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Estimation of Urban Surface Emissivity Based on Sub-Pixel Classification of Landsat8 Imagery

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Abstract: *Information about the spatial distribution of urban surface emissivity is essential for surface temperature estimation. The latter is critical in many applications, such as estimation of surface sensible and latent heat fluxes, energy budget, urban canopy modeling, bio-climatic studies and urban planning. This study proposes an estimation of urban surface emissivity, which is primarily based on spectral mixture analysis. The urban surface is assumed to consist of three fundamental land cover components, namely vegetation, impervious and soil that refer to the urban environment. Due to the complexity of the urban environment, the impervious component is further divided into two land cover components: high-albedo and low-albedo impervious. Emissivity values are assigned to each component based on emissivity distributions derived from the landsat8. Following the proposed method, by combining the fraction of each cover component with a respective emissivity value, an overall emissivity for a given pixel is estimated. The methodology is applicable to visible and near infrared satellite imagery. Therefore it could be used to derive emissivity maps from most multispectral satellite sensors. The proposed approach was applied to landsat8 multispectral data for the city of Darkhan-Uul, Mongolia. Emissivity, as well as land surface temperature maps in the spectral region of 10.6 - 11.2 μm (landsat8 band 10) and 11.5-12.5 (landsat8 band 11) were derived.*

Keywords:*Emissivity, urban, Landsat8*

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I. Introduction

Land surface temperature (LST) is key parameter for understanding the energy and hydrological balance in the ground surface –atmosphere system. Thermal infrared remote sensing provides a unique tool for estimating LST in large areas. The present study focuses on the problem of determining emissivity and land surface temperature from Landsat 8 data. The Landsat 8 channels 10 and 11 (10.6–11.2 mm and 11.5–12.5 mm) are used widely for deriving surface temperature for daytime passes. The temperature derived from channels 10 and 11 are slightly different due to atmospheric water vapor absorption. An approach based on the differential absorption in two adjacent infrared channels, called the 'split-window' technique, is used for determination of surface temperature. A further complication arises because the land surface, in general, does not behave as a perfect emitter of infrared radiation and presents a high variability. A variety of LST algorithms have been developed to solve these problems. Different authors (3, 8) proved that the inclusion of the total water vapor in the algorithm to allow for atmospheric variability permits the elimination of a significant quantity of error in the retrieval of sea surface temperature (SST). Several techniques have been proposed to derive the precipitable water and the channel transmittance ratio from split window channels (2, 7, 5, 4, 6, and 9). However, these techniques have been limited to SST and are strongly dependent on the atmospheric situations considered. Recently Sobrino et al. (8) have proposed an improved technique based on the Klesspies and McMillin approach. In this work, an attempt has been made to. Additionally the study area has low atmospheric water vapor content and low probability of cloudiness.

II. The Study Area And Data

In this study include Ulaanbaatar city region of Mongolia. The range of this study area is considered on (Figure 1). The most popular split window algorithm is used for improved estimation of LST and emissivity. The satellite data was brightness temperature channel 10 and 11 of the Landsat8 for the 18 June, 2015.

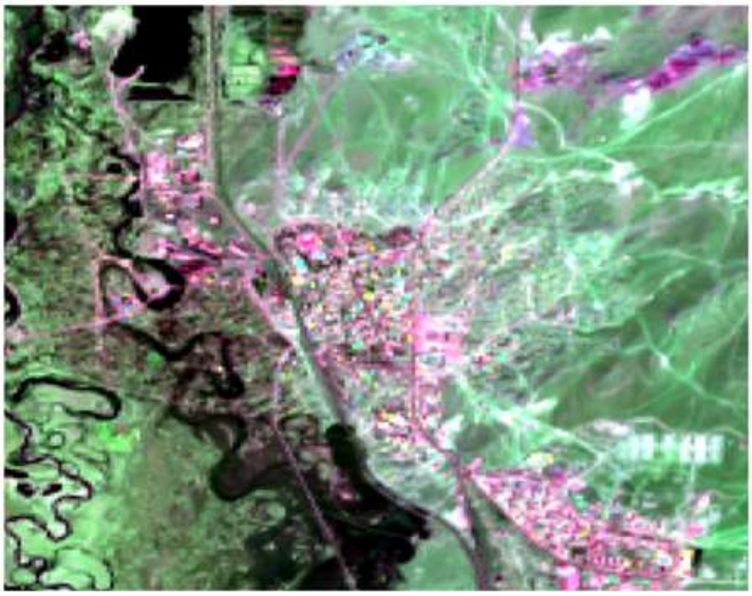

Figure1.The study area (region of Darkhan city)

III. Method

3.1 Thermal emissivity and NDVI

The influence of water content on the emissivity of natural surfaces is largely explained by the high absorptivity of water in the thermal region. The NDVI measurements were made with a combined red and near-infrared radiometer, developed at the NASA/Goddard Space Flight Center, which measures the reflected radiation in the bands (0.58-0.68 μm) and (0.73-1.1μm). NDVI= (NIR-RED)/ (NIR+RED) (1)

Where NIR and RED are the near-infrared and red reflectances, respectively. The emissivity used in split-window algorithm is a critical parameter for the accuracy of LST. NDVI values indicating the density of vegetation can be used as a proxy indicator for estimating emissivity. In this study, emissivity was estimated via an empirical algorithm based on the relationship between emissivity and the logarithm of NDVI (10) in the range [0.955, 0.985]. The emissivity of channel 10, $\varepsilon 4$, and the emissivity difference of channels 10 and 11, $\varepsilon 4 - \varepsilon 5$ ($\Delta\varepsilon$), are as follows:

$\varepsilon 4 = 0.9897 + 0.029 \ln(NDVI)$ (2)

and

$\Delta\varepsilon = 0.01019 + 0.01344 \ln(NDVI)$ (3)

3.2 Split-window algorithm for LST

General form of split-window algorithm

If T10 and T11 are respectively the brightness temperatures in channels 10 and 11 of Landsat8 data, the general form of the split-window equation can be written as:

$LST = T10 + A\,(T10 - T11) + B$ (4)

Where LST represents the land surface temperature, A and B are the coefficients determined by the impact of atmospheric conditions and other related factors on the thermal spectral radiance and its transmission in channels 4 and 5.Using the parameters A0, P and M given by Becker and Li (1), Sobrino and Li (8) proposed a simplified algorithm with the two coefficients A and B as:

$A = (M - P)/2$ (5)

and

$B = A0 + T4\,(P-1)$ (6)

Where the parameters A0, P and M have been calculated by Becker and Li (1) as:

$A0 = 1.274$

$P = 1 + 0.15616(1-\varepsilon)/\varepsilon - 0.482\,\Delta\varepsilon/\varepsilon$ (7)

and

$M = 6.26 + 3.98(1-\varepsilon)/\varepsilon + 38.33\,\Delta\varepsilon/\varepsilon$ (8)

in which $\varepsilon = (\varepsilon 10 + \varepsilon 11)/2$ and $\Delta\varepsilon = \varepsilon 10 - \varepsilon 11$. From equations (5)-(8), we can see that the important coefficients A and B in the algorithm are directly expressed as the functions of surface emissivity in channels 10 and 11. It seems that the effects of atmospheric conditions are expressed as constants. We found A=2.41 and B=1.33 using above mentioned method. Thus equation (4) for Mongolian soil surface becomes following as:

LST =T4+2.41(T4 - T5) +1.33   (9)

This equation (9), termed the simple modified LST method for Mongolian soil surface.

IV. Result AndDiscussion

The results of above mentioned a modified split window algorithm was carried out by emissivity and NDVI empiricalalgorithmbased on the relationshipbetweenemissivity and the logarithmofNDVI. The estimated LST values 23-35^{o}C in the river and forestmountain area, 35-50^{o}C was in the Darkhan city and steppe area on Figure 2.

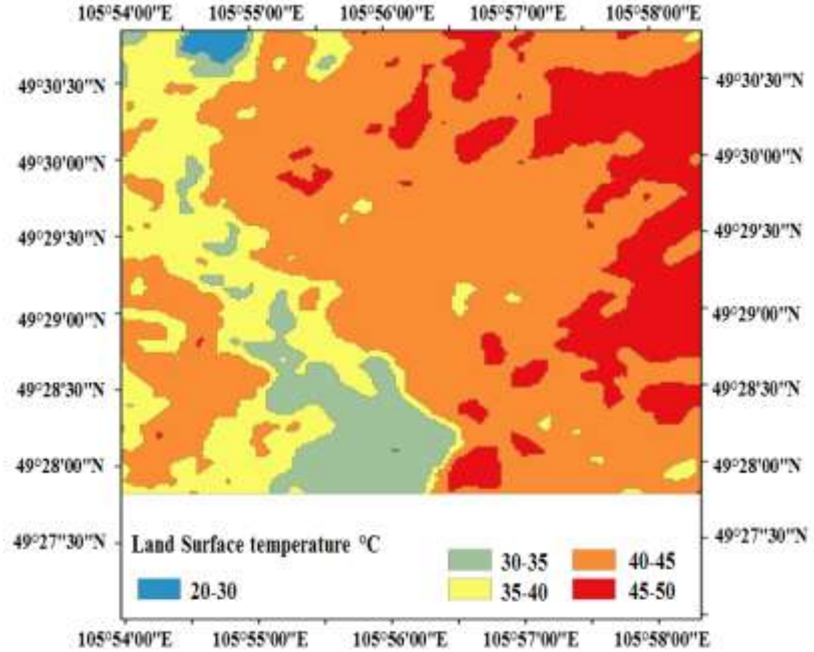

Figure 2. The Land Surface Temperature 18 June, 2015 Region of Darkhan city

The flowing field of Kharaa River over the land of Darkhan town is parallel to low temperature of the air (Celcius) also it is deeper than the level of the river in such temperature as more then 1.5 meter. At highest temperature, at 45-55 ºC, the plant is overgrown8 and the sandy desert soil overlaps.

V. Conclusion

The split window algorithms have been analyzed to find an optimal algorithm for estimating surface temperatures from thermal bands of Landsat8 data in Darkhan-Uul city region. In this study we have shown that the surface temperature can be expressed as a linear combination of the channel brightness temperatures in two adjacent channels- the coefficients of this relationship depending only on emissivities, not on the particular atmospheric characteristics. Errors in the assumed emissivities can lead to errors in the land surface temperature, but these errors are much less important than they would be without this first-order emissivity correction. The coefficients derived in this paper and displayed in equations (5)-(8) may certainly be improved when actual data is available which not a simple matter is.

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