TARGETING DISSEMINATION OF SUBMERGENCE TOLERANT RICE IN ASSAM, INDIA: A GEOMATICS APPROACH

D. D. Sinha (1), A. N. Singh (1), Tri D. Setiyono (2), and U. S. Singh (3)

[1]International Rice Research Institute (IRRI) - India Country Office, New Delhi 110 012
[2]International Rice Research Institute (IRRI) - Headquarters, Metro Manila 1301, Philippines
International Potato Center (CIP) – India Country Office, New Delhi 110 012
Email: d.sinha@irri.org, a.n.singh@irri.org, t.setiyono@irri.org, u.singh@cgiar.org

KEY WORDS: Radarsat-2, Flood-tolerant rice variety, Swarna-Sub1, NFSM, BGREI, STRASA

ABSTRACT: Assam, situated in the north-eastern region of India, covers an area of 78,438 sq. km. Rice occupies about two-third of the total cropped area in the state, and is grown in 2.47 million ha area during kharif (rainy) and rabi (summer) seasons. The 2.04 t/ha rice (paddy) productivity in Assam is below the national average of 3.29 t/ha of rice productivity of India, despite having good alluvial soils. Rice productivity in Assam is mainly constrained by the frequent spells of floods during kharif season. An estimated of 0.475 million ha (ca 19% of the net sown area) in the state is chronically flood-prone. Swarna Sub1, a flood-tolerant rice variety has been developed by the International Rice Research Institute (IRRI) by introduction of Sub1 gene in the parent variety Swarna, providing it submergence tolerance up to 15 days. The Government of Assam wanted to introduce this variety in the state in 2011. To facilitate effective dissemination of Swarna-Sub1 rice seeds, this study used remote sensing and GIS to identify villages experiencing flash food with maximum duration of 15 days. Such endeavor involved analysis of 21 flood-prone districts of Assam using flood inundation layer, based on Radarsat-2 multi-temporal data (C-band Synthetic Aperture Radar, SAR wide range at 100 m resolution with HH polarization; SAR narrow range at 50 m resolution; standard range at 25 m resolution). All available SAR data from 2007 to 2010 were used. The year-wise layers of different flood dates were digitized in ArcGIS and areas where flood water stagnated for 15 days or less in different flood cycles in a year were clipped. This process was repeated for all the four flood years and a merged data layer was created. The merged data layer was intersected with village administrative boundary and villages were selected. These selected villages represent the submergence areas of 15 days or less, recommended locations for dissemination of Sub1 rice variety seeds. A total of 6997 villages in 21 districts were identified for seed dissemination through an IRRI-implemented project- Stress Tolerant Rice for Farmers in Africa and South Asia (STRASA). Dissemination of Swarna-Sub1 seeds was carried out under the National Food Security Mission (NFSM) of the Government of India during 2011. In 2012, more seed multiplication was carried out and in 2013, about 30,000 ha was covered by Swarna-Sub1 in Assam. Following its success, Sub1 gene was introgressed into two most popular rice varieties of Assam-Ranjit and Bahadur. These varieties, Ranjit-Sub1 and Bahadur-Sub1, were released for cultivation in 2018. Sub1 rice varieties have now covered a significant area in Assam. This study demonstrated the use case of remote sensing and GIS technologies to target dissemination of flood-tolerant rice varieties with the ultimate goal of reducing vulnerability of rice farmers to flood-induced crop production loss and thereby increasing farmers' rice productivity and also helped farmers grow flood tolerant rice in those flooded areas where no crop could be taken otherwise.

1. INTRODUCTION

Assam, with a geographical area of 7.843 Mha and a population of 31.17 million (2011), is the largest among the seven northeastern states of India. Rice is grown on about 2.55 Mha (average of triennium ending 2011-12), and is the staple food of about 90% population of the state. The rice productivity of the state is below the national average (2.06t/ha compared to national 2.46 t/ha in 2012-13), despite having fertile alluvial soils and good rainfall conditions. This is due to the frequent spell of floods and sometimes occurrence of drought in the state. An estimated 0.5 Mha rice area in the state is chronically flood-prone and another 0.1 Mha drought-prone. Rice yield in the flood-prone ecosystem is low and crop failure is common due to abnormal flooding and uneven distribution of rainfall in this ecosystem.

In order to tackle the problem of submergence due to flash flooding, a submergence tolerant gene *SUB1* has recently been incorporated by IRRI in several popular rice varieties of South and Southeast Asia. These varieties can survive two weeks of complete submergence and still produce a high yield. In India, Swarna-Sub 1, the first variety with *SUB1* gene incorporated in the mega rice variety Swarna (MTU 7029), was released in the year 2009. Subsequently, Sambha Mahsuri-Sub1 was released by the State Variety Release Committee of Uttar Pradesh in 2013. Another

variety, IR64-Sub1 has been identified through All India Co-ordinated Rice Improvement Programme (AICRIP) for release, whereas Ciherang-Sub1 has been nominated for AICRIP testing. Few other popular rice varieties of the country with *SUB1* gene are also in the process of release. Swarna and IR-64 are popular rice varieties in several districts of Assam and Swarna- Sub1, IR-64 Sub1 and other Sub1 varieties can help in increasing rice productivity of the flood-prone areas of the state. IRRI has also taken a catalytic approach toward working with research institutions, government agencies, non-profit organizations, the public and private sector seed corporations and companies, as well as small seed growers in multiplying and disseminating seeds of this variety to farmers (IRRI, 2010).
Realizing the potential of Swarna-Sub1 and other Sub1 varieties in increasing rice production in the submergence-prone rice growing areas of eastern India and Andhra Pradesh, Govt. of India has been supporting their dissemination through National Food Security Mission (NFSM) and Bringing Green Revolution to Eastern India (BGREI) programmes by distributing seed minikits (5 kg seeds packets), and conducting large scale cluster demonstrations. In order to ensure that the seed distribution and cluster demonstration of Swarna- Sub1 and other Sub1 varieties, through NFSM, BGREI programme and other sources, are taken up only in the targeted environments where its full potential can be harnessed, the present study using satellite remote sensing technique was taken up to identify areas where submergence of about two weeks or less duration occurs. Werle et al. (2000) have used Radarsat Scan SAR data for flood damage mapping in Bangladesh. Brown *et al*. (1999) have used Radarsat data for flood monitoring in U.K., whereas Pradhan (2009) has developed a flood inundation model for Malaysia using Radarsat data. Flood risk zonation maps showing high, medium and low flood risk zones have also been made for Jagatsingpur and Puri districts of Orissa, India, using Radarsat data (Sinha *et al*, 2011). Targetted dissemination of submergence tolerant rice variety in flood-prone district of North Bihar has also been done. (Sinha *et al*, 2012).

1.1 Study Area And Environmental Conditions

The study area covers the 21 flood-prone districts of Assam viz., (Baksa, Barpeta, Bongaigaon, Cachar, Chirang, Darrang, Dhemaji, Dibrugarh, Golaghat, Goalpara, Hailakandi, Jorhat, Kamrup, Karimganj, Lakhimpur, Marigaon, Nagaon, Nalbari, Sibsagar, Sonitpur and Udalgiri) shown in Figure 1. The two main rivers viz., the Brahmaputra and the Barak flow through the state. The Brahmaputra valley occupies about 5.6 million ha while the Barak valley is about 0.7 million ha. The Brahmaputra valley is an alluvial plain having varying topography. The Barak River flows from east to west through undulating plains. There are two hill districts viz. Karbi Anglong and North Cachar Hills in the state occupying about 1.5 million ha. The hills constitute a part of the Barail and the Meghalaya ranges with maximum altitude of about 1000 m above mean sea level. Thus the state has three distinct physiographic units - the plains, the plateaus and the hills.

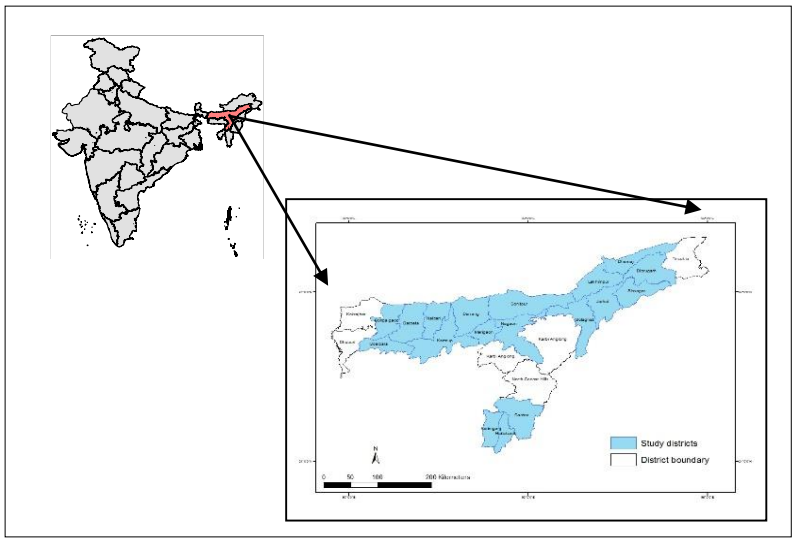

Figure 1. District-wise dissemination target of Sub1 rice varieties in Assam, India

The state has its climatic and physiographic features favorable for rice cultivation and the crop is grown in a wide range of agro-ecological situations. It is grown from hill slopes of Karbi- Anglong to very deep logged-water areas of North Lakhimpur and Dhemaji during very wet humid months to drier period of the year. Wide variation of physiographic features and climatic characteristics have resulted three distinct growing seasons of rice viz., ahu (Feb /March - June /July), sali (June /July - Nov /December) and boro (Nov /December -May /June). To match with diverse

land situations encountered with varying growing season, diverse varieties are traditionally grown in the state since unknown past.

1.2. Flooding And Submergence In Rice And Its Impact

Assam has a long recorded history of floods. The flood in Assam is caused by two major rivers- the mighty Brahmaputra in the north and Barak in the south. Flood in the state causes a huge destruction and loss to the economy, which is largely agrarian. A large extent of cropland is affected by floods in Assam. The crop area and number of farm families affected in recent years is provided in Table 1.

Table 1. Crop area and farm families affected due to flood in Assam (2007-13)

Year	Area affected (Mha)	No. Farm families affected (million)	Remarks
2007-08	0.455	1.577	
2008-09	0.315	0.756	
2009-10	NA	NA	Not a significant flood year. Some districts affected by drought.
2010-11	0.187	0.495	
2011-12	0.161	0.342	
2012-13	0.530	1.238	
NA- Data not available			

1.2 Characteristics Of Submergence-tolerant Rice Varieties

Following are some of the submergence-tolerant rice varieties with *SUB 1* gene, recently released/ under advance stage of testing in India, and their characteristics:

Swarna- Sub1 (IR 05F102), a rice variety developed by IRRI and released and notified by the Govt. of India for flash flood-prone areas of eastern India and other states in 2009, can tolerate complete submergence of about 14 to 17 days. This variety has all other characteristics of Swarna, except for the submergence tolerance and the lighter husk colour of its grain. Swarna is one of the most popular high yielding (4.5-7t/ha), long duration (155 days maturity) variety of India and is also grown in several areas of Assam. Swarna-Sub1 can be a good replacement in Swarna growing area, where flash flooding is a problem. On an average Swarna-Sub1 offers yield advantage of 1-2 t/ha over Swarna under flooded condition.

IR64-Sub1 (IR07F102), a variety in the process of release, is medium duration (125-130 days maturity) with long slender (fine) grain. IR64 is a popular variety in some districts of Assam and hence IR64-Sub1 can be good replacement in flood-prone areas of those districts. Potential yield is 4-4.5 t/ha.

Sambha Mahsuri-Sub1, a variety released for flood-prone areas of Uttar Pradesh and other states in 2013, is a semi-dwarf (82-85cm plant height), medium duration variety (145 days maturity) and has a fine grain quality. This variety has also all the characteristics of Sambha Mahsuri, a popular variety in several states of India and has the additional advantage of submergence tolerance of about two weeks. Potential yield is 5.5- 6 t/ha.

Ciherang- Sub1, a variety under advanced stage of testing in India and may be released soon, has submergence tolerance better than Swarna- Sub1 and Sambha-Sub1. The grain quality is fine and the yield is also high. Besides the above rice varieties.

1.3 Flood Frequency And Severity

Flood in Assam has been reported to increase after the 1950 earthquake which created extensive landslides in the adjoining hills and rise in the bed load of river Brahmaputra. Between 1951 to 2000, floods occurred in Assam in 1954, 1962, 1966, 1972, 1974, 1977, 1978, 1984, 1986, 1987, 1988, 1989, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999 and 2000 (source: www.aasc.gov.in). The number of villages affected by floods between 1982 to 1999 has been reported to exceed 5000 in 1987, 1988, 1991, 1993, 1996, 1997, 1998 and 1999. In the year 1988, about 8700 villages were affected by flood.

Floods in the state are caused by high rainfall occurring in the area and also due to water brought by the rivers from the upper catchments. Flooding and submergence of varying durations occur during the monsoon season. Flood can begin at the onset of monsoon in June to early October every year but the timing, severity and frequency vary from year to year. Moderate to severe flooding occurs every 2 to 3 years, even though mild flooding (for 2 to 3 days) is common every year (Deka and Gauchan, 2012). Depending on the severity, number of days of submergence and crop stage during the flood, there may be complete or partial loss of yield in rice.

2. MATERIALS AND METHODS

2.1 Data Used

i. Flood inundation layer, based on Radarsat-2 analysis from NRSC, Hyderabad
ii. Rice growing area map
iii. Assam State Administrative Atlas (Dept. of Census, Govt. of India), 2001

2.2 Methodology

All the available Radarsarsat-2 SAR-based flood maps for the study districts for 2007, 2008, 2009 and 2010 were downloaded from NRSC website and geo-referenced. For example, in the year 2008, available flood inundation layers were of 17 June, 30 June, 9 July,16 July,19 July,23 July,25 July, 2-4 Aug,8 Aug,9 Aug,12 Aug, 23 Aug,30 Aug and 2 Sep, 12Sep shown in Figure 1. In which the datasets are used for analysis are 23 July and 4 Aug. Since for the dissemination of Swarna Sub1 and other sub1 rice, the area selected should have a maximum water inundation period of 15 days or less, flood layer maps were accordingly selected and digitized for analysis. The flood layers used in analysis is given in Table 2. The flood layers of different dates have been digitized in ArcGIS 9.1. The methodology used in this study shown in Figure 3. During the analysis of these dates, the following three conditions of submergence were considered (Figure 4):

i) In some of the areas, water stagnation is seen on both the dates (23 July and 4 Aug 2008) i.e., more than 13 days of water stagnation but it is not exactly known as to when the water receded,
ii) water receded on 4 Aug i.e., water stagnation less than 13 days, and
iii) Some new areas where flood was not existing on 4 Aug but were flooded in between 12 Aug.

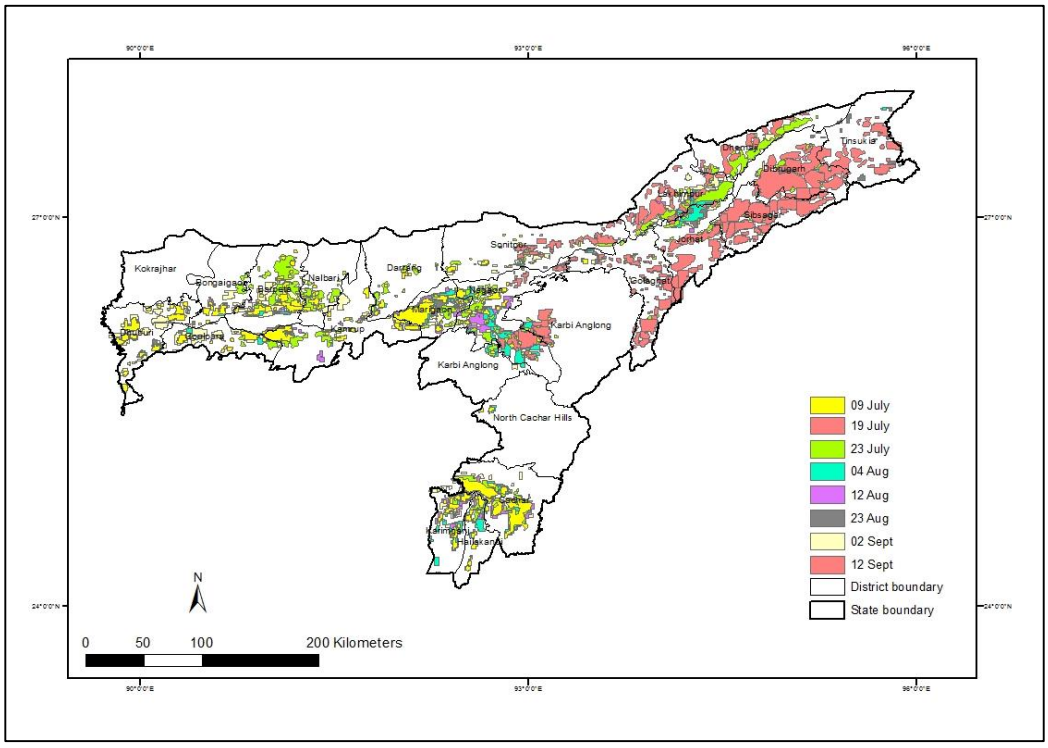

Figure 2. Flood area in Assam in 2018 delineated based on the dates of occurrence. Flood layer was derived from Radarsarsat-2 SAR data.

This process was repeated for every other datasets. The stagnation of water was different on different dates in the study districts and the dates for analysis were accordingly selected. Finally, all combinations of flood data sets (.shp) for the study districts were opened in one window to get those flooded areas where water stagnation was for 15 days

or less in a year. Since we have 4 consecutive year flood inundation data i.e., 2007, 2008, 2009 and 2010 these four year datasets were merged and final data base (.shp) were made. For Darrang district, the flood datasets of year 2007, 2008 and 2010 used.

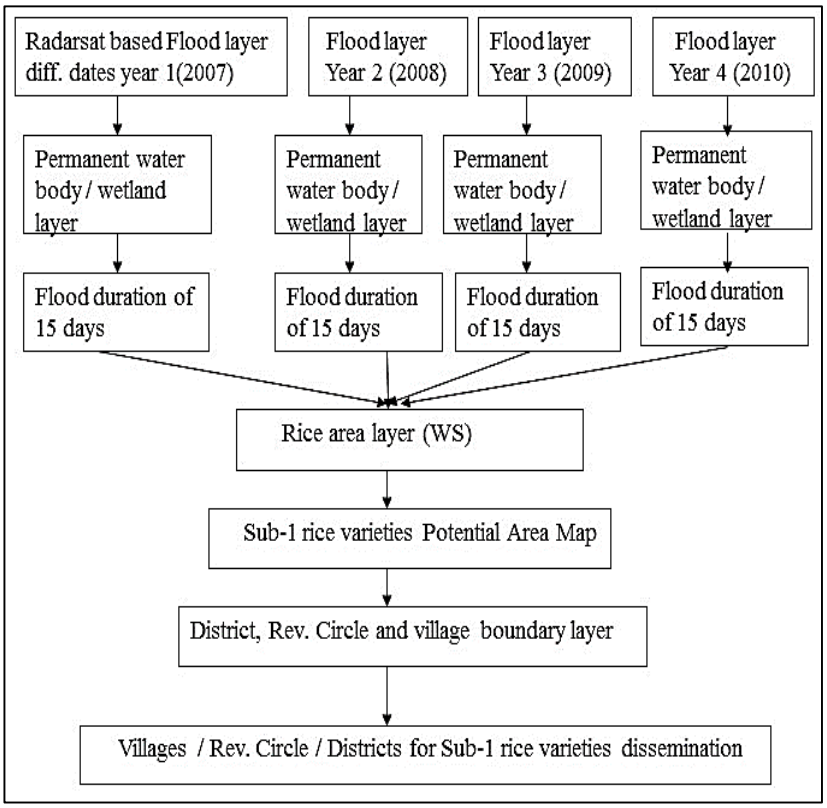

Figure 3. Flow chart of methodology for dissemination of Sub 1 rice varieties

2009 data not used due to data unavailability in the initial period and no flood on 31July and 19 Aug. However, for Sonitpur and Dhemaji districts, the flood datasets of year 2007, 2008, 2009 and 2010 used. In case of 2009, 1 July and 15 July data used. In case of district Lakhimpur the flood datasets of year 2007, 2008, 2009 and 2010 used. In case of 2009, 6 July and 15 July data used. In remaining 14 districts (Barpeta, Bongaigaon, Cachar, Dibrugarh,Golaghat, Goalpara, Hailakandi, Jorhat, Kamrup, Karimganj, Marigaon, Nagaon, Nalbari and Sibsagar), the available flood datasets of year 2007, 2008 and 2010 were used, along with 1 July and 15 July 2009. This gives us actual flooded area with stagnancy of water up to two weeks in the four years. For the village level information, maps of all the study districts were taken from the Administrative Atlas of the Directorate of Operations, Assam (Controller of Publications, 2007). These maps were scanned, geo-referenced. The flood inundation layer (.shp) and village layer (.shp) were brought in the same projection (Geographic lat/long) and overlaid in the same window to find out the villages with 15 days or less water stagnation. The villages having only small area (10% or less area) inundated were excluded from the final village data base (.shp). Using intersect (both .shp) command in Arc GIS, villages where submergence occurred for two weeks or slightly less were selected. The final selected submergence Revenue Circle (RC) boundary were overlaid onto *kharif* rice map (.img) taken from Gumma *et al*. (2011) to know whether rice is being cultivated in those villages. Ground truth data (GPS observation data) were also used for checking the accuracy of the final map.

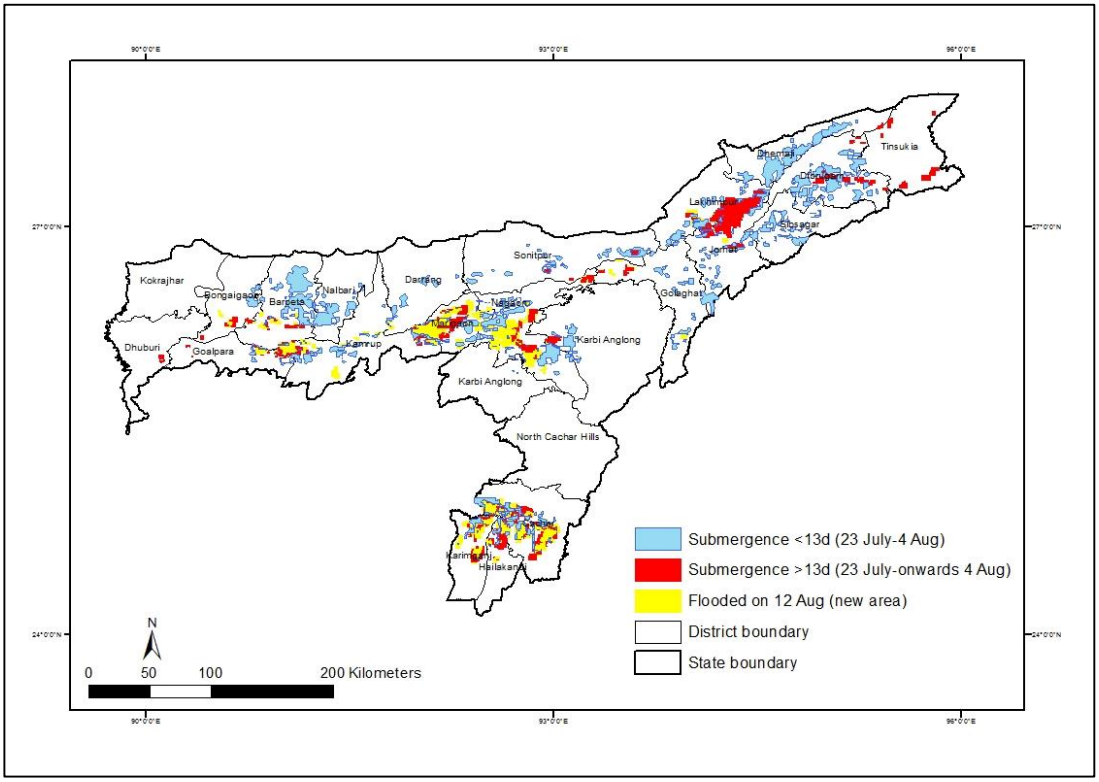

Figure 4. Flood area in Assam during 2018 delineated based on duration: either less or more than 13 days. Flood layer was derived from Radarsarsat-2 SAR data.

Table 2. Summary of available and analyzed flood datasets for Assam derived from Radarsat-2 SAR data

Year	Available Data	Data used in analysis
2007	22 July	22-July
	5 Aug	5-Aug
	15 Sep	
2008	17 June and 30 June	
	9 July, 16 July, 19 July, 23 July, 25 July	23-July
	2 Aug, 4 Aug, 8 Aug, 9 Aug,12 Aug, 23 Aug, and 30 Aug	2 Aug and 4 Aug
	2 Sep and 12 Sep	
2009	1 July, 6 July,8 July, 9 July, 11 July, 15 July and 31 July	1 July, 6 July, 15 Jul and 31 July
	2 Aug, 6 Aug, 16 Aug, 19 Aug and 28 Aug	19 Aug
2010	19 June, 21 June, 24 June and 29 June	
	1 July, 3 July, 8 July, 18 July, 20 July, 25 July,28 July and 31July	1 July and 20 July
	6 Aug,11 Aug,16 Aug,17 Aug,18 Aug, 20 Aug,23 Aug, 26 Aug and 29Aug	
	6 Sep and 11Sep	

3. RESULTS AND DISCUSSIONS

Flood layers based on Radarsat-2 SAR data have been used in identifying RC which get submerged for two weeks or less using the methodology described earlier. Based on the maps of 2007, 2008, 2009 and 2010 area where inundation occurred for 15 days or less has been prepared. Sub 1 rice varieties growing potential area map has been made and shown in Figure 5. However, the Figure 6 depicts the village boundary of Subansiri RC overlaid with submergence-prone area for Sub 1 rice varieties in Lakhimpur district. Subansiri RC for dissemination of submergence- tolerant rice variety (Sub 1) in Lakhimpur district is shown in Figure 7 as examples. The final output showing the number of RC and villages selected in the 21 districts for targeted dissemination is given in Table 3.

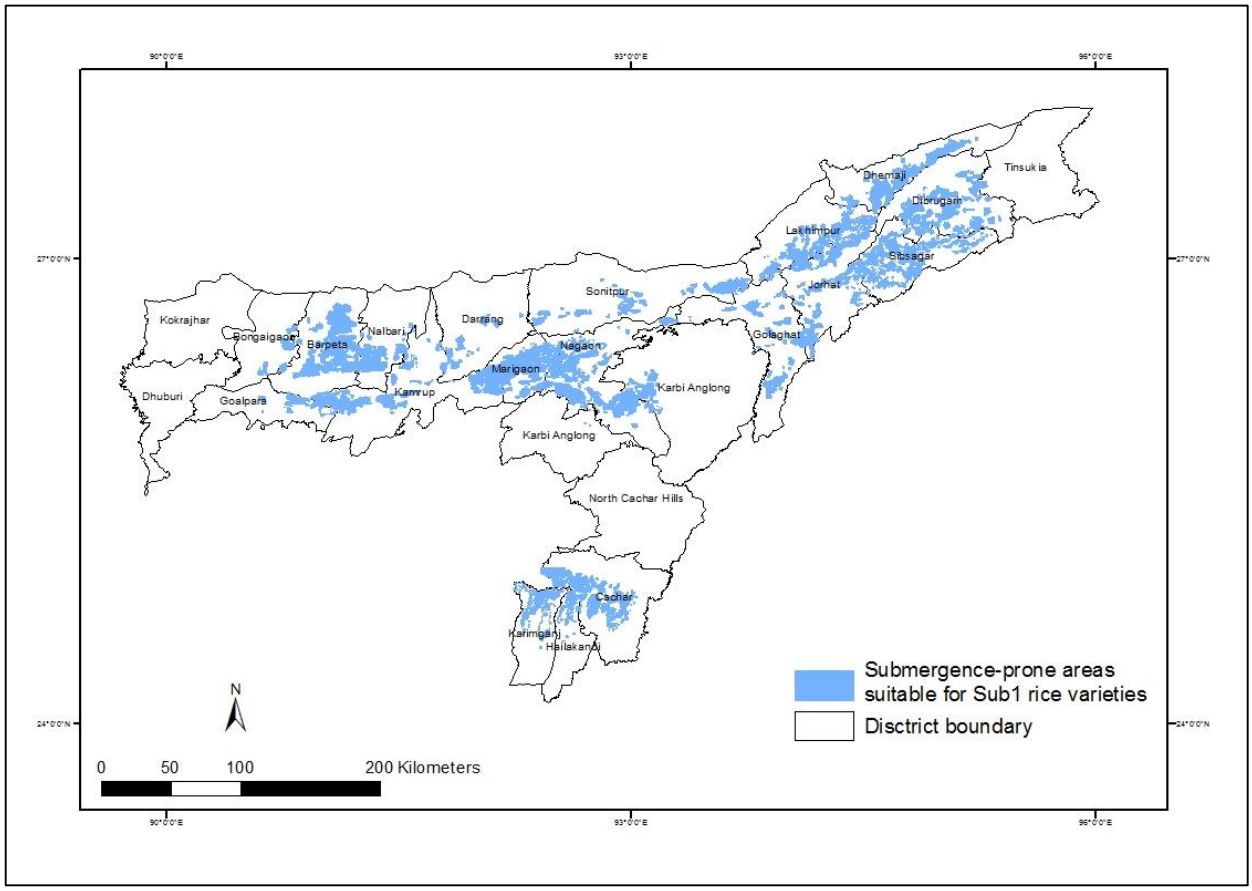

Figure 5. Submergence-prone areas suitable for targeted dissemination of Sub 1 rice varieties in study districts of Assam

A total of 6997 villages in 93 RC have been identified in the 21 study districts where Swarna Sub1 can be successfully grown (Table 3). A detailed RC list were also prepared for each block, which is not being presented here due to brevity. RC Bajali of district Barpeta, RC Goreswar and Rangia from district Kamrup now has been parts of newly formed district Baska. RC Barnagar of district Barpeta and RC Bijni from Bongaigaon now has been parts of newly formed district Chirang. RC Dalgaon, Mangaldoi and Pathorighat of district Darrang and RC Dhekaijuli of district Sonitpur now has been parts of newly formed district Udalgiri. RC Subansiri of district Dhemaji now has been part of Lakhimpur district and RC Dhakuakana of district Lakhimpur now has been part of Dhemaji.

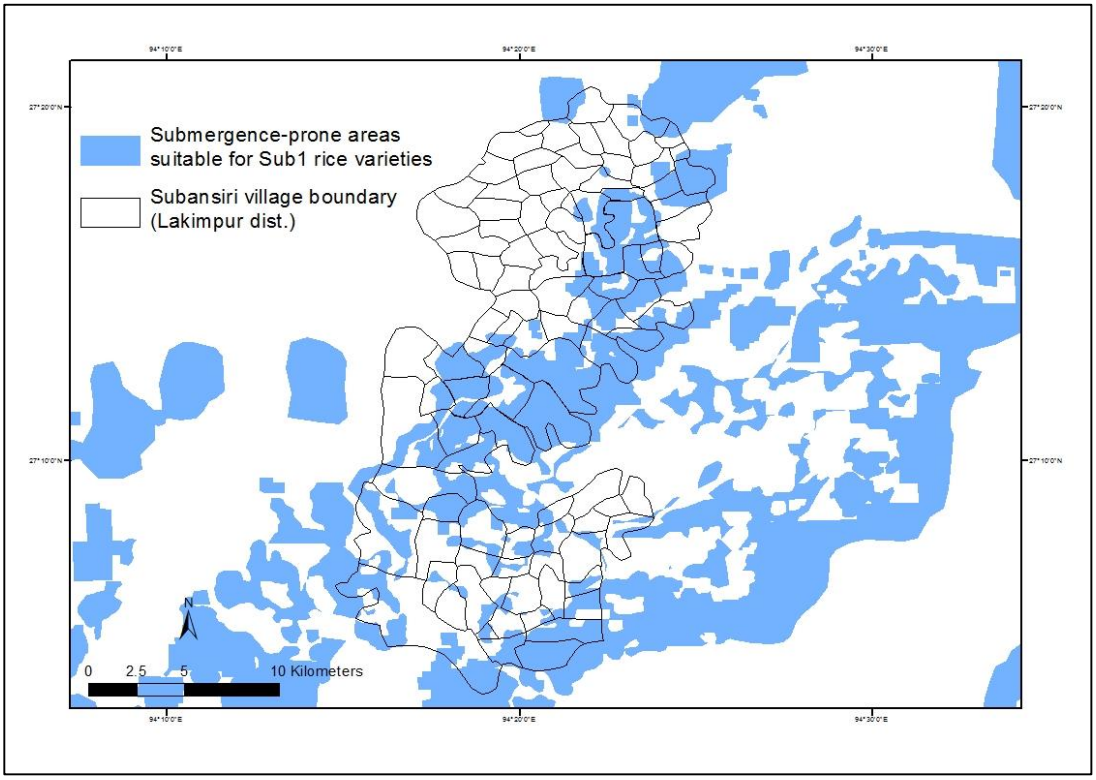

Figure 6. Village boundary overlaid with submergence-prone area suitable for Sub 1 rice varieties

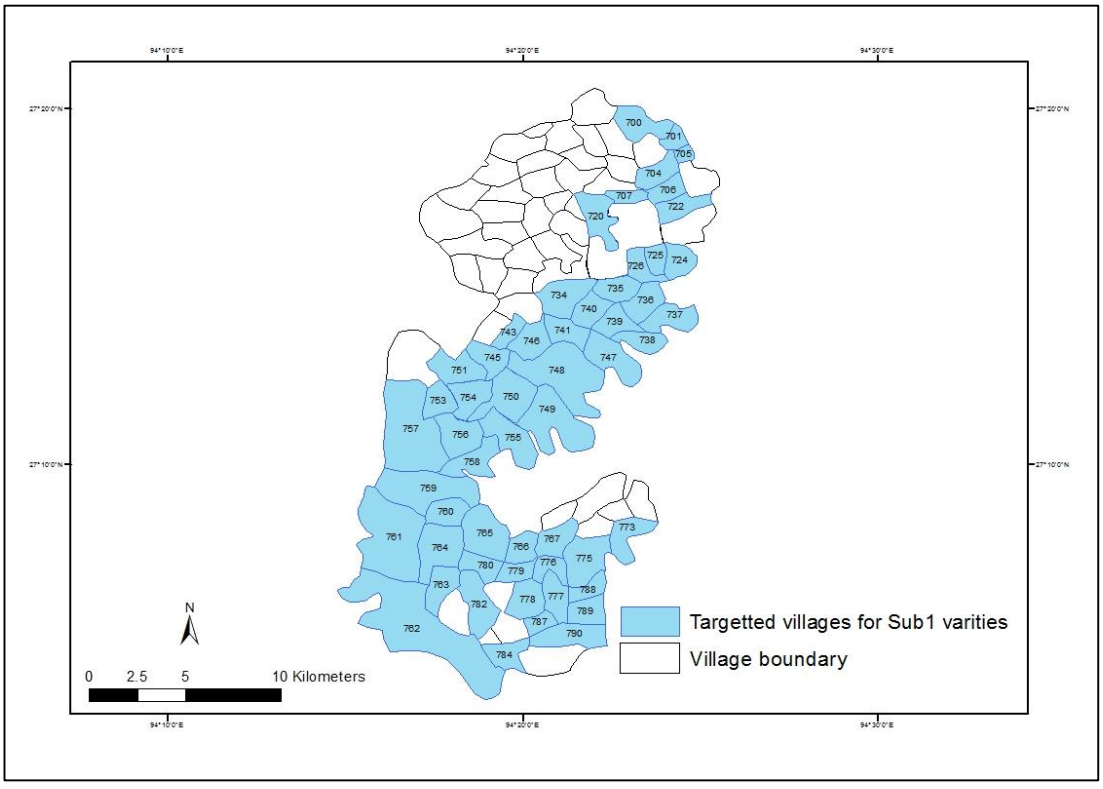

Figure 7. Depicts the villages for targeted dissemination for Sub 1 rice varieties in Subansiri RC, District Lakhimpur, Assam

Table 3. List of flood-affected villages suitable for dissemination of submergence-tolerant rice in Assam

District	Villages suitable for dissemination of submergence-tolerant rice
Barpeta	450
Bongaigaon	103
Cachar	459
Darrang	173
Dhemaji	475
Dibrugarh	744
Golaghat	163
Golapara	108
Hailakandi	99
Jorhat	436
Kamrup	451
Karimganj	405
Lakhimpur	580
Marigaon	479
Nagaon	618
Nalbari	87
Sibsagar	590
Sonitpur	577
Total	**6997**

4. CONCLUSION

IRRI and the Dept. of Agriculture and co-operation, Govt. of India are trying to disseminate submergence tolerant rice varieties in the flood-prone areas. Specifically, the target area must be within the criteria for potential survival of submergence tolerant rice which is submergence of for nor more than 13 days. This study successfully delineated such flood layer from Radarsat-2 SAR data and by overlaying the flood layer with administrative boundary of RC the study identified 6997 villages spread over 93 RC in 21 districts in Assam as suitable areas for dissemination of flood tolerant rice. Based on this study, dissemination of Swarna-Sub1 seed minikits were carried out under the National Food Security Mission (NFSM) of the Government of India during the years 2011 and 2012 in several identified RC of Assam. The dissemination of the variety has helped to grow rice even in some of those flooded areas where no crop could be taken earlier. It also helped farmers in getting much higher rice yield in the submergence-prone area. The present study has shown that remote sensing and GIS are helpful in large scale targeted dissemination of flood-tolerant rice varieties.

5. REFERENCES

Brown R E, Zmuda A D, Slates J, Corr D, Rast M and Stuttard M., 1999. Flood and soil moisture monitoring in the U.K. using Radarsat. Towards Digital Earth.Proceeding of the International symposium on Digital Earth.Science Press.pp. 1-7.

Controller of Publications, 2007. Administrative Atlas Assam, Census of India 2001. Controller of Publications, Delhi pp 656.

Gumma,M.K Nelson A, Thenkabil, P.S and Singh A N., 2011. Mapping rice areas of South Asia using MODIS multi-temporal data. J. Appl. Remote Sens. (5) 053547, pp. 1-26.

IRRI., 2010. Annual Report 2009. Los Benos (Philippines: International Rice Research Institute), pp. 36.

Pradhan Biswajeet., 2009. Effective flood monitoring system using GIS tools and remote sensing data. Applied Geoinformatics for society and Environment. Stuttgart Univ. of Applied Sciences. Pp. 63-71.

Sinha, D. D., Singh, A.N., and Singh, U.S., 2011. Targetted Dissemination of Submergence Tolerant Rice Variety and Flood Risk Zoning in Eastern India using Space Technology.National Symposium on Empowering Rural India through Space Technology Indian Society of Remote Sensing, Souvenir Nov. 9-11, Bhopal, India, pp. 84.

Sinha, D. D., Singh, A.N., and Singh, U.S., 2012. Targetted Dissemination of Submergence Tolerant Rice Variety in North Bihar using Remote Sensing and GIS. Proc. Regional conference on Geomatics in Disaster Risk Management: Special Reference to Eastern India. Indian Society of Geomatics, Feb. 23-24, 2012, T.M. University Bhagalpur, Bihar, India. Pp. 46.p

Werle D, Martin T C and Hasan K., 2000. Flood and coastal zone monitoring in Bangladesh with Radarsat Sensor. Technical Experience and Institutional Challenges. John Hopkins Apl. Technical Digest. 21(1). pp.148-154.

NRSC (www.nrsc.gov.in)