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Fodder crops assessment using multi-temporal Landsat-8 data by NDVI based classification in Haryana state of India

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Abstract
This study highlights the application of multi-temporal Landsat-8 imageries to identify and discriminate fodder crops from food crops and estimate the area utilized for fodder cultivation in three districts of Haryana during 2016 in *Rabi* season. Atmospherically, corrected NDVI based spectral-temporal profiles showed that the time of sowing plays an important role to differentiate fodder crops from other crops. ISODATA unsupervised classification approach was used to image classification. Accuracy assessment was carried out between four classes (fodder crops, plantation, forest and other crops) and 91.49% as overall accuracy of classification was observed. The total area under fodder cultivation was estimated as 6.37 per thousand hectares (ha) with 3.60 per thousand hectares in Kurukshetra, 1.94 per thousand hectares in Ambala and 0.83 per thousand hectares in Yamunanagar. Thus it covered an area of approximately 4855 square kilometers which included Ambala, Krukshetra and Yamunanagar districts of Haryana.

Keywords: Area assessment, Fodder crops, Landsat-8, NDVI, Spectral-temporal

Abbreviations: DN: Digital number; **GIS:** Geographic information system; **GPS:** Global positioning system; **NDVI:** Normalized difference vegetation index; **RS:** Remote sensing; **TD:** Transformed divergence; **TOA:** Top of atmosphere

Introduction

India has one of the largest livestock populations in the world. However, its productivity is low when compared to other developing countries because of the non-availability of proper feed and fodder resources (Kumar *et al.*, 2008). Fodder crops are plant species that are raised for feeding livestock. The important sources of fodder are crop residues (dry fodder), cultivated fodder (green fodder) and fodder from forests, permanent pastures and grazing lands. Most of the fodder requirement is met by feeding crop residues and grazing land. Only 4.9% of total cultivated land is devoted for fodder crop production leading to a net deficit of 35.6% of green fodder in India (Anonymous, 2013). Different fodder crops grown in India are sorghum (jowar), berseem (egyptian clover), lucerne (alfalfa), pearl millet (bajra), maize (makka), oats (jai), cowpea (lobia) etc. Berseem is a leguminous crop and multi-cut in nature, therefore, green fodder availability remains for longer duration (November-April) (Kumari *et al.*, 2016; Kantwa *et al.*, 2019). Sorghum among *Kharif* crops and berseem among *Rabi* crops occupied more than 50% of the total area cultivated under fodder in India (Anonymous, 2006). Besides improving livestock productivity (Gupta *et al.,* 2019), fodder crops are also used in improving the soil structure, environment protection from pollution, reclamation of degraded land and others (Hirata *et al.*, 2011).

Remote sensing has been used for crop monitoring for a long period throughout the world. Crop production forecast helps different organizations for taking decisions regarding its storage, distribution, procurement price, import/export policies etc. Forecasting agriculture output using space, agrometerology and land based observations (FASAL) crop monitoring programme operational in India, is an integrated approach for giving multiple forecast for major crops at national and state levels. In the recent years, the availability of high temporal resolution has been improved and several studies have been carried out using multi-temporal approach to record crop phenology. Dutta *et al.*(1998) made a comparison between single-date and multi-date data for wheat classification and concluded that multi-date data gave better accuracy of 91.56% as compared to single date data. Bhagia *et al.* (2017) used multi-temporal data for identification and area estimation for pulses in major growing regions in northern and southern India and was able to achieve accuracy of 50-80.77% in mapping pulses in scattered regions. But the work on fodder crops has not been extensively reported as compared to major food crops. Starks *et al.* (2004) and Guo *et al.* (2010) used hyperspectral spectro-radiometer to assess the quality of fodder. Roumiguie *et al*. (2015) used MODIS fCover time series data for validation of forage production index. No specific work based on mapping of fodder crops has been done in India too. Hence, this study was carried out to assess the present status of fodder crops during *Rabi* season in different districts of Haryana using high resolution multi-date Landsat-8 OLI data.

Materials and Methods

Study area: The study was carried out during 2016 in Ambala, Kurukshetra and Yamunanagar districts of Haryana state, India (Fig 1). The area lies between the 30° 2' 47" to 30° 28' 5"latitudes and 77° 35' 35" to 77° 3' 38" longitudes bounded by Himachal Pradesh in north, Uttar Pradesh in east, Punjab in west and other districts of Haryana in south. It covered an area of approximately 4855 square kilometers. Yamuna, Markanda, Tangri and Beghnaand rivers mainly drain these districts (GWCB, 2010). Groundwater is also an important source of irrigation. The climate is mainly dry with very hot summer (mid-March to last week of June), followed by southwest monsoon lasting up to September and cold winters (late November to first week of March). The average annual rainfall of these districts is 902 mm. The area is mainly covered by silty loam, light loam and loam soils. The commonly grown fodder crops during the year in the study area were sorghum, berseem, maize, jowar, barley and oats.

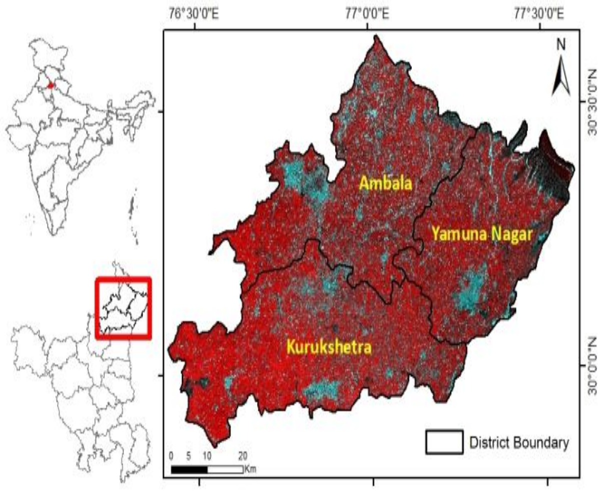

Fig 1. The study area covering Ambala, Kurukshetra and Yamunanagar districts of Haryana

Satellite data used: In this study, Landsat-8 OLI data was used for fodder crops assessment during the period of October, 2016 to February, 2017. Landsat-8 data was downloaded from USGS Earth Explorer (USGS, 2016). On five dates (19.10.2016; 20.11.2016; 22.12.2016; 23.01.2017 and 24.02.2017), Landsat data were used with employing of path 147 in each data and at row 39 with spatial resolution of 30 meter. However, Landsat-8 image dated 19-10-2017 was considered as reference image and other images were co-registered to this master image.

Ground truth data collection: GPS survey was carried out to collect randomly information on fodder crops and other crops at the beginning of February, 2017 in the study area. Most of the area was covered by berseem among the fodder crops, and by wheat as well as sugarcane among the food crops.

Conversion to TOA reflectance**:** To reduce the scene to scene variability so as to compare multi-temporal images even from multi-sensors, TOA reflectance values were used instead of DN at sensor spectral radiance. Since TOA reflectance eliminated the cosine effect of different solar zenith angles because of the time difference between data acquisitions, it compensated for different values of the exo-atmospheric solar irradiance arising from spectral band differences and fixed for the variation in the earth-sun distance among different data acquisition dates (Chander *et al*., 2009). DN values were converted to TOA reflectance using reflectance scaling coefficients given in the MTL metadata by the following equation (Giannini *et al*., 2015; Congedo *et al*., 2016; Singh *et al*., 2016).

Step-1 DN to radiance-

$$L_\lambda = \frac{(\mathrm{Lmax} - \mathrm{Lmin})}{\mathrm{DN}_{\mathrm{max}}} \mathrm{DN}_{\mathrm{max}} + \mathrm{Lmin}$$

Step-2 Radiance to apparent reflectance-

$$\rho_{A(\lambda)} = \frac{\pi L_\lambda d^2}{E_\theta(\lambda) Cos\theta_s}$$

In ERDAS imagine, DN to TOA reflectance algorithm was prepared using the above two steps and images were converted into TOA reflectance. But the equation did not account for sun angle correction, therefore, TOA reflectance images were corrected for sun angle using equations.

Atmospheric correction: Atmospheric correction was particularly important for comparison and analysis of multi-temporal images (Hadjimitsis *et al*., 2010). Histogram minimum method was applied to multi-date satellite images using the minimum value from each band. These values were subtracted from each TOA reflectance values of their respective spectral band. The satellite imageries acquired from October, 2016 to February, 2017 were used to derive atmospherically corrected normalized difference vegetation index (NDVI; Rouse *et al*., 1974; Hadjimitsis *et al*., 2010; Tsheko *et al*., 2015).

Signature generation and evaluation: Band 2 to Band 7 of date 24-Feb-17 were stacked with five date NDVI images to generate the spectral-temporal profiles. So a total of 5 band image was generated. The band designation was Band 1: 19-10-2016, Band 2: 20-11-2016, Band 3: 22-12-2016, Band 4: 23-01-2017, Band 5: 24-02-2017. Decision rules were generated from the ground truth data collected. Several training sites were merged into nine sites namely fodder crops, wheat, sugarcane, other crops, plantation, forest, urban, sand and water were created. The major problem in generating sites for fodder crops was small field size. At a time not more than 3-4 pixels were taken to define a particular site which were later on merged together.

To evaluate signature separability, transformed divergence (TD) was used as an indicator. The scale of TD ranged from 0 for completely overlapping classes to 2000 for completely separated classes (Jensen, 2007). The value close to 2000 or between 1900 to 2000 showed best separability and between 1700 and 1900 indicated good separability. The TD value less than 1700 showed poor class separability. The best average separability between fodder crop and other classes using all bands was namely wheat with TD 1973; sugarcane with TD 2000; other crops with TD 2000; plantation with TD 2000; forest with TD 2000; urban area with TD 2000; water with TD 2000 and sand with TD 2000.

Hierarchical decision rule based classification: Hierarchical decision rule based classification algorithm has been used for over the years worldwide for land use land cover classification (Thakkar *et al*., 2014; 2017) as well as for crop classification like for wheat (Dutta *et al*., 1998). After checking the separability of signatures, maximum likelihood classification was done using reflectance-NDVI stacked imagery.

Accuracy assessment: After the completion of classification, it was important to assess the accuracy of classification (Lillesand *et al*., 2004). Random samples were collected from the classified images, which acted as testing pixels. The accuracy report gave a measure of overall accuracy, producer's accuracy, user's accuracy and Kappa statistic, which were as follows:

$$\text{Overall accuracy (\%)} = \frac{\text{Sum of correctly classified pixels}}{\text{Total number of pixels}} * 100$$

$$\text{Producer's accuracy (\%)} = \frac{\text{Number of correctly classified pixels of a class}}{\text{Total number of pixels in reference data}} * 100$$

$$\text{User's accuracy (\%)} = \frac{\text{Number of correctly classified pixels of a class}}{\text{Total number of pixels in that class}} * 100$$

Producer's accuracy was a measure of omission error whereas user's accuracy was a measure of commission error. Kappa coefficient reflected the measure of difference in actual agreement and expected agreement (Stehman *et al*., 1996).

$$\hat{K} = \frac{\text{Observed Accuracy} - \text{Chance Agreement}}{(1 - \text{Chance Agreement})}$$

The scale of Kappa statistic ranged from 1 to -1. In case of perfect agreement, the Kappa statistic was equal to 1. In rare cases values could be negative indicating agreement was less than the chance.

Area estimation: Area estimate was obtained through complete enumeration by pixel count method. Pixel count was taken from the histogram of classified image. Each pixel represented an area of 30 × 30 = 900 square meters.

Results and Discussion

NDVI based temporal profiles: From the multi-date Landsat-8 reflectance images, atmospherically corrected NDVI was generated to analyze the spectral-temporal behaviour of the fodder and other crops during the *Rabi* season. The data of October was considered for a better understanding of the time of sowing. In spite of 16 days repeativity of the Landsat-8, data acquired on 4-Nov-16, 6-Dec-16, 7-Jan-17 and 8-Feb-17 were heavily covered with clouds so they were not taken into consideration in this study. The main fodder crop and food crop identified from spectral-temporal profiles and ground based data were berseem and wheat respectively. Growth profiles of a particular crop were observed almost similar in the entire study area due to the similar weather conditions, sowing time of *Rabi* crops, management practices etc. Sugarcane profiles were quite distinct from other crops as it maintained high and constant NDVI upto January after that NDVI dropped as it reached the harvesting stage. Wheat, mostly sown by mid-end of November, occupied most of the cultivated area. Berseem was the major fodder crop cultivated, sown by mid-end of October. The difference in the date of sowing of berseem and wheat was considered as an important factor in distinguishing both of them.

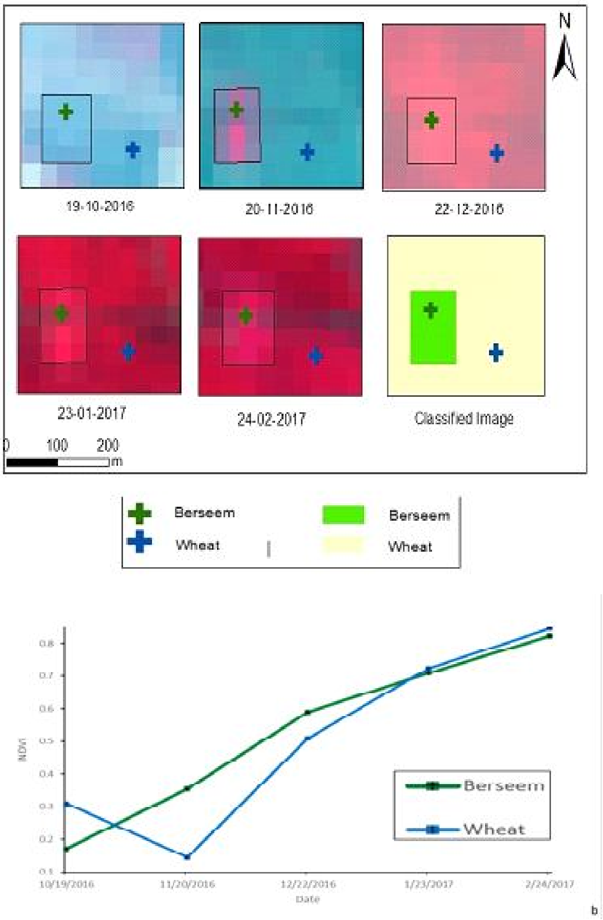

Fig 2. Variations in tone of berseem (a) and wheat over the time period NDVI-temporal profiles for two GT Points (b)

The variation in spectral properties and NDVI with time for berseem and wheat was observed (Fig 2). While in January and February NDVI values of wheat approach very close to that of berseem, hence it was quite difficult to distinguish them based on their maturity. Other spectral profiles indicating sowing in October and harvesting in February were grouped into other agricultural crops class. Non-agricultural classes like water, urban and sand were evidently demarcated owing to their different spectral characteristic from vegetation. Forest and plantation showed very low variation in NDVI throughout the season (Fig 3).

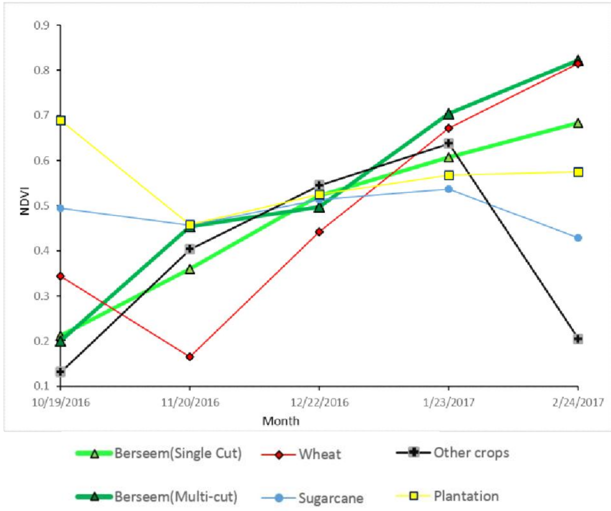

Fig 3. NDVI based temporal profiles for different vegetation classes

Classification and accuracy assessment: Classification of different crops was carried out by hierarchical decision rule based classification in ERDAS software using the training sites for 9 different classes that were generated based on the spectral growth profiles. The nine classes were again reclassified into seven classes where wheat and sugarcane were merged with other crop class (Fig 4). The objective was to discriminate fodder crops accurately from other crops. Therefore, for the purpose of accuracy of assessment 4 classes were selected, namely fodder crops, plantation, forest and other crops (Table 1). It was estimated using the error matrix. Total of 282 random samples were collected from the image, out of which 258 were classified correctly. The overall accuracy of classification was 91.49%. Some smaller patches, as observed during survey, of berseem could not be classified correctly since the size of fields were less than 30 meters which was less than 30 m resolution of Landsat-8. The overall Kappa coefficient (K^) value was 0.886. Incorrect classification of fodder crops at some places was probably due to small size of berseem fields *i.e.* less than or around 30 meters and late sown berseem or early sown wheat (at the beginning of November), which were expected to show similar trend.

Area estimation: The total area occupied by fodder crops was calculated by direct pixel based counting method, where each pixel represented 900 square meters of area. The total area under fodder cultivation in three districts was estimated as 6.37 per thousand hectares (ha) with 3.60 per thousand ha in Kurukshetra, 1.94 per thousand

Table 1. Accuracy assessment of classified images

Classified data	Reference data				Classified totals	Producers accuracy	User accuracy	Kappa
	Fodder crops	Other crops	Plantation	Forest				
Fodder Crops	74	11	0	0	85	100.00%	87.06%	0.8245
Other Crops	0	69	4	1	74	78.41%	93.24%	0.9018
Plantation	0	8	54	0	62	93.10%	87.10%	0.8376
Forest	0	0	0	61	61	98.39%	100.00%	1
Reference total	74	88	58	62	282			

Overall classification accuracy = 91.49 %

Overall Kappa statistics = 0.8860

ha in Ambala and 0.83 per thousand ha in Yamunanagar (Fig 5).Thus it covered an area of approximately 4855 square kilometers which included Ambala, Krukshetra and Yamunanagar districts of Haryana.

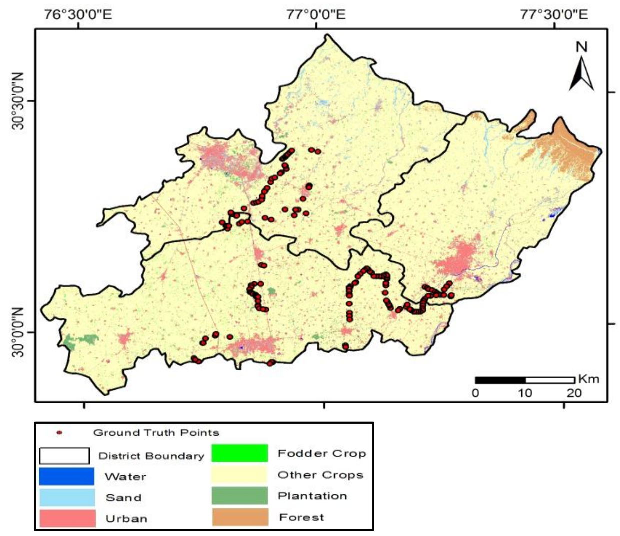

Fig 4. Classified image of study area

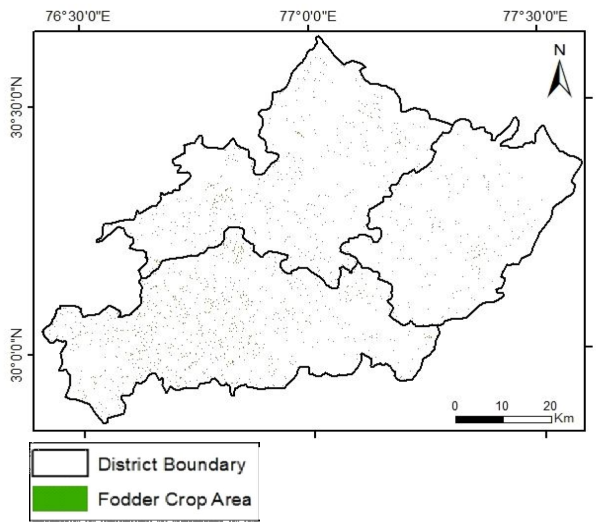

Fig 5. Area under fodder cultivation

Conclusion

An attempt was made to identify and discriminate the fodder crops in different districts of Haryana followed by its area estimation using Landsat-8 OLI imagery for *rabi* season. NDVI was derived from the imagery to generate spectral-temporal profile for different crops at ground truth (GT) sites, showed different growth pattern. The best time to discriminate wheat and berseem was October-December as berseem was sown by end of middle to end of October whereas wheat was sown by middle to end of November. Kurukshetra had the highest area under fodder cultivation, whereas lowest area was in Yamunanagar district with an overall classification accuracy of 91.49%. This study is expected to help in estimating the availability of fodder so that fodder cultivation plan can be framed which will help to supply the fodder throughout year to improve the livestock productivity.

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