Chapter

Adaptation Strategies for Climate Variability in the High Rainfall Zone of India, Assam

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Abstract

The NICRA project is being implemented in two villages *viz.,* Chamua (since 2010–2011) and Ganakdalani (since 2012–2013 till 2016–2017), which are situated in the west of Lakhimpur district of North Bank Plains Zone of Assam. Chamua village is situated in Kherajkhat Mauza (Taluka), which is 45 km away from North Lakhimpur, the headquarter of district Lakhimpur. On the other hand, Ganakdoloni is situated at Dhalpur Mauza, situated 60 km away from North Lakhimpur and 15 km away from the local township Narayanpur. During 2017–2018 four villages *viz., Jakaipelua, Borbali, Borkhet, and Nogaya* were adopted under the project. Analysis of long-term rainfall data confirmed the significant decreasing trend of annual as well as monsoonal rainfall in both the Brahmaputra and Barak basins of Assam, India. Variability of rainfall has been increasing in terms of the increased frequency of high-intensity rains and the reduced number of rainy days, leading to localized flash floods and the occurrence of multiple dry spells. Mean season-wise rainfall 2011–2021 indicates long dry periods during the winter season, leading to prolonged dry spells affecting crop growth. About 69% of total rainfall (average annual rainfall of Assam is 2000 mm) is received during the monsoon season, resulting in flash floods leading to crop damage. Out of 12 years of investigation, 10 years are deficit years, resulting in crop stress both during the monsoon and post-monsoon period. Preparation and implementation of real-time crop contingencies are important in responding to weather aberrations in different strategies like preparedness, real-time response, etc. Identification of various adaptation strategies, including climate-resilient crops and cultivars, rainwater harvesting and recycling, efficient energy management through farm mechanization, dissemination of weather information, and weather-based agro-advisories to farmers in a real-time basis, is important adaptation technologies for building climate-resilient agriculture. The study showed that adaption of climate-resilient crop and cropping system and use of harvested rainwater resulted in a 12 to 30% increase in yield observed by the cultivation of high-yielding rice varieties (HYVs) (*Ranjit, Gitesh, Mahsuri*, etc.) when sown in time (before 15th June) over late sowing conditions (after 20th June). In the case of early season drought, replacement of long duration traditional varieties with short duration HYV and life-saving irrigation using harvested rainwater increased yield by about 59% (short duration var. *Dishang*) over non-irrigated fields. In case of mid-season and terminal drought, application of an additional dose of 22 kg ha^{-1} MOP at maximum tillering to grain growth period an increase in yield of about 33% (*Ranjit*), 32% (*Gitesh*), 64% (*Shraboni*), and 57.5% (*Mulagabharu*) has been observed over farmers' practice. In highly flood-affected areas under lowland situations replacement of submergence tolerant varieties (*Jalashree* and *Jalkuwari*) with traditional deepwater rice varieties resulted in reduced crop loss due to the genetic trait of the deepwater rice, which can withstand water logging for a long period. With an increase in the level of mechanization through the use of machinery available in the custom hiring center the human and animal hour requirement for paddy cultivation was reduced from 795 to 350 $hrha^{-1}$ and 353 to 23 $hrha^{-1}$, respectively. Alternate land use in terms of low-cost poly house, vermicompost production, and mushroom cultivation also resulted in nutritional security and generation of higher income for the farmers

Keywords: climate change, ecosystem, extreme weather, vulnerability, National Innovations on climate resilient agriculture (NICRA), North Bank Plains zone (NBPZ) of Assam

1. Introduction

Climate change has become an important area of concern for India to ensure food and nutritional security for the growing population. Climate change has been one of the most talked about subjects by both scientists and common people today. The major concern has been the question of food security soon under the changed climatic situation. Climate is changing and this change is now for real. It has come as a daunting challenge to agriculture and agriculturists. The impacts of climate change are global, but countries like India are more vulnerable because of the high population depending on agriculture. The Government of India has accorded high priority to research and development to cope with climate change in the agriculture sector. The Prime Minister's National Action Plan on climate change has identified agriculture as one of the eight national missions. Therefore, the time has come to shift our focus from assessing the impact on agriculture to the management-based solution to cope with food production sustainability. Many researchers are underway to evolve climate-friendly, climate-smart, and climate-neutral agricultural technology for the benefit of society.

The impact of climate change has been increasingly visible in terms of change in temperature, precipitation, retreating ice caps and glaciers, sea level rise, atmospheric circulation pattern, and ecosystems. Climate change is not simply the increasing temperature but is indeed responsible for the increasing frequency of extreme weather events, such as heat waves, cold waves, droughts, and floods. In India, the increased frequency of pronounced heat waves, cold waves, droughts, and floods has already been realized in the last few decades. Analysis of long-term rainfall data confirmed the significant decreasing trend of annual as well as monsoonal rainfall in both the Brahmaputra and Barak basins of Assam, India [1]. Variability of rainfall has been increasing in terms of the increased frequency of high-intensity rains and the reduced number of rainy days, leading to localized flash floods and the occurrence of multiple dry spells [2]. The chapter will deal with strategies to adapt to climate variability from farmers' perspectives based on the experiences of the All-India Network Project on

Class	All classes	
	Number	%age
Marginal (<1 ha)	1,669,252	62.2
Small (1.0–2.0 ha)	561,078	20.9
Semi medium (2.0–4.0 ha)	351,245	13.1
Medium (4.0–10.0 ha)	96,418	3.5
Large(> 10.0 ha)	5004	0.2

Table 1.
Number of land holdings according to size classes of Assam [3].

National Innovations on Climate Resilient Agriculture (NICRA) being implemented in the North Bank Plains Zone of Assam (NBPZ), India since 2011.

1.1 Physiography of Assam

Assam is one of the states of northeast India situated between 24°and 28°16′N latitude and 89°4′and 96°E longitude. It is surrounded by Bhutan and Arunachal Pradesh in the north, Arunachal, Nagaland, and Manipur in the east, Mizoram, Tripura, and Meghalaya in the south, and Bangladesh, Meghalaya, and West Bengal in the west. Assam has a geographical area of 78,523 square km comprising fertile land and water resources. Despite these resources, Assam is lagging in the agriculture sector. The farming community mostly belongs to small (20.9%) and marginal (62.2%), with large farmers being very low (0.19%). The average farm size is decreasing over the years (1.11 ha) (**Table 1**) [3].

The physiography of the state can be divided into three distinct units: the plain, the plateau, and the hills. Two primary units for agricultural development in Assam are the Brahmaputra and the Barak valley, accounting for 80.8% of the total geographical area. The state of Assam has been divided into six agro-climatic zones based on physiographic variation, climate, soil, farming systems, crops and cropping systems, and hydrology under the National Agricultural Research Project (NARP) (**Table 2**).

1.2 Soil and climate of Assam

The major portion of the soils of Assam belongs to Inceptisols (49.3%) followed by Entisols (32.3%), Alfisols (12.3%), and Ultisols (6.1%). The texture of the soils varies from sandy loam to clay loam depending on the agroclimatic conditions and physiographic units. The soil of Assam is acidic having a pH range from 4.2 to 5.8. The average status of available nitrogen, phosphorus, and potassium status in the soil is low to medium, with a slight variation in the content [5, 6]. The soil of the state as a whole is deficient in boron and marginal in the case of zinc, iron, and aluminum toxicity are also observed sporadically.

The climate of Assam is humid subtropical in nature with warm humid summer and cool dry winter. The rainfall in Assam is in general high, but its distribution over time and space is not uniform and even. The monsoon period is characterized by high-intensity rainfall, while the winter (December to February) is virtually dry. Flood is a regular feature affecting the *Kharif* rice (winter paddy) production in about 7.75 Lakh ha of agricultural land annually. The mean annual maximum temperature

Sl. No.	Agro-Climatic Zones	Number of Districts	Net cropped area(ha)	Area sowed more than once	Cropping Intensity (%)
1	Lower Brahmaputra Valley Zone	10	9,29,757	4,69,422	150
2	North Bank Plain Zone	5	5,36,598	3,36,323	163
3	Central Barak Valley Zone	2	3,27,637	85,615	126
4	Upper Brahmaputra Valley Zone	5	6,20,320	1,94,629	131
5	Barak Valley Zones	3	2,41,715	1,01,989	142
6	Hill Zones	2	1,54,570	1,00,824	165
	Assam	**27**	**28,10,597**	**12,88,865**	**146**

Table 2.
Agro-climatic zones of Assam [4].

lies between 23.6°C and 31.7°C, while the mean minimum temperature varies from 10°C to 25.2°C. The interception of bright sunshine is only 36 to 38% of the astronomically possible sunshine hours from June to August due to continuous overcast sky. Though sunshine hours are the longest from November to February (70 to 74%) radiation is not up to the desired level due to foggy weather.

1.3 Flood

A flood is a natural calamity where the state is exposed to vagaries of climate to an extreme scale, endangering the life and property of the farmers. The state is home to a mega network of rivers comprising 48 major and 128 small rivers, which are responsible for the annual floods, resulting in an average annual loss of Rs.200 crores for the state. Horticulture crops occupy 7.57 and 15.25% of total land and total cropped area, respectively.

1.4 Land use pattern

Assam has a total geographical area of 78,523 square km, of which 24.91% is under forest. The net cropped area constitutes 35.1% of total land area and 70.66% of total cultivated area. About 58.5% area is mono-cropped, especially with winter rice, with the cropping intensity being 146% (RKVY-Assam, 2022). About 186 lakh hectares and 1.51 lakh hectares are remaining fallow and waste. The state has a population of 31.17 million and the population of the state is expected to swell to 35.6 million by 2025, putting tremendous pressure on land and water resources.

1.5 Irrigation status in Assam

Irrigation is very critical in terms of nullifying the ill effect of weather vagaries, getting a response to input and other management practices, and exploiting the genetic potential of modern varieties. Irrigation has gained much importance given weather extremities line flood and drought-like situations frequently occurring as a result of climate change. At present only 18.5% of the net cultivated area of the state is under irrigation.

1.6 Present status of rainfall and temperature variability

1.6.1 Temperature

According to the fourth assessment report of the Intergovernmental Panel on Climate Change (2021), the increase in global surface temperature from 1850 to 1900 is assessed to be 1.09 [0.95 to 1.20] °C [7]. In the northeast region of India, the annual mean temperature is reported to be rising at a rate of 0.04°C per decade [8]. Assam also exhibits warming trends throughout with minor spatial variations. Analysis of temperature data during 1961–2010 reveals a warming trend in both mean maximum and minimum temperature. The magnitude of minimum temperature was higher compared to those of maximum temperature. Similar trends were also observed by other researchers [9].

1.6.2 Rainfall scenario of Assam

Assam experiences an average annual rainfall of 1980 mm, while during pre-monsoon (March–May), monsoon (June–September), post-monsoon (October–November), and winter period (December–February) average rainfall received is 486.5 mm (24.57%), 1279 mm (64.64%), 150.3 mm (7.59%), and 63.3 mm (3.20%), respectively (**Table 3**).

Deka and Mahanta reported a declining tendency of annual rainfall at a rate of 7.9 mm per 100 years in the NE region of India [10]. The summer monsoon rainfall in the region is decreasing (−48.0 mm/100 years), while rainfall during the post-monsoon season exhibited an increasing trend (+36.3 mm/100 years). The contribution of June, August, and September rainfall to annual rainfall exhibits a decreasing trend, while the contribution of July and October rainfall marks a rising trend [11]. On an annual basis, a long-term decreasing trend of rainfall has been observed in both the Brahmaputra basin and the Barak basin of Assam. Decreasing tendency (39.1 mm/decade) in the Barak valley, while in the Brahmaputra basin the annual decreasing trend was 9.6 mm per decade also reported [11]. About 72 million hectares of net sown area in India is rainfed, which is practiced in diverse climates and agro-ecologies contributing to about 40% of

Rainfall	Normal rainfall	Normal rainy days (No.)
Pre-monsoon (March–May)	486.5	32
Monsoon (June–September)	1279.0	56
Post-monsoon (Oct–Nov)	150.3	9
Dry periods (Dec–Feb)	63.3	8
Total	**1979.1**	**105**

Table 3.
Mean season-wise annual rainfall and rainy days in NBPZ of Assam [5].

the country's food basket. The agricultural production, productivity, and stability in rainfed areas are more vulnerable to climate variability, particularly during the kharif season, due to high dependency on the southwest monsoon. Monsoon failures result in a drought that has serious implications for small and marginal farmers. The annual average rainfall and the seasonal monthly distribution of rainfall for two districts of Assam (the study area and the adjacent district of the domain area) situated in the NBPZ of Assam had been shown in **Figures 1–4**, respectively.

1.7 Crops and cropping systems

See **Tables 4** and 5.

1.8 Climate change in India and Assam

Climate change and its variability are emerging as major challenges facing Indian agriculture. The high inter and intra-seasonal variability in rainfall distribution, rainfall events, and extreme temperature are causing crop damages and losses to the farmers [12]. In many parts of India, the frequency of occurrence of cold nights declined, while the frequency of occurrence of warm nights and warm days significantly

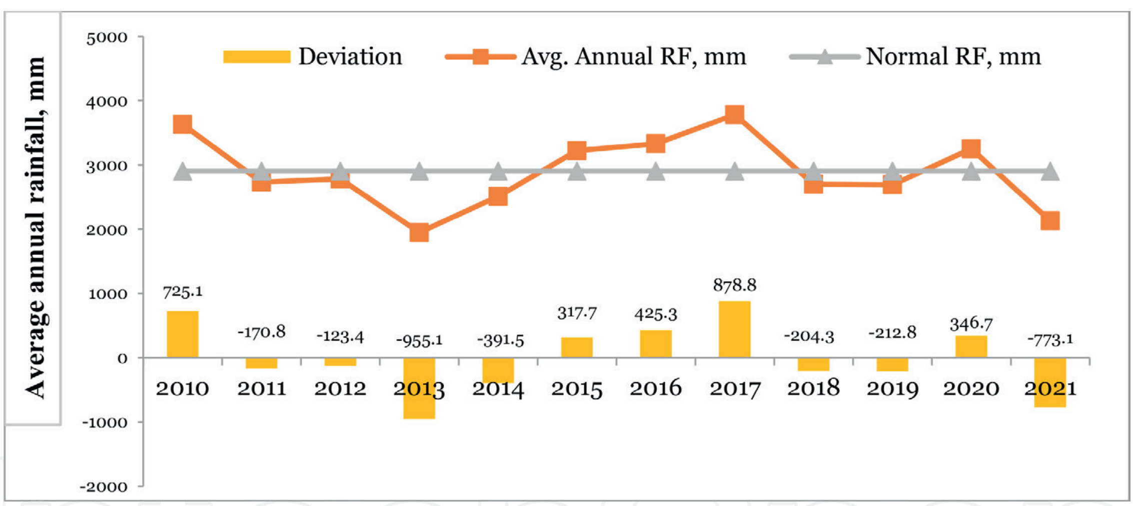

Figure 1.
Average annual rainfall, normal rainfall, and the deviation for Lakhimpur district of Assam (2010–2021).

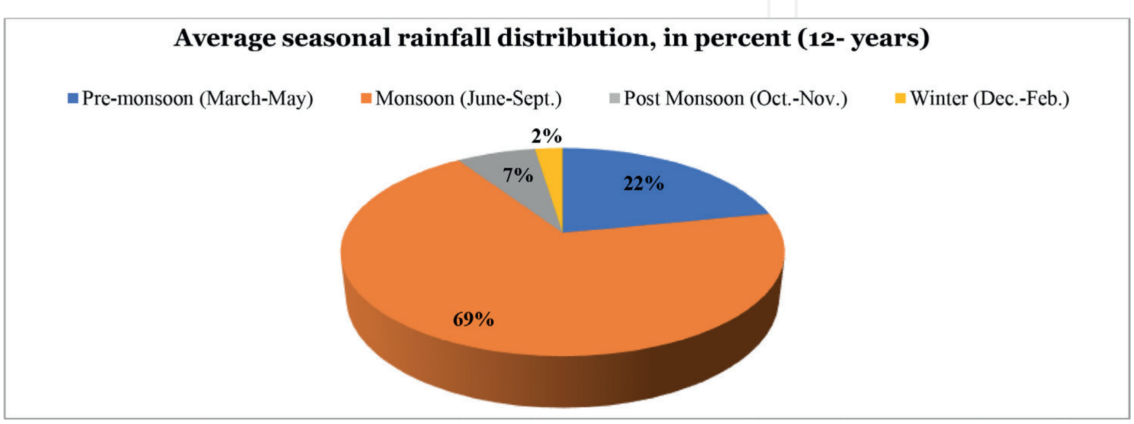

Figure 2.
Average seasonal rainfall for the Lakhimpur district of Assam (2010–2021).

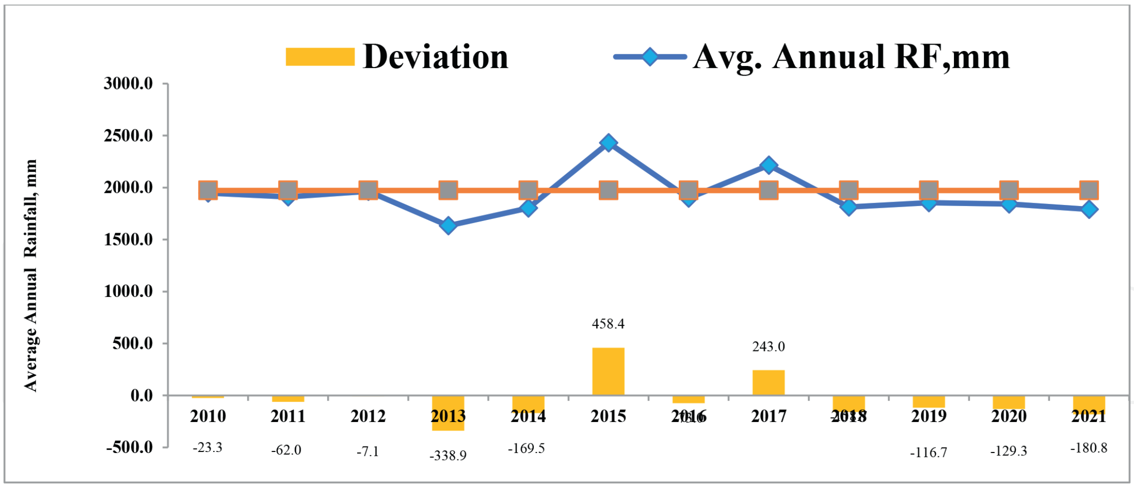

Figure 3.
Average annual rainfall, normal rainfall, and the deviation for Biswanath district of Assam (2010–2021).

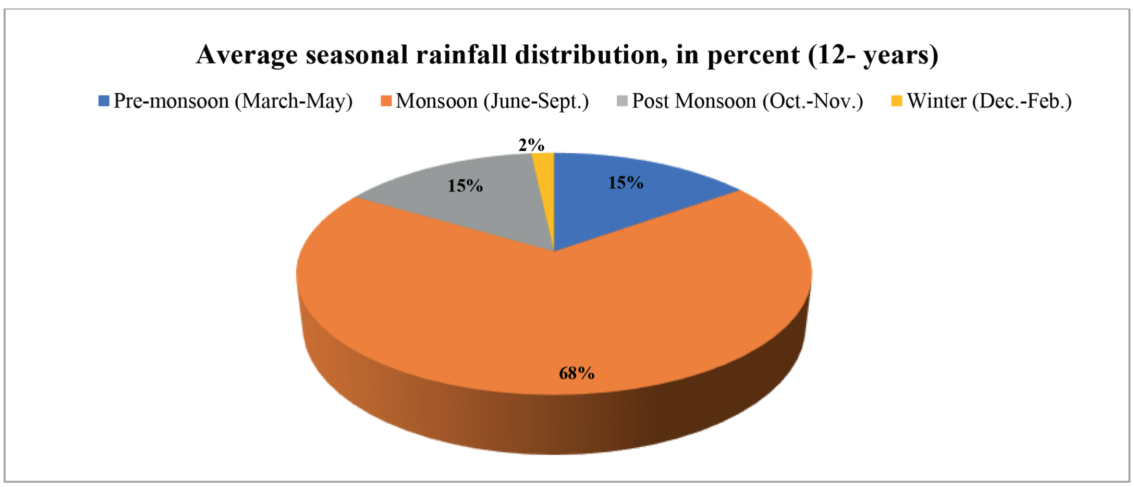

Figure 4.
Average seasonal rainfall for Biswanath district of Assam (2010–2021).

increased. Overall climate change pattern has already begun affecting the Indian agriculture sector adversely by enhancing abiotic and biotic stress to the crops and livestock. Various future climate models indicate a consistent warming trend over India, in short, mid as well as long-term scenarios [13]. Overall, the temperature rise is likely to be much higher during the *rabi* (October/November to January/February) than the *Kharif* (June/July to October/November) season. In addition, droughts and floods as well as cold and heat waves are likely to increase due to increased variability in temperature and may cause crop losses up to 30% by 2080. Assam also exhibits warming trends throughout with minor spatial variations. Analysis of temperature data from 1961 to 2010 revealed a warming trend in mean maximum temperature over Dibrugarh (0.120°C) per year, Jorhat (0.006°C per year), Nagaon (0.007°C/per year, Diphu (0.001°C per year and Guwahati 0.016°C. Tezpur, however, showed a decreasing trend of mean maximum temperature at the rate of 0.007°C per year. The magnitudes of trends of minimum temperature were higher compared to maximum temperature. The long-term (1901 to 2010) mean annual rainfall of the Brahmaputra basin is 2293 mm with a standard deviation of 225 mm. Barak valley basin receives 3204 mm rainfall with a stand's deviation of 420 mm. On an annual basis, a long-term decreasing trend of rainfall has been observed in both the basins [11].

Crop	Season	Sowing time	Variety	Duration (days)	Average yield (qha^{-1})
Direct seeded early *Ahu*	Autumn	Mid-February	*Luit*, *Kapilee*, IR 50, IR 36, *Dishang*	110–120	20–25
Transplanted early *Ahu*	Autumn	Mid-February	*Luit*, *Kapilee*, *Govind*, IR 36, *Rasi*, IR 50, *Jaya*	125–135	25–35
Normal *Ahu* direct seeded	Autumn	March/April	*Rasi*, IR 36, *Govind*, *Banglami*, *Rangadoria*, *Maibee*	105–120	25–30
Normal *Ahu* transplanted	Autumn	March/April sowing in nursery	*Lachit*, *Chilarai*, *Gopinath*, *Luit*	125–140	30–35
Sali Rice	*Kharif*	May/June in nursery	*Ranjit*, *Bahadur*, *Maniram*, *Mahsuri*, *KetekiJoha*	130–150	45–60
Boro	*Rabi*	November/ December sowing in nursery	*Joymoti*, *Kanaklata*, *Dinanath*, *Swarnabh*	160–170	50–65
Bao	Autumn	March/April	*Panindra*, *Padmanath*, *Maguri*, *Panchanan*, *Padumoni*	200–240	25–35
Maize	*Kharif*	March–May	*Ganga*, *Vivek maize* hybrid 47, *Vivek maize* hybrid 53, *Novjot*, Bio-9544	110–130	45–50
Greengram	*Kharif*	Mid-August to Mid-September	T-44, *Pratap*, K-851, ML-56, ML-131, *Kopergaon*	60–70	10–12
Blackgram	*Kharif*	Mid-August to Mid-September	T-9,T-27, Pant U-19, T-122, SB-121	80–90	10–12
Sesamum	*Kharif*	July-1st fortnight of August	*Madhavi*, *Gouri*, *Vinayak*, ST-1683	70–85	8–9
Toria	*Rabi*	Mid-October to Mid-November	TS-36, TS-38, TS-46, TS-67	90–95	10–12
Jute	Autumn	Mid-March to May	*Sonali*, *Shyamali*, *Bohagi*, *Navin*	110–120	22–26*
Pea	*Rabi*	Mid-October	*Rachna*, Pant 14	120–125	10–12
Sugarcane	Autumn	February /March	*Daria*, *Kalang*, *Barak*, *Dhansiri*, *Luhit*	280–300	700–800**
Potato	*Rabi*	October/ November	*Kufri Pokhraj*, *Kufri Jyoti*, *Kufri Megha*	80–110	85–100

**Fiber yield.*
***Cane yield.*

Table 4.
Major rainfed crops of Assam [5].

As per the findings of the State Action Plan for Climate Change, the annual mean temperature has increased by 0.59°C and the annual rainfall has decreased by −2.96/ mm per year over the last six decades (1960–2000). Climate change projections for Assam indicate that the mean average temperature is likely to rise by +1.7–2.2°C by

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Kharif-**rainfed crops**						*Rabi*-**rainfed crops**						
Rice	**Maize**	**Blackgram Greengram**	**Jute**	**Sugarcane**	**Sesame**	**Toria**	**Potato**	**Lentil**	**Pea**	**Rajmah**	**Sugarcane**	*Boro* **Rice**
Sali: June/July	Feb–April	Mid-Aug to Mid-Sept (Kharif)	March–May	Feb–March	July 1st fortnight of August	Mid-Oct to Mid-Nov	Mid-Oct to Mid-Nov.	Mid-Oct to Mid-Nov.	Mid Oct	Mid-Oct to Nov.	Oct	Nov-Dec
Ahu: March/April	—	Mid-Feb to March (Summer)	—	—	—	—	—	—		—	—	—
Bao rice: March/April			—	—	—	—	—	—	—	—	—	—

Table 5.
Normal sowing window of the rainfed crops.

mid-century between 1971 and 2000. There is likely to be an increase in extreme rainfall events by +5 to 38%, including floods. There is a chance of an increase in droughts weeks are going to rise as well, by more than 75% concerning the baseline (1971–2000) in the southern districts of Assam. As regards floods, projections increase the rise in events by more than 25% [14].

1.9 Impact of climate change on agriculture of Assam

The impact of climate change on agriculture is both direct and indirect. The direct impact of climate change would be small on rainy season crops but the crops will become vulnerable due to increased incidence of weather extremes, such as changes in rainy days, rainfall intensity, duration and frequency of drought and flood, diurnal asymmetry of temperature, change in humidity, and pest incidence and virulence. Winter crop production may become more vulnerable and the climate impact on cereals will vary widely in the rainy season as well as the winter season. Rainfed agriculture is likely to be more vulnerable because of the high dependency on monsoon and aberrant behavior of the south-west (SW) monsoon [15].

1.10 Farm mechanization

Agricultural productivity goes hand in hand with the mechanization of different agricultural operations, which aims at achieving timeliness of operations, efficient use of inputs *viz.,* seed, fertilizer, and chemicals, *etc.*, improvement in quality of produce, safety and comfort of farmers, reduction in the cost of produce and drudgery of farmers [16]. Mechanization would increase land and labor productivity and reduce the drudgery of humans and animals. In the changing climatic environment, the frequency of destructive weather aberrations (such as heat waves, heavy rainfall events, drought, and floods) affects the agriculture sector more vulnerable. In such situations, timely completion of farm operations is very important, which could be accomplished through the use of improved implements and machines. Thus, mechanization is the key to building climate-resilient agriculture in the country [17, 18].

Assam has the largest cultivable plain land in northeast India but power consumption for mechanization is 0.75 $kWha^{-1}$, which is still below the national average of 1.5 $kWha^{-1}$. For sustainable food grain production and drudgery reduction, the mechanization of agriculture is mandatory to an optimum level. Three main sources of farm power being utilized for these tools, machines, and equipment are manual (human), draft animal, and mechanical power. In many developing countries, up to 80% of farm power is provided by animal sources of power (**Table 6**) [18].

1.11 Real-time contingency planning–concept

Real-time contingency planning is considered as "any contingency measure either technology related (land, soil, water, and crop) or institutional and policy-based, which is implemented based on real-time weather pattern (including extreme events) in any crop growing season." [19] Real-time contingency planning (RTCP) was conceptualized to minimize crop production and productivity losses and to improve the efficiency of the rainfed production system. The major objectives of RTCP are:

Operation	Implement/machinery	
	Bullock drawn/manual	**Tractor drawn**
Land preparation	Indigenous plow, mold board plow	Mold board plow, 2 bottom mold board plow, disc plow, heavy-duty disc harrow
Tillage	Indigenous plow, ladder	Harrows, cultivators, clod crushers, levelers, rotary tillers, rotavators, puddlers
Sowing	Broadcasting, transplanting, manual rice transplanter	Rice transplanter, self-propelled paddy transplanter
Residue incorporation		Disc plow/ harrow
Interculture	*Bindha*/weeder, hand hoes/*kodal*	Cultivators, rotary tillers, cultivators with rigid and spring-loaded tynes
Weeding	Japanese rice weeder/dryland	—
	Weeder, cono weeder/ hoes/ *kodal*/ sprayer, long handled weeders, hoe-cum-rake, wheel hoes	
Plant protection	Manual sprayers, handheld sprayers, backpack and knapsack sprayers, knapsack power sprayer-cum-duster, dusters	—
Foliar sprays	Manual sprayers, manual sprayers, handheld sprayers, backpack and knapsack sprayers, knapsack power sprayer-cum-duster, dusters	—
Harvesting	Sickle/desi plow, paddy reaper	Digger, mowers, self-propelled paddy harvester

Table 6.
Farm types of machinery and implements mostly used by the farmers of the region [5].

- To establish a crop with the optimum plant population during the delayed onset of monsoon.
- To ensure better performance of crops during seasonal drought (early/mid and terminal draught) and extreme events.
- To enhance performance, improve productivity, and income.
- To enhance the adaptive capacity and livelihood of the farmer.

1.12 Crop and cropping system to cope with weather aberration

The whole concept of farming revolves around the seed. Identification of crops and varieties that fit well into changed climatic conditions is a common denominator for sustainable crop production in all land use conditions. An ideal variety should be high yielding, plastic enough to withstand weather aberration, tolerant to multiple abiotic and biotic stresses, responsive to augmented carbon dioxide levels and fit well to farming situations. Sowing the right varieties of the right crops at the right time under the right land use conditions makes a significant difference in attaining higher yields. Efforts have been made by ICAR and State Agricultural Universities to develop high yielding varieties (HYVs) suitable for biotic and abiotic stresses. The short-duration varieties and several climate-ready varieties have already been released to cope with the aberrant climatic conditions.

1.13 Weather aberration during the last decade

Due to aberrant weather conditions, Indian agriculture, in general, is experiencing the delayed onset of monsoon, deviation in rainfall, early season drought, mid-season drought, terminal drought, and flash floods. Most of the studies during the last decades in India have pointed out that India's annual rainfall, together with monsoon rainfall, is trendless and is mainly random in nature over a long period, particularly on an Indian scale. However, large inter-annual and decadal variations have been observed. The summer monsoon rainfall has sown significant decreasing trends in the subdivision of south Assam (−12.5 mm) per decade. The declining trend of annual rainfall at a rate of 7.9 mm/100 years is also reported [10]. The summer monsoon rainfall in the region is decreasing (−48.0 mm/100 years), while rainfall during the post-monsoon season showed an increasing tendency (36.3 mm/1000 years).

1.14 Crop production architecture

Packages for climate neutral variety, flood stress resistant variety, and insect pest resistant/tolerant varieties are to be developed over the years. Science of robotic application in production farm for weed management, etc., and application of GPS in farm planning and soil fertility management will have to be perfected.

Opinions for and against the SRI method of rice cultivation will require to be scientifically assessed to bring in needed refinement for water saving method of rice production. Designing and prototyping suitable farm types of machinery to suit changed crop production planning will need focused attention. A multidisciplinary team involving an agronomist, plant breeder, biotechnologist, meteorologist, entomologist and pathologist, and engineers will have to come together to remodel the crop production module. A team consisting of an expert from different branches of horticulture will have to initiate research to develop smart farming for small farmers, a model of hi-tech/climate control horticulture spreading the dimension to the hydroponic and aeroponic horticulture, including vertical space utilization in the greenhouse and soil-less farming, rooftop farming, *etc*.

The way the rainfall pattern is changing–sometimes early, sometimes late, sometimes scanty, sometimes in excess, sometimes erratic. Therefore, our established method of crop production will demand a change, necessitating advancing sowing time in some cases and delaying the time in some others.

Since 2011, under National Innovations in Climate Resilient Agriculture (NICRA), 23 centers of AICRPDA are conducting on-station and on-farm demonstrations/trials under NICRA with a focus on RTCP implementation and preparedness to cope with weather aberrations. Similarly, alternate and resilient crops and cropping systems are demonstrated in AICRPDA-NICRA villages as preparedness to cope with weather aberration.

2. Adoption of climate-resilient technologies to minimize the effect of climate change in AICRPDA-NICRA adopted villages of Lakhimpur district of Assam – a case study

2.1 Methodology

2.1.1 Climate vulnerability

The climate of the village is characterized by hot and humid summer and dry and cool winter. The village is situated in a high rainfall zone. The long-term average annual rainfall of two nearby stations of the village is 1987 mm (Biswanath Chariali) and 2900 mm (north Lakhimpur) with 125 numbers of rainy days. The rainy season in the village starts in March and the quantum of rainfall as well as the number of rainy days increases gradually and reaches the maximum in July/ August and then declines to a minimum during November/December. Temperatures of the village generally remain within a comfortable range, however, when there is a dry spell during the summer season, high temperature along with high humidity increases insect pests and diseases of crops. August is the hottest month and February is the coldest month.

In recent years, a substantial reduction in rainfall amount during monsoon season is noticed in this region. The village experienced drought-like situations in recent years *viz.,* 2001, 2005, 2006, 2009, and 2011. There was a substantial yield reduction of *Sali* rice during those years. In the Lakhimpur district of Assam, there is a reduction in rainfall at the rate of 0.52, 1.86, and 0.24 mm per annum during pre-monsoon, monsoon, and post-monsoon seasons, respectively [9].

Chamua and its adjoining villages have different weather-related problems, such as dry spells, during the growing season of *Sali* rice, scanty rainfall during the *rabi* season, and the occurrence of occasional flash floods in a portion of the village. Almost every year the Ganakdalani village is affected by 3–5 numbers of flash floods of 7 to 15 days duration during *the kharif* season. On the other hand, during *rabi* season due to prolonged dry spells, soil moisture deficit is a problem. Due to the presence of only low-lying land situations, there is limited scope for crop diversification. *Sali* rice grown in the village suffers from floods every year.

2.1.2 Soil type

The altitude of the village varies from 83 m to 90 m, which indicates that the village has different land situations varying from upland to lowland which remains flooded continuously for about 6 to 7 months. The soils in this village are mainly Inceptisols. The soils are of sandy loam to silty clay loamy with pH ranges from 4.7 to 6.4. The organic matter content of the soils of the village varies from 0.34 to 3.03%. The status of available nitrogen (275–540 $kgha^{-1}$) and potassium (138 to 330 $Kgha^{-1}$) is medium; however available phosphorus (21.4–54.0 $kgha^{-1}$) content of the soil is low to medium [20]. High soil acidity, high phosphate fixation, micronutrient deficiency, iron toxicity, periodic soil moisture stress during winter seasons, etc., are some of the soil-related problems of this village.

During 2010–2011, participatory rural appraisal (PRA) has been conducted by a team of scientists of AICRP for Dryland Agriculture, Biswanath Chariali Center with extension experts at Chamua and Ganakdalani village. Following problems have been identified during participatory rural appraisal (PRA).

2.2 Constraints

2.2.1 Weather constraints

Following information about the weather/climate variability in the village was extracted during the PRA study in the village.

- Early season drought/normal onset followed by 15–20 days dry spell, mid-season drought, long dry spell, etc. (2001, 2005, 2006, and 2009).
- Erratic and scanty rainfall during *rabi* season.
- Occasional flash flood due to very heavy rainfall in a portion of the village.
- Groundwater is contaminated with arsenic and problems of iron toxicity.
- High rainfall and inundation of fields at the time of harvest of Ahu rice are limiting factors.

2.2.2 Production constraints

- Small and fragmented land holdings (marginal and small farmers).
- No farm mechanization.
- Upland (25 ha) of the village remains fallow.
- *Sali* rice dominated the rainfed monocropping system with indigenous cultivars.

2.2.3 Constraints related to cultivars

- Farmers grow only a few high-yielding rice varieties, such as *Ranjit and Mahsuri*, on a limited scale.
- Farmers of the village do not grow short or medium-duration cultivars that are suitable for an early vacation of the land for subsequent *rabi* crop.
- Farmers of the village use their seeds year after year.

2.2.4 Constraints related to agronomic practices

- Farmers do not follow scientific water management practices in paddy fields.
- Farmers generally go for haphazard planting or broadcasting instead of planting in rows or line sowing. It has been established that there is a yield reduction of 1.5 to 1.8 tha^{-1} due to haphazard planting.
- No soil test-based nutrients management/INM.

2.2.5 Constraints related to insect-pests and diseases

- Major insect pests of rice in NICRA village are stem borer, gall midge, caseworm, hispa, etc. The major diseases are blast, blight, brown spot, false smut, etc. Farmers of the village do not use any control measures to protect the crop from the insect-pests and diseases. Weeds infestation is a major problem in *Ahu* rice.

2.3 Objectives

To overcome the climatic constraints interventions under National Innovations on Climate Resilient Agriculture (NICRA) under All India Coordinated Research Project for Dryland Agriculture are being implemented under adaptive strategies for adaptation to the climate change effect from 2011 to 2012 to evaluate the technology options for adaptation to the climatic vulnerability through on-farm interventions. The interventions are categorized under two heads viz., real-time contingency planning (RTCP) and preparedness. Under RTCP, interventions are implemented to cope with delayed onset of monsoon, early season/mid-season/terminal drought through the demonstration of proven technologies. As preparedness, interventions are being demonstrated under different themes, such as rainwater management, crops and cropping system, alternate land use, and energy management. With more than 150 participants farmers with the following objectives -.

1. Real-time contingency plan implementation in a participatory mode.

2. Preparedness.

2.3.1 Real-time contingency plan (RTCP) implementation

2.3.1.1 Interventions in case of delayed onset of monsoon

In Assam, the monsoon starts in the first week of June. However, delayed onset of the monsoon was observed in 2011 and 2014 by 15 days and 14 days, respectively, in the village. The villages receive an average rainfall of 400 mm during the pre-monsoon months (March to May). Farmers used to sow the rice seeds in nursery beds depending on the monsoon rainfall. But delay in monsoon affects timely sowing of long-duration rice varieties (more than 150 days) before 15th June. It leads to delay in transplanting and hence affects the production. Farmers were advised to use harvested rainwater in farm ponds during pre-monsoon months to prepare the rice nursery beds in time using water lifting pumps of custom hiring center (CHC). This helped in the timely transplanting of rice seedlings, which facilitated a better establishment, better growth, and better yield of long-duration cultivars as compared to fields of other nearby villages where transplanting was delayed due to delay in sowing. An increase in yield from 12 to 30% has been observed among the rice varieties (*Ranjit, Gitesh, Mahsuri*, etc.) when sown in time (before 15th June) over late sowing conditions (after 20th June).

2.3.1.2 Interventions in case of early season drought

The villages experienced early season droughts of 14 days, 19 days, 11 days, 21 days, and 8 days in 2011, 2014, 2015, 2016, and 2018, respectively. In 2015, in the month of

August, the NICRA village Chamua received 63% less rainfall than a normal one. The rainfall activities in the month were reduced substantially, and the village experienced two dry spells of 6 (10 to 15 August 2015) and 13 (17 to 29 August) days' duration. The effect of dry spell was not prominent in the case of long and medium duration varieties, which were grown in the lowlands, however, short duration cultivars (*Dishang, Luit*) and farmers' varieties, which were cultivated in the uplands of the village and were at early tillering/PI stage affected considerably. Even rice varieties grown in the medium lands (tillering stage) were affected to some extent. The effect of a dry spell on short-duration varieties grown in the medium land situations was comparatively lower than those grown in the upland situation. As the real-time response, farmers of the village were advised to irrigate short-duration cultivars (*Dishang*), which were in tillering or PI stage with supplemental irrigation of 5 cm depth from harvested rainwater. There is an increase in yield of 59% (*Dishang*) over non-irrigated fields.

2.3.1.3 Interventions in case of mid-season drought

The village experienced a mid-season drought of 12 days, 21 days, and 25 days in 2015, 2016, and 2018, respectively. Though the effect of a dry spell on *Sali* paddy was not very much prominent in lowland, early transplanted short-duration varieties grown in the upland situation (active vegetative, early tillering, and PI stage) were affected considerably. During 2016 and 2018, in the medium land situation, long dry spells affected the PI stage of medium duration varieties. In real-time response, farmers were advised to irrigate (2 cm depth) the crop by harvested rainwater in the farm ponds using water lifting pump from the custom hiring center.

2.3.1.4 Interventions in case of terminal drought

The occurrence of terminal drought in long-duration rice varieties in upland and medium land situations has been observed in NICRA adopted villages of the Lakhimpur district of Assam. The terminal drought of a duration of 14, 25, 25, 25, 9, and 25 days during 2011, 2013, 2014, 2015, 2016, and 2017, respectively, have been observed. As a contingency, short and medium-duration rice cultivars were cultivated in upland and mid-land situations, respectively as these varieties can escape mid-season and terminal dry spells. There is an if long duration high yielding and traditional cultivars were cultivated in upland and mid-land situations the crop would have suffered from terminal drought which was experienced by the village. Short-duration cultivars–*Luit, Kolong, Dishang*, and *Lachit*, and medium-duration cultivars–*Shraboni*, *Mohon,* and *Mulagabharu,* were demonstrated as contingency plans for the management of mid-season and terminal droughts. An increase in yield of 26% (*Dishang*), 17% (*Luit*), 14% (*Shraboni*), and 18% (*Mulagabharu*) has been observed over farmers' practice*, that is,* . cultivation of long-duration cultivars irrespective of the land situation.

2.3.1.5 Flash flood management through varietal manipulation

Unlike NICRA village Chamua, a flash flood is the major weather aberration in the NICRA village Ganakdoloni. Every year the entire village is affected by 3–5 numbers of the flash flood of 7 to 15 days duration, affecting the *Sali* rice grown in that village. In 2012, *Sali* rice grown in the village was under intermittent submergence for a total of 32 days and there was a total crop failure. Different *Sali* rice varieties, including submergence tolerance variety–*Jalkunwari,* grown in the field were damaged. However, one variety–*Jalashree,* withstand the intermittent submergence and was able to give some yield (9.0 qt/ha). In 2013, submergence tolerance (*Jalashree* and *Swana sub-1)*, staggered planting (*Gitesh* and *Prafulla*), and *Bao* rice varieties (*Kekowa, Tulshi, Dhushuri, Bahadur, Maguri*, and *Rangabao*) were in the village. In 2014, locally available six varieties of deepwater rice (*Bao rice*) *viz., Kekowa* (23 qha^{-1}), *Rangabao* (26 qha^{-1}), *Dhushuri* (24 qha^{-1}), *Maguri* (23 qha^{-1}), *Bahadur* (19 qha^{-1}), was demonstrated in farmers' field of Ganakdoloni. Four improved *Bao* cultivars, namely, *Panchanan, Panindra, Basudev,* and *Padmapani* were collected from RARS, Lakhimpur, and cultivated in the village. Despite a very long submergence period (more than 40 days) local *Bao* varieties performed well, however, improved *Bao* varieties were damaged completely by flash floods.

From the experiences gained from the on-farm trials conducted at farmers' fields of the village during 2012–2013, 2013–2014, and 2014–2015, it was found that the normal farmers' varieties, including *Ranjit, Mahsuri, Punjublahi,* etc., could not withstand and were completely damaged. Though submergence tolerant rice varieties can withstand submergence up to 15 days during the seedling and tillering stages, the same varieties fail to survive if exposed to submergence for a few days during or after the panicle initiation stage. Submergence tolerant rice varieties (such as *Jalkunwari and Jalashree)* evaluated in the village did not perform well or exhibited total crop failure in cases when the plants at the panicle initiation (PI) or grain filling stage were exposed to submergence during the latter part of September or in October (as in case of 2012) the flash floods. Some of the improved *Bao rice* varieties were evaluated, which failed to survive during 2013–2014. Against the failure of normal, submergence tolerant improved *Bao rice* varieties evaluated in different crop seasons, six traditional *bao* varieties evaluated in the study area could survive intermittent submergences in both the crop seasons (2013 & 2014). The traditional *bao* rice varieties are having some special characteristics, such as tall stature, elongation ability, and kneeing ability, which are suitable for withstanding short or long-duration submergence.

2.3.1.6 Drought management through nutrient management in Sali paddy

Before the implementation of the NICRA project, farmers of the NICRA village Chamua did not apply any chemical fertilizers in the *Sali* rice growing field. Nutrient management through the balanced application of fertilizers (N, P, and K), and proper method of application proved to be beneficial even in situations like mid-season and terminal drought. Midterm corrections in the case of mid-season and terminal drought were suggested in terms of the application of an additional dose of 22 kg ha^{-1} MOP in maximum tillering to grain growth period to the farmers of NICRA village. An increase in yield of 33% (*Ranjit*), 32% (*Gitesh*), 64% (*Shraboni*), and 57.5% (*Mulagabharu*) has been observed over farmers' practice.

2.3.1.7 Management of drought with alternate crop and crop diversification

Before the implementation of the NICRA project, rice crop was grown on all types of the land situation available (up, medium, and lowland) in the NICRA village Chamua. As rainfed rice requires a higher quantity of water during crop growing season, rice crops are grown in the upland as well as well-drained medium land situations in the village often suffer from a mid-season as well as terminal drought. In a worse situation (experienced in 2006 and 2011), the yield of rice grown in the upland areas of the village even goes below 9 qha^{-1}. Therefore, an alternate strategy of growing high-value crops, such as ginger, turmeric, sesame, black gram, green gram, summer vegetables, and winter vegetables, was taken up as a contingency measure for the management of drought (delayed onset of monsoon, mid-season, and terminal drought). Crop diversification with high-value crops along with organic mulch-cum-manuring proved to be more resilient to stressful situations arising during mid-season and terminal dry spells during *kharif* as well in *rabi* season. Therefore, farmers of NICRA village Chamua were encouraged to take up crop diversification to cope with rainfall variability instead of growing *Sali* rice, especially in upland situations.

2.3.2 Preparedness

2.3.2.1 Rainwater management

Thirteen farm ponds and a canal of 0.5 km length were renovated at *Chamua* village for rainwater harvesting during pre-monsoon and monsoon seasons after the implementation of NICRA. Rainwater harvesting in the renovated farm ponds during pre-monsoon months is used for sowing *Sali* rice in a nursery bed in case of delayed onset of monsoon. Rainwater harvesting in the canal and farm ponds during the monsoon months is efficiently utilized for providing 1–2 supplemental irrigation in *rabi* crops, such as potato and rapeseed. It has also acted as a source of drinking water for the grazing animals during the dry period of the year. Mulching with locally available organic mulch material in ginger, turmeric, potato, tomato, etc. was found more productive than the crops grown without mulching.

2.3.2.2 Crops and cropping system

In upland well-drained loamy soils, short-duration varieties (*Dishang, Luit*) performed consistently better as compared to the farmers' cultivar or long-duration cultivars. It also facilitates the early vacation of the field, thereby helping the farmers to grow *rabi* crops on the same piece of land. In the case of medium land and moderately well-drained soil, medium duration varieties performed better despite the occurrence of terminal dry spells. In lowland situations and soils with poor drainage, the effect of a terminal dry spell is the minimum. Therefore, long duration varieties are grown instead of farmers' variety or medium duration varieties. Efforts are being made to introduce maize in the adopted village. It was observed that this crop can be sown in all types of the land situation available in the village in the driest period (in terms of rainfall received) of the year (December to February) after the harvest of *Sali* rice as well as other *rabi* crops, such as potato and rapeseed. Under NICRA, land situation-specific, profitable, and climate-resilient double cropping systems were identified and implemented in the adopted villages and it was observed that rice equivalent yield, as well as net income, increased significantly in all the identified double cropping systems as compared to the existing monocropping of rice. Growing alternate crops and crop diversification not only helped the farmers to minimize the risk due to extreme weather events but also in better income generation and nutritional security. In flash flood-prone areas, traditional *Bao* rice varieties (*Kekowa, Rangabao, Maguri, etc.*) performed better than the improved submergence tolerant varieties (*Jalashree, Jalkuwari, Padumoni, Panindra*, etc.). It was observed that submergence tolerant varieties could not withstand an intermittent flash flood. Presently, the farmers of *Ganakdalani* village have adopted traditional *Bao* rice varieties and almost 80% of the rice cultivated area of the village is under traditional *Bao* rice.

2.3.2.3 Alternate land use

During 2014–2015, seven low-cost polyhouses were erected in Chamua village under NICRA for demonstration of the cultivation of high-value off-season vegetables and raising vegetable seedlings in advance of *rabi* season. Protected cultivation under low-cost poly houses facilitated the cultivation of high-value crops, such as off-season leafy vegetables, *ghost chilli*, tomato, and cucumber, for better profitability. It was observed that farmers earned on an average Rs. 40,000.00 per year from a low-cost polyhouse of 100 square meters size.

Vermicompost production helped the farmers to meet their organic manure requirement as well as profit from selling the same to other farmers. Average vermicompost production was 1000 kg per tank per annum. From 2018 to 2019, mushroom cultivation was also demonstrated for better nutritional security of the farmers. An average income of Rs.7280.00 has been realized by the farmers as an alternate source of income.

2.3.2.4 Energy management

Since resource-poor farmers cannot afford to purchase the costly farm implements/machines of their own, therefore, custom hiring centers with need-based farm implements/machines (rotavator, cultivator, thresher, reaper, transplanter, water lifting pumps, duster, sprayers, *etc.*) was established under NICRA project for timely completion of farm operations. These implements were made available for hire by the needy at cheaper rates fixed by the NICRA village management committee.

Timely farm operations carried out with the help of the custom hiring center facilitated the farmers to complete sowing or transplanting in time. A study conducted on mechanization revealed that with an increase in the level of mechanization, the human and animal hour requirement for paddy cultivation was reduced from 795 to 350 and 353 to 23 $hrha^{-1}$, respectively. Thus, mechanization helped in a substantial reduction of the drudgery of humans and animals.

2.4 Resource characterization

The total land area under the NICRA village was categorized into upland, medium land, and lowland based on the soil survey report. Soil health cards were also prepared. The presence of a high level of arsenic in groundwater was detected. To minimize the effect of arsenic contamination, a low-cost filter technology (*Arsiron Nilogon*) was demonstrated at the village in collaboration with Central University, Tezpur, Assam.

A mini agromet observatory has been established for the collection of rainfall and temperature data. Dissemination of agromet advisory service to the farmers helped in the decision-making process in the preparedness stage of real-time contingency planning, such as land-related (e.g., land situation wise decision making), rainwater harvesting (mulching, farm pond, micro irrigation system, etc.), crop-related (selection of suitable crop/varieties), and management related (management of insect-pest, diseases, nutrient, weed, etc.).

2.5 Integrated farming system (IFS) is one of the most potent nature-based adaptation strategies

A "whole-farm" approach or integrated farming systems that supplement traditional crops with farming vegetables, fruits, poultry, or fish is re-emerging as a nature-based solution to boosting productivity in climate-stressed regions. A whole-farm approach or pond-based IFS, however, helped increase production, employment, and income by generating a mix of enterprises based on rice, vegetables, fruits, fish, pigs, and poultry. The integrated farming system adopted, tapped into on-farm resources and reduced dependence on external inputs, such as fertilizers and pesticides. The study found that the net returns under an integrated system that included ponds, rice, vegetables, and pigs were eight times higher than the normal farmer practice of growing a single crop. Scientific fish farming and multiple uses of water for growing vegetables, livestock, and irrigation can enhance productivity, income, and employment, as well as resilience against climate change. The integrated farming approach provides year-round production, employment, and income, reducing farming risks during climate uncertainty (**Table 7**) [19].

Adaptation options	Farmers adapted measures
Crop variety change	HYV as well as a hybrid variety of rice, vegetables, jute, maize, wheat, rapeseeds, and mustards
Crop switching/ Mix cropping	1. Mix cropping among winter rice, summer rice, *rabi* vegetables, rape and mustard, jute, wheat, *kharif* vegetables. 2. Crop switching from sugarcane, jute, buckwheat, banana, and lemon to mainly horticultural crops (high-value crops), food crops to non-food crops.
Adjusting planting dates	1. 10–15 days delay in sowing of winter (*Sali*) rice to get the benefits of early monsoon. 2. 15–20 days earlier plantation of summer (*Boro*) rice variety to avoid crop loss due to rain during harvesting time. 3. Delayed planting of *Sali* varieties, such as *Hatisali and Boradhan,* during heavy rainfall. 4. Late plantation of rice, such as *Hira* (*Sali*), in September to avoid heavy monsoon rainfall. 5. Adjusting planting dates of hybrid vegetables, such as turnip, by late planting due to heavy rainfall.
Increase the use of fertilizers	**Rice** 1. N-urea has increased to 20 kgbigha^{-1} from 10 to 15 kgbigha^{-1}earlier. 2. P_2O_5-phosphorous has increased to 25 kgbigha^{-1}from earlier 15–18 kgbigha^{-1}. 3. K_2O-potash increased to 10–12 kgbigha^{-1}from earlier 4–5 kg per hectare. **Vegetables** 1. For *kharif* vegetables, such as tomato, brinjal, and chili urea, is used is 20–22 kgbigha^{-1}, for capsicum, cauliflower cabbage, turnip, carrot it is 25–30 kgbigha^{-1}, broccoli requires up to urea 50 kgbigha^{-1}. 2. P_2O_5-phosphorous used for cabbage, cauliflower, turnip, brinjal, tomato, capsicum, and broccoli are 50–70 kgbigha^{-1}. 3. K_2O-potash requirement is 15–20 kg for cabbage, cauliflower, tomato, turnip, and capsicum. 4. In addition to this well rotten FYM or compost application in nursery beds is used to improve the soil's physical condition. 5. Borax up to 25 kg is used for some vegetables like cauliflower. 6. Organic manures are used up to 2 quintals per bigha by some farmers.

Adaptation options	Farmers adapted measures
Pest and Disease management	1. Farmers use various chemicals, such as *boric acid powder, Bordeaux, ustad, profax, DAP, captan, mancozeb, dithane Z-78, Karathane, bavistin, calixin, and bentate,* to control pest and diseases. 2. After sowing, some local practices, such as covering the seeds with a thin layer of sand mixed with well-dried cow dung, wood fine ash, and dried tree leaves, are mashed and spread in to protect from insects like *thrips*. 3. Dried grass and a banana leaf or thin layers of straw are used in nursery beds of vegetables to prevent displacement of seeds as well as protect from water-borne disease. 4. Burning rice strips and rice plant roots after harvesting to control insects. 5. Seedling tips of rice are trimmed before sowing. 6. Vegetables, such as French beans seeds, are protected by applying black pepper powder to the seeds which prevent storage pests. 7. Applying lime before planting vegetables, such as cauliflower, pea, and carrot.
Using shades or shelter	1. Shading is done by the banana stem to protect the crops from harsh sun rays. 2. Use local plants, such as *Khoria* and *Gancha,* that not only shelters the plants but also help to increase soil fertility.

Table 7.
Documented the following adaptation strategies at the farm level from the field study [5].

The successful interventions under NICRA have also been upscaled across three districts of Assam in collaboration with Krishi Vigyan Kendras and convergence with other state departments, input agencies as well as different financial institutes helped the farmers in terms of technical guidance, agricultural inputs, and financial assistance.

3. Conclusion

Climate change is a complex phenomenon and has many manifestations. It is very difficult to generalize possible remedial measures. An increase in temperate will adversely affect crops by accelerating crop growth rate, reducing crop duration, and crop yield, increasing the rate of evaporation/evapotranspiration, and decreasing fertilizer use efficiency and negative impact on soil health. However, location-specific adaptation and mitigation measures are essential to face the impact of extremes. The social and physical impacts of climate change are heterogeneous as the magnitude and direction of climate change across the globe vary and even within the same regions experiencing climate change are likely to vary [8]. Experiences gained from NICRA implementation showed a changing trend of agricultural practices to cope with changing weather aberrations. The cost-effective and easily adaptable technologies are the backbones for enhancing farmers' income in such situations. Change in variety plays an important role in withstanding crop loss. Likewise, alternate land use systems are very much beneficial for the small and marginal farmers to increase income as well as nutritional security. There is a need for low-cost technologies in the form of variety, small machinery, and other technologies so that farmers could get benefit from the limited resources available to them.

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