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Temporal Monitoring of Monsoon Crop Using MODIS 16 Days Composite NDVI Data for Food Security

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Abstract

Bangladesh is an agricultural country and rice is our main crop. It has three types namely *Aus, Aman* and *Boro*. The area of *Aman* is (52.46%) higher than that of *Boro* (36.43%) and remaining are *Aus*. SPARRSO has been successfully monitored *Aman* and *Boro* rice for last two decades. Due to less percentage of *Aus* rice (Monsoon crop) area and planting time mostly in monsoon period no one has monitored it regularly. But accurate and timely information on *Aus* growth and their acreages are essential for strengthening countries food security. Conventional methods of collecting this information are relatively costly and time consuming. Contrarily, satellite observation with its unique capability to observe the earth's surface repeatedly over large area offers a potential means for country scale monitoring of crop condition. The optical remote sensing NOAA, Terra/Aqua, SPOT, Landsat images are not so enough for temporal monitoring of *Aus* rice due to cloud cover in monsoon period. RADARSAT data is very much useful for such purpose but data is not available as it is very expensive. So study of *Aus* rice monitoring using MODIS, 16-days composite, NDVI images at 250 m resolution may effectively use for such purpose. The study reveals that about 263011 hectare areas have been found in Barisal region under *Aus* rice cultivation in 2010.

Key words: Conventional, Satellite observation, MODIS, NDVI, RADARSAT

Introduction

In Bangladesh, rice occupies a very important position in maintaining food security of the country. It has three types namely *Aus, Aman* and *Boro*. The area of *Aman* rice (52.46%) is higher than that of *Boro* (36.43%) and remaining are *Aus* (BBS, 2010). *Aus* and *Aman* are rain fed and its production largely depends on southwest (SW) monsoon rainfall and *Boro* is irrigated. Extreme high rainfall in monsoon season come floods and lack of adequate rainfall causes droughts reduces the *Aus* rice production. Being a highly populated poor country, these damages render hardship and suffering to the people. Reliable and timely information on agricultural crops particularly of rice is an important input for the policy and decision makers dealing with the strategic planning for price fixing, procurement, storage, transportation, distribution of rice crops. Remote sensing technology has been successfully utilized for monitoring the *Aman* and *Boro* rice areas in Bangladesh Space Research and Remote Sensing Organization (SPARRSO) since long time. Due to less percentage of *Aus* rice area compare to *Aman* and *Boro* and planting time mostly in monsoon period no one has monitored it regularly. But accurate and timely information on *Aus* growth and their acreages are essential for strengthening countries food security. Timely availability of cloud-free satellite data is a major constraint particularly in monsoon season when the sky often remains overcast with cloud. The optical remote sensing National Oceanic Space Administration-Advanced Very High Resolution Radiometer (NOAA-AVHRR) and Terra/Aqua-MODIS raw images are not so enough for temporal monitoring of *Aman* rice due to cloud cover in monsoon period. Landsat and Satellite Pour l'Observation de la Terre (SPOT) data also not frequent enough for monitoring changes in crop parameters during the critical crop growth periods because data of these sensors have an interval of 16 and 26 days, respectively. RADARSAT data is very much useful for such purpose but data is not available as it is very expensive. So monitoring of *Aus* rice using Moderate Resolution Imaging Spectro-radiometer (MODIS), 16-day maximum-value composite, Normalized Difference Vegetation Index (NDVI) images at 250 m resolution is useful for such purpose. The underlying idea in adopting a 16-day compositing strategy is that, there is a good possibility of getting a cloud-free occasion in every 16 days time period in a particular season. Various studies have been performed on monitoring crops using MODIS maximum value composite time series data (Fensholt *et al*., 2005; Kevin *et al*., 2005; Pei *et al*., 2006; Rizzi *et al*., 2006, Sarker *et al*., 2007).

In the present research, an attempt has been made to construct the temporal and spatial growth profile of *Aus* rice 2010 over Barisal region of Bangladesh based on MODIS 16-day composites NDVI incorporate with Geographic Information System (GIS) and Global Positioning System (GPS). The temporal growth pattern is the growth curve of the crop representing the growth of crop in its full life cycle. The spatial growth pattern reveals the cropping practices of a particular crop in a specified area for a particular crop season. Masked layers of settlement, river and non-crop areas have been applied to composite NDVI images for generation of actual *Aus* rice plantation area.

Materials and Methods

Study area

The study area covers the Barisal region of Bangladesh extending from 23.10° N to 21.50° N latitudes and from 89.30° E to 90.35° E longitudes. It is South of Bangladesh and North of Bay of Bengal. Fig. 1 shows the study area in Bangladesh map in magenta color.

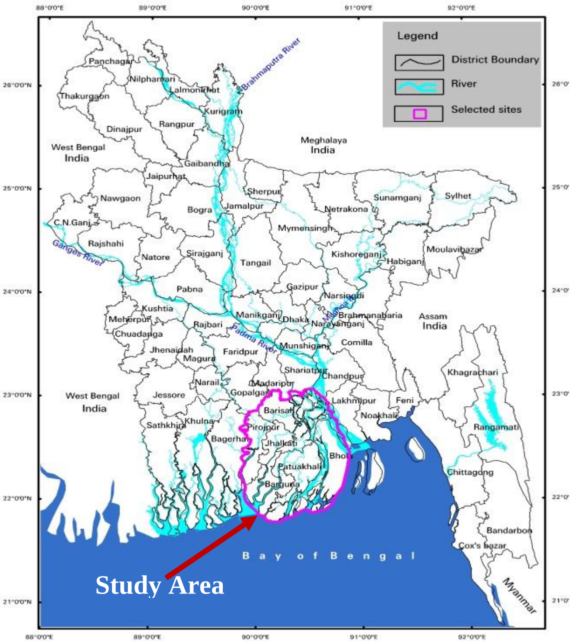

Fig. 1. Map of Bangladesh showing sixty-four districts as well as main rivers and selected study area

Data used

Terra-MODIS 16-day composite 250 m resolution NDVI data have been used during the period from late May to September for the year 2010. The composite data sets were Julian day129 for the time period May 8 to May 23, day 145 for May 24 to June 09, day 161 for June 10 to June 24, day 177 for June 25 to July 10, day 193 for July 11 July 27. Each data set contains two frames to cover Bangladesh. These frames are h 25 v 06 and h 26 v 06. Landsat-Thematic Mapper (TM) data for the year 2010 have been used for generation of forest, river and urban areas.

MODIS-16 day composite NDVI data

In the present study we have utilized the Normalized Difference Vegetation Index (NDVI), a commonly used band combination as follows (Tucker *et al.*, 2001; Goward *et al.*, 1985).

NDVI = $(P_{nir} – P_{vis})/(P_{nir} + P_{vis})$. Here $P_{nir} – P_{vis}$ are spectral responses of the pixel in near infrared and visible region of the solar spectrum corresponding to band 1 and band 2, respectively of Terra/Aqua-MODIS. The strong correlation of NDVI with vegetation characteristics is due to the near infrared radiation being strongly reflected by the green vegetation while the visible red radiation is strongly absorbed by chlorophyll pigment. NDVI has a range of –1.0 to + 1.0. Area without or with low vegetation cover (such as bare soil or urban area) as well as non-photo-synthetically active vegetation NDVI value is relatively less. NDVI values near zero or negatives are observed for clouds, shadows, snow and water. At the beginning of the growing season, NDVI values for the vegetation areas close to zero. The NDVI values increase gradually with the increase in the vegetation cover thus, observing changes in the NDVIs can monitor the development of vegetation during growing season. If there is a decline in the photosynthetic activity, the NDVI values will decrease accordingly. The underlying idea in adopting a MODIS 16-day composition NDVI strategy is that, there is a good possibility of getting a cloud-free occasion in every 16 days time period in a particular season.

Software used

- ERDAS 9.3 for image processing
- ArcGIS 9.1for GIS analysis
- MRT Swath and MODIS tool for Re-projection of MIDIS data

Crop and crop seasons

Bangladesh grows a wide variety of crops, which are broadly classified, according to seasons in which they are grown, into three categories, namely (a) *Kharif 1* (March 16 - May 15); (b) *Kharif 2* (May 16 - October 15) and (c) *Rabi* (October 16 to March 15) seasons. *Kharif* crops are grown in the spring or summer season and harvested in late summer or in early winter. *Kharif* crops include *Aus*, *Aman* and *Boro* rice. *Aus* rice is planted in April to May and harvest in July to August (BBS).

Procedure of data generation

Construction of temporal and spatial growth profiles of *Aus* rice involves pre-processing of MODIS data, generation of mask for settlement, rivers and non-crop areas, extraction of NDVI images of Bangladesh. Procedures are shown in Fig. 2.

Generation of NDVI image of Bangladesh

For temporal monitoring of *Aus* rice NDVI images of Bangladesh has been generated from MODIS 16-day composite 250m-resolution NDVI data during the period May to August for the year 2010.

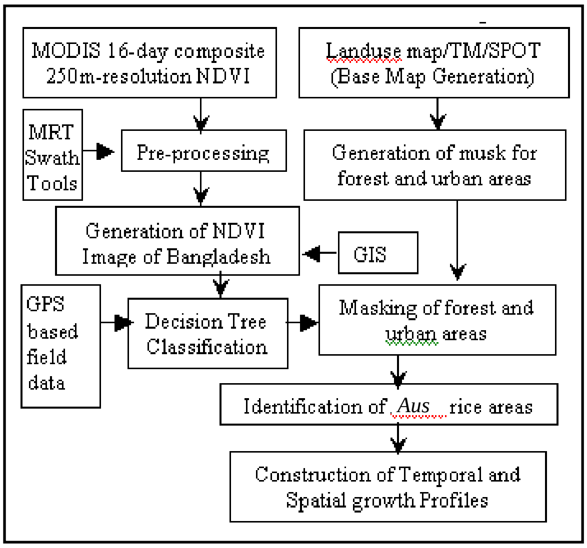

Fig. 2. Flow-chart of construction of temporal and spatial growth profiles

The data are normally in HDF format. It is not compatible in ERDAS imagine or ENVI software. So, MODIS Re-projection Tools (MRT) has been used for (i) separation of individual bands, (ii) convert HDF format to ERDAS format (TIF) as well as geo-referencing. In geo-referencing/re-sampling the following projection parameters have been used. Projection: Sinusoidal geographic, Spheroid: WGS 84; Datum: WGS 84; Radius of sphere: 6371007.18100 meters; Longitude of center of meridian: 0.00000 degree; False Easting: 0.00000 m; False Northing: 0.00000 m.

As mentioned in section data used that the data for Bangladesh has two frames. We made it in one by using mosaiced module in ERDAS software and also converted TIF format to IMG format during this option. Using International boundary of Bangladesh in GIS layer, the area has been extracted from the image. Subsequently study areas (Barisal region, Bangladesh) have been extracted from AOI layer of study area. Fig. 3a and 3b shows an example of extracted NDVI image of

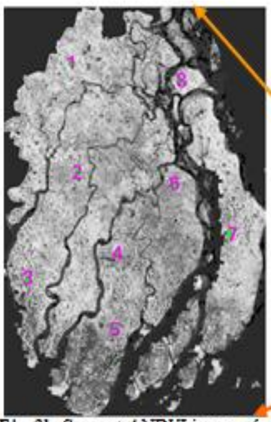

Fig. 3b. Generated NDVI image of Study area June 25, 2010 and eight selected sites

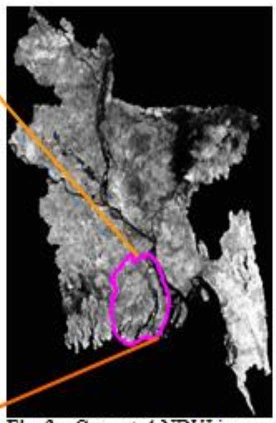

Fig. 3a. Generated NDVI image of Bangladesh, June 25, 2010

Bangladesh and selected study area June 25, 2010 image. Other images during *Aus* season of 2010 have also been generated in similar way. The generated NDVI time series images contain settlement, river and other non-crop areas also.

Generation of mask for settlement and non-crop areas

In some cases the response of settlement canopies and that of *Aus* rice were similar. In this case the settlement areas from MODIS data cannot be separated from the crop areas using digital classification technique. As settlement is generally a permanent feature, settlement areas were removed from the images using masks generated through digitization of high-resolution images (Landsat-TM with the ground resolution of 30 meter) and urban areas have been collected from database of SPARRSO.

Classification of Aus rice areas based on percentage of crop coverage in NDVI images

The objective of this classification is to generate classes of *Aus* rice having different percentage of crop coverage. Classification was carried out on the images on June 25, as the spectral response of *Aus* rice was maximum in these images and helped to identify the different classes easily.

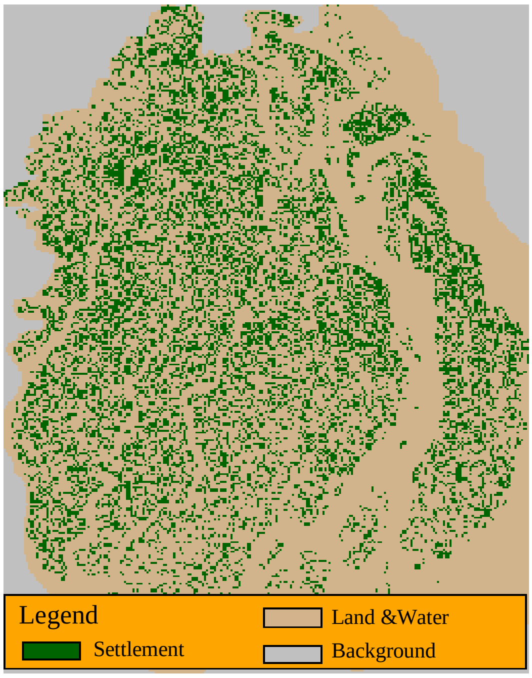

Fig. 4. Settlement mask layer of study area

A decision tree classification scheme was employed for the classification of *Aus* rice. The threshold value of each sample cluster in the NDVI images was determined from the knowledge of crop coverage obtained during GPS based field visit. The scheme was applied to the images after masking-out the settlement and other areas.

Principal chain of the decision tree contains three classes named water, bare soil/non-vegetation mixed area and *Aus* rice. The *Aus* rice is split into four classes and each contains different percentage of *Aus* rice coverage. Water area was separated very easily by the negative value of NDVI. The bare soil areas were also easily separated by the lower NDVI values (0.0 to 0.15). The remaining vegetation groups were identified by relatively higher values (>0.15) of NDVI. The higher the value of NDVI, the higher is the percentage coverage of green vegetation within the pixel. When the pixel has NDVI values higher than 0.75, the pixel is covered with *Aus* rice higher than 80%. When NDVI value is 0.15 to 0.4, the pixel covered *Aus* rice areas less than 40%. When value is 0.4 to 0.6, the pixel covered *Aus* rice areas between 40-60% and when NDVI value is 0.6 to 0.75, the pixel covered *Aus* rice areas between 60-80%. The different classes of *Aus* rice (*Aus1– Aus4*) obtained from the images of July 25 were used as masks for obtaining these classes in the other images in the time series. In this way, the classification of *Aus* rice having the same merit as obtains in July 25 images were transferred to images of other dates. Fig. 6a, 6b, and 6c shows the classified NDVI images of May 08, May 24, June 09, June 25, July 11 and July 27, respectively.

Generation of layer stack

In order to generate the temporal growth profiles during the period May 28 to September 1 based on MODIS 16-day composite NDVI, the NDVI

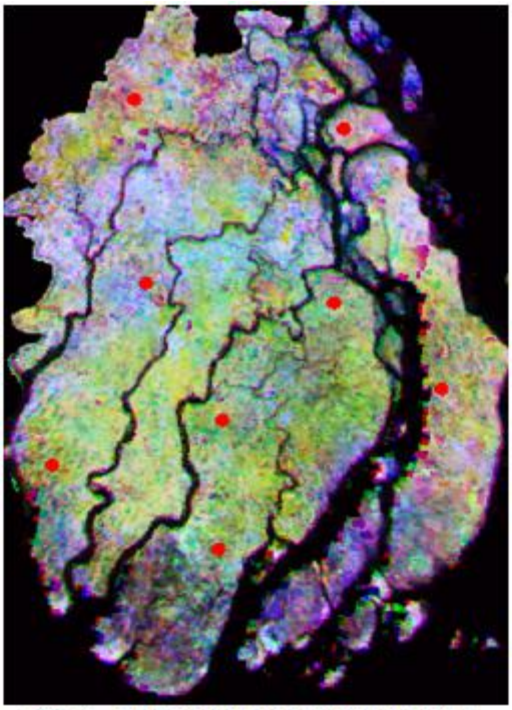

Fig. 5. FCC of layer stack of study area

images were stacked to form a data layer for the year 2010. The stacked images contain six NDVI images (May 08, May 24, June 09, June 25, July 11 and July 27) for the year 2010. Fig. 5 shows the False Color Composite (FCC) of layer stack.

Field data collection, verification and incorporation

To verify the classified image of 16 days composite NDVI of October 16 (maximum growing period), a field survey has been conducted. During field visit information aimed at accuracy of classified image of *Aus* rice areas based on percentage of crop coverage and also water class was collected. This was collected as a sample basis. During field visit Differential GPS have been carried out. The information of water areas was found in highly accurate and percentage of *Aus* rice areas was found little bit different. Differential GPS was used to collect field-wise information on crop/cover types. GPS coordinate of around 20 points of study area have been collected. After the fieldwork, field data have been incorporated into MODIS 16-day composite NDVI time series data according to information collected from field and for final analysis these were brought into ERDAS environments. Table 1 shows the *Aus* rice area of Barisal region in 2010.

Table 1. *Aus* rice area of Barisal region in 2010

Region	*Aus* rice area estimated from Images (hector)	*Aus* rice area collected from BBS (hector)	Different (%)
Barisal	263011	263765	0.26%

Bangladesh Bureau of Statistics, 2010

Generation of temporal crop growth profiles

Spectral profile generated from layer stacks throughout the season early May to late July for the year 2010. The spectral profiles have been taken according to the sites mentioned in Fig. 1. 3X3 window and mean value have been consider during the construction of spectral profiles derived from generated layer stacks (Fig. 5). In this way we can easily identify the increase and decrease of crop growth condition in a specified time over the study areas (Sarker *et al*. 2007).

Results and Discussion

Identification of the areas of Aus rice

Based on the classified NDVI images during May 28 to September 1, 2010 it is clearly seen in Fig. (6a-6c) that there are four crop classes according to percentage of crop coverage already described in data generation section. In the Fig. (6a-6c) dark green and blue color shows settlement mask/non-crop area and water, respectively. It is seen from the Fig. (6a-6c) that more percent of crop coverage appeared in June 25 (Fig. 6b) compare to other images. Red color shows percentage of crop coverage more i.e. greater that 80% crop coverage. Progressive increase of red color in Fig. (6a-6c) continued up to June 25 then gradually decreased

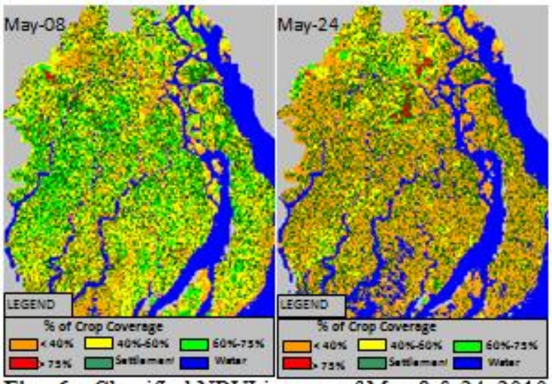

Fig. 6a. Classified NDVI images of May 8 & 24, 2010

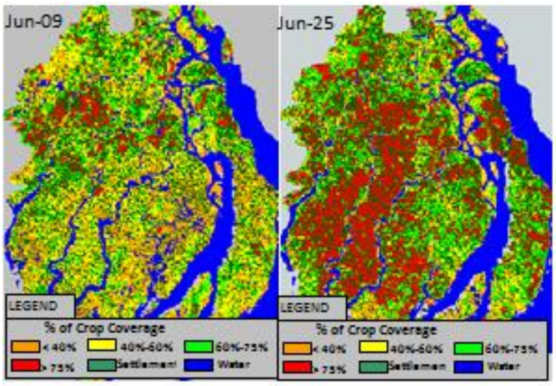

Fig. 6b. Classified NDVI images of Jun 9 & 25, 2010

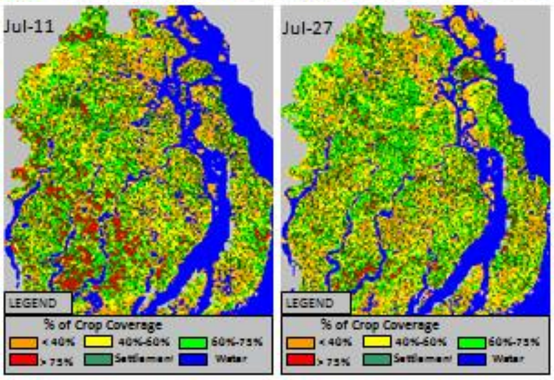

Fig. 6c. Classified NDVI images of July 11 & 27, 2010

in July due to ripening of *Aus* rice. It is seen from the image of July 25 that red color disappeared from most of the part of the image due to harvest of *Aus* rice but some part of the images shows red color due to newly growing of vegetation, these are also the area of *Aus* rice which are planted late.

Analysis of temporal and spatial growth profiles of Aus rice

For analysis of temporal and spatial growth profiles eight sites have been taken for number of sample clusters. These cluster masks were then used for obtaining mean NDVI value of each sample cluster in the NDVI time series data. Plotting the mean NDVI values of a sample cluster of the whole time series, the temporal growth pattern for the crops have been constructed. According to the procedure described earlier, each sample cluster for *Aus* rice represents a specific class of *Aus* rice based on percentage of crop coverage. Fig. 3b shows the site of each selected cluster. In this figure all the sites fall under the class of *Aus* rice except site 8. Site 8 contained settlement canopies shown in Fig. 7b (high resolution TM image).

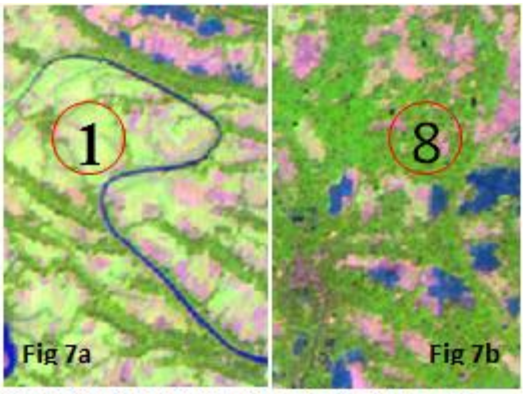

Fig. 7. Enlarge form of Landsat TM images showing *Aus* rice area in Fig. 7a of site 1 and settlement area in Fig. 7b of site 8.

Site 1 also shown in Fig. 7a as a sample of *Aus* rice site as well as *Boro* rice area. In sites 2, 3, 4, 5, 6 and 7 of Fig. 8 that, starting from 1st week of May (May 8), NDVI values decreased up to last week of May and then increased up to 1st week of July then gradually decreased up to July 27. Most of the sites, the magnitudes of the curves are higher in June 25 to July 11 indicating the *Aus* rice areas. This is the typical pattern of *Aus* rice in the context of Bangladesh. Some of the curves have lower magnitude during full growth period (June 25 to July 11) due to sparse *Aus* rice canopies. In site 1 starting from May 8 the curve gradually increased

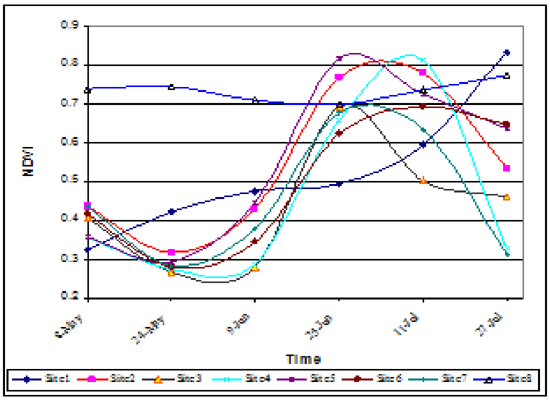

Fig. 8. Temporal growth profiles of *Aus* rice during the period (May to July 2010)

up to July 27. This site also *Aus* rice area but may have late plantation due to *Boro* rice some. Some of the fields of these regions have dual crops. Site 1 is one of them. In site 8, it is clearly seen that, NDVI values are almost similar and magnitudes of the curves are also same throughout the season. These are the permanent vegetation (homestead) area.

Conclusions

An attempt has been made in this study to characterize the temporal and spatial growth patterns of *Aus* rice in Bangladesh using MODIS, 16 days composite NDVI time series data for 2010. For temporal growth profiles, eight sites have been selected during the *Aus* rice period May 8 to July 27 for 2010. The study reveals that out of eight sites, five sites were found almost same magnitude of growth profiles during planting, growing and flowering stage of *Aus* rice. Only one site (i.e., site1) found late plantation and also late full growth stage due to plantation of *Aus* rice after harvested of *Boro* rice (Fig 7a). Field verification was conducted caring with differential GPS during full growth period of *Aus* rice. The field observation results verified with the office of Agriculture Extension and found the percentages of *Aus* rice coverage are almost 99% accurate. So it is evident that in absence of MODIS raw/optical data due to cloud in monsoon period or lack of microwave /RADARSAT data it may possible to monitor *Aus* rice using MODIS 16-day composites NDVI data.

Acknowledgements

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