Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231-6345 (Online)
An Open Access, Online International Journal Available at http://www.cibtech.org/jls.htm
2014 Vol. 4 (3) July-September, pp.30-34/Matinfar and Soorghali
Research Article

ESTIMATE EVAPOTRANSPIRATION (ET) USING SEBS MODEL BASED ON LANDSAT 5 (TM) THERMAL DATA AND GIS

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ABSTRACT
Land surface evapotranspiration (ET) is of prime interest for environmental applications, such as optimizing irrigation water use, irrigation system performance, crop water deficit, drought mitigation strategies, and accurate initialization of climate prediction models especially in arid and semiarid catchments where water shortage is a critical problem. A convenient and practical model to estimate actual evapotranspiration is the SEBS model. In this study, using spectral data and Landsat 5(TM) thermal band using to estimate actual evapotranspiration rates range from plain Silakhor Iran's Lorestan province has been estimated**.** Also, in order to validate the results of the model, the results compared with the Penman montith results. Statistical analysis showed significant differences between the results of the two methods. Hence it can be concluded that the SEBS model is based on satellite data can be a valuable alternative to traditional methods of estimating actual evapotranspiration**.**

Keywords: *TM Thermal Bands, SEBS, Thermal Data*

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 (G_0) are calculated based on land surface temperature (T_{sfc}) 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. The aim of this study was to calculate the actual evapotranspiration using SEBS algorithm for Silakhor plain.

MATERIALS AND METHODS

Location and Data

Study area located in Silakhor plain, Lorestan province of Iran, between the 48° 48´ to the east, and 48° 59´North (Figure 1). In this study, Landsat 5 (TM) images have been used to date 07/26/2009. The image processing software ILWIS version 7/3 is used.

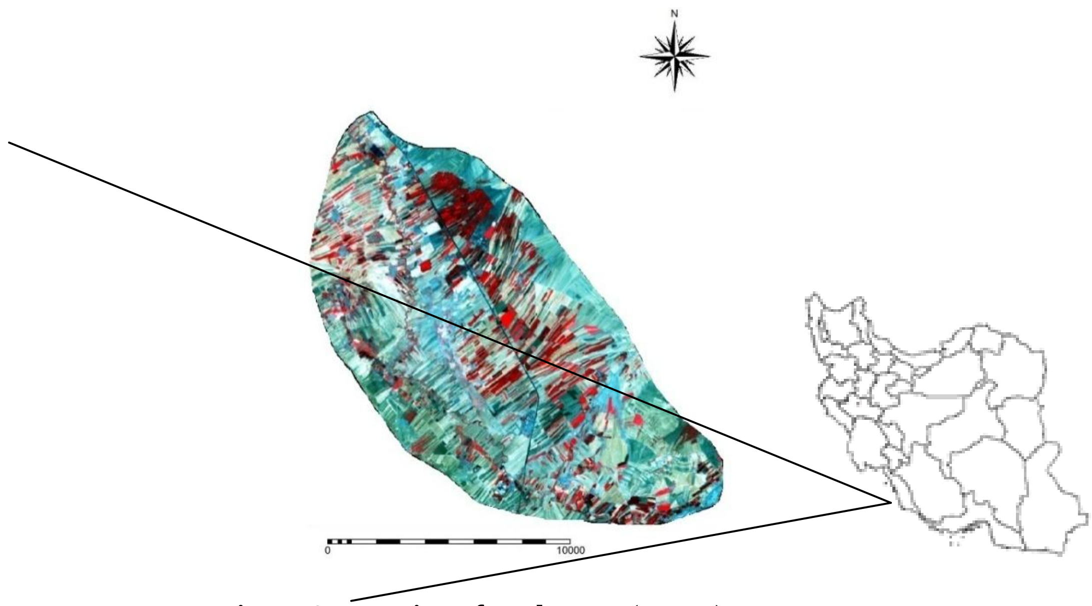

Figure 1: Location of study area (TM_{432})

Table 1: Some climatological data of study area

Specific humidity	Sunshine hours per day	Pressure at surface(Pa)	Pressure at reference height(Pa)	Wind speed(m/s)
0.625	**11.9**	**837.1**	**837.05**	**9**

The SEBS (Su 2002) was proposed to estimate theatmospheric turbulent fluxes, the evaporative fraction, and the actual ET using satellite earth observation data, in combination with land surface meteorological observation information.

Evapotranspiration

The surface energy balance is commonly written as**:**

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

where Rn is the net radiation flux, G_0 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.

In this study, the SEBS retrieval algorithm is applied to the TM data to evaluate its applicability within an arid environment. Firstly, the TM data from the three TM instrument subsystems (visible and near-infrared (VNIR), short wave infrared (SWIR), and thermal infrared (TIR)) were reprojected into the same spatial resolution. 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:

$\Lambda r = 1 - \frac{\mathrm{H - Hwet}}{\mathrm{Hdry - Hwet}}$ (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:

$\Lambda = \frac{\lambda E}{Rn - G} = \frac{\Lambda r . \lambda \mathrm{E\ wet}}{Rn - G}$ (3)

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:

$\lambda E = \Lambda(Rn - G0)$ (4)

Finally, the daily actual ET can be written:

$\mathrm{ET} = 8.64 * 10^7 * \overset{24}{\Lambda} * \frac{Rn - G0}{\lambda \rho w}$ (5)

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 G_0 for 24 h is normally assumed negligible (G average).

Sufficient information must be provided so that another researcher can repeat the experiments that are described in the paper. If reference is made to a method published elsewhere in a journal or document that may not be readily available to most readers, then details of the method are to be included. If a published method is modified, it must be described. Where commercially available software has been used, details of the supplier should be given in brackets or the reference given in full in the reference list.

Determination of Pivotal Parameters

Land surface parameters play an important role in the air land interaction over the study area. Study of this interaction requires an understanding of land surface parameters in time and space at various scales. Because a satellite is able to observe the global surface continuously from space, it can be used to monitor land surface parameters. The most common (and useful) land surface parameters include the land surface temperature (Figure2a), the surface albedo (Figure2b), the NDVI (Figure3a), Emissivity (Figure3b) and the vegetation coverage Pv (or fractional vegetation cover fc).These parameters are required for the application of SEBS at the regional scale.

FAO Penman-Monteith Method

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

$ETo = \frac{0.408\ \Delta(Rn - G) + \gamma\left(\frac{890}{T+273}\right)U2(es - ea)}{\Delta + \gamma(1 + 0.34U2)}$ (6)

where ET_o reference evapotranspiration [mm day^{-1}], R_n 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), u_2 wind speed at 2 m height (m s^{-1}), e_s saturation vapour pressure (kPa), e_a actual vapour pressure (kPa), e_s-e_a saturation vapour pressure deficit (kPa), Δ slope vapour pressure curve (kPa $°C^{-1}$), γ psychrometric constant (kPa $°C^{-1}$).

RESULTS AND DISCUSSION

The paper demonstrates one the first applications of the remote sensing method, SEBS, to determine spatial variation of actual evapotranspiration for the Silakhor plain in Lorestan Province of Iran.

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 Doorod, Chalanchvlan and Borojerd on 07/26/2009 and is equal to 7.094 mm per day, A value close to the calculated evapotranspiration SEBS (6.15mm/day (Figure 4)) on the same day.

In this study, 30 meter spatial resolution, Landsat5 TM image of 07/26/2009 was used to delineate the spatial variation in ETa. The snapshot computed in this study demonstrates that water bodies have highest ETa, farm and pasture transpire at a higher rate than cultivated land on 07/26/2009. Volumetrically, farm and pasture account for about 58% of the ETa in this particular day, the highest of all land cover types. Agricultural field ETa is only 24% of the overall ETa from the investigated area. However, in addition to ETa, knowledge of the contribution of the each land use to livelihoods and productive use is essential: 1) to compute beneficial vs. non-beneficial uses of water and 2) to devise strategies to improve water management/productivity. We can see that, although irrigation requires over 50% of the diverted stream flow and groundwater in the basin, it accounts for a much more modest portion of basin evapotranspiration. In this study, we do not know the beneficial values of forest in terms of timber produced and in terms of hydrological services in maintaining base-flows and catchment yield. Therefore, it is not possible to make further comparisons, nor assess the water productivity. Clearly, a snapshot indicates an overall annual trend in spatial ETa in the basin, due to the relative magnitudes of the areas of each type of land use. However, some form of seasonal and annual integration is also desirable to account for, among other things, reduced forest ETa in the dry season and conversely relative increase in irrigated ETa. Temporal integration is currently only feasible using MODIS or AVHRR data at 1km2 resolution, which then loses the ability to define ETa precisely by land use class.

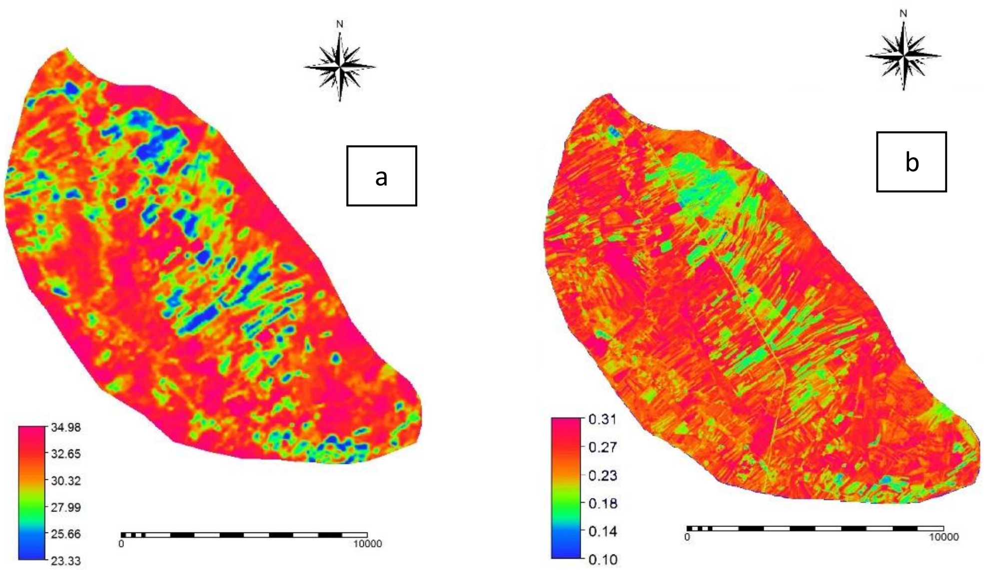

Figure 2: Land surface temperature (a) and Albedo (b)

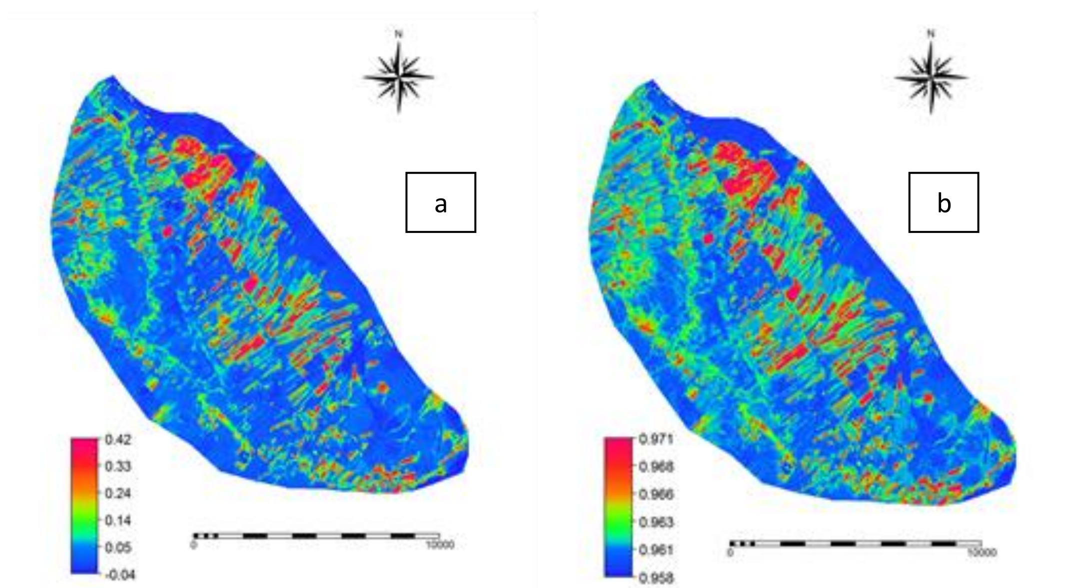

Figure 3: NDVI (a) and Emissivity (b) of study area

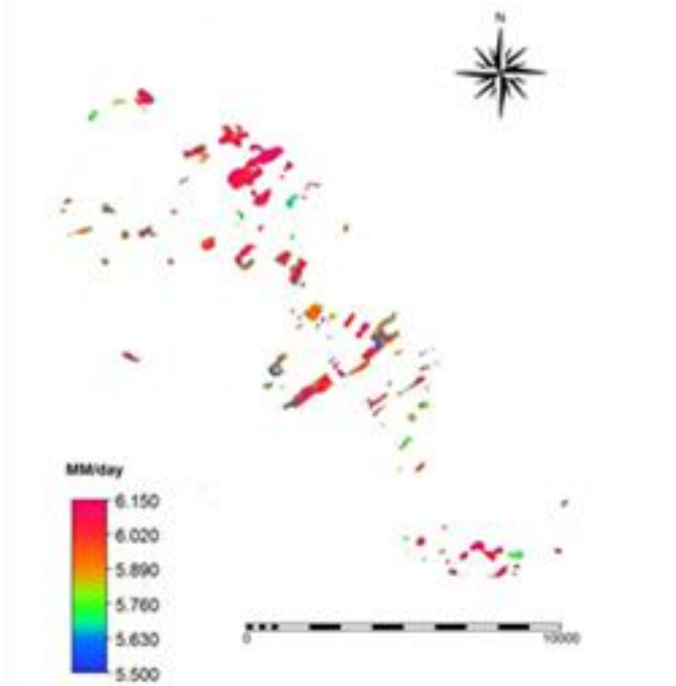

Figure 4: Evapotranspiration of study area

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