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Short Communication

Derivation of land surface temperature using satellite imagery and its relationship with vegetation index

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Land surface temperature (LST) is one of the important parameters in the physics of land-surface processes, energy balance, studies of global change and heat balance, climate change, estimation of evapotranspiration using remote sensing (Reginato *et al.,* 1985; Rivas and Caselles, 2004).As the amount of vegetation cover increases, the radiative temperature recorded by a sensor approximates more closely to the temperatures of green leaves, and the canopy temperature at spectral vegetation maximum or complete canopy cover (Weng and Lu, 2008; Parmar and Gontia, 2016). LST is also a function of varying surface soil water content and vegetation cover (Owen *et al.,* 1998). The spatial and temporal distribution of LSTs from remote sensing imagery can be used to support the water resource management and agriculture related studies with limited land based meteorological data. LST derived from remote sensing imagery can be used to discriminate senescent vegetation (French *et al.,* 2000), land use/land cover (LULC) analysis and vegetation index-LST relationship. Shah *et al.* (2012) derived the minimum and maximum air temperatures using land surface temperature (Ts) and normalized differential vegetation index (NDVI) products from the moderate resolution imaging spectroradiometer (MODIS) sensor and compared with air temperature data from automatic weather stations over Gujarat region of India. The estimated minimum temperature using MODIS data showed good agreement with the measured values. The objectives of this research were to estimate LST using Landsat imagery and to analyse its relationship with vegetation index.

The study area comprises the canal command area of Ozat-II dam across river Ozatin Junagadh district, Gujarat. The location of the command area lies between latitude 21^{0}12’46"N to 21^{0}33’04"N and longitude 70^{0}25’07"E to 70^{0}53’24"E. The canal system comprises of 20.6 km long main canal.The daily temperature data were collected from the Agrometeorology Cell, Junagadh Agricultural University, Junagadh. The satellite images of Landsat 8 Operational Land Imager (OLI) of date of pass 25 March 2014(LC81500452014084LGN00) was downloaded from Earth Explorer www.earthexplorer.usgs.gov (U.S. Geological Survey, 2015a).Geomatica V10.0, ArcGIS 10.3 and GRASS GIS7.0.1 were used forimage processing, image correction, clipping of area of interest, preparation of vegetation index and estimation of LST, etc.

Estimation of brightness temperature (T_B) LSE, LST and NDVI

The different bands of the image were converted to at-sensor reflectance using reflectance rescaling coefficients provided in the Landsat-8 OLI metadata file usingGRASS GIS7.0.1 software. The methodology as per U.S. Geological Survey (2015b) was adopted to convert digital number (DN) values to top of atmosphere reflectance for OLI image.The brightness temperature(T_B in Kelvin) was estimated using following equation.

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda}+1\right)} \quad (1)$$

Where,

K_1 = Thermal constant of bands from metadata image file (774.89 for Band-10, 480.49 for Band-11, K_2 = Thermal constant of bands from metadata image file (1321.08 for Band-10, 1201.14 for Band-11), L_λ = Top of atmospheric spectral radiance layer (Watts m² sr µm).

The land surface emissivity (LSE)of the study area was estimated using normalized difference vegetation index (NDVI) threshold method for both bands of Landsat-8 i.e. 10 and 11.

$$LSE = \varepsilon s(1\text{-}FVC)+\varepsilon v \times FVC \quad (2)$$

Where, εs= soil emissivity values (0.971 for Band-10, 0.977 for Band-11) and *εv*= vegetative emissivity values (0.987 for Band-10, 0.989 for Band-11) of the corresponding bands (Skokovic *et al.*, 2014). The fractional vegetation cover (FVC) was estimated for the image using NDVI (soil) and NDVI (vegetation). The NDVI was calculated as,

Table: 1: Landsat derived NDVI, FVC, LST and LSE values of selected locations in canal command.

Location	NDVI	FVC	LST	LSE
70.522 E 21.375 N	0.658	0.732	40.7	0.984
70.477 E 21.396 N	0.613	0.667	36.3	0.983
70.467 E 21.370 N	0.623	0.681	35.3	0.983
70.519 E 21.390N	0.764	0.887	34.0	0.986
70.521 E 21.395 N	0.593	0.638	33.8	0.982
70.573 E 21.382 N	0.696	0.788	33.2	0.985
70.542 E 21.383 N	0.227	0.106	36.1	0.975
70.513 E 21.378 N	0.161	0.068	35.9	0.974
70.481 E 21.370 N	0.208	0.078	35.6	0.975
70.472 E 21.394 N	0.310	0.226	37.5	0.977
70.486 E 21.375 N	0.365	0.305	38.1	0.978
70.499 E 21.379 N	0.257	0.149	38.6	0.976
70.535 E 21.386 N	0.368	0.311	36.7	0.978
70.521 E 21.378 N	0.346	0.278	37.5	0.977
70.556 E 21.380 N	0.387	0.338	36.9	0.978
Average	0.438	0.417	36.4	0.980

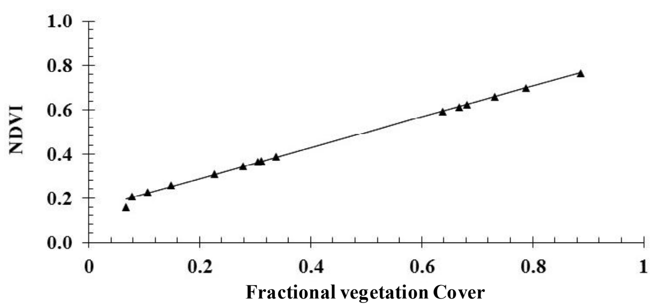

Fig.1: Relationship between remote sensing based fractional vegetation cover with NDVI

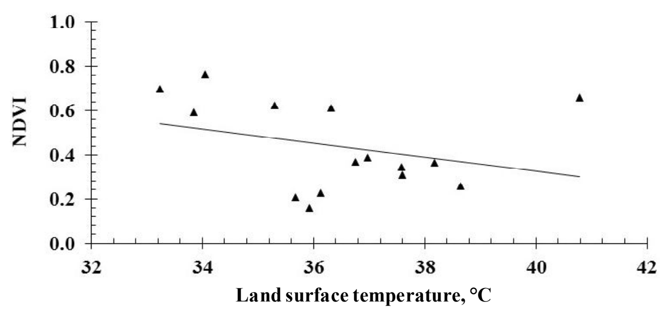

Fig.2: Relationship between remote sensing based LST (^{0}C) with NDVI

$$NDVI = \frac{NIR\ (Band-5) - R(Band-4)}{NIR\ (Band-5) + R\ (Band-4)} \quad (3)$$

Where,NIR is the spectral reflectance of the vegetated land surface in the near infrared (NIR) (Band 5) and R is red (Band 4) band.

The land surface temperature (LST) was estimated by applying a structured mathematical algorithm viz., Split-Window (SW) algorithm using brightness temperature of two bands of TIR, mean and difference in land surface emissivity.The LSEs estimated for bands 10 and 11 were used to find out the mean and difference of LSEs. The coefficient values (Skokovic *et al.*, 2014) were used to calculate LST as per the brightness temperature of band 10 and band 11 using LSE.

The spectral reflectance of the vegetated land surface in the near infrared (NIR) (Band 5) and red (Band 4)Landsat 8 bands were used to estimate the NDVI and NDVI map was generated. The NDVI values at 15 selected were found to range between 0.16 and 0.764 (Table 1). Using the NDVI, the reclassified NDVI (soil) and NDVI (vegetation) were used to calculate the fractional vegetation cover (FVC). The values of FVC were ranged from 0.068 to 0.887 with average value of 0.417 for the selected locations in the command area. The soil and vegetative emissivity values were 0.971 and 0.987 respectively of band-10 and 0.977 and 0.986 respectively of band-11 as per the metadata of Landsat-8 image.The calculated mean values of LSE of band 10 and 11 were ranged between 0.974 and 0.986 over the canal command area (Table 1).The LST values for the selected locations in the command area were ranged from 33.2^{0}C to 40.7^{0}C with the average value as 36.4^{0}C.

The temperature in village settlement, road, barren land and exposed dry soil was ranged from 38.4^{0}C to 41.8^{0}C. The lower range of temperature was found varying from 33.4^{0}C to 40.8^{0}C in the agricultural cropped area near the bank of the Ozat river in the North-East part of the canal command, where the NDVI values were high as 0.55 to 0.84. The relationship between the fraction vegetation cover (FVC) and NDVI and the trend was found positive (Fig. 1), whereas Fig. 2 shows the relationship between the LST (^{0}C) and NDVI was negative trend.

On the date of pass of the Landsat satellite (25th March 2014, DOY:84), the measured maximum soil temperature at depth of 5 cm was 44.2^{0}C, while the LST estimated from the satellite image using the split-window method was 41.8^{0}C, which show under estimation. The difference between the estimated LST values and the measured air temperature values can be associated partly with the effects of surface roughness on surface temperature and emissivity not considered (Weng, 2001).Shah *et al.* (2012) estimated the maximum air temperature using MODIS data over Gujarat and showed a good retrieval accuracy. Thus the satellite imagery can be effectively used to retrieve LST maps for large areas.

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