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# Irrigated Cropland Identification using Remote Sensing in India

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**Abstract**

The present paper has been carried out for estimating the irrigated area from the Landsat-8 satellite data in Hamirpur district of Uttar Pradesh. In this study, Normalized Difference Vegetation Index (NDVI) and LST based algorithm had been used to retrieving the irrigated area. Conversion of the TIR band into temperature (Ts) for both spring and summer time images according to Chander et al. (2003). The NDVI was carried out in the spring and summer time of the year after that differencing and thresholding method was applied on the NDVI of spring and summer images to separate the significantly changed areas. In the identified significantly changed area (crop Area), a logical expression (NDVI ≥ 0.30) AND (T≤ 293°K) was applied on NDVI and LST images to differentiate the irrigated cropland areas of the non irrigated croplands. We have cross checked the estimated irrigated area with district irrigation department data and found 98% accuracy.



**Keywords**: *NDVI, LST, Brightness Temperature; LSE, FVC, Landsat.*

## 1. Introduction

The world's population is increasing speedily and agricultural food production must increase to keep up with the continuously growing demand (1). Agriculture is the world's largest water-use sector and has strong influence on the water cycle, mostly in arid and sub-arid regions through the extraction of water from below ground and diversion of surface water(1). Water appear abundant on our planet; however, less than 1% of the world's freshwater is available for human use and about 70 percent of it is used for irrigation of agriculture(2). Different studies have shown the usefulness of satellite remote sensing data for producing the information on total irrigated area and area under different crops (3), (4) condition of crops (5), (6)and crop production (7), (8), (9). Present days the most popular

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approaches are differencing techniques on multispectral bands or a kind of vegetation indices such as simple ratio(SR), NDVI (Normalized Difference Vegetation Index), NDWI (Normalized Difference Wetness Index),Green Vegetation Index or on the Principal Components (10), (11), (12), (13), (14), (15), (16). Toomanian have explored the possibility to estimate the irrigated area by using Landsat images to NOAA AVHRR NDVI images(17).

Remotely sensed data are suitable to judge large areas, and considerable effort has been built to characterize vegetation using satellite data. Basic relationships exist between spectral reflectance and vegetative characteristics. These relationships permit the use of spectral transforms to define biophysical parameters for plants. The normalized difference vegetation index has been shown to be associated to plant canopy variables, which also relate to ET(18), (19) & (20), (21).

The present research has focused to unfold the relationships among the soil moisture, surface temperature (ST ) and vegetation indices (e.g., ST/NDVI) using remote sensing data. One of the utmost important land environmental variables, relative to climatology, hydrology, and ecology, is soil moisture(22). Samuel N. Gowarda revealed that Ts declines with the enlarge in soil moisture and is negatively correlated with NDVI(23).

Land surface temperature (LST) and surface emissivity are key variables for explaining the biophysical processes which govern the balances of land surface water and energy. Knowledge of how the fluxes of energy and water vary at the local and regional scale supply boundary conditions for models of atmospheric movement and water movement in the soils (29). Once Vidal have used the thermal band (TIR) of AVHRR data to investigate the water balance in the irrigated land(30). Based on Vidal and Perrier (1990), it is concluded that land surface temperature (ST) could really be a promising indicator of irrigation.

Ts in the irrigated areas is generally much lower than in rainfed areas because of their higher moisture content, but the NDVI is greater than in rainfed areas. Integration of LST & NDVI would therefore be a excellent tool for identification of irrigated areas. After all, it was also observed that forests, have the same ST range as the irrigated agriculture land in the spring image. It was therefore necessary to cut apart forest and grassland from the irrigated lands by a differencing and thresholding method using both spring and summer time images, since forest, grassland and permanent trees are evergreen in both season of the year without any significant phenological change.

district is about 4,121.9 km2.

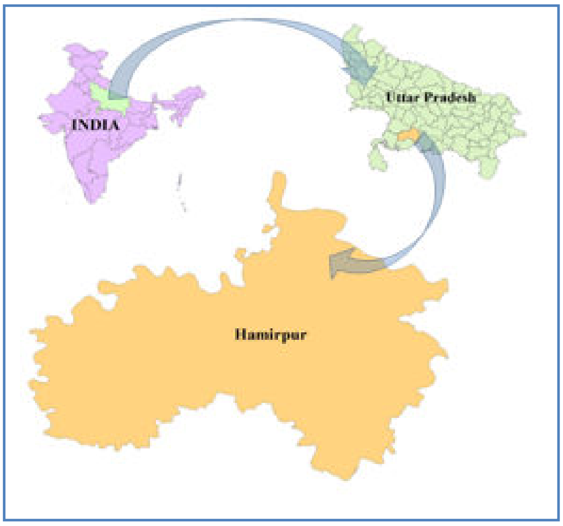


Figure 1: Location Map of the Study Area.

## 2. Data & Methods

### 2.1 Study Area:

Hamirpur is located at 25.95°N latitude and 80.15°E longitude. It has an average elevation of 80 metres. The district is bounded by districts Jalaun , Kanpur and Fatehpur in the North, Banda in the East, Mahoba in South and Districts of Jhansi and Jalaun on the West. As per 2001 census, the district has a population of 1043724. It has 4 tehsils,7 blocks and 647 villages. Average maximum and minimum temperatures are 43.0o C and 3.0o C respectively. Total area covered by Hamirpur

### 2.2 Data Used

The Landsat Satellite imagery December & May 2014 (Landsat-8 OLI_TIRS) were used in present study area. The detail of the satellite images is given below:

Satellite digital data: Landsat - 8
Bands : Red, Near Infrared (NIR)
Spatial resolution : 30m
Software Used: QGIS, Microsoft Excel

### 2.3Methodology

In this study for calculation of NDVI images, Landsat-8 satellite image acquired from earth explorer. The images were corrected to detach atmospheric effects and were then re-sampled to a 30-m pixel size using the nearest neighbor method. Conversion of the thermal band into temperature (ST) for both spring and summer images according to Chander et al. (2003); The NDVI was carried out for spring and summer time of the year after that Differencing and thresholding method was applied on the NDVI of spring and summer images to separate the significantly changed areas (for example, irrigated land and rainfed cropland where ΔNDVI > 0.1) from the non-significant phenological change land cover such as forests, grassland, or permanent tree crops and water (e.g.ΔNDVI < 0.1).

A preliminary assessment in the study area specify that LST in the irrigated areas is generally 2-4°K lower than in rainfed areas because of their higher moisture, since the NDVI is greater than in rainfed areas in the same climate condition (24).

In the identified significantly changed area, a logical expression (NDVI ≥ 0.30) AND (T≤ 293°K) was applied on NDVI and LST images to differentiate the irrigated cropland areas from the non irrigated croplands. The thresholds of NDVI and LST may be slightly different from scene to scene and from spring to summer time.

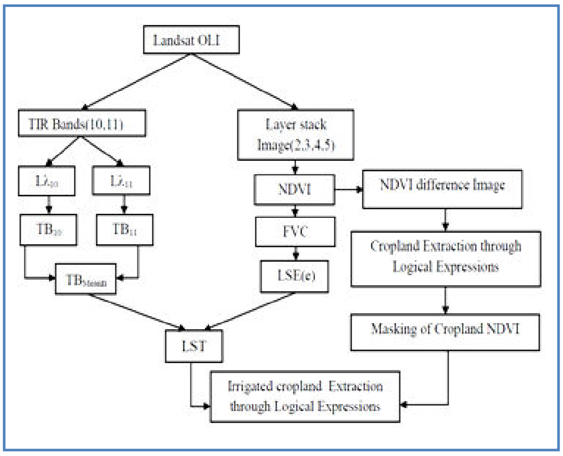


Figure 2**:** Flow chart of methodology.

### 3. Results and Discussion

Our results indicate that the irrigated area in the winter season in Hamirpur District is about 91441.98hectares in 2014.Total Agriculture area (Irrigated and Rain-fed) reported in 2014 is 324935 hectares so that only 28.14 % agricultural area is irrigated. Canals are the main source of irrigation and are constructed by the different rivers like Yamuna, Betwa, Dashan, Barma, Ken, Chandrawal and Pandwaha. Figure.3 shows the spatial distribution of irrigation area in the Hamirpur District. More intensive irrigation can be observed in the southern part of the area, the east and west part of the area showed moderately irrigated and most of the central part is rain-fed area. We have cross checked the estimated irrigated area with District irrigation department data and found 98% accuracy(Sankhikiya Patrika, Hamirpur 2014). Field verification is needed for improving the accuracy of irrigated area and cross checking the results , but this part is not carried out in the study area due to lack of resources.

Table 1: Comparison of Remote sensing & Govt. data.

| District | Irrigated area from Remote Sensing (ha) | Irrigated area from Govt. Statistics( ha ) | Difference (%) |
|---|---|---|---|
| Hamirpur | 91441.98 | 93302 | 1.99 |

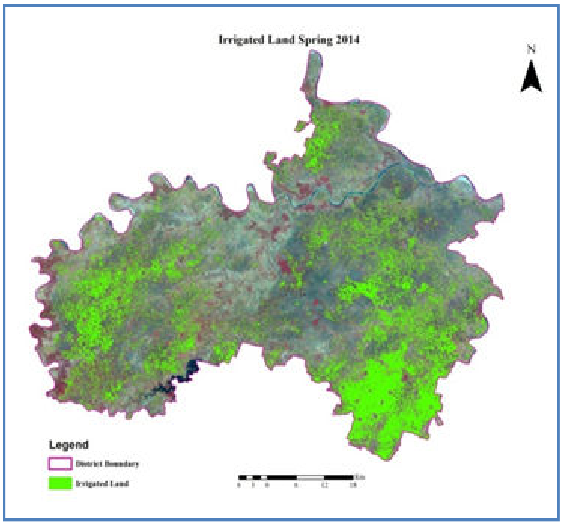


Figure 3: Distribution of spring irrigated cropland in the study area.

**3.1 Retrieval of Land Surface Temperature-**The brightness temperatures(TB) from OLI thermal band (10&11) were averaged then used to calculate the land surface temperature using the Sobrino equation(25).Land Surface temperature in present study area ranges 281.780K to 294.990K in the month of December and 301.700K to 3230K in the month of May.

$$LST = TB / 1 + (\lambda * TB / \rho) * Ln(\varepsilon) \quad (i)$$

Where,

$\rho = h \times c/\sigma$ {1.438 ×10-2 m K}

$\lambda$= wavelength of emitted radiance ( = 11.5 µm)

$\sigma$ = Boltzman universal constant (1.38 ×10-23 J/K)

h = Planck universal constant (6.626×10-34 J s)

c = velocity of light (2.998 ×108 m/s)

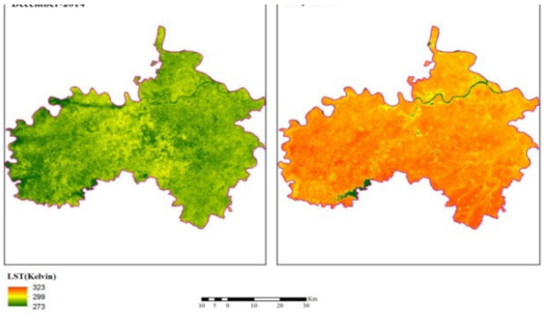


Figure 4**:** Land Surface Temperature of the study area.

**3.1.1 Brightness temperature(TB)-** Brightness temperature is the microwave radiation radiance traveling upward from the top of Earth's atmosphere. Calibration process has been done for converting thermal DN values of thermal bands of TIR to TB. For finding brightness temperature of an area the Top of Atmospheric (TOA) spectral radiance of (Lλ) was needed. TB for both the TIRs bands was calculated by using the following formula.(26)

$$TB = K_2 / \ln((K_1 / L_\lambda) + 1) \quad (ii)$$

Where,

$K_1$ and $K_2$ are thermal conversion constant and it differ for both TIR bands (table 2)

Lλ – Top of Atmospheric spectral radiance.

The value of Top of Atmospheric spectral radiance ($L_\lambda$) was determined by multiplying $M_L$factor of TIR bands with its corresponding thermal infrared band and adding additive rescaling factor with it(27).

$$L_\lambda = M_L * Q_{cal} + A_L \quad (iii)$$

Where,

$L_\lambda$ - Top of Atmospheric Radiance in watts/ ($m^2$*srad*µm)

$M_L$-Band specific multiplicative rescaling factor (radiance_mult_band_10/11)

$Q_{cal}$ - for band 10/ 11 image.

$A_L$ - Band specific additive rescaling factor

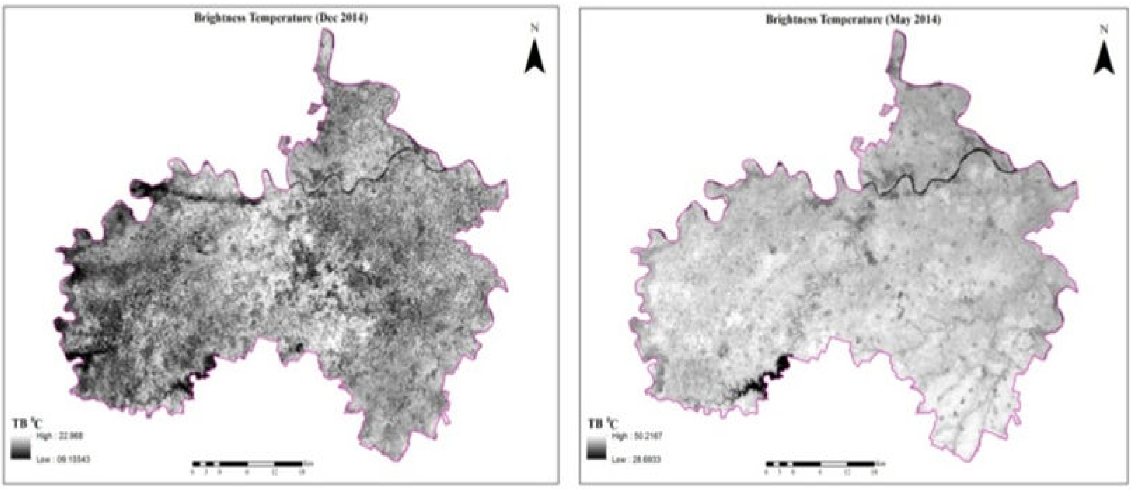


Figure 5: Distribution of spring irrigated cropland in the study area.

**3.1.2 Land surface emissivity:** It is necessary to be calculate the LSE of the region to find out Land surface temperature . LSE was estimated using NDVI threshold method.(28) LSE(ε) = 0.004*FVC + 0.986(iv)

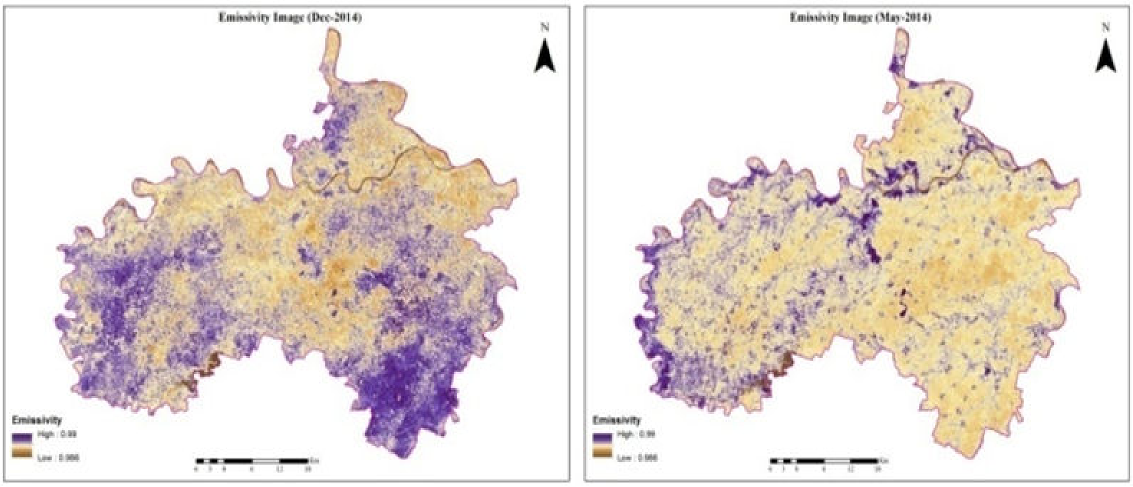


Figure 6: Land Surface Emissivity of the study area.

Fractional vegetation cover (FVC ) was calculated as suggested by Sobrino(28)using NDVI.

**3.2 NDVI Calculation**

OLI bands 2, 3, 4 and 5 were layer stacked and converted it to reflectance values then NDVI was calculated using Q-GIS software for spring and summer of the year. The output value of NDVI ranged between -0.15 and 0.59 in the month of December and -0.29 to 0.69 in the month of may in 2014.Differencing and thresholding method have been used on the NDVI of spring and summer season satellite images to separate the significantly changed areas (for example, irrigated cropland and rain fed cropland where (ΔNDVI > 0.1) from the non-significant phenological change land cover such as forests, grassland, or permanent trees and water (e.g.ΔNDVI < 0.1).

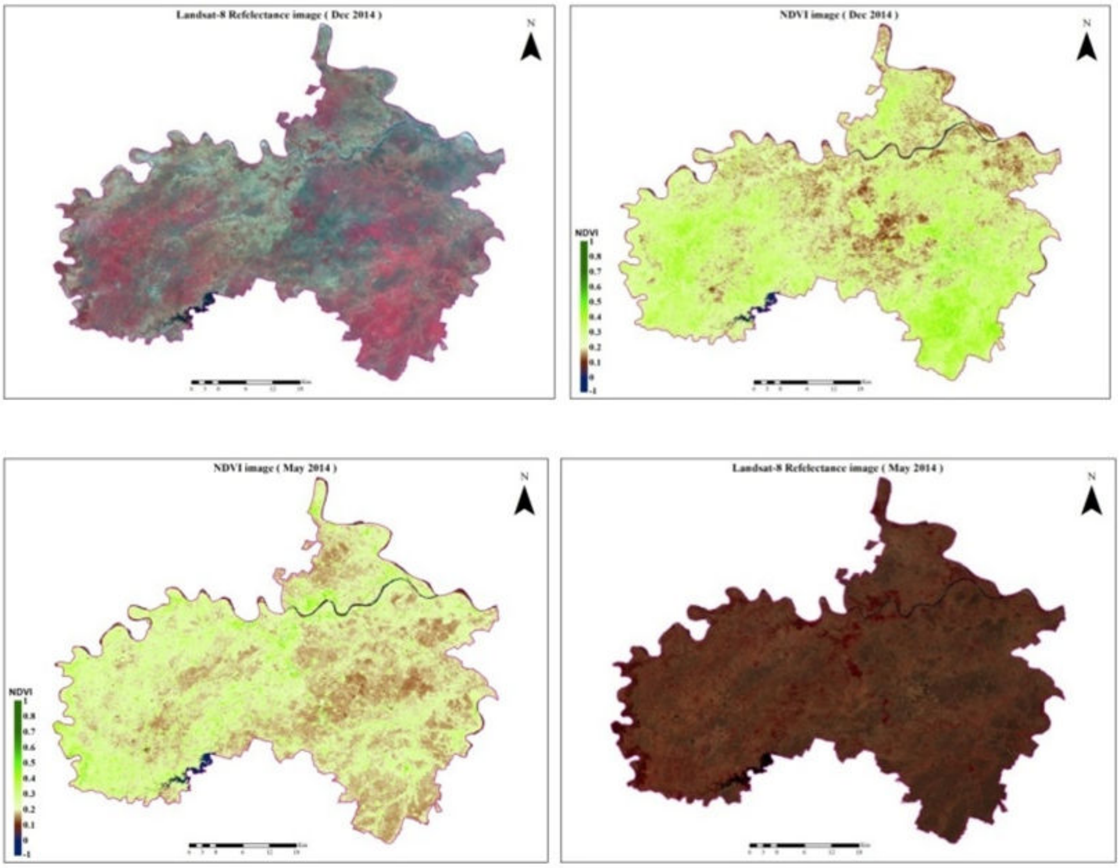


Figure 7: NDVI images of the study study area.

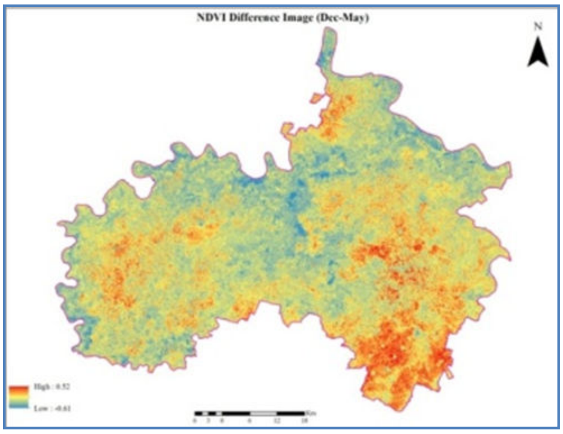


Figure 8: NDVI Deference image of the study area.

## 4. Conclusions

The study indicates that high temporal & spatial resolution remote sensing data that is Landsat data can improve monitoring of irrigation in a large region. Furthermore, it is free-cost, convenient and facile to obtain Landsat data.

In this study not only NDVI but also LST deriving from Landsat data is used to determine the irrigated area, and the results express that the combination of both is effective to obtain the useful information about crop developing conditions and canopy temperatures, both of which are relative to soil moisture.

For bettering the accuracy of irrigated area, we recommend that a detailed investigation of crop calendar of different locations in the present study area should be achieve. And experiments to determine NDVI and LST thresholds of locations with various climates, topography and crop calendars which may impact irrigation system & soil moisture are recommended in the future after successfully bring about more accurate irrigation area.

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