Indian J. Dryland Agric. Res. & Dev. 2022 37(2): 23-30 10.5958/2231-6701.2022.00011.2

Overview of Dryland Agriculture Research and Achievements in North Bank Plain Zone of Assam

P.K. Sarma, N. Baruah, B. Borkotoki, J. Kalita, A. Sonowal, Rupam Borah, Rupshree Borah, N. Kalita, N. Kakati and L.B. Bharali

All India Coordinated Research Project for Dryland Agriculture Centre

Assam Agriculture University, Biswanath Chariali – 784 176, Assam

Email: sarmahpk@gmail.com

Brief history of the Centre

The All India Coordinated Research Project for Dryland Agriculture Centre at Jorhat under Assam Agriculture University was started in 2005. Later, in 2010, the Centre was shifted to the present location at Biswanath Chariali which is located in Biswanath District in North Bank Plains Zone of Assam. The Centre is catering to the dry land research needs of North Bank Plain Zone (NBPZ) of Assam and the state in general since 2010.

Agro-climatic zone characteristics

The zone belongs to NARP Agro-climatic Zone 'North Bank Plains Zone (NBPZ) with six domain districts viz., Darrang, Udalguri, Sonitpur, Biswanath, Lakhimpur and Dhemaji. The climatic of the zone is sub-tropical having hot and humid summer, dry and cold winter and high relative humidity. Summer is experienced from May to August, cold winter from December to January and a mild winter is experienced from September to November and February to April. The zone receives 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), the 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. The average maximum temperature is recorded in July-August (about 33-34 ˚C during 28th to 34th SMW) and minimum temperature (6.9-8.2 ˚C during January). July and August month are the hottest months and January-February are the coolest months. Flood is common in every year and sometimes flood occurs even in September in Dhemaji and Lakhimpur districts. Approx. 105 days rainy days per year is generally experienced in the North Bank Plan Zone of Assam.

Mean season-wise and annual rainfall and rainy days (AICRPDA, Biswanath Chariali)

Rainfall	Normal rainfall (mm)	Normal rainy days (No.)
Pre-monsoon (March-May)	486.5	32
Monsoon (June-September)	1279.0	56
Post-monsoon (October-November)	150.3	9
Dry periods (December-February)	63.3	8
Total	1979.1	105

Major soil types

The major soil types in the zone are sandy loam and clay loam soils.

Major rainfed crops

The major rainfed crops cultivated in the zone during *kharif* are Sali rice, Boro rice, Bao rice, maize, greengram, blackgram and sesamum, during *rabi* are toria, jute, pea, sugarcane and potato and during autumn Ahu rice.

Dryland agriculture problems

The major problems of dryland agriculture in domain districts of the centre are

Weather aberrations

- Recurring flood during the monsoon season leading to extensive damage of crop fields. Prolonged dry spells during *rabi* season leading to poor crop yields and non-remunerative crop production.

Soil and land management related

- Predominance of acid soils resulting in low crop productivity
- Injudicious application of agro-chemicals leading to soil degradation
- Sand casting of agricultural field in Dhemaji and Lakhimpur districts resulting in conversion of fertile agricultural lands to unproductive land.

Socio-economic factors

- Predominance of small and marginal farmers hinders adoption of modern technology in agriculture
- Fragmentation of land holdings and practice of mono-cropping
- Non-adoption of community farming
- Lack of adequate farm mechanization due to non-availability of suitable agricultural machineries for cultivation in small land holdings.
- Market risks
- Non-availability of quality seed/planting material of improved crop varieties
- Underdeveloped livestock and fishery sectors

Research initiatives since inception of the centre

The North Bank Plains Zone (NBPZ) of Assam consists of 6 districts *viz*., Dhemaji, Lakhimpur, Biswanath, Sonitpur, Darrang and Udalguri. The zone covers a total area of 14.42 lakh ha with dominant upland situation. The Centre is presently undertaking research activities in diverse rainfed agro-ecologies of NBPZ of Assam and a multidisciplinary team of agronomist, soil scientists and water conservation engineer are involved in the need based location-specific research. The hallmark of the programme is the need based location-specific research of small and marginal farmers based on natural resource management and socioeconomic status. The on-station trials of AICRPDA center are carried out in the experimental farm of Biswanath College of Agriculture which represents the upland situation. The rice based cropping system research under midland and lowland situations is carried out at Regional Agricultural Research Station, North Lakhimpur, as well as at research field of Krishi Vigyan Kendra, Sonitpur under Assam Agricultural University (AAU), for development of technologies for medium/lowland situations of the zone. The collaborative on-station and on-farm technology assessment and refinement is carried out in six agroclimatic zones of Assam both at Regional Agricultural Research stations and Krishi Vigyan Kendras of AAU for inclusion of suitable rainfed technologies in state package of practices which is a joint venture of Department of Agriculture, Assam and AAU. The technologies are subsequently included in various extension programmes for various projects of government of India implemented by government of Assam through state Department of Agriculture, AICRPDA, NICRA, TSP, various AICRP projects and NABARD.

Significant achievements

Resource characterization

Agro-climatic resource characterization and crop planning of Sonitpur district revealed that the annual rainfall varied from 1358 mm (2001) to 2573 mm (2004) with mean value at 2027 ± 55.54 mm. The rainy season in the region starts in mid-March and quantum of rainfall as well as number of rainy days increases gradually and reaches maximum in the month of July and then decline to minimum during November/December. During the study period, highest monthly rainfall recorded was 668 mm in the month of July. June and July were the wettest months (362 mm) while December (11 mm) was the driest month. Coefficient of variation (CV) of monthly rainfall from April to September was less than 50 which reveals that rainfall during these months are almost stable.

The seasonal and annual rainfall of the zone was verified with Mann-Kendall trend test and Sen's slope estimator for the period of 1984 to 2016. A significant decreasing trend of annual and monsoon rainfall with slope magnitude of -15.09 mm / yr and -29.03 mm / yr, respectively, was identified and a positive significant trend of coefficient of variation of monthly rainfall for a 10-year moving period was observed for the month of June (R^2 = 0.63), September (R^2 = 0.59) and October (R^2 = 0.57). The study indicated that the rainfall fluctuations with large amplitudes and increasing frequency of intermittent dry spells and flash floods in the region has been increasing and also likely to increase in future.

Analysis of 27 years (1984-2012) rainfall data of NBPZ showed that seasonal drought occurred in both *kharif* and *rabi* season, however frequency of occurrence of drought was more in *rabi* as compared to *kharif* season. It was also found that the longest agricultural drought of 4 weeks was experienced during *kharif* season, while in *rabi*, the drought was mostly prolonged for 5 weeks and in some case, it continued up to 11 weeks. The rainy days with more than 100 mm rainfall in the region has been increasing, though it is not statistically significant. Decadal change in CV of monthly rainfall during June and September in the region was observed to be remarkable. It was observed that number of dry spells (early, mid and late season) and flash floods in the region have been increasing. The region suffered from early, mid and late season drought in recent years 2001, 2005, 2006, 2009, 2011, 2013, 2014, 2015 and 2016.

Rainwater management

A concrete rainwater harvesting structure was constructed during 2012-13 having catchment area of about 320 m^2 with maximum water storage capacity of 528.26 m^3, for covering a command area of about 6000 m^2 for data generation on catchment-storage-command area relationships and to develop farm pond technology for the domain districts. The evaporation was 40-43.5% of the total stored water and seepage is considered to be negligible (concrete lining), whereas, the dead storage were observed to be around 17-33.22%. The lifesaving irrigation (3-5 cm) is applied mainly through drip irrigation, and sprinkler irrigation systems or with the hose pipes as well, in the crops based on the 10-days continuous dry spell during the crop period. The average amount of water used for irrigation during a year is 200-250 m^3, for the crops with 300% cropping intensity. The monthly PET of the station was calculated and the average of annual PET was found to be 1138 mm, which is lesser by 887 mm as compared to the normal annual rainfall. Thus, the region has high rainwater harvest potential (887 mm annually). Normally, from March to October there was surplus water (935 mm) which is known as humid part of the year while total crop growth period is even longer. With 50% probability level of rainfall there was 884 mm excess water and with 75% probability the excess amount of water was about 40 mm**.** The excess water can be harvested and can be used for irrigation not only to *rabi* crops but also for irrigating rice crop during dry spells. The rainwater collected from a catchment area of 224 m^2 (a roof area of 124 m^2 of a house + pond top surface area

of 100 m^2) was sufficient to harvest rainwater of 319 m^3 in a farm pond of same volume. The water collected in the pond was sufficient for providing two irrigations (0.06 m depth) in the potato crop cultivated in the area of 1840 m^2, resulting in an increase in the tuber yield by 136% as compared to the rainfed potato crop (52.43 q/ha). Supplemental irrigation by using harvested rainwater resulted in higher yield of 14,179 kg/ha (85.6% increase) and 894 kg/ha (107% increase) in case of potato (Kufri Jyoti) and rapeseed (TS-36), respectively. Based on the on-station study during 2013-15, the polythene sheet lining was found to be the best over the other lining materials viz., cow dung + soil plaster (2:5 ratio) and cement + soil plaster (2:10 ratio). With a rainwater harvest potential of 2.45 ha-cm in cement lined tank, 2.07 ha-cm harvested rainwater can be used to irrigate potato land of 0.99 ha, 0.31 ha and 0.21 ha by one, two and three times irrigation at 25, 25 & 60 days; and 25, 60 & 80 days after planting, respectively.

Mulching-cum-manuring with locally available agricultural waste materials and weeds like rice straw, straw of rapeseed, water hyacinth etc is proved to be useful for management of intermittent dry spells in both *kharif* (turmeric and ginger) and *rabi* (tomato and potato) seasons. In potato, labour requirements were reduced considerably as intercultural operations like earthling up, weeding and irrigation need not be performed in mulched crop. It was observed that mulching in tomato not only assist in the better growth of the crop, but also considerably increase the length of fruiting (harvesting) period of the crop as compared to the crops grown without mulching. Combination of lifesaving irrigation and ridge and furrow systems gives better system yield and RWUE in both the greengram and blackgram cropping systems over the flat bed and control.

Cropping systems

Under cropping system research, experiments were conducted mostly on intercropping and sequential cropping with 300% cropping intensity. The 300% cropping intensity trial was formulated including cereal crop, pulses and oilseeds with medium and short duration varieties of the respective crops developed from Assam Agricultural University. From the on-station trial of 3 years results and multi-location trial (MLT) and on-farm trial (OFT), some of the technologies have been included in package of practices. In groundnut-based cropping system, broad bed & furrow (bed size of 150-30 cm) recorded highest system yield and B:C ratio. Among the cropping sequences, groundnut- rajmah sequence was found better as compared to other sequences. Among the intercropping systems evaluated, highest system productivity and B:C ratio was recorded in rajmah + lentil (1:1) followed by rajmah+ linseed (2:1) system. In maize based triple cropping systems under rainfed upland situations, maize+ greengram (paired row) - rajmah – blackgram sequence was found better followed by maize+ blackgram (paired row) - rajmah – greengram sequence. In the medium land situation of KVK, Sonitpur, rice-toria sequence gave the highest system yield in conventional tillage (CT) transplanted Sali rice- zero tillage (ZT) toria followed by CT wet DSR – ZT toria. However, CT wet DSR – ZT toria gave the highest B:C ratio. In upland situations of the Biwanath Chariali, system yield of minimum tillage (MT) maize -ZT Greengram- ZT toria was found to be at par with CT maize-CT green gram-CT toria. However, in terms of B:C ratio, MT maize -ZT green gram- ZT toria was better than the conventional system.

Nutrient management

In a permanent manurial experiment, application of 75% RDF + 3 t/ha vermicompost in each crop gives the highest system yield and B:C ratio in both the cropping sequences (rice – grreen gram-toria and maize-green gram-rajmah) in the rainfed upland situation of the NBPZ of Assam. This was followed by application of 50% RDF + 3 t/ha vermicompost in each crop which was at par with 75% RDF + 1 t/ha vermicompost in each crop. However, in terms of B:C ratio, application of 75% RDF + 1 t/ha vermicompost in each crop was more beneficial than 50% RDF + 3 t/ha vermicompost in each crop. Manure addition significantly improved the soil physico-chemical and biological properties, and sequestrated organic C in soil compared to control and RDF treatments.

Alternate land use

Under alternate land use system four intercrops (Assam lemon, Colocasia, ginger and fodder congosignal) are being evaluated to study the interaction effect with *Gmelina arborea* (Gomari) and *Michelia champaca* (Titachopa). The study revealed that Gomari performed better in terms of growth parameters viz. height, collar diameter and canopy spread as compared to titachopa. Higher yield was observed in intercrops grown under titachappa as compared to the intercrops grown under Gomari. This may be due to higher shading effect of Gamari than Titachappa.

Energy management

In groundnut, two harrowings and one pulverization with power tiller resulted in higher crop yield and energy use efficiency (3.64%) compared to conventional tillage which recorded the lowest energy use efficiency of 0.22%.

Evaluation of improved varieties

In a varietal evaluation programme on pigeonpea, BAC 1 (Biswanath Arhar Collection 1), matured in 250-260 days exhibited highest seed yields followed by BAC 2, compared to recommended variety T21. An early maturing pigeonpea variety ICPL 88039 (matured in 150 days) exhibited lower but comparable seed yield than recommended variety. The observations indicate that ICPL 88039 is a promising early maturing pigeonpea genotype for the region under normal

sown condition. Rice var. Dehangi is found suitable for rainfed upland direct seeded condition over the checks Banglami and Rangadoria in the NBPZ. A medium duration rice variety, TTB 404 performed the best followed by Komal, Satyaranjan and Chandrama. The observations indicated that there is possibility of identifying better varieties than the existing recommended and cultivated varieties in the medium duration group even with lesser maturity duration. A bulk population of Niger viz. NB-1 has been developed which exhibited higher seed yield than the recommended variety NG 1.

Technologies developed for North Bank Plains Zone of Assam

Rainwater management

- Rainwater harvesting and efficient utilization for enhancing crop productivity through harvested rainwater in ahu rice-green gram- rajmah and ahu rice- green gram- potato sequences.
- Farm pond technology for higher cropping intensity (300%) and system productivity of rice-greengram-toria) and maize-greengram-potato.

Cropping systems

Intercropping systems

Annual:

- Pigeonpea + ginger/turmeric
- Sugarcane (spring) + cowpea
- Sugarcane (autumn) + toria
- Cowpea/ maize (fodder) + soybean/toria
- Sesamum + blackgram (1:1)
- Pigeonpea + sesame/blackgram/greengram
- Oat + pea
- Oat + lhesari
- Maize + pea/khesari
- Maize + cowpea/rice bean
- Teosinte + cowpea/rice bean
- Pea (grain) + oat (fodder)
- Lentil + oat (fodder)

Perennial:

- Arecanut + banana + pineapple
- Arecanut + blackpepper + banana + pineapple
- Coconut + ginger + turmeric
- Coconut + betelvine + assam lemon + banana + pineapple + ginger
- Guinea + cowpea/ricebean
- Hybrid Napier + cowpea

Double /Triple cropping system

- Maize-toria-greengram
- Maize-linseed-greengram
- Maize-buckwheat-greengram
- Maize-niger-greengram
- Maize-rajmah-greengram
- Maize-potato-greengram
- Maize-toria-blackgram
- Maize-linseed-blackgram
- Maize-buckwheat-blackgram
- Maize-niger-blackgram
- Maize-rajmah-blackgram
- Maize-potato-blackgram
- Direct seeded *Ahu* rice-greengram- toria
- Direct seeded *ahu* rice-greengram- rajmah
- Direct seeded *ahu* rice-greengram- potato

Nutrient management

Integrated nutrient management practices

Crop/ Cropping sequence	INM Practice
Ahu rice (rice-rice, rice-legume-rice, rice fallow)	Application of organic manure (compost or FYM) @ 1 t/ha (on dry weight basis) along with mixed inoculum of *Azospirillum amazonense*A-10 and *Bacillus megaterium* P-5 @ 4 kg/ ha (0.4-0.5 kg/a.i./ha), rock phosphate @ 10 kg P_2O_5/ha (56 kg/ha or 7.5 kg/a.i./ha) and muriate of potash @ 40 kg K_2O/ha for rice in rice-rice, rice-legume-rice, and sole rice sequences.
Ahu rice-greengram-toria	Application of 75% recommended dose of fertilizers + 3 ton/ha of vermicompost in each crop in *ahu* rice-based cropping system viz. *ahu* rice -greengram-toria.
Sali rice (rice-rice, rice-legume, rice fallow)	Organic manure @ 1 t/ha (on dry weight basis) mixed inoculum of Azospirillium amazonense A-10 and Bacillus megaterium P-5 @ 4 kg/ ha (0.4 to0.5 kg/a.i./ha), rock phosphate @ 10 kg P_2O_5 (56 kg/ha), MOP @ 40 kg K_2O/ha for rice in rice-rice, rice-legume-rice, and sole rice sequence. In low land *kharif* rice (Sali), incorporation of 45 days old dhaincha can substitute 50% of recommended NPK.

Crop/ Cropping sequence	INM Practice
	Nitrogenous fertilizers can also be supplemented by using azolla. About 500 kg fresh azolla/ha is to be inoculated in the field ponded with 5-10 cm depth of water for about 2-3 weeks prior to final puddling. At the time of inoculation 8-10 kg P_2O_5 /ha in the form of SSP is to be applied in the field, and the corresponding quantities of phosphatic fertilizer is to be reduced at the time of transplanting. Fresh azolla @ 500 kg/ ha also can be applied in the standing water in transplanted crop after establishment of seedlings. There is no need for application of additional phosphatic fertilizer in the field at the time of inoculation with fresh azolla after transplanting when recommended doses of phosphatic fertilizer is applied at the time of transplanting.
Boro rice	Same as Sali rice
Bao rice (Deep water rice)	Application of neem coated urea @ 30 kg/ha in two equal splits as basal and maximum tillering stage.
Maize	Compost or FYM @ 4.5 t/ha along with recommended dose of fertilizer.
Maize- greengram-rajmah	Application of 75% recommended dose of fertilizers + 3 ton/ha of vermicompost in each crop in maize based cropping system viz. Maize-Greengram-Rajmah.
Rapeseed	Application of FYM or compost @ 2-3 t/ha along with recommended dose of fertilizers. Apply 75% of N and P when seeds are inoculated with Azotobacter @ 40 g/kg seed and PSB@ 40 g/kg seed. Foliar application of water-soluble complex fertilizer (19:19:19) @ 0.5% + $ZnSO_4$ @ 0.5% and borax @ 0.5% during dry spell (>10 days) and in siliqua formation and flowering stage along with recommended dose of fertilizers.
Rapeseed-blackgram	For integrated sulphur management in rapeseed-blackgram (summer) sequence sulphur should be applied @ 20 kg/ha as gypsum (100 kg/ha) + 25% recommended dose of NPK in the form of urea: DAP: MOP + biofertilizer *Azotobacter* and PSB @ 50 g each/kg of seeds + 2-ton FYM/ ha to each crop.
Potato	Ten tonnes or 5 truckloads or 20 cart loads of well decomposed FYM/ha along with recommended dose of fertilizers
Blackgram/ greengram	Application of FYM or compost @ 4 to 5 t/ ha along with seed inoculation *Rhizobium* culture @ 50 g/ kg of seeds and fertilizer dose of 10:35:15 kg N, P_2O_5:K_2O/ha. Application of 0.4% *Ipomoea carnea* biochar with recommended dose fertilizers in summer greengram.
Rabi pulses / oilseeds	Application of lime @ 1/10th of lime requirements of soil (based on SMP method) in furrows integrated with FYM @ 2 t/ha together with 50% recommended dose of NPK is recommended in acid soils (pH <5.5).

Foliar nutrition

Sali rice: Spray 2% KCl solution on leaves as and when dryspell appears.

Toria: Two foliar applications of 1% urea at flowering and pod filling stages along with basal application of recommended fertilizer dose, i.e., 60 Kg N, 30 kg P_2O_5 and 30 kg K_2O/ha.

Contingency crop planning

For *kharif* planning

a. Suggested crops/varieties/cropping systems for delayed onset of monsoon

Delay by 2 weeks (8th 12th June)

Rainfed upland situation

- Summer vegetables/summer pulse (blackgram) - toria / potato/*rabi* vegetables like chilli/pea/cole crops.
- Summer vegetables -Amaranthus, pointed gourd, bottle gourd, ridge gourd, etc.
- Summer pulse (blackgram) - SGC-16, SGC-20-1, etc.
- Toria variety -TS-38, TS-46, TS-67, Jeuti, Yellow sarson (Benoy).
- Rice - *rabi* crops like toria/potato/*rabi* vegetables.
- Rice variety - Luit, Dishang, Inglongkiri, selected local cultivars.
- Mustard variety - TM-2, PM 26, PM 27, NRCHB-101 (notified).
- Potato variety - Kufri Pukhraj, Kufri Jyoti, Kufri Chandramukhi, Local variety.
- *Rabi* vegetables - Cole crops.

Medium land/Low land situation

- *Sali* rice (winter rice) monocropping.
- *Sali* rice (Ranjit, Bahadur, Shraboni, Mahsuri, Maniram, Piolee, Kushal).
- Rice - toria/potato/*rabi* vegetables.
- Rice variety - TTB-404, selected local cultivars.
- Toria variety - TS-38, TS-46, TS-67, Jeuti, Yellow sarson (Benoy).
- Potato variety - Kufri Pokhraj, Kufri Jyoti, Kufri Megha, Local variety.
- *Rabi* vegetables - Cole crops, French bean, chilli, capsicum, Solanaceous vegetable.
- Jute - toria/potato/*rabi* vegetables.
- Jute variety: Sabujsona, Tarun, Navin, Apeswaree, local variety etc.

Delay by 4 weeks (1st week of July)

- Provide partial shade by planting Arhar/dhaicha as intercrop.
- Mulching with locally available organic materials.

- Staggered planting of rice (Gitesh, prafulla).
- Planting or direct sowing with the photo and insensitive varieties like Luit and kapili.
- Planting with photo and insensitive HYV rice variety (Monohor sali).

Delay by 6 weeks (3rd week of July)

Sowing of sprouted seeds of *Sali* rice (short duration varieties-Satyaranjan, Basundhara, Jaya, Swarnaprabha), *Ahu* rice (Luit, Lachit, Sonamukhi both direct seeded and transplanted), sesame (TC 25, Vinayak, AAU SHL TIL 1), toria (TS-38, TS-46, TS-67, Jeuti, Yellow sarson), potato (Kufri Pokhraj, Kufri Jyoti, Kufri Megha, Local variety, etc).

- Mulching with locally available organic materials.
- Staggered planting of rice (Gitesh, Prafulla) with old seedling.
- Planting or direct sowing with the photo insensitive varieties like Luit, Kapilee etc.

Delay by 8 weeks (1st week of August)

- Delayed transplanted Sali varieties (Gitesh/Prafulla, Basundhara, Jaya, Swarnaprabha);
- Maize, greengram/blackgram/sesame, toria, potato
- Mulching with locally available organic materials.
- Staggered planting of rice (Gitesh, Prafulla) with old seedling.
- Application of life saving irrigation.
- Closer spacing and more no of seedling/hill.
- Planning for early *rabi* vegetables (cauliflower, cabbage etc).

b. Crop, soil, water and nutrient management strategies during seasonal drought

Early season drought

Upland situation

Rice: Clay or clay loam with pH 4.5-6 is suitable for rice cultivation. Application of 5 cm irrigation water 3 days after disappearance of ponding water is recommended in medium and heavy soil. In *kharif* rice, height of bunds should be 30 cm to retain rain water for higher yield. N, P_2O_5 and K_2O of Sali rice 60:20:40 and 20:10:10 for semi dwarf and tall varieties along with 10 t FYM per ha has to be applied during land preparation.

Potato: Well drained sandy loam and loam soil, rich in organic matter are suitable. Water management: furrow method of irrigation has to be applied. Three irrigations should be applied, 1st at 25 days (stolon formation stage), 2nd at 60 days (tuber formation stage) and 3rd at 80 days (tuber development stage). For rainfed condition, N, P_2O_5 and K_2O of 60:50:50 and for irrigated condition, N, P_2O_5 and K_2O of 60:100:100 along with 10 t FYM per ha has to be applied during land preparation.

Rapeseed-Mustard: Sandy soil to light soil is suitable for growing of rapeseed and mustard. Water management: 6 cm depth of water may be applied at 50% flowering and at early siliqua formation stage. In case a rainfall of 20-25 mm is received during this period, no post irrigation is required. For rapeseed, N, P_2O_5 and K_2O of 40:35:15 and 60:40:40 & Borax of 10 kg/ha is recommended for rainfed and irrigated condition, respectively along with 2-3 t FYM per ha. For mustard N, P_2O_5 and K_2O of 80:40:30 & Borax of 7.5 kg/ha along with 2-3 t FYM per ha has to be applied during land preparation is recommended.

- Medium land/medium low land situation
- Weeding and repeated inter-cultivation
- Replanting in dead hills
- Lifesaving irrigation from harvested rainwater
- Increase bund height (upto 30 cm) in rice fields for soil moisture conservation.
- Supplemental irrigation through STW /farm pond in the nursery bed of rice.
- Application of sufficient quantity of FYM or compost in the nursery bed and main field.
- Spraying of Mancozeb @ 2.5 g/l or Edifenphos 2.0 ml/l or Carbendazim @ 1g/l against brown spot disease in rice.

Mid-season drought

- Reduce plant population by thinning in toria and jute
- Spray of antitranspirant i.e. Kaolin @ 5%
- Mulching with available farm waste/crop residues
- Life saving irrigation from harvested rainwater, if available
- Weeding and dust mulching at critical stages of growth.

Terminal drought

- Application of 2% KCl if irrigation facilities is not available
- Incorporation of MOP 22.5 kg/ha in medium and lowland situations
- Spray of 1% KCl solution at flowering stage and 2% urea spray at pod initiation stage of pulses
- Spray of 2% KCl solution in rice as and when dryspell appears before flowering
- Life-saving irrigation, if available from harvested rainwater
- Harvest the crop at physiological maturity stage.

c. Suggested contingency measures for transient water logging/partial inundation situation

In addition to the occasional drought in the domain districts of North Bank Plain Zone of Assam, intermittent flash floods are common during monsoon season, particularly in North Lakhimpur and Dhemaji districts.

Crop	Suggested contingency measures			
	Seeding/nursery stage	Vegetative stage	Reproductive stage	At harvest
Rice	• Community nursery for rice seedlings • Mat nursery for machine transplanting	• Drain out excess water • Need based plant protection measures	• Drain out excess water • Need based plant protection measure	• Harvest the crop at physiological maturity • Shift the bundles to drier place and hang the bundles on bamboo line for sun drying
	• Drain out excess water • Pump out excess water, if possible	• Gap filling with more no of seedlings • Replanting/direct seedlings with the photo-insensitive short duration varieties		• Sun drying of grains to attain proper moisture content
Blackgram, greengram, sesame, maize	• Drain out excess water. • Re-sowing of the crop	• Drain out excess water • Need based plant Protection measures	• Drain out excess water • Need based plant • Protection measure	• Harvest the crop at physiological maturity • Shift the bundles • To drier place like • Roof top for drying

For *rabi* planning

b. Suggested crops and varieties for delayed season

Rice: Short duration varieties-Dishang, Luit for upland situation; medium duration varieties - TTB-404 (Shraboni) for medium land situation; long duration variety- Ranjit, Ranjit sub-1, Bahadur sub-1, local cultivars.

Rabi crops: Potato: Kufri Megha up to mid-December; Toria: TS-67,Jeuti, TS-46 up to first week of December.

Fodder crops: Hybrid Napier (CO-4), Congosignal, Setaria, *Rabi* Maize, Oats

Agroforestry systems

Tree species: *Gmelina arborea* (Gomari) and *Micheliachampaca* (Titachopa) Intercrops: Assam Lemon, Ginger, Colocasia and congo signal (fodder); Spacing: S_1: 4 m × 4 m; S_2: 4 m × 6 m; S_3: 4 m × 8 m

Impact of technologies

Three technologies are included in state package of practices viz., optimum planting time for small tubers potato cultivars, maize based cropping sequence under rainfed upland conditions of Assam and intercropping of sesamum with green gram and black gram. The developed technologies are being upscaled for enhancing crop productivity by replacing traditional cultivation practices. Two technologies have been developed and recommended for inclusion in state package of practices where AICRPDA scientists collaborated viz, application of 0.4% biochar prepared from crop residues or weed biomass with recommended dose of fertilizer (15: 35: 15 N: P_2O_5:K_2O kg/ha) in greengram and low-cost vermicomposting technology. The low-cost technologies are being popularized through KVKs of Assam Agricultural University and have received wide acceptance among the farmers.

The centre contributed and played major role in development of the contingency plans for the domain districts in particular and state in general in collaboration with ICAR- CRIDA, Hyderabad. Demonstrations of climate resilient technologies generated by the centre and technology developed at AAU have made significant impact on the livelihood of the farmers of the adopted villages under NICRA and TSP. The villages adopted under TSP, NICRA and NICRA upscaling programme have contributed towards horizontal spread of technology to nearby areas in terms of improved seed as well as other improved technologies. Further, on-farm demonstration of the technologies developed under AICRPDA and disseminated in collaboration with KVKs have aided in spread of improved technologies among the farmers of the domain districts as well as the state. Dissemination of weather-based advisories in collaboration with GKMS, department of agro-meteorology have benefited the farmers of the domain districts in adopting timely contingency measures which have helped the farmers in realizing higher income from the farming enterprises.

Demonstration of climate resilient technologies through exhibition of NICRA model in state and national levels have generated awareness amongst the farmers, scientist and policy makers regarding various climate resilient technologies suitable for Assam in particular and the NE India in general. 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 on a real-time basis is important adaptation technologies for climate resilient agriculture. Adoption of climate resilient crops and cropping systems and use of harvested rainwater resulted in a 12 to 30% increase in yield with 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 case of early season drought, replacement of long duration traditional varieties with short duration HYVs and providing life-saving irrigation using harvested rainwater increased yield by about 59% (short duration var. *Dishang*) over farmers' method. In case of mid-season and terminal drought, application of an additional dose of 22 kg/ha MOP at maximum tillering to grain growth period increased rice yield by about 33% (*Ranjit*), 32% (*Gitesh*), 64% (*Shraboni*), and 57.5% (*Mulagabharu*) over farmers' practice. In flood-affected areas under lowland situations, cultivation of submergence tolerant varieties (*Jalashree* and *Jalkuwari*) resulted in higher yields.

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 crops/varieties), management related (management of insect-pests, diseases, nutrient, weed, etc).

The TSP programme by AICRPDA centre, Biswanath Chariali was implemented in village Jalakiasuti, Sissiborgaon block, Dhemaji district, Assam. Implementation of the project resulted in successful adoption of Custom Hiring Centre, low-cost vermicomposting technology, HYVs of crops etc. Income from tertiary occupation like production and sale of *Eri* yarn, sale of carpets, tie and dyed products etc. played a major role towards self-sufficiency. Introduction of upgraded pig breed (Hampshire cross) and goat breed (Beetle) improved the economy of farmers through increased meat production and breed upgradation of local livestock population. Empowerment of women folk through allied activities like mushroom cultivation, rearing dual purpose poultry Vanaraja and Khaki Campbell duck resulted in enhanced household income.

Way forward

Assam agriculture is mainly rice-centric. Out of net sown area of 26.99 lakh ha, total area under rice in Assam is 23.6 lakh ha. Out of 26.99 lakh ha of net sown area, net irrigated area in Assam is only 2.54 ha. Therefore, more focus should be given on rainfed rice based cropping systems for sustainability of the production system. Moreover, Assam is highly vulnerable to vagaries of climate and recent change in rainfall pattern has led to occurrence of flash flood and prolonged dry spells during the *kharif* season. The state agriculture is dominated by small and marginal farmers representing 18 and 36%, respectively. Therefore, technologies which address the problems of these farmers are urgent need of the hour to make agriculture an attractive proposition. Therefore, climate resilient technologies *viz.,* varieties with submergence tolerance and drought tolerance need to be developed to address these vulnerabilities. Rainwater is the key input in rainfed agriculture. The success in rainfed agriculture lays in the wise use of natural resources, in particular rainwater. The rainwater harvesting structures have to be standardised as per the precipitation and land situations in various regions of the NBPZ in particular and the state in general. Emphasis should be on the use of various micro-irrigation methods such as drip, sprinkler and rain guns for enhancing the water use efficiency from the harvested rainwater. Research on different land configurations such as ridge and furrow bed systems, broad-bed furrow systems, raised bed furrow systems to be conducted for management of excess and deficit rainfall keeping in view wide variability in the rainfall pattern due to climate change. Even though Assam falls under high rainfall zones of India, prolonged winter dry spells make cultivation of *rabi* crops risk-prone. Harvesting and utilization of excess rainfall received during *kharif* season may boost the production of *rabi* crops which will also act as insurance against crop failure during *kharif* season due to high intensity flood. Efforts may be made to introduce millet crops particularly under intercropping and sequential cropping systems. More emphasis to be laid on low water requiring crops like buckwheat, niger, linseed etc. Research on crop residue management and crop diversification is required for sustainable land use system. Research on organic farming, conservation agriculture and natural farming to be carried out for soil carbon management and reducing GHG emissions from soils. Standardization of CA techniques with low-cost farm machinery tools for the poor and marginal farmers is the need of the hour. Work has also to be done on spray of CDM cultures for quick *in situ* decomposition of crop residues. Extensive work has to be done with nanofertilizers so as to improve fertilizer use efficiencies along with reducing the chemical load to the soil.