Evaluation of SEBAL Algorithm Accuracy for Estimation of Evapotranspiration in Wheat Fields in Jiroft city, Iran

Bentolhoda Kamalipur[1], Asadola Khorani[2], Masod Bakhtiyari Kia[3]

[1]Master of Remote Sensing and Geographic Information Systems, Hormozgan University
[2]Associate Professor of Remote Sensing and Geographic Information Systems, Hormozgan University
[3]Assistant Professor of Information Systems and Geographic Information Systems, Hormozgan University
.hoda_kp@hotmail.com

Abstract: The aim of this study was to investigate the accuracy of SEBAL algorithm in estimating evapotranspiration in wheat fields in Jiroft, one of Iran's largest agricultural poles. In this study, evapotranspiration was calculated using the SEBAL algorithm for the experimental FAO - Penman - Monteith, Hargreves - Somoni, Penman-Monteith methods of the American Society for Civil Engineers, Turc and Priestly-Taylor. In this research to extract meteorological data, the statistics of Jiroft Meteorological Office for Miandeh Jiroft Meteorological Station in 2015 was used. To extract remote sensing images, the satellite images of Landsat 7, ETM+ satelite sensor were used. To assess the SEBAL Model for estimating the evapotranspiration rate, Root Mean Square Error (RMSE), and Mean Absolute Error (MAE) were used. To perform mathematical calculations, the excel software, and to perform mathematical calculations on the image layers, the Envi.5.1 software, and then to draw shapefile map, to extract numbers and to prepare output images, ArcGis9.3 were used. The results of the study showed that the least squared error was related to the FAO Penman-Monteith method, which was equal to 0.353 mm/day. Similarly, the FAO Penman-Monteith method has the highest amount of determination coefficient R^2 (0.66). The results showed that evapotranspiration calculated using SEBAL algorithms is more in line with FAO Penman-Monteith experimental method.

[Kamalipur B, Khorani A, Bakhtiyari Kia M. **Evaluation of SEBAL Algorithm Accuracy for Estimation of Evapotranspiration in Wheat Fields in Jiroft city, Iran.** *Stem Cell* 2019;10(1):8-19]. ISSN: 1945-4570 (print); ISSN: 1945-4732 (online). http://www.sciencepub.net/stem. 2. doi:10.7537/marsscj100119.02.

Keywords: SEBAL Algorithm, Evapotranspiration, FAO Penman-Monteith Method, Remote Sensing

1. Introduction

Iran is a climatically dry and semi-arid country in the world, so that, on the one hand, the average annual precipitation is about one third of the average dryland and less than one-third of the world's average rainfall on the earth. On the other hand, the evaporation rate of the surface accounts for about 94 % of total water consumption. Therefore, by improving water consumption management in this sector and increasing the consumption efficiency, it is possible to remarkably reduce water consumption. One way to improve water consumption management and ultimately increase water efficiency is accurate estimation of evapotranspiration or estimation of water consumption of plants.

Water balance is one of fundamental topics in hydrology that provides the possibility to quantitatively estimate water sources and their changes under the effect of different factors including nutrition by dams, extraction of water by pumping from the wells, decreased downfall or increased evaporation from watershed area surface due to climatic changes (Sokolov Chapman, 1974).

Evapotranspiration is one of the main components of water balance of each area and one of the key factors for proper programming and suitable irrigation to improve water efficiency in irrigated lands (Li et al., 2003). On the other hand, evapotranspiration plays a significant role in the global climate through the hydrological cycle and the estimate has important uses in forecasting runoff, prediction of product performance and user design (Kustas and Norman, 1996). It is also effective on natural disasters (such as drought) (Ogawa et al., 1999).

There are many methods to calculate the amount of evapotranspiration in different climates and geographies using meteorologicla data, which have been developed and tested. These methods range from simple empirical relationships to methods with complex physical basis. Since most of these methods use point (data) measurements to estimate evapotranspiration, they are only suitable for local areas and because of the dynamic nature and regional changes of evapotranspiration, they cannot be generalized to the basins (Li & Lyons, 2002).

One of the common methods for estimating evapotranspiration, especially in large areas, is the use of remote sensing and geographic information technology. Remote sensing has the potential to estimate evapotranspiration, in addition to examining the spatial distribution, because it is the only technology that can extract significant parameters such as surface temperature, albedo coefficient and vegetation index in a consistent or environmentally compatible, and economically feasible manner (Kustas & Norman, 1996).

SEBAL algorithm is one of the ways to help measure remote sensor data so that it can calculate the actual evapotranspiration (Bastiaanssen, 2005).

SEBAL algorithm was first suggested for areas with low ups and downs and insignificant topography (of farms). In spite of the problems and concern regarding the use of SEBAL algorithm, many advantages and benefits have also been mentioned for it. For example, the use of satellite imagery and SEBAL algorithm results in estimation of real evapotranspiration spatially and temporally in different scales and surfaces (farm, plain, and watershed). Using other methods to do the same thing, such as continuous sampling to determine soil moisture balance, installing multiple lysimeters or other related equipment are more costly and time-consuming than the SEBAL algorithm (Pour-Mohammadi et al., 2011).

Therefore, in this study, the evapotranspiration of wheat in some fields of Jiroft plain, in Iran are estimated. In order to estimate evapotranspiration in the area, which is one of the most important agricultural poles in the country, Landsat imagery and SEBAL algorithm were used. According to the mentioned issues, the following question is raised:

Calculating evapotranspiration using SEBAL algorithm is more consistent with which of the empirical methods of estimation?

FAO Penman-Monteith Experimental Method

FAO Penman-Monteith is the standard method for calculating reference evapotranspiration using meteorological data. The Penman-Monteith method is also the only estimation method proposed for most countries with dry and semi-arid climate, including Iran (Alizadeh, 2006).

The Penman-Monteith equation is summarized as follows:

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} \times u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34 u_2)}$$

Where

ETo: a reference crop evapotranspiration (mm/day)

Rn: the net radiation at the crop surface (MJm-2d-1)

T: the average temperature at 2 meters above ground level

U2: Wind speed at 2 m above ground level ms-1

ea-ed: Vapor pressure deficiency at a height of 2 meters (Kpa)

Δ: Slope of vapor pressure curve (KPaC-1)

Y: the coefficient of psychrometry (KPaC-1)

G: Heat flux into the soil (MJm-2d-1)

In all the methods used to calculate the reference crop evapotranspiration (ETo) or potential evapotranspiration (ETp), to generalize the results to the desired coverage levels such as crops, pasture, gardens or forests, it is necessary to multiply the values obtained by the crop coefficient (Kc). The crop coefficient depends on the type of plant, the growth stage and the weather conditions, in addition to reference evapotranspiration.

$$ET_{crop} = k_c(ET_o)$$

It should be noted that the crop coefficient is not a constant value and changes over the course of plant growth. To determine the crop coefficient and its use to convert the ETo to the evapotranspiration of the desired crop according to the proposed FAO method for the growth period of the plant, the variation curve for the crop coefficient is plotted so that at each stage of the growth, the coefficient proportional to the same stage is applied (Alizadeh, 2000).

Penman-Montieth Method for the American Society of Civil Engineers (ASCE)

The standard equation provided by the American Society of Civil Engineers (ASCE) to calculate the reference crop evapotranspiration in the hourly period is as follows:

(ASCE-EWRI), 2005; Walter et al., 2000; Temesgen et al., 2005)

$$ETo= \frac{0.408\Delta(Rn-G)+\gamma(37/(Thr+273))U2(e^o(Thr)-ea)}{+\gamma(CdU2)\ \Delta}$$

Where constant Cd in the denominator is a function of plant resistance time step and aerodynamic resistance, and change with the variation of the type of reference crop and the time interval of day and night. For the hourly time interval, the value of C d during the daily time interval is 0.24 (Allen et al., 2006).

Priestley-Taylor

This method is simplified based on the Penman method, and the aerodynamic component of the

Penman equation is replaced by an experimental coefficient, which is known as the Priestley-Taylor parameter (Priestley and Taylor, 1972).

$$ET_O = 1.26\frac{\Delta}{\Delta+\gamma}(\frac{R_n-G}{\lambda})$$

All components of the above equation are explained in the previous method, except for λ, which is the latent evaporation heat of MJKg-1, and is obtained from the following equation:

$$\lambda = 2.501 - (2.361 * 10^{-3})T$$

Hargreves

Hargreaves equation (1985), with maximum and minimum temperature, can calculate evapotranspiration for 24-hour, weekly, 10-day and monthly periods (Kupai et al., 2008).

$$ET_O = 0.0023 * (Tmean + 17.8) * (T\max - T\min)^{0.5} * Ra$$

ETo: Reference crop evapotranspiration (mm/day)

T max: Maximum daily temperature (^oC)

T min: Minimum daily temperature (^oC)

T mean: Mean temperature (^oC)

Ra: Incoming radiation at the top of the atmosphere (mm/day)

Turc

Turc in 1961 for 10-day periods, and for the climatic conditions of Western Europe, has presented the following equations. (Kupai et al., 2008).

RH> 50%

$$ET_O = 0.013(\frac{T}{T+15})(Rs+50)$$

RH < 50%

$$ET_O = 0.013(\frac{T}{T+15})(Rs+50)\left(1+\frac{50-RH}{70}\right)$$

Where

ETo: Reference crop evapotranspiration (mm/day)

T: Mean temperature (^oC)

Rs: Solar Radiation (mm/day)

Rh: Average relative humidity (%)

Blaney Cradle

One of the oldest methods for estimating evapotranspiration is Blaney Cradle's method. The proposed method was later calibrated by Pruitt, a professor of the University of California and was provided as follows to estimate grass reference evapotranspiration:

ETo=a+b [P (0.46T+8.13)]

Eto: Grass reference evapotranspiration in millimeters per day (mm/day) .

P: A coefficient related to the length of the day or annual percentage of sunlight per month described daily (Average hours of light each day of the month divided by all sunlight hours of the year multiplied by 100).

T: Average monthly temperature, ºC .

a, b: Climate coefficients .

Review of Literature

Ramos et al. (2009), using SEBAL algorithm examined evapotranspiration of Flumen region, Ebro Plain, in the northeast of Spain for 4 years and compared them with lysimetric values. The obtained results showed that SEBAL algorithm was able to accurately estimate daily evapotranspiration for wheat, corn and grass. In this study, the values of actual evapotranspiration obtained using SAEBAL method for grass had 0.3 mm/day deviation versus Lysimeter measurement and 0.36 mm/day deviation versus Penman-Monteith method. In addition, in this study, actual evapotranspiration of corn and wheat and real evapotranspiration obtained by the Lysimeter method had a good fit for research fields (with a deviation of ± 0.6 mm/day). Meanwhile, in this study, between the values of evapotranspiration measured for the plain by SEBAL and Penman-Montenegro on the area scale an error of 20 % was obtained.

To evaluate biomass performance and evapotranspiration, Mokhtari (2005) used SEBAL model to calculate the evapotranspiration of the two crops of sugar beet and corn in Borkhar plain in Isfahan province, Iran. The results of this study showed that total evapotranspiration calculated in this area in 2005 using the SEBAL model for sugar beet was about 20 % lower and it was 15 percent higher for corn than the Penman-Monteneum model.

Gholami-Sefid-Koohi (2009), studied the potential of using a combination of Normalized Difference Vegetation Index (NDVI) from Moderate Resolution Imaging Spectroradiometer (MODIS) and ground information for calculating the actual evapotranspiration of wheat. The statistical results of the method used in this study compared to the FAO Penman - Monteith show that the use of this method has the Root Mean Square Error (RMSE) of 18 mm, Mean Absolute Error (MAE) of 16 Mm, Mean Error (ME) of 1.1 mm and an error index of 91.1 % during the growing season for wheat.

Arshad (2007), using the energy balance algorithm on the surface level in Kermanshah province, Iran calculated the actual evapotranspiration on the surface of wheat and barley fields, in three warm, temperate and cold climates. In this study, 271 images of NOAA-AVHRR satellite for 18 years during the plant growth period were used. In this research, in order to increase the accuracy of some of the relationships and parameters of the energy balance model, a series of meteorological and environmental data were gathered at the time of satellite transit from the study area.

Energy balance algorithm calculations were used as inputs of performance prediction model and the results showed that these inputs are capable of predicting the yield of wheat and barley. The results of the research indicate that using the remote sensing technique, it is possible to accurately estimate the actual evapotranspiration of the plant.

According to the results obtained, it is possible to state that using SEBAL method and MODIS sensor images, the power of surface parameters such as surface temperature of the land, surface albedo, surface leakage and vegetation index are well calculated. Finally, using these parameters, the amount of actual evapotranspiration is well estimated in daily time period, in the sub-basin of Mashhad watershed, which has a dry and semiarid climate (Nouri et al. 2010).

Shahzad and Iftikhar (2008) carried out an estimate of real evapotranspiration on a regional scale using remote sensing data and ground measurements for the Punjab center in Pakistan. They used Landsat 7 ETM + satellite images and SEBAL algorithms to estimate actual evapotranspiration. The area of the studied land was 192347 km2 and it had a dry and semi-arid climate. Their results showed that the use of SEBAL model and Landsat 7 satellite imagery was a suitable method for estimating the actual evapotranspiration and its results are acceptable and satisfactory.

Li et al (2008) using NOAA images and SEBAL algorithm studied the water consumption and water productivity in the northern plains of China, which is comprised of 83 provinces. The researchers reported the relative error between seasonal evapotranspiration values with Lysimeter weighing data and the error value was estimated to be about ¾ of percent. On the other hand, the highest and lowest yields were estimated at 1.67 and 0.5 kg per cubic meter of water consumption, respectively.

Hafeez et al (2005) using seven MODIS images and SEBAL method estimated the Plant water requirement on various dates during the summer of 2002, for the Yellow River Basin of China. The real 24-hour evapotranspiration was obtained with respect to instantaneous evapotranspiration. Then, using the land data a real seasonal evapotranspiration map was prepared. The results showed that there is a correlation between actual evapotranspiration in different dates. Then the results were compared with the potential evapotranspiration generated at the climatological station, which a difference of 5% confirmed the SEBAL results.

In another study, the actual evapotranspiration of plants under environmental stresses in Azadegan plain in Khuzestan province, Iran was estimated using SEBAL algorithm. The results of this research for each of the existing sites in the region (wheat, pasture plants, and canebrakes), presented a separate evapotranspiration. Evapotranspiration obtained from the SEBAL algorithm showed about 85% correlation with the evapotranspiration calculated by Penman-Monteith equation (Pour-Mohammadi et al. 2010).

Research Hypothesis

Considering the question raised and by studying the different sources in this field, the following hypothesis is proposed:

Evapotranspiration calculated using SEBAL algorithm is more consistent with FAO Penman-Monteith experimental method.

Materials and Methods

The Study Area

In this research, to extract meteorological data, the statistics of Jiroft Meteorological Office for Miandeh Jiroft Meteorological Station in 2015 was used. The data included minimum and maximum (Celsius) temperature, minimum and maximum relative humidity (percentage), wind speed (Kts), sunshine hours, altitude from sesa level (m), latitude and longitude. At this stage, meteorological data and satellite images were collected through the Meteorological Office of Jiroft and United States Geological Survey (USGS).

Gathering Meteorological Data

In this research to extract meteorological data, the statistics of Jiroft Meteorological Office for Miandeh Jiroft Meteorological Station in 2015 was used. The data included minimum and maximum (Celsius) temperature, minimum and maximum relative humidity (percentage), wind speed (Kts), sunshine hours, altitude from sesal level (m), altitude and longitude.

Extracting Required Satellite Images

In this research, to extract remote sensor images, Landsat 7 satellite imagery, Sensor ETM + were used. Pictures taken on dates 14 and 30 January and 3 March and 20 April 2015 were collected.

Figure 1: The range of land studied in Google Earth

Table 1: Date of collecting images

Shooting date (Julius Day)	Image number
January 14, 2015 (fourteenth day of the year)	1
January 30, 2015 (the thirtieth day of the year)	2
March 3, 2015 (Sixty second day of the year)	3
April 20, 2015 (one hundred and tenth day of the year)	4

Landsat 7 was launched into space in April 1999 and used the sensor ETM + to monitor land complications of the earth's surface. The spatial resolution of the images is 15 meters in panchromatic band and 30 meters in the multispectral band and 60 meters in the infrared thermal band. The radiometric resolution of the images is 8 bytes and its repetition period is 16 days (Table 1).

Software Used

In this research, to perform mathematical calculations, the software excel, and to perform mathematical calculations on the image layers, the Envi.5.1 software were used. Then to draw the (shapefile) map, to extract numbers and taking output images ArcGis9.3 software was used.

Findings

In this study, the surface temperature is increasing from the image No 1 to image No 3 and this temperature increase is consistent with the meteorological data in the mentioned months and the reason is the normal temperature increase from December to March. But in Figure 4, which is related to the April, there is a slight decrease in temperature. The temperature values were obtained between 290. 505 to 304.54 K.

Since the daily amount of evapotranspiration is more practical than the instantaneous values, the instantaneous evapotranspiration is converted to daily value using the reference fraction of evapotranspiration. In SEBAL algorithm, to convert the instantaneous values to daily evapotranspiration values, it is assumed that the reference fraction of evapotranspiration during the 21 hours of the day is almost fixed. The values vary from -39. 23 to -6. 76 K.

The following tables show the values obtained from the SEBAL method and the values obtained from the experimental methods. Then comparison chart was drafted.

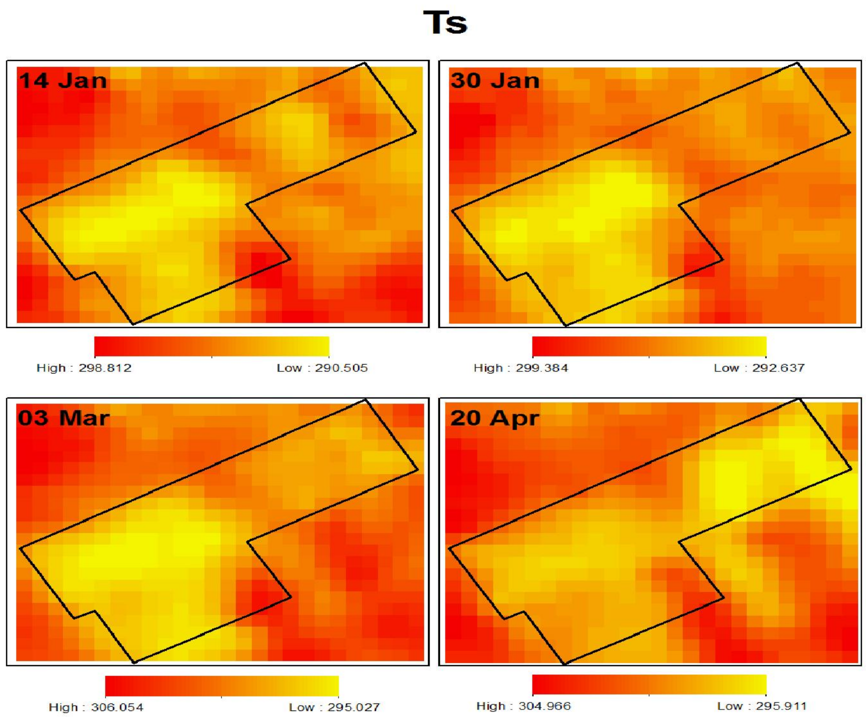


Figure 2: The surface temperature (Kelvin) for all images

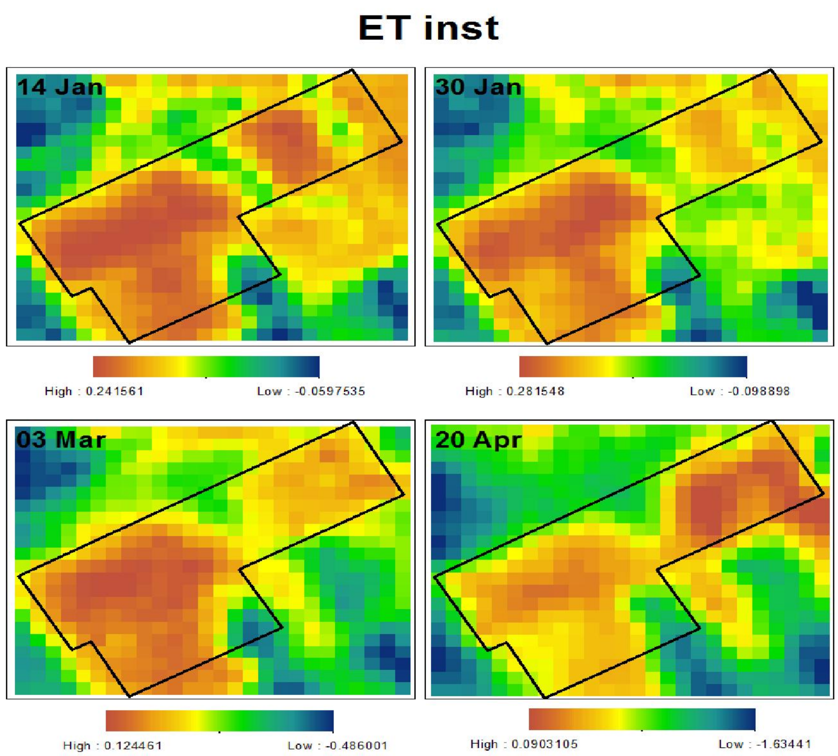


Figure 3: Instantaneous Evapotranspiration for All Images

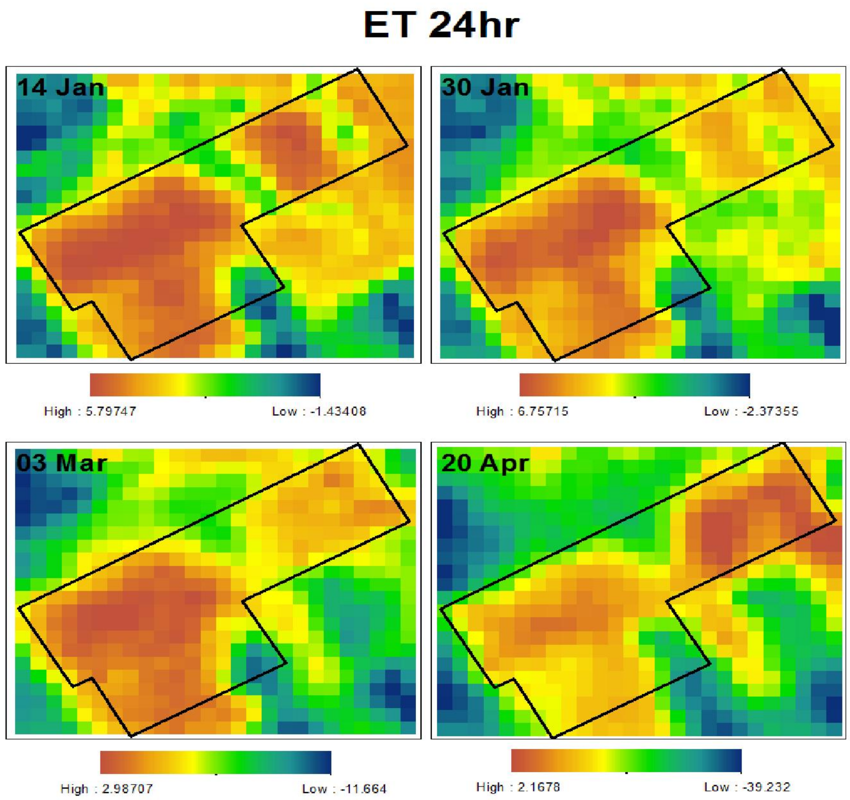


Figure 4: 24 -hour reference evapotranspiration for all images

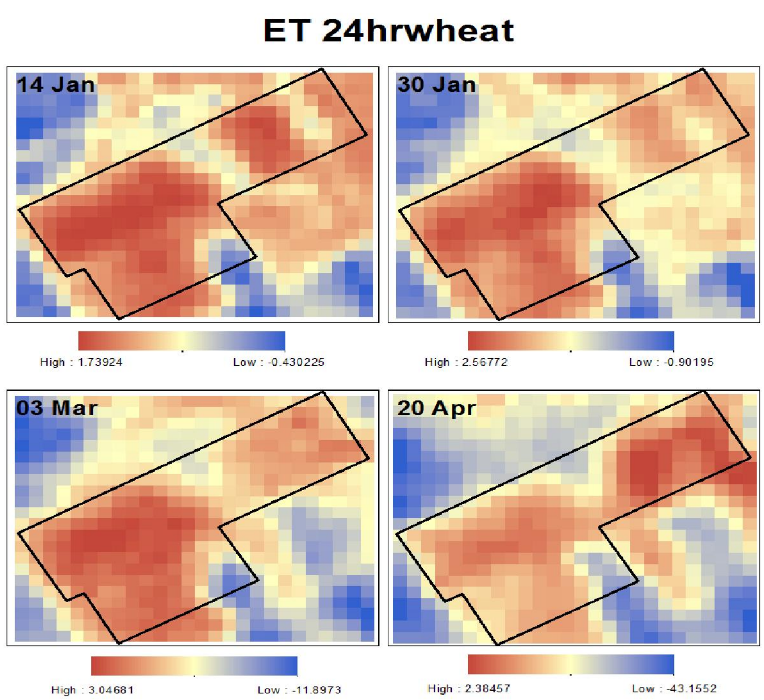


Figure 5: 24 -hour wheat evapotranspiration for all images

Table 2: Comparison of evapotranspiration values obtained from empirical methods using SEBAL algorithm (mm/day)

Image	SEBAL	FAO Penman - Monteith	Hargreves - Samani	Blaney Cradle	Penman- Monteith (ASCE)	Turc	Priesly-Taylor
1	1.74	1.8	1.75	0.86	1.17	0.11	0.13
2	2.57	½	2.64	1.58	1.45	0.17	0.2
3	3.05	3.3	9.15	5.11	7.02	0.5	1.65
4	2.38	2.84	16.77	7.9	10.1	1.15	3.43

Table 3: Comparison of Evapotranspiration from the FAO Penman-Monteith Experimental Method using SEBAL Algorithm (mm/day)

Image	SEBAL	FAO Penman - Monteith	Absolute error	Average absolute error	Square error	Squared mean square error	R^2
1	1.74	1.8	0.06	0.31	0.0036	0.353	0.66
2	2.57	2.1	0.47		0.2209		
3	3.05	3.3	0.25		0.0625		
4	2.38	2.84	0.46		0.2116		

Table 4: Comparison of Evapotranspiration from the Hargreaves - Samani Experimental Method using SEBAL Algorithm (mm)

Image	SEBAL	Hargreves - Samani	Absolute error	Average absolute error	Square error	Squared mean square error	R^2
1	1.74	1.75	0.01	5.143	0.0001	7.815	0.12
2	2.57	2.64	0.07		0.0049		
3	3.05	9.15	6.1		37. 21		
4	2.38	16.77	14.39		207. 0721		

Table 5: Comparison of Evapotranspiration from the Blaney Cradle Experimental Method using SEBAL Algorithm (mm/day)

Image	SEBAL	Blaney Cradle	Absolute error	Average absolute error	Square error	Squared mean square error	R^2
1	1.74	0.86	0.88	2.3625	0.7744	3.02	0.19
2	2.57	1058	0.99		0.9801		
3	3.05	5.15	2.06		4.2436		
4	2.38	7.9	5.52		30.4704		

Table 6: Comparison of evapotranspiration values obtained from the Penman-Monteith empirical method of the American Society of Civil Engineers using the SEBAL algorithm (mm/day)

Image	SEBAL	Penman Mantieth (ASCE)	Absolute error	Average absolute error	Square error	Squared mean square error	R^2
1	1.74	1.17	0.57	3.345	0.3249	4.386	0.195
2	2.57	1.45	1.12		1.2544		
3	3.05	7.02	3.97		15.7609		
4	2.38	10.1	7.72		59.5984		

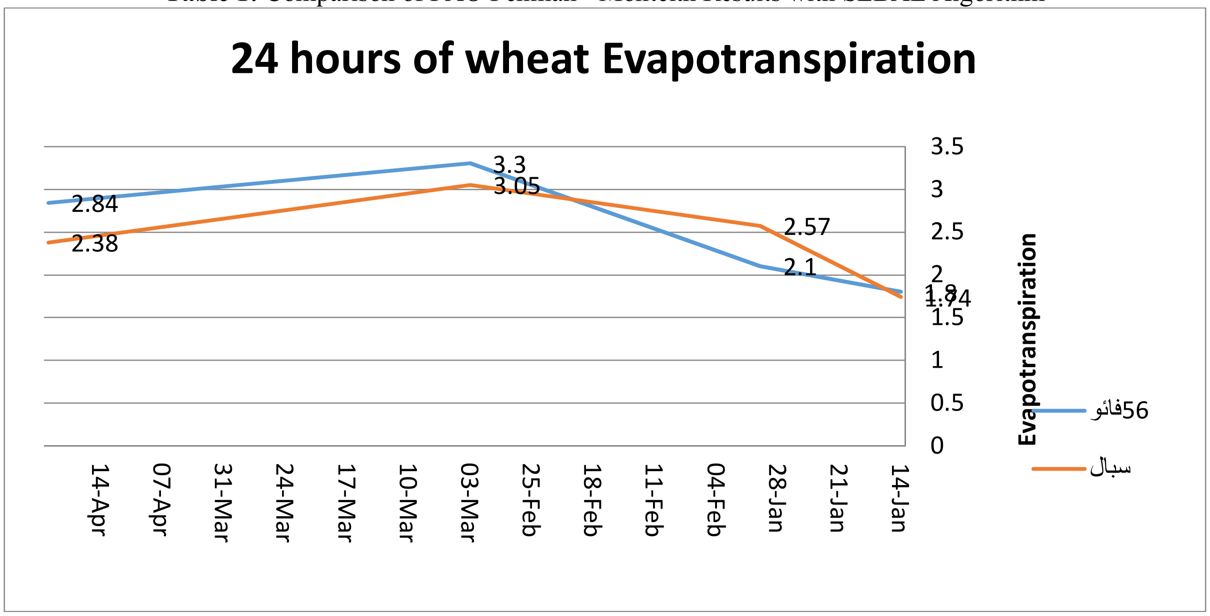
Table 7: Comparison of Evapotranspiration from the Turc Empirical Method using SEBAL Algorithm (mm/day)

Image	SEBAL	Turc	Absolute error	Average absolute error	Square error	Squared mean square error	R^2
1	1.74	0.11	1.63	1.9525	2.6569	2.027	0.06
2	2.57	0.17	2.4		5.76		
3	3.05	0.5	2.55		7.02		
4	2.38	1.15	1.23		10.1		

Table 8: Comparison of evapotranspiration values obtained from Priestly- Taylor's empirical method using SEBAL algorithm (mm/day)

Image	SEBAL	Priesly-Taylor	Absolute error	Average absolute error	Square error	Squared mean square error	R^2
1	1.74	0.13	1.61	1.6075	2.5921	1.68	0.09
2	2.57	0.2	2.37		5.6169		
3	3.05	1.65	1.4		1.96		
4	2.38	3.43	1.05		1.1025		

Table 1: Comparison of FAO Penman - Monteith Results with SEBAL Algorithm



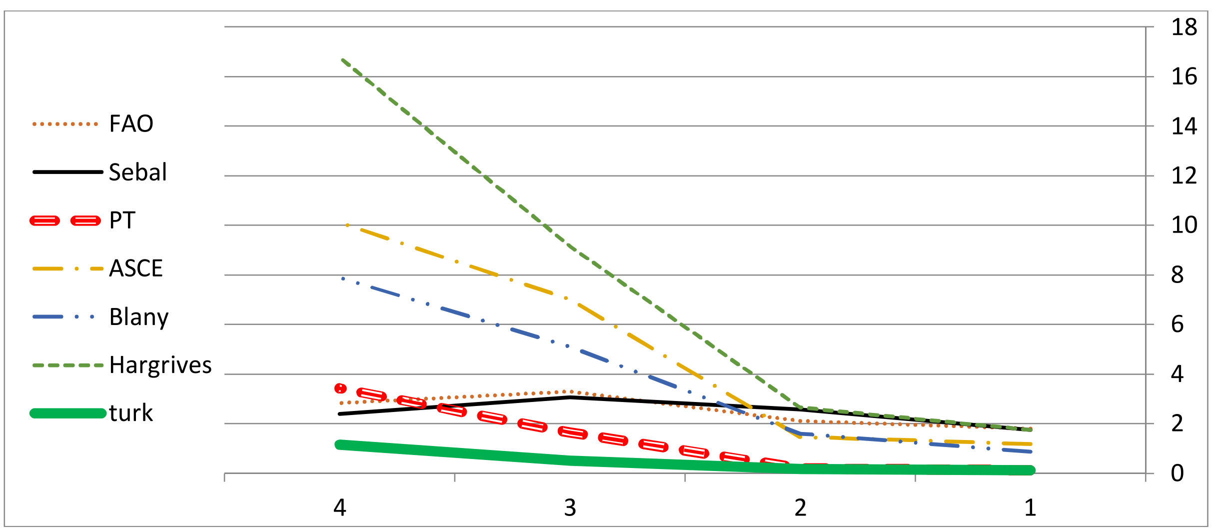


Figure 2: Comparison of the results of empirical methods and the results of the SEBAL algorithm

Testing the Hypothesis

This study is based on the hypothesis that calculated evapotranspiration using the SEBAL algorithm is more consistent with the FAO Penman - Monteith experimental method.

In order to evaluate the SEBAL model in predicting evapotranspiration, Root Mean Square Error (RMSE) and Mean Absolute Error (MAE), have been used.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (x_i - x_m)^2}{n}}$$

$$MAE = \frac{\sum_{i=1}^{n} |x_i - x_m|}{n}$$

Where:

Xm and Xi are the values obtained from the SEBAL model and the FAO Penman-Monteith method, and n is the total number of data. The more the statistical indicators are closer to zero, it means that the values obtained from SEBAL have less error.

After estimating the data necessary to determine the daily evapotranspiration rate, the results of the SEBAL algorithm were compared with the amount of evapotranspiration calculated by experimental methods.

The results showed that the highest mean squared error is related to the Hargreves-samani method, which is equal to: 7.82 mm/day and the least squared error is related to the FAO 56 Penman-Monteith method, which is equal to: 0.353 mm/day. Similarly, FAO 56 Penman-Monteith method has the highest coefficient of determination R2 (0.66, and the Turc method has the lowest coefficient of determination of R2 (0.66).

It should be noted that the Hargreves-samani method in the early stages of growth is more consistent with the SEBAL method.

In general, all methods in the early stages of growth are more consistent with SEBAL method.

Moreover, the evapotranspiration was calculated from the empirical methods, which, in order of higher determination coefficient with the results of the SEBAL algorithm are: Penman Mantieth, FAO Penman Mantieth, American Society of Civil Engineers - Blaney Cradle - Hargreves Samani – Priesly-Taylor and Turc. The results showed that evapotranspiration calculated using SEBAL algorithm is more consistent with FAO Penman - Mantieth compared to other empirical methods.

Conclusion

In this study, the values of actual evapotranspiration obtained from the SEBAL method for wheat with RMSE 0.35 mm/day deflection versus FAO - Penman - Monteith and with Mae 0.31 mm/day deflection versus FAO Penman - Monteith. In addition, the value of the coefficient of determination (R 2) was equal to 0.66. The results showed that evapotranspiration calculated using SEBAL algorithm is more consistent with FAO Penman– Monteith compared to other empirical methods.

The results obtained from this study are sufficiently reliable and attributable, and the results are consistent with the results of studies by: Kapitala et al. (2013), Dehghan and Alizadeh (2012), Abedi Kupai et al. (2008), Sadat Hosseini et al. 2014), Santos et al. (2009), Akbari et al. (2011), Rahemi-Khoob et al. (2006) and Zamn-Sani (2015).

These results compared with the results of (Akbari et al., 2011) indicated that the Mean Absolute Error and Mean Square Error Roots are slightly different.

In other research, Kapetalau et al. (2013) achieved a good agreement or error coefficients RMSE 0.34, Mae error 0.28 and coefficient of determination (R2).

The good correlation between the SEBAL and computational methods showed that relying on evapotranspiration in a wide area can be modeled and used in the planning of irrigation and water resources plans (Yaghoob-Zadeh, et al., 2015).

The Penman-Monteith method with minimum data (temperature and wind speed) and Hargreves were compared in Khuzestan province, Iran and the researchers concluded that the Penman-Monteith method performed better than the Hargreves method with the minimum data (Rahimi-Khoob, et al., 2006).

Dehghan and Alizadeh 2012 studied and evaluated different methods of estimating the evapotranspiration of the reference plant in the conditions of limited climatic data in Khorasan Razavi province, Iran. The results of their research showed that, if there is no net irradiation and wind speed data, the FAO Penman-Monteith method is a good option for estimation in Khorasan Razavi province, so that the RMSE rate is less than 0.71 mm/day.

References

Persian References

1. Arshad, 2007. Evaluation of Agricultural Drought Risk Using Remote Sensing: Developing an Executive Model for Kermanshah Province. Ph.D. Thesis, Tarbiat Modarres University.

2. Akbari M., Seif Z., Zare Abyaneh H., 2011. Estimate of evapotranspiration and potential for evapotranspiration in various climatic conditions using remote sensing. Water and Watershed (Agricultural Sciences and Technology), Vol. 26, No. 4, Pages 835-844.
3. Akbari M., Mirlatifi S. M., Marid S., and Dirgers P. 2003. Application of Remote Sensing in Estimating Water Consumption in Irrigation Networks, Case Study: Right Network of Esfahan Cascade. Journal of Agricultural Engineering Researches, No. 17, Volume 4 (Winter:) 82-65.
4. Pour-Mohamadi S., Rezaani M., Cheraghi A., Mokhtari M., Rahimian M., 2011: Assessment and estimation of water balance components in arid areas using remote sensing geographic information system, Case Study of Yazd Manshad Watershed.
5. Pour-Mohammadi, S. Rahimian, MD, 1389. Supply of water needed to maintain the equilibrium of natural ecosystems and agriculture using the SEBAL algorithm (Case Study of Azadegan plain), Proceedings of the 6th National Conference on Watershed Management and the 4th National Conference on Watershed erosion, Department of Watershed Management, Faculty of Natural Resources and Marine Science, Tarbiat Modares University.
6. Hasanpour B., Mirzaii F., Senior P., Mathematical Factor, 2010. National Institute for Management of Irrigation Networks and Designation of the Estimation of Evapotranspiration by Ground-Energy Energy Algorithm.
7. Husayny, A., Zare, M., Mokhtary, M. H., 2014. Applied Aquatic Climate Biannual, Year 1, Issue 1, Autumn and Winter 2014, Issue 1, pp. 61-72.
8. Rahimi-Khoob, Ali (2006). Investigating Minimal Meteorological Data in Penman-Monteith Equation. Case Study of Khuzestan Province, National Conference on Irrigation and Drainage Networks, Shahid Chamran University of Ahvaz, Faculty of Water Engineering, 1-8 pp.
9. Sepas-Khah, A. 1998, A retrospective study on the methods for calculating evapotranspiration of crops, educational seminar of Shiraz University.
10. Abedi Koohpaji J., Islaniyan S., Amiri M., 2008. The 2nd National Conference on Irrigation and Drainage Management, Title: Comparison of Four Methods for Estimating the Reference Level Evapotranspiration and Transition with Microlysimetric Data in Isfahan Region.
11. Alizadeh A., 20006. Water, Soil & Plant Relationship, Imam Reza University. Astan Quds Razavi Publishing House.
12. Ghulmi-Sefid-Koohi, M. Mirlatfi, 2009. Conference on the 10th National Irrigation and Evaporation Seminar entitled "Calculation of Real Evapotranspiration of Wheat Using Remote Sensing" Case Study: Gorganroud Basin.
13. Nouri S., Sanaynejad H., Hasheminia M., 2010. The first international conference on plant, water, soil and air modeling with real evapotranspiration forecasting on a regional scale using SEBAL algorithm and MODIS images.

References

1. Allen, R.G., L.S. Pereira, D. Raes and M. Smith. 1998. Crop Evapotranspiration Guidelines for computing crop water requirements. FAO Irrigation and Drainage Paper, No. 56, Rome, Italy, 300 pp.
2. Allen, R. G., Pruitt, W. O., Wright, J. L., Howell, T. A., Ventura, F., Snyder, R., Itenfisu, D., Steduto, P., Berengena, J., Yrisarry, J. B., Smith, M., Pereira, L. S., Raes, D., Perrier, A., Alves, I., Walter, I., Elliott, R. 2006. A recommendation on standardized surface resistance for hourly calculation of reference ETo by the FAO 56 Penman-Monteith method. Agric. Water Manage., (81), 1–22.
3. Hafeez, M.M., Chemin,Y., Van De Giesen, N and Bouman, B.A.M. 2002. Field evapotranspiration estimation in central Luzan, Philippines, using different sensors: Landsat 7 ETM+, Terra Modis and Aster. Symposium on Geospatial Theory, Processing and Applications, Ottawa.
4. Hafeez, M., Khan, S. 2005. Remote sensing application for estimation of irrigation water consumption in Liuyuankou irrigation system in China, The 16th Congress of the Modelling and Simulation Society of Australia and New Zealand, PP.223-224.
5. Hargreaves, G.H. 1994. Defining and using reference evapotranspiration. Journal of Irrigation and Drainage Engineering, 120(6):1132-39.
6. Kustas, W. P., and Norman, J. M. 1996. Use of remote sensing for evapotranspiration monitoring over land surfaces. Journal of Science Hydrology 41: 495-516.
7. Li, F., and Lyons, T. J. 2002. Remote estimation of regional evapotranspiration. Environmental Modelling and Software 17: 61-75.
8. Li, Y. L., Cui, J. Y., Zhang, T. H., and Zhao, H. Li. 2003. Measurement of evapotranspiration of irrigated spri wheat and maize in a semi- arid region of North China. Agricultural Water Management 61: 1-1.

9. Michael, M. G. and Bastiaanssen, W. G. M. 2002. A new simple method to determine crop coefficients for water allocation planning from satellites: results from Kenya. Irrigation and Drainage Systems 14: 237-256.
10. Mokhtari, M.H. (2005), Agricultural Drought Impact Assessment Using Remote Sensing: A Case study, Borkhar district –Iran. M.sc Thesis, ITC, Enschede, The Netherlands.
11. Ramos, J.G., Cratchley, C.R., Kay, J.A., Casterad, M.A., Martinez-cob, A. and Dominguez, R. (2009), Evaluation of satellite evapotranspiration estimates using ground-meteorological data available for the Flumen District into the Ebro valley of N.E. Spain. Agricultural Water Management, 96 (2009) 638-652.
12. Temesgen, B., Eching, S., Davidoff, B. and Frame, K. 2005. Comparison of some reference evapotranspiration equations for California J J. Irrig. and Drain. Engrg.,Volume 131, Issue 1, pp. 73-84J.
13. Walter, I. A., Allen, R. G., Elliott, R., Jensen, M. E., Itenfisu, D., Mecham, B., Howell, T. A., Snyder, R., Brown, P., Echings, S., Spofford, T., Hattendorf, M., Cuenca, R. H., Wright, J. L., Martin, D., November 2000. In: ASCE's Standardized Reference Evapotranspiration Equation. Proceedings of the 4th National Irrigation Symposium, ASAE, Phoenix, AZ.

1/25/2019