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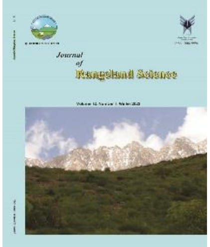

Research and Full Length Article:

Estimation of Evapotranspiration of Rangeland Cover Using SEBAL Algorithm in Robat Mahidasht Region, Kermanshah, Iran

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Abstract. Rangelands are the most important plant ecosystems in Iran that have multiple and vital roles in economic stability and food security in the country. In recent decades, with increasing population, increasing forage consumption, climate change and rainfall fluctuations, most of the country's pastures have been destroyed or faced with a degradation trend. Therefore, in order to strengthen this vital ecosystem in the country, rangeland management components have a special priority and importance. One of the main components of rangeland management is the study on the water requirement of rangeland plants. The water required by the plant is equivalent to its evapotranspiration. Estimation of evapotranspiration using meteorological station data can be done at different time intervals; But determining its spatial distribution on a large scale is not possible. Remote sensing techniques and evapotranspiration estimation algorithms based on the surface energy balance of the earth are among the methods that are able to produce maps with appropriate temporal and spatial coverage. In this study, 4 images of LANDSAT 5 processed (from June to July of 2010), and evapotranspiration of the Mahidasht region, Kermansh province, Iran were estimated. Then, Sentinel 2 images were used to identify the existing rangelands in the Robat Mahidasht region by Maximum Likelihood classification method. The evapotranspiration of the rangelands was obtained using Surface Energy Balance Algorithm for Land (SEBAL) maps. Based on the results, it was observed that the difference of estimating the actual evapotranspiration between the SEBAL algorithm and lysimetric measurements was a maximum value of 9.7%, which is acceptable. The coefficient of determination between SEBAL and lysimetric data was (R^2=0.99) and mean absolute difference was 0.53 mm/day. The estimated evapotranspiration rates of rangeland cover at the four Landsat imaging dates were 2.1, 3.46, 3.4, and 3.44 mm/day. Also, the results showed less rangeland evapotranspiration than other coverings like forest and agriculture, which is due to the dryness of the topsoil profile and shallow depth of most of the rangeland plants, especially annuals species. It was concluded that SEBAL algorithm is a suitable method for estimating the evapotranspiration of rangeland cover with acceptable accuracy.

Key words: Remote sensing, SEBAL, Merek watershed, Image classification, Sentinel II

Introduction

Rangeland vegetation is the largest natural cover spread in the world. Rangelands are any extensive areas of land that are occupied by native herbaceous or shrubby vegetation which are grazed by domestic or wild herbivores. They are geographical regions dominated by grass and grass-like species with or without scattered woody plants, occupying about 40%-50% of the land area of the Earth (Alemneh and Getabalew, 2019). In the arid and semi-arid regions of the world, water catchments are often predominantly used as rangeland. Catchment management influences the quality and quantity of water that flows into rivers, lakes and wetlands and has a major impact on the life of dams reservoir. Currently, more than 916,000 rural and nomadic families are depending on rangelands in Iran. According to the latest estimates, the country's rangelands are about 847 thousand km^2. Rangelands are of important roles in meeting the forage needs of livestock, recharge groundwater aquifers, exploiting rangeland by-products, producing medicinal and industrial products, air purification and prevention, preventing soil erosion and floods. In general, it could be noted that increasing of regional rangeland cover degradation and drought are the main causes of dusty days increasing from 2000 to 2016 (Nouri *et al.*, 2019). Rangelands are meeting wildlife needs and recreational aspects. In addition to the mentioned effects, the role of the country's rangelands in carbon sequestration through rangeland plants has a major share of carbon sequestration in the country with about $ 2 billion annual production of the country's pastures, we will understand the importance of this vegetation better. Therefore, protection, restoration, improvement and optimal use of rangelands in the form of proper and efficient management and in order to sustain this natural ecosystem are necessary. Uncertainty poses a problem for land and resource managers as they seek to adapt to changes and mitigate the adverse effects of climate change (Alemneh and Getabalew**,** 2019).

Climate changes including reduced rainfall have caused drought and fragility in a significant portion of valuable forest and rangeland cover (Heshmati *et al.*, 2017). In studies of vegetation drought around the world, climatic factors have been mentioned as one of the effective and main parameters, so these factors should be given priority in studies (Hosseini *et al.*, 2014). Drought stress is one of the most important factors limiting the growth of plants in their habitats (Sepahvand *et al.*, 2021)**.** The use of NDWI for the period (1985 to 2018) highlights the importance of the water deficit in the region (R^2=0.72) (Guerine *et al.*, 2020). Therefore, it can be said that focusing on methods that can estimate the water requirement of rangeland cover, which in most sources is synonymous with evapotranspiration of this cover, is of great importance. Drought and reduction of available moisture of vegetation including rangelands have led to the study of water needs of rangelands and the development of methods that can estimate this need reproducibly and on a large scale, it has a special importance and position. Under rainfed condition, water use efficiency (WUE) refers to rain water that is directly used by the plant during growth with higher value resulting in “more yield per drop” of rain water (Koech *et al.*, 2015). Estimation of long-term pasture production using important factors of climate and soil characteristics on forage production is inevitable. Reduced water and precipitation are important factors limiting production of fodder, especially in arid and semi-arid areas (Fakhimi and Arzani, 2020). Evapotranspiration estimation is a basic requirement for hydrological and ecological monitoring, and water resources management, and the use of remote sensing allows continuous monitoring of this factor (Keshavarz *et al.*, 2011). Evapotranspiration is one of the important factors in the hydrological cycle and is one of the determinants of energy equations at ground level and water balance and its estimation is required in various fields such as hydrology, agriculture, rangeland and rangeland management and water resources management (Mir Yaghoob Zade, *et al.*, 2014). Remote sensing is a very useful technology that is preferred over other methods to study vegetation from the past to the present (Falahatkar *et al.*, 2018). In recent decades, many algorithms have been designed to estimate evapotranspiration, most of which are based on energy balance. More broadly, remote sensing provides a relatively accurate estimate of evapotranspiration in very large areas using satellite data and minimal use of ground data and multiple algorithms. Remote sensing has the ability to estimate the amount of evapotranspiration and even to study its spatial distribution (Mir Yaghoob Zade *et al.*, 2014; Kazemi Nia, 2017). Remote sensing is the only method that can provide surface temperature parameters, albedo coefficient and vegetation characteristics in a way that are compatible or environmentally friendly, and also economically viable. Various methods have been developed to use this data in surface flux estimation approaches (Mir Yaghoob Zade, *et al.*, 2014). One of the algorithms used in the analysis of satellite images to estimate the evapotranspiration and plant coefficients of different products is the Surface Energy Balancing Algorithm for Land (SEBAL) model (Ghamar Nia *et al.*, 2017). The SEBAL is a relatively new algorithm that has been used in most parts of the world to estimate evapotranspiration and other surface heat fluxes and has had satisfactory results (Mir Yaghoob Zade *et al.*, 2014). SEBAL model is a robust tool to calculate the soil moisture in rangelands by the means of remote sensing (Nouri and Faramarzi, 2017). The aim of this study was to determine the evapotranspiration of rangeland cover using Landsat 5 satellite data processing and the implementation of SEBAL algorithm to calculate the actual evapotranspiration of rangeland areas and Robat-Mahidasht, Kermanshah, Iran.

Material and Methods

In this study, data from Landsat 5 satellites in 2010 obtained from USGS site, meteorological data of synoptic stations of Kermanshah and climatology station of Mahidasht obtained from Kermanshah Meteorological Office, Iran to perform calculations of SEBAL algorithm and also sentinel 2 data related to 2018 obtained from the site USGS were used for information listed in Table 1. It should be noted that the Landsat satellite data have been used in order to implement the SEBAL algorithm and to determine evapotranspiration on 4 consecutive imaging dates by this satellite in the study area and Sentinel II images have been used to determine the distribution of rangelands in Robat-Mahidasht area. Google images and field visits were also used to control the exact boundaries of rangelands and to determine the uses of the range.

Table 1. Specifications of the images used in the research

Data type	Imaging date				No. of Bands	Bands
Landsat 5 (TM) 167-36	25 Ju 2010	11 Jul 2010	27 Jul 2010	12 Aug 2010	7	6 bands 30 1 band 120
Sentinel II	Frame SPD 23 June 2018		Frame SPC3 Jul 2018		13	5 bands 10 6 bands 20 2 bands 60

Study area

The study area is a part of Merek watershed, which is one of the main sub-basins of Qarahsu watershed and is considered as a branch of Karkheh river basin in the general division, and is located in Karkheh-e-Olia section. This area is geographically located in Kermanshah province, Iran and forms a part of Mahidasht-Sanjabi plains between longitudes 46°31′ to 47°06′ E and latitude 34°05′ to 34°32′ N. Fig. 1 shows the geographical location of the hydrological unit of Robat Mahidasht in Kermanshah province and throughout Iran.

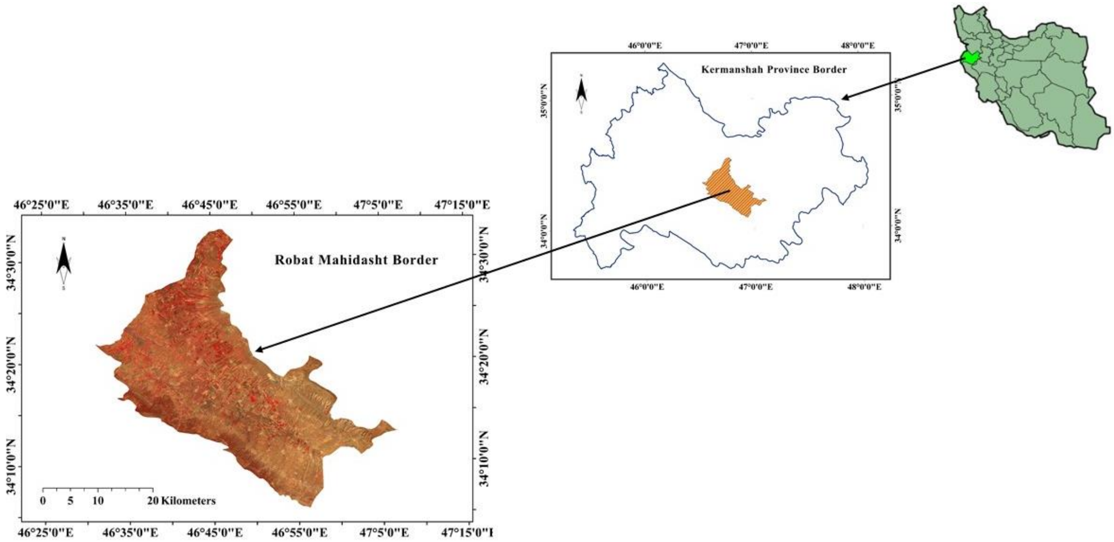

Fig. 1. Location of the study area in Kermanshah province, Iran

The area of this region is 992.35 km^2, which forms the middle part of Sanjabi-Mahidasht plain and includes about 67.68% of lands under Merek watershed and 36.77% of lands in Sanjabi-Mahidasht plain. In this area, there are 3 districts and 121 villages. The study unit of Robat Mahidasht is a relatively mountainous region where 35.3% of the lands are mountains and hills. The highest peak is located on the western border and in the heights of Ghazi mountain with an altitude of 2367 m above sea level. The general slope in the lands is about 8.6% and their direction is northwest. The lowest point in this area is in the east of Doab village and at the junction of Merek river with Qarahsu river with an altitude of 1315 m above sea level. The Merek River is the main waterway of this hydrological unit, direction of flow is from the southeast to a length of 110.5 km to the northwest with an average weight, slope of 0.09%; This outlet of Merek watershed is located in the east of Doab village.

Climate

Robat Mahidasht climate is Mediterranean and cold semi-arid regions based on the modified De Marthon division (Kazemi and Sharifi, 2018). In order to extract the meteorological parameters required for the implementation of the SEBAL algorithm applied data from Kermanshah synoptic station with a geographical position of longitudes 47°15′ E and a latitude of 34°35′ N, that is in the vicinity of the study area. Based on the analysis of information collected from the Kermanshah station, climatic parameters in the Robat-Mahidasht region were as follows:

Thermal parameters including average monthly temperature, average maximum, average minimum, absolute maximum and absolute minimum based on the information of Kermanshah station were 14.2°, 22.7°, 5.7°, 43.3°, -23.9°C, respectively. The average annual rainfall based on Kermanshah station data is 477 mm. The highest rainfall was in March as 94 mm and the lowest in August as 0.3 mm (Table 2). The vapor transfer process is highly dependent on wind and air turbulence, which transports large amounts of air from the evaporation surface. Kermanshah station data were used to determine wind speed and direction. In the SEBAL for computing aerodynamic resistance and estimating sensible heat, speed of wind at 2 or 10 m from ground was obtained by synoptic station data and was converted to speed in 200 m from the ground. In general, changes in relative humidity indicate that the relative humidity increases with decreasing air temperature and decreases with increasing air temperature. The average monthly and annual evaporation in the region derived from Kermanshah station (Table 2). The average speed, direction and percentage of dominant wind in Kermanshah station are shown in Table 2. Based on data in Table 2, in Mahidasht region, wind has two main directions, west direction in seven months of the year (in the crop season) and south east direction that includes rest of the year (nearly 5 months in autumn and winter seasons); therefore, it can be seen that west direction wind has the most effectiveness in evapotranspiration process in the crop season. In addition, the most evaporation amounts happen from May to September in a way that west dominant wind is more than other months.

Table 2. Monthly distribution of rainfall, Relative humidity, Potential Evaporation and wind speed (m/s), direction and percentage of dominant wind in Kermanshah stations, Iran

Meteorology data	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Precipitation (mm)	27.2	59	73.2	66.1	65.3	94	62.3	27.6	0.7	0.7	0.3	0.6	477
Relative humidity%	42	60	71	73.5	70	64	60	52	33	27	26.5	29	51
Evaporation (mm)	99.2	101.6	22.9	0	0	0	100.8	194.8	291	356.5	359.3	293.1	1919
Wind direction	W	SE	SE	SE	SE	SE	W	W	W	W	W	W	
Speed of wind (m/s)	3.9	3.9	4.1	4.0	4.3	4.2	4.4	4.3	4.3	4.0	4.1	4.0	
Dominant wind%	13	14	12.8	12.4	15	14.5	13	18.6	20	25	19	22	
Slow wind%	50	48	52	50	41	38	36	38	36	40	39	43	
Other wind direction%	37	38	35	44	48	51	44	44	44	35	42	35	

Research Method

SEBAL algorithm

The Surface Energy Balance Algorithm for Land (SEBAL) is a satellite image processing model that calculates the potential evapotranspiration and actual evapotranspiration as well as the energy exchange between the surface and the atmosphere by 25 computational steps. The general equation of the SEBAL model (Bastiaanssen *et al.*, 1998) is defined as (Eq 1):

ET=Rn-G-H (1)

Where:

ET, evapotranspiration;

Rn, net radiation;

G, soil heat flux;

H sensible heat flux into the air.

Bastiaanssen (1995) defined the equation for determining net radiation is (Eq 2):

$$R_n = (1-\alpha) \times R_{S\downarrow} + C - (1-\varepsilon_0) \times R_{L\downarrow} \quad (2)$$

Where:

α, surface albedo;

$R_S\downarrow$, shortwave radiation emitted from the sun;

$R_L\downarrow$, long wave radiation to the ground;

$R_L\uparrow$, long wave radiation reflected from the earth to the atmosphere; and

ε_0, Atmospheric emissivity.

Soil heat flux was estimated as amount of soil heat flux (Tasumi *et al.*, 2000; Bastiaanssen *et al.*, 2002) in (Eq. 3):

$$G = R_n \times \left(\frac{T_s - 273}{\alpha}\right) \times (0.0038 \times \alpha + 0.0074 \times \alpha^2) \times (1 - 0.98 \times NDVI^4) \quad (3)$$

Where:

G =soil heat flux (W/m^2);

$R_{n,=}$ net radiation (W/m^2);

NDVI,=the normalized plant index;

Ts,= surface temperature (Kelvin degrees); and
α, =albedo (dimention less).
The sensible heat flux was calculated by the following equation (Morse *et al.* 2000) (Eq 4):

$$H = \frac{\rho \times C_p \times dT}{r_{ah}} \quad (4)$$

Where:
H is the sensible heat flux (W/m^2),
ρ is the air density as a function of atmospheric pressure (kg/m^3),
C_p is the air heat capacity that is 1004 (J/kg/K),
dT is the temperature difference between T1 and T2, and r_{ah} is the aerodynamic resistance to heat transfer (s / m) between Z1 and Z2.
After calculating the parameters used in the SEBAL algorithm, first the instantaneous evapotranspiration (Tasumi *et al.*, 2003) and then, the 24-hour evapotranspiration were calculated by the following equation (Eq 5):

$$ET_{inst} = \frac{\lambda * ET}{\lambda} \times 3600 \quad (5)$$

Where:
$ET_{inst.}$ is instantaneous evapotranspiration (mm/hr),
λ is the latent heat of vaporization (J/kg), 3600 to convert evapotranspiration from instantaneous to hour. In the following equation (Allen *et al.*, 2002),
24-hour evapotranspiration is calculated as follows (Eq 6):

$$ET_{24} = \frac{86400 \times \Lambda \times (Rn_{24} - G_{24})}{\lambda} \quad (6)$$

Where
ET_{24}= 24-hour evapotranspiration:
Rn_{24} = the 24-hour net radiation,
G_{024} =the daily soil heat flux, 86400 the number of 24-hour seconds, and
λ t=he latent heat of vaporization (J/Kg).
The latent heat of evaporation causes the actual 24-hour evapotranspiration to be expressed in mm / day.
Based on the SEBAL, four images of Landsat satellite were processed. For preparing evapotranspiration maps by SEBAL, bands 1-5 and 7 to compute albedo, ε_0, ε_{NB}, … and band 6 are used to compute R_{Lout}, R_{Lin}, surface temperature, etc. The evapotranspiration map was determined for Robat Mahidasht region and rangelands cover within the area.

Lysimeter data

To compare and validate the results obtained from SEBAL, the data of a drainage lysimeter were used with dimensions of 1×1.5×1.5m located in Agricultural Research Station of Mahidasht with coordinates at 46°50′36″ E and 34°06′38″ N. This lysimeter was installed in the corn field and measured the actual evapotranspiration rate of the crop during the growing season. The data of this lysimetric station were used to compare the evapotranspiration maps obtained from the SEBAL algorithm.

In order to investigate the rate of evapotranspiration in the rangeland cover, Sentinel II images were used, which are temporally consistent with Landsat images; These images were related to the two frames SPC and SPD on the dates of 2018/07/03 and 2018/06/23 and cover the study area of Mahidasht. Using Sentinel II mosaic images and ENVI 5.3 software, in the first step, radiometric and atmospheric correction was performed, then obtained an 843 band composition image, which performs vegetation detection well.

Results

Calculations of evapotranspiration in the study area

The information required for the calculations of the Sabal algorithm was obtained from the data of Kermanshah Islagah during satellite imaging (Table 3). According to the method of SEBAL algorithm in solving the surface energy balance equation to determine evapotranspiration in Robat-Mahidasht region, first Landsat images were processed on the four mentioned dates and the evapotranspiration maps were finally prepared (Fig. 2.).

The results showed that the highest rate of evapotranspiration in the desired period was related to cultivated area with a value of 9.01 mm per day. In Fig.2, we can see over time from June to August that dry lands and pastures had been dried up in Robat Mahidasht and the area with low evapotranspiration has been expanded. Evapotranspiration maps in late July and early August shows high rate of daily actual evapotranspiration in irrigated farms and forests because these two covers have access to more water. As it can be seen, the rates of evapotranspiration in altitudes and plains are close because cover of altitudes in Robat Mahidasht specially in south west of region is oak forest where trees have deep roots and more leaves to photosynthesize, so they can get more water for evapotranspiration, and in the plains, high rate of evapotranspiration is related to irrigated farms. In the late July and early August, areas with less evapotranspiration are widespread.

Table 3. Climatic information of Robat Mahidasht in Landsat imaging dates

Date 0f imagery	Minimum temp. (°C)	Maximum temp. (°C)	Wind Speed (m/s)	Evaporation (mm/day)	RH% 18.5	RH% 12.5	RH% 6.5	Rainfall (mm)
2010/06/25	12.6	29.6	1.35	10.3	16	13	51	0
2010/07/11	14.8	41.4	2.42	14.2	9	8	35	0
2010/07/27	13.2	37.6	2	11.9	13	13	45	0
2010/08/12	12.6	38.4	1.75	12.5	13	10	34	0

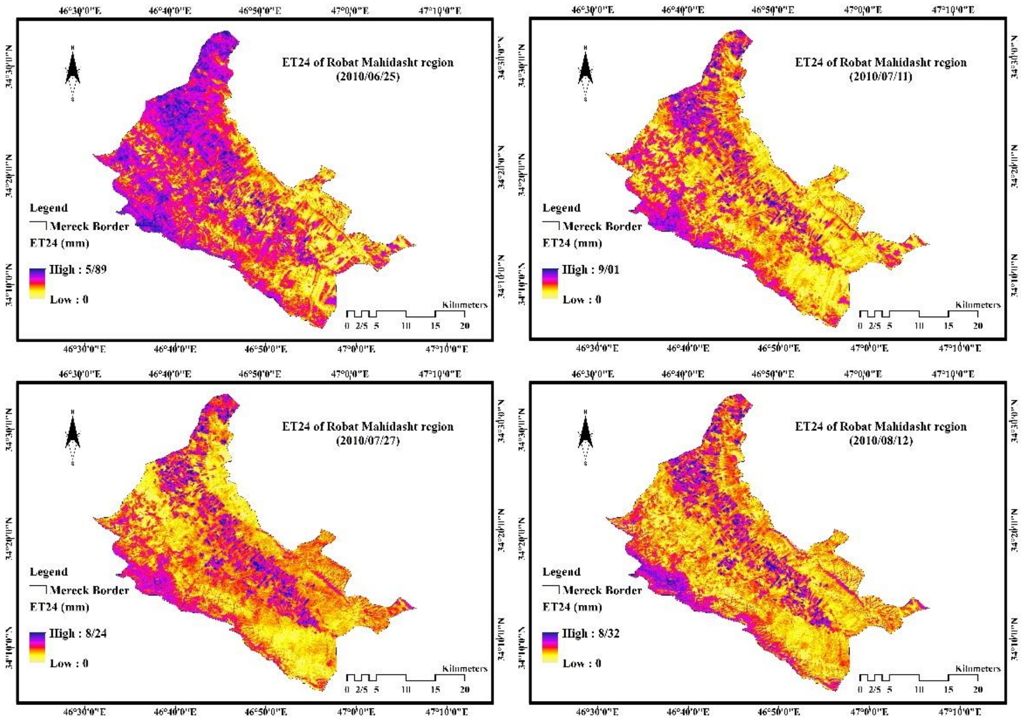

Fig. 2. The daily evapotranspiration calculated maps on four Landsat imaging dates.

In the next step, the results of evapotranspiration calculated by SEBAL algorithm were matched with lysimetric and meteorological data and the accuracy of this algorithm was determined in comparison with the data measured in the field as described (Table 4).

Based on Tables 3 and 4, evapotranspiration calculated by SEBAL and lysimeter are consistent with changes of wind speed and temperature. The lowest and highest values of Eta (thr actual evapotranspiration) from SEBAL are 3.97 and 7.35 mm/day, respectively. There are maximum differences 9.79% between SEBAL and lysimetric data and average differences o.53 mm/day, and the correlation coefficient between the two series SEBAL and lysimeter data was (r=0.99); which indicates that SEBAL estimates are acceptable. Since the estimation accuracy of the algorithm is significantly close to the ground reality, the obtained maps can be used to determine the evapotranspiration rate of different covers and land uses.

For calculating ETa of rangelands, first mosaiced Sentinel 2 images were used (SPC and SPD frames), then land use classification in Robat Mahidasht area was done based on the Maximum Likelihood classification method. Result of 5 classes of land use classification (forests, rangelands, agriculture areas, cities, and water bodies) showed a total kappa coefficient as 0.81. According to the obtained results of classification, the rangelands located in the area were determined. The boundary of rangeland polygons was corrected using Google Earth software and field boundary control. Fig. 3 shows the modified rangeland boundary in the Robat Mahidasht region. According to the results, the area of Mahidasht rangelands is 148 km^2. The rangelands are spread on the south and north of the area (Fig. 3).

Table 4. Comparison daily evapotranspiration in corn field and estimated by SEBAL (mm/day)

Date	Lysimeter	SEBAL	Diffrence	Error%	Average of diffrences (mm/day)
2010/06/25	4.13	3.97	0.16	3.87	
2010/07/11	7.74	7.20	0.54	6.97	0.53
2010/07/27	7.45	6.72	0.73	9.79	
2010/08/12	8.05	7.35	0.7	8.69	

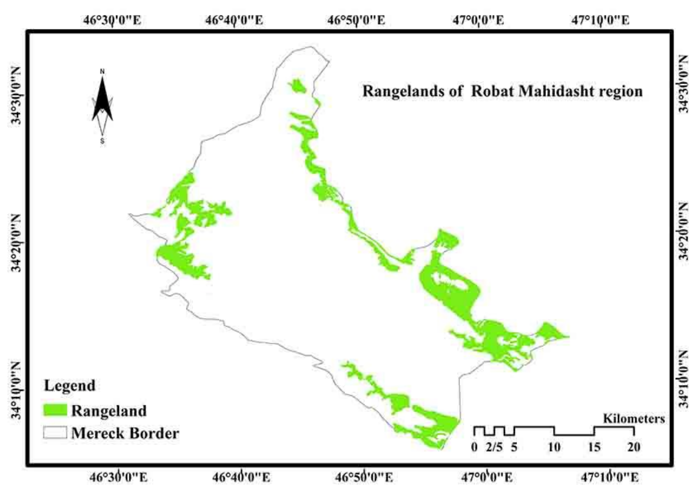

Fig. 3. The modified rangeland boundary in the Robat Mahidasht region, Kermanshah, Iran

According to the distribution map of rangelands in Robat Mahidasht region, the actual evapotranspiration map has been cut in the 4 imaging dates of Landsat satellite and the calculations related to the determination of evapotranspiration in the region were done.The results of calculations are shown (Table 5.) and average evapotranspiration in June to August is 2.1, 3,46, 3.40, and 4.02 mm/day, respectively. Also, Fig. 4 shows distribution of daily evapotranspiration in Robat Mahidasht.

In Table 5, average daily evapotranspiration in rangelands is lower than non rangelands. The standard deviation in rangelands showed less variability inter species. In Robat Mahidasht region, the differences of evapotranspiration estimated between rangelands and non-rangeland areas in 4 imaging dates were 0.88, 0.89, 0.62, and 0.61, respectivly.

Table 5. Comparison of evapotranspiration of rangelands and Non rangelands area in Robat Mahidasht

Evapotranspiration	2010/06/25		2010/07/11		2010/07/27		2010/08/12	
	Non Range	Range	Non Range	Range	Non Range	Range	Non Range	Range
Minimum (mm/day)	0	0	0	0	0	0	0	0
Maximum (mm/day)	5.94	6.26	9.01	8.62	8.24	7.77	8.32	8.31
Average (mm/day)	2.98	2.1	4.33	3.46	4.02	3.4	4.07	3.44
Standard Deviation	0.97	0.74	1.19	1.01	1.01	0.9	1.24	1.22

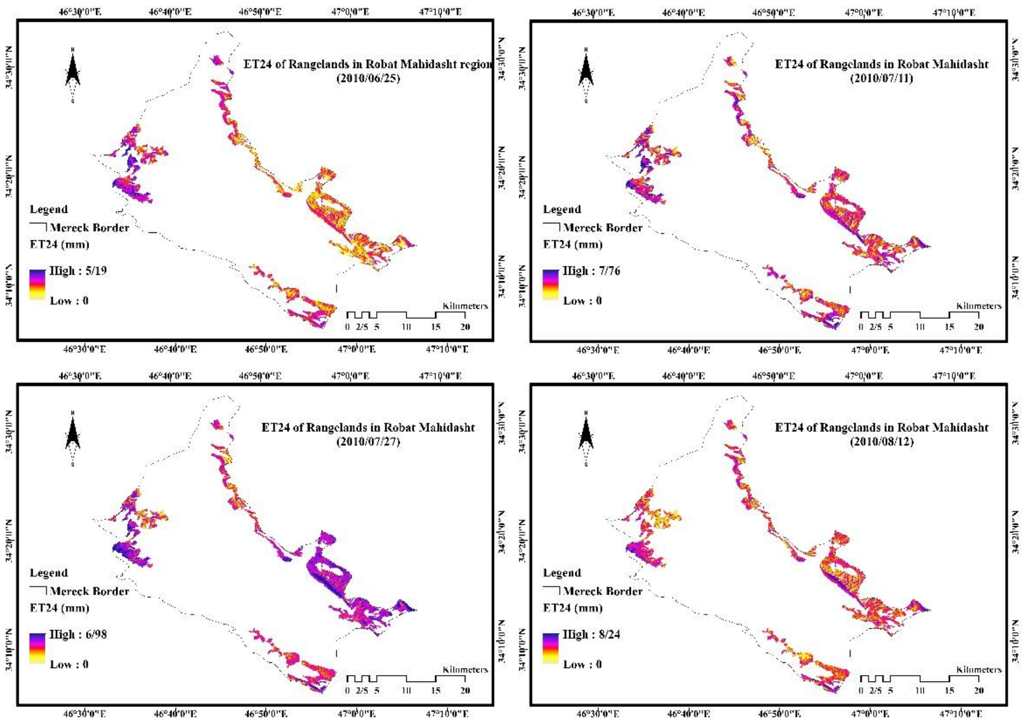

Fig. 4. Rangelands evapotranspiration map of Robat Mahidasht region

The second important point is the water requirement of the rangeland cover. If there is enough moisture, value of ET_a will have significant differences with reality. In the study period, the actual amount of evapotranspiration of the rangeland cover was estimated as 277 mm, and this shows the actual amount of evapotranspiration of the rangeland cover during the annual period of plant activity which is more than available moisture for rangelands.

Fig. 5 shows that in Robat Mahidasht region, forest cover has the highest amount of evapotranspiration and rangeland cover has the lowest amount; the difference between forest and rangeland cover ranged from 1.04 to 1.55 mm/day. This may depend on the physiological factors affecting evapotranspiration and physiography in the region.

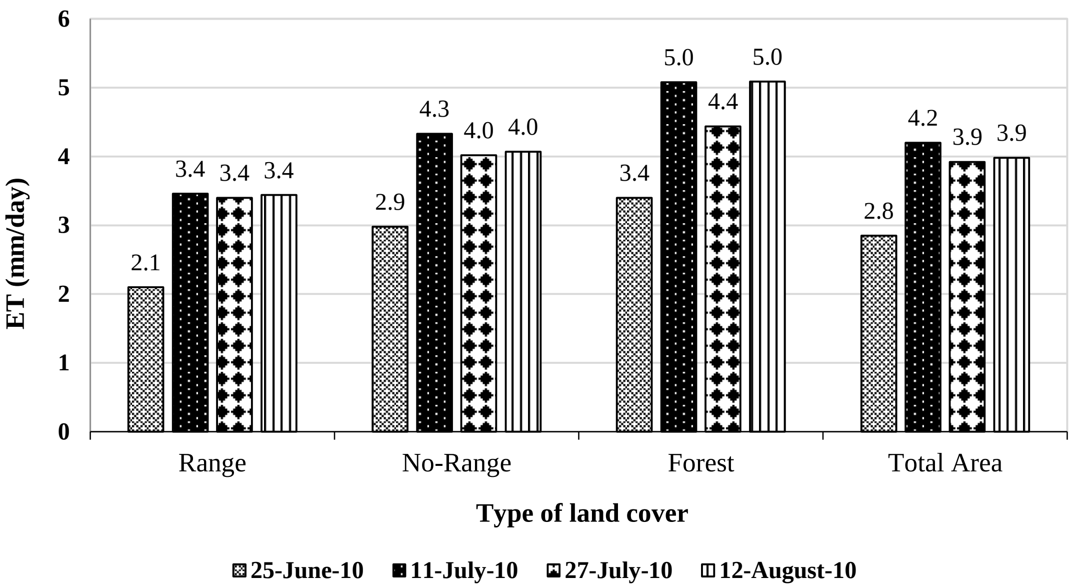

Fig. 5. Comparison of evapotranspiration of rangeland and other covers in Robat Mahidasht region

Discussion

The results of applying SEBAL algorithm in Malayer rangelands showed that there was no significant difference between daily ET computed by SEBAL method and Penn man Monteith equation (Nouri and Faramarzi, 2017). One of the most important vegetations in Kermanshah province and Robat Mahidasht region is rangeland cover. To estimate the evapotranspiration of this cover by cutting the evapotranspiration map of Robat-Mahidasht region on the four dates of June to August 2010, which are shown in Fig. 4, the amount of evapotranspiration in Robat Mahidasht rangelands has been determined. The maps show evapotranspiration of rangelands less than other plant covers and in a small part of the southwest of the region, which has an altitude of over 2100 m, evapotranspiration is more. On the other hand, the rate of evapotranspiration in the rangelands showed a clear relationship between the height of the rangelands and the rate of evapotranspiration. The rangelands with more altitude and lower surface temperature have more amount of evapotranspiration. Earth's surface temperature changes in the opposite direction to evapotranspiration, and there is a strong significant relationship between slope shadow, altitude and ecological potential with the amount (Najafi Far *et al.*, 2016; Bahrami *et al.*, 2019); In areas with good and dense vegetation and low surface temperature, evapotranspiration is higher than other areas (Bahrami *et al.*, 2019). Comparison of evapotranspiration rate on four consecutive imaging dates shows that in all 4 mentioned dates, the rangeland cover had values less than other land uses. According to the Table 5 and Fig. 5, it can be seen that the average rate of evapotranspiration of rangeland cover is less than the average of other land uses and forest cover had the most amount of evapotranspiration. Based on these calculations, it is found that the water requirement for rangelands cover and the amounts of available moisture are insufficient. Reduction of soil moisture significantly affects the stability of the rangelands, and available moisture in the soil profile can affect the growth, vigor and survival of rangeland plants. The lower leaf area index (LAI), shallower root depth, higher albedo, lower surface roughness and lower transfer of energy and momentum all contribute to reduce evapotranspiration in soybean areas (Pinto Dias *et al.*, 2015); According to Pinto Dias study, evapotranspiration was 1024.7, 1009.5, 678.5, and 567.3 mm in growth period for forest, Cerrado, soybean, and pasture respectively. Modeled results in Upper Xingu River Basin showed about 40% less evapotranspiration in agricultural ecosystems (pasture and soybean catchments) than in natural ecosystems (forest and cerrado catchments) that support our finding in Robat Mahidasht.

The prepared maps show significant changes in the rate of evapotranspiration in the Robat Mahidasht, so by over time from early July to late August, the rate of evapotranspiration from the plains to the mountains decreases. The ET*c* maps generated by the model for seven Landsat overpass days showed a very good progression of ET_c with time during the growing season in 2005 as the surface conditions continuously changed (Singh *et al.,* 2008). The *ETa* amount depends mainly on water and energy availability (Sanchez *et al.*, 2019). During dry months (<100 mm/month), although less water is available for evapotranspiration, lower cloudy conditions allow higher radiation and consequently more evaporation. The opposite occurs during wet months. During the first months of this comparison period (May–August) as *ETa* seems to be limited by the energy availability and not by water availability (Sanchez et al., 2019).

In this study, results show that SEBAL algorithm can have a good estimate of evapotranspiration. It was found that using the SEBAL method, which is a remote sensing algorithm, and using images with appropriate band composition and image resolution, such as Landsat 5 satellite images, evapotranspiration maps can be prepared with good accuracy for different vegetation. There was no difference between FAO Penman-Monteith method and SEBAL; therefore, the accuracy of SEBAL algorithm can be acceptable. The results showed that there was no difference between daily ET, computed SEBAL and Penn man Monteith significantly (Nouri and Faramarzi, 2017). In Robat Mahidasht region, the comparison of data obtained from direct lysimetric measurements and maps obtained from SEBAL method confirmed the good consistency and accuracy of SEBAL method, so in four imaging dates, the difference between direct ground estimation and SEBAL data was 0.53 mm per day and coefficient of determination was (R^2=0.99) which indicates a 9% difference in estimation between the two methods. The research conducted in Qazvin plain also confirms the results of this research; Execution of SEBAL algorithm in Qazvin plain and comparison with drained lysimeter data showed the value of coefficient of determination was (R^2=0.99) and the average absolute difference of 0.446 mm/day between lysimetric and SEBAL estimates. This result indicates the appropriateness of the application of remote sensing method in estimating evapotranspiration in this region (Malek Pour *et al.*, 2017). Also, it was found that the use of Landsat satellite images and preparation of evapotranspiration map in the appropriate time series can significantly improve the estimate of evapotranspiration and it can help to better classify the area by Sentinel II images to extract different land uses like rangelands, forests, agricultures (dry or irrigated) and so on.

Due to the extent of the rangelands in predominantly semi-arid regions, this cover is faced with a shortage of available water, and this problem will cause slow growth and in more severe cases, dryness of rangeland masses. The cover crop mixture was never able to fully develop due to several factors: declining temperatures slowed maturation, shortening days reduced available energy, and inadequate precipitation limited growth (Hankerson *et al.,* 2012).

Conclusion

We found that the use of remote sensing to estimate the spatial distribution of ETa was encouraging. Using remote sensing-based estimates of ETa can help document differences in water use between different covers across a region, thereby providing critical information for water resources management. Evapotranspiration of rangelands due to climatologic, physiologic and fisiographic limits is less than other covers in Robat Mahidasht region, Iran.

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برآورد تبخیر- تعرق پوشش مرتعی با استفاده از الگوریتم سبال (مطالعه موردی: منطقه رباط ماهیدشت، کرمانشاه)

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چکیده. مراتع یکی از مهم‌ترین اکوسیستم‌های گیاهی در ایران هستند که نقشی چندگانه و حیاتی دارند. در دهه‌های اخیر با افزایش جمعیت، افزایش مصرف علوفه، تغییرات اقلیمی و نوسانات بارندگی، اغلب مراتع کشور دچار تخریب شده یا با روند قهقرایی روبه‌رو گشته‌اند. بنابراین به منظور تقویت این اکوسیستم حیاتی در کشور، مؤلفه‌های مدیریتی مراتع دارای اولویت و اهمیت ویژه‌ای هستند. یکی از اجزاء اصلی مدیریت مراتع، بررسی آب مورد نیاز آنها می‌باشد. آب مورد نیاز گیاه معادل تبخیر- تعرق آن محسوب می‌شود. برآورد تبخیر- تعرق با استفاده از داده‌های ایستگاه هواشناسی می‌تواند در بازه‌های زمانی مختلف انجام شود؛ ولی تعیین توزیع مکانی آن در مقیاس بزرگ قابل انجام نمی‌باشد. تکنیک سنجش از دور و الگوریتم‌های برآورد تبخیر- تعرق که بر پایه بیلان انرژی سطح زمین استوار هستند از جمله روش‌هایی می‌باشند که قادر به تولید نقشه‌های با پراکنش مکانی مناسب بوده که با به‌کارگیری داده‌های نقطه‌ای هواشناسی برای تولید نقشه‌های با پوشش زمانی و مکانی مناسب، مفید خواهند بود. در این پژوهش تبخیر- تعرق با استفاده از تصاویر ماهواره لندست ۵ و الگوریتم سبال (SEBAL) در منطقه رباط ماهیدشت کرمانشاه برآورد و با نتایج با داده‌های لایسی‌متری مقایسه شد. سپس با استفاده از تصاویر سنتینل ۲ و روش طبقه‌بندی Maximum Likelihood، مراتع موجود در منطقه مشخص شد. در ادامه نقشه تبخیر- تعرق مراتع به‌دست آمد. بر پایه نتایج به دست آمده، خطای برآورد تبخیر- تعرق واقعی با الگوریتم سبال و لایسی‌متر حداکثر٪۹/۷ بوده که بسیار مناسب می‌باشد. ضریب تبیین بین داده‌های تبخیر- تعرق حاصل از سبال و مقادیر اندازه‌گیری شده به‌وسیله لایسی‌متر مقدار ۰/۹۹ و میانگین اختلاف برآورد ۰/۵۳ میلی‌متر در روز بود. میزان تبخیر-تعرق پوشش مرتعی در چهار تاریخ تصویربرداری (از ۲۵ ژوئن تا ۱۲ اوت) ماهواره لندست به ترتیب ۲/۱، ۳/۴۶، ۳/۴، و ۳/۴۴ میلی‌متر در روز برآورد شد. هم‌چنین نتایج، تبخیر- تعرق مراتع را کم‌تر از اراضی جنگلی و کشاورزی آبی نشان داد که این امر به علت خشکی پروفیل خاک سطحی و عمق کم ریشه در بخش عمده‌ای از گیاهان مرتعی به‌ویژه گیاهان یکساله می‌باشد. نتیجه آن‌که الگوریتم سبال روشی مناسب برای برآورد تبخیر- تعرق پوشش مرتعی با دقت قابل قبول است.

کلمات کلیدی: سنجش از دور، سبال، حوزه آبخیز مرک، طبقه بندی تصاویر، سنتینل ۲