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# Applicability of satellite data in estimating actual evapotranspiration by SEBS algorithm (Mughan plain, Ardabil, Iran)

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**Abstract**

Land surface evapotranspiration (ET) is of importance for environmental applications including optimization of irrigation water use, irrigation system performance, crop dehydration, drought mitigation strategies. In this regard, the SEBS algorithm is one of the most widely used algorithms in the field of calculating real evaporation and transpiration. This algorithm uses satellite equipment observations and meteorological information to estimate the energy flux and includes a tool to determine the land surface (such as albedo, surface emissivity, surface temperature, vegetation index, etc.) from satellite images. In this research, using the spectral data and thermal band of Landsat 8, the actual evapotranspiration rate of Iran's Mughan plain in Ardabil province has been estimated. Also, in order to validate the results of the model, the results were compared with the results of the Penman month. Comparing the results of the SEBS algorithm with FAO-Penman-Monteith shows similar values, so it can be concluded that the SEBS algorithm can be a suitable alternative to the traditional methods of calculating Actual evapotranspiration.

## 1. Introduction

Evapotranspiration (ET) is the combination of the energy and water cycle and also links the ecological processes of land surface hydrological processes. Accurate determination of regional ET and estimate of the evolution of the climate, water resources planning and management, agricultural water saving crop production simulation and environmental issues have important practical significance.

The surface heat fluxes are the basis for calculating ET using meteorological observations way (Weiqiang et al., 2012).

ET is a key component of the water balance and a major consumptive use of irrigation water and precipitation on farmland. Remote sensing based on field observation and models which rely on land surface energy balance are presently most suited for estimating crop water use at both field and regional scales, such as the Surface Energy Balance Algorithm for Land (SEBAL; Bastiaanssen et al., 1998), the Surface Energy Balance Index (SEBI; Menenti and Choudhury 1993), the Simplified Surface Energy Balance Index (S-SEBI; Roerink et al., 2000), the Surface Energy Balance System (SEBS; Su 2002), and Mapping Evapotranspiration with Internalized Calibration (METRIC; Allen et al., 2007).

The following sections describe the main models in detail. SEBAL (Bastiaanssen et al., 1998) uses hot and cold points within the satellite images to develop an empirical temperature difference equation. It is a single-source model that resolves the energy balance for latent heat flux (λ E) as a residual. Net radiation flux (Rn) and soil heat flux (G0) are calculated based on land surface temperature (Tsfc) and albedo, vegetation variables. Sensible heat flux (H) is estimated using the bulk aerodynamic resistance model. SEBS is based on the Crop Water Stress Index (CWSI; Jackson et al., 1981), idea in which the surface meteorological scaling of CWSI is replaced with planetary boundary layer (PBL) scaling. It uses the contrast between wet and dry areas appearing within a remotely sensed scene to derive ET from the relative evaporative fraction.

SEBS (Su 2002) was coming from the SEBI concept. It uses a dynamic model for aerodynamic roughness length for heat (Su et al., 2001), bulk atmospheric similarity and Monin–Obukhov similarity theories for PBL to estimate regional ET, and atmospheric surface layer scaling for estimating ET at local scale.

Yang et al. (2021) conducted a study to estimate evapotranspiration (ET) by combining Bayesian Model Averaging (BMA) with machine learning algorithms. The objective of this study was to reduce errors and

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uncertainties among multiple ET models to improve daily ET estimation. The BMA method was used to combine eight ET models using Landsat 8 satellite data, including four energy balance models (e.g., SEBS, SEBAL, SEBI, and SSEB) and four machine learning algorithms (namely, Polynomials, Random Forest, Stacked Regression, and Support Vector Machine). The performance of each model and the BMA method was validated through on-site measurements in a semi-arid region. The results indicated that the BMA method outperformed the eight individual models. Four significant models obtained through the BMA method were ranked based on Random Forest, SVM, SEBS, and SEBAL. The combination of BMA with machine learning can significantly improve the accuracy of daily ET estimation, reduce uncertainties among models, and leverage the distinct advantages of empirical and physical-based models to obtain more reliable ET estimates.

Wang et al. (2017), in the Heihe River Basin, Northwestern China, estimated daily ET using the SEBS algorithm, and assessed its performance with Eddy Covariance and Priestley-Taylor methods. The results revealed that the SEBS model has a relatively accurate performance, particularly for vegetated areas.

Shamloo et al. (2021), evaluated the SEBS algorithm to estimate maize ET and crop coefficient using Landsat 8 images in the Adana Mediterranean Area, Turkey. According to the results, the SEBAL estimated ET values mostly corresponded to the FAO-PM method with $R^2 = 0.91$ and RMSE = 1.14 mm/day. It was also highly correlated with Turc, Hargreaves, and Makkink methods.

Aim of this study was to calculate the actual evapotranspiration using SEBS algorithm for mughan plain.

## 2. Method

### 2.1. Case Studies

The study area is located in the northwest of Iran, specifically in Ardabil province, between the cities of Parsabad and Bilasuvar (Moghan Plain), (Figure 1). The area has an average elevation of 100 meters above sea level. The dominant crop in the study area at the time of image acquisition and actual evapotranspiration estimation is wheat.

### 2.2. Material and Dataset

The used images must be cloud-free. In this research, the OLI sensor images from Landsat 8 satellite were utilized. The Digital Image used corresponds to the date of 04/04/2021, and the local time is approximately 11:00 AM. To calculate evapotranspiration, bands 1 to 7, and also band 10 (thermal band) were utilized.

The climate data used in the model and for calculating the reference evapotranspiration (ETr). In this research, data from two synoptic stations, Parsabad and Pileh Savar, were utilized, and the final values were obtained by averaging the corresponding measurements from these two stations.

The image processing software ILWIS version 7/3 is used.

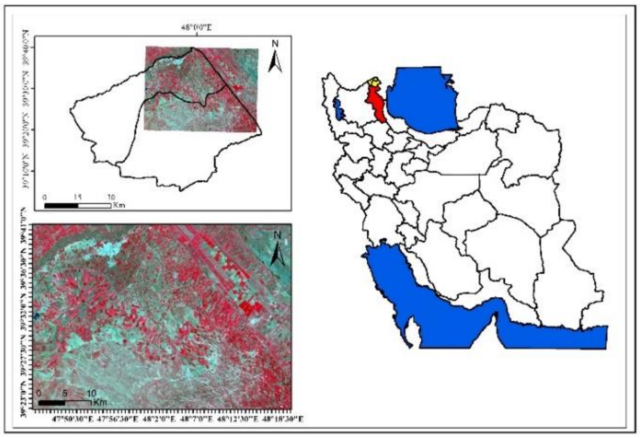

**Figure 1.** Study area

### 2.3. Methods

#### 2.3.1. The SEBS Method

SEBS is based on the Crop Water Stress Index (CWSI; Jackson et al., 1981), idea in which the surface meteorological scaling of CWSI is replaced with planetary boundary layer (PBL) scaling. It uses the contrast between wet and dry areas appearing within a remotely sensed scene to derive ET from the relative evaporative fraction.

The basis of this method is to use the energy balance equation and calculate the latent heat flux as the residual of this equation for each pixel. This approach follows similar theoretical principles as the SEBAL algorithm.

The required input data include layers generated from satellite images and data obtained from weather stations. The output of the SEBS algorithm, unlike the SEBAL algorithm, provides daily actual evapotranspiration.

##### 2.3.1.1. Evapotranspiration

The surface energy balance is commonly written as:

$$Rn = G0 + H + \lambda E \qquad (1)$$

where Rn is the net radiation flux, G0 is the soil surface heat flux, H is the sensible heat flux, and λE is the latent heat flux. The unit of energy balance terms is watts per square meter.

To estimate the evaporative fraction, SEBS makes use of energy balance at limiting cases at dry limit and wet limit, such that the relative evaporation (ratio of the actual evaporation to the evaporation at wet limit) can be derived as:

$$\Lambda r = 1 - \frac{H - Hwet}{Hdry - Hwet} \qquad (2)$$

where the H wet is sensible heat flux at the wet limit and H dry sensible heat flux at the dry limit. The estimations of H wet and H dry were detailed by Su (2002). The evaporative fraction (ratio of latent heat flux to available energy) is estimated by:

$$Rn - G \quad (3)$$

$$\Lambda = \frac{\lambda E}{Rn-G} = \frac{\Lambda r.\lambda E\ wet}{Rn-G} \quad (4)$$

where λE wet is the latent heat flux at the wet limit (i.e., the evaporation is only limited by the available energy under the given surface and atmospheric conditions). The latent heat flux (λE) can then be calculated by:

$$\lambda E = \Lambda(Rn - G0) \quad (5)$$

Finally, the daily actual ET can be written:

$$ET = 8.64 \times 107 \times \Lambda 24 \times \frac{Rn-G0}{\lambda \rho w} \quad (6)$$

where ρw is the density of water (1, 000 kgm-3) and Rn is the average daily net radiation in this equation. Moreover, the soil heat flux G0 for 24 h is normally assumed negligible (G average).

### 2.3.2. FAO Penman-Monteith Method

Reference crop evapotranspiration according to FAO Penman-Monteith model is:

$$ET0 = \frac{0.408\Delta(Rn-G)+\gamma\left(\frac{890}{T+273}\right)U2(es-ea)}{\Delta+\gamma(1+0.34U2)} \quad (7)$$

where ETo reference evapotranspiration [mm day-1], Rn net radiation at 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), u2 wind speed at 2 m height (m s-1), es saturation vapour pressure (kPa), ea actual vapour pressure (kPa), es-ea saturation vapour pressure deficit (kPa), Δ slope vapour pressure curve (kPa °C-1), γ psychrometric constant (kPa °C-1).

## 3. Results

### 3.1. Daily actual evapotranspiration by SEBS

The results of the daily evapotranspiration calculated by the SEBS algorithm are presented in Figure number 2.

### 3.2. Daily actual evapotranspiration by FAO Penman-Monteith Method

The amount of daily reference evaporation and transpiration was calculated using FAO by the average of meteorological data of 2 stations and the number is equal to 4.5 mm/day.

## 4. Discussion

The study aimed to estimate actual evapotranspiration using the SEBS algorithms and spectral data from the OLI and TIRS sensors of the Landsat 8 satellite in the Mughan plain of Ardabil province. The results of the analysis revealed valuable insights into the performance of these algorithms and their applicability in the specific study area.

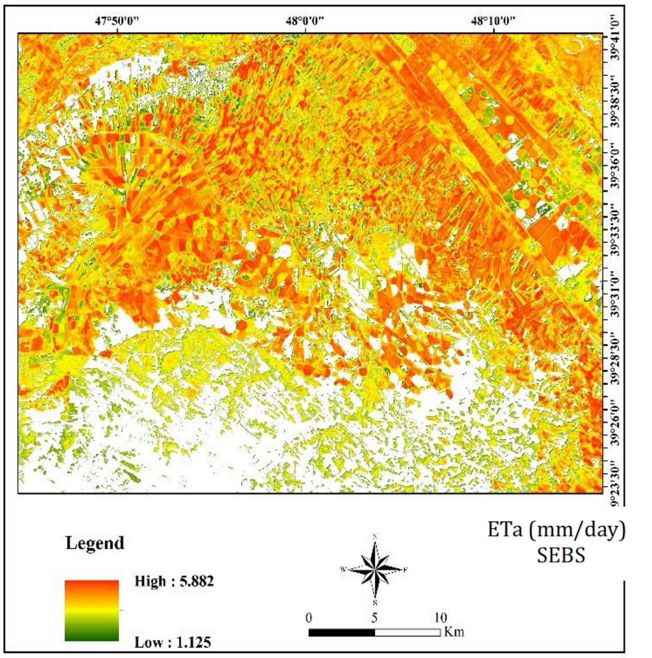


**Figure 2.** Daily actual evapotranspiration (SEBS)

The paper demonstrates one the first applications of the remote sensing method, SEBS, to determine spatial variation of actual evapotranspiration. Also, in order to validate the calculated evapotranspiration SEBS, reference evapotranspiration using the FAO Penman - Monteith was calculated (Equation 6).

Evapotranspiration estimated by the FAO Penman - Monteith using weather data stations is equal to 4.5 mm per day, A value close to the calculated evapotranspiration SEBS on the same day.

The results indicated that both SEBAL and SEBS algorithms have relatively high capabilities in estimating instantaneous evapotranspiration using spectral data. This finding highlights the potential of satellite data for accurately estimating evapotranspiration for various plant species. However, it is essential to consider the trade-off between the finer spatial resolution and computational complexity when choosing the most suitable algorithm for a particular study.

The results of this research, in comparison with the findings of previous studies such as the calculation of actual evapotranspiration using the SEBS algorithm by Yang and colleagues (2021), Wang et al. (2017) and Shamloo et al. (2021) are consistent.

## 5. Conclusion

The SEBS algorithm displays the actual Evapotranspiration rate in an equal range (1.125 to 5.88 mm), which shows the ability of this algorithm to separate areas with different evaporation and transpiration rates. Another advantage of SEBS algorithm is the simplicity of its implementation. SEBS algorithm can be very useful for inaccessible areas as well as areas for which weather station data is not available.

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