24} * (R_n - G / \lambda\, \rho_w)$$

where E_{daily} is the daily actual ET (mm day^{-1}), λ_0^{24} is the daily evaporative fraction, and ρ_w is the density of water.

Statistical analysis:

The correlation and linear regression analysis were applied to the computations of the different methodologies in order to observe the behavior of the methods. The quality of the fit between any two methodologies was presented in terms of the coefficient of determination, r^2.

RESULTS AND DISCUSSION

Estimating reference evapotranspiration (Et_o):

The estimated average Et_o values (mm day^{-1}) by Penman-Montieth (PM), Penman (P), radiation (R), and Hargreaves-Samani (HS) methods using the agrometeorological data of 2012/2013 were presented in Table 3. In general, results showed the same trend in Et_o values calculated by the four climatic models. The lowest values were recorded in December, except for the PM method which recorded in January, while the highest values were recorded in June, except for the Radiation method which was recorded in July. The highest average Et_o value was 12.6 $mmday^{-1}$ for PM in June, while the lowest value was 1.8 $mmday^{-1}$ for HS in December.

Table.3. Average reference evapotranspiration values ($mmday^{-1}$) Estimated using the models of Penman-Montieth (PM-FAO 56), Penman (P-FAO 24), Radiation (R), and Hargreaves-Samani (HS) with the agrometeorological data of 2012.

Month	PM	P	R	HS
Jan.	3.8	2.4	3.1	1.9
Feb.	5.0	3.3	4.0	2.6
Mar.	6.3	4.6	5.2	4.3
Apr.	8.9	6.3	6.7	6.5
May	10.9	7.8	8.0	8.1
Jun.	12.6	8.8	8.6	9.1
Jul.	12.1	8.5	8.7	8.6
Aug.	11.3	8.0	8.7	7.8
Sep.	10.0	6.4	7.1	5.3
Oct.	7.7	4.7	5.3	3.6
Nov.	5.7	3.3	4.0	2.5
Dec.	3.9	2.3	3.0	1.8
Mean	8.2	5.5	6.0	5.2

Data reveal that the average values of Et_o were 8.2 (100), 6.0 (73.2), 55 (67.1) and 5.2 (63.4) for PM, R, P and HS, respectively. The differences in Et_o values obtained for the tested methods may attributed to the Lowest correlation found between Et_o values estimated by HS and minimum temperature (T_{min}) and maximum temperature (T_{max}), minimum relative humidity (RH_{min}), solar radiation (R_s) and sunshine hours (n), which were 0.89, 0.74, -0.04, 0.9 and 0.88, respectively. in comparison with that found for the other tested climatic models. This result was in agreement with those reported by Droogers and Allen (2002) and Temesgen *et al.* (2005) who stated that HS equation tends to underestimate Et_o values in very dry and windy regions. The observed variations in the reference evapotranspiration values calculated for the tested crops using the different climatic models and even the remote sensing model (SEBS) may attributed to the variations in weather parameters values used in the calculations.

Since the Penman-Monteith method (FAO-56 PM) was recommended by the Food and Agriculture Organization of the United Nations (FAO) as the standard sole method to calculate Et_o whenever the required input data are available (Allen *et al.* 1998; Droogers and Allen, 2002), therefore, a regression analysis was done to develop relationships between Et_o values estimated by FAO-56 PM and the P, R, and HS methods. The obtained relationships were expressed as follows:

Et_o PM (mm) = 1.059 + 1.228 Et_o P (mm) $r^2 = 0.8869$

Et_o PM (mm) = -0.049 + 1.304 Et_o R (mm) $r^2 = 0.8334$

Et_o PM (mm) = 2.624 + 1.137 Et_o HS (mm) $r^2 = 0.7604$

The high values of the coefficient of determination (r^2 = 0.76 - 0.89) indicate that the given equations can be used within the range of the examined values to describe the relationship between Et_o estimated by PM-FAO 56 and the P–FAO 24, R, and HS methods.

Estimating daily evapotranspiration using SEBS Model:

The temporal variation maps of daily Et_a values generated by SEBS model on 9 Landsat7 ETM+ images acquired during the 2012/2013 winter season were illustrated in Figure 2. For wheat crop, the Et_a values used in mapping actual evapotranspiration (Et_a) varied from 1.0 to 5.0 mmday^{-1}, with the smaller and higher values observed on 30 December 2012 and 5 April 2013, respectively. For green onion crop, Et_a values varied from 1.1 to 5.5 mmday^{-1} for the same respective images. For Sugar beet crop, the Et_a values varied from 1.45 to 4.2 mmday^{-1} for 30 December 2012 and 5 April 2013 images, respectively. Larger values of Et_a were the result of high temperature and low relative humidity conditions that were common in the study area during the growing season.

The temporal study for actual evapotranspiration values (Et_a) produced from this study showed that the highest values of Et_a were associated with the highest rate of the growth of crop particularly during the stage of growth development, while the lowest values of Et_a were related to the initial growth stage where the rate of growth and development was low. The produced maps showed also the spatial variation in the values of Et_a for different cultivated areas as attributed to the differences in crop type.

A regression analysis was done to express relationships between Et_a values estimated by FAO-56 PM and the remote sensing model (SEBS) for the tested crops. The obtained relationships were shown as follows:

For wheat crop, Et_a SEBS (mm) = 3.019 + 0.395 Et_a PM (mm) $r^2 = 0.273$

For Sugar beet crop, Et_a SEBS (mm) = 1.470 + 0.268 Et_a PM (mm) $r^2 = 0.712$

For green onion crop,Et_a SEBS (mm) = 3.422 + 0.735 Et_a PM (mm) $r^2 = 0.348$

The low values of the determination coefficient (r^2 = 0.27-0.71) indicate that the given equations can be carefully used within the range of the examined values to describe the relationship between Et_a estimated by FAO-56 PM and by the SEBS methods.

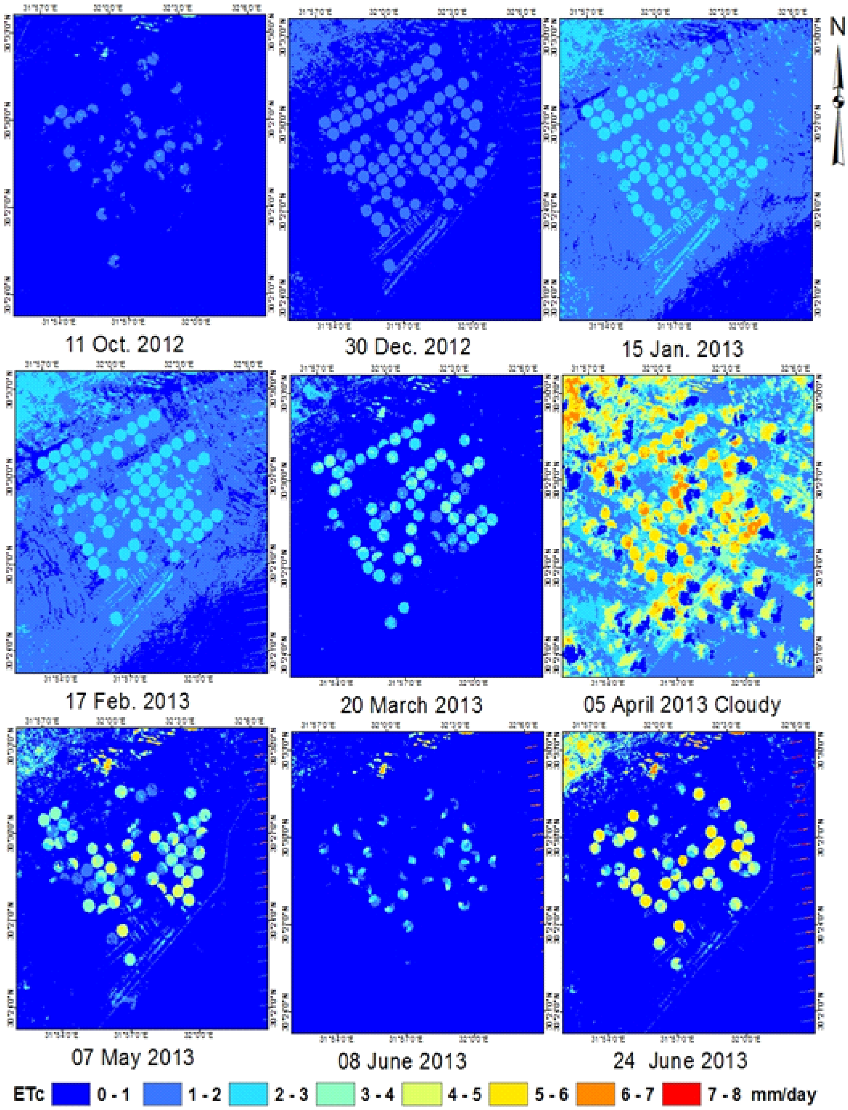
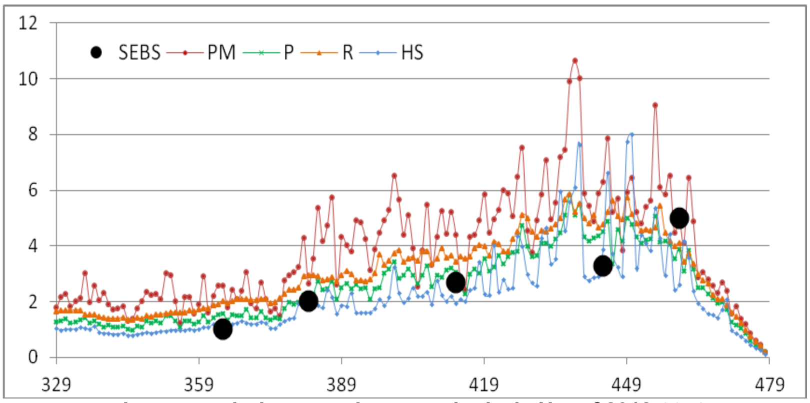


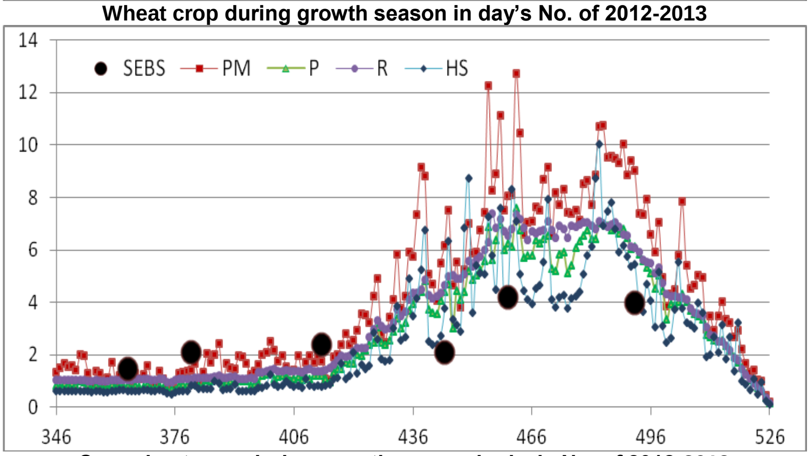
Fig.2. Daily actual evapotranspiration maps of the 2012/2013 winter season at the experimental site using Landsat 7 ETM+ images.

Estimating seasonal actual evapotranspiration (Et_a)

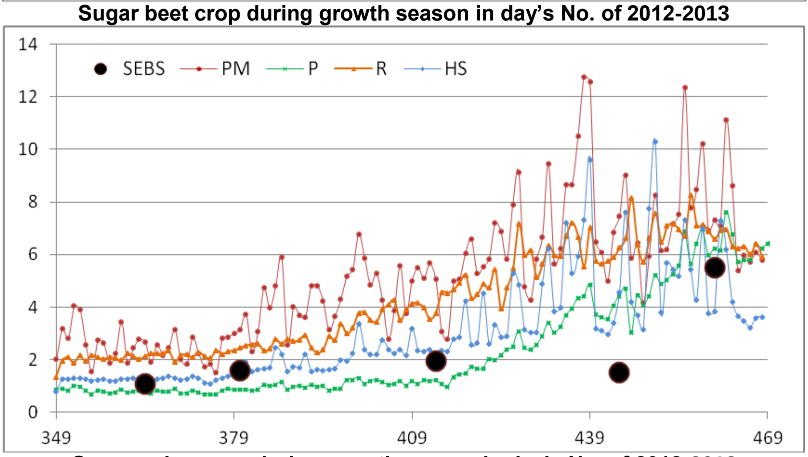
The average actual evapotranspiration values (Et_a) as estimated by the four climatic models and the remote sensing model (SEBS) wheat, sugar beet, and green onion crops were illustrated in Figure (2). The average estimated Et_a values using SEBS, PM, P, R, and HS methods were 2.80, 4.31, 3.00, 3.36, and 2.32 for wheat crop, 2.45, 4.51, 3.22, 3.53 and 2.43 for sugar beet crop and 2.33, 5.13, 3.61, 4.24 and 2.76 $mmday^{-1}$ for green onion crop respectively.



Wheat crop during growth season in day's No. of 2012-2013



Sugar beet crop during growth season in day's No. of 2012-2013



Green onion crop during growth season in day's No. of 2012-2013

Fig.3 Estimated actual evapotranspiration (Et_a) values in mm day^{-1} by the different climatic methods for the winter growing seasons of wheat, Sugar beet, and green onion crops.

The seasonal values of the actual evapotranspiration (Eta) may calculate based on the positive correlation (0.99) between the seasonal Eta and the average daily Eta determined using any of the climatic methods or the remote sensing (SEBS). Therefore, the calculated seasonal Et_a values using SEBS, PM, P, R, and HS methods were 384, 574, 382, 450, and 329 for wheat crop, 423, 726, 497, 570 and 435 for Sugar beet crop and 306, 614, 414, 508 and 360 $mmseason^{-1}$ for green onion crop respectively. The obtained results were not comparable to those reported by Ali (2008) and Khalifa *et al.* (2011), who indicated that Et_a of wheat crop was 490 $mmseason^{-1}$. However, The estimated Et_a values For Sugar beet crop using PM is in agreement with that obtained by Ali (2008) using the same climatic model for Sugar beet crop, it was 557 $mmseason^{-1}$. This difference in Et_a using the climatic or remote sensing methods may be attributed to the lack of similarity in the weather conditions, crop growth conditions and crop characteristics and consequently the crop production under which the reported values were estimated.

The comparison between daily evapotranspiration values as estimated by the SEBS remote sensing model and the PM, P, R, and HS climatic models was illustrated in Figure 3. Results indicated that SEBS model may estimate lower than actual ET values than those estimated using the tested climatic models except for the 5 April 2013 image for wheat and green onion crops and 30 Dec 2012 for Sugar beet crop. Results showed that, the daily actual evapotranspiration values estimated by SEBS model were close to those estimated by HS model, which could be due to that the HS model depends mainly on air temperature.

CONCLUSIONS

From the aforementioned results it could be concluded that there were a clear differences between the estimated Et_o values using the tested climatic and remote sensing models. In addition, the Et_a values estimated by SEBS, P, R, and HS methods were lower than those estimated by PM method. Results indicated that SEBS model may estimate low actual ET values compared with those estimated using the tested climatic models,

The actual evapotranspiration values (Et_a) as estimated for the growing seasons of the tested crops using SEBS, PM, P, R, and HS methods were 384, 574, 382, 450, and 329 for wheat crop, 423, 726, 497, 570 and 435 for Sugar beet crop and 306, 614, 414, 508 and 360 mm/season for green onion crop, respectively.

The substantial differences between actual evapotranspiration Et_a for the same crop using different climatic models for estimating reference evapotranspiration Et_o revealed the essential need to get accurate crop coefficients. However the remote sensing can help to overcome this problem by the direct measurements of the actual evapotranspiration which includes the actual crop coefficient values.

From the most important advantages of estimating evapotranspiration using the energy balance through satellite images were estimate the spatial and the possibility of producing maps reflect the water balance of the region under study which helps in improving water management not only in wide areas but also in small areas, as well as on tracking the time for water uses in the region under investigation by tracking the variability in evapotranspiration values. The remote sensing model (SEBS) needs more validation for multiple years and sites to be used as an alternative to traditional methods of estimating actual evapotranspiration at the field level.

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تقدير البخر- نتح باستخدام بيانات الاستشعار عن بعد وبعض النماذج المناخية

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يهدف هذا البحث إلي تقييم قيم البخر-نتح المقدرة باستخدام نموذج نظام توازن طاقة السطح (SEBS) مع أربعة نماذج مناخية تستخدم على نطاق واسع في المنطقة هي :بنمان-مونتيث(PM) ، بنمان(P) ، الإشعاع(R) ، هارجريفز-سماني .(HS) تم استخدام نموذج الاستشعار عن بعد (SEBS) لتقدير قيم البخر نتح الفعلية اليومية لزراعات القمح وبنجر السكر والبصل الأخضر باستخدام تسعة صور من القمر الصناعي لاندسات ETM7L-+ لتمثل الموسم الشتوي .2012/2013 (موقع الدراسة عبارة عن مزرعة خاصة) شركة السادس من أكتوبر الزراعية (بمحافظة الإسماعيلية) تقع بين خطي طول 31.92/32.62 شرقا ودائرتي عرض 30.38/30.52شمالا.

وقد دلت النتائج المتحصل عليها أن هناك اختلافات واضحة بين قيم البخر-نتح الفعلي (Eta) المقدرة باستخدام أي من النماذج المناخية أو الاستشعار عن بعد التي تم اختبارها .وكانت القيم المتحصل عليها من جميع النماذج المختبرة أقل من تلك المتحصل عليها عند استخدام نموذج .PM وأظهرت النتائج أن قيم البخر-نتح الفعلي المقدرة من نموذج (SEBS) بصفة عامة اقل من نظيرتها المقدرة بالنماذج المناخية الأخرى ,وكانت قيم البخر نتح الفعلية المقدرة على أساس موسمي باستخدام كل منSEBS ، PM ، P ، R ، HS هي 384 ،574 ،382 ،450 ، 329 بالنسبة للقمح ، 423 ، 726 ، 497 ، 570 ، 435 لبنجر السكر و 306 ، 614 ، 414 ، 508و 360 مم/موسم لمحصول البصل الأخضر على الترتيب .من نتائج هذا البحث ,تتضح الحاجة لدراسات وتأكيدات أكثر لتقييم العوامل التي يمكن ان تؤثر على قيم نموذج (SEBS) تحت ظروف المناطق الجافة ,كذلك المزيد من التحقق من خلال عدة مواسم متتالية لمحاصيل متنوعة في مناطق مختلفة حتى يمكن التوصية باستخدامه كأحد الطرق المعتمدة لتقدير البخر-نتح الفعلي بطريقة مباشرة في وجود المحصول على المستوى الحقلي.