IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol.-6, Issue-6, June 2018 E-ISSN: 2347-2693

Spatial Growth Pattern of Potato in West Bengal using Multi-temporal MODIS NDVI Data

Ramprasad Kundu[1*], Dibyendu Dutta[2], Abhisek Chakrabarty[1], Manoj Kumar Nanda[3]

[1]Vidyasagar University, Midnapur, West Bengal, India
[2] National Remote Sensing Centre, Hyderabad, India
[3]Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, West Bengal, India

*Corresponding author: ramrsgis@gmail.com

Available online at: www.ijcseonline.org

Accepted: 07/Jun/2018, Published: 30/Jun/2018

Abstract— In the agriculture economy, understanding of spatial crop growing pattern is significant to agricultural structure adjustment and regional food safety policy. The phenlogical profile of crop can reflect a real trend of crop growth and therefore have been used to interpret seasonal crop growing patterns. Accurate identification of potato growing areas from other crop is not so easy because of their similar characteristics in the proposed study area. This study proposed a method to precisely predict the spatial potato crop growing pattern in the potato bowl districts of West Bengal by using 16-day composite MODIS NDVI data (MOD13Q1) in the potato cropping year of 2012-13 and 2013-14. Based on time series NDVI data and vast knowledge of field investigation a threshold value was set to build decision trees to pick up the potato crop as well as to eliminate the other crops. As a result, the potato crop area was successfully segregated from the multi-temporal NDVI data. Both predicted potato growing areas derived from MODIS NDVI data and the actual potato growing area is deployed for evaluation and the results give a satisfactory accuracy in both potato cropping year of 2012-13 and 2013-14. This result demonstrated that MODIS NDVI data are potentially good data source for spatial potato crop growing area extraction.

Keywords— Potato Crop, Crop Phenology, MODIS, NDVI, Decision Trees

I. Introduction

Potato is a major supplementary staple food crop in India. It plays a major role in the agricultural economy of India. In recent years, the potato growing area has been considerably increased due to improvement in the keeping quality of potato and demand from the food processing industry. At present, more than 80% of potato is cultivated in the Indo-Gangetic plains of North India including West Bengal, which is one of the most productive potato growing region. To determine the crop acreage and estimated production, storage requirement and disease susceptibility monitoring of crop area is important for the agricultural managers.

In multi- and mixed cropped areas, separation of individual crop is difficult based upon single date satellite data, but optimally sampled temporal satellite data would be able to pick up the unique phonological growth curve of the potato crop, and thereby discrimination of crops using remote sensing technique. Remote sensing technique is reliable, cost effective, repetitive and cover a large swath over the traditional method which is cumbersome, time consuming and seldom provides information in near real time. To capture the phonological cycle, there is a need to acquire space based information on short temporal time frame and at critical growth stages. High resolution optical sensors are constrained by their temporal resolution and is cost prohibitive. MODIS data on the other hand, having almost daily overpass with moderate spatial resolution and can be opted for mapping of the homogeneous crop area. As a rapid development of remote sensing technology, MODIS (Terra/Aqua) satellite had been launched by NASA which provides synoptic and frequent coverage of the earth in 36 spectral bands between 0.41 and 14.39 µm. It can offer several types of remote sensing data product to vegetation study with higher spatial resolution. Among these products, MODIS 16-days composite data (MOD13Q1 V005) have unique capabilities to provide sufficient spatial and temporal resolution to detect the multi-temporal spectral responses from specific crop types.

Several studies have been carried out for crop phenology research using MODIS derived time series vegetation index (VI) data (Wu et al., 2010; Zhang et al., 2003). Several studies have been done by many researchers to establish the utility of time-series MODIS composite vegetation index (VI) data for discriminating the crop types and extraction of crops planting area under different management practices (Sakamoto et al., 2006; Wardlow et al., 2007; Wardlow & Egbert, 2008) and monitoring general crop phenology (Sakamoto et al., 2005; Wardlow et al., 2006). Zhang et al. (2006) approached a new methodology of piecewise logistic model to show the qualitatively realistic spatial distribution of phenological metrics and cropping patterns in agricultural areas. Hmimina et al. (2013) investigated the potential use of MODIS 16 day's composite time series NDVI data for monitoring the seasonal dynamics of different types of vegetation cover that are representative of the major terrestrial biomes and showed that inflection points of a model fitted to a MODIS 16days composite NDVI time series allow accurate estimates of the onset of greenness and the onset of yellowing in deciduous forests. Wardlow et al. (2008) assessed the quantitative and qualitative assessment of large-area crop mapping using time-series MODIS 250 m NDVI data to evaluate the overall map quality and highlight the mapping accuracy. Due to medium to small size of crop land in West Bengal, the uses of medium or courser resolution of MODIS data for detail crop area extraction is most challenging work because of larger footprint. To overcome the situation, some researchers proposed the image fusion techniques for simulating the high spatio-temporal resolution images (Zhang et al., 2013, Huang et al., 2013).

The objective of the present study is to extraction of potato crop growing areas and to evaluate the spatio-temporal efficiency of MODIS NDVI time series data for detecting the agro-phenological crop pattern of potato.

II. MATERIALS AND METHODS

2.1 Study Area

In this section, the study was conducted over the potato bowl of west Bengal, one of the most productive potato growing regions in India, which consists of Hooghly, Paschim Medinipur, Bankura, Burdwan and a small part of Howrah district. The geographic extent varies from $21^0$48'02"N to $23^0$52'58"N latitude and $86^0$33'46"E to $88^0$30'24"E longitude, covering a total area of 27911 sq. Km. Out of the total geographical area 3426 sq km is forest and 17578 sq km is agricultural land (62.97% of geographic area) of which potato area covers 15.13% of agricultural. The most of potato growing area is under Gangetic plain region with nearly level to gently sloping and enriched by alluvial soil of river Ganga. The soils of the eastern part consist of deep alluvium while the western part of Burdwan, Bankura and Paschim Medinipur consist of red and lateritic soils, vindhyan alluvial soil and recent alluvium. In West Bengal, according to the local crop calendar potato crop is sown in the month of November as a main winter crop and harvested in the month of March. The average crop duration of the potato crop is 95-105 days. The climatic condition of this region varies mainly in tropical humid type and the average temperature from 12^0C to 32^0C during winter months. Supplementary irrigation is applied during this period due to low amount of rainfall for potato crop production.

2.2 Data Used

2.2.1 EO Data Used

In the present study, Terra MODIS NDVI product (MOD13Q1 V005) of 16-day composites with 250m spatial resolution, which were corrected through geometric correction, atmospheric calibration, and validated as well as quality assured through the EOS program of NASA (Huete et al., 2002, Justice et al., 2002). It was used to detect the spatio-temporal agro-phenological crop pattern of potato.

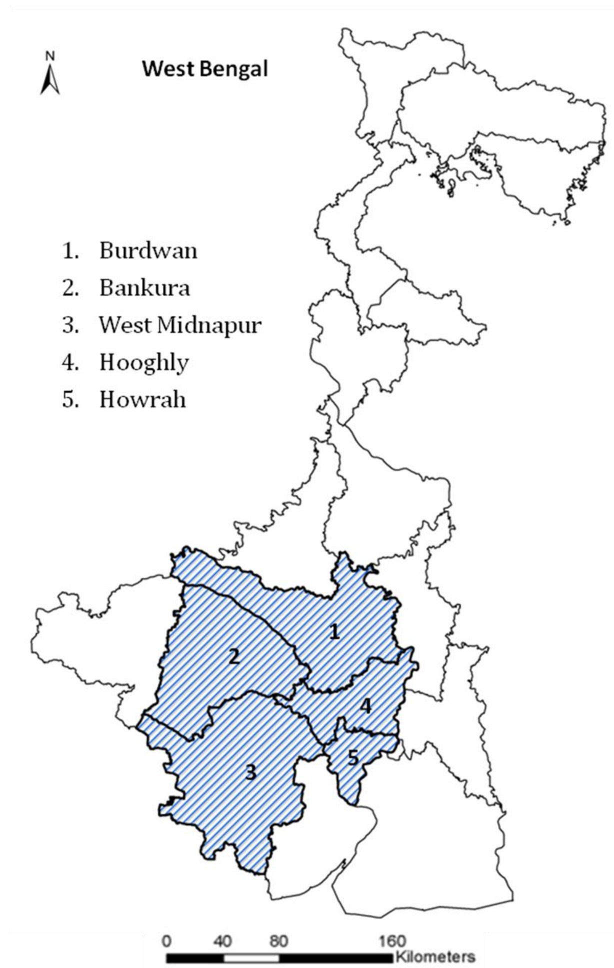

Figure-1: Study Area

2.2.2 Geographic Data Used

Various ancillary layers were generated in GIS environment for spatial analysis. These include administrative boundary, field surveying data and GPS points collected from potato fields. SOI toposheets in 1:50,000 scale was used for administrative boundary delineation. Altogether 269 GPS points collected from potato field were digitized and point layers were created along with attribute information.

Table-1: MODIS NDVI Product Details Used for the Study

Data Product	Path/Row	Date of Acquisition		Spatial Resolution
		2012-13	**2013-14**	
MODIS NDVI MOD13Q1 V005	h25/v06 h26/v06	November 29, 2012	November 29, 2013	250 m.
		December 15, 2012	December 15, 2013	
		January 01, 2013	January 01, 2014	
		January 17, 2013	January 17, 2014	
		February 02, 2013	February 02, 2014	
		February 18, 2013	February 18, 2014	
		March 06, 2013	March 06, 2014	

2.3 Methodology

2.3.1 MODIS Data Processing

The MODIS VI products obtained from Nasa Land Processes Distributed Active Archive Centre (*http://reverb.echo.nasa.gov*) was rescaled and re-projected from Sinusoidal projection to UTM system with WGS84 datum by using MODIS Conversion Toolkit (MCTK 2.0). The maximum value composite (MVC) of 16 days NDVI data was used to reduce cloud cover affect while maintaining temporal resolution for precise phenological estimates. As described by Huete et al. (2002) the MOD13Q1 NDVI values were constructed using the Constrained View Angle Maximum Value Composite (CV-AMVC) algorithm on a 16-day compositing period (see MOD13 V.05 user guide). The processed gridded data were joined to cover the entire study area and layer stacked.

2.3.2 Identification of Crop Phenology

The dynamic changes in crop growth life cycle can be characterized using their seasonal fluctuation in the NDVI time-series data. Temporal NDVI profile of any crop is characterized by one peak at the maximum vegetative stage. On annual cycle the number of crops in a given field will exhibit corresponding maxima. For example, if a cropland has a multiple cropping system, then the temporal NDVI should contain more than one NDVI maxima. The number of local maximum growth peaks are detected from the NDVI time series data which then used to investigate the number of cultivated crops in the particular cropland during the whole growing year. If we rearrange that maximum growth peaks in respect of time throughout the whole year, the local crop phenological calendar can be produced and it would be quite simple to identify the potato crop in respect of the crop season.

In the study area the potato is grown as asynchronized fashion depending upon the availability of water, cultivar and date of harvesting of kharif crop. Normally, the potato crop is sowed in last of November and achieves a maximum peak of growth in the last of January. The harvesting time of potato crops is last of February to early of March. On the other side, summer rice is planted in the month February in double cropped agricultural area. So January is the best time for distinguishing the potato crop from other crops.

Table-2: Potato Crop Phenological Calendar of the Study Area

Potato Phenology	November	December	January	February	March
Sowing Time	▬	▬			
Sprout Development	▬	▬			
Tuber Initiation Stage		▬	▬		
Tuber Bulking Stage			▬	▬	
Maturity Stage				▬	
Harvesting Time				▬	▬

2.3.3 Extraction of Crop Area

ISODATA clustering technique was used in ERDAS Imagine (ver. 9.0) image processing software to extract the crop pixels from non crop areas. Potato crop pixels were extracted from others based on NDVI threshold which is discussed later on.

2.3.4 Determining of Threshold Values and Implementation of Decision Tree Algorithm

Based on the cropping system and local crop calendar potato crop phenology was detected. Field survey data points were overlain on the extracted time series crop pixels and examined the potato crop phenology to eliminate the outliers. Based upon time series NDVI data and 269 field data points phonological profile of potato crop was generated. Based on lots of experiments, a threshold value was set to pick up the potato crop as well as to eliminate the other crops. An NDVI value > 0.31 at starting and 0.62 at peak of vegetation growth was considered to be a potato pixel. Based upon the NDVI threshold values, a decision tree classifier was developed to segregate the potato pixels.

2.3.5 Field Validation

Field validation was done based upon the GPS points collected from the field. GPS point data was collected from the potato fields using "Garmin eTrex Legend Cx" twelve channel GPS receiver. To understand the local crop calendar the GPS points were also collected from other crop area. The potato crop areas of the chosen fields were surveyed during field campaign from January 1st week to February 1st week. To segregate the potato crop area as well as differentiate of potato crop from other crop using the crop phenology those GPS points were utilized.

3. RESULT AND ANALYSIS

3.1 Potato Crop Phenology

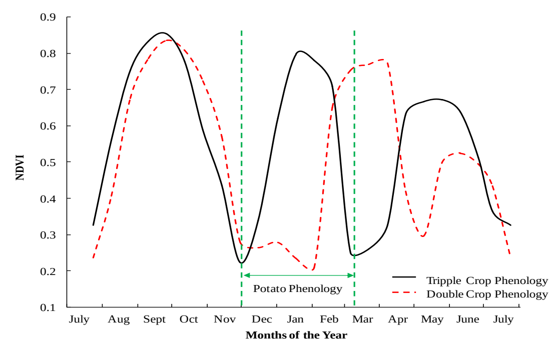

Figure-2: Phenological profiles of cropping patterns in the study area

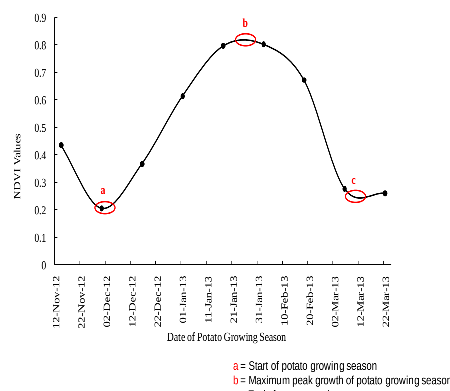

Figure-3: Potato Phenological Profile using

Fig. 2 shows the temporal NDVI pattern of the cropping systems (derived from MODIS NDVI data) throughout the years of the study. The signatures of abnormal pixels were eliminated. In the fig. 2 triple crop and double crop phenological profile were showed in smooth line and dotted line respectively. In triple cropped areas there are 3 peaks of different width and amplitude where first peak indicates the maximum tillering of kharif rice (aman paddy) which was cross checked according to the local crop calendar (July to November), the second and third maxima are due to potato and boro rice respectively in consecutive manner.

In double cropped areas there are two major NDVI maxima and two other secondary maxima. The first maxima matches well with triple cropped areas, but for the second crop there is a lag of about 2 months in comparison to the triple cropped areas signifying that the crop is not potato but summer rice. The same has been verified on the ground. Between 1st and 2nd maxima there is a small secondary maxima which could be due to grasses naturally grown in the fallow land under moist soil condition. The 2nd secondary maxima is attributed to fodder crop after harvesting of paddy. In fig. 3 Potato phonological curve was generated based upon the 269 field observations, the geographic coordinates of which has been overlaid on the NDVI profile and values were extracted and presented as an average value over the temporal scale.

3.2 Extraction of Potato Crop Area

Potato crop area was extracted based on the decision tree algorithm which was built using the threshold value of potato crops and knowledge of potato phenology. The district-wise extracted potato crop area based on MODIS NDVI time series data are given in table 3. Based upon the threshold NDVI total area under potato was estimated to be 2398.10 sq km. in the potato cropping year of 2012-13 whereas 592.96 sq km. (24.73%) in Burdwan, 319.61 sq km. (13.33%) in Bankura, 549.36 sq km (22.91%) in Paschim Medinipur, 875.22 sq km. (36.50%) in Hooghly and 60.94 sq km. (2.54%) in Howrah district respectively. In the potato cropping year of 2013-14 estimated potato crop area was 2622.90 sq km. in the total entire study area whereas the district wise estimated potato crop area ware 662.56 sq km. (25.26%), 341.06 sq km. (13.0%), 594.52 sq km. (2.66%), 950.89 sq km. (36.25%) and 73.88 sq km. (2.82%) in the districts of Burdwan, Bankura, Paschim Medinipur, Hooghly and Howrah respectively.

3.3 Spatial Pattern of Potato Crop area

The spatial distribution pattern of potato crop over the study area during 2012–2013 and 2013-14 is presented in Figure 4 and 5 respectively. The spatial distribution of potato growth is well related to the potato crop phenological profile. However, district-wise spatial variation of potato crop phenology is found to a little extent. In regional perspective Figure 4 represents spatio-temporal variability of crop growth due to asynchronous sowing. These figures represent geographically coherent patterns which are in corroboration with local crop calendar. It is also noted from the figure 4 greenness of potato crop started at the end of November till beginning of December in the northern part of Paschim Medinipur, south western part of Bankura, south eastern part of Burdwan and central part of Hooghly district. Later on progressive increase in potato area was observed in all the districts. In most of areas the phonological maxima is observed during the end of January till the beginning of February and the harvesting date is during the last week of February to early of March as is shown in figure 4. The spatial distribution matches well with field observations. However, some variabilities across different districts are noticeable which could be attributed to availability of optimum soil moisture, harvesting date of kharif crop and logistic supports.

3.4 Ground Validation

The Accuracy of the predicted potato crop area was assessed against the actual potato crop area in ground collected from the department of Agriculture, West Bengal. The district wise percentage of prediction errors are 4.18%, 21.61%, 6.26%, 12.61%, 21.67% in the districts of Burdwan, Bankura, Paschim Medinipur, Hooghly and Howrah respectively in the year of 2012-13 whereas in the cropping year of 2013-14 the errors of those respective districts was 14.59%, 14.74%, 3.02%, 4.75%, 2.63%. Results of the performance indicators used in the validation of predicted crop area in respect of ground data are provided in table 4. In the cropping year of 2012-13 and 2013-14 standard deviations is 306.23 and 332.60 whereas the error of standard deviations is 136.95 and 148.74. The correlation between predicted potato crop area and actual crop area revealed consistent similarity in both cropping years. In the 2012-13 cropping year RMSE error was 21.90 and mean bias error (MBE) was 19.85 whereas the percentage of MBE was 0.040 which indicated the tendency of overestimation. On the other hand, in the cropping year 2013-14 the RMSE was 22.90 whereas the percentage of

MBE was -0.024 which indicated that the predictions are smaller in value than observations.

Table-3: Comparison of Modelled Potato Crop Area with Ground Data

Districts	2012-13			2013-14		
	MODIS Data (Sq. Km.)	Ground Data (Sq. Km.)	Prediction Error (%)	MODIS Data (Sq. Km.)	Ground Data(Sq. Km.)	Prediction Error (%)
Burdwan	592.96	569.14	4.18	662.56	578.22	14.59
Bankura	319.61	262.81	21.61	341.06	297.25	14.74
Paschim Medinipur	549.36	586.07	6.26	594.52	613.01	3.02
Hooghly	875.22	1001.55	12.61	950.89	998.3	4.75
Howrah	60.94	77.8	21.67	73.88	75.87	2.63

Table-4: Statistical Validation and Performance Indicator

Cropping Year	Mean	Std. Dev.	Std. Dev. Error	r2	RMSE	MBE	MBE%
2012-13	479.62	306.23	136.95	0.975	21.90	19.85	0.040
2013-14	524.58	332.60	148.74	0.979	22.90	-12.05	-0.024

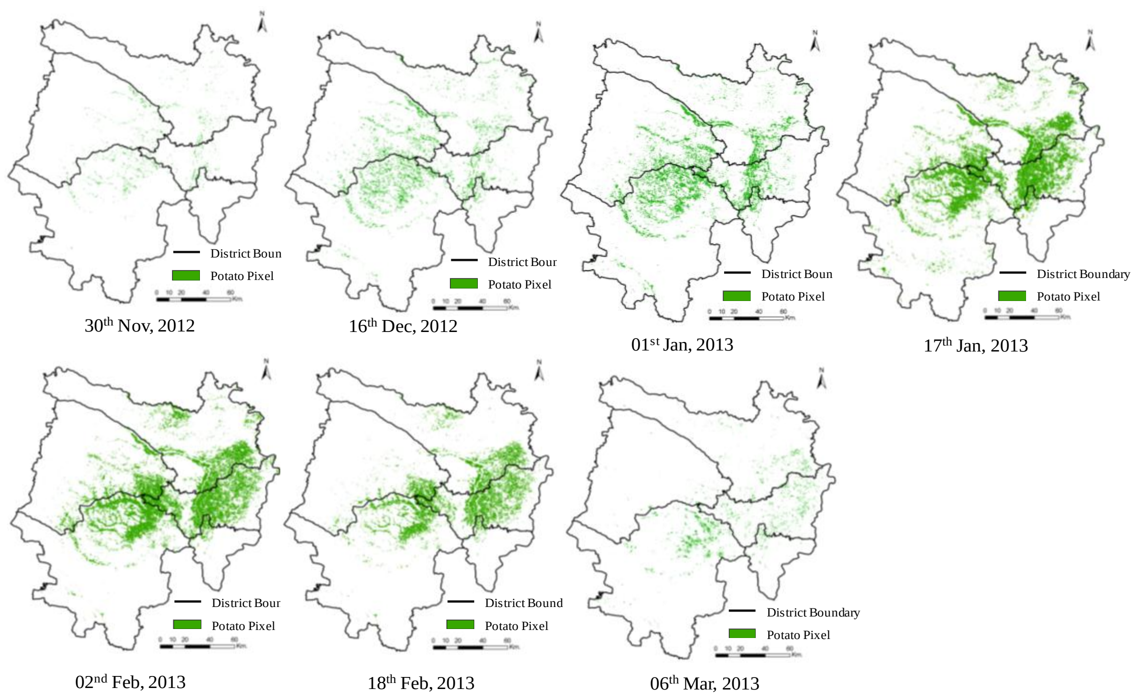

Figure- 4: Spatial Distribution of Potato Crop in 2012-13 from MODIS 250m NDVI Data

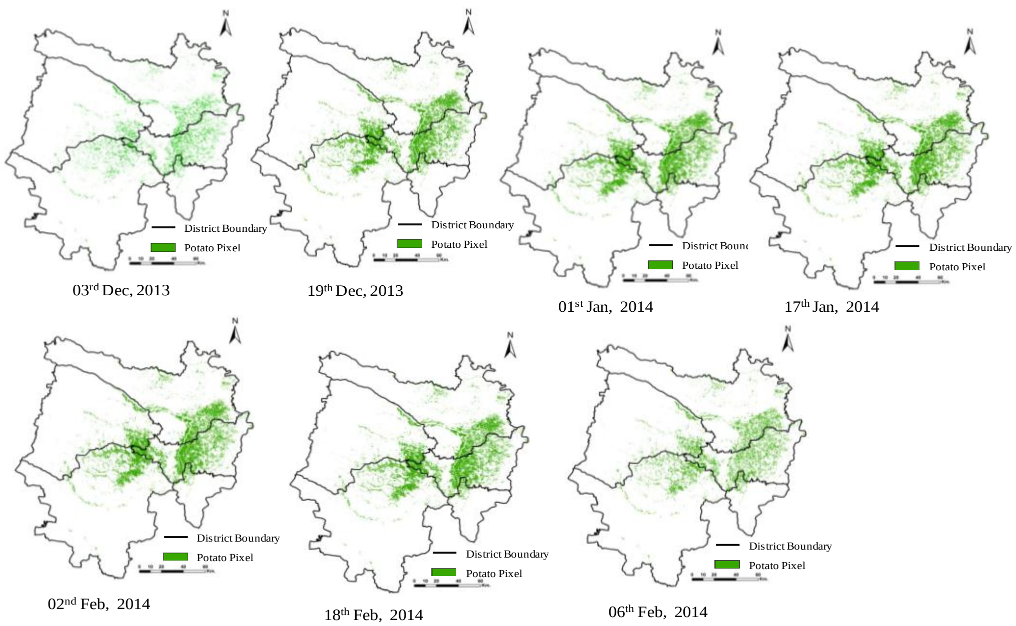

Figure- 5: Spatial Distribution of Potato Crop in 2013-14 from MODIS 250m

In the present study MODIS time series NDVI data was utilized to find out the spatial pattern of potato crop over 5 major potato producing districts of West Bengal. Based on the temporal pattern characteristics of the cropping systems and potato phenological profile, the spatial pattern of potato crop was successfully extracted. Compared MODIS NDVI derived data result with that of actual data, the extraction accuracy were satisfying. The best fit regression lines or predictive equations were found by comparing satellite derived data and ground data. The results also showed that MODIS NDVI satellite remote sensing data are the better choice to be used to measure the potato crop growing areas where the high resolution spatial and high repitivity temporal data is not available. Though, the spatial distribution of potato crop growth profile is well related with the potato crop phenological profile but in some districts spatial variation of potato crop phenology is found due to asynchronous sowing fashion depending upon the availability of water, cultivar and date of harvesting of kharif crop.

The study has been done for two potato growing season. The output results should be verified conducting further research studies considering several potato cultivation seasons in the potato bowl districts as well as in other potato growing areas of West Bengal. The output results would be more accurate if spatial and temporal high resolution satellite data could be used. In the present study several potato crop management factors like application of irrigation, doses of fertilizers, varieties of seed, tilling other several types of environmental factors, are not taken care. So, further study should be carried out with proper consideration of above mentioned factors.

ACKNOWLEDGEMENTS

Authors are thankful to RRSC-East/ISRO for providing the technical facility to carry out the study. We would also like to acknowledge State Agriculture Department Officials for providing the ground data, constant support and useful suggestions during the course of research.

REFERENCE

[1] A. Huete, K. Didan, T. Miura, E. Rodriguez, P. E, X. Gao, and L. G. Ferreira, *"Overview of the radiometric and biophysical performance of the MODIS vegetation indices"*, Remote Sensing of Environment, vol. 83, pp. 195–213, 2002.

[2] A. Chitradevi, S. Vijayalakshmi, "*Random Forest for Multitemporal and Multiscale Classification of Remote Sensing Satellite Imagery*", International Journal of Computer Sciences and Engineering, Vol. 4, Issue. 2, pp. 59-65, 2016.

[3] B.D. Wardlow, J.H. Kastens, S.L. Egbert, *"Using USDA crop progress data for the evaluation of greenup onset date calculated from MODIS 250-meter data"*, Photogrammetric Engineering and Remote Sensing, vol. 72, pp. 1225−1234, 2006.

[4] B.D. Wardlow, S.L. Egbert and J.H. Kastens, *"Analysis of time-series MODIS 250 m vegetation index data for crop classification in the US Central Great Plains"*, Remote Sensing of Environment, vol. 108, pp. 290−310, 2007.

[5] B.D. Wardlow and S.L. Egbert, *"Large-area crop mapping using time-series MODIS 250 m NDVI data: An assessment for the U.S. Central Great Plains"*, Remote Sens. Environ., vol. 112, no. 3, pp. 1096–1116, 2008.

[6] B. Huang, H. Zhang, H. Song, J. Wang and C. Song, *"fusion of remote-sensing imagery: generating simultaneously high-resolution synthetic spatial–temporal–spectral earth observations"*, Remote Sens. Lett., vol. 4, pp. 561–569, 2013.

[7] C.O. Justice, J.B.G. Townshend, E.F. Vermote, E. Masuoka, R.E. Wolfe, N. Saleous, D.P. Roy and J.T. Morisette, *"An overview of MODIS land data processing and product status"*, Remote Sens. Environ, vol. 83, pp. 3–15, 2002.

[8] G. Hmimina, E. Dufrêne, J.Y. Pontailler, N. Delpierre, M. Aubinet, B. Caquet, A. De Grandcourt, B. Burban, C. Flechard, A. Granier, P. Gross, B. Heinesch, B. Longdoz, C. Moureaux, J.M. Ourcival, S. Rambal, L. Saint André, and K. Soudani, *"Evaluation of the potential of MODIS satellite data to predict vegetation phenology in different biomes: An investigation using ground-based NDVI measurements"*, Remote Sens. Environ., vol. 132, pp. 145–158, 2013.

[9] H. Zhang, J. Chen, B. Huang, H. Song and Y. Li, *"Reconstructing seasonal variation of Landsat vegetation index related to leaf area index by fusing with MODIS data"*, IEEE J. Select. Topics Appl. Earth Observ. Remote Sens, vol. 1, pp. 1–11, 2013.

[10] M. Zhang, Z. Qin, X. Liu and S. Ustin, *"Detection of stress in tomatoes indiced by late blight disease in California, USA, using hyperspectral remote sensing"*, International Journal of Applied Earth Observation and Geoinformation, vol. 4, no. 4, pp. 295-310, 2003.

[11] Ramesh K.N, Meenavathi M.B, "*Agriculture Crop Area mapping in images acquired using Low Altitude Remote Sensing*", International Journal of Computer Sciences and Engineering, Vol.6, Issue. 1, pp. 55-62, 2018.

[12] T. Sakamoto, M. Yokozawa, H. Toritani, M. Shibayama, N. Ishitsuka, and H. Ohno, *"A crop phenology detection method using time-series MODIS data"*, Remote Sens. Environ., vol. 96, no. 3–4, pp. 366–374, 2005.

[13] T. Sakamoto, N. Van Nguyen, H. Ohno, N. Ishitsuka, and M. Yokozawa, *"Spatio-temporal distribution of rice phenology and cropping systems in the Mekong Delta with special reference to the seasonal water flow of the Mekong and Bassac rivers"*, Remote Sens. Environ., vol. 100, no. 1, pp. 1–16, 2006.

[14] W.B. Wu, P. Yang, H.J. Tang, Q.B. Zhou, Z.X. Chen, and R. Shibasaki, *"Characterizing Spatial Patterns of Phenology in Cropland of China Based on Remotely Sensed Data"*, Agric. Sci. China, vol. 9, no. 1, pp. 101–112, 2010.

[15] X. Zhang, M. A. Friedl, C. Schaaf, *"Global Vegetation Phenology from Moderate Resolution Imaging Spectroradiometer (MODIS): Evaluation of Global Patterns and Comparison with in situ Measurements"*, Journal of Geo-physical Research, vol. 111: G04017, 2006.

