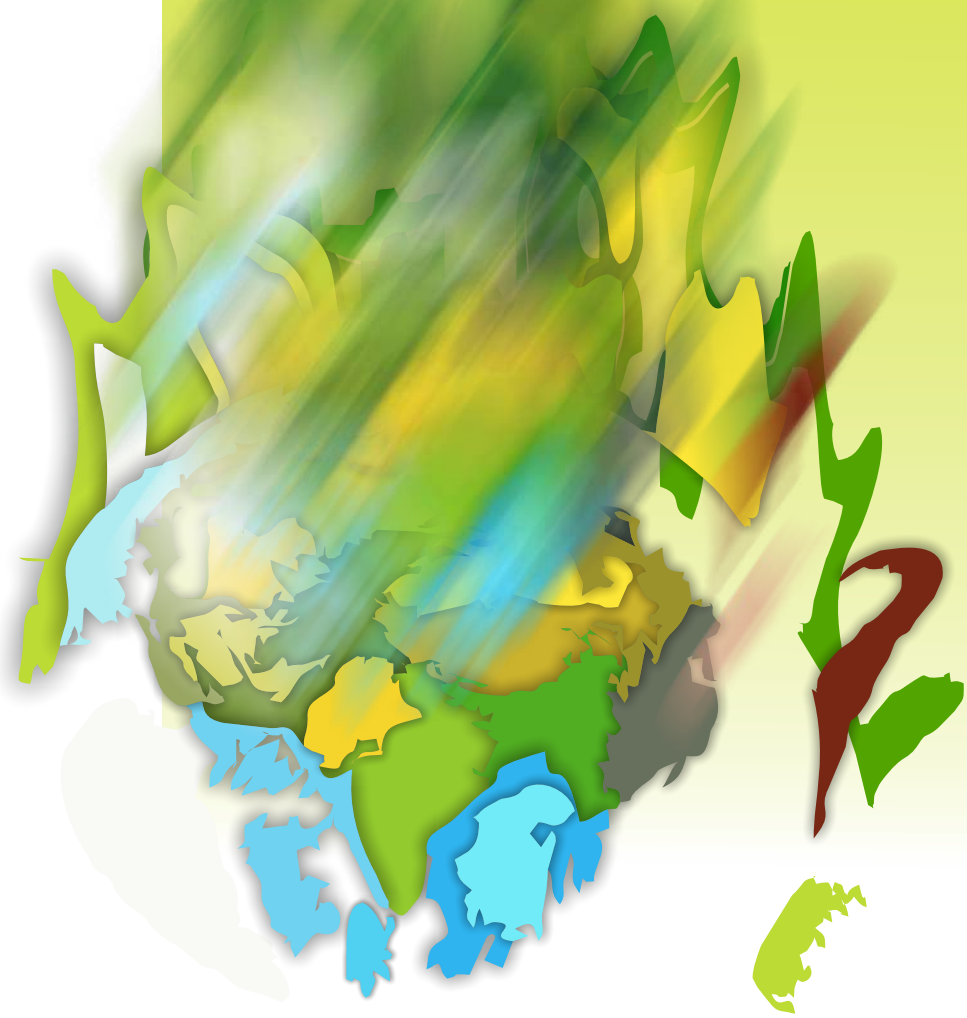
ICAR Policy Paper

Climate Change and Indian Agriculture:

Impacts, Coping Strategies, Programmes and Policy



Ch. Srinivasa Rao, Ravi Shankar Prasad and Trilochan Mohapatra

Indian Council of Agricultural Research
Ministry of Agriculture and Farmers' Welfare
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ग्रामीण विकास तथा पंचायती राज मंत्री
भारत सरकार
कृषि भवन, नई दिल्ली

**MINISTER OF AGRICULTURE & FARMERS' WELFARE,
RURAL DEVELOPMENT AND PANCHAYATI RAJ
GOVERNMENT OF INDIA
KRISHI BHAWAN, NEW DELHI**

MESSAGE

Human interference with natural resources has significantly changed the environment and its ecosystem since last few decades. Dreadful climate change events like floods, cyclones, droughts, heatwaves, unseasonal rainfall patterns, etc., are affecting one or other part of the country underlining the strong need for climate adaptation. These extreme events are severely affecting the farm productivity thereby threatening the food and nutritional security, besides, hampering the growth and development of the nation. The demand for food is increasing considerably due to increase in population. Hence, the top most priority should be bringing harmony in the livelihoods of farming community by building resilience to the rural economy.

I firmly believe that assessment of nature and magnitude of the impacts of climate change on natural ecosystems and human society would provide better opportunity for proper decision making. An integrated analysis is essential to address the complex developmental issues that balance both the socio-economic growth and environmental sustainability. Ministry of Agriculture and Farmers' Welfare, and Ministry of Rural Development have initiated several programmes and policies towards climate actions for stabilizing rural economy in India with lower carbon foot-print. These actions and programmes are amply supported by policies which need to be implemented at ground level towards climate change adaptation to achieve Sustainable Development Goals (SDGs) in totality.

I congratulate Dr. Trilochan Mohapatra, Secretary, DARE and DG, ICAR and his dedicated team for developing this policy document on climate change, its impacts and programmes & policies for adaptation covering field crops, livestock, horticulture, poultry and fishery besides global climate change negotiation process under the UNFCCC. I believe, this information would be very useful to all the stakeholders including policy-makers, researchers, rural extension workers and the farming community in achieving overall objective of climate change adaptation in Indian Agriculture.

(Narendra Singh Tomar)

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मंत्री
पर्यावरण, वन एवं जलवायु परिवर्तन,
सूचना एवं प्रसारण और
भारी उद्योग एवं लोक उद्यम
भारत सरकार

MINISTER OF
ENVIRONMENT, FOREST & CLIMATE CHANGE,
INFORMATION & BROADCASTING AND
HEAVY INDUSTRIES & PUBLIC ENTERPRISES
GOVERNMENT OF INDIA

सत्यमेव जयते

स्वच्छ भारत
एक कदम स्वच्छता की ओर

प्रकाश जावडेकर
Prakash Javadekar

MESSAGE

Agriculture is a primary and the most important sector of Indian economy. Nearly two-thirds of the population are dependent on agriculture sector for their livelihood. More than fifty per cent of Indian agriculture is rainfed, and climate change impacts are increasingly threating the sustainability of food systems in the country. Increased frequency of droughts, floods, cyclones, heat wave, cold wave, hailstorms, sea water intrusion leading to coastal salinity are serious concerns adversely affecting the agriculture sector and rural economy. United Nations Framework Convention on Climate Change (UNFCCC) negotiation process involves knowledge sharing of global best practices towards climate change adaptation and co-benefits in agriculture and implementation process towards reducing climate change impacts in all the sphere of life. Knowledge on future climate risks on agriculture sector and with proper planning and decision making contribute immensely in combating climate change impacts. Accordingly, Indian Council of Agriculture Research (ICAR) has developed location-specific climate resilient technologies covering field crops, livestock, horticulture, poultry and fishery, and being implemented under several national programmes. Climate adaptation actions need to be implemented more intensely in synergistic way involving programmes of various Ministries such as Agriculture and Farmers Welfare, Environment, Forestry and Climate Change, Earth Sciences, Water Resources, Rural Development and others.

I sincerely compliment the several initiatives taken by UNFCCC bringing several countries together in sensitization of global climate change issues and its impacts particularly on agriculture. Ministry of Environment, Forest and Climate Change is the nodal Ministry for overall reporting of various aspects of climate change in the country. The contribution of Indian Council of Agriculture Research (ICAR) in improving the assessment methodologies for climate change and promoting village level implementation is remarkable. Various programmes initiated and implemented by ICAR are greatly contributing to climate change adaptation in agriculture and its co-benefits.

I appreciate this multi-ministerial team for documenting overall status of climate change, impacts, programmes and policies related to agriculture in India. I am sure this technical document will be useful for various ministries and all the stakeholders associated with the process of climate change adaptation in agriculture sector.

Date: 31.12.2019

(Prakash Javadekar)

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Climate Change and Indian Agriculture:

Impacts, Coping Strategies, Programmes and Policy

Climate and agriculture are intensely interconnected with global processes. Even a small change in climate affects agriculture adversely decreasing the production rate. Climate change effect through global warming phenomenon increases the average atmospheric temperature, which has become a mega trend changing the global future significantly. In 1972, the club of Rome Report officially confirmed that the global warming as an international issue; and the World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) also declared that Carbon dioxide (CO_2) is the principal cause of climate change because of its highest contribution in global warming. Assessment of the effects of global climatic variations on agriculture is imperative to adapt farming and to enhance agricultural production (Fraser *et al.,* 2008).

Climate Change: Global Status

'Climate change' is a defining issue currently. A lot of significant long-term changes are happening in global climatic system which are visible all over the world. The direct solar radiations (enormous amount of heat/energy) striking on earth's surface is being trapped by Green House Gases (GHGs) like carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), *etc.*, resulting in atmospheric temperature increase. Specifically, the CO_2 levels are at peak and its concentration has reached up to 410 ppm (http://scripssco2.ucsd.edu) at present, which is a principal cause of warming effect (Figure-1). Geographical and phenological shifts occur due to the modification in ecological construction through global climate change (Van den Bossche and Coetzer, 2008; Slenning, 2010). Global warming or climate change impacts include rising sea levels, more frequent extreme weather conditions, changes in precipitation and expansion of deserts as well. By 2100, the mean global sea levels are projected to rise from 18 cm to 140 cm (IPCC, 2007). The world has been facing environmental problems for the last 15 years (Sathaye, 2007). In 2019, several parts of Europe have registered highest temperatures over the past 100 years. Several variations in climate like devastating floods, cyclones, droughts, storms, heat waves, melting of glaciers, changes in pattern and rate of precipitation, diseases in agricultural productivity, shortage of fresh water, damage to ecosystem and environment, *etc.*, are indicators of climate change, and South Asian countries were adversely affected for the past few years. There is a necessity of taking possible actions to overcome these negative changes. The Marshall Island pledged to minimize the Carbon (C) emission rates by 32 percent by 2025 with a net total of zero emissions by 2050 (Saddington and David, 2016). The Bangladesh government has reported

that around 68,51,147 people were affected due to tidal wave of heavy storm of about 150 km/hr with a 20 feet height (Islam and Nazrul, 2008).

Economic Losses of Climate Change in Agriculture

Economic losses from natural disasters are rising globally, and agriculture sector is highly vulnerable to these disasters. According to the United Nations Office for Disaster Risk Reduction (UNISDR) (2018), disaster-hit countries experienced direct economic losses to the tune of US$ 2908 billion during 1998–2017. Of the total losses, 77 percent were due to climate related disasters. Climate change impacts are more pronounced on agriculture sector in the recent past. Government of India's economic survey (2018) estimated that the annual loss of US$ 9-10 billion was due to the adverse effects of climate change.

Climate Change Impacts in South Asia and India

Right from the Himalayas to the coastal South Asian countries must always be prepared to combat the effects of global warming (Stern, 2006). As predicted, the South Asian zones may experience a warming effect of 2° to 6° C during the 21st century (Ravindranath, 2007). Specifically, Indian sub-continent and other continents are highly vulnerable to all kinds of existing climate change issues.

Floods: In 2008, millions of people were forced to live in shelter-houses in Bihar due to floods. About 20 million people faced the similar problem in Mumbai in 2005. In Delhi and Haryana, millions over worth of properties were destroyed when Yamuna river was flooded above the danger level in 2008. Worst floods ever affected Kerala (a South Indian state) in 2018 due to unusual high rainfall. Millions of people were evacuated from their places. As predicted by Computer Science Engineering (CSE): FACT 17, the western semi-arid zones of India will receive maximum rainfall than normal, while the central parts of India will experience rainfall reduction of 10 to 20 per cent during winter by 2050s. Few years back, the Chennai city experienced high level of floods, and the same city in 2019 was the worst hit with severe drinking water crisis leading to large scale migrations. Climate change is threatening the existence of Maldives islands, and also the human capabilities. The future sea levels are about to increase in the range of 10-100 cm by 2100, the entire Maldives island could be submerged (https://www.worldbank.org/en/news/feature/2010/04/06/climate-change-in-the-maldives).

Droughts: Arid regions in South Asia, including dry regions of Rajasthan in India and some regions of Pakistan, are facing severe drought. However, due to frequently occurring different kinds of droughts (late onset, mid-season and terminal), 2/3rd of India's agriculture areas are under rain-fed condition. Western Rajasthan, parts of Haryana, Uttar Pradesh, Maharashtra, Southern Bihar, Madhya Pradesh, Southern Gujarat, Northern parts of Andhra Pradesh, and Karnataka are regularly facing dryness, and these regions are highly vulnerable to drought (Bhadwal *et al.,* 2007). The arid and semi-arid zones are vulnerable to the losses of economic activities and livelihoods due to the changes in rate of precipitation.

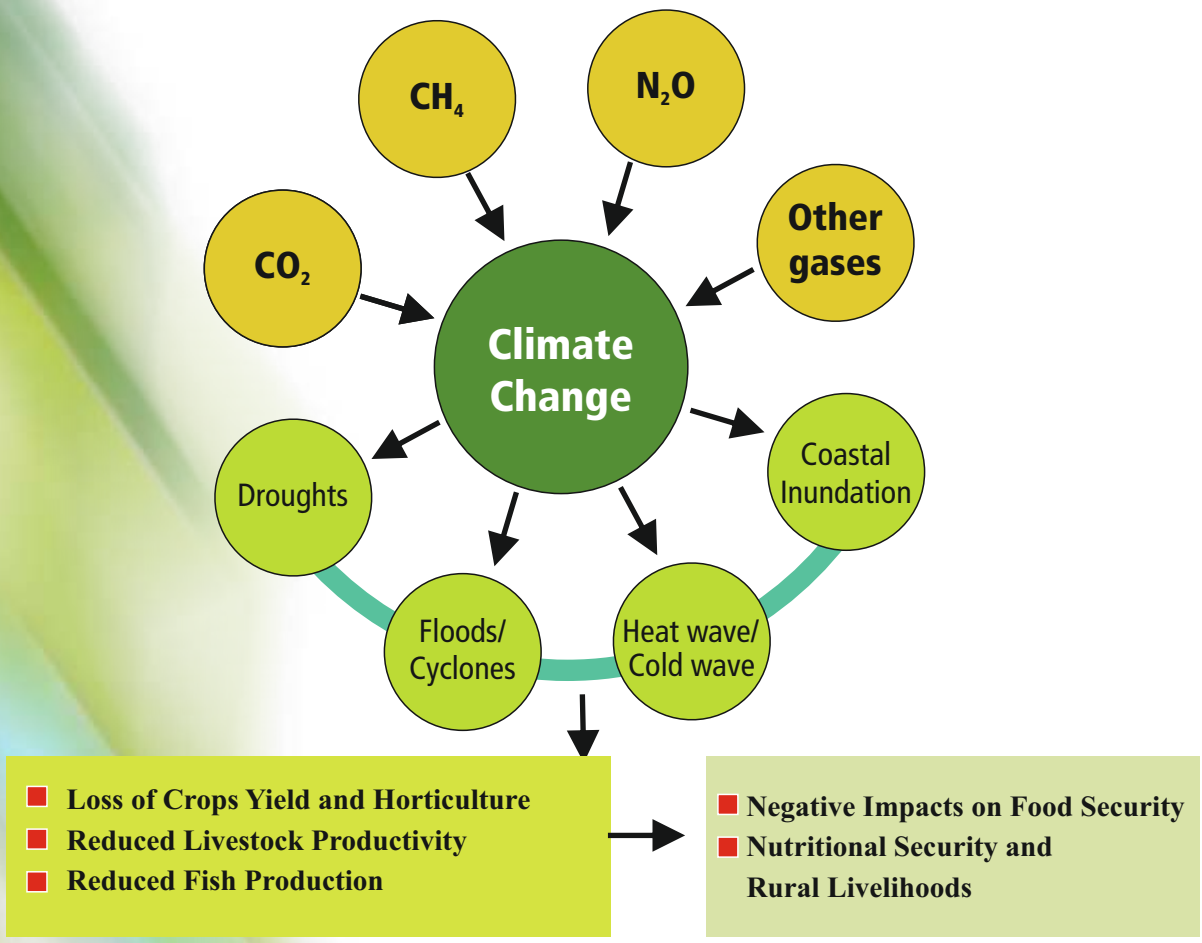

Figure 1: Causes and impact of climate change on agriculture and allied sectors

Extreme Events (Cyclones and storms): Another troublesome indicator of global climate change such as storms, cyclones, landslides, *etc*., extremely affect South Asian countries. Around nine million people in the world were severely affected due to the destructive cyclones (UN assessment). The super cyclone in 1999 hit Orissa took toll of over a million lives besides properties loss in the coastal areas (Ahluwalia and Malhotra, 2006). Similar is the case with the coastal state of Andhra Pradesh during Hud-Hud cyclone in 2014.

Heatwaves: Frequency and intensity of heatwaves are raising in India adversely affecting all allied sectors of agriculture including dairy, poultry, fishery, *etc*. Low water availability coupled with heatwaves have severe consequences on food security of the country. Drinking water crisis for humans and livestock besides drying of long-standing horticulture orchards was seen. India and its neighbouring countries experienced a severe and longest heatwave from mid-May to mid-June in 2019. Chiru in Rajasthan state, India documented a record of high temperature up to 50.8° C (123.4° F), which is almost missed by fraction of degree *i.e.*, 51.0° C (123.8° F) highest set in 2016. As of 12 June 2019, the second largest heatwave period (32 days) ever was documented.

Melting of glaciers: Future situations of South Asia may become adverse due to melting of glaciers and snow in the Himalayan regions. The Himalayan glaciers are rapidly

melting down because of high temperature and if it continues in future, the fresh water stock for survival will be at great risk (Bajracharya, *et.al*. 2007). Satellite data project that the rate of retreat of 30 km long Gangotri Glacier in the last 30 years has been more than 3 folds the rate of the past 200 years or so (Rao, 2007).

Sectoral Impacts of Climate Change

'Agriculture' is the main occupation for 50 percent of population in India. Agriculture and allied sectors contribute 15.4 per cent of the Indian GDP (OECD, 2017). Farming activities are carried out by the selection of crop which is specific to suit climate, soil type, resource availability, *etc.* Therefore, farming production and productivity is completely dependent on climatic conditions (Srinivasarao *et al.,* 2016a; Bal and Minhas, 2017). Weather disruptions, like changes in temperature, precipitation and solar radiation, affect the agriculture ecosystem including livestock, arable and hydrology sectors. As per the global report prediction, a loss of 10-40 per cent in crop productivity is estimated for 2100 (https://icar.org.in/node/1738). Around 70 per cent of South Asian people's life is still in rural zones, and of 75 per cent of them are poor (Ahluwalia and Malhotra, 2006). Enhancement of crop productivity is highly necessary for safeguarding the food and national security, particularly the resource-poor who would be the most affected, like small and marginal farmers (Figure 2).

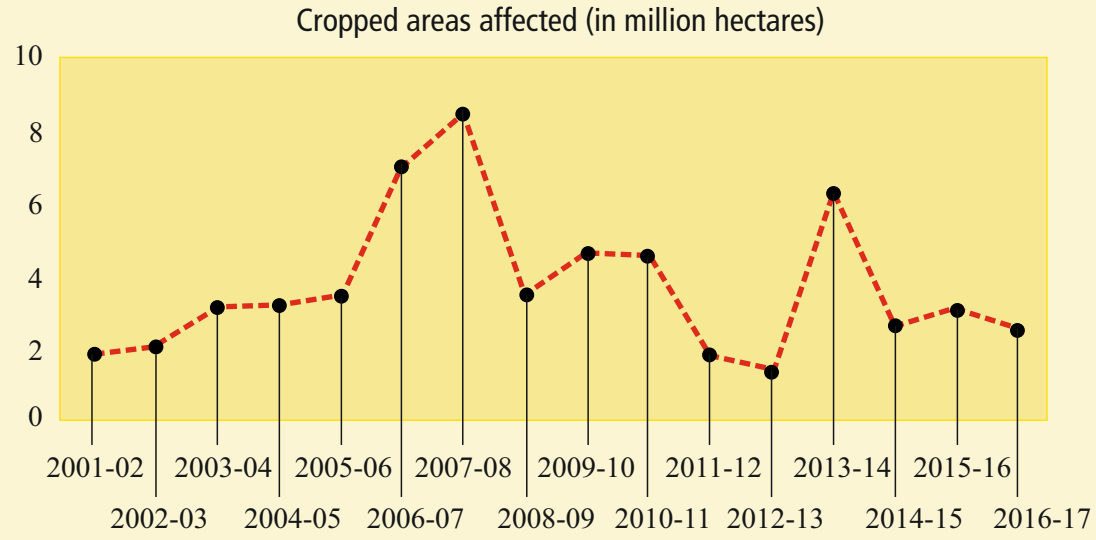

Figure 2: Year-wise damage due to natural extreme events in India
[Source: Envistats India 2018 (Website: http://mospi.nic.in/publication/envistats-india-2018)]

Sector-wise Effects of Climate Change in Agriculture

Field crops: An average of 30 per cent decrease in crop yields is expected by mid-21st century in South Asian countries. North Indian states and Bangladesh are highly susceptible due to erratic changes in rainfall and temperature (World Bank, 2008). For example, in India, an increase in temperature by 1.5° C and decrease in the precipitation of 2 mm, reduces the rice yield by 3 to 15 percent (Ahluwalia and Malhotra, 2006). Climatic changes driven by increasing Green House Gases (GHGs) possibly affects the yield and productivity of agricultural crops from region to region. According to the Met Office (United Kingdom's National Weather Service), the normal crop yield is anticipated to decrease by 50 per cent in Pakistan. The production of maize in European countries is expected to increase by 25 percent in ideal hydrologic conditions (en.wikipedia.org). The drastic changes in climate alters the progressive stages of pathogens that eventually affect the growth and yields of crops severely, and also could lead to an increase in pest and insect population, ultimately devastating the overall productivity.

Horticulture: Vegetable crops when exposed to extreme high temperatures are subject to very high transpiration losses, and it also limits fruit setting in citrus fruits. High temperature causes burning or scorching effect of blossoms, predominantly on young trees. Fruit setting stage of navel oranges is recorded to be severely affected by high temperatures during flowering (Davies, 1986). High temperature induces moisture stress condition leading to sunburn and cracking symptoms in fruit trees like apricot, cherries and apples. The temperature enhancement at ripening stage causes fruit burning and cracking in litchi plantation (Kumar and Kumar, 2007). Most of the vegetable crops are severely affected by flooding, particularly tomato. Another possibility of causing severe damage to crops is due to the accumulation of endogenous ethylene (Drew, 1979). If the ozone concentration reaches to >50 ppb/day, yield of vegetable crops will be reduced by 5 to 15 percent (Raj, 2009).

Livestock, Poultry and Fishery sectors: The climate change, whether it is global, regional or in a smaller scale, has a greater impact on biological production, or sum of those processes acts directly on individual organisms or species. The growth and development of any species with some specific characteristics is governed by their resilience and tolerance to the changes in their environment. Global climate changes affect numerous factors which are associated with production, reproduction, health and adaptability of every animal. Higher temperatures abruptly change the animal's body physiology (Pereira *et al.*, 2008) such as rise in respiration rates (> 70-80/minute), blood flow and body temperature (>102.5º F). In Bangladesh, decrease in livestock production due to diseases, lack of forage, heat stress and breeding strategies resulted in huge economic losses (Chowdhury and Monzur, 2016). The correlation between performance of cattle production and temperature-humidity index is negative (Shinde *et al.*, 1990; Mandal *et al*., 2002). Erratic changes in weather conditions directly impact the production level of animal by 58 per cent and reproduction by 63.3 per cent (Singh *et al.,* 2012). Dairy breeds are more vulnerable to heat stress than the meat breeds. An increase in metabolic heat production in higher milk producing breeds leads to higher

susceptibility to heat stress; while the low milk producing animals are resistant (Dash *et al.*, 2016). Increase in temperature and temperature-humidity index value beyond the critical threshold level reduces the dry matter intake and milk yield. It also interrupts physiology of animal's body (West, 2003). During 2009-10, the extreme events like floods and cyclones devastated agricultural production in large range in southern and central Mozambique, consequently loss of livestock, its infrastructure and feed (Musemwa *et al.*, 2012).

Poultries are extremely sensitive to temperature-associated issues, specifically heat stress. Endocrinological changes caused by prolonged heat stress in broiler chickens enhance lipid accumulation, reduced lipolysis, and induced amino acid catabolism (Geraert *et al.* 1996). Due to heat stress, feed intake of poultries will be reduced (Deng *et al*., 2012), which leads to less body weight, egg production and quality of meat, and also reduces the thickness of eggshell and increases the egg breakage (Lin *et al.,* 2004). Heat stress has negative effect on strength, weight, ash content and thickness of the eggshell (Miller and Sunde, 1975). Rising environmental temperature may cause seasonal improvement in growth and development of fishes, but increases the risks to the populations living beyond the thermal tolerance zone (Morgan *et al.,* 2001). The rise in temperature of 1° C will affect the mortality of fish and its geographical distribution (Vivekanandan *et al.,* 2009). The temperature rises of 0.37° C to 0.67° C alter the pattern of monsoon seasonal variations, eventually shifting the breeding period of Indian main carps from June to March in West Bengal and Orissa's fish hatcheries (DARE/ICAR Annual Report, 2008-09).

Adaptation and its Co-benefits of Mitigation in Agriculture Sector

'Adaptation led Mitigation' to climate change is the only option to prepare our community, locality, country, and the societies for the consequences of same. 'Adaptation' is nothing but the adjustments in human or natural ecosystem in response to climate change, and it moderately harm or destruct the opportunities (IPCC, 2007). Practically, it means changing the regular activities because of change in climate but not completely different, rather purposefully modifying the existing practice. Hence, risk management is a key factor of adoption, and it may require complex governance processes. While 'Mitigation' is any technological modification that reduces the addition of inputs and its emission (GHGs into atmosphere) per unit of output (IPCC). Adaptation in agriculture sector means disseminating the knowledge on the negative impacts of climate change to reduce farmers' vulnerability by improving their adaptive capacity. However, the individual must be accompanied by groups, government supportive policies, agricultural extension services, research and some risk management tools. Adaptation and adaptation-led-mitigation is the central strategy in agriculture sector of India, and the same is reflected in various international forums.

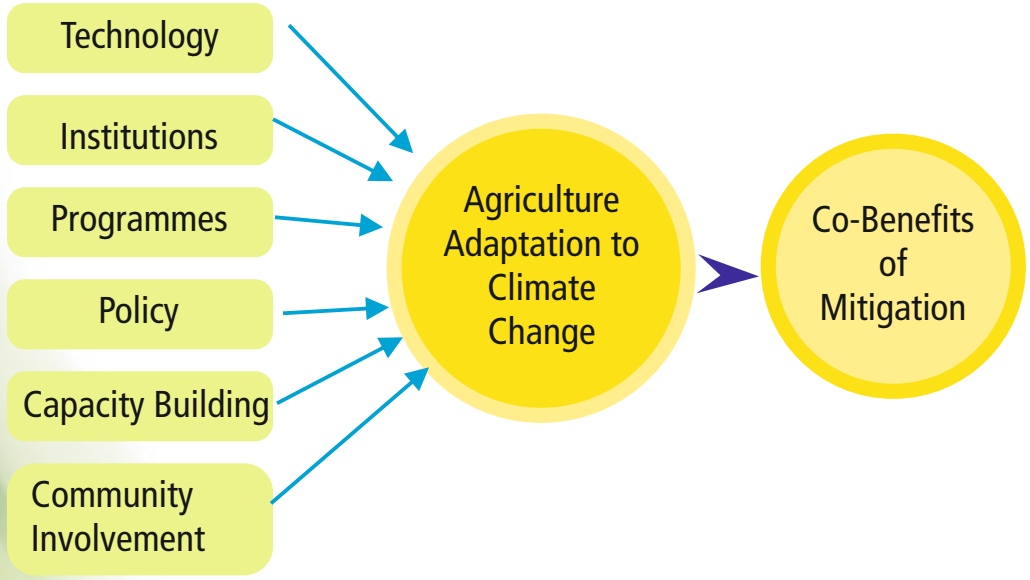

Figure 3: Policy of climate change adaptation and co-benefits of mitigation in agriculture sector in India

Adaptation Strategies Combating Climate Change

The effect of change in frequency and magnitude of natural disasters on agriculture sector is devastating by placing many lives and livelihoods of various communities at risk. Specifically, this sector is already threatened by land degradation, less water availability and biodiversity losses became even more vulnerable to climate change. Most important driver to climate change adaptation is technology. Awareness and capacity building is critical among all the stakeholders from farmers to policy makers for overall climate change adaptation (Figure 3 & Figure 4). Community-driven programmes and village institutions' involvement are critical to adapt to climate change over to those of individuals. There is a strong need to convergence of multi-ministries' programmes at village or mandal level for deriving benefits of national or state-level climate adaptation programmes.

Adaptation strategies with improved farming techniques/practices can

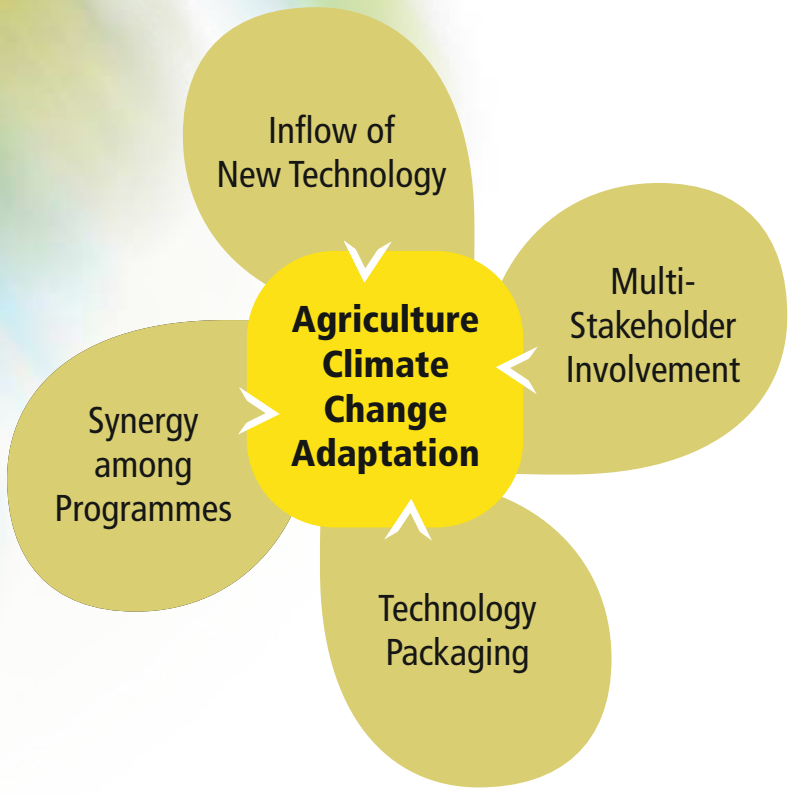

Figure 4: Key strategies essential for climate change adaptation in agriculture sector

potentially decrease the vulnerability of adverse impacts of climate change. Most of the adaptation technologies have co-benefits of mitigation by removing, reducing or displacing the emissions of atmospheric carbon dioxide, methane and nitrous oxide with some co-benefits (FAO, 2012). Water management is the critical factor for overall climate change adaptation in India and elsewhere. When water is limited, the priority should go to livestock followed by horticulture and then to annual crops (Figure 5). Half of the Indian agriculture is rain dependent and therefore, rain water conservation (*in-situ* as well as *ex-situ* in terms of farm or community ponds) is the highly prioritised adaptation strategy (Figure 6). This enables the provision of drinking water for livestock sector.

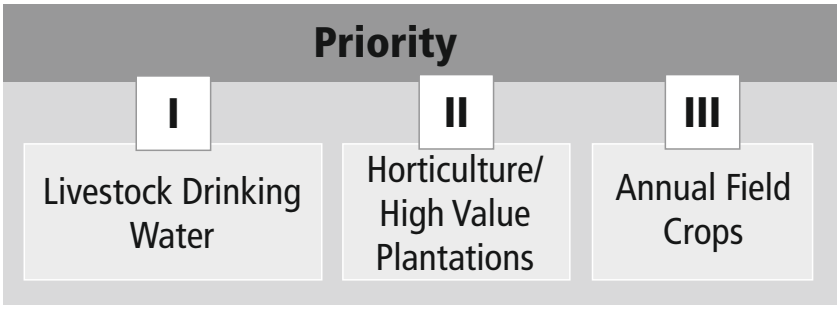

Figure 5: Priority of water utilization in agriculture sub-sectors under limited water availability

Water Resource Conservation Techniques

In-situ Soil Moisture Conservation

- Subsoiling- Enhances soil moisture and nutrient availability.
- Conservation furrows- Percolated rain water is conserved in plant root zone.
- Trench-cum-bunding- Allow percolation of rain water and retain moisture at the root zone for longer period.
- Broad bed furrows- Improves drainage and conserve soil moisture.
- Ridges and furrows- Retains soil moisture and maintains proper drainage.
- Zero-tillage- Utilizes residual soil moisture, adds organic matter and reduces cost of cultivation.
- Plastic mulching- Controls weeds, conserves soil moisture, reduces soil erosion, improves soil structure and enhances soil organic matter content.
- Crop intensification with conserved soil moisture- sunhemp seed production in rice fallows- Conservation and effective utilization of residual soil moisture.
- Compartmental bunding- Moisture conservation.
- Pusa hydrogel- Absorption and retention of soil moisture; slow release for longer period.
- Pani pipe technology- Reduces the number of irrigations and recharges the ground water.

Water Saving Techniques

- SRI method of paddy cultivation- Utilizes less water, less seed, less chemical fertilizers and pesticides.
- Direct seeding of paddy with drum seeder- Conserves seed, moisture, labour and produces more tillers.
- Broadcasting of paddy- Labor saving and low cost of cultivation.
- Drip irrigation- High water use efficiency.

Figure 6: Different resource conservation technologies for climate change adaptation in Indian agriculture

Efficient rice, wheat and sugarcane production systems are most important for conserving water resources. Several land treatments for *in-situ* rain water conservations, location-specific designs of farm ponds for harvesting of runoff under high intensity rains were made available by the Indian Council of Agricultural Research (ICAR).

Livestock is critical for the stability of livelihoods of small holder farmers in India and other developing countries. Three-tier strategy such as better breed, feed and shelter management is recommended by the ICAR for sustainable livestock production. Combination of these strategies could not only contribute to climate change adaptation but also reduce GHG's emissions particularly methane. These include modifying the feeding habits like improvement in forage quality, using specific dietary additives and usage of fodder grasses can increase the digestive process and eventually reduces the emission from enteric fermentation (Figure 7). The value of different feeds as CH_4 gas production potential of various livestock feeds, is presented in Figure 8. Usage of dry straw as a feed to the cattle liberates huge amount of CH_4 (around 6 ml/100 mg of digested substrate as against the least amount of <2 ml/100 mg in case of fresh tree leaves followed by cereal grains (Bhatta *et al.*, 2015). Combination of different feed additives might have a synergetic

Figure 7: Better feed management strategies for Climate change adaptation and CH_4 emission reduction from livestock sector

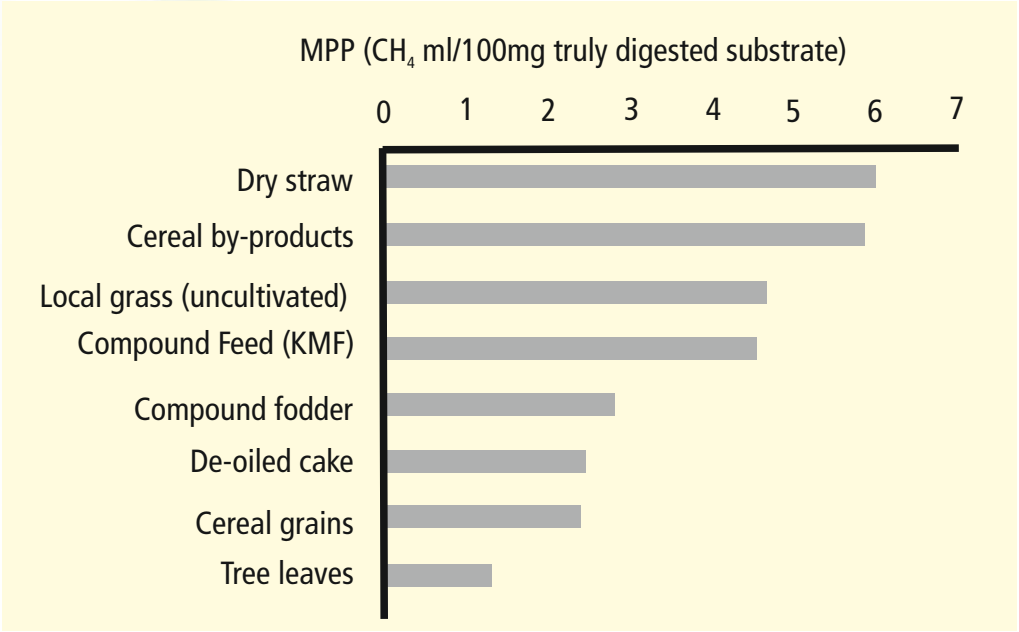

Figure 8: Methane Production Potential (MPP) of different categories of livestock feed [*Source: Bhatta et al., 2015*]

reducing effect in controlling of methane emission. Selection of location-suitable aquatic species, enhancing feeding efficiency, adoption of herbivorous and omnivorous aquaculture will possibly reduce GHG emission from input use besides productivity of fisheries. Overall strategy of climate change adaptation with the implementation of various technological interventions is illustrated in Figure 9.

Figure 9: Climate change adaptation technologies with co-benefits of mitigation

United Nations Framework Convention on Climate Change (UNFCCC) and Agriculture sector-based Climate Change Negotiation Process

The Ministry of Environment, Forestry and Climate Change (MoEF & CC) is a central government nodal agency structured for UNFCCC for planning, co-ordination and controlling the execution of India's environmental and forestry policies and programmes with respect to the conservation of natural resources, biodiversity, forests and wildlife by abating the atmosphere pollution (http://moef.gov.in/). The UNFCCC is a 'Rio Convention' came into existence in 1994, designed/aimed to prevent all hazardous activities of human which interfere the global climate. It has a Universal Membership of about 197 countries to act against climate change issues in the interest of human safety by stabilizing the green house gas concentration in atmosphere (https://unfccc.int/portal_espanol/informacion_basica/la_convencion/items/6196.php).

The Indian Council of Agricultural Research (ICAR) under the Ministry of Agriculture and Farmers Welfare, Govt. of India, took proactive role in institutionalizing the climate adaptation process in the agriculture sector. Its initiative to evaluate the vulnerability of Indian agriculture to global climate change and analysis of the adaptation and mitigation strategies is amply recognized within and across the world. In 2004, ICAR launched a National Network Project on "Impacts, Adaptation and Vulnerability of Indian Agriculture to Climate Change" to focus on comprehensive understanding of climate change impacts on agriculture sectors like cereal crops, horticulture crops, plantation crops, livestock, fish, soil, water, agroforestry, market and policy collaborating with 15 industries during the X plan (A case study of ICAR). A mega project named "National Initiatives for Climate Resilient Agriculture (NICRA) functioned with multi-stakeholder participation in order to bring the stability of food production through climate adaptation and mitigation strategies. Large-scale infrastructure was established across the country for taking up climate change research and technology development. India was proactive in developing district agriculture contingency plans for all rural districts towards preparedness and real time response to climate change impacts.

India also helped the SAARC partners to develop such initiatives. These initiatives and experiences were amply shared among participating countries of UNFCCC process during in-session workshops (as listed below under Koronivia Joint Work on Agriculture (KJWA) section) and negotiation process during 2013-2019. ICAR also contributed to multi-ministerial demonstration of climate change mitigation initiatives at UNFCCC through global climate change negotiations in Subsidiary Body for Scientific and Technological Advice (SBSTA) and Conference of Parties (COP). ICAR has also been contributing to refinements in measuring climate change through its participation of Intergovernmental Panel on Climate Change (IPCC), as illustrated in Figure 10.

A side event was organized by the Ministry of Agriculture, Government of India at the Indian pavilion on 5th December 2015 towards scaling up adaptation strategies for climate

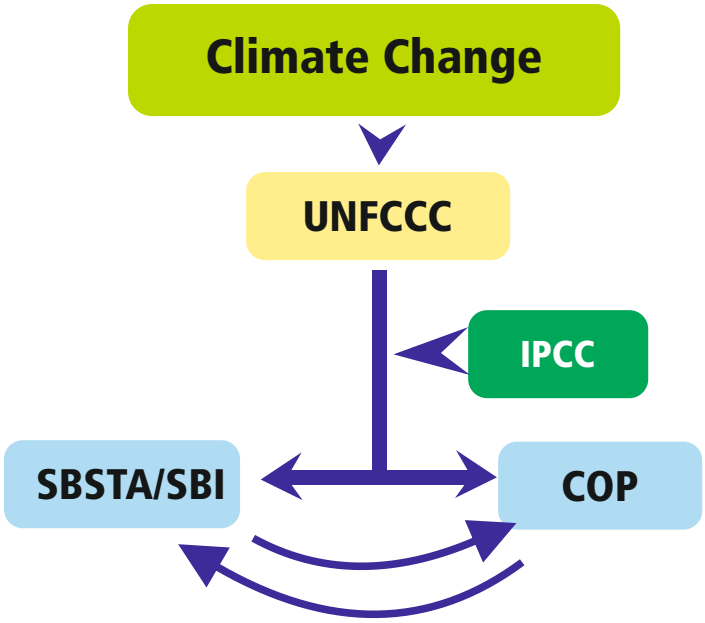

Figure 10: United Nations Framework Convention on Climate Change Process and Subsidiary Bodies

resilient agriculture in India – COP 21, Paris, France. Various adaptation strategies promoted by ICAR/DARE and National Adaptation Fund were discussed and presented to the participants who attended this side event in the pavilion

Sharing the technologies, programs and policies of Government of India towards climate resilient agriculture at UNFCCC-SABSTA-42, Germany (2015-16)

Koronivia Joint Work on Agriculture (KJWA)

The Koronivia Joint Work on Agriculture (KJWA) is a decision arrived at the 23rd Conference of the Parties to the UNFCCC (COP-23) in November 2017, officially acknowledging the significance of the agriculture and allied sectors in adapting to and mitigating climate change. In partnership with other actors at the international and national level, FAO is working to support the development and implementation of the KJWA. At the (COP-23), the Koronivia Joint Work on Agriculture (decision 4/CP.23) was adopted – a landmark agreement for the agriculture negotiations under the

Indian Pavilion and Side Event on Climate Resilient Agriculture at COP-21, Paris, France (2015)

climate convention which emphasizes the key role of agriculture and food security in the international climate change agenda. The agenda item on issues related to agriculture under the Subsidiary Body for Scientific and Technological Advice (SBSTA) was first formalized in 2011 (decision 2/CP.17), followed by five in-session workshops on the status of scientific knowledge concerning agriculture and climate change. Rich exchanges among countries paved the way towards the KJWA, which calls for collaboration between SBSTA and the Subsidiary Body of Implementation (SBI) on specific elements, including through workshops and expert meetings and thus, widening the scope of the conversation from a scientific and technical focus to implementation. The KJWA decision provides a list of specific elements on which Parties are initially invited to exchange their views. Under this decision, FAO supports countries providing technical support to adapt to and mitigate climate change, working in close collaboration with UNFCCC and other partners. Parties and observers have been invited to submit views by May 6, 2019 on: Methods and approaches; for assessing adaptation, adaptation co-benefits and improved soil carbon, soil health and soil fertility under grassland and cropland as well as integrated systems including water management. Workshops related to these topics will then be organized at the 50th sessions of the UNFCCC Subsidiary Bodies (SBI50 and SBSTA 50) during June 17-27, 2019 which were listed below along with previous in-session workshops.

So far, seven in-session workshops and reports on work related to agriculture were undertaken by the Conference of the Parties (COP and its subsidiary bodies like SBSTA and SBI) (Source: https://unfccc.int/fr/node/192864). The topics of workshops organized are presented below along with details of location

1) Current state of scientific knowledge on how to enhance the adaptation of agriculture to climate change impacts while promoting rural development, sustainable development and productivity of agricultural systems and food security in all countries, particularly in developing countries (2013 in SBSTA 39 at Warsaw, Poland).
2) Development of early warning systems and contingency plans in relation to extreme weather events and its effects such as desertification, drought, floods, landslides, storm surge, soil

erosion, and saline water intrusion (2015 at SBSTA 42 Bonn, Germany)

3) Assessment of risk and vulnerability of agricultural systems to different climate change scenarios at local, regional, and national levels, including but not limited to pests and diseases (2015 at SBSTA 42 Bonn, Germany)

4) Identification of adaptation measures, taking into account the diversity of the agricultural systems, indigenous knowledge systems, and the differences in scale as well as possible co-benefits and sharing experiences in research and development and on the ground activities, including socio-economic, environmental and gender aspects (2016 at SBSTA 44, Bonn, Germany). Identification and assessment of agricultural practices and technologies to enhance productivity in a sustainable manner, food security and resilience, considering the differences in agro-ecological zones and farming systems such as different grassland and cropland practices and systems (2016 at SBSTA 44, Bonn, Germany).

5) Modalities for implementation of the outcomes of the five in-session workshops on issues related to agriculture and other future topics that may arise from this work (2018 at COP-24 at Katowice, Poland).

6) Methods and approaches for assessing adaptation, adaptation co-benefits and resilience (2019 at SBSTA 50, Bonn, Germany)

7) Improved soil carbon, soil health and soil fertility under grassland and cropland as well as integrated systems, including water management (2019 at SBSTA 50 at Bonn, Germany).

In continuation with above workshops, continuous dialogue and enhanced knowledge sharing is scheduled in the forthcoming UNFCCC process. Indian statements and presentations displaying climate adaptation initiatives of the ICAR, Ministry of Agriculture and Farmers Welfare, Government of India are available on UNFCCC website and views on at the following links:

https://unfccc.int/files/land_use_and_climate_change/agriculture/application/pdf/india_(early_warning_and_contingency_plans).pdf

http://unfccc.int/files/land_use_and_climate_change/agriculture/application/pdf/india_(risk_&_vulnarability_agril_systems)_new.pdf

https://unfccc.int/sites/default/files/resource/India%20%28Carbon%2C%20Soil%20Health%20and%20Fertilizer%20along%20with%20Water%29.pdf

https://unfccc.int/sites/default/files/resource/India%20%28Methods%20and%20Approaches%20of%20Climate%20Adaptation%29.pdf

Sharing the knowledge and technologies for climate resilient agriculture in India

SAARC-APN regional consultations on climate resilient policies, strategies and programs held at ICAR-NAARM, Hyderabad, April, 2018

Regional Climate Policies at Asian Pacific Network (APN) and SAARC Level

Besides UNFCCC, regional climate policies play a significant role towards climate adaptation and mitigation co-benefits. Various climate adaptation strategies, programmes and policies of Agriculture sector of SAARC countries (India, Sri lanka, Nepal, Bhutan, Maldives, Bangladesh and Pakistan) were discussed at the National Academy of Agricultural Research Management (ICAR-NAARM), Hyderabad during April, 2018 in order to share the knowledge and implement programmes of Climate Change Adaptation in the respective countries (source: ICAR website). This consultation workshop was organized for SAARC Country representatives under South Asian Association for Regional Cooperation (SAARC) and Asia Pacific Network for Global Change Research (APN). SAARC countries are highly vulnerable due to its tropical climate, long sea coast or island ecosystem *etc*. Key strategies and way forward in the form of key messages originated from these workshops are; a) Promoting, training and capacity building among regional countries; b) Contingency plan implementation process; c) Agro-advisories; d) Soil health and carbon sequestration; e) Livestock feed management; f) Minimizing coastal vulnerability and g) Innovative village institutions .

Government of India Initiatives for Climate Change Adaptation

Govt. of India took several initiatives for formulating most efficient missions aiming to combat global warming and for climate change adaptation, as discussed below (Reference: Handbook 2018). All these missions implemented package of several technologies developed by the ICAR. Some important initiatives are presented below with key objectives.

National Mission on Sustainable Agriculture (NMSA):

This Mission was structured under the National Action Plan on Climate Change (NAPCC) and made operational during 2014-15. It aimed to synergize resource conservation, enhancing or restoring the soil fertility, thereby, improving productivity with focus on soil health management, Integrated Farming System (IFS), integrated animal component and Water Use Efficiency (WUE) specifically in drylands or rainfed agriculture areas.

National Adaptation Fund for Climate Change (NAFCC):

This Scheme was implemented during 2015-16 mainly for supporting concrete adaptation activities dealing with mitigating the adverse effects of global climate change in sectors such as agriculture, water, forestry, animal husbandry, tourism, *etc.*

Pradhan Mantri Krishi Sinchayee Yojna (PMSKY):

This Scheme was planned and formulated to give more priority on water conservation and its management in agriculture with the vision to extend the area under irrigation from 1st July 2015. The main motto of this Scheme is 'Har Khet Ko Paani' to improve water use efficiency, 'More crop per drop' to provide end-to-end solutions in water source creation, distribution channels and its management.

Pradhan Mantri Fasal Bima Yojna (PMFBY):

This Scheme was introduced on 14th January, 2016 in order to reduce the agricultural distress and farmer's welfare without affecting substantial hikes in the Minimum Support Prices (MSP) on agricultural produces during monsoon fluctuations or any other natural calamity by providing full insured amount on crop losses.

Soil Health Card (SHC):

This Scheme was launched in February, 2015 by the Narendra Modi Govt. to issue soil health cards (SHC) to the farmers providing detailed information on test based soil nutrient status of their own land along with recommended dose of fertilizers for improving productivity through judicious use of inputs. The Govt. of India targeted to issue 10.48 crores of SHCs since inception of the Scheme.

Green India Mission (GIM):

This Mission was started in February 2014 and outlined under NAPCC. The main objective of this Mission was to protect, restore and enhance the diminishing forest cover in India, and to fight climate change with adaptation and mitigation measures.

National Water Mission (NWM):

A Mission was mounted to ensure Integrated Water Resource Management (IWRM) for conserving the water sources and minimizing its wastage, and also to optimize Water Use Efficiency (WUE) by 20 per cent including agriculture sector.

Paramparagat Krishi Vikas Yojna (PKVY):

It is an extended component of Soil Health Management (SHM) launched in 2015 under NMSA with the objective of supporting and promoting organic farming through adoption of organic village by cluster approach, which in turn result in improvement of soil health.

National Action Plan on Climate Change (NAPCC) and State Action Plan on Climate Change (SAPCC):

The NAPCC was released on 30th June 2008 in order to create awareness among public, Govt. agencies, industries, scientists and the society on the risks posed by global climate changes, and steps to encounter the same. It pulls all the existing Government's national plans on energy efficiency agriculture, renewable energy, water, and others. The SAPCC have enlisted climate adaptation and mitigation strategies aligned with eight national missions under NAPCC. (http://www.arthapedia.in/index.php?title=National_Action_Plan_on_Climate_Change_(NAPCC) & www.iea.org

Agricultural Contingency Plans and National Innovations on Climate Resilient Agriculture (NICRA):

Agricultural Contingency Plans are technical documents comprising integrated information on field crops, livestock, horticulture, poultry and fishery and technological solutions for all weather-related problems for the respective farming activities. These are useful to plan earlier towards sustainable agriculture system during weather aberrations and extreme climatic conditions. NICRA is a Network Project of the Indian Council of Agricultural Research (ICAR) started in February 2011 with the objective of enhancing resilience of Indian agriculture to adverse climate changes by adopting innovative technologies. The Project consists of research, technology demonstration, capacity building and sponsored grants (Srinivasarao *et al.,* 2017 & 2019).

Sub-mission on Agro-forestry:

This Mission was launched during 2016-17 with the objective of planting trees on farm bunds. Agroforestry has the potential to bring sustainability in agriculture and also achieving the optimum productivity by mitigating the impact of climate change.

National Livestock Mission:

This Mission was initiated by the Ministry of Agriculture and Farmers' Welfare and got commenced from 2014-15 focussing mainly on livestock development through sustainable approach ultimately protecting the natural environment, ensuring bio-security, conserving animal bio-diversity and farmers' livelihood.

Innovative Poultry Productivity Project:

The National Livestock Mission launched this Project on pilot basis during 2017-18 in 15 recognized poultry potential states to provide nutritional support to the poor farmers and also give supplementary income.

Blue Revolution (Neel Kranti Mission):

The main objective of this Mission is to improve the fishery production, and enhancing the productivity of both marine and inland aquaculture and fishery resources. The objectives of Neel Kranti Mission are to enhance the overall fish production through sustainability, usage of new technologies to modernize the fishery, ensuring food and nutritional security,

to generate the employment opportunities and empowerment of fishers and aquaculture farmers.

Fodder Development Scheme:

This Scheme was implemented by the Department of Animal Husbandry in 2005-06 to establish fodder block making units, grassland development, fodder seed production and distribution, and biotechnology research.

National Biogas and Manure Management Programme (NBMMP):

The Ministry of New and Renewable Energy installed this programme in 2014 for the development of rural and semi-urban households by setting up the family type biogas plants.

National Mission on Himalayan Studies:

The Ministry of Environment, Forest & Climate Change (MoEFCC) launched this Mission to support innovative studies and related interventions on sustenance and development of the natural, ecological, cultural, and socio-economic capital values and assets of the Indian Himalayan Region.

Agro-Advisory Services:

The weather information-based service came into existence to contribute to crop or livestock management strategies by providing real time location and crop specific agro-met services. A website 'Crop Weather Outlook' provides all kinds of services related to crop management.

Neem Coated Urea:

It is a form of urea fertilizer coated with neem extracted material, which acts as a slow releaser of nitrogen reducing the pest and disease infestation ultimately minimizing the usage of chemicals in farming by achieving the overall increase in crop yield.

National Adaptation Fund:

The National Adaptation Fund for Climate Change (NAFCC) is a Central Sector Scheme which was set up during 2015-16. The overall aim of NAFCC is to support concrete adaptation activities which mitigate the adverse effects of climate change. The activities under this Scheme are implemented in a project mode. The projects related to adaptation in sectors such as agriculture, animal husbandry, water, forestry, tourism, *etc.*, are eligible for funding under NAFCC. The National Bank for Agriculture and Rural Development (NABARD) is the National Implementing Entity (NIE). Technologies generated by ICAR and State Government Universities are being implemented in coherent package to developing resilient capacity of vulnerable regions in India.

National Action Programme to Combat Desertification:

This programme was initiated and sponsored by UNCCD and MoEFCC to mitigate the effects of drought in dryland regions through community-based approach of drought management which can lead to the empowerment of local communities. The objectives were set up to combat desertification *viz.* prevention of land degradation, recovery of partly degraded land and reclamation of desertified land.

State Government Initiatives for Climate Change Adaptation

Not only has the national action planned executing schemes to mitigate the global climate change, rather the State Governments of India also working on it. The State Action Plan on Climate Change (SAPCC) is a flexible and dynamic policy framework follows a continuous interaction process for bringing changes in national, state and local levels. It was directed by National Government to create a coherent national framework under the line of NAPCC. The Govt. of Maharashtra targeted to stabilize the income of 83 per cent of the rainfed and dryland farmers under this Scheme covering the major areas such as farm mechanization, protected cultivation, creation of irrigation potential, processing and marketing and human resource development as well (www.mahades.maharashtra.gov.in/MPSIMS). Further, Maharashtra took the lead scale to bring the stability of agriculture systems in the state. Similarly, the Government of Karnataka initiated State Rainfed Farming Mission for adaptation of large rainfed tracts of the state for drought conditions. Government of Andhra Pradesh initiated Neeru-Chettu for greening the state, besides million farm ponds for climate change adaptation for vulnerable regions of the state. Mission Kakateeya in Telangana showed the positive impacts of water conservation, soil health and enhanced greening. Large scale farm ponds in the state of Rajasthan contributed to critical irrigation during mid-season droughts. Similarly, several other states initiated climate adaptation programs covering different sub-sectors of agriculture.

ICAR supported in the technical backstopping and large-scale awareness in all the regions of the country towards climate change adaptation and co-benefits derived through adaptation process (Srinivasarao *et al.,* 2016a).

Impacts of National Programmes and Policies

Impacts of Irrigation policies:
During the last 20 years in South Asia, the ground water resources have been developed in all the countries. The average productivity of paddy, wheat, corn and groundnut has increased from 2.32 to 2.97 metric tons (Mt)/hectare. Irrigation, generated additional food of 24 million metric tons, which eventually reduced GHGs emission by 7 Mt carbon dioxide equivalent (CO_2e). Minimizing the GHGs emission by avoiding conversion of forest lands to cropland is estimated at 68.14 Mt CO_2e. The energy usage for pumping ground water has produced 30.5 Mt CO_2e of GHGs, resulting the negative balance of 47.8 Mt CO_2e (mitigation benefit). Micro type irrigation smart technologies have a triple benefit, which saves water, energy and increases overall yield. Almost, 20-45 per cent worldwide increase in production reported from micro-irrigation. The estimated 30 per cent increase in efficiency yielded additional production of 3.48 Mt by saving 0.73 million hectare meters of water, thereby, reducing emission of 5.65 Mt CO_2e (Joshi and Tyagi, 2017). "More crop per Drop" is a strong message in overall water utilization strategy in Indian agriculture. The Prime Minister Krishi Sinchayee Yojana (PMSKY) besides MGNREGA have contributed immensely for water resources conservation and ground water recharge and utilization in the country.

Both field crops and horticulture sub-sectors positively impacted with improved water use efficiency related programmes and policies.

Impacts of Fertilizer Policies: The rate of consumption of fertilizer has grown rapidly in South Asian countries. The fertilizer policies in India has grown positively by enhancing crop production and productivity. The additional food grain production of 13.66 Mt using fertilizers avoided the conversion of 11.48 million hectares of forestland to cropland, thereby, reducing 2013 Mt of GHGs emissions (Joshi and Tyagi, 2017). Soil Health Card mission of the Govt. of India has a great potential for not only improved productivity but also for need-based nutrient application, and improved soil health which contribute to climate change adaptation. Neem coated urea is another important step by the National Government leading to reduced fertilizer input cost, improved nutrient use efficiency and reduced GHGs from fertilizer nutrient sources.

Agro-forestry Policy: Forestry and agro-forestry policy of the Govt. of India have greater role in climate adaptation and mitigation. Area under agro-forestry is on upward trend towards more carbon fixation and reduced GHGs. Inclusion of pricing policy would contribute to stability of livelihoods of agro-forestry farmers of India besides environmental services. Location-specific agro-forestry species identification along with associated technology was promoted by ICAR through its network.

Livestock, Poultry and Fishery Sector Policies: The Department of Agriculture and Allied sectors has been providing assistance to the State Governments for the control of animal diseases, scientific management and upgradation of genetic resources, increasing availability of nutritious feed and fodder, sustainable development of processing and marketing facilities, and enhancement of production and profitability of livestock and fisheries enterprises. During 2017-18, the record milk production was registered at 176.3 mt in comparison with 132.4 mt during 2012-13. Several livestock related policies contributed to animal health, vaccination, fodder availability, artificial insemination besides marketing and promotion agripreneurship ecosystems in India. During the financial year 2017-18, the total fish production in India is estimated at 12.61 Million Metric tonnes. Similar advances were made in poultry sectors.

Contingency Plans and Resilient Model Villages: The major impacts of agriculture contingency plans and climate resilient villages established by ICAR are: a) Large-scale awareness created from different hierarchy besides capacity building to about million stakeholders involved in resilient agriculture through preparedness workshops, interface meetings, village institutions, field visits *etc.;* b) seed systems and farm machinery through Custom Hiring Centres for timely sowing and farm operations established; c) prioritised technologies required for resilient agriculture implemented for example in Madhya Pradesh, and crops were saved through rain gun-based lifesaving irrigation in Andhra Pradesh; d) sowing area reduction was off-set during drought years region (2014, 2015, 2016) to the extent of 6-9 percent. One hundred fifty-one resilient villages established by ICAR are being replicated in the state Government programmes. Village carbon balance computed through implementation of climate resilient villages was enhanced off setting GHG emissions (Srinivasarao *et al.,* 2016b). This is the one of the

important initiative implemented at the ground level by multi- stakeholder involvement with strong technical support and scientific knowledge flow besides systematic monitoring.

Insurance Policies: Insurance policies have been introduced and revisited in the interest of the farmers to reduce distress and preparedness compensation. Though registrations are at moderate level, there is ample opportunity to strengthen the agriculture insurance under the Prime Minister Crop Insurance Scheme. Lot of value addition to the insurance policy was done besides premium reduction.

Agriculture and Rural Development Ministries Aggregated: In 2019, the Government of India had taken the decision to bring two important Ministries such as Agriculture and Rural Development headed by a single Minister. This is another important step contributing that climate change adaptation technologies are implemented in holistic way at the village level as adaptation process is community driven. With aggregating two important Ministries, larger synergy is possible in implementing climate adaptation technologies at the ground level, and expected to strengthen further the overall climate adaptation process in agriculture and allied sub-sectors in India.

Conclusions

Global climate change, its causes and impacts are one of the most emerging issues in science and technology domain. India, a tropical country, is facing its impacts through droughts, floods, cyclones, heat waves, hailstorms, and coastal salinity which have become threats to sustainable development. About 70 per cent of the Indian population is directly or indirectly associated with agriculture and sub-sectors, and major Sustainability Development Goals (SDGs) are expected to be met from this sector. Increasing global temperature due to the emission of enormous amount of green-house gases from various sources is the cause of climate change and impacts. Extreme temperature and its erratic events disrupt the activities of all the existing lives on the planet by means of severe damage or loss. Assessment of the impacts and a comprehensive understanding of the benefits of adaptation options over combating the uncommon incidents of climate change is pivotal in the current scenario to sustain life. So far in the journey of Indian agriculture sector, climate adaptation strategies have shown positive impacts. Still much more needed in the light of emerging

Recommendations

1. Preparation of nations to compensate these changes requires intensive and inclusive steps for mitigation by adaptation of innovative practices. Commitment to achieve the goal of sustainable agriculture and to create eco-friendly environment within our community must be strengthened by the adaptation strategies. Large-scale climate awareness is a must, and should be taken forward by multi-ministerial platforms.
2. Reduced food losses should be considered as one of the greatest climate change mitigation action. Besides creating awareness accounting of food losses should be taken up by Ministry of Agriculture and Farmers Welfare and Rural Development with Civil Supplies, Ministry of Civil Aviation and other Ministries related to food production and distribution.
3. Differential and better incentive mechanisms to the farmers and practitioners who practice Good Agriculture Practices (GAP) related to water and fertilizer saving, residue recycling and integrated farming systems. They can be done by water use monitoring system in the field and fertilizer use monitoring at sole points.
4. Impacts of several national and state-level climate action programmes and policies by academic institutions should be taken up and need-based changes be made based on these impact studies.
5. Nevertheless, continuous monitoring and evaluation of the adaptation measures ease the understanding level, and also enables further needed alterations of such measures.
6. A strategic approach of both central and state programmes on climate change mitigation is crucial to progress the adaptive ability by addressing the existing climate risks and its future vulnerabilities. Intensive and a comprehensive programme is essential with collective responsibilities and climate actions under NAPCC and SAPCC.
7. Lack of data on the rate of adaptation and the existing knowledge-level imposes further limits on evaluation of global climate change and its future risks. Much more location-specific research is necessary to develop innovative way of adaptive measures and co-benefits of mitigation for reduced green-house gas emission in the sector.
8. Aggregation of Ministry of Agriculture and Farmers Welfare and Ministry of Rural Development contributes to the effective implementation of several national and also state programmes in synergistic way.
9. Besides, action plans should be drawn and collected to be promoted by all the Ministries at the village as a unit, be it the Ministry of Water Resources, Animal Husbandry and Fishery, Earth Sciences, Environment, Forestry and Climate Change along with Ministry of Agriculture Farmers Welfare and Rural Development.
10. National adaptation fund sponsored projects need to be region specific. Package of climate adaptive technologies implemented under these projects should be monitored by the experts and needful guidance to be taken periodically for better implementation.
11. Quantification of impacts should be made mandatory in project sanctioning mechanisms.
12. Overall objectivity of future agriculture in India and elsewhere, is to have food production stability and its enhancement despite of climate change with its impacts with enhanced efficiency and lower carbon foot print.

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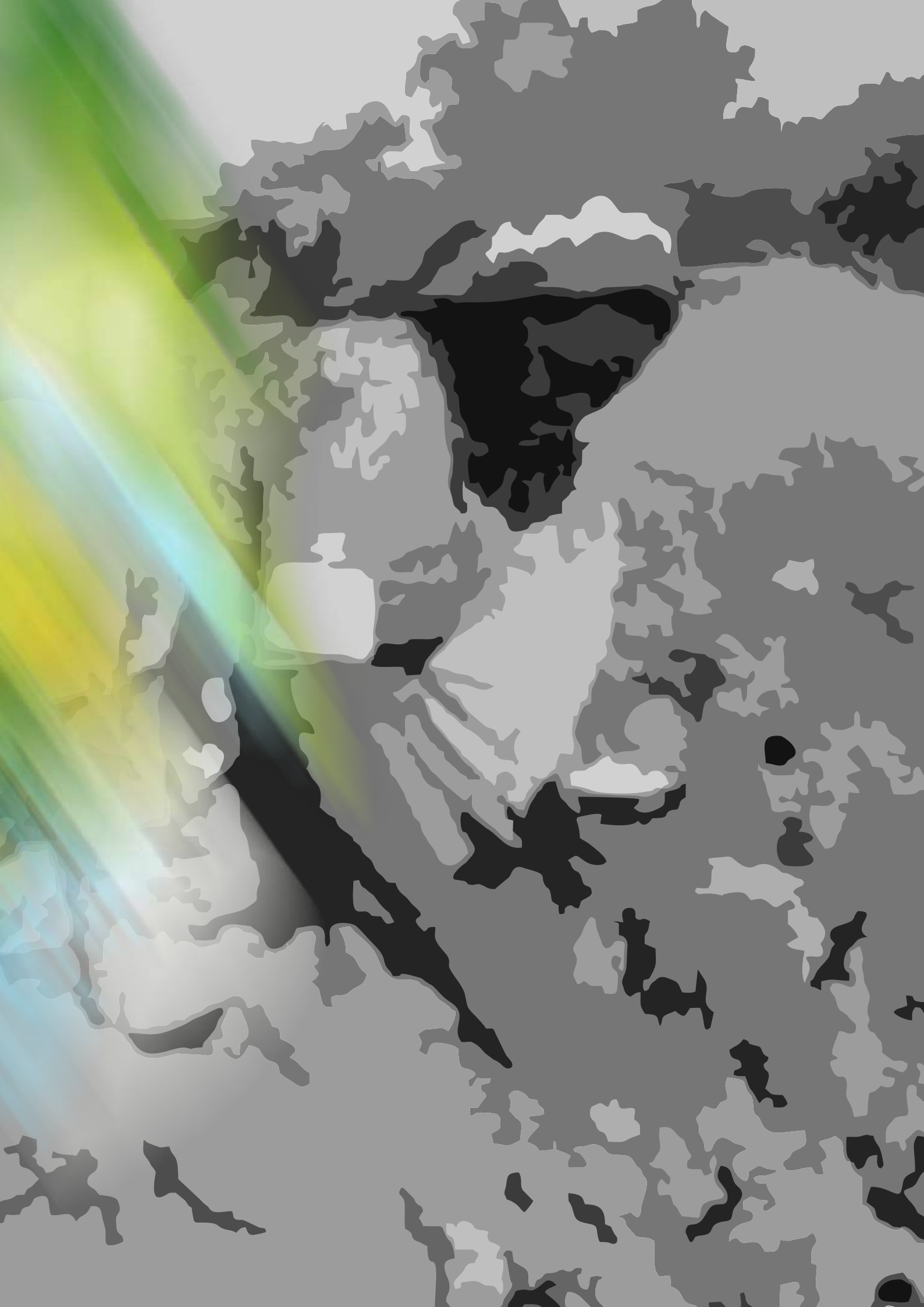

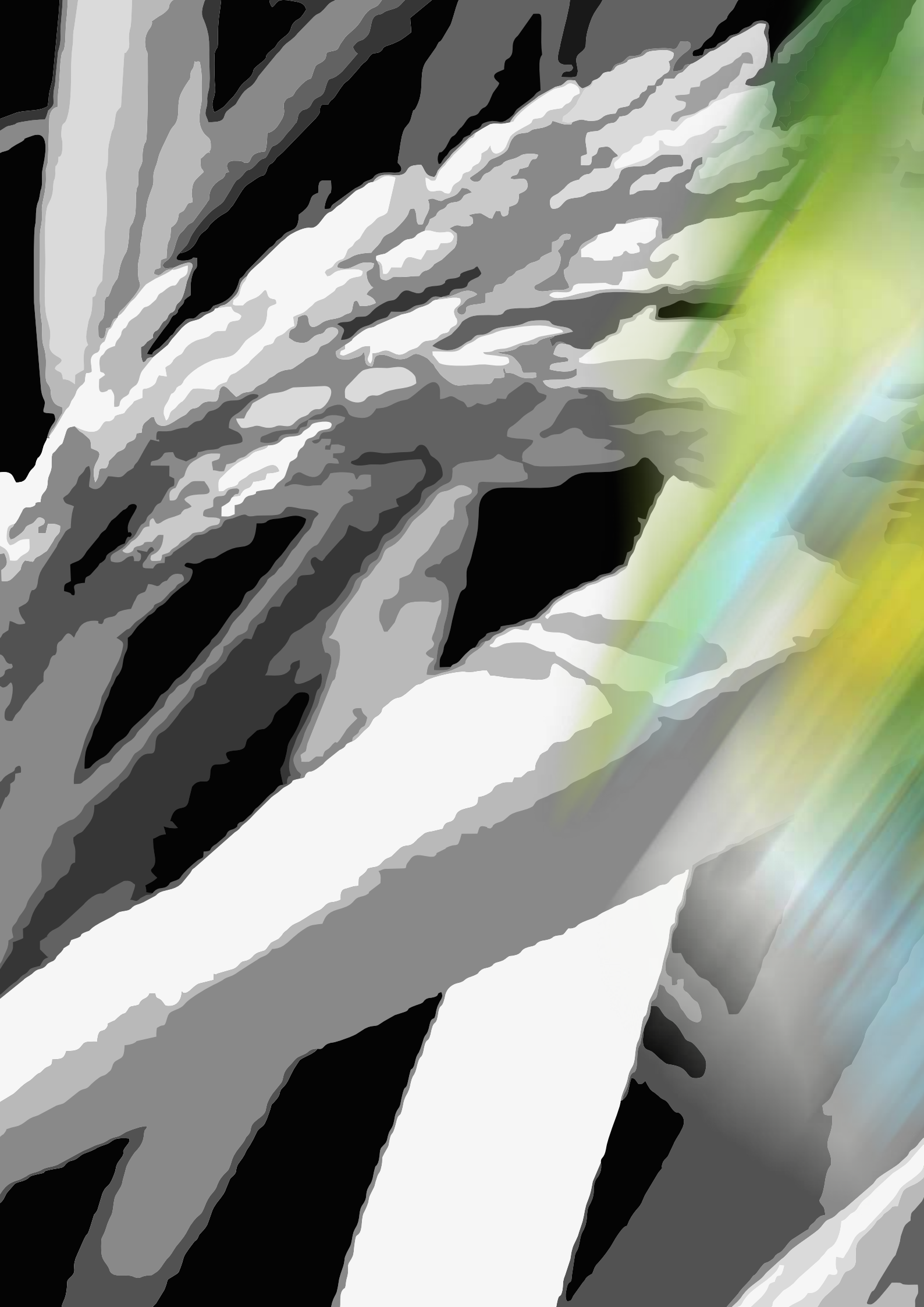

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