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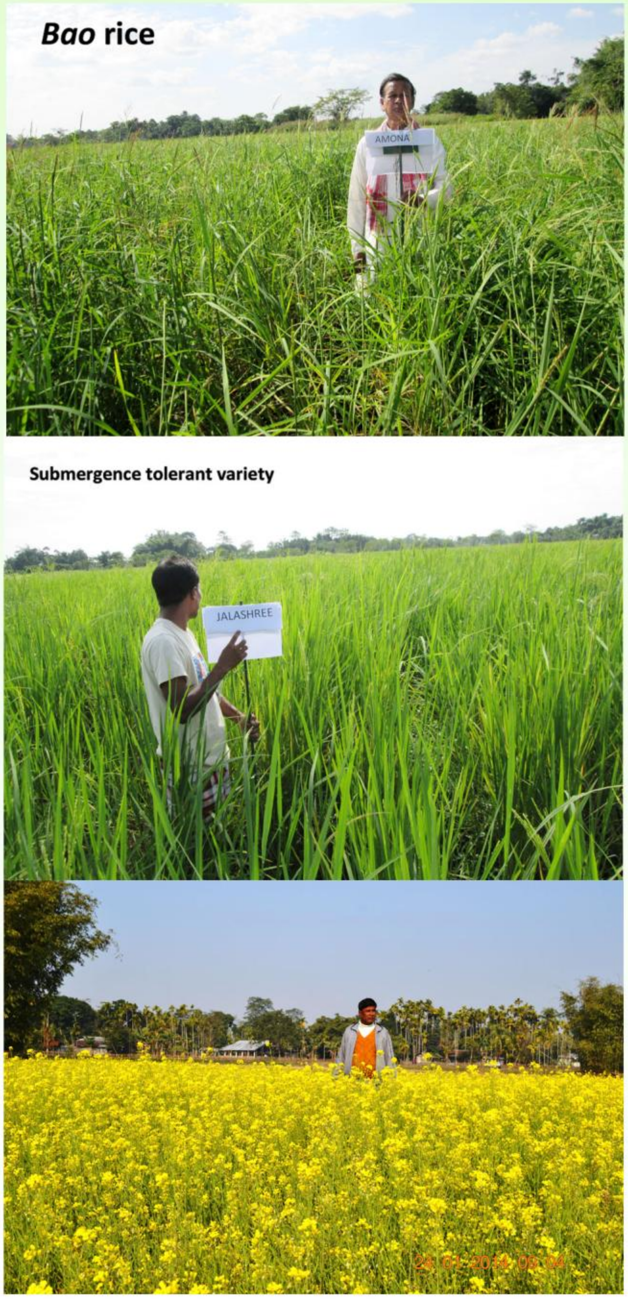
RESILIENT AGRICULTURE FOR FLASH FLOOD AFFECTED AREAS OF NORTH BANK PLAINS ZONE OF ASSAM



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National Initiative on Climate Resilient Agriculture
All India Coordinated Research Project for Dryland Agriculture
BN College of Agriculture, Assam Agricultural University
Biswanath Chariali-784176, Assam
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Resilient Agriculture for Flash Flood Affected Areas of North Bank Plains Zone of Assam

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1.0 INTRODUCTION

The economy of Assam is predominantly agrarian, where more than 87 percent of the population lives in the rural areas and this sector contributes 40% to the state GDP (Bhowmick *et al.*, 2005). The net cropped area of the state is 28.11 lakh hectares (35.85 percent of the geographical area of the state) with gross cropped area of 41.74 lakh hectares and cropping intensity of 148.51 percent. Rice dominates the agriculture scenario of the state which accounting nearly 60 percent of gross cropped area and 89 percent of net cropped area with annual production of 51.93 lakh tones (Anonymous, 2014). Among three types of rice grown in Assam, winter or *kharif* rice occupies 69 percent of the total area under rice and contributes 72 percent of total rice production (Deka and Neog, 2015). Rice is grown almost entirely as rainfed and availability of irrigation in the state is less than 10 percent of the total cropped area. Rainfed rice production of the state is adversely affected by several constrains including risks of weather like flood and drought. The flood is one of the major problems causing sluggish growth of agricultural sector in the state. Due to occurrence of high intensity-rainfall, the incidence of floods has been a typical in Assam, making the state highly vulnerable to risk and uncertainty. The multiple waves of flood during the monsoon season caused extensive damage not only to the standing rice crop but also caused permanent loss of areas due to heavy siltation. According to an estimate about 2.5 lakhs ha of rice fields are chronically, while about 1.0 lakh ha is occasionally affected by the floods. (Table 1:). Out of six agro-climatic zone of Assam, the maximum flood affected areas of 133, 000 ha (39% of total) are found in the north bank plains zone (NBPZ). Thus NBPZ of Assam is one of the most climatologically vulnerable agro- climatic zones due to its location in the eastern Himalayan periphery, fragile geo-environmental setting and economic under-development. The presence of network of Himalayan river system, heavy rainfall and soil erosion in upper catchment area in Arunachal hills, deposition of new alluvial soils in riverbed as well as in plains adds up the problems of flash flood in this zone.

Agro - climatic zones of Assam

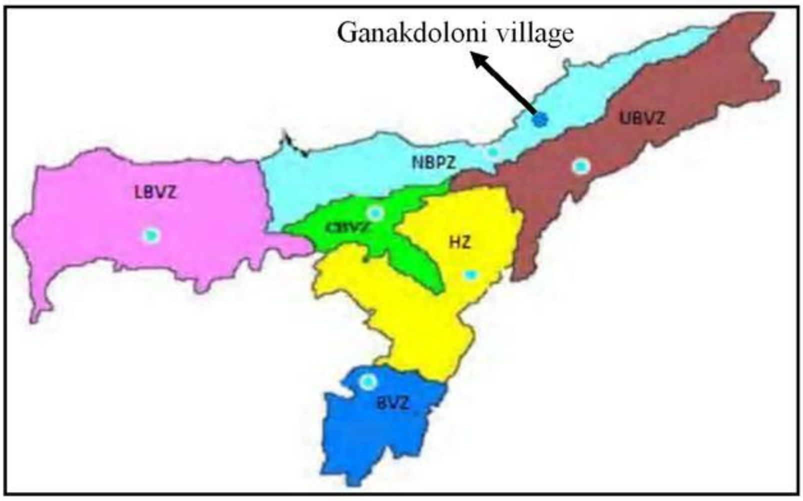

Table 1: Estimates of flood-prone area of Assam ('000 ha)

Agroclmatic zone	Net cropped area	Chronically flood prone area	Occasionally flood prone area	Total flood prone area	% to net cropped area
North bank plains (NBPZ)	470	93	40	133	28
Upper Brahmaputra Valley (UBVZ)	480	45	16	61	13
Central Brahmaputra Valley (CBVZ)	295	16	8	24	8
Lowe Brhmaputra Valley (LBVZ)	920	92	17	109	12
Barak Valley (BVZ)	247	4	10	14	6
Assam Total	2412	250	91	341	14

Source: *Hydrology and Groundwater Resource Development (1980)*

Climate crisis is perhaps one of the biggest challenges faced by humanity of today. The human induced climate change is likely to have an adverse impact on rice production in tropical countries, which is not only due to the direct effect of higher temperatures, but to problems associated with extreme weather events and sea-level rise such as drought, submergence and salinity (Wassmann *et al.*, 2009). The change in climatic variability in NE India is also already visible in terms of erratic behavior of rainfall like increased frequency of high intensity rains leading to localized flash flood, reduced number of rainy days, occurrence of mid season/terminal dry spells etc (Nath and Deka, 2010). From the study of long term (1901–2010) weather data, Deka *et al.*, (2015) reported significant decreasing trend of annual as well as monsoon rainfall in the Brahmaputra and Barak basin of Assam and significant decreasing trend of monsoon rainfall during the recent 30-year period was due to significant decrease of July and September rainfall. Recent rainfall fluctuations with larger amplitudes indicate greater degree of uncertainties of heavy floods or short spell drought events, which pose major challenges to agriculture, water and allied sectors in the near future (Deka *et al.*, 2013). Therefore, innate problem of monsoon flash flood and complete submergence of the rice fields in low laying areas in Assam (more particularly in NBPZ of Assam) will be aggravated due to increasing rainfall variability in future.

The predominantly small farmer-oriented monocrop farming in NBPZ of Assam is often affected by monsoon floods and the problem is likely to increase in future due to climate change. At the same time, same soils in flood affected areas become very dry during flood free months result in soil moisture stress. Though, rice research has helped to improve productivity in shallow low land areas, modern technologies have yet to make an impact in the flood prone areas. However, for overall increase in productivity and for building a climate resilient agriculture the thrust has to be on enhancing productivity in flood prone areas of Assam. Therefore, need of the hour is to grab the opportunities for increasing agricultural productivity in flash flood prone ecosystem of the region, which can be achieved through identifying, evolving and demonstrating appropriate climate resilient technology like flood escaping or flood tolerant cropping system or intensive crop production with irrigation in the flood free month. Though some flood resilient technologies have already been identified, many more have to be done for these vulnerable areas. Introduction of summer (*boro*) rice in the flood-prone areas of Assam has gained momentum and contributed tremendously to increasing rice production in flood affected areas (Talukdar and Deka, 2005), however, the technology is not well adopted in all vulnerable areas of Assam. For instance, the *boro* rice area in the perennial flood-prone district of Nagaon jumped from 5 percent in 1970s to the highest of 29% of total rice area in the 1990s; however, in case of Lakhimpur district same was from less than 1% to 13% (Bhowmick *et al.*, 2005). As *boro* rice cultivation needs intensive irrigation result in higher cost of cultivation. The Higher cost of cultivation is not affordable to the small and marginal farmers of flood affected areas of NBPZ of Assam leading to low adoption of the technology.

Submergence creates the damages to rice plants as consequence of slow rates of gas exchange, severe shading by turbid water, mechanical damages due to strong flow rates and solute carrying capacity of flooded water (Michael and Phool, 2001). In flash flood affected areas of NBPZ, flash floods causing submerges to the standing rice crop for 7-15 days at a stretch, resulting in decrease in yield or even mortality of the rice crop. To overcome this problem, submergence tolerance rice varieties can be introduced. But, the limitation of these varieties is that they can tolerate submerge up to 15 days, that is up to tillering stage of the crop. Moreover, submergence depth influences the performance of these varieties. The higher submergence depth adds more stress to the rice plants which adversely affect the performance of these varieties. Therefore, performance of the submergence tolerance rice varieties for different locations of NBPZ of Assam is needs to be evaluated (Neog & Sarma, 2014).

In NBPZ of Assam, spell of heavy rainfall continues up to mid of October, hence flash floods may occur at any time up to the mid of October. Submergence of rice crop in any time between the last week of September to mid of October coincides with panicle initiation stage of rice crop, result in drastic reduction of yield or total crop failure. This problem can be addressed by introducing deep water or floating rice varieties in such situations. Deep water rice varieties can encounter both occasional droughts and floods up to 3-4 m, and possess genes for stem elongation and/or submergence tolerance (Sarma *et al*., 1997). In such cases, revisiting our traditional genetic resources may be useful for better management of flash flood. Thus evaluation of performance of traditional or improved deep water rice varieties is one of the critical needs for ushering climate resilience to agriculture.

In flood affected areas of NBPZ of Assam, at the end of the rainy season when drainage channels become empty, the accumulated surface water starts to recede and the lands become dry. From mid November to April land of these areas remains free from water logging. Due to deposition of silt in upper soil layer during floods and occurrence of scanty and erratic rainfall during winter months, soils of the areas suffers from severe soil moisture deficit during *rabi* season. Against all odds, the flood free period in these localities should be captured for growing suitable *rabi* crops with or without supplemental irrigations. Therefore, better management of vast fallow lands in flood free months is critical for providing economic security to the farm families of these areas.

Considering this background, field studies were conducted in farmers' field to develop and demonstrate appropriate climate resilient crop management strategies to enhance the productivity in flash flood affected areas of North Bank Plains Zone of Assam.

2.0 MATERIAL AND METHODS

Field experiments as well as demonstrations were conducted in flash floods affected village *'Ganakdoloni'* located at Lakhimpur district of NBPZ of Assam covering 20 ha of area involving 40 farmers of the village to evaluate performance flash flood resilient technologies for the locality in three years during 2012-13, 2013-14 and 2014-15. Each of the participants farmers were considered as a replication. In almost every year the paddy field of village is affected by 3- 5 numbers of flash flood of 7 to 15 days duration from June to mid of October. Using long term rainfall data (1985 -2011) of Lakhimpur, the nearest weather station of the village, long term shift of rainfall patter of the region was analyzed. Soil physic-chemical properties of the study area were also analyzed and characterized. During *kharif* performance of three submergence tolerance cultivars *viz*., *Jalashree, Jalkunwari and Swarna Sub-1* and six traditional deep water rice cultivars *viz., Kekowa, Tulshi, Dhushuri, Bahadur, Maguri, Ranga Bao* and four improved deep water rice varities *viz*., *Panchanan, Panindra, Basudev and Padmapani* were evaluated. During *rabi* seasons two rapeseed cultivars *viz*., TS-36 and TS-38 were grown for performance evaluation in flash flood affected area of NBPZ of Assam. Crops were gown following recommended agronomic practices for the agro-climatatic zone.

3.0 RESULTS AND DISCUSSION

3.1 Village profile

'Gonakdoloni' village of Lakhimpur district of NBPZ of Assam was selected for conducting field experiments cum demonstration for climate resilient technology under NICRA project of AICRP for Dryland Agriculture, Assam Agricultural University. The latitude, longitude and altitude of the village are 26°55′28″, 93°47′01″ and 240 ft, respectively. The village is located at foot hill of Arunachal hill and a small tributary of Brahmaputra *viz. Pichala* is passing through the village. Intermittent flash flood is the major weather aberration in the village. The village is often affected by 3 to 5 numbers of intermittent flash floods of 7 to 15 days duration in every year during June to October. When there is heavy rainfall in the region or in Arunachal hill, *Pichala* river is laden with plenty of water and often exceeds the carrying capacity and water comes out of the river which results in flash floods in that village. Most of the farmers of village are small and marginal and they have been following monocropping of winter (*Sali)* rice. But multiple submergences of standing *Sali* crop with flooding depth of more than 1.5 m leads to extensive damage to their crop in almost every year. Due to distress agriculture many of the young farmers of the village were compelled to leave the village in search of alternate source of livelihood.

3.2 Seasonal rainfall analysis

The annual average rainfall and rainy days of the region was 2949.6 mm and 125.41 days respectively. The rainfall amount and rainy days during different season namely winter, pre-monsoon, monsoon and post monsoon were 2.2, 18.6, 67.2, 12.0 percent, respectively of the total rainfall and 4.7, 25.2, 57.1, 12.9 percent, respectively of total rainy days. The coefficient of variation of seasonal rainfall was highest (78.0%) during winter season, followed by summer (41.0%). However, the coefficient of variation (CV) was moderate during post monsoon season and lowest (17.6%) during monsoon season. Likewise the coefficient of variation of seasonal rainy days was highest (60.9%) during winter season followed by pre-monsoon (26.2%). However, the coefficient of variation (CV) was moderate during post monsoon and lowest (10.7%) during monsoon season. (Table 2:)

Table 2: Seasonal rainfall analysis of Lakhimpur (1985-2011)

Season		Winter	Pre-Monsoon	Monsoon	Post Monsoon	Annual
Rainfall	Mean	65.7	547.8	1982.2	353.9	2949.63
	SD	51.3	224.8	349.1	123.2	494.28
	CV	78.0	41.0	17.6	34.8	16.76
Rainy days	Mean	5.9	31.6	71.7	16.2	125.41
	SD	3.6	8.3	7.7	4.2	14.24
	CV	60.9	26.2	10.7	25.7	11.36

3.3 Long term shift of rainfall

Analysis of long term rainfall data indicates that the annual rainfall and total number of rainy days is decreasing in the region. Analysis also indicates that number of high intensity rainfall event is increasing; resulting in the increased frequency of flash flood as well as intermittent dry spells in the zone. Number of rainy days with more than 100 mm rainfall is increasing in Lakhimpur (Fig.1) district. Critical analysis of rainfall data revealed that abnormalities in distribution rainfall during monsoon has been increasing in recent years and the region has been facing more numbers of dry spells as well as wet spells leading to flash flood.

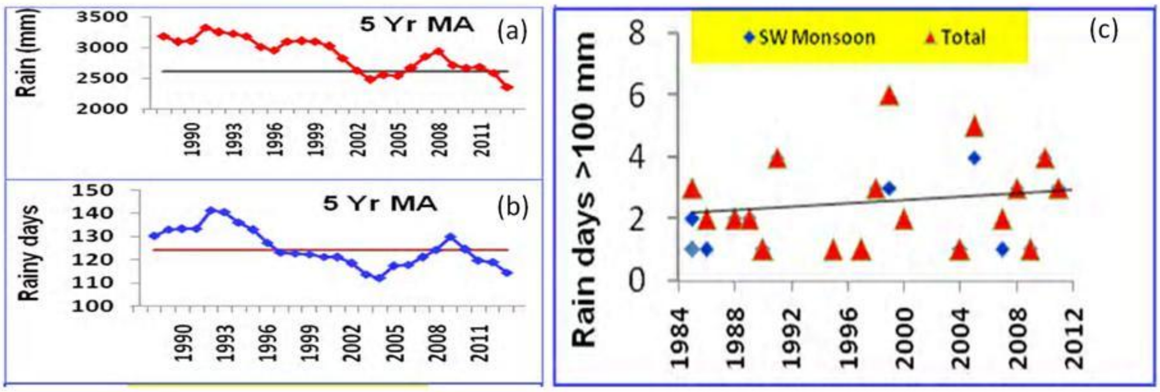

Fig.1: Variation in annual rainfall (a), rainy days (b) and rainy days with more than 100 mm rainfall (c) at Lakhimpur, Assam during 1984 to 2012.

3.4 Soil characteristics of Gonakdoloni village

Texture and other physico-chemical properties of soils of flash flood affected Ganakdoloni village were analyzed and results are presented in Table 3. Taxonomically, the soil belongs to fine loamy, mixed mineralogy, hyperthermic family of Typic Fluvaquents. The soils of this village are deep, imperfectly drained and showed no evidences of development of any diagnostic horizon. The soils are fine loamy in the series control section, clay loam surface texture, strongly acidic (pH < 4.5), severely flooded, very gently sloping land (1-3% slope) with severe erodibility. The organic matter content of the soils of village is high and status of available nitrogen, potassium and phosphorus content is medium.

 

Representative Pedon	Landscape of Ganakdolony series

Table 3 : Physico-chemical properties of the soils of Ganakdoloni village

Horizon	Depth (cm)	Texture	Structure	pH	OC (gkg^{-1})	CEC
Ap	0 - 15	Clay loam	Sub angular blocky	4.28	8.5	9.0
AC	15 - 35	Silty clay loam	Sub angular blocky	5.12	5.5	8.6
2C1	35 - 55	Silty clay loam	Sub angular blocky	5.64	7.2	7.3
2C2	55 - 75	Silty clay	Sub angular blocky	5.80	5.1	8.1
2C3	75 - 95	Silty clay	Sub angular blocky	5.41	6.2	8.0
2C4	95 - 115	Silty clay	Sub angular blocky	5.40	4.7	7.5
3C1	115 - 145	Sandy loam	Massive	5.34	2.2	5.3
4C1	145-165	Loamy sand	Single grain	4.19	3.6	4.6

Based on analysis of different weather parameters (rainfall pattern, flood, dry spells etc) and soil parameters (soil texture, nutrient availability, drainage etc) of the locality, the rice crop is identified as the most suitable crop. Maize, rapeseed, banana *etc* are as identified as moderately suitable and potato is identified as marginally suitable crop for *Ganakdoloni* locality.

3.5 Rainfall daring the study period

The weekly and seasonal variation of rainfall of Lakhimpur during 2012, 2013 and 2014 are presented in Fig. 3. Total annual rainfalls of the station were 2822, 1981 and 2721 mm during 2012, 2013 and 2014, respectively. During 2012 and 2014 rainfall was almost normal, however during 2013, there was 32 percent deficit of total annual rainfall in the the region.

During 2012, the region experienced with two very long of dry spells; first dry spell was from the beginning of January to mid of March, 2012 and second was from the second week of October, 2012 to mid of March, 2013. The region received about 24 percent surplus (700 mm) and 22.7 percent deficit rainfall (235 mm) during pre-monsoon and post monsoon season, respectively; while monsoon season received 1872 mm rainfall which was almost equal to the normal. There were many weeks with very high and continuous rainfall during 2012. From 36 to 41 SMW, the area received very heavy (640 mm) rainfall, leading several intermittent flash flood events.

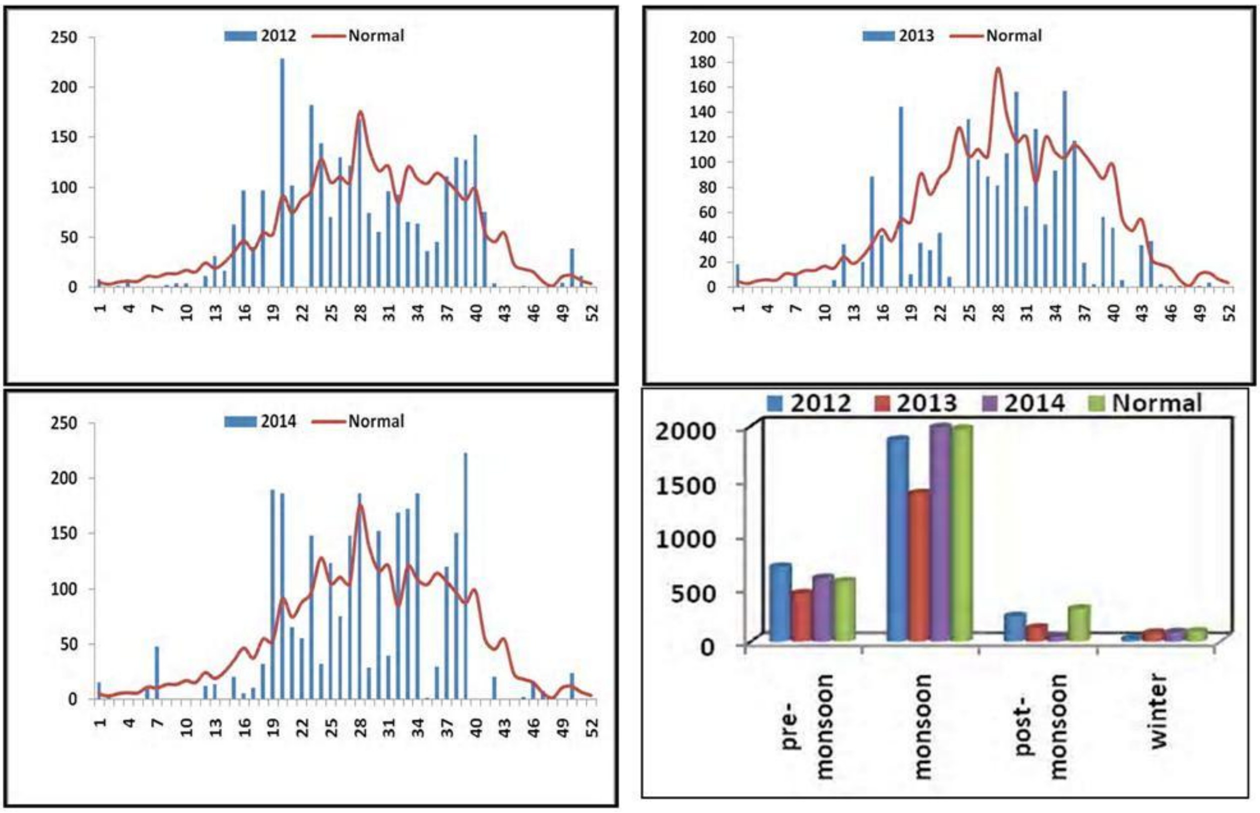

Fig. 2: Weekly (a, b & c) and seasonal (d) rainfall in Lakhimpur during 2012, 2013 and 2014

During 2013, in monsoon season, a total rainfall of 1375 mm was received by the region which was deficit by 582 mm compared to normal (1957 mm). During post monsoon, 132.6 mm of rainfall was received which was deficit by 62 percent as compared to normal rainfall (342 mm). During pre-monsoon season 447 mm of rainfall was received which was deficit by 18.6 percent compared to normal (543 mm). Though onset of monsoon was delayed by two to three weeks, no prominent dry spells were observed except one during 37/38 SMWs, when crop was grain filling stage. In spite of deficit in rainfall in monsoon (30%) and post monsoon (58%) season, the region encountered with many numbers heavy rainfall events that caused multiple number flash floods in some areas of the region.

During 2014, the region experienced drought like situation during winter season which prolonged up to the month of April, 2015. There were 60.4 and 81.9 percent deficit of rainfall during March and April, respectively. During pre-monsoon season the region received 588 mm of rainfall, out of which 326 mm was received during the month of May, 2014. Onset of monsoon was delayed by two weeks (19 June). There was dry spell of three weeks *viz*. 22, 23 and 24 standard met week with rainfall deficit of 10, 43 and 86 percent, respectively. Rainfall in the remaining part of the monsoon season was almost normal. During monsoon, the region experienced with a numbers of heavy wet spells, which resulted in flash flood in some location in the region. There were only two rainy days in the month of October and rainfall deficit was 89 percent during post monsoon season. A total of 50.3 mm rainfall received during the month of November, 2014 which was helpful for establishment of *rabi* crops in the village.

3.6 Occurrence of flash flood during study period

During 2012, *Ganakdoloni* village was affected by four numbers of flash floods causing intermittent submergence to *Sali* rice grown in the village for 32 days (Table 4:). First submergence was from 23 June to 1 July (9 days) when crop was at seedling stage. Subsequently, rice field of the village was submerged for three times from 12 to 19 September, 21 to 28 September and 2 to 8 October, 2012. During 2013 the village was affected by four flash flood of total duration of 36 days between 18 July to 8 September, 2013 (Table 4:) Continuous (> 3 days) and heavy rainfall in the region as well as in the nearby Arunachal during June to October resulted in overflowing of *Pichala* river leading to flash flood in the paddy fields of the village. (Fig.4:)

Table 4: Period of submergence of *Sali* rice in Ganakdoloni village during 2012 and 2013

2012		2013	
23 June to 1 July	9 days	18 -27 July	10 days
12 to 19 Sept	8 days	07-13 Aug	7 days
21 to 28 Sept	8 days	14 -20 Aug	7 days
2 to 8 Oct	7 days	28 Aug - 8 Sept	12 days
Total	**32 days**	**Total**	**36 days**

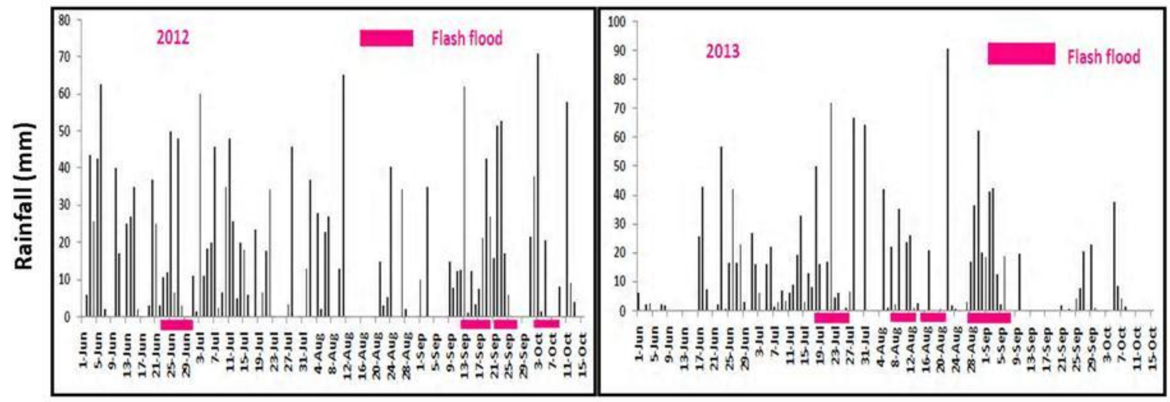

Fig. 3 Rainfall and occurrence flash floods in *Ganakdoloni* village during 2012 and 2013

3.7 Flooding depth in paddy fields of Ganakdoloni village

Flooding depth in two sites (field-1 and field -2) of the crop field of *Ganakdoloni* village was monitored from June to mid October, 2014 and presented along with daily rainfall in Fig. 4: The region received about 558 mm rainfall during pre-monsoon months. As a result inundation of paddy fields started in the month of April/May. In absence of flash flood, water logging depth of the crop field was less than 50 cm; however, the water logging or flooding depth increased up to 180 cm during flash floods in the village (Fig. 4). In case of heavy and continuous rainfall in the region as well as in the state of Arunachal, flooding depth in the crop fields of the village continuously remained above 100 cm for 2-3 months.

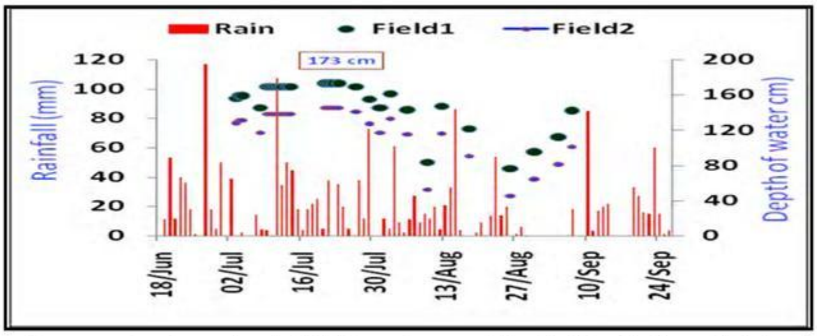

Fig. 4: Depth of water (cm) and rainfall (mm) at paddy field of *Ganakdoloni* during 2014

During 2014, in field-1, depth of water varied from 80 to 173 cm, while in field - 2, the depth varied from 45 to 130 cm during monsoon months. In case of Field -1, depth of water remained continuously above 100 cm for more than three months during monsoon season of the year.

3.8 Evaluation of performance of flash flood resilient technologies

3.8.1 Performance of submergence tolerant rice cultivars

Submergence tolerance rice cultivar - *Jalashree* was grown in the farmers' field of *Ganakdoloni* village consecutively for two years during 2012 and 2013. While submergence tolerant variety of *Jalkunwari and Swarna Sub-1* was grown in 2012 and 2013, respectively. During, 2012, paddy field of the village was submerged for four times due to occurrence of four flash floods (Table 5). During 2013, paddy field of the village was affected by four flash floods occurring during 18 to 27 July (10 days), 7 to 13 August (7 days), 14 to 20 August (7 days) and 28 August to 8 September (12 days) (Table 5).

Table 5: Crop growth stages of rice crop and period of submergence during 2012 and 2013

2012		2013	
Crop stage	Duration in days	Crop stage	Duration in days
Seedling	9 (23 June to 1 July)	Tillering (early)	10 (18 -27 July)
Tillering	8 (12 to 19 Sept)	Tillering	7 (07 -13 Aug)
Tillering	8 (21 to 28 Sept)	Tillering	7 (14 -20 Aug)
PI stage	7 days (2 to 8 Oct)	Tillering	12 (28 Aug to 8 Sept)
Total	**32 days**	**Total**	**36 days**

During 2012, while both *Jalashree* and *Jalkunwari* were at very early seedling stage in the nursery bed (three days after sowing), flash flood submerged the nursery continuously for 9 days from 23 June to 1 July, 2012. It was encouraging for both the farmers as well as for the scientists that no seedlings of both cultivars were damaged in spite of prolonged submergence of 9 days at a very early growth stage of the varieties (Fig.5).

Fig. 5: Seedlings of *Jalashree* after 9 days of submergence during 2012

During 2012, while rice varieties were at tillering and panicle initiation stage in the main field, the crop was affected by three spells of submergences (Table 5). All normal/farmers varieties (like- *Ranjit, Mahsuri, Punjublahi* etc) were completely damaged by flash floods (Fig. 6). Submergence tolerance variety *Jalkunwari* was also not able to survive might be due to exposure of PI stage of the variety to submergence due to occurrence of flash floods during third week of September and first week of October. Unlike *Jalkunwari, Jalashree* showed more tolerance to submergence which might be due to greater regeneration ability of the variety under extended submergence. During 2012, the vegetative growth of *Jalashree* might be extended under multiple submergence stretched up to 8 October.

Fig. 6: Field view just after transplanting and at grain filling stage at *Ganakdoloni* village during 2012.

During 2013, though both *Jalashree and Swarna Sub -1* were exposed four waves of flash floods, submergences affected only the tillering stage and both the varieties was able withstand intermittent submergences of 36 days (Fig. 7 & 8). Though *Jalashree* was exposed to submergence continuously for ten days at early tillering stage (7 days after transplanting), the crop survived and performed well (Fig. 7).

Fig. 7: Submergence of *Jalashree* for 10 days (a) at early tillering stage and (b) at flowering stage during 2013

Fig. 8: Farmer's variety (*Punjablahi*) was completely damaged, but *Jalashree* and *Swarna Sub-1* withstood flash floods during 2013

3.8.1.1 Yield of Submergence tolerance varieties

Yield of the *Jalashree* and *Swarna sub-1* grown in the *Ganakdoloni* village are presented in Table 6. During the first crop season (2012) the seed yield of *Jalashree* was only 900 kg ha^{-1}, while in the second crop season (2013) seed yield of the variety was substantially higher (2850 kg ha^{-1}) as compared to the first crop season. Considerable reduction of yield of *Jalshree* during first crop season might be due to intermittent submergence continued up to the PI stage of the variety, while in case of the second season (2013) last submergence (28 Aug to 8 Sept) was coincided with tillering stage of the variety. During 2012, *Jalashree* was able give some grain yield might due to greater regeneration ability and extension of vegetative growth of the variety under extended submergence. Poor crop growth and lower yield of *Jalashrsee* during first crop season as compared to the second crop season might also be attributed to higher submergence depth as during 2012 the variety was gown in the field-1. During 2013; the variety was grown in field-2, where flooding depth was lesser as compared to field -1. (Fig. 9:).

Fig. 9: Performance of *Jalashree* at *Ganakdoloni* village

Jalkunwari, which was grown in the first crop season, was completely destroyed might be due to submergence of the variety at PI stage. Thus, *Jalashree* might have some advantage over *Jalkunwari.*

Table 6: Yield of submergence tolerance cultivars - *Jalashree* and Swarna Sub-1 at Ganakdoloni, *Lakhimpur* during 2012 and 2013

Sl No	Name of the varieties	Yield (kg ha^{-1})			Increased in yield as compared to farmers variety (%)	Net return (Rs ha^{-1})	B:C ratio
		2012	2013	Mean			
1	Jalashree	900	2850	1875	100	4750	1.34
3	Swarna sub-1	-	2531	2531	100	11310	1.55

Submergence tolerant variety *'Swarna sub-1'* was grown during 2013 recorded grain yield of 2531 kg ha^{-1} which was considerably lower as compared to *Jalashree* (2850 kgha^{-1}).

3.8.1.2 Performance of deep water or *Bao* rice

Deep water rice or floating rice popularly known as *Bao dhaan* in Assam is generally grown in flood affected low laying areas which remains submerged at least for seven to eight months and can endure water depth more than 100 cm. While no other crop can be grown including normal paddy cultivars due to long duration water logging, farmers have been traditionally cultivating deep water rice cultivars in those areas. Deep water rice cultivars have the following characteristics -

- They can be grown with the water depth of more than one meter (Ahmed *et al*., 2011).
- Duration of deep water varieties are 270 to 300 days – sown in March-April and harvest in November-December (Ahmed *et al*., 2011).

- Having excellent stem elongation capacity under rising water level during flood up to 3 to 4 m. The stem elongation ability of deep water rice varieties reported as high as 24.8 cmday^{-1} (Sarma *et al.*, 1997).
- Having the kneeing ability of 38^0 angles for all tillers (Sarma *et al.*, 1997).
- Two to three cuttings of leaves of *Bao* from June to Mid September is common practice followed by the farmers of Assam to meet fodder demand, when there is acute shortage of green fodder during the monsoon season.
- Iron rich red kernel of *Bao* paddy has demand in the international market
- *Bao* varieties have drought tolerance during early as well later stage of the growth (Sarma *et al.*, 1997).

Fig. 10: Kneeing ability of deep water rice: (a) *Maguri* and (b) *Tulshi*

Earlier farmers of *Ganakdoloni* village did not cultivate deep water rice varieties extensively in their field. It was observed that due to occurrence of multiple numbers of flash floods with water logging depth of more than 150 cm which sometimes continued up to mid of October, normal verities grown by the farmers were often damaged to a greater extent. Submergence tolerance rice varieties also could not perform well (total failure of the crop) when PI or grain filling stage of these varieties exposed to submergence due to occurrence flash flood in last week of September or October. Therefore performance evaluation of traditional or improved deep water rice varieties with better yield potential in flash flood affected areas is one of the critical needs of the region.

Fig. 11: Elongation ability of *Bao* rice: (a) *Tushi* (4.6 m) and (b) *Kekowa* (1.8 m)

During 2013, performances of six traditional deep water rice varieties *viz., Kekowa, Bahdur, Tulshi, Rangabao, Dhushuri and Maguri* were evaluated. During 2014, along with these traditional varieties, four improved deep water varieties *viz. Panchanan, Panindra, Basudev and Padmapani* were cultivated to evaluate their performances. In both the years, *Bao* varieties were sown between mid of March to mid of April.

During 2013, in-spite of occurrence of four intermittent flash floods between July to September, all the six traditional deep water rice varieties endured flash floods and performed well. However, all other varieties normally grown by the farmers were completely damaged by flash floods. Similarly, during 2014, in spite of prolonged submergence (> 40 days) traditional deep water varieties performed well, however all four improved *Bao* varieties (Panchanan, Panindra, Basudev and Padmapani) could not withstand high depth of water logging (>150 cm) occurred for long period of time.

Fig. 12: Normal varieties of *Sali* rice were damaged, but *Bao* varieties performed well during 2013

Table 7: Performance of *Bao* varieties at *Ganakdoloi* village during 2013 and 2014

Sl No	Name	Mean Height (m)	Special characteristics observed
1	*Kekowa*	2.2	Maximum cuttings (3-4) possible
2	*Tulshi*	2.5 to 4.6	Maximum elongation ability
3	*Dhushuri*	2.0	Having both elongation and submergence ability
4	*Bahadur*	1.9	No Kneeing ability, have the elongation ability
5	*Maguri*	2.1	Having both elongation and kneeing ability
6	*Ranga Bao*	2.5 to 3.5	Having both elongation and kneeing ability

All traditional deep water rice cultivars except *Bahadur* had both elongation and kneeing ability, however, *Bahdur* had only the elongation ability. *Tulshi* had the highest elongation ability (4.6 m), which was followed by *Rangabao, Maguri, Dhusuri, Bahadur and Kekowa* (Table 7:*).*

Fig. 13: Performance of various *Bao* cultivars in *Ganakdoloni* village during 2013

Fig. 14: Performance of various *Bao* cultivars in *Ganakdoloni* village during 2014

3.8.1.3 Yield of deep water rice varieties

Grain yield of *Bao* varieties grown at *Ganakdoloni* village during 2013 and 2014 are presented in Table 8.

Table 8: Yield of traditional and improved *Bao* varieties at Ganakdoloni village during 2013 and 2014

Variety	Yield (kg ha^{-1})			% increase in yield as compared to the normal or farmers' variety	Net returns (Rs ha^{-1})	B:C ratio
	2013	2014	Mean			
Kekowa	2672	2275	2474	100	12735	2.1
Dhusuri	3000	2438	2719	100	15190	2.3
Rangabao	1900	1628	1764	100	5640	1.5

Maguri	2813	2321	2567	100	13670	2.1
Bahdur	2963	2200	2582	100	13815	2.2
Tulshi	2400	2100	2250	100	10500	1.9
Panchanan /Panindra /Basudev /Padmapani	-	0.0	-	-	-	-

Average grain yield of different *Bao* varieties varied from 1628 to 3000 kg ha^{-1} in two different crop seasons (2013 and 2014). Among the cultivars, *Dhusuri* and *Rangabao* recorded the highest and lowest grain yield, respectively in the both the seasons. *Dhusuri* recorded grain yield of 3000 and 2438 kg ha^{-1}, while *Rangabao* recorded 1628 to 1900 kg ha^{-1} in 2013 and 2014, respectively. Comparatively higher grain yield were also recorded in *Bahadur* (2963 to 2200 kg ha^{-1}), *Maguri* (2321 to 2813 kg ha^{-1}) and *Kekowa* (2275 to 2672 kg ha^{-1}). *Tulshi*, which had the highest elongation ability, recorded gain yield of 2100 to 2400 kg ha^{-1} in different crop seasons. In all the varieties, yield was substantially higher in first crop season (2013) as compared to the second crop season (2013). Lower grain yield of all *Bao* varieties during 2013 might be due to the fact that, at sowing time (mid of March to Mid of April), soils of the village was very dry and soil moisture stress condition continued up to first week of May, 2014 leading to poor emergence, heavy weed infestation and poor crop stands which was ultimately reflected on grain yield. Moreover, during 2014, flooding depth was considerably higher which was maintained continuously for more than three months (July to September), which caused limited supply of assimilates to the developing grains (sources limitation) and / or because of limited capacity of the reproductive organs to accept assimilates (sink capacity). Similar results were reported by Kar *et al.*, (2010). However, improved *Bao* cultivars could not withstand such high flooding depth for the prolonged period of time.

3.8.1.4 Green leaf cutting of deep water rice for fodder

In Assam, farmers generally cut the leaves of *Bao* rice (2 to 3 times) from July to September and use the cut leaves as green fodder for their livestock. Sometimes farmers leave their animals to go of the standing *Bao* paddy field for open grazing. July to October is the period of shortage of fodder in Assam and this problem is more acute in flood affected areas. Sometimes farmers sacrifice grain yield of *Bao* rice for green fodder. Therefore, economic importance of *Bao* rice should be judged for both grain and green fodder yield. During 2014, an observation trial was conducted in the farmers' field of *Ganakdoloni* village to study the performance of *Bao* varieties in terms of fodder and grain yield. Three varieties namely – *Kekowa, Dhusuri and Rangabao* were selected and grown for this purpose. Four cutting treatments were imposed i.e. no cutting, one cutting, two cuttings and three cuttings in the trial. Green fodder yield and grain yield of the varieties are presented in Table 9. In all the varieties no considerable difference in grain yield was observed between one cutting and no cutting of leaves. However, in case of cutting of leaves for two times, considerable reduction of grain yield (as compared to one or no cutting) was observed. If three cuttings were made, grain yield was reduced to a great extent in all the varieties. Green fodder production was maximum in *Kekowa*, followed by *Rangabao*, *Dhusuri*.

Table 9: Grain yield and fodder yield of Bao varieties cultivated during 2014 at *Ganakdoloni, Lakhimpur*

Name of cultivar	Green fodder yield (q ha^{-1})				Grain yield (q ha^{-1})			
	1st cut (12 Aug)	2nd cut (26 Aug)	3rd cut (17 Sept)	Total	No cut	1st cut	2nd cut	3rd cut
Kekowa bao	144.4	65.0	12.5	221.9	22.75	22.29	6.5	1.5
Ranga bao	66.6	43.7	9.8	120.1	16.28	16.10	9.7	2.0
Dhusuri bao	55.6	32.1	10.2	97.9	24.38	22.85	8.6	2.2

3.8.2 Performance of rapeseed in flood free months

Farmers of *Ganakdoloni* village had been following monocropping of *Sali* rice which was often affected by intermittent flash floods. However, crop field of the village remains free from the water logging from November to April. Therefore, land can be utilized for growing *rabi* crops like rapeseed, maize etc in flood free months. However, farmers of village showed reluctance to grow any *rabi* crop as stray cattle are a great setback in that locality which cause extensive damage to *rabi* crops.

To capture the flood free months and for increasing productivity of soils of *Ganakdoloni* village it is important to evaluate the performance of *rabi* crops in that village. During 2012 -13, rapeseed variety TS-38 was grown in three hectare of land involving twenty farmers of the village. The variety TS-38 performed well and an average yield of 690 kg ha^{-1} was recorded.

Fig. 15: Performance of TS -38 and TS-36 at *Ganakdoloni* village during 2012-13 and 2013-14

During 2013-2014, two rapeseed variety TS-36 and TS-38 were grown in 2 ha of land involving same number of farmers as the previous year. Like previous year, though no irrigation was given, both the cultivars performed well. The yield and B:C ratio was slightly higher in of case of TS-38 yield as compared to TS-36.

Table 10: Yield of rapeseed (TS-36 and TS-38) at Ganakdoloni village during 2012-13 and 2013-14

Variety	Yield (kg ha^{-1})			Net returns (Rs ha^{-1})	B:C ratio	RWUE (kg $ha^{-1}mm^{-1}$)
	2012-13	2013-14	Mean			
TS-36	-	754	754.0	16160	2.2	9.29
TS-38	690	875	782.5	17300	2.3	9.64

Therefore it can be concluded that rapeseed can be successfully grown as rainfed crop in flood free period (November to April) in *Gankdoloni* village with average yield more than 750 kgha^{-1} net income of Rs. 16,730 ha^{-1} and B:C ratio of 2.25. Some other *rabi* crops like maize, rapeseed, potato and winter vegetables have been identified as moderately or marginally suitable crops for *Ganakdoloni* village. Nutrient availability and soil moisture deficit are two major limiting factors of soils of *Ganakdoloni* village during during *rabi* season. However, these problems can be addressed through better nutrient management and use of ground or surface water for irrigations. During flood free months summer rice can be successfully grown in the village with assured irrigation. The perennial river *Pichala* passing though the village can be better utilized as source of irrigation water. Thus *Pichala* river which is presently considered as the sorrow of the village, can converted in to cause of happiness for the people of the village.

4.0 SUMMARY

1. Rice dominates the agriculture scenario of Assam which accounting nearly 60 percent of gross cropped area and 89 percent of net cropped area with an annual production of 45.57 lakh tones. The crop is grown almost entirely as rainfed and availability of irrigation in the state is less than 10 percent of the total cropped areas. Rainfed rice production of the state is adversely affected by several constrains including risks of weather hazards like flood and drought.

2. The flood is the major problem that causes sluggish growth of agricultural sector in Assam. Multiple waves of flood resulting from high intensity rainfall spells during the monsoon season cause extensive damage not only to the standing rice crop but also cause permanent loss of rice cultivated areas due to heavy siltation.

3. In Assam, the maximum flood affected area of 133,000 ha (39 % of total) are found in the North Bank Plains Zone, which is one of the most climatologically vulnerable agro-climatic zones of the country due to its location in the eastern Himalayan periphery, fragile geo-environmental setting and economic under-development. Moreover, presence of network of Himalayan river system, heavy rainfall and soil erosion in upper catchment area in Arunachal hills, deposition of new alluvial soils in riverbed as well as in plains adds up the problems of flash flood in this zone.

4. The innate problem of long duration as well as flash flood in NBPZ of Assam will be aggravated as a result of increasing rainfall variability associated with global climate change. Thus the problem in rice production due to occurrence of floods in the zone is likely to increase in future.

5. Though, improve technology for higher rice production are available for shallow low land areas of Assam, modern technologies have yet to make an impact in the flood prone areas. Need of the hour is to build a climate resilient agriculture for increasing productivity in flood prone ecosystem through identifying, evolving and demonstrating appropriate climate resilient technologies like flood escaping or flood tolerant cropping system or intensive crop production with irrigation in the flood free months.

6. Introduction of summer (*boro*) rice in the flood-prone areas of Assam has gained momentum and contributed tremendously to increasing rice production flood affected areas. But the technology is not well adopted in vulnerable areas as *boro* rice cultivation needs intensive irrigation resulting in higher cost of cultivation. The Higher cost of cultivation is not affordable to the small and marginal farmers of flood affected areas of NBPZ of Assam, leading to low adoption of the technology.

7. Flash floods cause submerges to the standing rice crop for 7-15 days at a stretch result in mortality of the rice plants in extreme cases. This problem can be overcome by

introducing submergence tolerant rice varieties which can tolerate submerge up to 15 days at seedlings and tillering stage. However, in NBPZ, heavy rainfall spells may be continued up to mid of October. In such situation, PI stage of crop may coincide with submergence leading to total crop failure.

8. The problem of flash flood and long duration water stagnation can be addressed by introducing deep water or floating rice varieties having ability to tolerate both occasional droughts and floods up to 3-4 m depth and possess genes for stem elongation, kneeing ability and submergence tolerance.

9. In flood affected areas of NBPZ, at the end of the rainy season when drainage channels become empty, the accumulated surface water starts to recede and the lands become dry and the area remain free from water logging from November to April. Better management of vast fallow lands in flood free months in such situations for growing *rabi* crops is essential for increasing productivity of the flood affected areas of this zone.

10. *Ganakdoloni* village of Lakhimpur district is situated in NBPZ of Assam had been selected for evaluation of performance of flash flood resilient technologies under NICRA-AICRPDA, AAU, Biswanath Chariali. The village is often affected by 3 to 5 numbers of intermittent flash floods of 7 to 15 days duration in every year, which adversely affect rice crop grown in the village.

11. Based on analysis of weather parameters (rainfall pattern, flood, dry spells etc) and soil parameters (soil texture, nutrient availability, drainage etc), paddy is identified as the most suitable crop, maize, rapeseed, banana etc are identified as moderately suitable and potato is identified as marginally suitable crop for *Ganakdoloni* village.

12. During monsoon season the locality received almost normal rainfall in 2012 (1872 mm) and 2014 (1987 mm), however, rainfall during monsoon season of 2013 was reduced by 30 percent (1375 mm). During post monsoon season the region received deficit rainfall in all the years and deficits were 23, 58 and 85 percent during 2012, 2013 and 2014 respectively.

13. During 2012 and 2013, *Sali* paddy grown in *Ganakdoloni* village was affected by four flash floods which were stretched from 23 June to 8 October and 18 July to 8 September during first and second year, respectively. During 2014, flooding depth was measured in two sites of paddy field which varied from 80 to 173 cm and 45 to 130 cm in Field -1 and Field -2, respectively from June to mid September.

14. During 2012 while both the submergence tolerant varieties - *Jalashree and Jalkunwari* were at very early seedling stage, flash flood submerged them continuously for 9 days (23 June to 1 July). In spite of such long duration submergence no seedlings of both cultivars were damaged.

15. In both the crop seasons (2012 and 2013) normal/farmers varities grown were completely destroyed by intermittent flash floods. On the other hand submergence tolerant variety *Jalashree* survived flash floods and yielded 900 kg and 2850 kg ha^{-1} in first and second crop season, respectively. The higher grain yield during the second season might be due to the fact that the variety was exposed to waves of submergence during tillering stage only, however during the first crop season intermittent submergences were stretched up to 8 October, 2012.

16. Yield of traditional deep water rice verities (*Kekowa, Bahdur, Tulshi, Rangabao, Dhushuri and Maguri*) tested during 2013 and 2014 was varied from 1628 to 3000 kg ha^{-1}. Among the cultivars, *Dhusuri* and *Rangabao* recorded the highest and lowest grain yield, respectively in the both the seasons. *Dhusuri* recorded grain yield of 3000 and 2438 kg ha^{-1}, while *Rangabao* recorded 1628 to 1900 kg ha^{-1} in 2013 and 2013-14 respectively. Gain yield of all the *Bao* varieties was substantially higher in first crop season (2013) as compared to the second crop season (2014) which might be due to exposure of seedling stage of the crop to soil moisture in second crop season.

17. During 2012-13 and 13-14, two rapeseed variety TS-36 and TS-38 were grown in 2 ha of land involving 20 farmers. Rapeseed can be successfully grown as rainfed crop in flood free period (November to April) in *Gankdoloni* village with average yield more than 750 $kgha^{-1}$, net income of Rs. 16,730 ha^{-1} and B:C ratio of 2.25.

18. Nutrient availability and soil moisture deficit are two major limiting factors during *rabi* season in Ganakdoloni village. These problems can be addressed through better nutrient management and use of ground or surface water for intensive irrigations. During flood free months summer rice can be successfully grown in the village with intensive irrigation.

19. The perennial river *Pichala* passing though the village can be better utilized as source of irrigation water. Thus *Pichala* river which is presently considered as the sorrow of the village, can be converted into an asset for the village.

Crops/varieties/other suggestions

After detail study of soil and weather resources of the village and evaluating performances of different crop based climate resilient technologies following crops and varieties are suggested for for *kharif* and *rabi* season for *Ganakdoloni* village.

(A) For Situation -1 (field -1): Flooding depth varied between 100 to 180 cm.

Kharif	*Rabi/Summer*
Traditional deep water rice cultivars like *Kekowa, Maguri, Dhusuri, Bahdur* etc	*Boro* paddy (with irrigation)/rapeseed, maize, winter vegetables (as rainfed or with irrigation and nutrient management).

(B) For Situation 2 (field -2): Flooding depth varied between 50 to 100 cm

Kharif	*Rabi/Summer*
Submergence tolerant rice varieties –Jalashree, Swarna Sub-1 etc	*Boro* paddy (with irrigation)/rapeseed, maize, winter vegetables (as rain fed or with irrigation and nutrient management).

Moreover, following investigations needs to be taken up for having full proof climate resilient agriculture for the flash affected *Ganakdoloni* village as well as for areas with similar situations of north bank plain zone of Assam.

1. Performance improved submergence tolerant rice varieties like *Ranjit-Sub-1* and improved deep water rice cultivars for field situation -2.
2. Performance of *boro* rice with irrigation.
3. Performance of different *rabi* crops like Maize, potato, pea, winter vegetables *etc* with adequate water and nutrient management.

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