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Study on SEBAL Model and Suggesting a Modified Model for Measuring Evapotranspiration

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Abstract

In the current research, SEBAL[1] method has been used in order to find a quick way with a desirable accuracy for measuring the real evapotranspiration in farming areas of Maiamei rural district in Mashhad. Therefore, satellite images from Landsat and the meteorological information of the region for 29 April 2002 (9 Ordibehesht 1381) were provided and the SEBAL calculations were applied on the images with the help of the software ILWIS. Then the relation between the surface parameters (temperature and the vegetation) with the energy components resulted from this method was studied. By conducting research on the treatment of this method on different vegetations, it was concluded that the regions with a wider range of vegetation and a more various density, had less evapotranspiration while by reducing the range and increasing the density of vegetation in this area, the amount of evapotranspiration experiences a stepped rise. Also, the results of this research showed that there is a linear relation with a high accuracy (R2 = 0.96) between the surface temperature and the instantaneous latent heat flux which could be used to reduce the calculation steps of SEBAL model for the studied area and calculate the amount of evapotranspiration in a quicker and easier way by using a modified model.

Keywords: Energy Components, Evapotranspiration, Satellite Imagery, Surface Temperature, Vegetation

1. Introduction

Nowadays, the satellite GIS data has been widely used due to the features such as broad and integrated vision, using different parts of the electromagnetic spectrum for recording the characteristics of the events, repetitive covering, the speed of transmission and the variety in the form of data and the possibility of applying special computer hardware and software in the studies on irrigation and drainage.

Among the methods for measuring evapotranspiration, SEBAL (The Surface Energy Balance Algorithm for Land) is an appropriate approach for extensive works. SEBAL is a method based on image processing that includes 25 submodels in order to measure evapotranspiration as the remaining land surface energy balance[1]. The SEBAL model was firstly introduced and applied in the Netherlands by Bastiaanssen.

In Idaho, the United States, SEBAL method was experimented and validated seasonally and monthly with the Lycimeter results of the consumed water. The outcome for cumulative ET for the sugar beet farms, from 1 April to 30 September 1989, showed that the elimination of errors happens once the daily ET fluxes are accumulated during the time. The lycimeter shows the total ET equal to 705 mm per season that is really close to 714 mm predicted by SEBAL[2].

The accuracy of SEBAL model in estimating ET under different climate conditions in both scales of farm and region has been studied. The common accuracy in farm scale increases 85% per day and up to 95% in a season and the ET yearly accuracy for large regions was averagely 96%[3]. During a study on a cotton farm south of Ceara state in Brazil, the estimated values of daily ET measured by GIS algorithms of SEBAL and S-SEBI were compared with the measured values of the farm by the method of BREB and the outcome revealed that the GIS methods have a desirable

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accuracy, and also the better efficiency of the algorithm of SEBAL was significant by the differences of less than 0.5 mm/day and the mean absolute difference of 0.3 mm/day[4].

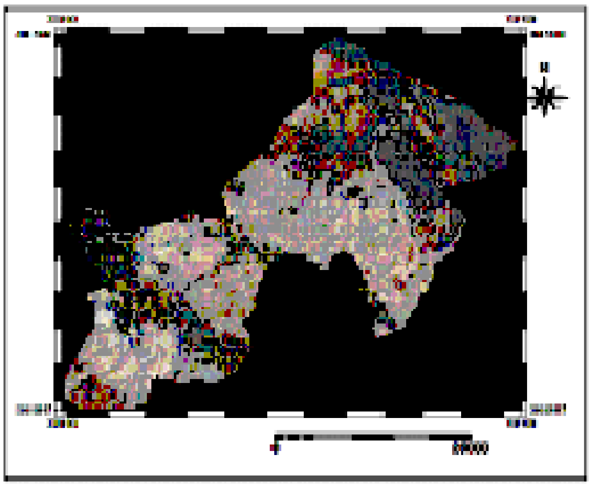

Figure 1. Color composite map of the study region.

2. Methods and Materials

2.1 The Studied Region

The current study has been conducted in Maiamei rural district, Mashhad, in order to calculate the daily evapotranspiration through GIS, in an area between the latitude of 36 degrees, 00 minutes and 41.13 seconds to 36 degrees, 28 minutes and 17.75 second in the North, and the longitude of 59 degrees, 39 minutes and 15.48 to 60 degrees, 18 minutes and 58.03 seconds in the East. Figure 1 shows the color composite of the studied region created by the composition of ETM+ bands 1, 2 and 3 (blue, green and red, respectively).

2.2 The Applied Software

The main software, which is used for compiling and analyzing the data, is ILWIS . ILWIS has a very good GIS and RS operation capability and is specially built for Land-Water analysis. In order to provide the map of the studied area and transfer it to ILWIS, the software Arc View GIS was used.

2.3 The Applied Software

SEBAL is an image processing model that calculates the evapotranspiration and other energy exchanges using the data from satellite images which measure the visible radiation, near infrared and heat infrared[3].

The approach to calculate evapotranspiration through this model is presented in the following according to the model flowchart in Figure 2.

The real instantaneous flux of evapotranspiration (latent heat flux of evaporation) for each pixel of the satellite image is calculated as the remaining of the equation of the surface energy balance:

$$\mathbf{E} = R_n - G - H \quad \text{..........................(1)}$$

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where LE is the flux of latent heat of evaporation, R_n net radiation at the surface, G soil heat flux and H sensible heat flux of the air, and the unit for the flux is $\frac{W}{m^2}$.

R_n is calculated through the following equation by subtracting the output radiant fluxes from the input radiant fluxes:

$$R_n = (1 - r_o)S\downarrow + \varepsilon_a \sigma T_a^4 - \varepsilon_o)\varepsilon_a \sigma T_a^4 - \varepsilon_o \sigma T_o^4 \quad \text{...(2)}$$

where ro is the surface albedo, a the apparent atmospheric radiation, o the surface radiation, δ Stefan Boltzman coefficient equal to 5.6697×10-8 $\frac{mW}{mK^4}$, Ta the temperature and T_o the surface temperature in Kelvin.

In order to estimate G from the experimental equation suggested by Bastiaanssen and Rebling[1], the soil heat flux was used[2].

$$\frac{G}{R_n} = \frac{(T_o - 273.15)}{100 r_a}$$

$$(0.32 r_a + 0.62 r_a^2)(1 - 0.98 NDVI^4) \quad \text{..(3)}$$

where ra is the average albedo (approximately 1.1 ro), when the soil heat flux is directly downwards. To is the surface temperature in Kelvin and NDVI is the normalized difference vegetation index.

The most difficult step in calculation in SEBAL method is the calculation of the sensible heat flux (H) that is calculated through the following equation:

$$H = \rho_a C_p \frac{dT}{r_{ah}} \quad \text{...........(4)}$$

where ρa is the air density in kg/m3, Cp is the heat capacity of air equal to 1004.16 Jkg -1K-1 and rah is the aerodynamic resistence against heat transfer. The calculations of sensible heat flux is corrected using the

Monin-Obukhov correction of atmospheric stability.
After the atmospheric correction of H, first instantaneous evaporative fraction is calculated by the following equation:

$$\Lambda_{ins} = \frac{\mathbf{E}}{R_n - G} = \frac{R_n - G - H}{R_n - G} \quad \text{....................(5)}$$

For the one-day periods of time, G is quite small and could be ignored and the net energy (Rn-G) is shortened to (Rn). Therefore, the daily actual evapotranspiration, ET24 (mm/day), can be calculated through the following equation:

$$ET_{24} = \frac{\Lambda_{ins} R_{n24}}{28.588} \quad \text{...(6)}$$

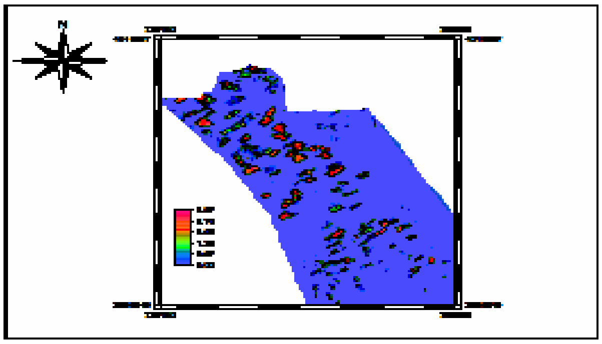

Figure 3. The daily evapotranspiration map for the farm areas for the date 29 April 2002.

3. Results

3.1 Evapotranspiration

The daily evapotranspiration map was calculated by implementing SEBAL model in ILWIS. The evapotranspiration for the studied region changes between 0 to 3.37 mm/day. The daily evapotranspiration map related to the farm areas of Maiamei rural district has been separated from the overall map and presented in Figure 3 in order to analyze the results more accurately.

3.2 The Relationship between Vegetation Cover and Evapotranspiration

In order to study the relation between vegetation and evapotranspiration, the farm areas were used as the critical areas of true evapotranspiration. Therefore, first of

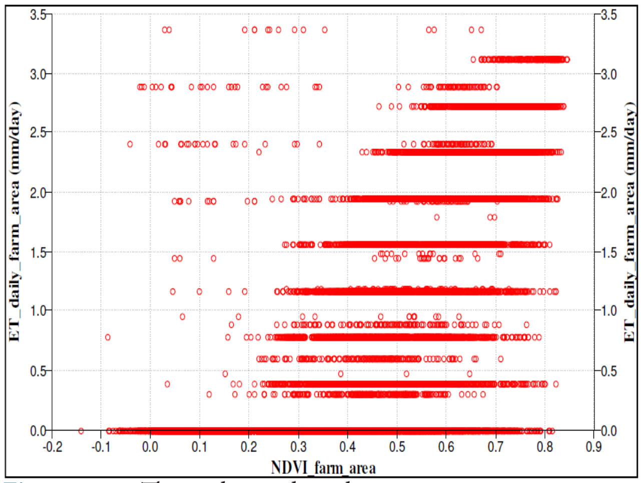

Figure 4. The relationship between vegetation cover (NDVI) and evapotranspiration.

In order to study the relation between vegetation and evapotranspiration, the farm areas were used as the critical areas of true evapotranspiration. Therefore, first of all, the NDVI map of the farm area was separated from the overall map and the table and chart of the evapotranspiration equation and NDVI was drawn by the Cross tool of ILWIS. The chart of the relation between vegetation and evapotranspiration has been presented in Figure 5. It should be noticed that the data table is not given due to the excessive number of pixels (data).
Figure 4 indicates that a greater range of vegetation with a various density, has less evapotranspiration and by reducing the range and increasing the density of vegetation, there will be a stepped rise in evapotranspiration.

3.3 The Relationship between the Surface Temperature and the Instantaneous Latent Heat Flux

Since the latent heat flux represents the amount of evapotranspiration in an energy unit, it is concluded that the instantaneous latent heat flux indicates the amount of instantaneous evapotranspiration. The relationship between the changes in the instantaneous latent heat flux and the surface temperature have been shown in Figure 5. As it is observed in the figure, there is a high correlation between the surface temperature and the instantaneous latent heat flux in the form of a reverse linear relation and it is shown by the linear equation below.

$$LH = -21.66\ To + 6741.27 \quad \text{.....(7)}$$

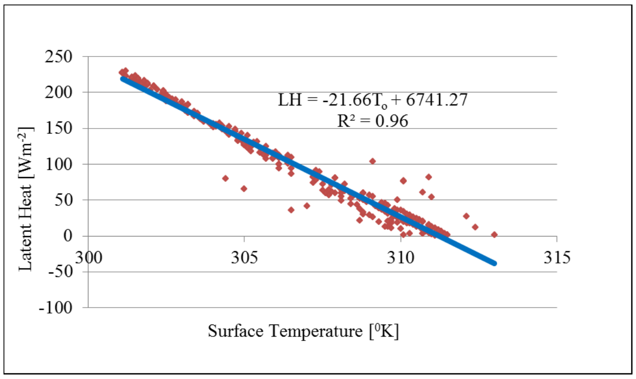

Figure 5. The relationship between the surface temperature and the instantaneous latent heat flux.

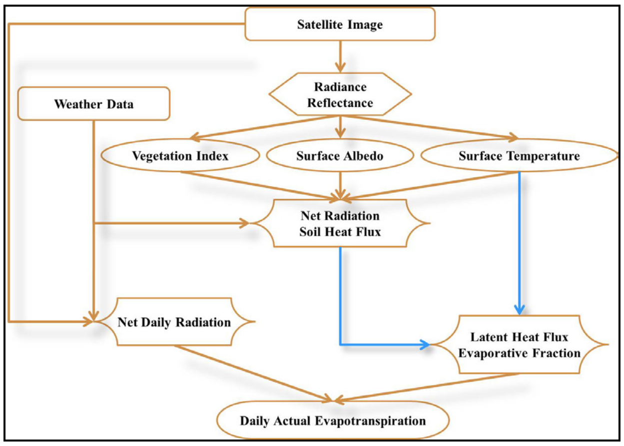

Figure 6. The flowchart of modified SEBAL model (by reducing the calculation steps).

3.4 Reducing the Calculation Steps in SEBAL in Order to Estimate Evapotranspiration

By applying the equation 7 in SEBAL model, the most difficult step in calculating evapotranspiration, i.e. calculating the sensible heat flux which needs a repeated process and complicated atmospheric corrections, was omitted and the instantaneous latent heat flux (instantaneous evapotranspiration flux) was estimated directly through the surface temperature without calculating sensible heat flux. The flowchart of this modified SEBAL model is shown in Figure 6.

The daily evapotranspiration map was calculated by the modified model of SEBAL again. hen the new map was compared with the previous one resulted from the whole calculations of SEBAL model. The graph in Figure 7 shows the similarity between the results of the new estimation of evapotranspiration with the old results. Therefore, the daily evapotranspiration map could be prepared by reducing the calculation steps without the need to conduct the complex calculations of the sensible heat flux.

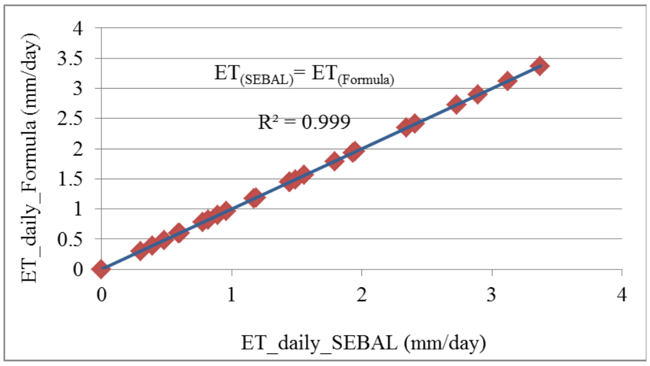

Figure 7. The relationship between the evapotranspiration resulted from whole SEBAL model and the one from modified SEBAL model.

4. Conclusion and Discussion

In the current research, the model of the surface energy balance algorithm for land was investigated for the studied area and the real evapotranspiration was estimated for 29 April 2002. Then the relation between all the energy fluxes was calculated with the surface parameters (temperature and vegetation). By studying the relationship between the vegetation cover and evapotranspiration in the rural district of Meiamei, it was found that the regions with a wider vegetation cover and a more various vegetation density had less evapotranspiration and as the range of vegetation reduces and the density increases, a stepped rise in evapotranspiration is expected. Also, it is concluded that there is a direct linear relationship (with a high accuracy where R2 = 0.96) between the surface temperature and the instantaneous latent heat flux. By applying this relation in SEBAL model, the most difficult step in the calculations of SEBAL i.e. the sensible heat flux was omitted and the evapotranspiration resulted from this method (modified model) was similar to the one from the SEBAL method. By using the approach obtained through the current study and reducing the calculation steps in SEBAL, a modified model of SEBAL could be used as an easier and a quicker way to calculate the amount of real evapotranspiration in Meiamei rural district in Mashhad. As a result, by implementing SEBAL model in any other region, the relation may be generalized or corrected and a modified general approach for calculating the evapotranspiration could be obtained for other areas.

5. References

1. Bastiaanssen WGM, Menenti M, Feddes RA, Holtslag AAM. A remote sensing Surface Energy Balance Algorithm for Land (SEBAL). 1. Formulation. J Hydrol. 1998; 212–3:198–212.
2. Allen RG, Morse A, Tasumi M, Trezza R, Bastiaanssen WGM, Wright JL, Kramber W. Evapotranspiration from a satellite-based surface energy balance for the snake plain aquifer in Idaho. Proceedings of USCID Conference San Luis Obispo; 2002 Jul.
3. Bastiaanssen WGM, Noordman EJM, Pelgrum H, Davids G, Thoreson BP, Allen RG.. SEBAL model with remotely sensed data to improve water-resources management under actual field conditions. ASCE Journal of Irrigation and Drainage Engineering. 2005; 131(1):85–93.
4. Santos CAC, Bezerra BG, Silva BB, Neale CMU. Assessment of daily actual evapotranspiration estimated by remote sensing algorithms. Anais 4th Simposio Brasileiro de Sensoriamento Remoto, Natal, Brasil (INPE); 2009 April 25–30. p. 427–34.