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Vegetation indices mapping for Bhiwani district of Haryana (India) through LANDSAT-7ETM+ and remote sensing techniques

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Abstract: This study describes the VIs Vegetation Condition Index in term of vegetation health of wheat crop; with help of LANDSAT-7ETM+ data based NDVI and LAI for Bhiwani District of Haryana states (India) and gave the spatial development pattern of wheat crop in year 2005 over the study area of India. NDVI is found to vary from 0.3 to 0.8. In northern and southern parts of study area NDVI varied from 0.6 to 0.7 but in western part of Bhiwani showed NDVI 0.2 to 0.4 due to fertility of soil and well canal destitution. LAI showed variation from 1 to 6 according to the health of crop as the same manner of NDVI because LAI VI is NDVI dependent only change the manner of representation of vegetation health, due to this fact relation curve (r^2=) between NDVI and LAI of four different growing date of sates are in successively increasing order 0.509, 0.563, 0.577 and 0.719. The study reveals that VIs can be mapped with LANDSAT-7ETM+ through remote sensing, which can be further used for many studies like crop yield or estimating evaptranspiration on regional basis for water management because satellite observations provide better spatial and temporal coverage, the VIs based system will provide efficient tools for monitoring health of crop for improvement of agricultural planning. VIs based monitoring will serve as a prototype in the other parts of the world where ground observations are limited or not available.

Keywords: Evapotranpiration, Remote Sensing, Vegetation Indices (VIs)

INTRODUCTION

Spectral VIs are the important parameters which are required by various Surface energy balance algorithm of remote sensing for estimating evapotranspiration. Evapotranspiartion is combined loss of water from crop and soil. Evapotranspiration is the important component of the hydrological cycle (Kumar *et. al.,* 2013). For instance, approximately 70% of the total water precipitation is believed to return to the atmosphere by evapotranspiration (Rosenberg *et.al.,* 1983). Studies concerning the hydrological cycle on a basin scale may help a better understanding of the relation that human changes can cause to water circulation and distribution, assisting managers to take better decisions to minimize damages to the environment and improving the use of water. Spectral VIs are techniques usually used to analyze canopy properties from remote sensing data (Bala *et al.,* 2015). The most common VIs are Leaf Area Index (LAI) and Normalised Difference Vegetation Index (NDVI). Remote sensing estimation of Leaf Area Index is based mainly on an empirical relationship between LAI, which is measured in land, and the spectral response observed by the sensor. NDVI is an appropriate index which is used as a measure of plant yield (Curran, 1983). It is also considered as the representative of LAI and is able to estimate the LAI in different ecosystems. As a result, NDVI−LAI can be applied to study the state of crop vegetation cover.Several studies indicate that NDVI and LAI are used for estimation and prediction of crop yield because both parameters are dependent on the state of vegetation cover (Curran, 1994; Bala *et al.,* 2015). The relationship between NDVI and vegetation cover can be established based on the distribution of vegetation cover which is weak and sparse or dense. In other words, NDVI is strongly influenced by soil reflectance in regions with sparse vegetation cover and with LAI index less than 3. Several studies have shown that how remote sensing can be used for estimating the crop yield (Bouman,1992; Moran *et al.*,1997; Moulin *et al.*, 1998; Layrol *et al.*, 2000; Locke *et al*., 2000; Yang and Everitt, 2000; Werner *et.al*., 2000; Rawat *et al*., 2012). Wiegand *et al*., 1991 found that the yield differences in different studied fields are mainly related to leaf area index and can be used for estimating the crop yield. Gupta *et.al.,* 2003 used the satellite images of LANDSAT-TM and IRS LISS-III for vegetation mapping and calculated the NDVI content for image LISS-III. Results showed significant correlation with NDVI real content at 99% confidence level. The objective of this paper is to map VI (NDVI and LAI) through Remote

Table 1. The LANDSAT-7ETM+ satellite images used in the study.

Study area	Date	Sun elevation angle	Sun azimuth angle	Pixel size
Bhiwani	15 Jan 2005	34.60°	147.69°	30 m × 30 m
	30Jan 2005	36.02°	145.92°	30 m × 30 m
	14Feb 2005	33.33°	149.16°	30 m × 30 m
	03Mar 2005	45.29°	138.42°	30 m × 30 m

sensing data set of LANDSAT-7ETM+ for estimating evapotranspiration on regional basis for water management (Kumar *et al.*, 2013; Bala *et al.*, 2015).

MATERIALS AND METHODS

Study area and remote sensing data: Bhiwani district is situated in the south-western part of Haryana and lies between 28.19º−29.05º N and 75.26º−76.28º E (Fig. 1). The geographical area of study area is 4,65,504 ha out of this 4,18,843 ha is cultivable and 3,93,134 ha is cultivated. The area under forest is 3442 ha, cultivable waste is 17,144 ha and land under non-agricultural use is 26,075 ha. Geographically it is the largest district of Haryana occupying 10.5% area of the state. Study area is a region with flat plains separated by sand dunes, ridges, and small hillocks. As it is located in the region of Thar Desert, there is low ground water level here and Dohan river is the only water body in study area. It is a tributary of river Ganga and is fed only by precipitation. A thin stream of Dohan flows towards south of this district and has a short expansion only till the outskirts of its villages.

Study area come under the tropical semi arid climate which is marked by extremely hot and dry summers and chilling cold winters. These climatic conditions are very common in Trans Gangetic Plains (TGP). Temperature during summer season may increase up to 45 ºC and during winters, mercury drops to the level of 2 ºC in Bhiwani district. Months of July and August experiences maximum rainfall caused by South west monsoons leading to 85% of its annual rains. The annual rainfall of 420 mm is distributed during monsoon and non monsoon periods. Rainfall is generally sparse here and monsoon months last from July to August. According to its climatic conditions water management is really necessary to mapping accurate evapotranspiration, need to map accurate vegetation indices, for those images were acquired for LANDSAT-7ETM+ for Path/Row (147/40) (Table1). After acquiring these images area of interest (AOI) is obtained with longitude 76.25º and latitude 29.05º with the help of remote sensing software ILWIS-3.4.

Indices calculation: For calculating indices (VIs) reflectance in near infrared (NIR) and red bands are required from satellite images from digital number (DN) to radiance and then reflectance were calculated as given below (eq 1− 4).

Conversion of DN to Radiance:

$Radiance\_Band_3 = ((158.6+4.5)/254) x (band_3-1)) - 4.5$ …eq.1

$Radiance\_Band_4 = ((157.5+4.5)/254) x (band_4-1)) - 4.5$ ...eq.2

Conversion of radiances in to reflectance

$Reflectance\_Band_3 = (Radiance\_Band_3 x3.14x0.9836)/(1551x0.65)$ …...eq.3

$Reflectance\_Band_4 = (Radiance\_Band_4 x3.14x0.9836)/(1044x0.65)$ ……eq.4

Normalized difference vegetation index (NDVI): The NDVI (Myneni *et al.*, 1995; Running, 1990) is derived from the red: near-infrared reflectance ratio as eq.5, where NIR and RED are the amounts of near-infrared and red light, respectively, reflected by the vegetation and captured by the sensor of the satellite. The formula is based on the fact that chlorophyll absorbs RED whereas the mesophyll leaf structure scatters NIR. NDVI values thus range from +1 to -1, where negative values correspond to an absence of vegetation (Myneni *et al.*, 1995; Shunlin, 2004). This index is widely used due to the simplicity and often provides acceptable results when the vegetation cover is not too dense or sparse. This is because the red reflectance remains constant in too dense cover, but reflectance is increased in infrared band and the saturation happens.

$$NDVI = \frac{NIR - RED}{NIR + RED}$$ …….eq.5

Leaf area index (LAI): LAI is a mathematical construct that does not have a direct relationship to NDVI. LAI is usually defined as the one sided area of leaves in a canopy per unit ground area of canopy cover but non flat leaves complicate the definition. LAI represents the total biomass and is indicative of crop yield, canopy resistance and heat flux. Choudhury *et al.*

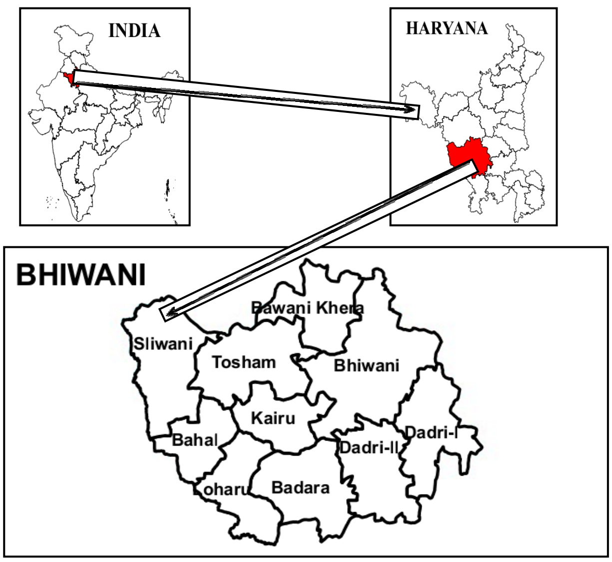

Fig. 1. *Location map of Bhiwani (Study area) district of Haryana (India).*

(1994) simulated relationships between NDVI and LAI as eq.6

$$LAI = -\frac{1}{c_3}\ln\left(\left(c_1 - SAVI\right)/c_2\right) \qquad \text{......eq.6}$$

where, SAVI factor proposed by Huete (1988) and given as

$$SAVI = \frac{NIR - RED}{NIR + RED + L}(1 + L) \qquad \text{....eq.7}$$

and L is a coefficient, In our study L was according to Shunlin (2004).

The procedure is limited to the use of the interpolation equation that is the average of many experiences developed by several authors. The default values for c_1, c_2 and c_3 are the average of many experiences developed by several authors (c_1= 0.69 c_2=0.59 and c_3= 0.91).

RESULTS AND DISCUSSION

Interpretation of remote sensing data sets: In the study region wheat, mustard and gram are the major crops grown during *Rabi* season (Table 2) followed by other crops grown in district include pulses, vegetables and fodder etc. (Sharma *et al*., 2014). VIs in respects of LAI as well as NDVI was mapped at different dates through LANDSAT-7ETM+ images (Table 1) for the study area.

Due to early stages of the crop having less density of crop canopy and some local abiotic affects, might be cloud cover over the sky, the first imagery (15^{th} January) showed low value of NDVI (Fig. 2a). Moreover, with the advancement of the crop stages and improvement in vegetation cover of crops, the imagery taken on 30^{th} January, 2005 (Fig. 3a) indicated higher NDVI value (0.3 to 0.8) followed by previous date. On the other hand, during January NDVI value must be 0.3 to 0.35, but higher NDVI value (0.8) on 30^{th} January,

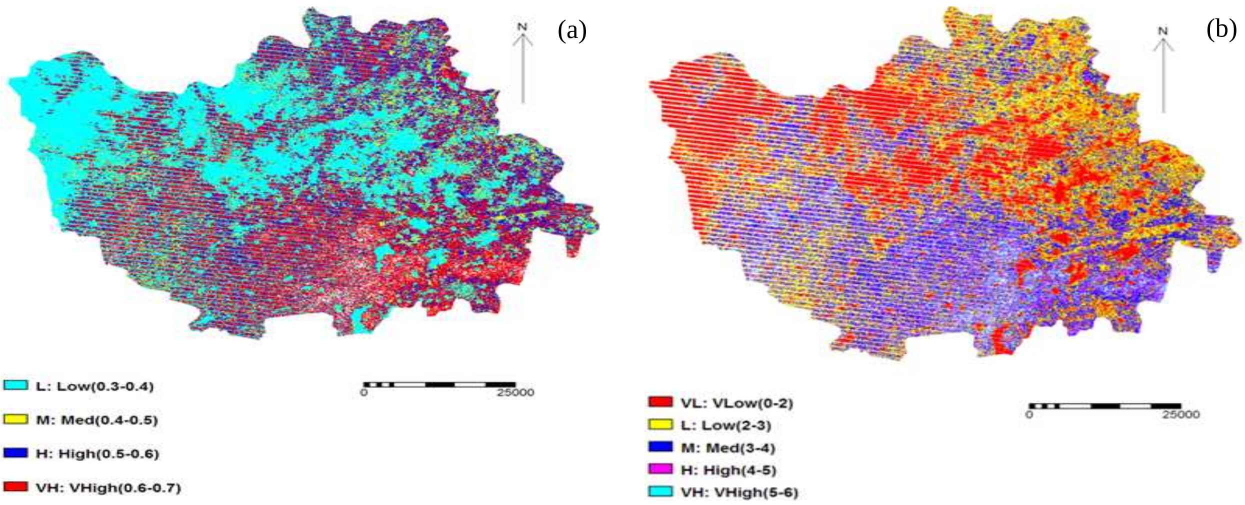

Fig. 2. *(a) NDVI and (b) LAI of Bhiwani from LANDSAT−7ETM+ image on 15^{th} January 2005.*

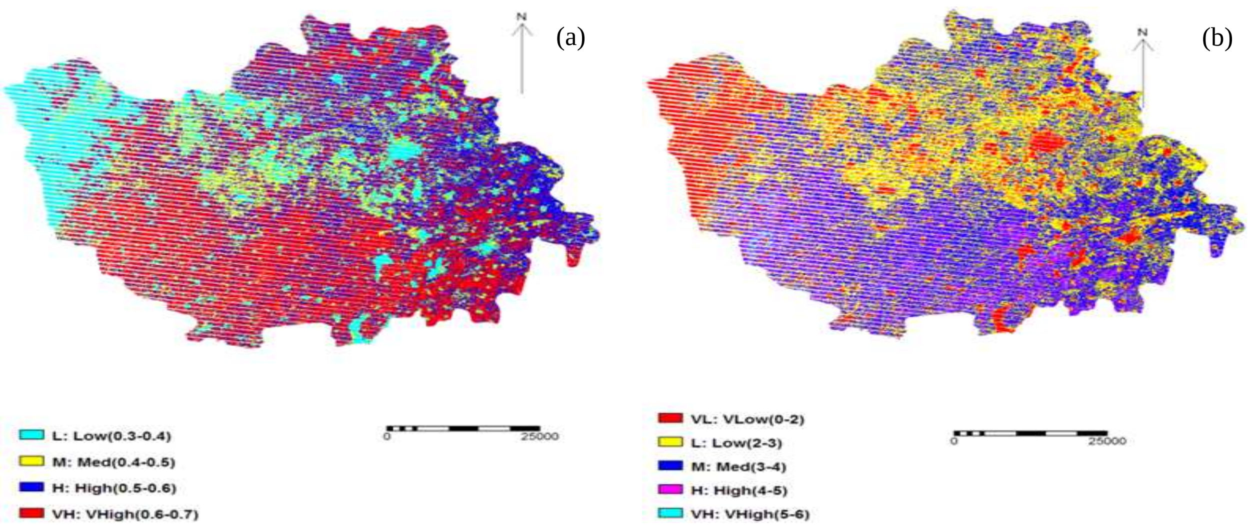

Fig. 3. *(a) NDVI and (b) LAI of Bhiwani from LANDSAT−7ETM+ image on 30^{th} January 2005.*

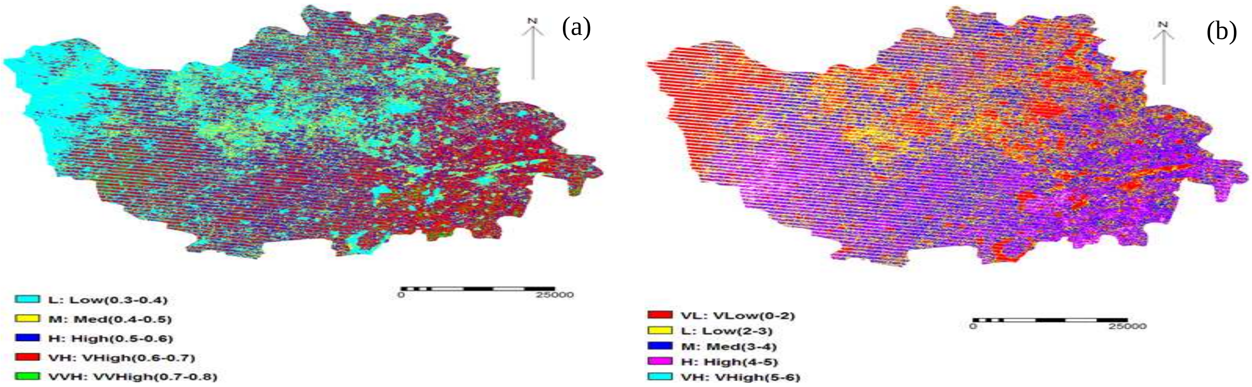

Fig. 4. *(a) NDVI and (b) LAI of Bhiwani from LANDSAT−7ETM+ image on 14th Febuary 2005.*

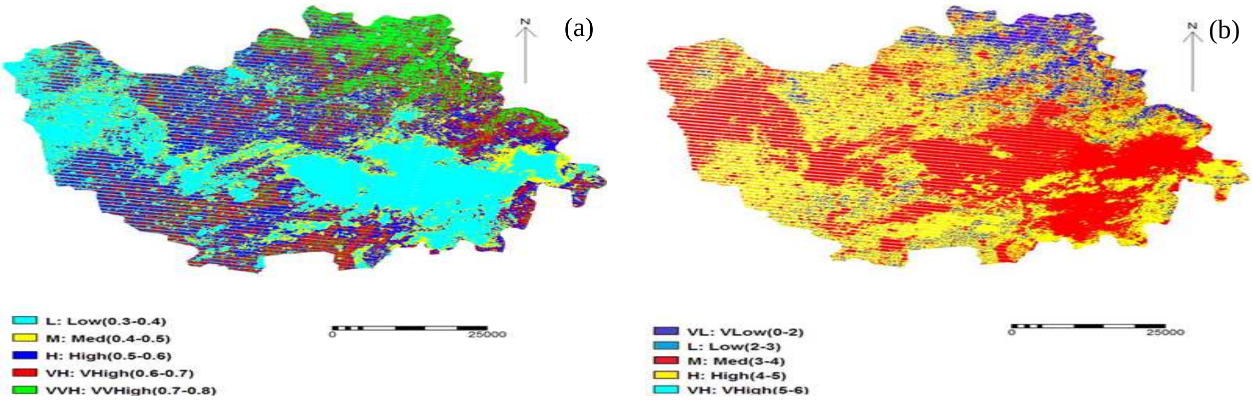

Fig. 5. *(a) NDVI and (b) LAI of Bhiwani from LANDSAT−7ETM+ image on 03th March 2005.*

2005 was recorded due to the maximum vegetative growth of wheat crop during that period followed by mustard, which was on flowering stage. Inspire of that, the areas having less NDVI may be due to the low fertility and low moisture holding capacity of loamy sand soils of the district (Punia *et al*., 2009). In addition to this, maximum area of 30th January imagery reported NDVI value 0.35, which means better health of wheat crop during last 15 days (15−30th January 2005). As the middle period of the *Rabi* season, imagery of 30th January showed the cropping pattern of the *Rabi*, in which wheat crop was distributed more in southern part of the district and occupied 1475.75 ('00 h) area than the mustard and gram, which occupied 1312.35 and 683.21('00 h), respectively.

Imagery on 14th February, 2005 (Fig. 4a) showed the similar trends of NDVI as it was observed with 30th January. It is because of no significant variations have been found in last 15 days. Additionally, NDVI for mustard reduced due to maturity of the crop; while, NDVI for wheat still increased because of crop attaining its flowering stages.

In respect of wheat growing area, 03rd March, 2005 (Fig. 5a) imagery showed NDVI value 0.6 with maximum number of pixels. In which, northern and southern parts of Bhiwani indicated NDVI between 0.48 – 0.6, however, eastern part showed NDVI from 0.2 to 0.3, because of mustard crop toward its harvesting. Similar type of study have been done by Chaurasia *et al*. (2011) using AWiFS data set and found NDVI pattern as per the our result, therefore, NDVI is the most promising VI for simulating biomass and crop

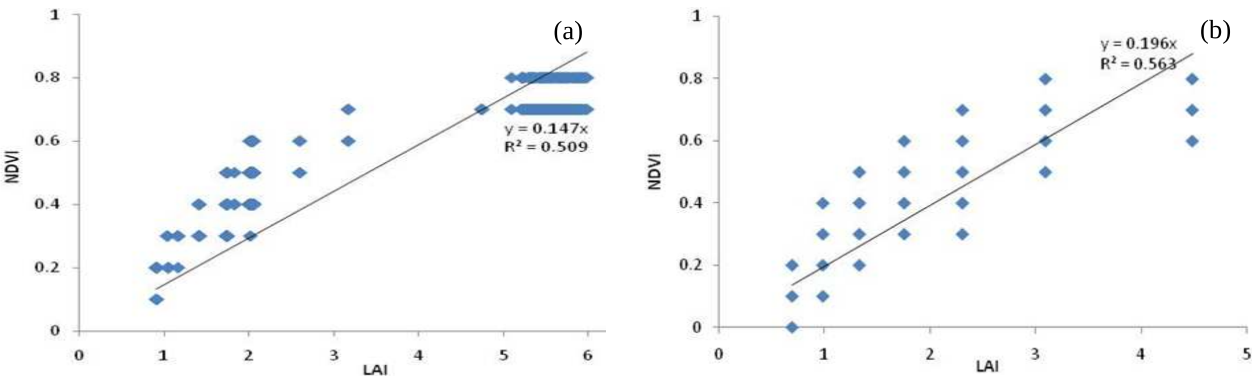

Fig. 6. *Relation between LAI and NDVI during (a) 15th Jan 2005 and (b) 30th Jan 2005.*

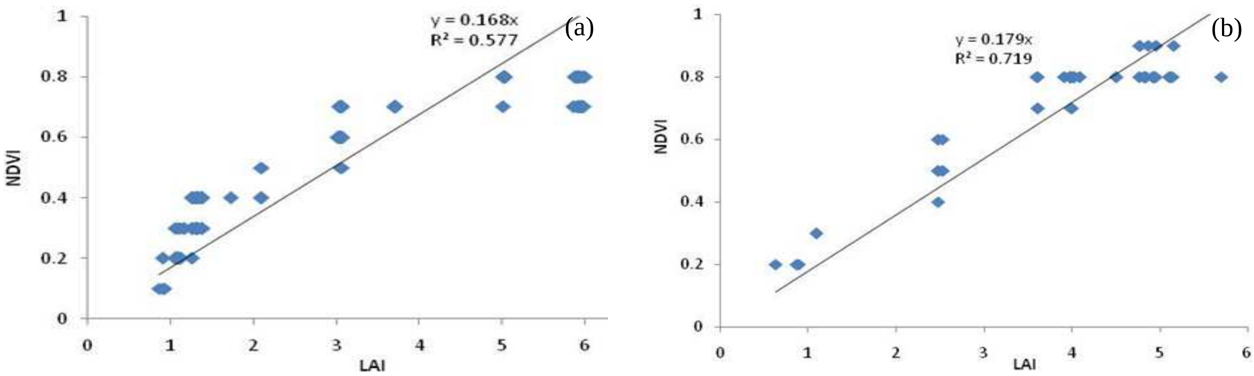

Fig. 7. *Relation between LAI and NDVI during (a) 14th Febaury 2005 and (b) 03th Mach 2005.*

yield in varying agro-climatic zones.

In respect of LAI, based on imagery of 15th January, lower value of LAI (0−2) showed by reddish part, however, higher LAI value (3−4) was indicated by blueish part of the imagery. Moreover, lower value of NDVI and LAI were observed, due to lesser density of crop till 15th January (r^2=0.509) (Fig. 6), while, the value of NDVI and LAI were increased as crop attains higher density (Nagler *et al*., 2004).

Similarly, imagery of 30th January, 2005 (Fig. 2b) showed the LAI range 2 − 5, which indicated LAI as 5 for yellow pixels and reddish for LAI 2. The improvement of LAI value and correlation between LAI and NDVI (r^2=0.569) during this period was due to the higher crop acreage cover because of better vegetative growth of crop (Fig. 6b).

LAI was found in the ranged from 1 to 4.5 for the imagery of 14th February, 2005 (Fig. 3b). Histogram illustrated that the maximum area of imagery was having LAI as 3.06, in which, Southern (Wheat dominate area) and eastern part of imagery showed LAI from 2 to 4.5, while, Northern and Eastern part indicated LAI between 1 to 4 and 1 to 2, respectively. Due to the better crop canopy during this period, there was an improvement in correlation (r^2=0.577), based on the relation curve drawn between LAI and NDVI (Fig. 7a).

Based on the imagery taken on 03rd March, 2005 (Fig. 4b), LAI was found in the range from 1 to 5. In which, based on the histogram, maximum area shown LAI as 5, but the Northern part of the district showed LAI between 0 to 2, because of maturity of mustard crop during this period. The highest correlation (r^2=0.719) between LAI and NDVI was found, as per the imagery of 03rd March, it is because of the wheat crop was having its pick of greenness and higher density of crop canopy (Rawat *et al.*, 2012).

Conclusion

The unique contribution of the above study is the development and validation of regionally applicable VIs-based wheat LAI models or health/growth stages of wheat. The usage of vegetation indices obtained after processing satellite images can be made with the precision of certain things. Firstly, it must emphasize that in the processes were used satellite images with medium spatial resolution (30 m) and which were processed with the available means. Secondly, such an analysis had taken into account large target areas because of the given spatial resolution images. The spectral vegetation indices derived from LANDSAT-7ETM+ images can be successfully used in the estimation of NDVI and LAI for study area. Vegetation health changes in images at particular date can be detected using NDVI, which reflects a health condition in given sites. According to our results from VIs vegetation growth of wheat crop at the core region of wheat at Bhiwani is good. All VIs have given good results because NDVI showed a significant relationship (r^2<0.5) with LAI. So we can map VIs with LANDSAT-7ETM+, which can be further used for many studies like crop yield or estimating evaptranspiration on regional basis for water management.

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