3. Climate Change and Resilient Agriculture

Green house gas (GHG) emissions in diversified agriculture on reclaimed sodic land: The Cool Farm Tool model used to estimate GHGs emission, integrates several globally determined empirical GHG quantification models. Estimated total GHG emission, i.e. global warming potential per hectare in terms of CO_2 equivalent (CO_2-eq) varied amongst different crop production systems. On an average, rice-wheat system emitted 1,823 kg CO_2-eq, whereas maize-wheat, fodder, vegetables and horticulture emitted 410, 245, 188 and 117 kg CO_2-eq from the respective areas of these cropping systems.The total emission from 1.8 ha area under diversified cropping system was 2,784 kg CO_2-eq as compared to 5,152 kg CO_2-eq from the rice–wheat system in the same area. On hectare basis, diversified agriculture system emitted 1,547 kg CO_2-eq/ha as compared to 2,862 kg CO_2-eq/ha in rice-wheat system. The global warming potential under diversified agriculture system was 46% (1,316 kg CO_2-eq/ha) less than that of rice-wheat.

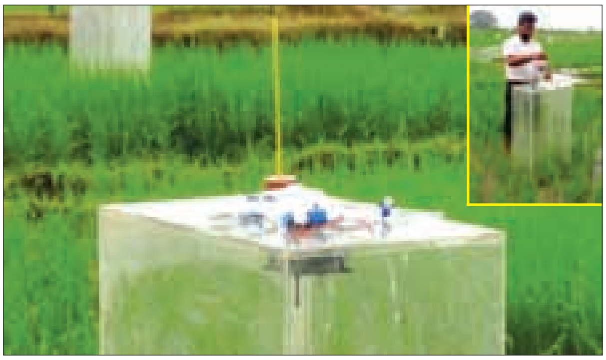
Quantification of green house gas emissions: Measurement of GHG fluxes (carbon dioxide and methane), moisture and heat in the soil-plant-atmosphere systems using the Eddy Covariance technique was carried out in rice-wheat rotation. The net ecosystem carbon dioxide exchange (NEE) and net ecosystem methane exchange (NEME) were monitored in rice and wheat crops and also during the fallow season. The gross primary productivity (GPP) and NEE was found to be highest between heading to ripening stage in rice, whereas it was maximum at flowering stage in wheat.

The net ecosystem methane exchange during rice growth period was the highest between active tillering to maximum tillering stage in rice. The diurnal variations in mean net ecosystem exchange in submerged rice ecosystem in both dry and wet seasons varied between + 0.2 to - 1.2 and + 0.4 to - 0.8 mg $CO_2/m^2/s$.

The cumulative seasonal methane emission was reduced by 75% in aerobic rice when compared with continuosly flooded rice. The seasonal emissions were lower in slow release N fertilizer, especially, when applied on the basis of Customized Leaf Color Chart (CLCC).

Measurement of CH_4 and N_2O fluxes in rice: Fluxes of methane CH_4 and N_2O were measured under different establishment methods and source of nitrogen in irrigated rice in a Typic Ustochrept soil. Maximum methane flux was noticed under the treatment of transplanted puddled and normal urea application combination compared to all other treatment combinations at different stages of the rice crop.

Closed chamber method was used to collect air samples from the experimental field and the air samples were analyzed by Gas Chromatography (Model SRI-8601C) equipped with a detector ECD and FID. The highest methane flux occurred in 72 days after sowing in all the treatment combinations. There is 54% reduction in CH_4 flux under the combination of aerobic rice and neem coated urea application followed by 49% reduction in aerobic rice and sulphur coated urea application compared to the combination of conventional puddling and normal application of urea. There is 33% reduction in N_2O flux under the combination of aerobic rice and neem coated urea application compared to conventional puddling and normal urea application.



Closed chambers used for collection of air samples at regular intervals from the paddy fields

Enhancing climate resilience through crop improvement and adaptation: Development of crop genotypes adapted to multiple climatic stresses is important for coping with climate variability. To address this, genetic enhancement of tolerance to drought, heat, flooding and salinity stresses in major food and horticultural crops is being attempted under NICRA. In wheat, 45 terminal heat tolerant advanced lines were evaluated in multi-locational trials.

Two rice genotypes, viz. Bhundi and Kalaketki were registered for submergence tolerance. Two lines CR2851-1-1-S-7-2B-1 and CR2839-1-S-11-1-B2-B-46-2B have been nominated for AICRP multi-location trial under coastal saline area. Further, three hybrids, IR58025A × NH-12-141R; APMS6A × NH-12-124R; APMS6A × NH-12-144R have entered multi location testing for heat tolerance.

Four lines, Somaly-2-023-3-5-1-2-1, IR 55178, SG 26-120 and IR 82310-B-B-67-2 confirmed the stability under late planting situation in 8 locations. Six promising lines of rice with superior NUE entered multi-location testing.

In pigeonpea, waterlogging tolerant (IPAC 79 and MAL 9) and drought tolerant genotypes (JSA 59, JKM 189, BSMR 736, RVK 275) were identified.

Assessment of hailstorm damage using satellite data: During February-March 2014 hailstorms struck central India and caused severe losses to several crops. Landsat-8 satellite data of pre- and post-hailstorm periods were used to map the hail streaks. High-resolution LISS-IV data were used to distinguish different crops within the hail streak so as to assess extent of damage to different crops in the study area. To detect changes in vegetation due to hailstorm damage, a NDVI difference image was generated by subtracting the pre- and post-hailstorm NDVI images. About six hailstorm-damaged streaks were identified in the study area. The mean length and width of streaks was about 18 and 5 km, respectively. The maximum length of streak was about 33 km, width was 8 km, perimeter was 76 km and area was 36,262 ha. Total damaged area under different crops estimated from the data was about 20,779 ha. Using LISS IV data, crop classification was performed by the minimum distance classifier method. Grape was the major crop affected due to hailstorm in the study area (about 3,122 ha). Damaged fields of papaya, pomegranate and sugarcane were also identified in the classified image.

Carbon-management index: In different wheat-based cropping systems, the index, based on the carbon pool index and carbon liability index, was maximum in zero-tilled narrow-bed with residue in 0-30 cm soil depth under conservation tillage vis-à-vis conventional tillage. Among the cropping systems, maize-wheat cropping system registered the highest carbon management index.

Carbon sequestration in vegetable-pea-Frenchbean cropping system: To reduce C emission, an experiment was conducted with different levels of FYM and recommended NPK in vegetable- pea-Frenchbean system. Application of 5.04 tonnes FYM/ha nullified 62 kg CO_2 emitted during FYM preparation through soil C sequestration. The highest net positive C sequestration (1,585 kg CO_2/ha) and highest C sequestration (1,792 kg CO_2/ha) can be achieved with 16.6 and 17.1 tonnes FYM/ha, respectively. The highest net positive C sequestering FYM application rate lead to 1,443 kg CO_2/ha ; higher C sequestration than the recommended NPK. It yielded 48% higher pods of vegetable pea - Frenchbean system than the recommended NPK.

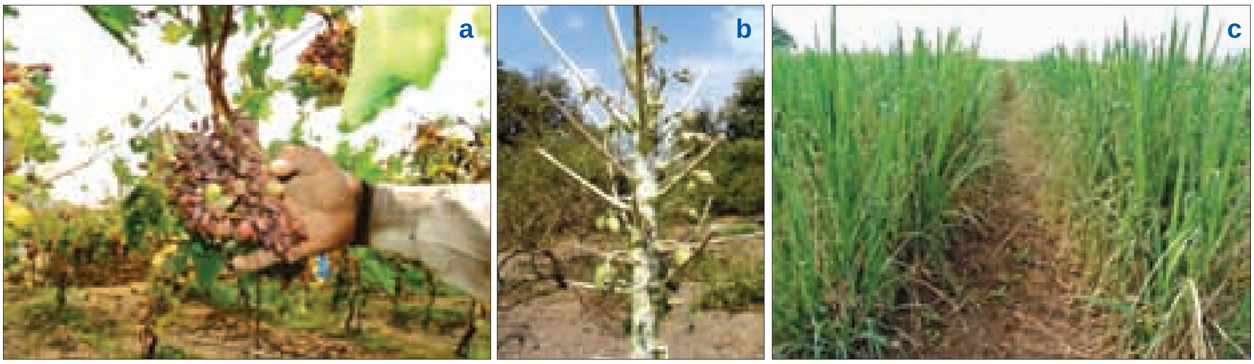
Impact of climate on breeding of carps: Delayed and deficit rainfall during the pre-monsoon season (especially during May) adversely affected fish seed production in Asom. As a strategy to overcome these circumstances, grass carps (*Ctenopharyngodon idella*) were bred during drought period as they are tolerant to deficit-rainfall situations. With reduced incubation period, fishes grew faster in the present situation than that observed in former years. This could be attributed to elevated ambient temperature in recent years.

Carbon sequestration in aquaculture ponds: The nursery and stocking ponds of Khurdha district, Odisha had sediment depth of 0.075 ± 0.030 m and 0.065 ± 0.021 m, respectively. The organic carbon was 1.19 ± 0.30% in nursery pond soil and 0.68 ± 0.11% in the stocking pond soil. The dry bulk density of soil was 1.06 ± 0.45 Mg/m^3 in nursery pond and 1.05 ± 0.37 Mg/m^3 in stocking pond. The carbon sequestration was 9.31 ± 3.93 Mg C/ha in the nursery pond soil and 4.46 ± 1.12 Mg C/ha in the stocking pond soil. Considering 1.0 cm depth, the average C pool was 1.30 and 0.70 Mg C/ha in nursery and stocking pond soil, respectively.

Impact of temperature: Pearson's correlation between maturity percentage and length at maturity of pelagic species showed that the variability in sea surface temperature (SST) negatively influenced the length at maturity of Bombay duck (*Harpadon nehereus*) and ribbon fish (*Trichiurus lepturus*).

For the period of five decades from 1960-2010, the SST plots showed rise in temperature by 0.4°C (average SST 28.38°C) for Andhra Pradesh, 0.9°C (average SST 28.33°C) for Odisha and 1.0°C (average SST 27.97°C) for West Bengal. Average annual chlorophyll-a values were highest for West Bengal with an average value of 4.04 mg/m^3, followed by Odisha (1.27 mg/m^3) and Andhra Pradesh (0.47 mg/m^3). Peak chlorophyll-a values were recorded from July-September for Andhra Pradesh, July-November for Odisha and August-December for West Bengal during 1997-2010. In trawls fish catch rates increased with decreasing SST along the NE coast of India.

Spawning biology of *Nemipterus japonicas:* The average SST during Apr-Sep (2011-2013) at Chennai was 29.9°C and at Mangalore 26.7°C and during Oct-Mar



Damaged fields of grape (a), papaya (b), sugarcane (c) due to hailstorm

27.8°C at Chennai and 27.3°C at Mangalore. Fish prefers lower temperatures for better reproductive output. Along the southeast coast species appeared to mature earlier, has lower life span and a lower fecundity. The proportion of spawners during Apr-Sep was 12.1% at Chennai and 60.1% at Mangalore and during October-March 58% at Chennai and 74.7% at Mangalore. However, the percentage of spawners was higher at Chennai during November, December and January. The L_{m50} was 140-145 mm at Chennai and 165-180 mm at Mangalore. L_{∞} estimates were 295 mm at Chennai and 330 mm at Mangalore. L_{m50}/L_{∞} (%) was 47.5% at Chennai and 50% at Mangalore. Fecundity estimates were 7,440-37,627 at Chennai and 38,500-571,913 at Mangalore.

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