Climate risk management at farmer's field through adaptation strategies for resource-poor farmers of Assam, Northeast India

Abstract

Farmers in Assam's North Bank Plains Zone are generally resource-poor and have limited adaptation ability; rainfall anomalies make the Zone's rainfed agriculture very sensitive, risky, and unprofitable. Participatory on-farm trials involving 25 farmers (5 from each village) representing different land situations for evaluating various adaptive strategies on rice-based cropping systems were conducted from 2011 to 2020. Ten years of rainfall data (2011-2021) are evaluated in connection to dry spells and their effects on rainfed rice-based farming systems. The village receives 2848.5 mm of annual rainfall, with distribution patterns of 25%, 67%, 5.0%, and 3% during the pre-monsoon, monsoon, post-monsoon, and winter seasons, respectively. Among the years under study, it has been observed that during 2010, 2015, 2016, 2017 and 2020, the district received excess annual rainfall and deficit in 2011, 2012, 2013, 2014, 2018, 2019 and 2021,respectively. The current studies were designed with two primary strategic components in mind *viz.*, Real-time Contingency Planning (RTCP) and Preparedness. Interventions under the RTCP were designed to deal with delayed monsoon onset, early-season drought, mid-season dryspell, and terminal drought in winter rice and *rabi* crops. Preparedness includes changes in cropping pattern, in situ and ex situ rainwater management systems, alternate land use under low-cost polyhouse, mushroom cultivation, vermicompost production, fodder bank and village seed bank to cope with weather aberrations. An increase in yield of HYV rice varieties Ranjit (33%), Mahsuri (12.3%) and Gitesh (32%) was observed when sowing was done before 15 June over late sowing conditions. An increase in yield of 21.73 % and 44.60%. 58.67% as compared to farmers' Practice during 2013-14, 2014-15, and 2016-17 respectively, has been observed. The performance of double cropping systems recorded the highest B: C ratio of 2.03 and 1.75 in winter rice + rapeseed followed by winter rice + potato sequence as compared to mono-cropping of winter rice.

***Keywords**: Rainfed agriculture Preparedness, early season drought, mid-season drought, terminal drought, dry spell*

1. INTRODUCTION

Several scientific studies have recognized the growing significance of climate change (Agrawal & Perrin 2008). These studies have demonstrated that the implications of climate change are expected to be harmful, particularly for overpopulated developing countries like India, because these nations rely heavily on natural resources such as water, forests, and rainfed agriculture. Therefore, the consequences of climate change are expected to be severe (Moorhead

2009). According to the Intergovernmental Panel on Climate Change's fourth assessment report (2021), the rise in global surface temperature between 1850 and 1900 is estimated to be 1.09 [0.95 to 1.20] °C (Arias et al. 2021).

Assam is a state in India's North Eastern Region with an area of 78,438 square kilometres. Almost 70% of the state's population depends on agriculture for a living, and low productivity is one of the problems affecting the state's growth. Subsistence farming, the dominance of small and marginal farmers, monocropping of rice, inadequate farm mechanization, weak rural and marketing infrastructure, a lack of sufficient finance facilities, and other issues have all had an impact on the state's agriculture (Sarmah, 2015). Climate change is also projected to impact agricultural productivity in the state. Furthermore, the growing frequency and intensity of extreme weather events, such as droughts and floods, are predicted to harm the state's growth and development (Das et al. 2010, De & Bodosa, 2015, Nath & Deka, 2010).

The NBPZ (North Bank Plain Zone) comprises six districts *viz.*, Dehemaji, Lakhimpur, Biswanath, Sonitpur, Darrang and Udalguri, covering an area of 14,421 km^2 that accounts for 18.37 per cent of the state area. The Zone is situated in the North Eastern corner of Assam. Arunachal Pradesh hills surround the Zone on the North and the east, The Brahmaputra river on the south and the lower Brahmaputra valley zone on the west. The Zone supports about 28 lakhs, equivalent to 17 per cent of the state population. The average population density of the Zone is 198 persons per km^2. The Zone is primarily agrarian, with about 70 per cent of the population depending on agriculture, including horticulture, animal husbandry, pisciculture, sericulture and forestry. Tea cultivation is widespread in the upland situations of the Zone, covering 75,328 ha of land (Anon, 2021). The general physiography of the Zone varies from undulating uplands on the Northern foothill belt to deeply flooded low-lying plains on the south. The Zone has an altitude of 35 to 140 meters above the mean sea level. Based on the topographic variations and fluvial activities of the rivers, the Zone can be delineated into five physiographic variations viz., Foothill belt, Old flood plain (upper terrace), Old flood plain (lower terrace), Recent flood plain (riverine belt) and Marshes and swamps. The Zone is interwoven by a large number of tributaries of the river Brahmaputra. The significant tributaries traversing the zones are Dihang, Subansiri, Ranganadi, Boginadi, Sonai –Rupai, Dikrang, Buroi, Bordikari, Jiabharali, Gabhoru, Belsiri and Pachnoi. An extensive Zone invariably experienced 3-4 flashes of flood during the active monsoon period.

In recent years, greater unpredictability in rainfall has resulted in flash floods and droughts in Assam's NBPZ (Neog et al.2016). Agricultural droughts of 4 to 11 weeks have been observed throughout the Kharif and rabi seasons, respectively, even though the chance of two consecutive wet weeks with 40 mm guaranteed rainfall during the winter rice growing season is ten weeks at 70% confidence level (Sarmah et al. 2013). Increased rainfall variability with massive amplitudes implies the risk of floods and short-term droughts, causing severe stress on agricultural production (Deka et al. 2013). Monsoon floods harm the small and marginal farmer-oriented rainfed rice-based production system and intermittent dry spells throughout the *Kharif* season, as well as a lengthy dry spell during the *rabi* season because the Zone is made up of young alluvial soils with low water retention capacity.

The following land situations are predominant in the Zone. (Bayan et al.2021).

1.1 Upland situation:

1. The water table remains at least 1m below the surface.
2. Soils are usually light-textured and well-drained.
3. Water stagnation rarely occurs.

1.2 Medium land:

1. The water table reaches the surface at the peak monsoon period, and land submergence rarely exceeds 25cm.
2. Soil texture varies from medium to heavy.
3. The water table typically goes down to about 1m below the surface after cessations of monsoon during November and December

1.3 Low land:

1. Land submergence may occur up to 50 cm in the peak monsoon period, and the soil remains saturated until November.

1.4 Deep water:

1. Land submergence may occur from 50 cm to 1.0 m during monsoon.
2. Soils are heavy textured and ill-drained.

1.5 Very deep water:

1. Land submergence may exceed 1m and reach up to 3m or more.
2. Soils are heavy textured with impeded drainage.

Although long-duration rice varieties in the lowlands were not impacted by mid-season or terminal dry spells, anthesis of long-duration rice may coincide with low temperature (below 20 °C) due to delayed transplanting beyond the third week of June, resulting in low yield (Neog et al. 2020). Selection of land situation-specific suitable rice varieties can successfull to mitigate the impact of intermittent dry spells (Neog et al. 2020). Farmers in the Zone are essentially resource-poor and have limited adaptation ability, making rainfed agriculture in the Zone very sensitive, risky, and unprofitable. Several adaptation measures must be explored to cope with seasonal droughts and sustain higher yields in the Zone, including adopting climate-tolerant crops and cultivars. Given the wide diversity in rice varietal types in this area, it is possible to successfully manage seasonal drought by identifying alternate rice varieties appropriate for varied land situations. As a result, non-traditional rice varieties with varying growth duration and adaptability to specific land situations may be developed to cope with dry spells of varying durations during the winter season, along with manipulation of agronomic practices such as changing sowing dates and completing farm operations on time. Despite the availability of varietal diversity and the capability of harvesting and recycling rainwater for timely seeding of winter rice in a nursery bed, the Zone lacks a comprehensive study for evaluating the climate-resilient adaptation potential of these agronomic approaches. In this study, an attempt was made to investigate rainfall variability in connection to the incidence of seasonal drought during the winter rice growing season in Assam's NBPZ. Furthermore, the potential for climate change adaptation of various agronomic approaches, such as the introduction of alternate varieties and the alteration of sowing time, were assessed using crop data collected from experiments conducted at farmers' fields. The following are some high-yielding crops grown under various land situations (Table 1).

Table 1: Suitable High yielding varieties of field crops under different land situations

Sl. No	Variety	Duration (Days)	Av. yield (tha^{-1})
Rice			
Short duration (Upland)			
1	Luit	100-110	3.2-3.6
2	Kapilee	90-95	2.5-3.5
3	Disang	100-110	3.5-4.0
Medium duration (Medium land)			
4	Satyaranjan	130-135	3.5-4.0
5	Basundhara	130-135	3.5-4.0
6	Mulagabhoru	135	4.0-4.6
7	Mahsuri	140-145	3.5-4.0
8	Shraboni	135	4.8-5.0
9	Numoli	130-135	5.0-5.5
10	Bahadur sub-1	140-145	5.5-6.0
Long duration (Low land)			
11	Ranjit	150-155	5.5-6.0
12	Bahadur	150-155	5.5-6.0
13	Prafulla	150-160	4.5-5.0
14	Gitesh	150-160	5.0-5.5
15	Ranjit sub-1	145-150	5.5-6.0
Potato			
17	Kufri Pokhraj	60-75	14.5 (rainfed) 20.0-25.0 (irrigated)
18	Kufri Jyoti	110-120	8.5-10.0 (rainfed) 15.0-16.0 (irrigated)
Toria			
19	TS-38	90-95	1.0-1.2
20	TS-67	90-95	1.0-1.2
21	Jeuti	90	0.67

(State Package of Practice, *kharif* crop of Assam,2021)

2. METHODOLOGY

The current study examines ten years of rainfall data (2011-2021) in connection to dry spells and their consequences on rainfed rice-based cropping systems. Chamua, Borbali, Nagaya, Borkhet, and Jakaipelua (Lat: 27° 02′ 18″, Long: 93° 52′ 46″, Alt: 83-90 m) villages of Assam's Lakhimpur district were selected for the study under "All India network project on National Innovations on Climate Resilient Agriculture (NICRA)". The land situations include upland, medium land, and lowland. From 2011 to 2020, participatory on-farm experiments were performed to evaluate potential adaptation methods for mitigating the effects of climate change on rice-based cropping systems. The study area receives an average of 2848.5 mm of precipitation per year, with 25%, 67%, 5.0%, and 3% during the pre-monsoon, monsoon, and post-monsoon seasons and winter seasons, respectively. The soils of the villages belong to soil odder Inceptisols, and texture varies from sandy to silty loam with a pH ranging from 4.7 to 6.4. The soil organic matter content varies between 0.34 and 3.03%. The available nitrogen (275-540 kg ha^{-1}) and potassium (138-330 kg ha^{-1}) are in the medium range. However, the available phosphorus content of soils (21.4–54.0 $kgha^{-1}$) is low to medium. This study area's soil-related issues include high soil acidity, high phosphate fixation, micronutrient deficiencies, iron toxicity, and periodic soil moisture stress throughout the winter (Dutta et al., 2015). On-farm trials were conducted with 25 farmers (5 from each village) representing various land situations. The performance of high-yielding rice varieties (HYVs) was compared with farmers' practices to determine the impact of interventions on yield. The study considers short-duration HYVs of rice such as Dishang, medium-duration rice varieties (Shraboni, Mahsuri), and long-duration submergence tolerance varieties such as Ranjit sub-1, Bahadur sub-1, Gitesh (for staggered planting) and Moniram. Similarly, during the winter season, improved varieties of potato (Kufri Pokhraj, Kufri Jyoti) and toria varieties (TS-38, TS-67, Jeuti) for delayed sowing were evaluated. Hence, the current investigations were designed with two critical strategic components: real-time contingency planning (RTCP) and Preparedness. Interventions under the RTCP were designed to deal with delayed onset of monsoon, early season drought, mid-season drought, and terminal drought in winter rice and rabi crops (Table 2a)

Preparedness includes changes in the cropping system, in situ and ex situ rainwater management systems, alternate land use like cultivation under low-cost polyhouse, mushroom cultivation, vermicompost production, fodder bank, village seed bank, etc., to cope with weather aberrations (Table 2b).

Table 2a. Details of on-farm demonstrations implemented as Real-Time Contingency practices (RTCP)

Weather aberration	Village	Farming situation	Crop	RTCP implemented	No. of farmers' fields covered	Area covered (ha)
a. Delayed onset of monsoon	Chamua	Upland	Rice	Sowing of rice seeds in nursery bed using harvested rainwater	6	2
	Nogaya	Medium land			6	2
	Borbali				6	2
	Borkhet	Low land			6	2
	Jakaipelua				6	2

b. Early season	Chamua	Upland		Irrigation with	3	0.4
drought	Nogaya	Medium		harvested	3	0.4
	Borbali	land	Potato	rainwater	3	0.4
	Borkhet				3	0.4
	Jakaipelua				3	0.4
c. Mid-season	Chamua	Upland		Irrigation with	3	0.4
drought	Nogaya	Medium		harvested	3	0.4
	Borbali	land	Potato	rainwater	3	0.4
	Borkhet	Low land			3	0.4
	Jakaipelua				3	0.4
d. Terminal	Chamua	Upland			10	04
drought	Nogaya	Medium	Sali rice,		2	0.4
	Borbali	land	potato	---	2	0.4
	Borkhet	Low land			2	0.4
	Jakaipelua				2	0.4
		Total			78	26.8

Table 2b. Details of on-farm demonstrations implemented as Preparedness

Theme	Village	Farming situation	Demonstrations	Preparedness	No. of demonstra tions	Area (ha)
a. Rain Water	Chamua	Upland	*In-situ* moisture	Mulching with	3	1
Management	Nagaya		Conservation	locally	3	0.5
	Borkhet			available mulch material in turmeric	3	0.5
	Chamua	Medium	Rainwater	Life-saving	6	2
	Borbali	land	harvesting in a	irrigation in *Sali*	6	2
	Borkhet		farm pond and	*rice*,	6	2
	Jalaipelua		efficient	potato, toria	6	2
	Nogaya		utilization		6	2
b. Crops and	Chamua	Upland	Demonstration	Sali rice:	5	2.5
Cropping	Borbali	and	of crop	Dishang	5	2.5
System	Borkhet	medium	varieties	Potato: Local	5	2.5
	Jalaipelua	land		Toria: TS-38,TS-	5	2.5
	Nogaya			67,Jeuti	5	2.5
	Chamua	Low	Demonstration	Submergence	3	0.25
	Borbali	land	of crop	tolerant	3	0.25
	Borkhet		varieties	rice varieties	3	0.25
	Jalaipelua			(Ranjit sub -1,	3	0.25
	Nogaya			Swarna sub-1,Bahadur sub-1)	3	0.25
c. Fodder	Jalaielua	Upland	Maintenance	Hybrid Napier	---	0.5

Bank / Low-cost poly house	Chamua	Upland	and production of green fodder as fodder Seed Bank Low-cost poly house	(variety- Co-Two and Co-4), Sateria, Congo signal, Oats, Maise Protective cultivation of vegetable crops	5	0.05
			Total		84	26.3

3. RESULTS AND DISCUSSION

3.1 Rainfall variability

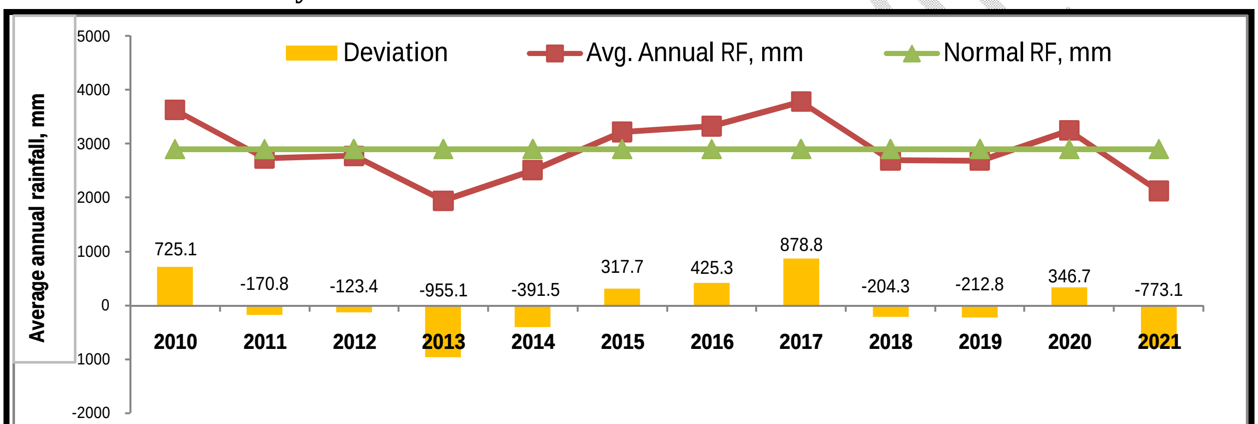

Fig 1: Average annual rainfall of Lakhimpur district of Assam (2010-2021) and deviation from average rainfall

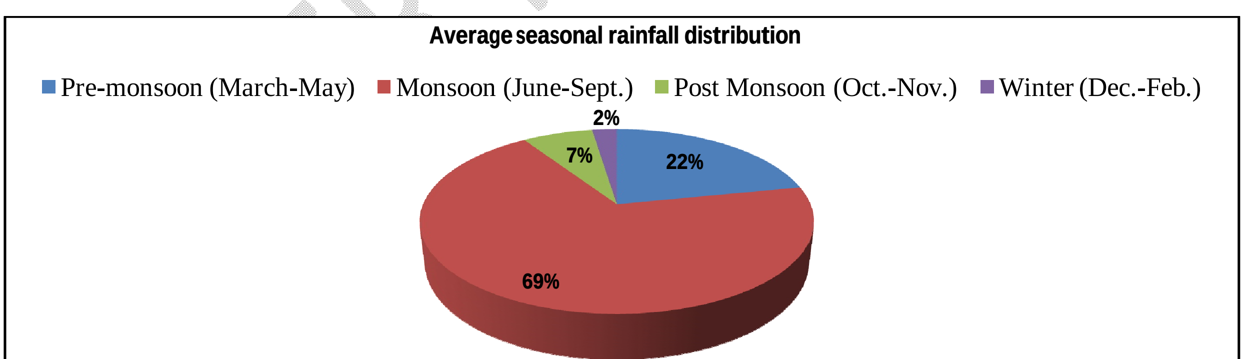

Fig 2: Average per cent distribution of seasonal rainfall of Lakhimpur district of Assam (2010-2021)

Monthly rainfall data was collected from the nearest Regional Agricultural Research Station (RARS), North Lakhimpur, from 2010 to 2021. However, rainfall data collected from a mini weather station situated at NICRA village Chamua vary from the data collected from

RARS, North Lakhimpur. It indicates the rainfall variability within the district (60 km from RARS). These two locations have observed a difference of 25%-36% in annual rainfall. The average annual rainfall of the Lakhimpur district is 2904mm. Among the years under study, it has been observed that during 2010, 2015, 2016, 2017 and 2020, the district received an excess annual rainfall of 725.1, 317.7, 425.3, 878.8 and 346.7 mm, respectively, as compared to the average annual rainfall. While, during 2011, 2012, 2013, 2014, 2018, 2019 and 2021 there is a deficit in annual rainfall of 170.8, 123.4, 955.1, 391.5, 204.3, 212.8 and 773.1 mm respectively (Fig 1). The village receives 22%, 69%, 7.0% and 2% pre-monsoon, monsoon, post-monsoon and winter seasons, respectively (Fig 2). Delayed onset of monsoon by 2 to 3 weeks was observed during 2013, 2014, 2018 and 2019. During 2013, there was a deficit in pre-monsoon (March-May) rainfall and post-monsoon (October-November) rainfall. In 2015, 50% of excess rainfall caused flash floods in many areas, but there was a substantial decrease in rainfall in July (46% deficit). A rainless period of 11 days (26 July to 3 August) caused a delay in the transplanting of winter rice. Likewise, in 2016 the village received 30% excess pre-monsoon rainfall. During June and July, a total of 32 rainy days were observed, out of which 14 rainy days with an intensity of 45-99 mm per day caused a flash flood. There is a rainfall deficit of 63%, 55% and 86% in August, October and November respectively. A mid-season and terminal dry spell in winter rice is widespread in NICRA-adopted villages due to its soil type and weather aberrations.

3.2 Impact of real-time contingencies measures during weather aberrations

3.2.1 Situation – I: Delayed onset of monsoon

The expected time of onset of monsoon in the NICRA village Chamua is the first week of June. Delayed onset of monsoon was observed during 2013 (3rd week), 2014 (2nd week), 2018 (2nd week) and 2019 (2nd week). Farmers do not face any problems raising nursery beds and sowing long-duration (>150 days) varieties of winter rice before mid-June when the onset is average. In case of delay in the onset of monsoon, the farmers of the village use harvested rainwater for the timely sowing of winter rice in the nursery bed. In general, nursery beds are raised in upland conditions. Maintaining the water level during nursery bed preparation is essential because seeds may float due to excess water at final land preparation. Timely sowing of long-duration varieties can escape low temperatures during anthesis resulting in higher production and economic return. An increase in yield of 33% in Ranjit, 12.3% in Mahsuri and 32% in Gitesh was observed when sowing was done before 15 June over late sowing condition (Table 3).

Table 3: Performance of long duration high yielding varieties of rice under normal and delayed sowing

Normal crop	Normal variety (duration: 155days)	Yield ($kgha^{-1}$) Sowing before 20 June	Sowing after 20 June	% increase in yield	RWUE (kgha-1-mm)	Net returns ($Rsha^{-1}$)	B: C ratio

Sali rice	Ranjit	4589	3445	33	2.49	25385	2.24
	Mahsuri	3130	2787	12.3	1.70	17055	1.83
	Gitesh	4712	3574	32	2.56	26615	2.20
	Bahadur	4120	-	-	2.24	20695	2.01
	Moniram	3987	-	-	2.16	19365	1.99
	Jalkunwari	3450	-	-	1.87	13995	1.58

3.2.2 Situation –II: Early season drought

During 2015, the village experienced an early season dry spell of 11 days (26 July to 3 August). Early transplanted short-duration varieties in upland conditions were affected considerably, while the effect was not prominent in medium-land and lowland conditions. In 2016, rainfall received during August was deficit by 63% with a dry spell of 13 days (17^{th} to 29^{th} August). Short-duration varieties grown in uplands were mainly affected. A dry spell of 8 days (12^{th} to 19^{th} August) was observed during 2018, but the effect was not prominent in winter rice. Likewise, in 2019 a dry spell of 17 days (29 July to 14 August) was observed affecting short-duration varieties. Farmers irrigated their rice fields with harvested rainwater with the help of a water-lifting pump available at the Custom Hiring Centre (CHC).

3.2.3 Situation-III: Mid-season drought

During 2015, the village was affected by a mid-season dry spell of 11 days (26 September to 7 October) which affected the panicle initiation stage of winter rice. The effect was prominent in long-duration rice cultivars. Likewise, in 2016 also, a mid-season dry spell affected the PI and grain-filling stage of winter rice. A rainfall deficit of 55% was observed in October. The villages experienced two mid-season dry spells of 10 days (3 October to 12 October 2018) and 21 days (14 October to 3 November 2018), respectively. A dry spell of 18 days (17 October to 13 November) was also observed in 2019. Though the effect of dry spells on winter rice was not very prominent in the lowland, the active vegetative, early tillering and PI stage of early transplanted short-duration varieties grown in the upland situation were affected considerably. In medium land situations, the 21 days long dry spell affected the PI stage of medium duration varieties. As a real-time response, farmers were advised to irrigate (2cm depth) the crop by harvesting rainwater in the farm ponds using the water lifting pump of the Custom hiring centre. Midterm corrections in the case of mid-season and terminal dry spells in winter rice were carried out in terms of the application of an additional dose of 22.5 kg MOP per hectare in maximum tillering to grain development period. Incorporation of 22.5 kg ha^{-1} MOP resulted in 12.56 % increase in yield as compared to without intervention (Table 4).

Table 4: Performance of short-duration high-yielding varieties rice (Dishang) and potato (kufri jyoti) grown under upland situations.

Farming situation	Intervention	Yield($kgha^{-1}$)	% increase	RWUE ($kgha^{-1}mm^{-1}$)	Net returns ($Rsha^{-1}$)	B: C ratio

		WI*	WoI**	in yield	WI*	WoI**	WI*	WoI**	WI*	WoI**
Upland land	Supplemental irrigation in rice (Dishang)	4520	3015	33.29	3.11	2.07	27700	15150	1.58	1.01
	Incorporation of MOP 22.5 kg ha^{-1} in rice (Dishang)	4086	3630	12.56	2.24	1.99	22860	18800	1.27	1.07
	Potato	25556.8	12279	51.58	120.268	57.778	85968	57790	1.5	1.9

* WI-with intervention **WoI-without intervention

3.2.4 Situation-IV: Terminal drought

The village experienced terminal dry spells in winter rice from 2013 to 2020. During 2013, a terminal dry spell extending from November to mid of February 2014 affected the grain-filling stages of lengthy and medium-duration varieties of winter rice. A terminal dry spell of 45 days (29 September to 12 November) followed by another dry spell of 89 days (24 November to the end of February 2015) was observed in 2014. Likewise, in 2015 also, there was a dry spell of 45 days (15 October to 30 November); in 2016, 96 days (14 October to 19 February 2017), and two terminal dry spells of 27 days (1 November to 27 November) and 33 days (29 November to 31 December) respectively in 2017, 21 days extending from 14 October to 3 November in 2018, 18 days (27 October to 13 November) and 11 days (20 November to 30 November) respectively in 2019 and 12 days (4 November to 15 November) and 13 days (23 November to 5 December) in 2020 have been observed the long-duration rice cultivars were in the milk dough stage (table 5). On the other hand, a terminal dry spell also coincides with the sowing of *rabi* crops. Thus it acts as an early season drought for the *rabi* crops affecting germination and early establishment of potato and toria in upland and medium land situations.

Table 5: Dry spells during crop growing season from 2014-2021

Year	**Dry spell** Duration (days)	Dates & Months	**Crop**	**Stage of the crop**
2014-15	18	1.06.14 – 18.06. 14	*Sali* rice	Sowing
	45	29.09.14 – 12.11.14	*Sali* rice	Grain filling stage (***LDC).
	89	24.11.14 – 28.02.15	Rapeseed, Potato, winter vegetables	Grain filling/tuber formation/active growth stage
2015-16	11	26.07.15- 3.08.15	*Sali* rice	Transplanting and early tillering stage in upland areas
	12	26.09.15- 7.10.15	*Sali* rice	PI Stage (***LDC), grain filling (*SDC) filling stage

	45	15.10.15- 30.11.15	*Sali* rice	Grain filling stage.
	23	17.12.15- 9.01.16	Rapeseed, Potato, winter vegetables	Grain filling/tuber formation/active growth stage
2016-17	18	22.01.16-8.02.16	Rabi crops	Harvesting of rabi crops
	14	6.08.16 – 29.08.16	*Sali rice*	Vegetative stage
	96	14.10.16-19.02.17	Rapeseed, Potato, winter vegetables	Flowering/grain filling /tuber formation stages
2017-18	27	01.11.17-27.11.17	Potato, toria, rabi vegetables	Vegetative growth stage, early establishment stage
	33	29.11.17 - 31.12.17	Potato, toria	Vegetative growth stage
	37	01.01. 18 - 06.02.18	Potato, Toria, rabi vegetables	Tuber formation, siliqua formation and vegetative growth stage
2018-19	65	01.03.18- 04.05.18	Turmeric, Ginger, Okra, ridge gourd	Turmeric, Ginger: Initial growth stage
	8	12.08.18- 19.08.18	Sali rice	Active vegetative growth stage
	10	03.10.18- 12.10.18	Sali rice	Tillering, PI (*SDC),
	21	14.10.18- 03.11.18	Sali rice, Potato, Toria	Sali rice: Maturity (SDC), tillering and PI (**MDC), Tillering (***LDC)
	25	05.01.19- 29.01.19	Potato, toria	Maturity stage
2019-20	17	29.07.19- 14.08.19	Sali rice	Transplanting, tillering
	18	27.10.19- 13.11.19	Sali rice	Grain filling, maturity
	11	20.11.19 -30.11.19	Sali rice, potato, toria	Maturity, sowing and early growth
	29	12.12.19- 09.01.20	Potato, toria	Reproductive stage
2020-21	12	4.11.20-15.11.20	Rice, potato,toria	Maturity and early vegetative stage
	13	23.11.20-05.12.20	Rice, potato,toria	Grain filling & maturity of rice and vegetative stage of potato& toria
	23	19.12.20-10.01.21	Rice, potato,toria	Maturity ,reproductive and flowering stage
	16	31.01.21-15.02.21	Potato,toria	Maturity stage
	10	17.02.21-26.02.21	Toria	Maturity stage

SDC-short duration Cultivar,MDC-Medium Duration Cultivar,***LDC-Long duration cultivar*

The following contingency plan was implemented for the management of mid-season and terminal drought in the village -

3.3 Replacing long duration high, yielding and traditional rice cultivars with short and medium-duration improved cultivars-

As a contingency plan, short and medium-duration rice varieties were transplanted in upland and midland areas, respectively, because these varieties can withstand mid-season and terminal dry spells. It was observed that when long-duration high-yielding or traditional cultivars were grown by farmers in upland and midland conditions, the crop suffered from the terminal drought during the study period in the NICRA villages. Short-duration varieties viz. Dishang and medium-duration varieties Shraboni and Mahsuri were grown as a contingency plan for managing mid-season and terminal droughts. An increase in yield of 21.73 %, and 44.60% 58.67% was observed compared to farmers' Practices during 2013-14, 2014-15, and 2016-17, respectively (Table 6). It has also been observed by application of t-test that there are significant differences in yield of short as well as medium-duration rice cultivars concerning Improved Practice (IP) and Farmer's Practice (FP). Improved Practice was found to be significant in both short and medium-duration rice cultivars in comparison to Farmer's Practice. An increase in rice yield by 21.73 % and 44.60%. 58.67% as compared to farmers' Practices during 2013-14, 2014-15, and 2016-17, respectively (Table 6). The t-test also revealed significant differences in yield between short and medium-duration rice cultivars with Improved Practice (IP) and Farmer's Practice (FP). Compared to Farmer's Practice, Improved Practice was significant in both short and medium-duration rice cultivars.

Table 6: Terminal drought management through short and medium-duration rice cultivars

Year	Short Duration					Medium duration				
	IP*	FP**	% increase in yield	Net returns (Rsha^{-1})	B: C ratio	IP*	FP**	% increase in yield	Net returns (Rsha^{-1})	B: C ratio
2013-14	2537.5	2080.0	21.73	2557.5	2.3	3850	3312.5	16.355	14141	2.3
2014-15	3128.0	2137.5	44.60	10755.5	1.67	4920.0	3000.0	64.0	28520	2.6
2016-17	2635.0	2210.0	58.67	5845	1.3	3548.3	2700	31.37	14978.3	1.7
Mean	2766.8	2142.5				4106.1	3004.1			
	t-test: 3.34					t-test: 2.43				

*Improved Practice **Farmers' Practice

**Improved Practice: short, medium or long-duration high-yielding varieties*

*** Farmers' Practice: Same variety (Local rice variety) was grown in the uplands/medium lands.*

3.4 Sowing of long and medium-duration rice cultivars in the first part of June

If long and medium-duration rice cultivars are sown in nursery beds before the third week of June, the crop might be harvested in November; otherwise, the crop would be prolonged until the middle of December. Thus, early seeding of long-duration cultivars is beneficial in managing terminal dry spells. Farmers were advised to finish sowing log-duration rice cultivars in the nursery bed by mid-June which aided in the early transplantation of rice seedlings, resulting in enhanced establishment, growth, and yield of long-duration varieties in the event of terminal drought.

3.5 Management of drought with alternate crop and crop diversification

Crop diversity is an excellent technique for climate variability (FAO, 2017). Crop diversification refers to changes in the combination of crops and kinds grown in a given area, as indicated by the proportion of land planted to various crops. Crop diversification's primary goals are to boost farmer income, promote nutritional security, minimize crop failure risk under severe weather conditions, reduce pest and disease incidence, and make better use of land and natural resources. Rice was produced in all available upland, medium land, and lowland situations in NICRA villages prior to the initiation of the NICRA project. The main crop cultivated in the villages was rainfed winter rice because rainfed rice requires more water during the crop growing season, rice is grown in the village's upland, and medium land situations frequently suffer from mid-season and terminal drought. In the worst-case scenario (as seen in 2006 and 2011), the rice yield in the village's upland situation falls below 900 $kgha^{-1}$. As a result, a contingency plan for drought management with an alternate strategy of cultivating high-value crops (improved varieties) such as ginger, turmeric, sesame, black gram, green gram, summer vegetables, and winter vegetables was promoted the study area.

Six farmers covering an area of approximately 3.2 ha were chosen for crop diversification demonstration under NICRA during 2013-2017. When diverse planting was used instead of mono-cropping of winter rice, all farmers generated significantly more income from the same land type and amount of rainfall. Crop diversification yielded a higher average net income of Rs 75,306.00 per year, which was higher than their income from monocropping winter rice (31,607.00 per year) (Table 7). This finding was supported by Neog *et al.*, 2018, who stated that crop diversification, particularly in upland areas, yields a high net income per year that was several times higher than their revenue from monocropping of winter rice.

Table 7: Performance of crop diversification at NICRA village during 2014-17

Name of the farmers	Crops grown (variety)	Area (ha)	CI (%)	Rice equivalent yield (Kgha^{-1})	Net Income (Rsha^{-1})	Increase in net return (Rsha^{-1})	B: C ratio	RWUE (kgha^{-1}mm^{-1})
Farmer 1	Rice (Disang), Potato (Pokhraj& local), Rapeseed (TS-36), Cauliflower (Hyd), Broccoli (Hyd), French bean (Parvati), Knolkhol (Hyd), Cabbage (Rear Ball), Pea (Hyd), Brinjal (JC-1), Tomato (MT-3), Radish (Bombay Red), Chili (Suhasini), Pumpkin (local)	0.67	152.25	103872.25	6,14,418.00	6,57,500.33	2.59	69.22
Farmer 2	Rice (Mahsuri), Rapeseed (TS-36), Potato (Local), Cauliflower (Hybrid), Cabbage (Rear Ball), Knolkhol (Hybrid), Tomato (MT-3), Brinjal (JC-1), Sugarcane (Local), Maise (All Rounder), Ridge gourd (Local), Chili (Hybrid), Cowpea (Hybrid)	0.53	148.25	176567.00	1,80,739.00	1,34,501.33	2.18	14.72
Farmer 3	Rice (Mala), Rapeseed (TS-36), Potato (Pookhraj), French bean (Parvati), Knolkhol (Hybrid), Tomato (MT-3) and bottle guard.	0.53	172.75	68275.25	3,66,724.00	4,56,335.00	1.93	40.67
Farmer 4	Rice (Mahsuri, Luit, Ranjit & Nania), Turmeric (Local), Potato (Pookhraj), Cabbage(Hybrid), Cucumber (Hybrid), Maise	0.53	153.50	85873.75	6,00,853.00	4,83,213.33	2.72	27.37

	(Allrounder), Ridge gourd (Local), Ladies finger (Pravani Kranti)							
Farmer 5	Cabbage (Rear ball), Rapeseed (TS-36), Potato (Pookhraj), Brinjal (JC-1), Tomato(MT-3), Turmeric(Local)	0.53	118.50	49630.00	3,01,925.00	2,91,425.50	2.34	38.58
Farmer 6	Rice (Mahsuri), Rice (Joha), Potato (Pookhraj), Rapeseed (TS-36), Broad bean(Local), Sugarcane (Local)	0.40	102.00	4630.00	75,306.00	66,906.00	3.87	
Farmers practice (mono-cropping)	Rice (Mashuri, Luit, Dishang, local variety)		100.00	3546.66	31,607.00	--	3.17	

3.6 Preparedness

Preparedness includes all the precautionary measures like changes in the cropping system, *in situ* and *ex situ* rainwater management systems, alternate land use like cultivation under low-cost polyhouse, mushroom cultivation, vermicompost production, fodder bank, village seed bank, etc., to cope with weather aberrations. These adaptation strategies have been proven to be very much beneficial for the farmers of the village.

3.6.1 Impact of rainwater management strategies

3.6.1.1 In-situ Rainwater management

Mulching with locally accessible agricultural mulch materials such as rice straw, rice husk, rapeseed straw, water hyacinth, and others was utilized to control periodic dry spells during *Kharif* and *rabi*. Most farmers in NICRA villages employ organic mulching as an adaptation approach during dry seasons. It is used in potatoes, tomato, turmeric and ginger. Mulching helps to conserve moisture, reduce weeds, and promote crop growth. Mulching is done in turmeric in April and May before crop emergence. Mulching saves labour costs significantly in potatoes because it eliminates the need for intercultural operations such as earthing up, weeding, and irrigation. Mulching with organic materials gives 30%,92% and 107% more yield in turmeric,potato and tomato,respectively than without mulching practice (Table 8).

Table 8: Performance of *In-situ* moisture conservation during 2018-19 and 2019-20 (2 years average data)

Crop (Variety)	Duration (days)	Yield ($Kgha^{-1}$)		% increase in yield	Net returns ($Rsha^{-1}$)		B: C ratio	
		*WM	**WoM		*WM	**WoM	*WM	**WoM
Turmeric (Megha turmeric-1)	300-315	34206	26301	30	525531	383637	7.34	5.64
Potato (Kufri Jyoti)	110-120	25613	15459	92	160500	170925	5.09	2.53
Tomato (M-27)	--	26405.5	8950.0	107	305340.00	--	6.95	--

* WM-with mulching **WoM- Without mulching

3.6.1.2 *Ex-situ* rainwater management

Renovation existing farm ponds for rainwater harvesting is a cost-effective technology for resource-poor farmers. Thirteen farm ponds scattered in Chamua village have been renovated under the NICRA project as rainwater harvesting structures. The water harvesting capacity of these farm ponds ranges from 300 to 6800 cubic meters (Table 9). Apart from these, a canal of 0.5 km has been renovated for harvesting rainwater with sluice gates at both ends. The village receives a good amount of pre-monsoon rainfall (March to May) and monsoon season (June to

September), harvested in the renovated farm ponds and extensively used during nursery bed raising of winter rice. Rice grown in upland areas often suffers from early-season and mid-season drought. Under such conditions, harvested rainwater is utilized as supplemental irrigation in winter rice and *rabi* crops like potato, rapeseed and *rabi* vegetables during prolonged dry spells.

Table 9: Details of renovated farm ponds of NICRA village

Sl. No.	Pond number	Pond details	Capacity (Cubic meter)	Remarks (if any)
1	Pond 1	Size: 52m × 22m (Approx.), depth: 2 ft-7 ft(Approx.), side slope of 30-45°	1411.3	Active, Used for irrigation; Rearing Hybrid duck-White picken
2	Pond 2	Size: 29.5m × 28m (Approx.), depth: 1 ft-6 ft (Approx.), side slope of 30-45°	1027.3	Active, Used for irrigation
3	Pond 3	Size: 22m × 19m (Approx.), depth: 1 ft-5 ft(Approx.), side slope of 30-45°	488.7	Active, Used for irrigation
4	Pond 4	Size: 17m × 16m (Approx.), depth: 0 ft-4 ft(Approx.), side slope of 30-45°	315.4	Active, Used for irrigation, at lean period dried off, grassy.
5	Pond 5	Size: 20m × 20m (Approx.), depth: 1 ft-6 ft (Approx.), side slope of 30-45°	446.9	Active, Used for irrigation, grassy, and overflow at times.
6	Pond 6	Size: 24m × 19m (Approx.), depth: 1 ft-8 ft(Approx.), side slope of 30-45°	481.6	Active, Used for irrigation, *rabi* crops
7	Pond 7	Size: 75m × 60m (Approx.), depth: 5 ft-8 ft(Approx.), side slope of 30-45°	6879.4	Active, Used for irrigation, *Kharif* and *rabi* crops
8	Pond 8	Size: 32m × 32m (Approx.), depth: 5 ft-20 ft (Approx.), side slope of 30-45°	1261.5	Active, Used for irrigation, Azolla production, *Kharif* and *rabi* crops Well Maintained.

Table 10: Performance of Potato with supplemental irrigation

Year	Yield (Kgha^{-1})		Increase in yield (%)	Net returns (Rsha^{-1})	B: C ratio
	WI*	WoI**			
2013-14	14179	9262	85.6	40153.00	2.13
2014-15	26748	14827	43.3	87216.00	2.19
2015-16	21563	9490	127.2	142350.00	2.94

2016-17	20943	10980	90.7	73328.00	2.00
2017-18	20750	11656	43.8	162500.00	3.61
2019-20	23433	13568	72.7	171830.00	2.70
Mean	21269.33	11630.50			
t-test: 5.03					

* WI-with supplemental irrigation **WoI-without supplemental irrigation

- *Number of supplemental irrigations -3*
- *Stages of providing irrigation: At the vegetative stage, stolen formation stage and tuber development stage.*
- *Amount of water given through each irrigation-2-5 cm depth*
- *Method of irrigation – flood irrigation from the farm pond.*

It was observed by application of a t-test that the performance of potatoes with and without supplement irrigation is highly significant (at 5% and 1% both**) with a similar pattern of coefficient of variation (CV %).

3.6.1.3 Impact of change in cropping systems

Double/relay cropping systems

Before the NICRA project's implementation, the farmers of the NICRA village practiced monocropping of winter rice. Farmers were continuously encouraged to take up another crop after harvesting winter rice in the village. The performance of double cropping systems like winter rice + Maize, winter rice + rapeseed, and winter rice + potato in the upland and medium land has been evaluated. Highest B: C ratio of 2.03 was observed in winter rice + rapeseed followed by winter rice + potato sequence (1.75) as compared to mono-cropping of winter rice (Table11).

Table11: Performance of double cropping (average data 2013-21)

(Double or relay cropping)							
Farming situation	Treatment	Yield ($kgha^{-1}$) Crop-1	Yield ($kgha^{-1}$) Crop-2	CEY (REY)	Cost of cultivation ($Rsha^{-1}$)	Net return ($Rsha^{-1}$)	B: C ratio
Upland	*Winter rice (Dishang) + Rapeseed(JT-90-1)*	4001.50	938.53	4599.50	33040.83	53656.50	2.03
	Winter rice(Dishang) + Potato (K. pokhraj)	3636.90	18040.72	15759.02	85915.17	107313.87	1.75

3.6.1.4 Impact of adoption of alternate land use system

i.Seed bank

Maintaining a seed bank is one of the mitigating measures for dealing with the consequences of extreme weather occurrences. Establishing a village seed bank assists small and marginal farmers in the community become self-sufficient in seed, which is one of the most significant inputs in agriculture. The following four farmers were entitled to plant variety rights on four indigenous rice varieties by the Protection of Plant Varieties and Farmers' Rights Authority (PPVFRA), Govt. of India, in November 2020 after fulfilling all the criteria of registration initiated in 2013. The term of protection of these varieties was considered from the date of grant of certificate, *i.e*. 19.11.2020. Registration is initially valid for six years with the provision of yearly renewal for 15 years. It will enable the farmers to produce, sell, market, distribute, import or export the variety. The details of varietial characters are enclosed in table 12.

Table 12: Characteristics of four indigenous rice varieties cultivated in NICRA village Chamua, Lakhimpur (Assam)

Sl. no	variety	Duration (days)	Stem length	Grain colour (lemma and palea)	Grain length	Decorticated grain shape	Decorticated grain colour	The aroma of decorticated grain	Land situation	Yield (qha^{-1})
1	Nania	160-170	Long	Straw	Medium	Medium slender	White	Present	Medium	20-24
2	Sokowa	165-170	Long	Black furrows on straw	short	Short slender	Light brown	Absent	Medium	30-45
3	Saha champa	165-170	Long	Straw	Long	Long slender	White	Absent	Medium to low land	20-25
4	Khagora sali	180-185	Very long	Straw with black tip	Short	Short bold	White	Absent	Low land	30-35

ii. Fodder bank

During the conduct of PRA (19 February 2011) at NICRA village Chamua, it was found that the fodder availability in the village gradually increased from the last part of October (the beginning of the harvesting of *Winter* rice) and availability became the maximum during December to April. Then onwards, fodder availability gradually dropped off, and it became the minimum from September to October (lean period). The village's substantial low productive *desi* cattle population depends on free grazing on vacant rice fields from November to May and non-cultivated upland (25 ha) of the village from June to October. Due to the conversion of non-cultivated upland to cropped land and the growing of more than one crop in the same field after implementing the NICRA project, the shortage of fodder has been increasing. The establishment of fodder banks made the farmers self-sufficient in fodder. The Chamua village had roughly 15 cows (3 farmers) of improved Jersey breed in 2010-11; however, the population of jersey cattle in the village has expanded to 40 at the end of March 2015. After NICRA interventions, 12 small farmers from the village community are adopting scientific dairy farming. For these two reasons, the village's fodder need has increased, and many of its farmers have begun their fodder farming. Some of the village's farmers also grew seasonal fodder crops such as congosignal, oats, and maize. A 'fodder seed bank' was developed at the NICRA village Chamua under NICRA in partnership with the All India Coordinated Research Project on Forage Crops, Jorhat Centre, AAU, Jorhat, to make fodder seedlings of diverse cultivars available to the farmers. The establishment of a fodder bank made the farmers self-sufficient in fodder.

iii. Mushroom cultivation

The impact of mushroom cultivation on nutritional and livelihood security has been evaluated during 2018-19 and 2020-21. Cultivation of oyster mushrooms has been carried out, covering five farmers. The highest additional income of Rs. 10,800.00 per annum has been observed among the farmers (Table 13).

Table 13: Performance of mushroom cultivation

Name of farmers	Village	2018-19		2020-21		Mean	
		Production (kg)	Income (Rs)	Production (kg)	Income (Rs)	Production (kg)	Income (Rs)
Farmer 1	Chamua	27	5400.00	48	9,600.00	37.5	7500.00
Farmer 2	Nogaya	24	4800.00	45	9000.00	34.5	6900.00
Farmer 3	Borkhet	--	--	72	10,800.00	--	--
Farmer 4	Chamua	--	--	25	5,000.00	--	--
Farmer 5	Chamua	--	--	10	2000.00	--	--

iv. Low-cost poly house

Farmers of the Chamua village adopted low-cost poly house cultivation of high-value seasonal vegetables and raised vegetable seedlings in advance of the rabi season. Due to high rainfall up to mid-October, raising seedlings of cole crops like tomato, brinjal, chilli, capsicum, and other vegetables is often tricky, causing delayed planting of rabi vegetables. Thus, low-cost poly houses are beneficial in various ways, including reducing the negative impact of rainfall on advancing vegetable growing seasons, improving the utilization of residual soil moisture due to early vegetable establishment, and increasing vegetable production. Among these crop cultivation of Bhut jolokia *(king chilli) and* Tomato was found to be more profitable .An average income of Rs 25,605.00 and 4950.00 with B:C ratio 3.4 and 3.65 per annum was obtained in Bhut Jolokia and Tomato, respectively (Table 14).

Table 14: Performance of high-value crop under poly house

Year	Number of farmers	Crop	Income (Rs)	yield (kgm^{-2})	B: C ratio
2015-16	1	*Bhut Jolokia (king chilli)*	5400	1.2	3.1
		Tomato (Hybrid)	400	3.5	3.5
		Cucumber (Hybrid)	1000	1.3	2.7
		cabbage)	300	2.1	
		Padina (Mint)	480	0.02	--
		Laik Sak (Brassica spp) Local	500	1.1	--
2018-19	3	Chilli (Local)	8850	2.1	3.5
	1	*Bhut Jalakia* (Local)	32300	3.1	3.7
	5	Leafy vegetable	2000	1.3	4
	5	Nursery (cabbage, cauliflower, knolkhol)	2500		5
2019-20	1	Tomato (Hybrid)	9500	3.5	3.8
	1	*Bhut Jalakia* (Local)	34210	3.8	3.42
	1	Nursery (Vegetable seedling)	3000		3
2020-21	3	*Bhut Jalakia*	30510	1.3	3.4
	2	Leafy Vegetable	3500	1.4	3.6
	3	Nursery (Vegetable seedling)	2500		2

v. Custom hiring centre

The custom hiring centre of NICRA village Chamua is run by the "Custom Hiring Centre Management Committee (CHCMC)", with 11 members, including one president and one secretary. The committee set the rate for hiring implements and changed it from time to time. Implements were distributed to the village's trained (by Farm Machinery Training and Testing Institute, Biswanath Chariali) youth at the monthly hiring fee set by the CHMC.

The operators have to report about conditions of the equipment, the area covered and the rent collected to the committee every week. Rent collected by the CHCMC was deposited to the account of the VCRMC, Chamua. In the present system operation, the operator has benefited the maximum. On average, 50% of overall earnings go to the operator, 40% to POL and equipment maintenance, and just 10% of earnings go to the committee. Though practically all of the implements/machines offered in the custom hiring centre of the NICRA village Chamua are used by farmers, some are more popular. Timely operations through custom hiring centres assisted farmers in completing sowing or transplanting on time and cultivating more than one crop for crop diversification.

Table 15: Improved implements used for various agricultural operations on custom hiring from 2014-19

Name of the implement used	Farm operation	No. of farmers and the area (ha)	Relative time-saving ha^{-1} over farmers practices	Relative Saving in cost of operation ha^{-1} over farmers' Practice (Rs^{-1})	Resource generated by hiring implements (Rs)
WLP	Nursery bed preparation of *winter rice*	204 (20.33) (Main field: 53.3 ha)	27.6 hrs	1875.00	12705.00
Power tiller	Ploughing	114 (27)	56.2 hrs	5250.00	36650.00
Cultivator	Ploughing	120 (56)	43.1 hrs	375.00	8400.00
Rotavator	Ploughing	80(45)	94.5 hrs	2250.00	10125.00
Rice Thresher	Threshing of rice	145 (45.1)	56 hrs	1875.00	22330.00
Sprayer	Spraying of chemicals	22 (13)	--	--	560.00

* Time consumed for irrigating 1 ha of land ** Costs incurred for irrigating 1 ha of land

vi. Agro met advisory service

Weather forecast-based agro-meteorological advisories provided by Agro Met Advisory Services, Sonitpur, were displayed regularly in the NICRA village Chamua. Agro-met advisory service assisted the farmers in making decisions in the preparedness stage of real-time contingency planning, such as land-related (e.g. land situation-wise decision making, raise bed or flatbed), rainwater harvesting (In situ water harvesting through mulching, rainwater harvesting in renovated farm ponds and micro irrigation system through harvested rainwater), crop-related (selection suitable crop varieties), management related (management of insect pests, diseases, nutrient and weed). Hence, agro-met advisory services are the sole option for real-time responses to meteorological anomalies; they play a critical role in agricultural contingency planning. Two of the case studies demonstrate the utility of agro-met advisory services for climate risk management are discussed below-

Case Study no.1

In May 2015, the village received unusually heavy rainfall (415 mm). During the grain-filling stage, the wet spell (50 per cent surplus rainfall) harmed the maize crop. During May 2015, the daily rainfall recorded in the village and the daily rainfall forecast (for the Lakhimpur district) received from IMD were practically the same. The weather information (weather forecast) available at the time was extremely helpful in addressing the problem caused by excessive rainfall via real-time agromet alerts. Farmers benefited from different agromet advisories issued and displayed in the village. The following advisories were displayed (on various dates during May 2015) depending on the forecast available at the time.

A) Drain the water from the maize-growing fields.

B) Collect the green cobs

C) If removing the water from the field is impossible, pick green cobs and crops for fodder.

Case Study No. 2

During January 2016, the weather was exceptional compared to normal in terms of cloudiness and relative humidity. Overcast skies for almost 14 days (9 to 26 January) and evening relative humidity of 70 to 90% with four wet days were particularly favourable for developing the late-blight disease in potatoes and tomatoes. The potato produced on 12 ha of land in the NICRA village was observed to be damaged, with a projected 50% yield reduction.

Agromet advisories were generated and displayed in the village based on the weather forecast (overcast sky, high relative humidity, and light rainfall). Farmers benefited from the agromet advisories, and due to the measures taken based on the forecast, the yield of potatoes increased by 127% (from 9490 to21563 $kgha^{-1}$) was obtained as compared to farmers who did not follow the advisories.

4. IMPACT ASSESSMENT

A study to assess the impact of the National Innovations on Climate Resilient Agriculture (NICRA) Project interventions on farm income and farm productivity of participant farmers found that the mean annual farm income score of participant farmers (Rs.115969.62) was significantly higher than that of non-participant farmers (Rs.79180.25). It also implied that NICRA Project treatments could improve agricultural productivity among participating farmers. Participant farmers had better mean rice productivity (3177.37 $kgha^{-1}$) than non-participant farmers (2296.72 $kgha^{-1}$). In the case of potatoes, participation farmers' mean productivity (15633.75 $kgha^{-1}$) was higher than that of non-participant farmers (10875.00 $kgha^{-1}$). Rapeseed productivity was 873.00 $kgha^{-1}$ among participants and 603.75 kgha-1 among non-participants, respectively (Sultana et al., 2020). The NICRA project had a strong positive influence on the agricultural income of the participating farmers. The majority of participants (68.75%) had a medium level of adoption, with 17.50% having a low level of adoption of climate-resilient agrotechnologies. Only 13.75% of the farmers who participated in the study had a high adoption of climate-resilient agrotechnologies. The majority of non-participant farmers (75.00%) had a low level of adoption, followed by 17.50%, who had a medium adoption of climate-resilient agrotechnologies. Only a tiny percentage (7.5%) showed a high adoption of climate-resilient agrotechnologies (Sultana et al., 2020).

5. CONCLUSION

Changing the climate in terms of weather aberrations like drought, flood, and temperature will be the greatest challenge for the human community in the coming years. Feeding the increasing global population with limited resources available for agricultural production is imperative. We have to double our farmer’s income with climate-resilient innovative technologies. For the resource-poor farmers of India, especially in the context of the Northeastern region, adopting cost-effective technologies is the only solution for mitigating the impact of climate change. The present investigation shows that changing crop or variety, manipulation of planting time, crop diversification, rainwater harvesting, and alternate land use systems are cost-effective and proven climate-resilient strategies for the region's farmers. Farmer's adoption is another factor affecting the production process. Understanding how climate change impacts agricultural production will help scientists research alternative options for mitigating and adapting to the threat of predicted climate change.

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