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Hydrological environment and Boro rice cultivation in Bangladesh and Assam

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Abstract: In Bangladesh and Assam, rice is the main agricultural products for local farmers situated as both the countries in the Brahmaputra basin. Rice is traditionally cultivated in the rainy season, but frequent floods and droughts make its production unstable. Bangladesh successfully increased the cultivated area of Boro rice in the dry season which enables stable rice production. On the contrary, in Assam, the introduction of Boro rice is marginal, and they still depend on rainfed rice for their subsistence. This study aims to investigate the mechanism of the recent disparity of rice cropping system between Bangladesh and Assam by using the high-resolution surface water data. The results show that topography or soil condition may be responsible for the difference of surface water variation in post-flood season and Boro rice introduction in the dry season between the two regions. Boro rice area showed remarkable increase in some districts of Bangladesh where surface water was available after flood, but the amount of surface water in post flood season and the extent of increased Boro rice area in February did not match well. The water supply technology for Boro rice cultivation should be investigated to reveal the mechanism of Boro rice variation in the flood years.
Key words: Bangladesh, Assam, Boro rice, Irrigation, Flood, Surface water.

Introduction

The Brahmaputra is one of the biggest river during Monsoon in Asia with the river basin of 573,000 km^2 where total 80 million people live in. Its main stream and tributaries flow across four countries; China, Bhutan, India and Bangladesh, but most of the population live in the lower part of the basin; 31 million in India and 47 million in Bangladesh (Rahman and Varis, 2009). In those regions, low-lying floodplain topography and humid monsoon climate provide the suitable condition for rice cultivation which is the main occupation of rural people.

Rice is traditionally cultivated during the rainy season as summer monsoon rainfall and river water inundation bring water supply for its cultivation. In Bangladesh, Aman rice is the main crop which is transplanted in August and harvested in December (Johnson, 1982). Also in Assam, Sali rice is grown in the same season (Bhagabati *et al.*, 2001). Those rice are usually grown under the rain-fed condition without artificial irrigation, but the problem is they are vulnerable to floods in summer season (Mowla, 1972; Brammer, 1990). In the lower part of the Brahmaputra basin, both rainwater floods and river water floods frequently submerge paddy fields under water, and severe floods cause huge damage on rice production once in several years (Hofer and Messerli, 2006). Not only floods, but also drought can affect rice cultivation during rainy season when monsoon activity becomes weak.

In Bangladesh, however, the traditional rice cropping system shows drastic change in recent years (Fig. 1a); while the cultivated area of Aman rice remains same level, the cultivation area of Boro rice has rapidly increased during the last three decades. Boro rice is grown during December to May in the dry season with the constant supply of irrigation water. The influence of drought and flood on Boro rice is less. Now the double cropping of Aman rice in the rainy season and Boro rice in the dry season is common in Bangladesh, which makes annual rice production more stable than before.

Though the cultivated area of Boro rice increases year by year in Bangladesh, it rapidly increased in 1988, 1998 and 2007 when severe floods occurred in the whole country. The cultivated area of Boro rice can usually increase with the introduction of irrigation systems such as power pump and tube well. In the severe flood years, especially the cultivated area of high yielding varieties (HYVs) of Boro rice increased much, and its area exceeded more than the irrigated area for Boro rice (Fig. 1b). These statistics indicates that the local farmers cultivated HYV Boro rice in new fields without introducing any irrigation facilities.

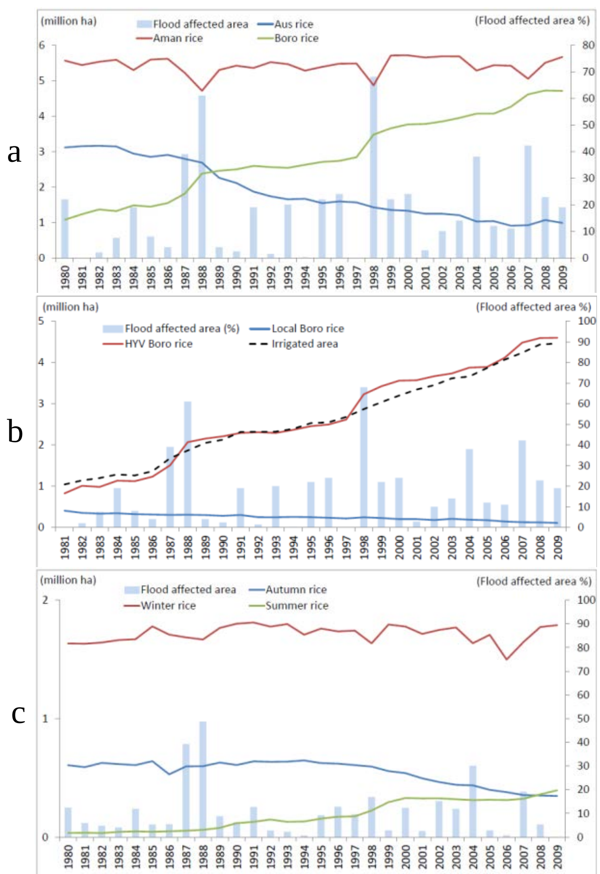

Fig. 1. Rice cultivated area (million hectare) and flood affected area (%) (a) in Bangladesh, (b) Boro rice area with irrigated area, (c) in Assam.

Why they could successfully increase the cultivated area of Boro rice without irrigation facilities after the severe flood? A hypothesis can be proposed for explaining the fact. The cultivation of Boro rice normally starts from December when the natural water is little available in fields. Water supply is the most limiting factor for Boro rice cultivation in the dry season. In flood years, residual water may be available in fields even after flood season, and farmers can increase the cultivated area of Boro rice by utilizing the residual water (Asada *et al*., 2005; Asada, 2012).

In Assam, on the other hand, the change of rice cropping system is relatively slow (Fig. 1c). Even in the severe flood years of 1988, 2004 and 2007, the introduction of Boro rice is very marginal. As the result, they still depend on Sali rice in the rainy season for most of the total production, though the cultivated area of Boro rice is slowly increasing. Unlike with Bangladesh, rice cropping system in Assam is still traditional with unstable annual production highly affected by flood and drought. Why they cannot increase the cultivated area of Boro rice drastically like Bangladesh? The second hypothesis is that residual water is not available in Assam after flood season and they must wait for irrigation facilities from government for increasing Boro rice area.

The information of surface water variation will be the key for solving the above questions in the lower Brahmaputra basin. This study aims to investigate the mechanism of the recent changes of rice cropping system in Bangladesh and Assam by using the high-resolution surface water data.

Materials and Methods

Land surface water coverage (LSWC) data was used in this study to investigate the seasonal and inter-annual variation of surface water. The daily LSWC was calculated in 10 km-grid resolution by combining the information from satellite-based sensors of MODIS and AMSR-E for the period from 2003 to 2010 (Takeuchi and Gonzalez, 2009). LSWC data is shown in percentage of water coverage in each grid. The grid-level data was converted into country (state)-level and district-level data to compare with statistics of rice cultivation. The number of districts used in this study is 20 in Bangladesh (excluding 3 districts in Chittagong Hill Tract in southeastern part of the country) and 23 in Assam.

The data of flood affected area in Bangladesh and Assam was obtained from Bangladesh Water Development Board (BWDB), Central Water Commission (CWC) in India, respectively. The data indicates the annual flood affected area in percentages of the total geographical area. An area to be included in the flood affected area needs only to be flooded once during the considered monsoon season (Chowdhury, 2003). It was used to define the severe flood years in each region.

The daily rainfall data was obtained from APHRODITE's Water Resources project (Asian Precipitation – Highly-Resolved Observational Data Integration towards Evaluation of Water Resources project, http://www.chikyu.ac.jp/precip/index.html). The 0.25-degree grid-level rainfall data sets were calculated primarily with data obtained from a rain-gauge observation network (Yatagai, 2012). The grid data was converted into district-level data.

The data of cultivated area and irrigated area of Aman, Sali and Boro rice in district level in Bangladesh and Assam were also collected from Agricultural Department of each government.

Results and Discussion

Hydrological condition of Bangladesh and Assam by LSWC data

LSWC data shows annual and seasonal variation of surface water, but the data contains all kinds of surface water including river channels, lakes, paddy fields and artificial canals. Therefore, anomaly value from 8-year average was considered for the analysis (Fig. 2). In severe flood years of 2004 and 2007, positive anomaly of LSWC is seen during rainy season both in Bangladesh and Assam. Negative anomaly of LSWC is seen in 2006 and 2009, which means drought condition due to weak monsoon activities.

a

b

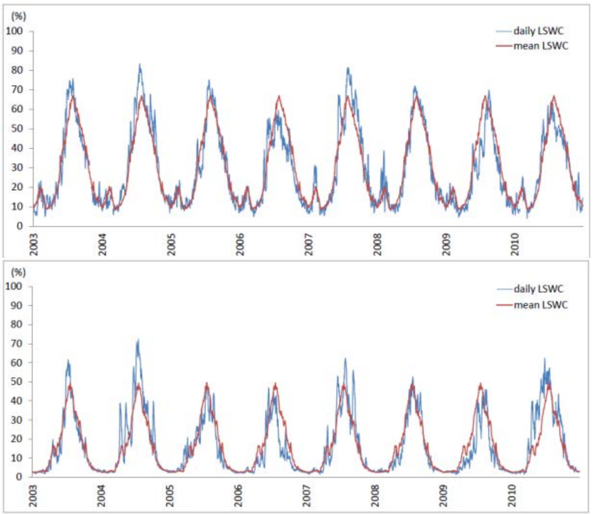

Fig. 2. Variation of LSWC in (a) Bangladesh and (b) Assam

When the positive anomaly of LSWC from June to September is compared with the flood affected area data for the period of 2003-2010, they show a good positive correlation (Fig. 3). In the years when positive anomaly is more, the flood affected area is more, and vice versa. Therefore, the positive anomaly of LSWC is used as a flood index in this study.

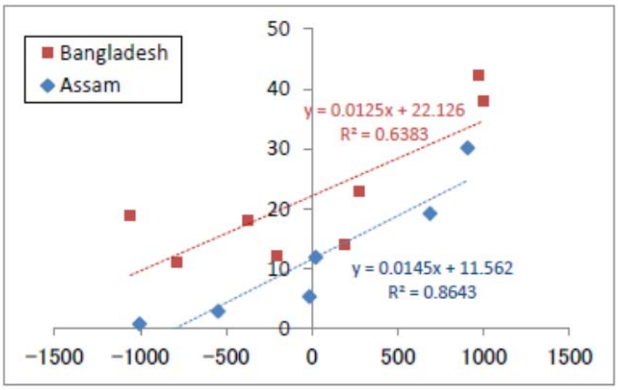

Fig. 3. LSWC anomaly during June-September (X) and Flood affected area (Y) for 2003-20010 in Bangladesh and Assam

Both in Bangladesh and Assam, LSWC value becomes larger in summer season and smaller in winter, which shows the seasonal variation of surface water associated with seasonal monsoon cycle. However, LSWC variation in Bangladesh shows a small peak in February, when neither rainfall nor river water inundation occur. The seasonal variation of mean LSWC in February seems to be related with Boro rice transplantation (Fig. 4). In many districts of Bangladesh, more LSWC increase from January to February means more Boro rice transplanted by supplying irrigation water. In the coastal districts and northeastern districts, however, LSWC in February does not correspond to Boro rice area. In Khulna and Patuakhali of the coastal districts, LSWC is high in February, but the Boro rice area is little. LSWC in the districts may not indicate the irrigation water for Boro cultivation, but the brackish water intrusion used for shrimp cultivation (Deb, 1998). In Sylhet and Kishoreganj of the northeastern Bangladesh, the surface water stays longer after flood season due to depressing topographical structure in the region (Johnson, 1982). Boro rice transplantation starts in the decreasing water condition from January to February without additional supply of irrigation water.

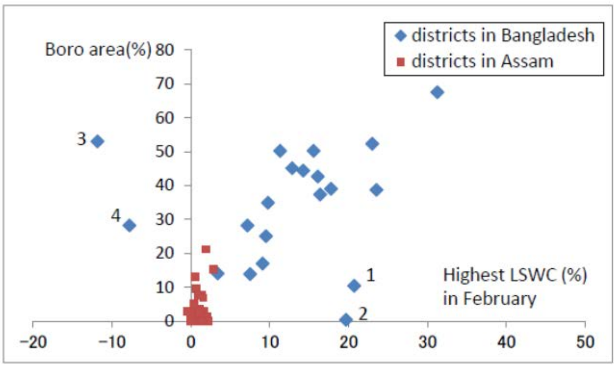

Fig. 4. The change of mean LSWC from value on 1st January to highest value in February (X) and Boro area (Y) in districts in Bangladesh and Assam. 1 Khulna district, 2 Patuakhali district, 3 Kishoreganj district, 4 Sylhet district

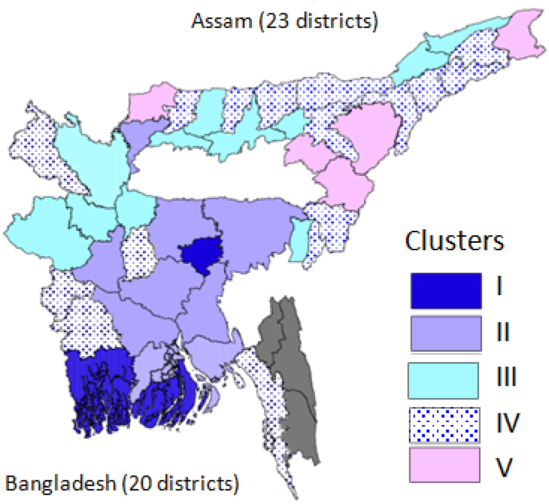

Fig. 5. Regional classifications by cluster analysis of mean LSWC variation

Regional classification by LSWC variation: Although Bangladesh and Assam are situated in the lower Brahmaputra floodplain and partly in the Ganges delta, the hydrological condition largely differs by district. Then, a regional classification was examined by cluster analysis for the 8-year mean LSWC variation of total 43 districts (Fig. 5). As the result, districts in Bangladesh and Assam were classified into 5 regions (Fig. 6).

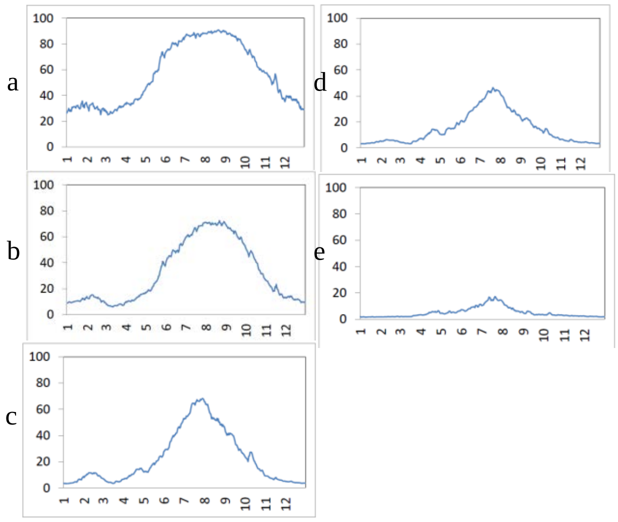

Fig. 6. Mean LSWC variation (%) in (a) Cluster I, (b) Cluster II, (c) Cluster III, (d) Cluster IV, (e) Cluster V.

Coastal districts and northeastern district in Bangladesh belong to Cluster I where the LSWC is higher throughout the year. LSWC exceeds 90 % in August and September, and does not fall below 20 % even in December. Districts in eastern Bangladesh belong to Cluster II with higher LSWC from June to October. Northwestern districts in Bangladesh and some districts in Assam belong to Cluster III with higher LSWC during shorter period in July and August. Districts in western Bangladesh and central-eastern Assam belong to Cluster IV where the LSWC is relatively less except for July. Hilly districts and the most upstream district in Assam belong to Cluster V where LSWC is little throughout the year. From the downstream (Cluster I) to the upstream (Cluster V) of the lower Brahmaputra basin, the surface water coverage gradually decreases which suggests the effect of basin scale topography.

Table 1. Characteristics of five clusters

Cluster	Annual rainfall	Irrigation (%) for Aman rice	Irrigation (%) for Boro rice	Boro rice area (%)
I	2126.0	0.8	147.4	21.7
II	2117.3	7.6	79.4	31.2
III	2122.5	4.8	30.1	20.8
IV	2019.8	10.4	31.3	12.7
V	2003.9	15.0	15.8	1.3

Characteristics of five clusters were summarized in Table 1. The variation of annual rainfall among five clusters is little, therefore, it can be said that the difference of mean LSWC variation by clusters is mainly attributed to topography or soil condition rather than rainfall amount. LSWC in rainy season is higher in Cluster I, II and III, but the irrigation for Aman rice cultivation during the season is little. This means LSWC in rainy season does not show the artificial water, but the natural water including river inundation and rain water. On the contrary, irrigation for Boro rice cultivation in dry season is higher in Cluster I, II, III and IV which indicates artificial water contributes to LSWC in the dry season, especially in February.

LSWC variation and Boro rice area in flood years

The influence of surface water on Boro rice area was examined in each cluster region. The accumulated anomaly of LSWC during June to September was used as the flood index, and top two flood years were selected for composite analysis in each district from 2003 to 2009.

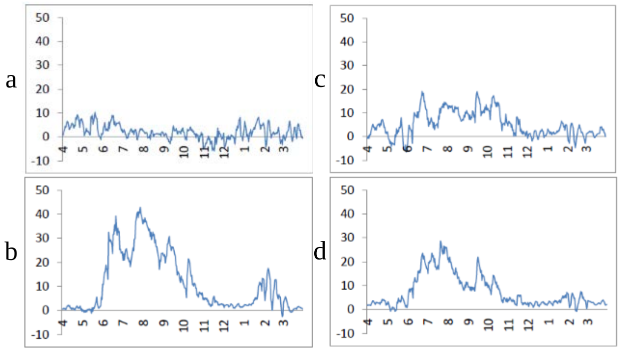

Fig. 7. LSWC anomaly (%) in flood years in Bangladesh. (a) Cluster I, (b) Cluster II, (c) Cluster III, (d) Cluster IV.

First, districts in Bangladesh were examined (Fig. 7). In districts of Cluster I, LSWC anomaly in flood years is positive during both flood season (June-September) and post flood season (October-January), but the anomaly is not large. In districts of Cluster II, III and IV, positive anomaly of LSWC continues in post flood season, which indicates the residual water after flood. Not only in districts of wetter region (Cluster II), but also in districts of drier region (Cluster IV), surface water is available after severe floods in Bangladesh. However, districts with more LSWC anomaly in post flood season do not always show the increase of Boro rice area (Fig. 9a). Districts with moderate amount of accumulated LSWC anomaly (500-700 %) show remarkable increase of Boro rice area, while districts with little LSWC anomaly (< 500 %) and too much LSWC (> 700 %) show little increase of Boro rice area.

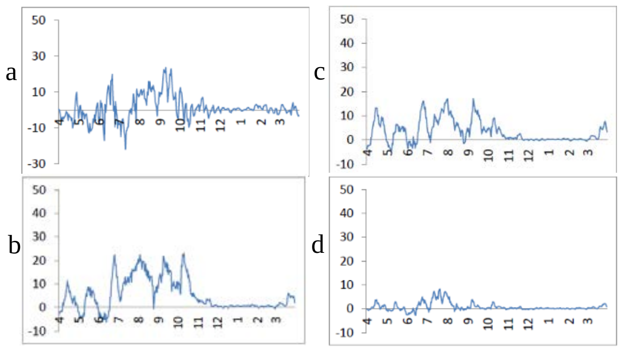

Fig. 8. LSWC anomaly (%) in flood years in Assam. (a) Cluster II, (b) Cluster III, (c) Cluster IV, (d) Cluster V.

Among districts with moderate amount of surface water during post flood season, increase of Boro rice area is not stable, but vary by district (Fig. 9a). Some districts show remarkable increase of Boro rice area, but other districts show only small increase of Boro rice even though the available amount of surface water is almost same. This suggests that the amount of surface water is not the only determining factor for increasing Boro rice area. The water utilizing technology and other social factors are also necessary for increasing Boro rice area in flood years.

In Assam, LSWC anomaly during June to September is relatively less, and it sometimes becomes negative even in flood years (Fig. 8). The positive anomaly of LSWC during post flood season is seen in districts of Cluster III and IV though the anomaly is much less than that in same clusters in Bangladesh. Therefore it can be considered that surface water cannot stay longer even in flood years due to topography or soil condition, and farmers cannot use flood water for Boro rice cultivation. In Assam, the accumulated anomaly of LSWC during post flood season is much less than that of Bangladesh (Fig. 9b), and the increase or decrease of Boro rice area is not related with the amount of surface water.

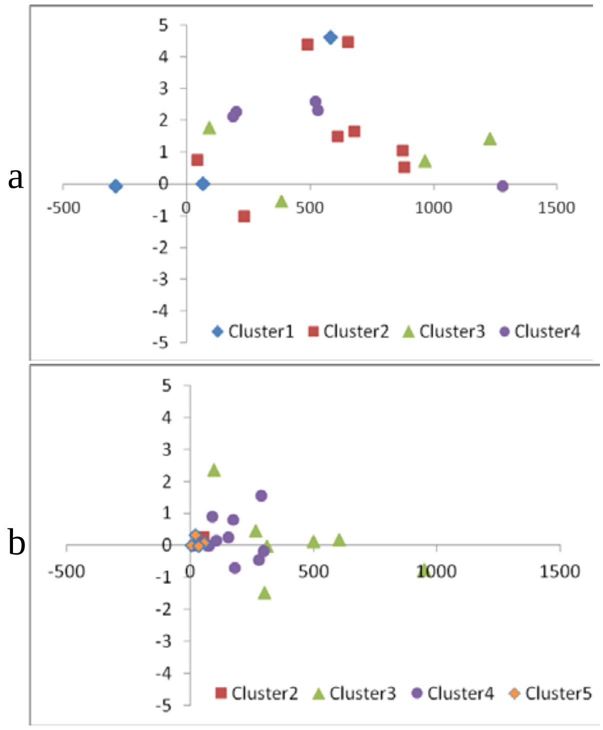

Fig. 9. LSWC anomaly during October to January (%) and Boro rice area change (%) in flood years. (a) Bangladesh, (b) Assam.

Conclusion

This study investigated the role of surface water for increasing Boro rice area in flood years in Bangladesh and Assam of the lower Brahmaputra basin by using the satellite-based LSWC data. The hypothesis that farmers used surface water after severe floods for Boro rice cultivation without introducing artificial irrigation was partly true in Bangladesh. In fact, the LSWC anomaly continued positive in October and November of post flood season, which could be utilized for increasing Boro rice area in some districts of Bangladesh. However, LSWC anomaly became almost zero in December and January and it again became positive in February of Boro rice transplanting season. This means farmers did not use residual water of floods directly for Boro rice cultivation as surface water almost disappears before transplanting season of Boro rice. Therefore, the water supplying technology for Boro rice cultivation should be investigated more to reveal the link between surface water during post flood season and field water used for Boro rice cultivation in February. The surface water is little seen after floods in many districts of Assam, and the Boro rice did not show significant increase like Bangladesh. Macro scale topography of the basin or soil condition may be responsible for the difference of surface water variation between Bangladesh and Assam.

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