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An estimation of the temperature of Lut desert using MODIS sensor data

G. Azizi[a*], S.K. Alavi Panah[a], N. Goodarzi[b], M. Kazemi[b]

[a] *Associate professor, Dept.of Physical Geography, Faculty of Geography, University of Tehran, Iran*
[b] *M.S.in Physical Geograph, Faculty of Geography, University of Tehran, Iran*

Abstract

Temperature is considered as the basic element of climate and also the environmental limiting factor in Lut Desert. In this research, in order to identify the temperature of Lut Desert located in east of central Iran, using remote sensing data, six series of MODIS sensor images related to June 24th & December 23rd 2002, and also January 22nd, March 22nd, June 22nd & September 24th 2003 were employed. The temperature rates have been estimated by using band numbers 31 and 32 with locative separation power of 1000 meters and considering the Sebal algorithm. According to the results of temperature evaluation, the mean for land surface temperature in Lut Desert within the mentioned images at 6 o'clock Grinwich mean time have been; 49.6, 18.2, 22.0, 36.4,55.7 and 54.2 °C, respectively. Setting relation between calculated surface temperatures and recorded temperatures by meteorology stations indicated a meaningful correlation at 0.001 level. The rate of calculated determinant coefficients has been ranging from 0.91 to 0.72 per hour. Hence, the linier algorithms within surface soil temperatures of the six studied images and the recorded temperatures through meteorology stations were determined. According to these algorithms, the highest calculated air temperature in the area with respect to images was 49.7 C° (at 12:00) in June 22nd 2003 and the lowest 11.5 °C (at 03:00) Jan 22nd 2003. The results of this survey indicate that using MODIS sensor images seems to be suitable for estimating the Lut Desert temperature as well as temperature in other similar areas.

Keywords: Lut Desert; MODIS Sensors; Sebal Algorithm; Surface soil temperature

1. Introduction

Lut pit in south-east of Iran, is one of the vastest, lowest lying, hottest, and driest pits in Iran plateau (Kardavani, P. 1972). According to Agricultural Jehad Economic Organization's division of the country into whole zones, Lut Desert Locates between 23°56′32.33″ - 34°07′13.97″ N and 55°17′41.86″ - 61°11′03.83″ E. The whole area of Lut Desert is 197347 km^2 which covers about 12% of Iran's whole area. Lut Desert extends to parts of some four provinces of: Southern Khorasan, Yazd, Kerman, Sistan & Ballochestan. Based on

calculations using climate classifier software and based upon Coopen′s climate classification, Lut desert locates in two regions Bsh (semi desert zone) that mostly includes northern parts, and Bwh (desert zone) that mainly includes southern parts of Lut Desert. Considering the situation and topography, this area is divided into three major units; northern, central, and southern (Alaee 2002). Based upon on the analysis of height digital information and with reference to available contour lines on 1:250000 maps, the average height in Lut Desert is 1090m. Since this area benefits from special dominated climatic circumstances, it possesses special geographical landscapes that make it worth attending to. A somehow precise evaluation of changing temperature rate in this area is thought as essential in the fields of:

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* Corresponding author. Tel.: +98 21 61112938, 09123841192
E-mail address: ghazizi@ut.ac.ir

studying suitable climatic conditions for the regions residents, tourism, better and more efficient control of water resources, applying cumulative architectural principals for suitable residence as well as determining the agricultural products compatible with the climate in this region. Regarding the limitation in the number of meteorological stations, along with the high costs of collecting terrestrial information through point gathering method in the area, employing thermal bands of satellite images is a suitable and low-cost measure to collect temperature information from almost all zone surfaces.

So far, few surveys using the remote sensing technique, have been done through which, the temperature of land surface has been estimated. The researches made by J.E. Nickol (1998), Fered Prata (2000), Kim Morris et al, (2004), general statictics and agriculture organization (1996), Akbari (2000), Sabz Abadi (2006), Tavakkoli Saboor (2001), Alavi Panah et al (2002), Moofati (2003) and Seradjian (2004) can be referred to as some examples. But a research which seems to have a close relation to the subject matter of this study was done by Tawn Kumar Sen (2004) under the title of: "Identifying rain water source using some satellite sensors and technique of Geographic Information system" in which land surface temperature has been measured by using MODIS sensor images.

2. Materials and Methods

MODIS sensors images of TERRA's satellite with BIL format were used for estimating Lut Desert temperature. The reason for selection of this sensor was its high band penetration, having got six thermal band limitations, day to day images, include several locative powers, and suitability of pixel dimentions. Six path images of recorded information were employed here by MODIS sensor. In line with the research subject, the images were such tried as to select the first days in each season. Therefore, 28

MODIS sensor bands were used in June 24 (7:11), December 23 (6:35) 2002 as well as in January 22 (6:45), March 22 (6:27), June 22 (6:50), and September 24 (7:02) 2003. In addition to the above-mentioned images, topography maps of scale 1:250000 and entirely covered soil maps of scale 1:1000000 were employed. The technique of creating color images was chosen to recognize the cloudy spots and the surface soil material of Lut Desert. In order to determine the representative algorithm, the manner of relating surface data, attained from sensor with hourly recorded air temperatures at six meteorological stations (for calculating area air temperature from the recorded information at the meteorological stations) of Birjand synoptic, Khoor-e-Birjand, Tabas, Robat-Posht Badam, Shahdad, and Bam during the study days were used. All the research processes were performed in ILwis 3.2, Arcview 3.2, R2v, and Spss soft wars.

For a preparation of the primary information, from available received images (through use of 26 land control points and under geometric correction), the limit of Lut Desert was distinguished. It should be noted that the atmospheric corrective operations were not preformed on the images. For a determination of the radiance power and estimating the region surface temperature (by using the images obtained from bands combination), entire soil covering map (scale 1:1000000), the area topography map (scale 1:250000), the entirely covering geomorphology map (scale 1:250000) as well as results of available reports and researches were digitalized. So, a cover of the region dominative surface soil, classified within eight classes, along with radiance power related to each class were also extracted with respect to the type of the region soil and available resources. It should be mentioned that different radiance powers of wet soil was taken in to view for the salty and desert plots of the region. The rates of radiance power related to each temperature class have been presented in table (1).

Table 1. The rates of radiance power in different surface soils in Lut Desert (Alavipanah 1382)

Surface Soil Material	Briny Soil	Lime	Stone	Salt	Sand	Kalut	Humid clay	Crushed Stone
Diffusivity Coefficient	0.950	0.985	0.959	0.950	0.914	0.920	0.950	0.900

To identify the cloudy spots over heading the area and their masks, benefit was made a combination of different bands at several stays. In this article, energy balance algorithm for land surface (Sebal) was used for determining land surface temperature. Sebal algorithm is a multi-

stage surface energy algorithm, based on physical relations which uses surface temperature, surface reflection, normalized NDVI plant difference index, and their internal relations for estimating the surface fluxes for different earth surface covers. Sebal's essential

items change the reflective and dispatched energies, measured by satellite, to the surface energy balance and earth's humidity indexes. Presently, this model has been accepted by the UN and is being employed in different parts of the world (Bastiaanssea et al, 1988). According to this, an estimation of the air temperature is performed within two stages:

A) calculating the surfsce soil temprature: In this stage, firstly spectrum radiance for bands 31

and 32 that cover the spectrum limit from 10.78 to 12.27, was calculated by using the following relation: (Xi-Hangjie 2003)

L_λ=Scale-Radiance(SI-Offset-Radiance)   (1)

Where:

SI: stands for bright degrees of image pixels

Scale-Radiance and Offset-Radiance: are constant coefficients for bands 31 and 32, respectively. The rates of these coefficients $(W/M^2/Mm/st)$ are indicated in table (2).

Table 2. Coefficient Rates of Offset-scale, Radiance-scale in bands 31 and 32 on MODIS sensor

	Radiance_Scale	Offset _Scale
Band Number 31	0.00084002	1577.339722
Band Number 32	0.0007297	1658.221191

Then, Brightness temprature is calculated by using the reversed Planck relation (relation (2)) (Vidar, 1989):

$$D = \frac{K_2}{Ln\left[\dfrac{\varepsilon K_1}{C} + 1\right]} \qquad (2)$$

Where:

D: the Brightness temperature of each band

C: Planck's constant. K_1 and K_2 are constant coefficients for the studying bands. With regard to the fact that atmospheric temperature is less than that of the earth surface, the atmosphere absorbs it leading to a lower temperature sensed by the sensor.

Then the Brightness temperature got from relation (2) which is separately calculated for bands 31 and 32, should be less than that of the earth surface temperature which improves the atmospheric effect. Hence, the calculation of surface temperature has been done based on the relation used by Kumar-sen (2004).

$T=0.39D^2+2.34D-0.7DD_1-1.34D^2{}_1+0.56$ (3)

Where:

T: the earth surface temperature (Kelvin)

D: Brightness temperature of band 31

D_1: Brightness temperature of band 32

Finally, the resulted temperature is changed in to degrees centigrade and classified into eight temperature classes.

B) Air temprature calculation: For calculating the air tmprature in the area at different day and night hours, a correlation was initially established between surface temperatures obtained from images and recorded temperatures from meteorological stations (available in the region). Then, based upon the meaningful level of the resulted correlation coefficients, the representative algorithms (relationship between calculated surface temperatures and the hourly air temperatures of meteorological stations) were obtained.

Later, and based on the resulted algorithms, the hourly air temperatures of the whole Lut desert area were presented through temperature images.

3. Results

Using the available information the surface soil of the area was classified in to 8 major classes. Feature (1) shows the obtained surface soil map and table (3) shows the area that covers each class of available surface soil in the region.

The surface soil temperature in the whole region has been determined for all images, with the rate of the 6 images and a pattern of classified map from surface soil temperature presented in Featured (2). The minimum, maximum, mean, and standard deviations of resulted temperatures are presented in table (4).

In table (5), the geographic coordinates of the hottest and coldest pixels are presented. The distinguishing coefficients that show the degree of coordination among the temperatures during the studied days are given in table (6).

Table (7) reflects the minimum, maximum and different standard deviation rates within the intended days.

These are presented to demonstrate the temperature ranges at the first and beginning of each season. The rates of distinguishing coefficients between surface soil temperature and recorded air (through meteorology stations) were also determined, and presented in table (8). Based on the "t student" test, these coefficients are meaningful at a level of 0.001. Representing algorithms of relationship among these rates have been calculated and presented in table (9). Finally, hourly air temperature for the whole area of Lut Desert has been obtained by using the established algorithms. Feature (3) shows some examples of hourly air temperatures on some of the studied days.
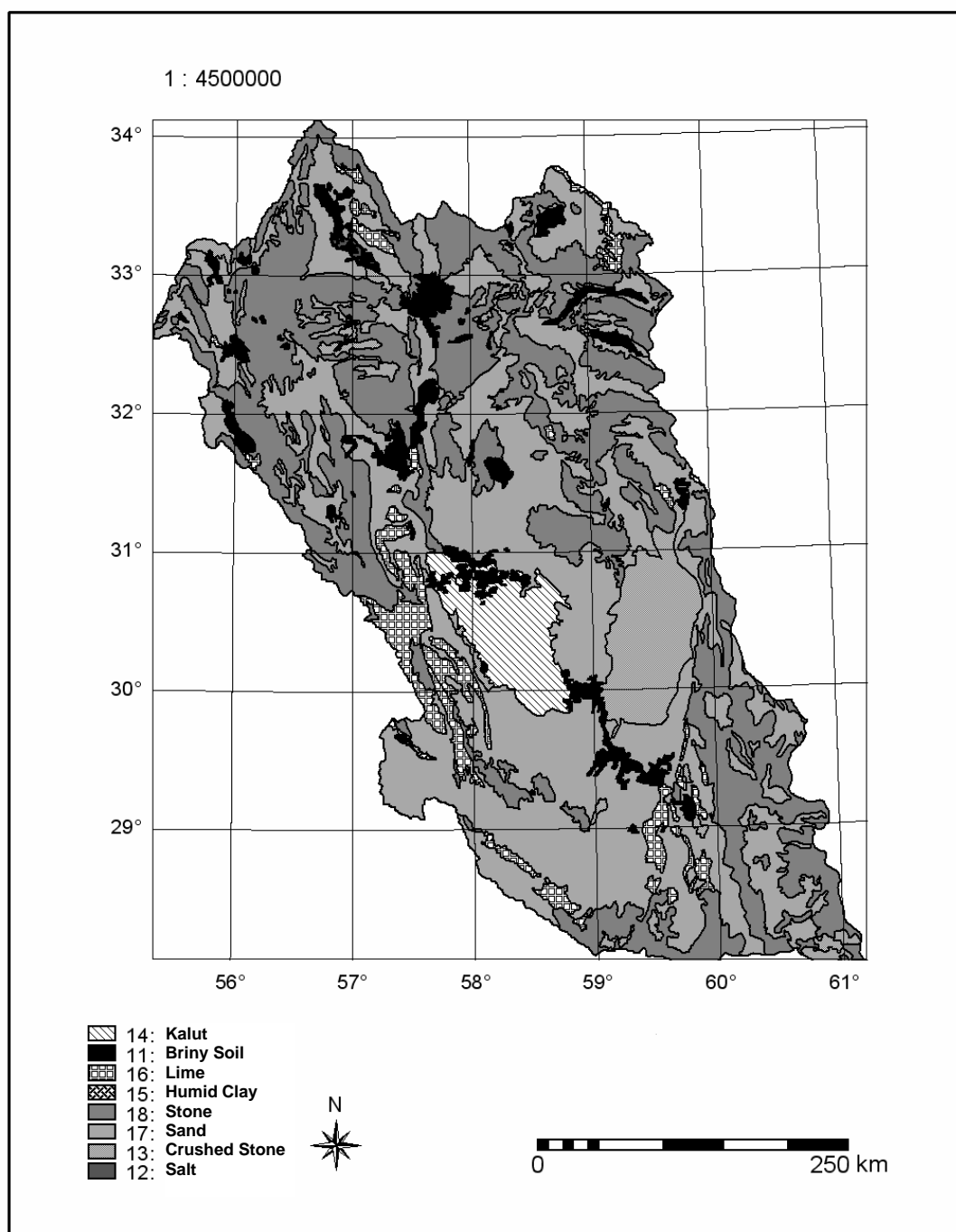
Fig. 1. Surface soil map of Lut Desert

Table 3. The area pertaining to each class of surface soil material in Lut Desert

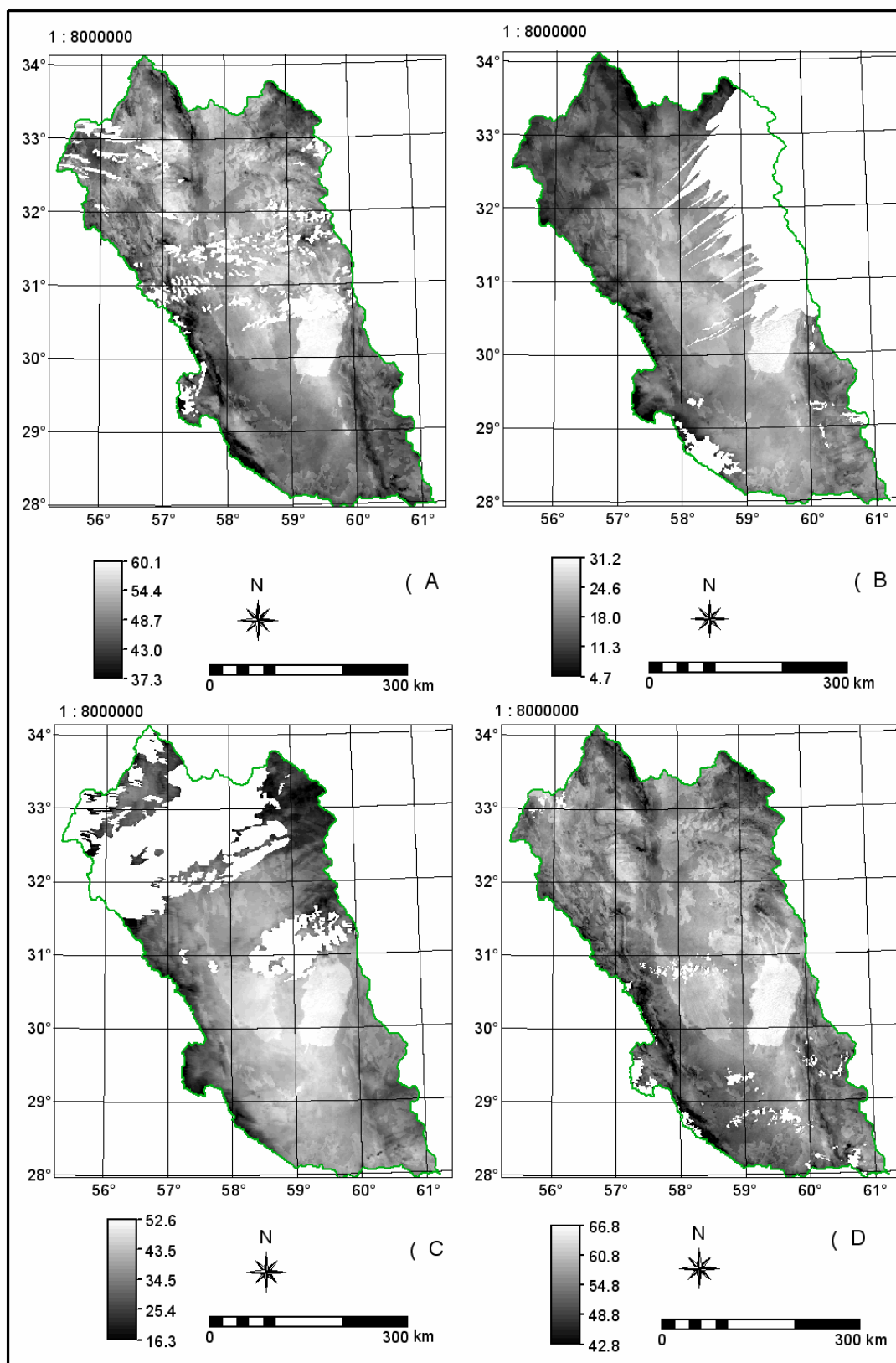| Area	Briny soil, Salt, Humid clay	Lime	Kalut	Stone	Sand	Crushed stone
(KM^2)	9076	9826	7510	89885	70157	10564

Fig. 2. Surface soil temperature in Lut Desert using Sebal algorithm on days (A) June 24th 2003, (B) December 23rd 2002, (C) March 23rd 2003, (D) June 22nd 2003

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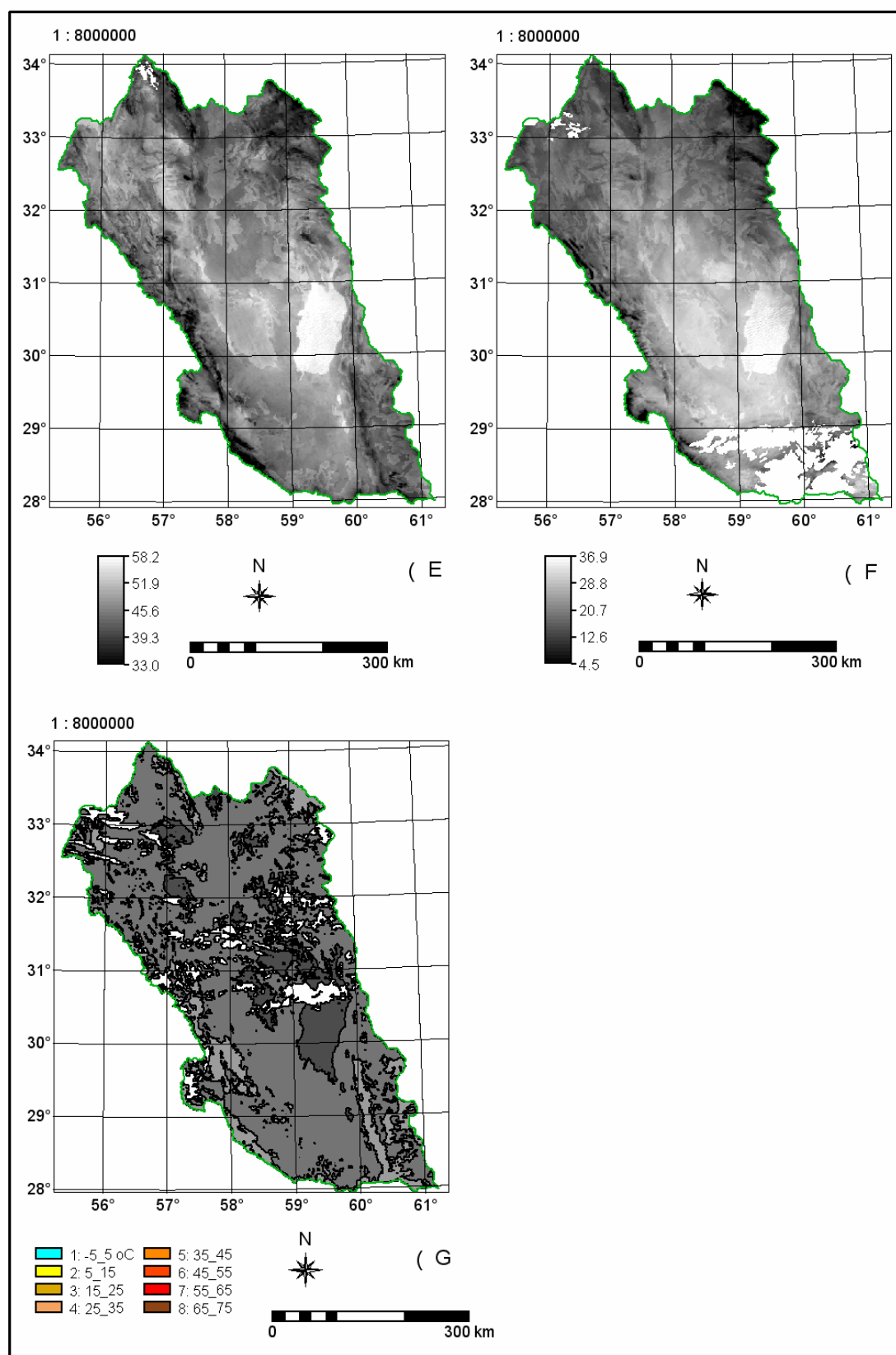*G. Azizi et al. / BIABAN 12 (2007) 7-15*

Fig. 2. (E) September 24th 2003, (F) an 22nd 2003 and also (G) classified surface soil temperature on June 24th 2002.

Table 4. Some statistical properties of temperature rates resulted from Sebal algorithem for the studied days

	LST 2002/6/24	LST 2002/12/23	LST 2003/1/22	LST 2003/3/22	LST 2003/6/22	LST 2003/9/24
Min	298	264/5	264/7	255	282/1	295/4
Max	339/5	308/6	314/5	329/2	344/1	335/5
Average	322/6	291/2	295	309/4	328/7	318/17
SD	4/7	5/3	6/9	8/7	4/8	4/9

Table 5. The geographic coordinates of the hottest and coldest pixels based on Sebal algorithm on studied days

	2002/6/24	2002/12/23	2003/1/22	2003/3/22	2003/6/22	2003/9/24
MIN	30 04 27 N	29 24 57 N	29 17 26 N	32 41 05 N	31 15 21 N	29 06 31 N
	57 31 57 E	57 13 13 E	57 14 26 E	55 38 57 E	56 28 05 E	57 24 54 E
MAX	30 37 56 N	30 19 44 N	30 23 43 N	29 59 02 N	30 42 59 N	30 24 17 N
	59 46 03 E	59 34 20 E	59 20 47 E	59 08 45 E	58 28 35 E	59 22 00 E

Table 6. Distinguishing coefficients among temperatures with the studied days

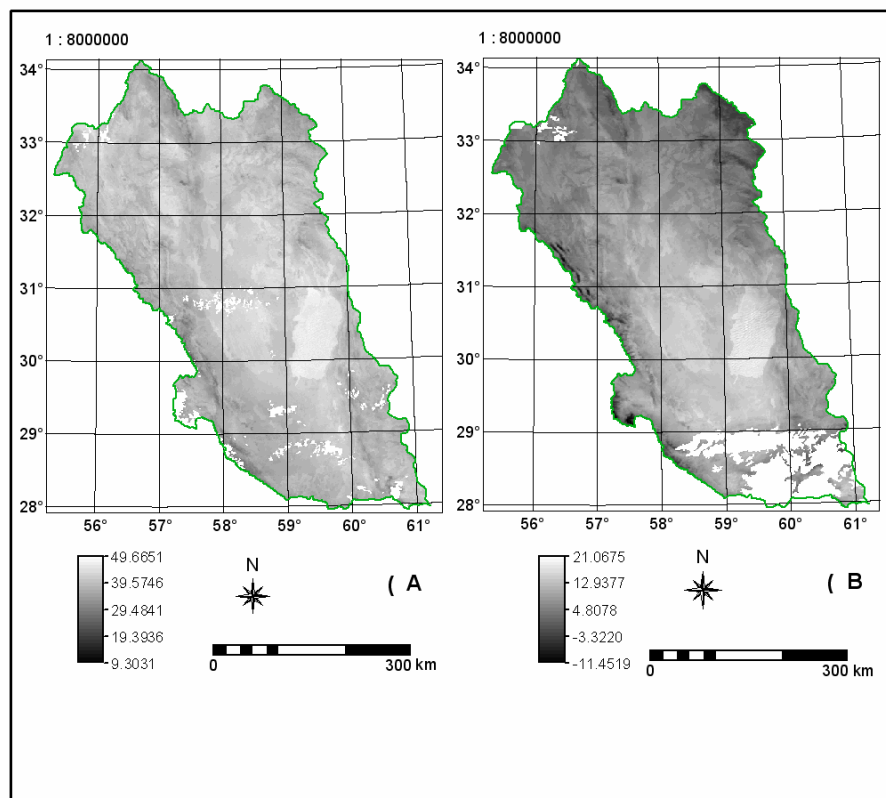|	T 2002/6/24	T2002/12/23	T 2003/1/22	T 2003/3/22	T 2003/6/22	T 2003/9/24
T 2002/6/24	1					
T2002/12/23	0/3136	1				
T 2003/1/22	0/2601	0/7056	1			
T 2003/3/22	0/25	0/5329	0/9409	1		
T2003/6/22	0/7056	0/3721	0/3364	0/3481	1	
T2003/9/24	0/6084	0/4624	0/5625	0/5476	0/7225	1

Fig. 3. Air temperature of Lut desert on days of 22 June at 12:00 Noon and 22 January at 03:00 AM in 2003

Table 7. Some statistical properties of temperature within the studied days (a) June 24th 2002, (b) December 23rd 2002, (c) March 22nd 2003, (d) June 22nd 2003,(e) September 24th 2003, January 22nd 2003

Subtracted images	Minimum difference	maximum difference	mean difference	standard deviation
a-b	13/7	50/7	31/2	4/6
a-c	-5/8	70/8	12/6	7/5
a-d	-29	34/6	-5/9	2/5
a-e	-16/5	21/4	4	3/1
a-f	6/1	57/8	27/9	6/2
b-a	-50/7	-13/7	-31/2	4/6
b-c	-34/7	32/3	-18/7	4/9
b-d	-58/6	6/3	-37/4	4/2
b-e	-44	-8/7	-27/7	3/7
b-f	-23/7	20/1	-4/9	3/6
c-a	-70/8	5/8	-12/6	7/5
c-b	-32/3	34/7	18/7	4/9
c-d	-74.5	25/2	-19	7/1
c-e	-64/6	6/5	-9/3	6/2
c-f	-32/9	36/3	13/1	4/3
d-a	-34/6	29	5/9	2.5
d-b	-6/3	58/6	37/4	4/2
d-c	-25/2	74/5	19	7/1
d-e	-31/9	22/9	9/9	2/6
d-f	-5/8	64/3	33/7	5/6
e-a	-21/4	16/1	-4	3/1
e-b	8/7	44	27/7	3/7
e-c	-6/5	64/6	9/3	6/2
e-d	-22/9	31/9	-9/9	2/6
e-f	4/4	51/7	23/7	4/7
f-a	-57/8	-6/1	-27/9	6/2
f-b	-20/1	23/7	4/9	3/6
f-c	-36/3	32/9	-13/1	4/3
f-d	-64/3	5/8	-33/7	5/6
f-e	-51/7	-4/4	-23/7	4/7

Table 8: Coefficients between calculated and recorded temperature at meteorological stations

R square	Time to Greenwich
0.720801	00:00
0.833569	03:00
0.87356	06:00
0.906304	09:00
0.891136	12:00
0.891136	15:00
0.824464	18:00
0.795664	21:00

Table 9: Liner relations between resulted temperatures (from satellite path available images) and recorded temperatures meteorological stations

Obtained Algorithm	Time to Greenwich
y=-2.562+0.579x	00:00
y=-6.032+0.653x	03:00
y=-2.002+0.672x	06:00
y=1.622+0.670x	09:00
y=3.379+0.651x	12:00
y=-0.819+0.709x	15:00
y=-1.865+0.654x	18:00
y=-2.877+0.616x	21:00

4. Conclusion

According to the results obtained from application of Sebal algorithm and obtained temperatures in the area, the highest calculated surface soil temperature, in the six available images was 71.1 °C as related to June 22nd 2003 and the lowest was −18 °C related to March 22nd 2003. The mean surface temperature for June 24th, December 23rd 2002, January 22nd, March 22nd, June 22nd, and December 24th 2003 were 2.6, 18.46, 22, 36.4, 55.7 and 45.3°C, respectively. The minimum surface soil temperature obtained for the mentioned days were 25, 8.5, 18.3, -8, 9.1 and 22.4°C respectively. The maximum surface soil temperatures that were obtained from images on the above mentioned days were 66.5, 35.6, 41.5,

5602, 71.1 and 62.5 ˚C, respectively. The mean difference between maximum temperatures according to images of the mentioned days was found out to be 1.5, 44.41, 49.8, 74.2, 62, and 40.1 C˚, respectively. The highest number of pixels in the images of the above-mentioned days were located at the temperature classes of 45-55 ˚C, 15-25 ˚C, 15-25 ˚C, 55-65 ˚C, 15-25 ˚C, respectively. The maximum difference between calculated temperatures from Sebal algorithm and on different day's states that the maximum difference among similar pixels of temperature was 74.65 ˚C in the six studied images. These are related to the temperature difference of the two similar pixels on June 22nd 2003 and March 22nd 2003. The minimum temperature difference between the same pixels in the six above-mentioned images are related to temperature differences between two similar pixels, related to January 22nd 2003 and June 22nd 2003, the difference being 5.8˚C. A determination of the relationship between surface soil temperature and hourly air temperature at meteorological stations prove that the highest determinant coefficient among calculated temperatures of the six studied images and the recorded temperatures at meteorological stations were: 09:00 (R^2=0.9), 12:00 (R^2=0.89), 15:00 (R^2=0.89), 06:00 (R^2=0.87), 03:00 (R^2=0.83), 18:00 (R^2=0.92), 21:00 (R^2=0.80), and 00:00 (R^2=0.72) according to Grinwich mean time. The closest available correlation was found to be at 09:00 o'clock, the reason for which could be the high time lapse between changing air and land surface temperatures.

When the recorded temperatures at meteorological stations are compared with the calculated temperatures, it becomes evident that use of MODIS sensor images and Sebal algorithm provide reasonable results for finding temperature in an area. Therefore the use of these images seems to be applicable for finding the needed information about the other places temperatures. In this research, because of a lack of coincidence in the studied images the resulted coordination as compared with actual coordination rates were low, resulting algorithms of low accuracy. Also, the errors resulting from the non-correspondence of the location of separative power in reflexive and thermal bands, geometry corrections, a lack of calibration of Sebal parameters in the studied regoin and no assurance of correction of the employed meteorological data also should be taken in to consideration. Employing a larger number and more update images with high location separative power, exact field measuring

for determining the exact type of surface soil in the region, exact geometric correction of images and calculating the radiance powers of different region surface soil materials, especially at salty-flats and desert regions can present the thermal and climatic features of the zone in a more exact and acceptable manner.

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