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Evapotranspiration estimation base upon SEBAL model and fieldwork

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ABSTRACT

It is important to estimate land surface evapotranspiration (ET) for water resources evaluation, drought monitoring and crop production simulation. The most important information needs to irrigation performance, is the evapotranspiration (ET) of the plants, especially field crops. Knowing about the crop was the necessity for calculating anything about it. When facing a water basin of very large area, agro-climatically transient in its various parts, treating the ET calculation by the energy-balance becomes interesting. Information about the vegetation cover is indeed minimal and often very well provided by satellite information. Some various satellites are used, Landsat7 ETM+, NOAA AVHRR, TERRA MODIS and TERRA ASTER. Only satellites able to provide temperature measurements are fulfilling the requirements of such analysis. Some meteorological satellites are also used for calculating ET in Global Climatologically Models, but are of too low spatial resolution for the application to crop ET per selected farm. Validations of such monitoring algorithms have been widely performed and are always found acceptable. It is concluded that SEBAL model is useful to calculate ET by means of remote sensing measurements and other meteorological data.

Key Words: remote sensing, evapotranspiration, satellite imagery, SEBAL.

INTRODUCTION

Actual Evapotranspiration ET_a is one of the most useful indicators to explain whether the water is used as “intended” or not. ET_a variations, both in space and time and from different land use classes (particularly from irrigated lands) are thought to be highly indicative for the adequacy, reliability and equity in water use; the knowledge of these terms is essential for judicious water resources management. Unfortunately, ET_a estimation under actual field conditions is still a very challenging task for scientists and water managers. The complexity associated with the estimation of *ET* has lead to the development of various methods for estimating this parameter over time [11, 1].

The methods for estimating ET can generally be grouped into 4 categories i.e. the hydrological methods (water balance), direct measurement (lysimeters), micrometeorological (energy balance) and empirical or combination methods (Thornth waite), based on energy balance or climatic factors [14, 16]. Most of these methods can only provide point estimates of ET which are not sufficient for system-level water management. Distributed physically-based hydrological models can compute *ET* patterns but require enormous amounts of field data which are often unavailable in many river basins in the world.

During the last two to three decades, significant progress has been made to estimate actual evapotranspiration (ET_a) using satellite remote sensing [3,9,12,13,15]. These methods provide a powerful means to compute ET_a from the scale of an individual pixel right up to an entire raster image.

Surface Energy Balance Algorithm for Land (SEBAL) avoids the problem (to input accurate surface data) by using the temperature difference between the air and the ground for each pixel which is scaled by surface temperature in contrast with dry and wet spot values. Thus, SEBAL is more attractive for operational applications [8,15].

SEBAL is one of the residual methods of the energy budget[4]. It combines empirical and physical parameterization. The inputs include local weather data (mainly wind speed) and satellite data (radiance). From the input data, the Rn (net solar radiation), NDVI, albedo, roughness length, and G (soil heat flux) are calculated. The sensible heat flux is calculated by contrasting two points cold and hot pixels(wet, well-irrigated vegetation and dry ground). Then, the ET is calculated as the residual of the energy budget [4,5].

The accuracy can be 85% on a daily basis and 95% on a seasonal basis [6]. However, the accuracy of the algorithm varies from 67% to 95% for instantaneous ET estimates and 70% to 98% for 1 to 10-day ET estimates in 18 literature studies [6]. There is a need to find how the algorithm is sensitive to its variables and equations. Then, the information can tell what are the key variables and equations for algorithm improvement and parameterization.

This study demonstrates the application of a remote sensing method, the Surface Energy Balance Algorithm(SEBAL) for Land [2,4] in koramabad region, Iran. Quantification of evapotranspiration from irrigated lands is very useful in cross-checking actual water use against water allocation and in understanding its implications for the specification and management of water rights in a region.

MATERIALS AND METHODS

The study region is located in the southwest of Khorram Abad extending to the airport (Fig. 1). It has hot and arid summer time, but the winters are somehow cold and humid. The rain starts in the November and ends in April. The average annual rainfall has been reported to be 516 mm and maximum rainfall to be 78mm in April.

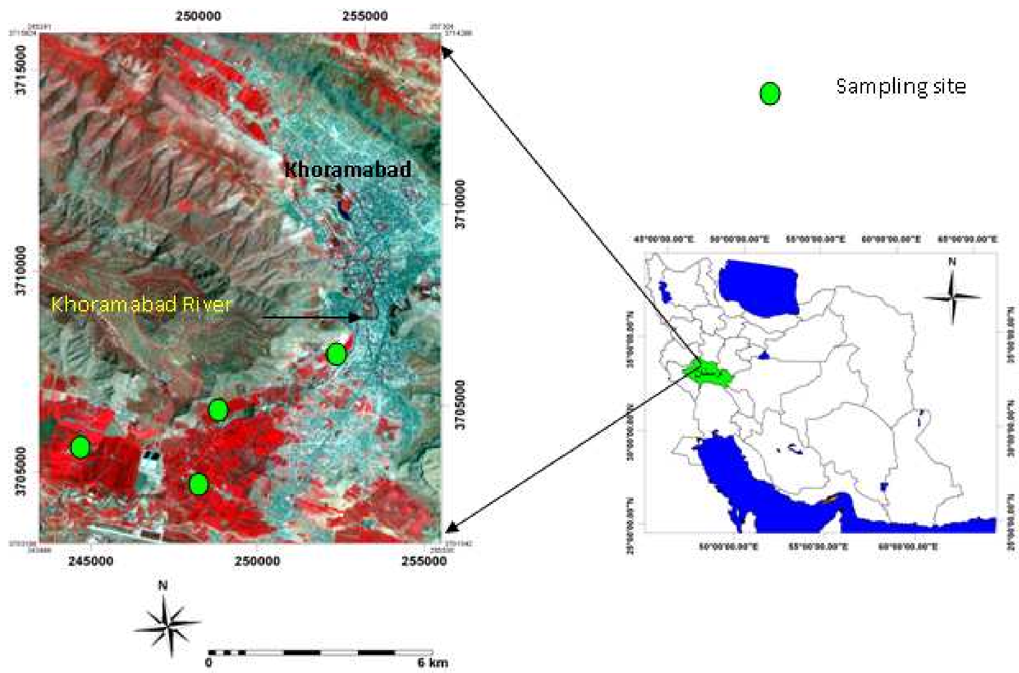

Figure 1: Location of studying area in Iran and Lorestane province

In this study, remotely sensed data from ETM^+ bands dated 17th June 2002, topographic maps at 1:50.000 scale and fieldwork have been used for analysis. The software's such as ILWIS 3, and ERDAS Imagine were used. Table (1) showed some environmental characteristic of Khoramabad region.

Table1: Rainfall and temperature in Khoramabad region,17_{th} june 2002

Day	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
T	2.7	3.9	3.5	3.9	3.9	5.2	5.2	3.9	5.3	4.8	4	4	4	4.2	4.6
P	0	0	0	0	4	2.5	0	0.5	1.5	3	1	0	0	0	4
Day	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
T	4	3.1	4	4	1.7	4.9	3.5	3.5	4.4	4.4	4	3	3	3.5	3.9
P	0	0	0	0	1.7	4.9	3.5	3.5	4.4	4.4	4	3	3	3.5	3.9

SEBAL computes a complete radiation and energy balance along with the resistances for momentum, heat and water vapors transport for each pixel [2,4,10]. The key input data for SEBAL consists of spectral radiance in the visible, near-infrared and thermal infrared part of the spectrum. In addition to satellite images, the SEBAL model requires the following routine weather data parameters (wind speed, humidity, solar radiation, air temperature).

Evaporation is calculated from the instantaneous evaporative fractionΛ, and the daily averaged net radiation, Rn24. The evaporative fraction Λ is computed from the instantaneous surface energy balance at satellite overpass on a pixel-by-pixel basis:

$$\lambda E = R_n - (G_0 + H) \tag{1}$$

Where: λE is the latent heat flux, Rn is the net radiation, G_0 is the soil heat flux and H is the sensible heat flux (Figure 2).

The latent heat flux describes the amount of energy consumed to maintain a certain crop evaporation rate. The surface albedo, surface temperature and vegetation index are derived from satellite measurements, and are used together to solve R_n, G_0 and H. The instantaneous latent heat flux, λE, is the calculated residual term of the energy budget, and it is then used to compute the instantaneous evaporative fractionΛ:

$$\Lambda = \frac{\lambda E}{\lambda E + H} = \frac{\lambda E}{R_n - G_0} \tag{2}$$

The instantaneous evaporative fraction Λ expresses the ratio of the actual to the crop evaporative demand when the atmospheric moisture conditions are in equilibrium with the soil moisture conditions. The instantaneous value can be used to calculate the daily value because evaporative fraction tends to be constant during daytime hours, although the H and λE fluxes vary considerably. The difference between the instantaneous evaporative fraction at satellite overpass and the evaporative fraction derived from the 24-hour integrated energy balance is marginal and may be neglected [6, 7, 9]. For time scales of 1 day or longer, G_0 can be ignored and net available energy (R_n - G_0) reduces to net radiation (R_n). At daily timescales, ET24 (mm/day) can be computed as:

$$ET_{24} = \frac{86400 \times 10^3}{\lambda \rho_w} \Lambda R_{n24} \tag{3}$$

Where: Rn24 (W/m2) is the 24-h averaged net radiation, λ (J/kg) is the latent heat of vaporization, and ρ_w (kg/m3) is the density of water.

$$R_n = G_0 + H + \lambda E$$

$$\Lambda = \frac{\lambda E}{R_n - G_0} = \frac{\lambda E}{\lambda E + H}$$

$$\lambda E = \Lambda\left(R_n - G_0\right)$$

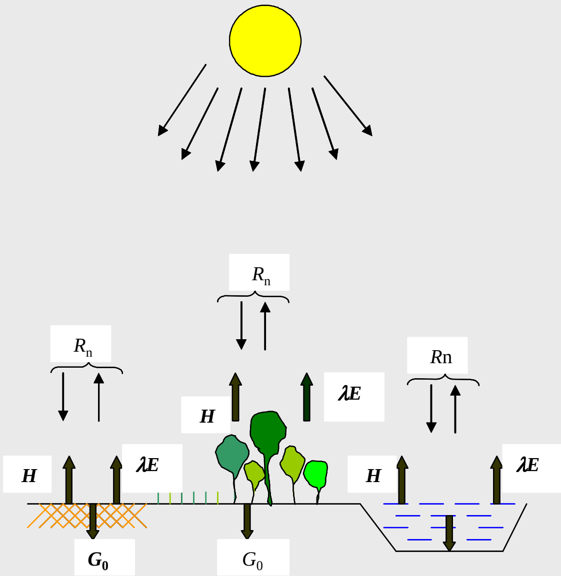

Figure 2: Various components of Energy Balance & main equations to compute latent heat flux

RESULTS AND DISCUSSION

The paper demonstrates one the first applications of the remote sensing method, SEBAL, to determine spatial variation of actual evapotranspiration for the Khoramabad region in Iran. Data for SEBAL processing can be sourced from Landsat, MODIS and ASTER at different scales but requires routine meteorological measurement of air temperature, humidity, wind speed and sunshine duration.

In this study, 30 meter spatial resolution, Landsat7 ETM^+ image of 17 th June 2002 was used to delineate the spatial variation in ET_a. The snapshot computed in this study demonstrates that water bodies have highest ET_a, winter wheat canopy and corn canopy transpire at a higher rate than cultivated land(fig.3), on June 17, 2002. Volumetrically, winter wheat canopy and corn canopy account for about 62% of the ET_a in this particular day, the highest of all land cover types. Agricultural field ET_a is only 32% of the overall ET_a from the investigated area. However, in addition to ET_a,, knowledge of the contribution of the each land use to livelihoods and productive use is essential: 1) to compute beneficial versus non-beneficial uses of water and 2) to devise strategies to improve water management/productivity. We can see that, although irrigation requires over 70% of the diverted stream flow and groundwater in the basin, it accounts for a much more modest portion of basin evapotranspiration. Clearly a snapshot indicates an overall annual trend in spatial ET_a in the region, 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 ET_a in the dry season and conversely relative increase in irrigated ET_a. Temporal integration is currently only feasible using MODIS or AVHRR data at $1km^2$ resolutions, which then loses the ability to define ET_a precisely by land use class. The interpretation of ET_a values depends on the knowledge of actual vegetation cover if accurate determinations of water use by vegetation are to be made.

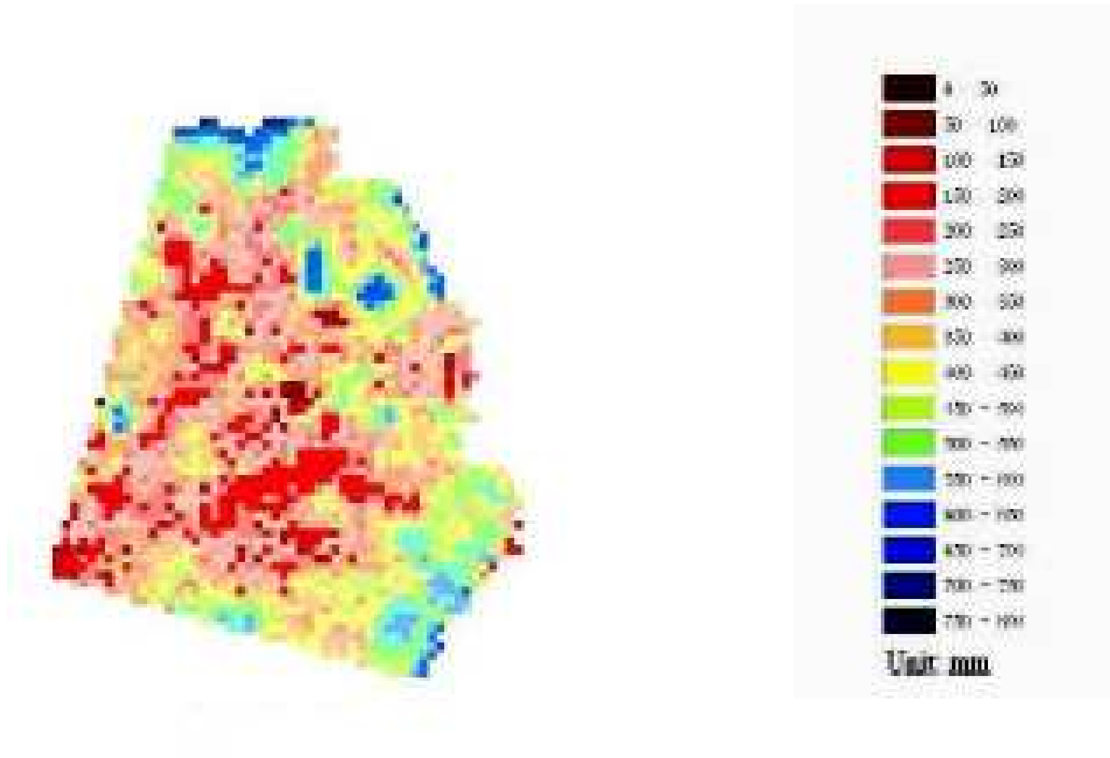

Figure3. Actual Evapotranspiration (ET_a) estimates using SEBAL for Landsat7 ETM+ imagery for Khormabad region. 17th June 2002.

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