Approach Paper on

Climate Resilient Agriculture

CHANAKYA UNIVERSITY

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FOREWORD

Agriculture in India is highly vulnerable to climate change and variability with 51% of cultivated area under rainfed conditions. 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 climatic extremes has increased resulting in increased risks to agricultural production and food security all over the world, including India. Global warming has led to a sharp rise in the annual average temperatures in India by 1.8°C between 1997 and 2019 as compared to a 0.5°C increase between 1901 and 2000. Further, the number of dry days as well as days with extremely high levels of rainfall have increased in India. As per Sixth Assessment Report of IPCC the global surface temperatures will continue to increase until at least the midcentury under all emissions scenario. The global warming of 1.5^{o}C and 2.0^{o}C will be exceeded during the 21st century unless the reduction in the carbon dioxide and other GHG emissions occur in the coming years. Climate resilient agriculture is gaining importance globally as evident from the recent deliberations in international fora such as UNFCCC, UNEP, UNDP, G20, BRICS, ASEAN, SAARC, QUAD etc.

Climate change also damages soil health, reduces soil carbon and nitrogen leading to ecosystem degradation, affecting pollination, increasing pressure from pests and diseases and diminishing water availability for agriculture. Adaptation measures such as cultivar improvements, agroforestry, community-based adaptation, farm and landscape diversification, urban agriculture, on-farm water management, water storage, soil moisture conservation and irrigation can significantly minimize the negative impacts and provide economic, institutional or ecological benefits and reduce vulnerability. Wide-scale adoption of climate resilient practices help farmers to enhance adaptive capacity against climatic variability, thereby reduce loss and damage.

In the past two decades, the State of Karnataka has endured 15 years of drought, characterized by varying degrees of severity. The response of the State Government to mitigate the impact of drought has been proactive and collaborative by taking appropriate measures on employment generation under MGNREGA and involving farmers in construction of farm ponds under *Krishi Bhagya* Scheme.

This approach paper is the outcome of a National workshop held at the Chanakya Centre for Sustainability, Chanakya University, Bengaluru, on 24th October, 2024, that provided insights into the current issues of climate change and its impact on agriculture, initiatives at national and local level to deal with and future directions towards making agriculture resilient to changing climate. The Chanakya Centre for Sustainability gratefully acknowledges the support of the Hon'ble Chancellor, Prof. M. K. Sridhar; Hon'ble Pro Chancellor, Shri M. P. Kumar; and Hon'ble Vice Chancellor, Prof. Yashavantha Dongre, as also the efforts of Dr. Chetan Singai, Dean, School of SLGPP and Dr. T. R. Kumaraswamy, Asst. Professor at SLGPP, Chanakya University. I would like to thank Dr. M. Prabhakar, Principal Investigator, National Innovations in Climate Resilient Agriculture (NICRA), ICAR-CRIDA, Hyderabad, for convening this important Workshop to synthesize different viewpoints, ideas and opinions to deal with climate change in agriculture; and the Experts from different domains of agriculture who took part in the panel discussion, enriching the Approach Paper. I am sure this publication will help in shaping appropriate agenda and policy directives to deal with changing climate in agriculture, particularly in the State of Karnataka and provide a platform at the University for education, research as well as outreach.

5 November, 2024
Bengaluru

(S. Ayyappan)
Chairman
Chanakya Centre for Sustainability

Climate Resilient Agriculture (CRA)

1. PREAMBLE

Climate change is already imperiling the livelihoods of farmers around the globe by exacerbating droughts, heat waves, floods and other extreme-weather events, as well as creating an influx of new pests and diseases. Climate change and food insecurity pose two of the greatest development challenges that the world must address. Global food demand is estimated to increase to feed a projected global population of 9.7 billion people by 2050 (FAO, 2009). Almost a third of the world's population could be exposed to heat waves by 2090 (IOM, 2023). More than 56 million people faced hunger issues as a result of extreme weather events in 2022 (WFP, 2023). The global average CO_2 concentrations exceeded pre-industrial values by 50% in 2022 and continue to raise further (WMO, 2023). The global climate change is driven by increasing anthropogenic greenhouse gas (GHG) concentrations, of which a significant proportion is attributable to agriculture (Environmental Protection Agency, 2024) and the global agri-food system emits one-third of all emissions (Crippa et al. 2021). Nearly 7% of global GDP is spent every year on activities that fuel climate change and nature-based solutions (UN, 2023).

With this backdrop, the Chanakya Centre for Sustainability, Chanakya University, Bengaluru, organized a National Workshop on Climate Resilient Agriculture (CRA). Deliberations emanated in this workshop on the impact of climate change on agriculture, adaptation and mitigation strategies, policy options and researchable issues for climate resilient agriculture have been brought out in this approach paper.

2. STATUS OF CLIMATE CHANGE

2.1 Global

As per Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report (AR6) Working Group III report, the GHG emissions need to be cut by 43% by 2030, compared to 2019 levels which is critical to limit temperature rise to 1.5°C by the end of this century and avoid the worst impacts of climate change. During the global brainstorming session of COP28 Climate Summit, Dubai, UAE (2023), the major outcomes included

- The decision on first global stocktake calls on Parties regarding the "beginning of the end" of the fossil fuel era, by tripling of renewable energy capacity and doubling energy efficiency improvements by 2030.
- Operationalization of the Loss and Damage Fund (USD 700 million) to assist the developing countries that are vulnerable to the adverse effects of climate change.
- Parties agreed on targets for the Global Goal on Adaptation (GGA) and its framework, which aims to guide adaptation planning and strategies at all levels, and to align the finance, technology and capacity-building support.

- Protecting terrestrial and marine ecosystems acting as sinks and reservoirs of greenhouse gases and conserving biodiversity.
- Avoiding deforestation and forest degradation by 2030 would eliminate about 14% of global emissions and enhance the capacity of forests to store more carbon.

2.2 National

India's engagements at COP-28, led by the Hon'ble Prime Minister of India voiced the concerns of Global South on climate finance availability to the developing nations to achieve their climate ambitions and implement their Nationally Determined Contributions (NDCs). He also highlighted on the Green Credits Initiative emphasizing the need to promote climate-positive actions which envisions the issue of green credits for plantations on waste/degraded lands and river catchment areas, to rejuvenate and revive natural ecosystems. A web platform was also launched which would serve as a repository of policies and best practices that incentivize environment-friendly actions to facilitate global collaboration, cooperation, and partnership through programs/mechanisms like Green Credits. Impacts and implications of climate change vulnerability in the Himalayan Region and ways of creating climate resilient development in the Indian Himalayan Region by making mountain communities green and resilient were discussed and elaborated on the importance of the National Mission for Sustaining the Himalayan Ecosystem (NMSHE) launched as part of National Action Plan on Climate Change (NAPCC), to better understand the linkages between climate change and the Himalayan ecosystem for improved adaptation. India's involvement in Mangrove Alliance illustrates a pivotal role played by the Government towards achieving holistic conservation efforts. The National Statement by the Hon'ble Union Minister for Environment, Forests & Climate Change, Shri Bhupender Yadav emphasized India's comprehensive approach to environmental conservation, addressing not only emissions but also land degradation, ecosystem restoration, and biodiversity enrichment. Overall, India's active participation at COP-28 positions the country as a proactive and influential player in the global fight against climate change, showcasing a commitment to collaborative, innovative, and localized solutions.

3. IMPACT OF CLIMATE CHANGE

3.1 Indian Agriculture

Indian Agriculture is highly vulnerable to climate change with 51% of cultivated area under rainfed conditions. 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 increasing due to increased atmospheric temperature, resulting in enhanced risks with substantial losses of agricultural production. As per the latest IPCC AR-6 Report, increase in rainfall, higher inter-annual variability, intense and frequent heatwaves, likely temperature increase by 1.5 to 4.0^{o}C and rise in sea level by

300 mm could be the major challenges for sustainable agriculture in the coming years (IPCC, 2021).

Climate change can affect Indian agriculture through direct and indirect effects on the crops, soils, livestock and pests. Increase in temperature can reduce crop duration, increases evapo-transpiration and crop respiration rates, alter photosynthesis process and reduce productivity. Productivity of most crops is likely to decrease by 10-40% by 2100 due to adverse impact of climate change (Gupta and Pathak, 2016). Climate change hastens nutrient mineralization yet reduces nutrient availability, soil organic matter content and fertilizer use efficiencies and also causes soil erosion. A reduction in the quantity and quality of irrigation water, ground water distribution and availability and melting of glaciers in Himalayas is noticed. The survival and distributions of pest populations is also altered causing emergence of new pest problems and possibility of minor pest becoming major pest. Some of the recent examples of such climate induced pest outbreak are mites in tea and chilies, coffee rot, brown plant hopper on rice, nodal blight on pomegranate, ring spot virus in areca nut, leafhoppers in groundnut, mealybugs and whiteflies on cotton and many horticultural crops. Climate change is likely to aggravate the heat stress in dairy animals, outbreaks of vector-borne diseases and reduce fodder quality and production ultimately affecting their reproductive performance and quality of milk. Increasing sea and river water temperature is likely to affect fish breeding, migration, harvest and marketing cost. The impact of climate change leads to physiological, ecological and operational difficulties in fisheries sector. Harmful algal blooms and increased microbial load leads to contamination issues. Further, the increase in extreme events affects the livelihoods of fisherman going to sea and their work days are lost.

3.2 Agriculture in Karnataka

More than three fourths of the land in Karnataka is under rainfed cultivation. Karnataka state has been divided into 10 agro-climatic zones, with dominant crops of cereals, pulses, oilseeds and cash crops. Important food crops in the state include ragi, paddy, jowar, maize and bajra; pulses like red gram, bengal gram, field bean, cowpea and horse gram; oilseed crops like groundnut, sunflower, safflower and sesame. Cotton, sugarcane, coffee, tobacco and mulberry are the major commercial crops.

The climate in Karnataka has been analysed at a district level for the historical period (1985-2015) and projected for the future period for two climate scenarios, *viz*., Representative Concentration Pathway (RCP) 4.5 and RCP 8.5 (Sarmah, 2021). Temperature in Karnataka showed a moderate warming trend during 1985 to 2015, for both the summer maximum and winter minimum temperatures. The summer maximum temperature has increased in the range of 0.18^0C to 0.61^0C, and the winter minimum temperature has increased in the range of 0.30^0C to 0.65^0C. During the historical period (1987-2016), annual rainfall has also increased up to 25%, with up to 15% increase in majority of the districts, and 20-25% increase in the Western Ghats districts. However, both *kharif* and *rabi* season rainfall variability was high during the period of 1985 to 2015. Temperature and rainfall projections for the districts of Karnataka under two climate change scenarios indicate the following:

Temperature: Warming of summer maximum temperature is projected to be in the range 0.5°C to 1.5°C in the short-term (2030s), and 1°C to 2.5°C in the long-term, considering RCP 4.5 and RCP 8.5 scenarios. Similarly winter minimum temperature is also projected to be warmer by 0.5°C to 2.5°C and 1°C to 2.5°C in the short- and long-term period, respectively, considering RCP 4.5 and RCP 8.5 scenarios. Temperature beyond 35^0C highly detrimental to crops like tomato.

Rainfall: An increase in Kharif season rainfall in the range of 5% to 25%, and 10% to 25%, is projected in the short-term (2030s), considering RCP 4.5 and RCP 8.5 scenarios. The percentage increase in rainfall during Kharif season, compared to the recent decades, is projected to be higher, particularly in districts receiving >1000 mm mean annual rainfall. An increase in Rabi season rainfall, in the range of 7% to 39%, and 10% to 35% is projected in the short-term (2030s), considering RCP 4.5 and RCP 8.5 scenarios. However, the variability of rainfall (Coefficient of Variation) shows mixed trends with rainfall variability projected with increase in some districts, and a decline in other districts. The Kharif season rainfall variability is projected to increase by 7% to 14% in 7 districts under RCP 4.5 scenario and 5% to 9% in 3 districts under RCP 8.5 scenario, and these districts receive <1000 mm mean annual rainfall. The quantum of annual rainfall and number of rainy days have increased in south interior Karnataka and Malnad regions. During the same period, a reduction in amount of annual rainfall and marginal increase in number of rainy days is observed in north interior Karnataka and coastal regions.

Rainy days: In Karnataka, an increase in the number of rainy days is projected for a majority of the districts, under both RCP 4.5 and 8.5 scenarios. The extended southwest monsoon rainfall and excess rains during September-October is detrimental to most of the horticultural crops like tomato, onions and potato (TOPs).

Heavy rainfall events: An increase in the occurrence of 'Very High' (>100 mm rainfall per day) and 'High' intensity (51-100 mm rainfall per day) rainfall events is projected, largely in the range of 1 to 2 events per annum in the projected period, under both RCP 4.5 and RCP 8.5 scenarios.

Drought years: IMD classifies 'Drought' years as those receiving <20% of the long period average rainfall. In Karnataka, 'Drought' years are projected to decline, in the range of 1 to 3 years under RCP 4.5 scenario, and 1 to 4 years under RCP 8.5 scenario, in a majority of the districts, compared to the historical period.

4. GLOBAL INITIATIVES ON CLIMATE RESILIENT AGRICULTURE

The international and national challenge of climate change creates a heightened focus on sustainable agriculture systems which is necessary to guarantee food security and improve environmental health that calls for the concept of Climate Resilient Agriculture (CRA) approach to address this ultimate challenge. FAO introduced the concept of Climate Smart Agriculture (CSA) at the 2010 Hague Conference on Agriculture, Food Security and Climate Change and there has been growing support at international and national levels for this approach. CSA is an integrated approach for developing actions needed to transform and reorient agricultural systems to effectively support development and ensure food security under climate change (FAO, 2017).

CSA supports reaching internationally agreed goals such as the 2030 Agenda for Sustainable Development, SDGs and the Paris Agreement. The CSA is a set of agricultural practices and technologies that are tailored to specific agro-ecological conditions and socio-economic contexts which aims to pursue the triple objectives of sustainably increasing productivity and incomes, adapting to climate change and reducing greenhouse gas emissions (FAO, 2024). The CSA approach seeks to reduce trade-offs and promote synergies between productivity, adaptation, and mitigation. Mitigation can often be a significant co-benefit of actions to strengthen adaptation and enhance food security, and thus mitigation action compatible with national development priorities for agriculture is an important aspect of CSA. FAO recommends the approach is implemented through five action points: expanding the evidence base for CSA, supporting enabling policy frameworks, strengthening national and local institutions, enhancing funding, and financing options, and implementing CSA practices at field level.

5. PRACTICES AND TECHNOLOGIES FOR RESILIENT AGRICULTURE

FAO (2017) outlined several practices to minimize the impact of climate change in agriculture.

5.1 Crop Production

Management practices and technologies for climate change adaptation and mitigation include practices with an explicit focus on adaptation and practices with a broader scope on reducing production risks and reducing emissions. Specific climate-smart approaches to crop production include:

- Growing genetically diverse improved crop varieties, suited to a range of agro-ecosystems and farming practices, and resilient to climate change.
- Use of quality seeds and planting materials of well-adapted crops and varieties.
- Carefully channeling the expansion of crop and grazing land to mitigate the loss of carbon storage that results from land-use change.
- Increasing energy use efficiency.
- Adopting integrated pest management as an ecosystem approach to crop production and protection.
- Promoting sustainable mechanization in combination with proper agronomic management to reduce greenhouse gas emissions from various farm and processing operations; and
- Developing simple and robust scientific tools to guide the decision-making of farmers on a seasonal and long-term basis.

5.2 Soil and Land Management

As a result of climate change, land degradation and losses in biodiversity, soil has become one of the world's most vulnerable resources. Sustainable soil and land management practices that are adapted to the local biophysical and socio-economic conditions can provide options for enhancing the interactions among soil, water, livestock and plants, which can prevent, slow or stop soil degradation and mitigate the impacts of climate change. Land degradation itself is a driver of climate change and exacerbates its impacts. The rehabilitation of degraded soils, which can be achieved by enhancing soil organic carbon and soil biodiversity, avoiding soil compaction and reducing soil erosion, provides a major opportunity for mitigating climate change.

- Conservation agriculture practices reduce fossil fuel emissions and increases the carbon sequestration.
- Integrated soil fertility management (ISFM) aims to make available required soil nutrients and reduces nutrient losses through soil and water conservation which reduces nitrous oxide emissions.
- Precise management of nitrogen.
- Agroforestry systems that integrate compatible leguminous shrubs and trees with crops restore SOM and N through the leaf litter, help fix N through symbiotic *Rhizobium*.
- Avoid monocropping.
- Adopt technologies to reduce the use of water and GHG emissions in rice cultivation through SRI, alternate wetting or drying etc.
- Improved grazing management on pastures or rangelands by altering plant species composition, rotational grazing and fire management.

5.3 Water Management

Climate change is expected to affect the hydrological cycle and the availability of freshwater resources for agriculture. Globally, agricultural water withdrawals represent 70% of all the withdrawals. The impact of climate change on water in agriculture will be affected by increased evaporative demand, changes in the amount of rainfall and rainfall patterns, exposure to drought, floods, snow and glacier melt, change in water quality and variations in river runoff and groundwater recharge, which are the two sources of water for irrigation. Climate change adaptation options for water management will necessarily combine policies, institutions, investments, crop and water management practices and capacity development. The mitigation options for water management include use of solar energy for irrigation, adopting water management strategies in rice production systems, livestock and fisheries.

5.4 Livestock

Livestock produces 14.5% of global anthropogenic greenhouse gas emissions. Climate change will also affect livestock production through it impacts on the supply and quality of pasture and forage crops, the production and prices of feed grains, and modifications in the distribution ranges of livestock diseases and pests. Livestock’s role in adaptation practices relates primarily to the management of organic matter and nutrients, and the diversification of incomes. Mitigation options are available along the entire livestock supply chain. They are mostly associated with feed production, enteric fermentation and manure management.

Some of the climate-smart agriculture practices include grassland restoration and management (e.g. silvipastoral systems); adopting rotational grazing; pasture management (perennial fodders, pastures and legumes); manure management through recycling and biodigestion; crop-livestock integration; improved feed conversion; sourcing low-emission feed; vaccines against methanogens in the rumen, etc. *Harit Dhara*, a low cost anti-methanogenic feed supplement developed by ICAR-National Institute of Animal Physiology & Nutrition, Bengaluru, has the potential to reduce cattle methane emission by 17-20% and enhance productivity by rechanneling saved biological energy.

5.5 Fisheries

The major impacts of climate change on fisheries include severe weather events, increased flooding in coastal and riparian zones, sea level rise, shifts in the distribution range of important species and ocean acidification. This sector also has the capacity for increasing carbon removal from the atmosphere through farming of seaweeds and improved coastal management through protection from mangrove forests and estuaries. Climate-smart fisheries strategies that can adapt to lower emissions are by adopting specific production systems such as Integrated Multi-Trophic Aquaculture (IMTA), intensive cage systems, etc., reducing fuel use in the global fishing fleet, reducing overcapacity and reducing the carbon imprint of the international trade in fish and fisheries products, which are the most highly traded food commodity. Further, sea weed farming provides opportunities for blue carbon economy.

6. METHODS AND ASSESSMENTS

The FAO (2024) prescribed detailed methodology for assessing, monitoring and evaluating climate resilient agriculture. Assessment, monitoring and evaluation are integral part of CRA planning and implementation. They are crucial for making decisions on the use of natural resources and to assess the past and future impacts of climate variability and change on agriculture and the vulnerability of communities. CRA options should be assessed for their effectiveness in achieving goals related to food security, climate change adaptation and mitigation as well as other development objectives. Some of the assessment methodologies adopted by different countries are Modelling System for Agricultural Impacts of Climate Change (MOSAICC), a modelling system for the assessment of the agricultural impacts of climate change. Global Livestock Environmental Assessment Model (GLEAM) analyzes multiple environmental dimensions in livestock sector, such as feed use, greenhouse gas emissions, land use and land degradation, nutrient and water use and interaction with biodiversity. Sustainability Assessment of Food and Agriculture (SAFA) assess the sustainability performance in the food and agriculture sector, including crop and livestock production, forestry and fisheries. Economics and Policy Innovations for Climate-Smart Agriculture (EPIC) programme is aimed at identifying and harmonizing climate-smart agricultural policies, analyzing impacts, effects, costs and benefits as well as incentives and barriers to the adoption of climate-smart agricultural practices. Ex-Ante Carbon-balance Tool (EX-ACT) quantifies the amount of greenhouse gas released or sequestered from agricultural production which covers the Agriculture, Forestry and Other Land Use (AFOLU) sector, coastal and inland wetlands, fisheries and aquaculture, agricultural inputs and infrastructure. Monitoring and Assessment of Greenhouse Gas Emissions and Mitigation Potential in Agriculture (MAGHG) project gathers data on GHG emissions in AFOLU sector for UNFCCC related reporting requirements which assists the countries in analyzing this data for improved actions to respond to climate change. The World Bank uses Country Climate and Development Reports (CCDRs), Climate-Smart Agriculture Country Profiles and develop Climate-Smart Agriculture Investment Plans (CSAIPs) to help countries promote sustainable agricultural practices.

In India, Social Accounting Matrix (SAM) framework is used to estimate the economy-wide effects arising out of agricultural interventions, keeping accord with the impacts on sectoral outputs and household incomes from the adoption of varying CSA interventions (Ajatasatru *et al*., 2024). Climate Change, Agriculture and Food Security (CCAFS)-Mitigation Option Tool (CCAFS-MOT) was used to estimate the GHG emissions from CSA practices in any production system (Kakraliya *et al*., 2021). Multivariate Probit (MVP) model assess the factors affecting the likelihood of adopting multiple CSA practices and Ordered Probit (OP) model estimates the level of adoption of CSA practices (Aryal *et al*., 2018).

7. INITIATIVES FOR CLIMATE RESILIENT AGRICULTURE

7.1 International

Climate resilient agriculture helps guide actions to transform agri-food systems towards green and climate resilient practices. It may contribute to policies including NDCs, Nationally Appropriate Mitigation Actions (NAMAs) and National Adaptation Plans (NAPs) by supporting transformative change in all the areas of agri-food systems including agricultural production, storage, transport, and consumption. For several countries, learning how to access and effectively use international financing options represents the first step in the long-term transition towards CRA. The current dynamics in international climate finance are in favour of CRA. There is potential for new and additional opportunities to use international financing for turning public and private agriculture investments into sustainable CRA investments.

FAO engages with international financing institutions, such as the Green Climate Fund (GCF) and the Global Environment Facility (GEF) and supports countries to access funds for the implementation of CRA projects. Global Alliance for Climate-Smart Agriculture (GACSA) initiated in 2015 is an inclusive, voluntary and action-oriented multi-stakeholder platform on CSA which aims to catalyze and help create transformational partnerships on agriculture, forestry, livestock and fisheries that reflect an integrated approach to the three pillars of CSA. FAO’s Economics and Policy Innovations for Climate-smart agriculture (EPIC) programme works with governments, research centres, universities and other institutional partners to support the transition to CSA by using sound economic and policy analysis (FAO, 2024). World Bank has also significantly scaled up its engagement and investments in CSA through its Climate Change Action Plan (2021-2025), that identified Agriculture, Food, Water and Land as one of the five key transitions needed to tackle the Paris Agreement. It also supports research programs such as with the CGIAR, which develops and supports climate-smart technologies and management methods, early warning systems, risk insurance, and other innovations that promote resilience and combat climate change (World Bank Group, 2024). In addition, several countries have their individual projects related to CSA such as Mitigation of Climate Change in Agriculture (MICCA) Programme in Kenya and United Republic of Tanzania; Benguela Current Commission (BCC) to support the fisheries sector of Angola, Namibia and South Africa; GEF funded projects in Bangladesh, Turkey, Kazakhstan, Kyrgyz Republic, Tajikistan, Turkey and Turkmenistan; International Centre for Agricultural Research in the Dry Areas (ICARDA) working to scale-up the adoption of proven CSA field interventions in Egypt, Jordan, Morocco and Tunisia, etc.

7.2 India

India recognizes that for ensuring country's food security both in the short- and long-term and making agriculture sustainable and climate-resilient, appropriate adaptation strategies have to be developed and has taken several initiatives to address this (Gupta and Pathak, 2016; Srinivasa Rao *et al*., 2019; Economic Survey, 2024). The National Mission for Sustainable Agriculture (NMSA), a part of NAPCC aims to address issues regarding sustainable agriculture, and devising appropriate adaptation and mitigation strategies for ensuring food security, enhanced livelihood opportunities and economic stability. It includes several sub-missions like Rainfed Area Development (RAD) programme focusing on development and conservation of natural resources along with farming systems; Sub-Mission on Agroforestry (SMAF) encouraging tree plantation on farm land '*Har Medh Par Ped*', along with crops/cropping systems that leads to higher carbon sequestration; National Bamboo Mission (NBM) emphasizing on bamboo sector; Soil Health Management (SHM) scheme promoting location as well as crop specific sustainable soil health management practices; *Paramparagat Krishi Vikas Yojana* (PKVY) promoting organic farming and On-Farm Water Management (OFWM) promoting water management in farmers' field focusing on enhancing on-farm water use efficiency. Green India Mission (GIM) outlined under NAPCC with an objective to protect, restore and enhance the diminishing forest cover in India, and to fight climate change with adaptation and mitigation measures.

The National Innovations in Climate Resilient Agriculture (NICRA), a flagship programme of the Indian Council of Agricultural Research (ICAR) undertakes systematic long-term research on the impact and adaptation of Indian agriculture to climate change covering not only grain crops but also horticulture, natural resource, livestock and fisheries (NICRA, 2023). The ICAR has evolved several rainfed agriculture technologies, which are being upscaled through the Integrated Watershed Management Program (IWMP) and Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS). All major programmes such as National Food Security Mission (NFSM), Mission for Integrated Development of Horticulture (MIDH), National Mission on Oilseed & Oil Palm (NMOOP) and *Rashtriya Krishi Vikas Yojana* (RKVY) emphasize on water harvesting & resource conservation in farmer's field. *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY) – Per Drop More Crop (PDMC) was launched to enhance physical access of water on farm and expand cultivable area under assured irrigation, improve on-farm water use efficiency through micro-irrigation systems, introduce sustainable water conservation practices, etc. National Water Mission (NWM) ensures Integrated Water

Resource Management (IWRM) for conserving the water sources and also to optimize Water Use Efficiency (WUE) by 20% including agriculture sector.

Soil Health Card (SHC) scheme provides soil nutrient status along with recommended dose of fertilizers for improving productivity through judicious use of inputs. The National Adaptation Fund for Climate Change (NAFCC) was established to meet the cost of adaptation to climate change. Climate-Smart Village (CSV) is an institutional approach to test, implement, modify and promote CSA at the local level and to enhance farmer's abilities to adapt to climate change. *Pradhan Mantri Fasal Bima Yojana* (PMFBY) enables farmers avail insurance cover against crop loss on account of natural calamities. To synergize extension mechanism National Mission on Agriculture Extension & Technologies (NAME&T) has been made operational. The project on 'Excellence on Climate Change Research for Plant Protection', implemented by ICRISAT, Hyderabad focused on the effect of climate change on disease and insect-pest problems of two most important legumes *viz.,* chickpea and pigeonpea under rainfed conditions in India.

National Livestock Mission (NLM) was initiated for increasing livestock production while protecting the environment, preserving animal bio-diversity, ensuring bio-security and farmers' livelihood. A major initiative has also been taken in fisheries with the launch of National Fisheries Development Board (NFDB) to achieve sustainable development of the fisheries sector. Neel Kranthi Mission aims to improve sustainable fish production. Initiatives such as *Amrit Dharohar* and *Sahbhagita* promote the conservation of wetlands and Ramsar sites of national and international importance.

India's adaptation-relevant action also includes steps taken to improve resilience in the economy through developmental programs such as *Swachh Bharat* Mission, *Pradhan Mantri Awas Yojana, Saubhagya* Scheme, etc. In addition, digital initiatives such as the Digital Agriculture Mission and e-National Agriculture Market (e-NAM) have also been taken up to facilitate the adoption of smart agriculture technologies, with the latter allowing better price discovery. The One Health concept, emphasizing the interconnectedness of human, animal, and environmental health, is crucial in addressing the challenges imposed by climate change. There are many One Health efforts underway in various Ministries of the Government of India, in private organizations in addition to a range of activities globally to deal with changing climate.

8. ACTION PLAN

8.1 Karnataka State

- Study the risks associated with climate change on agriculture sector at block level for effective planning and implementation of climate actions
- Upscale the resilient technologies identified under NICRA programme
- Prepare district action plans to deal with changing climate
- Initiate a dedicated programme on climate resilient agriculture for Karnataka in the highly risk prone regions of the state

8.2 Chanakya University

- Adopt a few villages in peri-urban Bengaluru to develop as climate-resilient villages Prepare short, medium and long-term plans for the selected villages to develop them as carbon neutral villages
- Establish automatic weather stations and provide timely agro-advisories to farmers in adopted villages in collaboration with UAS, Bengaluru and KVK, Bengaluru rural
- Establish custom hiring centres, seed banks and FPOs in the adopted villages
- Collaborate with University of Agricultural Sciences, Bengaluru; KVK, Bengaluru Rural; and Karnataka State Departments of Agriculture, Horticulture and Livestock for implementing climate resilient agriculture program in the selected villages
- Establish a rural technology park with integrated farming system, poly-house, micro-irrigation systems and organic farming in the Chanakya University campus
- Associate students of Chanakya university in socio-economic analysis of climate change and its impact on agriculture and livelihoods in the rural areas

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Programme of the National Workshop on 'Climate Resilient Agriculture'

24 October, 2024, *Sahyadri*, 1st Floor, Board Room, Chanakya University, Bengaluru

Time	Schedule
10.00 AM – 10.05 AM	Welcome and Introduction **Dr. Chetan Singai** Dean, School of Law Governance and Public Policy, Chanakya University, Bengaluru
10:05 AM – 10.15 AM	Welcome Address **Prof. Yashavantha Dongre** Vice Chancellor, Chanakya University, Bengaluru
10.15 AM – 10.25 AM	Setting the Context: Climate Smart Agriculture **Prof. S. Ayyappan** Former Secretary, DARE & DG, ICAR; Chairperson, Advisory Committee, Chanakya Centre for Sustainability, Bengaluru
10.25 AM - 10.55 AM	Presentation by Keynote Speaker **Dr. M. Prabhakar** Co-Chair for Workshop on Climate Smart Agriculture Workshop & Principal Investigator, NICRA Coordinator, ICAR-CRIDA, Hyderabad
10.55 AM – 11.05 PM	**Tea Break**
11.05 AM – 11.20 AM	**Dr. Raghavendra Bhatta** Deputy Director General (Animal Science), ICAR, New Delhi
11.20 AM – 11.35 AM	**Dr. Rashmi Alias** Joint Director of Agriculture (Seeds & State Farms), Department of Agriculture, Government of Karnataka, Bengaluru
11.35 AM – 11.50 AM	**Dr. N. K. Krishna Kumar** Former Deputy Director General (Horticulture), ICAR, New Delhi, At: Bengaluru
11.50 AM – 12.05 PM	**Dr. S. Bhaskar** Advisor, DAFW & Former ADG (AAF&CC), ICAR, New Delhi, At: Bengaluru
12.05 PM – 12.20 PM	**Dr. Grinson George** Director, ICAR-CMFRI, Kochi
12.20 PM – 12.35 PM	**Dr. C. M. Biradar** CMD, Global Green Growth (Formerly with ICARDA), At: Bengaluru

Time	Schedule
12.35 PM – 12.50 PM	**Dr. Mudalagiriyappa** Chief Scientist, Dryland Agriculture Project, UAS, GKVK, Bengaluru
12.50 PM – 1.05 PM	**Dr. H. S. Shivaramu** Director of Research, UAS, GKVK, Bengaluru
1.05 PM – 1.15 PM	**Dr. M.H. Manjunath** Agro-Meteorologist, UAS, GKVK, Bengaluru
1.15 PM – 2.00 PM	**Lunch**
2.00 PM – 2.15 PM	**Dr. M. N. Thimmegowda** Professor & Head (Agronomy), UAS, GKVK, Bengaluru
2.15 PM – 2.30 PM	**Dr. Sreenath Dixit** Principal Scientist & Strategic Advisor, ICRISAT, Hyderabad
2.30 PM – 2.45 PM	**Dr. P. G. Diwakar** Member, Advisory Committee for Chanakya Centre for Sustainability & Adjunct Professor, NIAS, Bengaluru
2.45 PM – 3.00 PM	**Dr. T. V. Ramachandra** Member, Advisory Committee for Chanakya Centre for Sustainability & ISRO Chair Professor, NIAS, Bengaluru
3.00 PM – 3.15 PM	**Dr. B. G. Hanumantharaya** Senior Scientist & Head, KVK, Hadenahalli, Doddaballapur Taluk, Bengaluru Rural District
3.15 PM – 3.25 PM	**Tea Break**
3.25 PM – 3.55 PM	Consolidation and Discussion on the Way Forward: Chair and Panellists of Workshop, Chairperson and Members of the Advisory Council, Bengaluru
3.55 PM – 4.00 PM	Vote of Thanks **Dr. T. R. Kumaraswamy** Assistant Professor, School of Law Governance and Public Policy, Chanakya University, Bengaluru

List of Participants

1.	**Prof. Yashawantha Dongre**, Vice Chancellor, Chanaya University
2.	**Prof. S. Ayyappan**, Former Secretary, DARE & Director General, ICAR; Chairperson, Advisory Committee, Chanakya Centre for Sustainability, Bengaluru
3.	**Dr. M. Prabhakar**, PI, NICRA, ICAR-CRIDA, Hyderabad & Co-Chair, National Workshop
4.	**Dr. Raghavendra Bhatta**, DDG (AS), ICAR, New Delhi
5.	**Dr. N. K. Krishna Kumar**, Former DDG (Hort) , ICAR, New Delhi
6.	**Dr. Grinson George**, Director, ICAR-CMFRI, Kochi
7.	**Dr. H.S. Shivaramu**, Director-Research, UAS, Bengaluru
8.	**Dr. S. Bhaskar**, Former ADG (AAF&CC), ICAR & Advisor, DAFW, New Delhi
9.	**Dr. Sreenath Dixit**, Principal Scientist & Strategic Advisor, ICRISAT, Hyderabad
10.	**Dr. C. M. Biradar**, CMD, Global Green Growth Initiatives, Bengaluru
11.	**Dr. Rashmi Alias**, JDA (S&SF), Govt. of Karnataka, Bengaluru
12.	**Dr. Mudalagiriyappa**, Chief Scientist., AICRPDA, UAS, Bengaluru
13.	**Dr. M. H. Manjunatha**, Professor, UAS, Bengaluru
14.	**Dr. M. N. Timmegowda**, Prof. & Head, UAS, Bengaluru
15.	**Dr. P. G. Diwakar**, Member, Advisory Comm. Chanakya Centre for Sust., Bengaluru
16.	**Dr. T. V. Ramachandra**, Member, Advisory Comm. Chanakya Centre for Sust., Bengaluru
17.	**Dr. B. G. Hanumantharaya**, Senior Scientist & Head, KVK, Bengaluru Rural
18.	**Dr. Chetan Singai**, Dean of School of Law Governance, Chanakya University, Bengaluru
19.	**Dr. Padmavathi**, Professor, Chanakya University, Bengaluru
20.	**Dr. T. R. Kumaraswamy**, Asst. Professor, School of Law Governance, Chanakya University, Bengaluru
21.	**Dr. Anusha M Virupannavar**, Chanakya University, Bengaluru
22.	**Dr. Meena Nair**, Chanakya University, Bengaluru
23.	**Ms. Gowri Dixit**, Chanakya University, Bengaluru
24.	**Ms. Damini**, Chanakya University, Bengaluru
25.	**Ms. Vennela Datla**, Chanakya University, Bengaluru
26.	**Ms. Tanisha Hiremath**, Chanakya University, Bengaluru
27.	**Shri Rajath**, Chanakya University, Bengaluru
28.	**Shri Aditya Srinivasan**, Chanakya University, Bengaluru
29.	**Shri K. Sai Krishna**, Chanakya University, Bengaluru

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