SEMINAR PROCEEDINGS

Seminar Organized under NEFORD-CUTS International Collaboration

On

Sustainable Agriculture in Changing Climate Scenario

19th March, 2016, Lucknow

Background & Objectives

Climate change is now real and happening. It has already started impacting the life of people all over. No wonder, world-wide efforts are being made and strategies developed for its mitigation and adaptation. The adaptation plans are, however, largely state-driven and top-down in approach, while the fact is that the climate change is locally experienced and can only be effectively addressed by engaging local groups and institutions. Technology interventions designed to address specific aspects of climate change, can only be effective and sustainable, if they are suited to the local context, meet the perceived needs of the community, and are within its management capacity. Sudden rise or fall in temperature, excessive rains causing floods or scanty rains leading to water stress and droughts, changing pests complexions, soil-health problems and salinity, are some important problems causing concern and need immediate attention. The Inter-Governmental Panel on Climate Change (IPCC) considered India to be 'acutely vulnerable to the impacts of the climate change'. However, a report on impacts of climate change on Indian agriculture maintained that these would be region- specific, and could be significant for poor people living in marginal areas. In Uttar Pradesh, the Eastern Region, characterized by the dominance of small and marginal resource-poor farmers often facing the problems of flood, drought, and salinity/sodicity, is likely to be largely affected by these impacts of climate change. Keeping these in view and also the fact that there already exists some robust technological options that could help reduce farmers' losses; it would be worth-while to discuss these developments among the CSOs/NGOs/KVKs who have the direct link with the farming communities and can assist them in building their capacity to better adapt to the climate change. Our purpose of organizing this seminar was to sensitize the partners with the problems as well as the latest developments towards mitigating climate change effect and also learning from each-others' experiences. The seminar was organized by NEFORD with the support of Indian Institute of Sugarcane Research (IISR), on the 19th March 2016 at IISR Library building.

Objectives:

- To understand problems of sustainability of agriculture in relation to climate change scenario.
- To review current status of knowledge on adaptation and mitigation for sustaining agricultural productivity.
- To review and understand the role being played by CSOs in this connection.
- To evolve future plan and strategy to engage CSOs in mitigation and adaptation strategies.

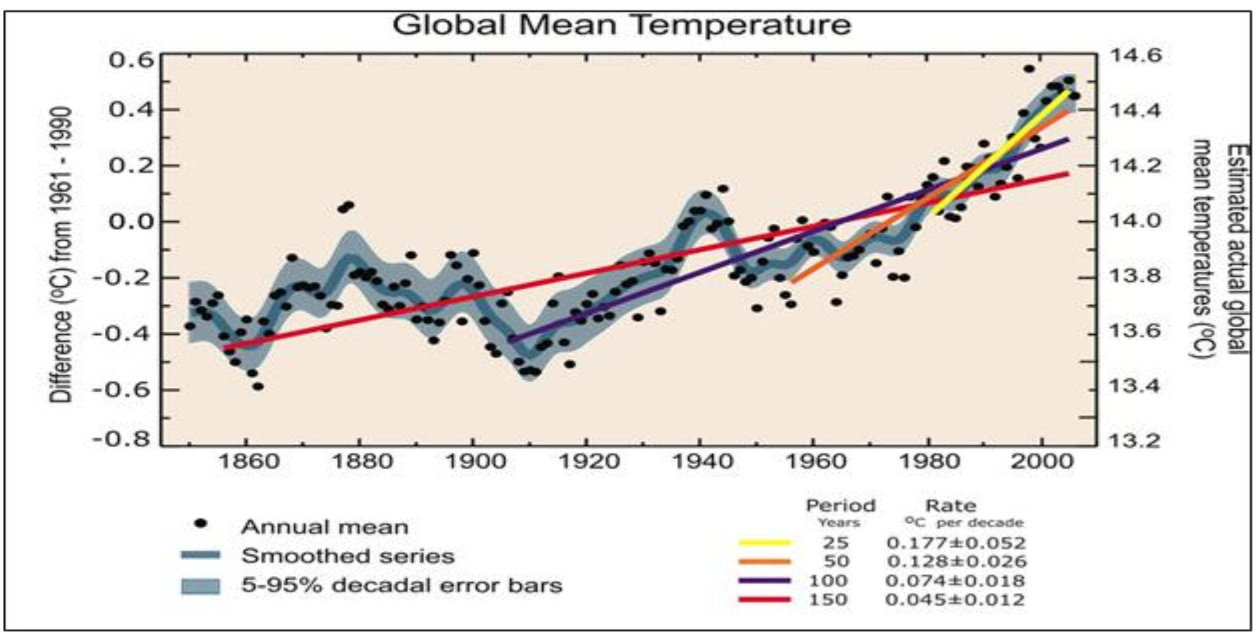
Based on the presentations and the discussions held during the seminar, the summary outcome are highlighted here:

1. Climate Change : Indicators, Predictions, Likely Impacts

Indicators:

Climate change is being felt all over. This is evident by various factors; the most important is the change in pattern of weather parameters. The long-term data analysis indicates increase in green-house gases (GHGs), especially the CO_2 and accelerated rise in temperature. At farm-level, the sudden rise/fall in temperature affects the crop adversely. Early rise in temperature during summer, which generally coincides with the grain filling in wheat, results in grain shriveling, reduced yield and quality. Similarly, sudden fall in temperature during winter, coinciding with flowering and grain formation in pigeon pea, results in flower drop and no yields. The rain fall is another parameter which has been directly hit by climate change. Its pattern over time clearly shows occurrence of early drought due to delayed and erratic monsoon. The decadal variation of rain fall in U.P. has shown that over the years the rain fall has declined, although the prediction is just the reverse. The average rain fall data during the last decade in U.P. was 682 mm, compared to the normal rain fall of 866 mm. Uncertainty of

Figure 1: Global Mean Temperature



monsoon has further added to the woes of farmers by frequent drought, flood and cyclones.

The other indicators include plateauing/declining of crop yields, increased soil-health problems, changes in pest and disease complexion, sea-level rise, decreasing ground-water table, increasing contamination of available natural resources, enhanced loss of bio-diversity, increased diseases and health hazards, increasing population migration, etc.**Predictions:**

Prediction of weather parameter changes have been made by many scientists and scientific organizations. Some of these were also mentioned by the speakers in the seminar, and are described below:

- Frequency and intensity of climatic extremes will increase.
- Hot extremes, heat waves will be more common in future.
- Global mean temperature may increase by 3.72 to 4.8 °C by end of this Century.
- Temperature increase will affect crop yield; 1 °C by 2020 to 3 °C by 2100 projected; less increase in temperature during Kharif than Rabi.

Reduction in agricultural yields in India in medium term (2010-2039): up to 4.5-9.0%: in long term (2040 and beyond) : > 25%, if no measures taken.

- Irrigated rice yields to reduce by 4% in 2020, 7% in 2050 and 10% in 2080.
- Rain-fed rice yields to reduce by 6% in the 2020.
- Wheat production may be reduced by 4% in 2020, 15% by 2050 and 20% by 2080.
- Mustard production may be reduced by 4% by 2020, 25% by 2050 and 50% by 2080.
- Production of maize, potato, sorghum may be reduced by 18, 12 and 8%, respectively, by 2020; situation will be much worse by 2050 and 2080.

Irrigation requirement in arid and semi-arid regions to increase by 10% for every 1° rise in temperature. The costal areas, Indo- Gangetic Plains, drought- and flood-prone regions, marine eco-system and parts of western Rajasthan, southern Gujarat, M.P., Maharashtra, north Karnataka, Telangana and south Bihar are among the most vulnerable and risk-prone to extreme events.

(c) Impacts of Climate Change on Indian Agriculture

Indian agriculture is highly prone to the risks due to climate change; especially to drought, because 2/3rd of the agricultural land in India is rain-fed, and even the irrigated system is dependent on monsoon. Flood is also a major problem in many parts of the country, especially in eastern part, where frequent flood events take place. In addition, frost in north-west, heat waves in central and northern parts and cyclone in eastern coast also cause havoc. In recent years, the frequency of these climatic extremes is getting higher due to the increased atmospheric temperature, resulting in increased risks with substantial loss of agricultural production.

Climate change affects agriculture both directly and indirectly, through its impact on crops, soils, livestock and pests. Increase in atmospheric carbon dioxide has a fertilization effect on crops with C_3 photosynthetic pathway and promotes their growth and productivity. Indirectly, the climate change affects agricultural land-use in India due to availability of irrigation water, soil organic matter transformation, soil erosion, changes in pest profiles, decline in arable lands due to submergence of coastal areas, and availability of energy. The probable impacts of climate change on various sectors of Indian agriculture are briefly described below:

Crop

- Increase in ambient CO_2 is beneficial since it leads to increased photosynthesis in several crops, especially crops with C3 mechanism of photosynthesis such as wheat and rice, and decreased evaporative losses. Despite this, the yields of major cereals crops like wheat is likely to be reduced due to decrease in crop growth duration, increased respiration, and /or reduction in rainfall/irrigation water supplies, due to rise in atmospheric temperature.

- Enhanced frequency and duration of extreme weather events such as flood, drought, cyclone and heat wave, adversely affect agricultural productivity.

- Reduction in yield in the rain-fed areas due to increased crop water demand and changes in rainfall pattern during monsoon.

- Decline in quality of fruits, vegetables, tea, coffee, aromatic, and medicinal plants.

- Alteration of agricultural pests and diseases, because of more pathogen and vector development, rapid pathogen transmission and increased host susceptibility.

- Threatened agricultural biodiversity by rainfall uncertainty and temperature increase, sea level rise, and increased frequency and severity of drought, cyclones and floods.

- Contrary to all the above negative impacts, predictions for decreased cold waves and frost events in future have been made, due to the atmospheric temperature rise, which would lead to a decreased probability of yield loss associated with frost damage in northern India in crops, such as mustard and vegetables.

Water

- Increased irrigation demand with increased temperature and higher evapo-transpiration (ET). This may also result in lowering groundwater table at some places.

- Melting of glaciers in the Himalayas may lead to increased water availability in the Ganges, Brahmaputra and their tributaries in the short run but in the long run the availability of water would decrease considerably.

- A significant increase in runoff is projected in the wet season that may lead to increase in frequency and duration of flood and also soil erosion. However, the excess water can be harvested for future use by expanding storage infrastructure.

- The water balance in different parts of India is predicted to be disturbed and the quality of groundwater along the coastal track will be more affected due to intrusion of sea-waters.

Soil

- Reduced quantity and quality of organic matter content, which is already quite low in Indian soil.

- Under elevated CO_2 concentration, crop residues have higher C: N ratio, which may reduce their rate of decomposition and nutrient supply.

- Increase of soil temperature will increase N mineralization, but its availability may decrease due to increased gaseous losses through processes, such as volatilization and de-nitrification.

- Change in rainfall volume and frequency and wind intensity may alter the severity, frequency and extent of soil erosion.

- Rise in sea level may lead to salt-water ingression in the coastal lands turning them less suitable for conventional agriculture.

Livestock

- Climate change has pronounced effect on feed and fodder production and nutrition of livestock. Increased temperature results in enhanced lignifications of plant tissues and reduced digestibility. Increased water scarcity would also decrease food and fodder production.

- In cooler areas, climate change has major impacts on vector-borne diseases of livestock by the expansion of vector populations. Changes in rainfall pattern may also influence expansion of vectors during wetter years, leading to large outbreaks of disease.

- Global warming would increase water, shelter, and energy requirement of livestock for meeting projected milk demands.

- Climate change is likely to aggravate the heat stress in dairy animals, adversely affecting their reproductive performance.

Fishery

- Increasing sea and river water temperature is likely to affect fish breeding, migration, and harvests.

- Impacts of increased temperature and tropical cyclonic activity would affect the capture, production and marketing costs of the marine fish.

- Coral bleaching is likely to increase due to higher sea surface temperature.

(d) Examples from Indian agriculture during last decade:

During the last decade, Indian agriculture, including crop, livestock, fishery and poultry, had to face several weather extremes due to climate change. Some of these impacts as recently observed in the crop, livestock, fishery and poultry sectors, are presented below.

- Droughts in 2002, 2004, 2006, 2009, 2010 and 2012; floods in 2005, 2006, 2008, 2010 and 2013; heat waves in May 2003 in Andhra Pradesh; cold waves in 2002-03 and 2005-06 and high temperature during January-March in 2004, 2005, 2010 are some of the recent examples of climatic extremes in India.

- The drought in 2002 was mainly on account of drastic failure of monsoon in the month of July, when the whole country was 51% deficient of rainfall than the normal. The deficiency in rainfall in north-west India was 62%, peninsular India 36% and north-east India 11%. Because of this drought, 18 million ha (m ha) area was left unsown, crop of 47 m ha was damaged with 29 m ton (MT) loss in production, dipping it to 183 MT in 2002, against 212 MT in 2001.

- Production of rice in 2002-03, fell drastically to 76 MT from 94 MT during the previous year. Production of oilseeds declined by 13.7%. Rabi rice, wheat, coarse cereals, pulses and oilseeds recorded negative growth rates of 31%, 4%, 13%, 10% and 14%; respectively; over the corresponding season in previous year. Cotton and sugarcane also recorded negative growth rates of 7.7% and 7.2%, respectively.

- Around 150 million cattle were affected due to lack of fodder and water. Decline in the average milk procurement went to the extent of 22% in Rajasthan, 8% in Madhya Pradesh and 7% in Tamil Nadu. The drought affected around 155 million farm dependable households. The total rural employment shrinkage was estimated at 1250 million man-days. The gross domestic product (GDP) in agriculture shrunk by 3.1% during that year. Although the overall impact of drought on GDP was restricted to only 1%, the loss of agricultural income was around Rs 39,000 crores.

- Cold wave of January 2003, resulted in poor fruiting in mango, papaya, banana, brinjal, tomato and potato, and also in winter maize and boro rice.

- Higher temperature during March in 2004, in the Indo-Gangetic Plains, caused wheat crop to mature earlier by 10-20 days, resulting in reduced wheat production of > 4 million tonnes in the country. Losses were also quite significant in other crops, such as mustard, peas, tomatoes, onion, garlic, and other vegetables and fruit crops.

- Similarly, irregular monsoon in 2009 caused significant reduction in rice production. Also, the Indian horticulture sector suffered badly. Apple productivity declined by 40-50% in the areas of Himachal Pradesh where elevation is 1500 m from mean sea level (MSL), partly due to warmer climate resulting in lack of chilling requirement during winter and warmer summers. This is also one of causes for shifting of apple production to higher elevation (2700 m MSL).

- In northern India, cold waves during December 2002 and January 2003 caused considerable damage to horticultural crops such as mango, guava, papaya, brinjal, tomato and potato crops. Frost during January 2008 in Rajasthan, affected mustard and cumin crops adversely, resulting in total crop failure. High temperature and moisture stress resulted in sun burn and cracking in apples, apricot, cherries and litchi and also caused dehydration injury to panicles and low fruit set in mango. The impact of climate change related events, like droughts and heavy rainfall, affected productivity of plantation crops, such as coconut and cashew (NPCC 2010).

(e) Experimental assessment of climate change effects

Series of experiments on different aspects, both under field and controlled conditions have been conducted and are in progress to assess impacts of the weather abnormalities and events, triggered by climate change. Some of these are mentioned below:

(i) Impacts on crops:

- Results have indicated that rise in atmospheric temperature reduces the biomass and yield of rice, green gram, pigeon pea, wheat, chickpea, mustard, onion and tomato. However, the elevated CO_2 concentrations resulted in higher biomass production in wheat, groundnut, sunflower, onion, tomato, coconut, cocoa, castor, sweet potato and areca nut (NPCC 2010).

- Field experiment at IARI, in small temperature tunnels and FACE showed that yield reduced gradually with rise in temperature, but some crops like rice, chickpea and mustard showed greater thermal tolerance, while wheat and groundnut proved to be more thermal sensitive. Green gram and potato showed intermediate level of tolerance for increased temperature. The elevated CO_2 could alleviate the negative impact of temperature increase up to 4°C in chickpea and 5°C in mustard. In other crops, elevated CO_2 may counter-effect the temperature increase to some extent.

- The projected climate change will not only influence the production and productivity of crops, but is also likely to affect quality of produce. Studies indicated that protein content of wheat, green gram and chickpea grains increased marginally with rise in temperature, whereas it decreased with rise in CO_2 level. Oil content of sunflower and mustard seed, increased under elevated CO_2 condition. In tomato, antioxidants were higher at elevated CO_2 concentrations. Increased storage temperature adversely affected the keeping quality of coconut copra and oil.

- Studies at IISR, Lucknow has indicated that rise in temperature improved sprouting (may also improve yield) in the winter-initiated ratoons ; increased sugar synthesis and rate of transport, but its storage may be affected ; enhanced probability of top borer infestation, incidence of early shoot borer and mealy bugs, provided no rain occurred. Disease development may also increase. The western disturbances adversely affect sugarcane production and recovery.

- Climate-change-induced multiple abiotic stresses affect sugarcane recovery as well as productivity (see the table below):

Abiotic stresses aggravating other abiotic/biotic stresses

Primary stress	**Aggravated abiotic stress**	**Aggravated biotic stress**
Water-logging	Salinity/ alkalinity/ acidity Fe toxicity Nutrient imbalance Deficiency of N, K	Red rot Wilt syndrome Pine apple disease White fly in ratoon, Cut worm Scale insect and Gurdaspur borer
Drought	Salinity	Wilt, smut, leaf scald, termites, shoot borer, pyrilla, mealy bugs, white flies, scale insect, mites, *etc*.
Salinity	Salt blight Boron toxicity	Shoot borer (*C. infuscatellus*)
Low Temp.	Water stress due to reduced hydraulic conductivity and *frost heaves* formation, localised partial salt stress, banded chlorosis	Stem borer (in Peninsular zone)
High Temp.	Drought effects	Stem borer, root borer

- Global simulation studies indicated that by 2080-2100, temperature increase may lead to 10-40% loss in crop production in India (IPCC 2007). Also, the studies conducted in India showed similar trend of decline in agricultural production with climate change, but at varying magnitudes. Analysis indicated the possibility of loss of 4-5 million tonnes in wheat production with every rise of 1^{o} C throughout the growing period. The yield loss in maize and sorghum due to rise in temperature is likely to be offset by the projected increase in rainfall during monsoon and the spatio-temporal variations in projected changes in temperature and rainfall are likely to lead to differential impacts in the different regions.

- Studies conducted on soybean have projected 50% increase in yield for a doubling of CO_2 in central India. However, a 3^oC rise in surface air temperature almost offsets the positive effects of doubling of CO_2 concentration.

- Mustard yields are likely to reduce in both irrigated and rainfed condition with spatial variation.

- Although many studies indicate adverse impacts of climate change, there are certain beneficial effects of climate change too. For example, improvement in coconut yields in west coast of India has been projected (NPCC 2010). Recently, a district level study assessed the vulnerability of agriculture in the Indo-Gangetic Plains (IGP) using three core components: (i) exposure to hazards, (ii) sensitivity to climate change, i.e. the amount of damage expected to be caused by a particular event, and (iii) adaptive capacity to recover from stress. Studies found that the districts located in the eastern and southern parts of Uttar Pradesh and Bihar are most vulnerable, whereas the districts in Punjab and Haryana are of low vulnerability, due to their higher adaptive capacity to recover from the climatic stresses.

(ii) Impacts on Dairy, Fishery and Poultry

- Studies conducted by National Dairy Research Institute, Karnal, indicated that global warming is likely to lead to a loss of 1.6 million tonnes in milk production by 2020 and 15 million tonnes by 2050, if no adaptation measures are taken. Lactating cows and buffaloes have higher body temperature and are unable to maintain thermal balance. Body temperature of buffaloes and cows producing milk is 1.5- 2^oC higher than their normal temperature, therefore, more efficient cooling devices are required to reduce thermal load of lactating animals (NPCC 2010).

- A rise in temperature could have important and rapid effects on the health of fish and their geographical distribution. With warming of sea surface, the oil sardine is able to find temperature to its preference, especially in the northern latitudes and eastern longitudes, thereby extending the distributional boundaries and also establishing fisheries in larger coastal areas. The dominant demersal fish, the threadfin breams, have responded to increase in SST by shifting the spawning season off Chennai coast. For instance, during past 30 years period, the spawning activity of *Nemipterus sp.* reduced in summer months and shifted towards cooler months.

- Analysis of historical data showed that the Indian mackerel is able to adapt to rise in sea surface temperature by extending distribution towards northern latitudes, and by descending to depths (NPCC 2010).

- In recent years, the phenomenon of Indian Major Carps maturing and spawning as early as in March is observed in West Bengal with its breeding season extending from 110 to 120 days. As a result, it has been possible to breed them twice a year at an interval of 30 to 60 days (NPCC 2010).

- In poultry sector, heat stress was significantly high in heavy meat type chickens as compared to light layer type and native type chickens. Increase in temperature from 31.6°C to 37.9°C decreased feed consumption and egg production.

2. Adaptation/Mitigation Strategy:

Potential adaptation strategies to deal with the impacts of climate change are: developing cultivars tolerant to heat and salinity stress and resistant to flood and drought, modifying crop management practices, improving water management, adopting new farm techniques such as resource conserving technologies (RCTs), crop diversification, improving pest management, better weather forecasts and crop insurance and harnessing indigenous technical knowledge of farmers. Some of these strategies are discussed below.

3 (a) Technological options

Climate-ready Crop Varieties

- Development of new crop varieties with higher yield potential and resistant to multiple stresses (drought, flood, salinity) will be the key to maintain yield stability. Improvement of germplasm of important crops for heat tolerance should be one of the targets of breeding programs.

- Germplasm with greater oxidative stress tolerance may be exploited as oxidative stress tolerance, where plant's defense mechanism is targeting abiotic stresses.

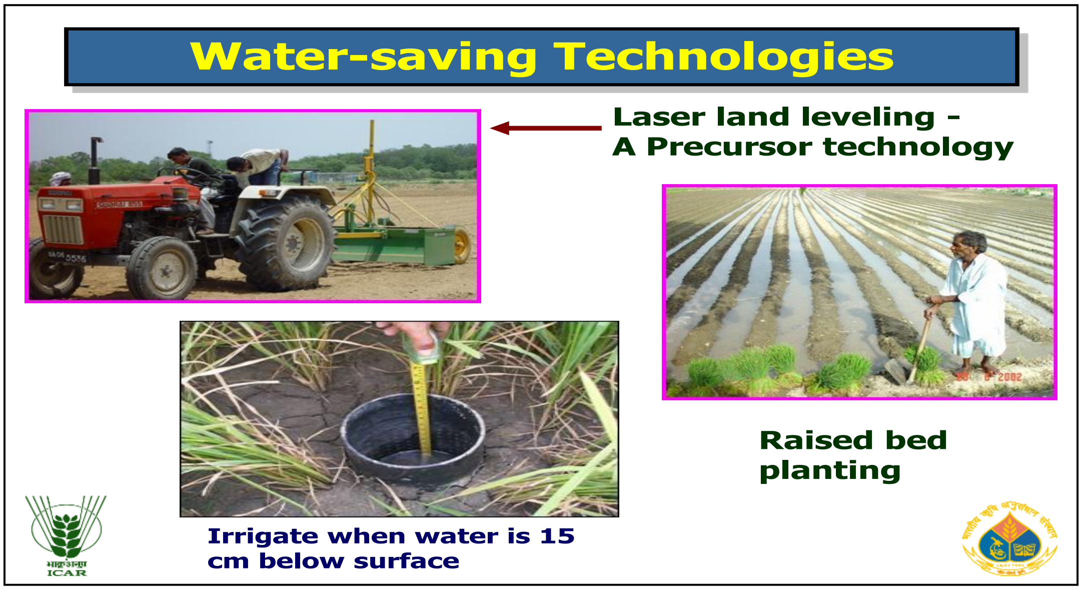
- In addition, it is important to improve the root efficiency for the uptake of water and nutrients from soil. Genetic engineering could play a pivotal role for 'gene pyramiding' to pool all desirable traits in a plant to get the 'ideal plant type' which may also be 'adverse climate tolerant' genotype.

Water-Saving Technologies:

- Efficient use of natural resources, such as water, is highly critical for adaptation to climate change. With hotter temperatures and changing precipitation patterns, water will further become a scarce resource. Serious attempts towards water conservation, water harvesting and improvement of irrigation accessibility and water-use-efficiency will be highly essential for crop production and livelihood management.

- On-farm water conservation techniques, micro-irrigation systems for better water- use-efficiency and selection of appropriate crop-need-based irrigation has to be promoted.

- Principles of increasing water infiltration with improvement of soil aggregation, decreasing runoff with use of contours, ridges, vegetative hedges and reducing soil evaporation with use of crop residues mulch could be employed for better management of soil-water.



Changing Planting Date

- Adjustment of planting dates to minimize the effect of high-temperature-induced spikelet sterility can be used to reduce yield instability, so that the flowering period does not coincide with the hottest period. Adaptation measures to reduce negative effects of increased climatic variability, as normally experienced in arid and semi-arid tropics, may include changing the cropping calendar to take advantage of the wet period and to avoid extreme weather events (e.g., typhoons and storms) during the growing season.

- Cropping systems may have to change to include growing suitable cultivars, increasing cropping intensities or crop diversification. For example, there is an urgent need for diversification of the conventional puddled transplanted rice and intensively tilled wheat to other cropping systems such as maize-wheat, pulse-wheat, maize-pulse, oil seed-wheat and direct-seeded rice-wheat. These systems have less demand for water and nutrient (with legume) and use resources more efficiently, thereby increasing farmers' income and exerting less pressure on the natural resource base.

Integrated Farming

- Small and marginal farmers having subsistence farming need assistance for making their agriculture profitable, so that they can improve their livelihoods and eventually help themselves escape from the ill effects of climate change. Integration should be made among crop production, livestock, agro-forestry and fish production to improve production, income and livelihood. This is especially important for small and marginal land holding situations, as prevailing in large part of the country.

- Major emphasis should be given on development of diverse technologies for optimization of farm resources, increased economic return, and improved sustainability in an integrated farming systems approach. New opportunities will be explored to introduce in the system to complement and synergize the productivity and income.

Crop Diversification

- Crop diversification helps ameliorating the adverse effects of seasonality on family income and peak labor demand, reduces risk due to fluctuating monsoonal patterns, helps asset improvement on farms, conserves rainwater and saves irrigation water, facilitates easier weed and nutrient management, reduces water-logging, and often results in better yield.

- Researches have indicated that areas of rice-fallows in the Indo-Gangetic Plains having adequate soil moisture can be brought under crop diversification and intensification with legumes and other crops. Diversification to other crops like pulses and oil seeds with less demand for water and nitrogen seems to be a good option for this region.

- Crop diversification and its associated changing tillage, crop establishment, nutrient management, and harvest practices will affect yield and soil fertility status.

Integrated Pest Management

- Changes in temperature and variability in rainfall, would affect pests incidence and virulence of major crops. This is because climate change will potentially affect the pest-weed-host relationship.

- Some of the potential adaptation strategies could be : (1) developing cultivars resistant to pests; (2) integrated pest management with more emphasis on biological control and changes in cultural practices, (3) pest forecasting using recent tools such as simulation modeling, (4) alternative production techniques, and (5) identification of crops, as well as locations, that are resistant to infestations and other risks.

Crop Insurance

- Crop insurance schemes, private and public, should be put in place to help the farmers for reducing the risk of crop failure due to extreme climatic events.

- Micro-finance has been quite successful among rural poor, including women. Low-cost access to financial services could be a boon for vulnerable farmers.

- Growing network of mobile telephony could further speed up SMS-based banking services and help farmers have better integration with financial institutions. There is a need to develop sustainable insurance system, while the rural poor are to be educated about availing such opportunities.

Conservation Agriculture

- Conservation agriculture and the RCTs have proved to be highly useful to enhance resource or input-use efficiency and provide immediate, identifiable and demonstrable economic benefits, such as reduction in production costs, savings in water, fuel and labor requirements, and timely establishment of crops resulting in improved yields.

- Yields of wheat in heat and water-stressed environments can be raised significantly by adopting the RCTs, which minimize unfavorable environmental impacts, especially in small and medium-scale farms. Zero-tillage can allow farmers to sow wheat sooner after rice harvest, so the crop heads and fills the grain before the onset of pre-monsoon hot weather.

Improved Nutrient Management

- The adverse impact of climate change on crop yield could be compensated with more and efficient use of plant nutrients. For example, yield reduction because of late sowing of rice as a result of delayed onset of monsoon, can be compensated with higher application of N.

- Improved nutrient management also offers promising opportunities for mitigating GHG emission. For example, technologies, including matching N supply with crop demand, use of proper fertilizer formulation and right method of application, use of N-transformation inhibitors, optimizing tillage, irrigation and drainage and growing of suitable crop cultivars, are some of the potential technologies to reduce N_2O emission.

Improved Weather-based Agro-Advisory

- Weather forecasting and early warning systems will be very useful in minimizing risks of climatic adversities. Information and communication technologies could greatly help researchers and administrators develop contingency plans.

3 (b) Policy Interventions and Programs:

The gravity of the problems due to climate change has been well recognized, both at the national and state level. The action plans have been developed and key interventions identified:

- As back as in 2008, the Government of India launched the National Action Plan on Climate Change and identified 8 National Missions and some key interventions under these missions. The key interventions on sustainable agriculture included (i) improved crop seeds, livestock and fish culture; (ii) water use efficiency ; (iii) pests management ; (iv) improved farm practices; (v) nutrient management ; (vi) agriculture insurance ; (vii) credit support ; (viii) markets ; (ix) access to information and ; (x) livelihood diversification.

- The program of action under National Mission on sustainable agriculture covers both adaptation and mitigation measures which will be implemented through four functional areas: (i) R& D; (ii) technologies, products and practices ;(iii) infrastructure development and (iv) capacity building.

- On the pattern of National Action Plan, the respective State Governments have formulated their own action plan keeping in view the specificity of need of their state.

- For example, the Government of U.P. came out with the U.P. State Action Plan on Climate Change 2014. It may be noted that climate change vulnerability to agriculture is among the highest in U.P. The high poverty level, rapid urbanization, flood, heat and cold waves, make U.P. the most vulnerable. The increase of 1.8°C to 2.1°C in maximum temperature by 2080 is predicted for U.P.

- As against 8 national missions, U.P. has formulated 7 missions: sustainable agriculture mission, solar mission, energy efficiency mission, green U.P. forestry mission, Jal mission, strategic knowledge and sustainable habitat mission.

- For sustainable agriculture mission, the Government has identified 9 different interventions, like establishment of climate change and agriculture cell, identification and mapping vulnerable areas, promotion of carbon sequestration agriculture practices, diversification of cropping systems, popularization of aerobic rice cultivation, agro-forestry and initiation of climate-responsive research programs.

- Among other missions, the Jal mission is quite important and plans to reduce gap between irrigation potential created and utilized, increase water-use-efficiency, integrated water resource management in over-exploited areas, rain water harvesting, assessment of impact of climate change on water resources of U.P. etc.

3. CSOs and community engagement :

Keeping in view the fact that climate change is locally experienced and can only be effectively addressed by engaging local groups and institutions and that all adaptation is local and local agencies, especially civil society organization, being closest to the problem, are the best suited to creating adaptive capacities. The following are the most significant functions that might be performed by CSOs to help communities adapt to climate change.

- CSOs occupy the spaces between national government, specialized institutions, private actors and public, by virtue of which they can play effective roles in preparing and helping communities undertake adaptive actions. Being close to the people and their constituent stakeholders, CSOs can help determine the extent of impact of climate change on local communities as well as their response.

- CSOs/NGOs can play a catalytic role in building up community awareness of climate change and its likely impact in their lives. They can help build up their capacities to undertake the needed adaptive actions to reduce vulnerability, mitigate risks and build resilience.

- The CSOs/NGOs can play the facilitating and advocacy role in securing an enabling regulatory frame work in regard to nature-based enterprises of the poor.

- CSOs/NGOs can help mobilize communities and resources for watershed and ecosystems development and their sustainability management. These efforts would not only help reduce poverty, but also advance the goals of nature conservation and climate smart adaptation.

- The competent and experienced NGOs can also help govt. and public agencies in developing and deploying implementable climate smart responses and adaptive actions. The NGOs are better placed in not only devising adoptable technical and social adaptive strategy, but also coordinating and mediating best practices and promising technologies at the community level as well as providing feedback to related public agencies. The NGOs can also help provide meteorology-based crop advisories for irrigation, pest, diseases, land and nutrient management that optimize land and water productivity.

4. Recommendations and follow up :

- **Status of climate change scenario**:

  - Presentations and discussions during seminar, helped review and understand the problem of sustainability of agriculture, strategies for mitigation in relation to climate change and the role of CSOs. Over the years, agricultural sustainability has declined which has further worsened due to the recent changes in climate. The climate change is being felt all over and is evident by various factors, such as change in weather parameters, increase in green house gases (GHGs), especially CO_2, increased temperatures and frequency of extreme events, droughts and floods, rise in sea-level, loss of bio-diversity, etc. Prediction of increase in temperature by 3.72 to 4.8 °C by end of the Century and its effect on crop yields have been predicted up to 4.5 to 9.0% in the medium term and >25% in the long term, if no measures are taken. Both direct and indirect effects of climate change on agriculture have been observed. Also, many of these effects have been verified by conducting lab and field experiments.

- World-wide efforts are being made and strategies developed for mitigation and adaptation to climate change. Adaptation plans are largely state driven and top-down in approach and are strongly biased towards technology, infrastructure and state managed natural resource development. However, the technology interventions designed to address specific aspects of climate change, can only be effective and sustainable, if they are suited to local context, meet the perceived needs of the community, and are within its management capacity and, hence, can only be effectively addressed by engaging, besides farmers, the local groups and institutions.

- All adaptation is local and hence, the agencies, especially civil society organizations (CSOs), being closest to the problems, are best suited to creating adaptive capacity. In other words, the civil society can help communities adapt to climate change more effectively than any public institutions.

- **State action plan:**

The state of Uttar Pradesh has already formulated a State Action Plan on Climate Change (SAPCC) in 2014, which has been envisioned to be an extension of the National Action Plan on Climate Change (NAPCC). The SAPCC has seven missions, instead of eight at the national level. The seven missions are: (1) Sustainable agriculture Mission, (2) Solar Mission, (3) Energy efficiency Mission, (4) Green UP Forestry Mission, (5) Jal Mission, (6) Strategic Knowledge Mission, and (7) Sustainable Habitat Mission. The Strategic Knowledge Mission of the state also covers the components of the Sustainable Himalayan Mission, which is the eighth mission of NAPCC. The Department of Environment, Uttar Pradesh (DOE-UP) was designated as the nodal department for action plan formulation, and a high level committee chaired by the Chief Secretary oversaw the process of formulation.

The SAPCC has also identified 93 priorities under its seven missions. The priority areas for Sustainable Agriculture Mission are: Establishment of climate change and agriculture cell (for co-ordination and monitoring), Identification of vulnerable areas and assessment of vulnerability, Establishment of climate field schools (one in each block), Promotion of carbon sequestration agricultural practices, Use of organic manures, Soil management practices, Farming systems approach for diversifying incomes and livelihoods, Diversification of cropping systems and promotion of abiotic stress-tolerant crop varieties, popularization of aerobic rice cultivation, agro-forestry and climate-responsive research program initiation.

Priority areas identified under other missions having relevance to sustainable agriculture include : Deployment of solar pumps in irrigation (Solar Mission), Enhancing agro-forestry and private plantation by land owners (Green UP Mission), Increasing water use efficiency in canal supply and on-farm water management (Jal Mission).

Mainstreaming climate change agenda in the policy and planning of different departments of the government of U.P., and integration with the activities of research institutions, academia, CSOs, and other stakeholders needs to be done on priority.

➢ **Technological options:**

- While newer problems are continuously arising due to climate change, the scientific community is equally concerned and making efforts towards developing technologies that can help mitigate climate change effects and reduce farm losses and instability (see Annexure-1 for details).

- **Stress-tolerant varieties:** Crop varieties tolerant to heat and salinity stress and resistant to flood and drought have already been developed, which not only improve, but also stabilize productivity and reduce losses. These varieties need to be promoted at faster speed, following innovative transfer of technology approaches. Also, several multiple-stress-tolerant crop varieties, such as flood combined with drought tolerance in rice, are in the pipe line and will soon be available to farmers.

- **Crop management practices:**

⇒ Besides climate-ready crop varieties, energy, water, labour, time and cost saving improved crop management options are also available to ensure efficient and cost-effective crop production. These include resource conserving technologies (RCTs), like zero-till sowing, direct seeding, residue management practices, and other crop establishment methods, like aerobic rice, SRI, Sanda (double transplanting) method of rice cultivation, intermittent drying and wetting; mulching and recycling of organic residues, demand-driven nutrient management based on soil test, leaf colour chart (LCC), use of slow release and coated fertilizers, etc. Also, location-specific cropping systems have been identified; many of them have less demand for water and nutrient (like legumes) and use resources more efficiently and, therefore, put less pressure on natural resources. Some specific examples are listed below:

⇒ Effect of slow-release-fertilizer, soluble-chemical-fertilizer (free form) and *Azotobacter* (free form) on oil content (%) and oil yield in *Sesamum indicum* crop grown in field conditions, has been well established.

⇒ To reduce water use for nursery raising and transplanting, aerobic rice cultivation, with improved varieties and hybrids, with high yield potential, need to be promoted. Integrated Crop Management practices for aerobic rice cultivation have already been developed and tested.

⇒ There is a need to promote zero-till wheat cultivation, which will not only reduce tillage cost, save water and energy, but also help timely sowing. This also ensures that there no lodging in wheat due to late rains (in the month of March) at grain maturation stage.

⇒ Equipments, like Happy Seeder that can sow wheat after the harvest of rice by incorporating the rice straw, should be subsidized and popularized.

⇒ Besides water-saving management practices, use of micro-irrigation systems, such as sprinkler and drip, use of easily transportable and reasonably cheap plastic pipes for efficient water-use, are highly recommended.

⇒ Organic farming may contribute to valuable frame work for a future sustainable agricultural production. A highly viable approach and especially suited for small holders, the organic farming is particularly useful in difficult environments as it reduces risks by encouraging localized input-based production and fosters soil and water conservation. Water captured in organic fields can also be 100% higher than in conventional fields during torrential rains.

⇒ In the changing climate scenario and growing instability in agriculture, community managed efforts could be more effective. Successful examples of *in-situ* water harvesting, practice of non-pesticide crop disease management, concept of organic village, etc. are already reported.

⇒ Interlinking and sharing ground-water drawn from bore wells where many of them go dry during summer/drought, but some have a regular recharge. An example of 2-3 villages in A.P. has being cited where every farmer gets one assured crop of kharif even in a drought year. Those whose bore wells do not have water to supply to the grid, have to pay for it on the agreed terms.

⇒ Some climate-moderating techniques, such as shade net, screen house, naturally ventilated plastic houses, etc. are also available and need to be promoted.

⇒ Promotion of agro-forestry and horticultural trees and high biomass food and non-food crop diversity for higher CO_2 sequestration and moderating farm temperature will also help in maintaining different strata of soil moisture and soil bio-diversity.

⇒ Live-stock and tree-based livelihood systems in rain-deficient areas are more sustainable when compared to field crop-based options. Livestock like goatery and trees like suitable fruit trees, agro-forestry and fodder trees, etc., have more resilience to weather aberrations/drought like situations.

- **Integrated pest management:**

  - Changes in weather parameters will affect pest incidence and virulence in major crops. This is because the climate change will potentially affect the pest/weed-host relationship. Some of the important adaptation strategies will include (i) developing crop varieties resistant to pests ; (ii) integrated pest management with emphasis on biological control and changes in cultural practices; (iii) pest forecasting using recent tools such as simulation modeling, and (iv) alternative crop production techniques.

- **Weather-based agro-advisory:**

  - Accuracy in medium range weather forecast, about a week in advance, could reduce damage under sudden and uncertain weather aberrations. Presently, a system is available in which the KVKs send SMS to the registered farmers on short range (3-4 days) weather forecast.

- **Policy support:**

  - Besides technologies, there are several other measures that go towards providing income security for farming households, and need to be linked up with the adaptation and mitigation strategy of the government. Some of these are:

⇒ Pricing policy

⇒ Procurement & marketing support, credit, etc.

⇒ Agricultural insurance, and

⇒ Disaster compensation & support for sustainable agriculture.

- **Role of CSOs**

  - While public agencies are better placed in understanding the science of climate change and how it will impact people, the competent and experienced CSOs/NGOs are best placed in not only devising adoptable technical and social adaptive strategy, but also coordinating and mediating best practices and promising technologies at the community level as well as providing feed back to public agencies. Their role could include:

⇒ Climate resilient technology testing and packaging according to the needs of local communities.

⇒ Technology dissemination to the farming community and other stake-holders.

⇒ Capacity building and awareness creation amongst different stake-holders.

⇒ Influencing government policies and research agenda of institutions.

⇒ Establishing linkages between different sectoral activities of government, private institutions, research organizations, service sector, etc. with the farming community and other stake-holders.

⇒ Follow up and making the stake-holders aware of government sponsored programs and climate change action plans envisaged under the state policy.

⇒ Community mobilization for risks mitigation, especially in cases of climate change leading to disasters, such as flood. Also, they can help mobilize the communities and resources for watershed and ecosystems development and sustainable management.

- **Follow up:**

- It was decided that the proceedings of the seminar should be sent to all the participants, particularly to CSOs/KVKs to make farmers aware of recommendations and help them use as per their needs. A suggestion was also made to have a similar discussion after about a year to review the implementation of these recommendations and suggest future action.

Annexture-1

List of technologies for climate change and mitigation and adaptation:

Technology	Technology detail	Remarks
1- Early warning and weather forecast.	KVKs send SMS to registered farmers on short range (3-4 d) weather forecast.	Help farmers plan their farming operations accordingly.
2- Climate resilient varieties **Rice:** • Submergence tolerant	- Swarna Sub-1 Sambha Sub-1 - CR 1009 Sub-1 - BR 11 Sub-1 - IR 64 Sub-1	Tolerate 12-15 days of submergence. Yield range: 4.5-5.5 t/ha
• Drought tolerance	- Sahbaghi dhan - DRR dhan 42 - DRR dhan 43 - DRR dhan 44 - Sushk samrat - Sukkha dhan 5 - Sukkha dhan 6	With 1-2 irrigations, the varieties yield more than 3.5t/ha in drought conditions.
• Salt tolerance	- CSR-36 - CSR-43 - CR dhan 402 - CR dhan 403 - CR dhan 405 - CR dhan 406 - Bina dhan 8 - Bina dhan 10	
• **Aerobic Rice**	- Gozaba - CR dhan 200 - CR dhan 201 - CR dhan 202 - CR dhan 203	115-day duration 5-5.5 t/ha yield

Wheat: • Salinity tolerant	- KRL 210	Mild salinity/alkalinity tolerance (3.5t/ha)
	- KRL 213	Mild salt salinity /alkalinity tolerance (3.7 t/ha)
	- KRL 19	High salt tolerant and non logging (2 to 3 t/ha)
• Short duration /heat tolerant	- Halna - NDW 1014 - WR 544 - PBW 154 - CBW 38	Maturity about 100–day duration ; yield ranges : 3.02-4.5 ton/ha
Pulses : • Urd bean	NDU 94-10 WBU109 KUG59 Pant U 31 Vamban7	Photo-thermo insensitive; tolerant to high temperature; short duration suitable for multiple cropping.
• Moong bean	HUM16 IPM2-3 Neha, SML668 Samrat,MH421	Photo-thermo insensitive, short duration suitable for spring/summer cultivation.
• Pigeon-pea	NDA1 Bahar	Low temperature tolerant
• Chick pea	Karnal Chana-1 ; ICCV-6 Pusa240	Tolerant to Salinity Tolerant to lodging
• Soybean	NRC-7 JS71-05	Tolerant to drought and pod shattering.

Sugarcane : • **Tolerant to abiotic stresses**	- Co 87263 (Saryu) - Co 87268 (Moti) - CoSe 96234 (Rashmi) - BO 128 (Pramod) - Co Lk 94184 (Birendra) - Co 0232 (Kamal) - BO 146	Early and WL, RF,LIC Early, DR, WL, high soil Ph Early, general stress Saline-sodic soils Early, DR, WL Early, WL DR, WL (DR=drought, WL=water logging, RF= rain-fed, LIC=low input condition)
3- Management practices • RCTs • SRI • Sanda Method • Alternate wetting and drying • Nutrient management	 Zero tillage, direct seeding, Happy Seeder (with straw incorporation). 10-12 day old seedlings, planted individually, preferably organic manure used. Double transplanting of rice Suited for assured irrigation condition. Use of right product: slow release and coated fertilizers. - Right time: LCC based fertilizer application. - Right rate: soil/plant test based application. - Right place: soil incorporation. - Right methods: foliar	 Water, energy, labor, time and cost saving techniques: Water saving, seeds saving and high yield. Water-saving and good for delayed monsoon conditions. Water-saving, with no penalty to yield. Improved nutrient-use efficiency.

• Mulching • Micro irrigation	/placement - Field cover with crop residue - Sprinkler and drip irrigation systems. - Use of easily transportable and reasonably cheap plastic pipes.	Moisture retention, weed suppression. Better water use efficiency.
4. Cropping systems * Pairing of appropriate crop varieties.	**Flood prone area :** - Flood tolerant rice (long duration)-short duration wheat, like Swarna sub-1 (rice)-Halna (wheat) **Drought-prone area :** - Sahbaghi dhan/Sushak Samrat(rice)-NDW1014(wheat) - Sahbaghi dhan-potato (Kufari Jyoti)-wheat(WR544).	Increases cropping intensity and total farm income.
5. Organic farming	- Long term, sustainable pesticide free agriculture. - Crop varieties which require low fertilizer doses are preferred for organic farming.	Especially suited to small farmers and vegetable growers. High price of produce in the market.
6. Mixed farming	- Line sowing of rice + pigeon-pea; maize pigeon-pea; Moong bean + pigeon-pea; wheat +	Safe guard against weather uncertainties.

	mustard; lentil+ chick pea	
7. Agro forestry	- Trees on bunds - Fruit trees with silvi-culture	Increased farm income and sustainability.
8. Community based sharing of common natural resources	- Interlinking and sharing ground water drawn from bore wells (A.P. example) - Organic village concept. - Non-pesticide village approach. - *In situ* water harvesting and conservation.	Resource and benefit sharing.
9. Climate moderating techniques	Shade net, screen house, naturally ventilated plastic houses.	Growing crops in adverse climate possible.

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