Indian Journal of Agricultural Sciences **92** (6): 716–20, June 2022/Article
https://doi.org/10.56093/ijas.v92i6.108325

Fodder crop estimation using Sentinel-2A/B satellite data for West Bengal, India

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Received: 11 December 2020; Accepted: 13 January 2022

ABSTRACT

Mapping, monitoring and estimation of fodder crop area can support farmers, policy makers to make right decisions in various conditions to improve the livestock productivity. The freely available high-resolution Sentinel-2 MSI data has increased the application of precision agriculture for a broader range. This study investigated the capabilities of Sentinel-2A/B MSI satellite data to identify and discriminate the fodder crops from other crops and estimate the area utilized for fodder cultivation in five districts of West Bengal during 2019–20 in *rabi* season (October to March). Multi-date NDVI based spectral profiles were generated from satellite imagery to ascertain the time of sowing which plays an important role to differentiate fodder crops from other crops. Image classification has been done through the ISODATA clustering technique. A field survey has been carried out in the study area and a total of 610 GT points were collected from different locations of fodder crops using handheld GPS and smartphone-based applications to validate the classification of crops. Accuracy assessment has also been performed between four classes (Fodder crops, Other crops, Forest and Waterbody) which is 81.61% for fodder crops, and 88.97% overall accuracy was observed in classification. The area under fodder cultivation was 0.68% of the total agricultural area, which has been estimated to the tune of 6.78 per thousand hectares. This study can be implemented for fodder crop identification and cultivation management plan to improve the livestock productivity by supply of fodder throughout the year.

Keywords: Fodder Area Assessment, Fodder Crops Estimation, ISODATA, NDVI, Sentinel-2A/B

India has the world's largest livestock population, but its productivity is lower than other developing countries due to lack of proper feed and fodder (Kumar *et al.* 2008). Major sources of fodder and feed supply are cultivated fodder (green fodder), fodder from forests, grazing lands, permanent pastures and crop residues (dry fodder). India is utilizing only about 4% cropland area for the cultivation of fodder (ICAR-IGFRI, Vision 2050, 2013). Therefore, India is facing a deficit of 41% concentrate feed ingredients, 35.6% green fodder, and 26% of dry fodder (ICAR-IGFRI, Vision 2050, 2013). India is growing various fodder crops like oats (*Avena sativa*), berseem (*Trifolium alexandrinum*), napier (*Pennisetum purpureum*), maize (*Zea mays*), cowpea (*Vigna unguiculata*), pearl millet (*Pennisetum glaucum*), sorghum (*Sorghum bicolor*) etc. Due to multi-cut nature, berseem and oats are grown all over the country to fulfill the green fodder requirement. India is occupying more than 50% area of total cultivated fodder for berseem among *rabi* crop and sorghum among *kharif* crop (ICAR-Forage Crops and Grasses (Handbook of Agriculture, 2006). Remote Sensing, Geospatial technology and availability of satellite data have provided new opportunities to crop mapping, monitoring, precision farming, yield estimation, crop management, production planning, crop disaster early warning and food security decision support. An integrated approach of MNCFC and Space Application Centre (SAC), ISRO is giving multiple forecasts for food crops at National and State level. In recent years, several studies have been conducted using multi-temporal approach to study crop phenology due to availability of high resolution satellite data. Recently, Singh *et al.* 2020 used multi-temporal satellite data for identification and area estimation for fodder crops in Haryana state of India and was estimated about 6.39 per thousand hectares in mapping fodder crops. Furthermore, no specific studies have been conducted in India so far based on the mapping of fodder crops using satellite data compared to major food crops. The objectives were to discriminate fodder crops from other crops and estimation of fodder crops area. This study will be helpful in fodder development plan by improving fodder availability to sustain the livestock.

MATERIALS AND METHODS

Study area: The state of West Bengal is one of the poorest state in the country and the main sources of their

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Table 1 Details of data acquired from earthexplorer.usgs.gov

Satellite	Sensor	Date	Band	Spatial Resolution
Sentinel-2A/B	MSI	11-11-2019		10 m
		31-12-2019	Band 2	
		25-01-2020	Band 3	
		09-02-2020	Band 4	
		29-02-2020	Band 8	
		10-03-2020		

livelihood are agriculture and livestock products. The area under fodder crop is less than the national average (4%), hence there is scope for growth in the growing area of fodder. Therefore, the dairy industry has a huge scope in West Bengal. Hence, West Bengal was chosen as study area and research work was carried out in Nadia, Murshidabad, Bardhaman, North 24 Parganas and Hooghly districts of West Bengal state, India.

The study area is located between the 22°10'08" to 24°51' 43" latitude and 86°43'11" to 89°04' 49" longitude and covers an area of approximately 22522 km^2. This state is a major rice producing region of India. Pre and post-monsoon rainfall is an important source of water requirement. In spite of that, groundwater is an important source of irrigation. Sub-humid tropical type climate prevails in the study area with an annual average precipitation of 1393 mm. Berseem, oats, napier, jowar and maize are usually grown as fodder crops in the study area during the year.

Satellite Data used: In this study, Sentinel-2A/B MSI data has been used for fodder crops evaluation from November 2019 to March 2020 for *rabi*. Sentinel-2 data was downloaded from USGS Earth Explorer (Drusch *et al*. 2012).

Sentinel-2A/B MSI has good repeativity of 5 days with two satellite. According to field survey data of study area, Sentinel-2A/B satellite data was chosen (Table 1). Data quality was better and less cloud cover (<10%) on the selected date. The data type is Level-1C of Sentinel-2A/B MSI and geometrically corrected reflectivity data of TOA. We processed 40 different Sentinel-2A/B MSI tiles from a total of five different dates to cover the study region with cloud-free images. We processed 40 different Sentinel-2A/B MSI tiles for the entire study area of five different dates. The quality of fodder discrimination is better in sentinel-2 data of 10 m resolution than 30 m Landsat data.

Classification of satellite data using ISODATA Clustering Method: Image classification is one of the important methods for crop identification and discrimination from remotely sensed data, which is widely used for crop identification, cropped area and yield estimation (Verma *et al.* 2017). Various classification techniques are available for crop identification like supervised, unsupervised (ISODATA and K mean techniques), machine leaning, random forest and support vector machine. Among these, the two most widely used techniques are ISODATA and K-mean clustering technique. ISODATA clustering technique was used for the image classification by Rozenstein and Karnieli (20110, Verma *et al.* (2017).

In this study, we used ISODATA clustering methods for classification of Sentinel-2A/B MSI imagery to identify fodder crops using Erdas Imagine Software. After checking the separability of signatures, ISODATA unsupervised classification has been done using reflectance-NDVI stacked imagery. ISODATA clustering method has been applied on the multi-date NDVI stack layer image. Initially, 200 min and 210 max classes, 30 iterations and convergence threshold 0.999 were given during the first classification. These classes were grouped based on spectral similarity and closeness to a similar signature. Then, each group of the class was matched with an ideal spectral signature of ground truth data and assigned class name. Classes with similar NDVI values have been merged in the single class. It showed significant mixing with similar spectral signature crops like oats with wheat and other crops. To overcome this, we have to repeat ISODATA algorithm 4–5 times with less

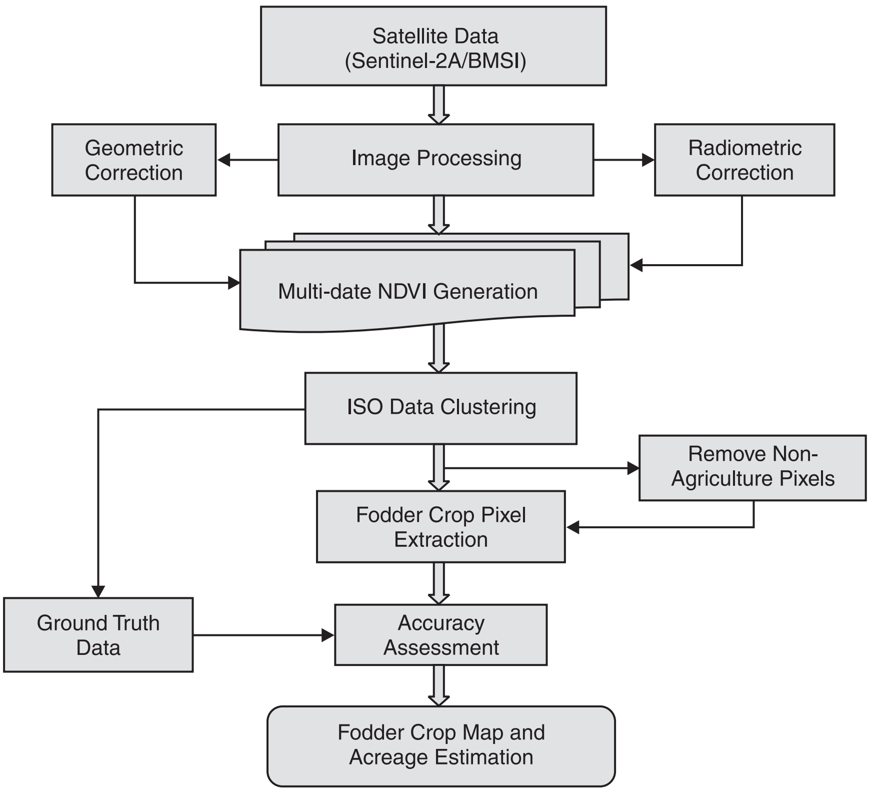

Fig 1 Methodology of study.

no. of classes and iterations. In the final classified image, 3 × 3 averaging filters were used to remove unwanted single pixels for the clean up of speckling effect (Fig 1).

Ground Truth Data Collection: A randomized GPS and Smartphone-based survey have been performed in February 2020. The geographic location of fodder and other crops have been also collected along with other parameters like crop growth stage, field size, name of the adjacent crop and photographs of the field. These points were used to validate the data during classification. Fodder crops were sown in first week of November–December in *rabi*. Total 610 Ground truth points (GT) were collected using Handheld GPS and smartphone-based application.

Normalized Differential Vegetation Index (NDVI) Generation and Evaluation: NDVI is widely used for vegetation index, crop mapping and monitoring developed by Rouse *et al*. 1974. The NDVI value varies with different stages of crop growth for each pixel. NDVI remains low at the time of sowing, rises by maturity and falls again at harvesting. These variations help to differentiate fodder crop from other crops. NDVI of five dates has been generated from TOA reflectance images of Sentinel-2A/B data:

$$\text{NDVI} = \frac{\text{Band } 8_{NIR} - \text{Band } 4_{Red}}{\text{Band } 8_{NIR} + \text{Band } 4_{Red}}$$

NDVI values showed different growth pattern of crops and their greenness conditions in study area. NDVI values vary for different classes like (NDVI< 0) for waterbody, (NDVI<0.1) for sand, (0.1≤NDVI≤0.4) for thin vegetation (paddy field, shrubs and grassland), (0.5≤NDVI≤0.7) for peak stage fodder and other crops, and (0.8≤NDVI≤0.9) for dense vegetation like forest.

Band 3, Band 4 and Band 8 of 29 February 2020 were stacked with six dates NDVI images to generate the spectral-temporal profiles. Here, original band of satellite data is also stacked with NDVI for better visualization. So, a total of 9 band image was generated, first 3 bands were reflectance and last 6 bands were NDVI. Ground truth (GT) points have been collected for ground truth and validation. Several GT points have been grouped into four classes, namely Fodder, Other Crops, Forest and Water. Crop growth profiles for berseem, oats, napier, rice field, maize and other crops are shown in Fig 2.

The berseem crop curve indicates a sudden shift in NDVI value due to lack of greenness. As berseem crop is multi-cut in nature, so these dips show the number of cuts (Fig 2).

Accuracy Assessment: It was necessary to assess the accuracy of the classification after the completion of the classification (Lillesand *et al.* 2004). Random points were generated from the classified image that were used as a reference pixel. The total accuracy report offers a measure of User's accuracy, Producer's accuracy, Overall accuracy and Kappa statistics $\hat{K}$ which are given as:

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

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

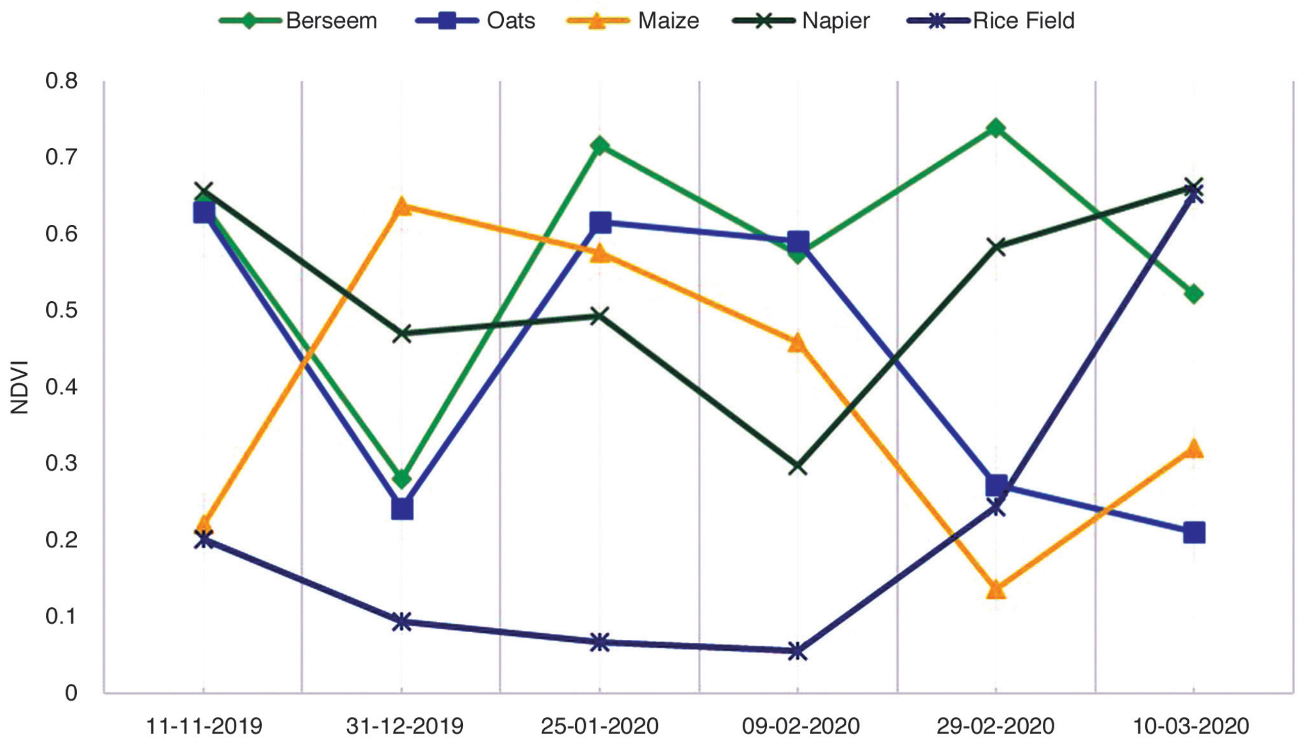

Fig 2 NDVI Profiles of different vegetation classes generated from Sentinel-2 satellite data.

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

$$\hat{K} = \frac{\text{Observed of correctly classified pixels of a class}}{(1 - \text{Chance Agreement})} \times 100$$

The Kappa coefficient represents the measurement of the difference in actual agreement and expected agreement (Stehman *et al.* 1996). The Kappa statistic value varies from 1 to -1, whereas, Kappa value equal to 1 represents the perfect agreement. In rare cases, the value may be negative, which indicates that the agreement is less than the chance. The same dataset of sample pixels is used for accuracy assessment so that the accuracy of classification can be compared between different layer combinations.

RESULTS AND DISCUSSION

During *rabi*, NDVI was generated from multi-date Sentinel-2A/B reflection images to analyze the spectral-temporal behaviour of fodder and other crops. The fodder and food crop identified from spectral-temporal profiles and ground-based data. In the *rabi* crops, the growth profile of a specific crop in the entire study area was almost the same due to the same weather conditions, sowing time and management practices etc. The profile of the paddy field was quite different from other crops as it remained low and constant NDVI from December–February, after which NDVI increased as it reached maturity. Oats and chari are the major fodder crop cultivated, sown by mid-October–November. The variation in the date of sowing of food crops and fodder crops played an important role in separating each other. Variations in spectral properties and NDVI have been observed over time for fodder crops and other crops (Fig. 2). While NDVI of other crops (paddy fields) reached very close to fodder crops in February and March. It was challenging to distinguish them based on their maturity. The non-agricultural classes such as waterbodies and urban were demarcated by their distinct spectral profiles from vegetation.

Classification and Accuracy Assessment: ISODATA clustering method adopted for classification of different crops and images were classified into 200–210 classes. Agriculture and cropland have been extracted from the classified image and then again reclassified into 100 classes segregating fodder crop from other crops. All fodder crops like oats, berseem, maize and napier were merged in fodder crop and potato, onion and mustard were grouped with other crops. This was done because its purpose was to differentiate fodder crops from other crops accurately and precisely. Therefore, four classes such as Fodder crops, Other crops, Waterbody and Forests have been chosen for accuracy assessment (Table 2).

Total 290 random points were generated from the classified image in Erdas Imagine software using accuracy assessment tool and manually assigned the reference point. Out of 290 random samples, 258 were correctly classified. Some of the small patches seen during the survey, Napier cannot be correctly classified because the size of the fields was less than 10 m of Sentinel-2A/B resolution. Confusion matrix was generated. The overall accuracy was observed 88.97% of classification. The Overall Kappa Coefficient (K^) value was 0.8485. In some place, incorrect classification of food crops was observed due to two reasons: (1) late sown oats and early sown rice (starting of November) would indicate similar patterns and (2) smaller field size of oats (<10 metres).

Area Estimation: The direct pixel-based calculation technique has been used for the acreage estimation of fodder crops. The histogram of the classified image has been used for pixel count. Each pixel denotes an area of $10 \times 10 = 100\ m^2$.

$$\text{Area (hectares)} = \frac{(\text{pixel count}) \times (10 \times 10)}{10000}$$

The total area of fodder crops in five districts was 0.68% of the total agricultural area, which was estimated as 37.78 per thousand hectares. (including 21.14 per thousand hectares in Nadia, 11.19 per thousand hectares in Murshidabad, 2.14 per thousand hectares in Bardhwan, 1.74 per thousand hectares in North 24 Parganas, 1.57 per thousand hectares in Hooghly districts) (Table 3).

Fodder crops were identified and discriminated using Sentinel-2A/B MSI imagery for the *rabi* season in different districts of West Bengal. Unsupervised ISODATA clustering method was adopted for the classification and acreage estimation of fodder crops in different districts of West Bengal. NDVI was generated from multi-date Sentinel-2A/B reflection images to analyze the spectral-temporal behaviour of fodder and other crops. The area under fodder cultivation was 0.68% of the total agricultural area. Nadia

Table 2 Accuracy Assessment of Classified Image

Classified Data	Waterbody	Forest	Other Crops	Fodder Crops	Classified Totals	Producers Accuracy	Users Accuracy	Kappa
Waterbody	40	1	0	0	41	100.00%	97.56%	0.9717
Forest	0	40	0	0	66	98.51%	100.00%	1
Other Crops	0	0	40	16	97	84.38%	83.51%	0.7534
Fodder Crops	0	0	15	40	86	81.61%	82.56%	0.7508
Reference Total	40	67	96	87	290			

Overall Classification Accuracy = 88.97%; Overall Kappa Statistics = 0.8485

Table 3 District wise Estimated Area

State	District	Estimated Area (ha)
West Bengal	Nadia	5126.9
	Murshidabad	4483.5
	Bardhaman	988
	N 24 Pgns	670.93
	Hoogly	352
Total		11621

had the highest area, while the lowest was in Hooghly, as it was mostly used for growing of rice crops. Overall classification accuracy of 88.97% was achieved. This study would help to estimate the availability of fodder to enable further intensification of the fodder cultivation plan, which would help in supply the availability of fodders and feed for the livestock industry throughout the year.

ACKNOWLEDGEMENT

This research was supported by the Space Applications Centre, ISRO, Ahmedabad (Project Number: 1007952).

REFERENCES

Drusch M, Del Bello U, Carlier S, Colin O, Fernandez V, Gascon F, Hoersch B, Isola C, Laberinti P and Martimort P. 2012. Sentinel-2: ESA's optical high-resolution mission for GMES operational services. *Remote Sensing of Environment.* **120**: 25–36.

FASAL. Retrieved from http://www.ncfc.gov.in/fasal.html on October 01, 2020.

ICAR. 2006. Forage Crops and Grasses, pp. 1353–1417. *Handbook of Agriculture*. ICAR-DKMA, New Delhi.

Kumar S, Krishnan R and Nigam S. 2008. Contribution of livestock in Indian Scenario. *Agriculture Situation in India*. 25–28.

Lillesand T M, Kiefer R W and Chipman J W. 2004. *Remote Sensing and Image Interpretation*. John Wiley & Sons.

Rouse J, Jr W, Haas R H, Schell J A and Deering D W. 1974. Monitoring vegetation systems in the Great Plains with ERTS, NASA SP-351. Third ERTS-1 Symposium, NASA, Washington, DC: 309–17.

Rozenstein O and Karnieli A. 2011. Comparison of methods for land-use classification incorporating remote sensing and GIS inputs. *Applied Geography* **31**(2): 533–44.

Singh M, Dutta S, Kala S, Dwivedi S, Meena R K, Meena V K, Kumar S, Kumar H and Onte S. 2020. Fodder crops assessment using multi-temporal Landsat-8 data by NDVI based classification in Haryana state of India. *Range Management and Agroforestry* **41**(1): 67–73.

Stehman S V. 1996. Estimating the Kappa coefficient and its variance under stratified random sampling. *Photogrammetry and Engineering Remote Sensing* **62**: 401–407.

Verma A K, Garg P K and Prasad K H. 2017. Sugarcane crop identification from LISS IV data using ISODATA, MLC, and indices based decision tree approach. *Arabian Journal of Geosciences* **10**(1): 16

Vision 2050. Published by ICAR-IGFRI 2013.