International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2021; SP-9(3): 01-08

Received: 01-03-2021
Accepted: 03-04-2021

Climate-smart agriculture (CSA): A way of agriculture risk management

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Abstract
CSA helps to ensure that climate change adaptation and mitigation are directly incorporated into agricultural development planning and investment strategies. CSA has the potential to increase productivity and resilience while reducing the vulnerability of millions of smallholder farmers. CSA can benefit smallholder farmers directly by increasing efficiency of precious inputs such as labour, seeds and fertilizers, water, pesticides, increasing food security, and opportunities for income generation. By protecting ecosystems, landscapes and environmental security, CSA helps protect natural resources for future generations, reduce GHG emissions. Several strategies like crop insurance, crop and weather information, agro-advisories, conservation agriculture, agro-forestry, integrated farming systems e-marketing etc. may used as tool of climate risk management / agriculture risk management in climate smart agriculture.

Keywords: climate-smart agriculture, mid-term mitigation, climate risk management

Introduction
Agriculture production and farm incomes in India are frequently affected by natural disasters such as droughts, floods, cyclones, storms, landslides and earthquakes. Susceptibility of agriculture to these disasters is compounded by the outbreak of epidemics and man-made disasters such as fire, sale of spurious seeds, fertilizers and pesticides, price crashes etc. All these events severely affect farmers through loss in production and farm income, and they are beyond the control of the farmers. With the growing commercialization of agriculture, the magnitude of loss due to unfavorable eventualities is increasing. The question is how to protect farmers by minimizing such losses. Agricultural Insurance is a means of protecting the agriculturist against financial losses due to uncertainties that may arise agricultural losses arising from named or all unforeseen perils beyond their control (AIC, 2008) [1].

The impact of climate variability and change on farmer's livelihood in different agroclimatic systems and the changes in risk management approaches have shaped the mitigation and the response strategies of farmers and societies over the years. Farming communities that do not have inbuilt buffering mechanisms, as in resource poor rain-fed regions, are disproportionately vulnerable to the severity of extreme climate events. Climate change caused by global warming is likely to increase the frequency of climatic extremes in the future and result in changes in cropping practices and patterns over time and space. Climate change further compounds the problem, as it threatens to alter the frequency, severity and complexity of climate events, as also the vulnerability of high-risk regions in different parts of the country. Climate smart agriculture is a way to manage agricultural production risks elegantly. Before 2050, the global population is expected to swell to more than 9.7 billion people (United Nations 2015). If the current trends in consumption patterns and food waste continue, it is estimated we will require 60 per cent more food by 2050. In India, most farmers are smallholders or landless peasants who will need to adapt to 'Climate-Smart Agriculture' in order to survive changing weather patterns.

Definitions (Give referenced definitions only
Climate Smart Agriculture (CSA) as a means to enhance productivity and incomes, resilience to climate change and carbon sequestration. It is defined as an approach that integrates the three dimensions of sustainable development (economic, social and environmental) by jointly addressing food security and climate challenges through: a) sustainably increasing agricultural

productivity and incomes; b) adapting and building resilience to climate change; and c) reducing and/or removing GHG emissions.

Climate-smart agriculture (CSA) may be defined as an approach for transforming and reorienting agricultural development under the new realities of climate change (Lipper *et al*. 2014) [13]. The most commonly used definition is provided by the Food and Agricultural Organisation of the United Nations (FAO), which defines CSA as "agriculture that sustainably increases productivity, enhances resilience (adaptation), reduces/removes GHGs (mitigation) where possible, and enhances achievement of national food security and development goals". In this definition, the principal goal of CSA is identified as food security and development (FAO 2013, Lipper *et al*. 2014) [6, 13]; while productivity, adaptation, and mitigation are identified as the three interlinked pillars necessary for achieving this goal. Climate Smart Agriculture (CSA) is defined as agricultural practices that sustainably increase productivity and system resilience while reducing greenhouse gas emissions [1].

Climate Smart Agriculture (CSA) aims

Climate Smart Agriculture (CSA) aims to achieve the goals of increased productivity / enhance the capacity of the agricultural systems to support food security, incorporating the need for adaptation / resilience and the potential for mitigation into sustainable agriculture development strategies. CSA proposes more integrated approaches to the closely linked challenges of food security, development and climate change adaptation / mitigation, to enable countries to identify options / methods with maximum benefits and sets of indicators to monitor towards achieving CSA goals and outcomes as a result.

Adaptation strategies

Adaptation is the key when it comes to CSA. "We need to transit to a more sustainable food system and mitigate climate change while at the same time adapt to climate change. Communities that are highly food-insecure or particularly vulnerable to climate change will necessarily prioritise adaptation, but many of the changes they might make to enhance resilience will also increase productivity and efficiency of inputs (fertilizer and water use), and even have co-benefits for mitigation,"

Climate Risk Management (CRM)

According to the International Research Institute for Climate and Society (IRI)[1] , climate risk management (CRM) refers to the use of climate information in a multidisciplinary scientific context to cope with climate's impacts on development and resource management problems. Further, IRI's definition elaborates that climate risk management covers a broad range of potential actions, including early-response systems, strategic diversification, dynamic resource-allocation rules, financial instruments, infrastructure design and capacity building. CRM is the use of climate information to cope with possible impacts of climate change on development and resource management (African Development Forum, 2010).

According to the World Meteorological Organization (WMO), climate-related risk management refers to appropriate climate information distribution through an efficient delivery system that can alert food officials to assure food and water security long before the actual natural hazard sets in.

According to the United Nations Framework Convention on Climate Change (2011) CRM refers to different aspects of the risk management process, including: (a) risk assessments for informed decision-making; (b) risk reduction: planning and preparation; and (c) risk sharing, pooling and transfer in the context of adaptation.

It is widely recognized that CRM revolves around the use of climate information and focuses on better management of climate variability as a starting point to determine vulnerability to the current climate conditions, including variability and weather extremes and then to assess how vulnerabilities might change as a result of climate change

Tools of Agriculture Risk Management (ARM)

Tools of the ARM commonly include early warning systems, irrigation infrastructure or improved agronomic or climate-smart agriculture practices such as agro-forestry or conservation agriculture etc.

Farmers are particularly vulnerable to climate change and ARM can play a key role in protecting them. All risks are eventually transmitted across the agriculture sector (and along the various supply chains), but production risks such as weather shocks and pests and diseases generally affect farmers the most. Farmers are also the members of the supply chain with the lowest adaptive capacity, the highest incidence of poverty and are therefore highly vulnerable.

History of climate-smart agriculture?

FAO coined the term CSA in the background document prepared for the 2010 Hague Conference on Food Security, Agriculture and Climate Change. The CSA concept was developed with a strong focus on food security, for now and the future, including adaptation to climate change. The CSA concept now has wide ownership among, governments, regional and international agencies, civil society and private sector. Climate-Smart Agriculture was placed on the political agenda during the UN Climate Summit on 23 September 2014. In 2011, Wageningen University & Research already initiated a global research alliance on Climate-Smart Agriculture. The Dutch government has now taken this subject to the international political arena. In New York, 75 countries agreed that measures should be taken to drastically increase food production with substantial reduction of resource usage and greenhouse gas emissions.

In the above context, Haryana in northern India, is a landlocked state that is scaling up implementation of the "Climate Resilient Agricultural Practices-Climate Smart Villages" Project. The objective is to strengthen the adaptive capacity of 75,000 farming families/communities in 250 villages of 10 largely paddy/wheat growing districts (Yamunanagar, Ambala, Kurukshetra, Karnal, Jind, Kaithal, Panipat, Sonepat, Sirsa and Fatehabad) to climate change and variability. The project was earlier piloted in 27 villages of District Karnal jointly by the International Maize and Wheat Improvement Center (CIMMYT), National Innovations in Climate Resilient Agriculture (NICRA) Project under Indian Council of Agricultural Research (ICAR) and the Department of Agriculture & Farmers Welfare, Government of Haryana. The climate smart villages in this pilot project successfully adopted a portfolio of interventions for managing water, weather, nutrient, carbon, energy and knowledge. Dr A. K. Sikka, Deputy Director General of the Natural Resource Management Division of the Indian Council of Agriculture Research's (ICAR) and leader of ICAR's National Initiative on Climate Resilient Agriculture (NICRA) was accompanied by Dr. D.K. Sharma, Director of the Central Soil Salinity Research Institute, and Dr. P.C. Sharma, one of the Institute's principal scientists, along with other scientists from ICAR and CIMMYT. Participants agreed that South Asian agriculture needs new technologies, community-based adaptation of relevant practices and the strengthening of local decision-making. The model of innovation platforms for strategic participatory research and learning at Climate-Smart Villages was recognised as an effective method to link science with development**.**

Agricultural insurance overview

Comprehensive Crop Insurance Scheme (CCIS), the first nationwide insurance scheme, from kharif 1985 to kharif 1999, was replaced by the National Agricultural Insurance Scheme (NAIS). The Agriculture Insurance Company of India Limited (AICI), the largest insurance provider to the agricultural sector in India, is responsible for implementing NAIS. In addition to NAIS, there are two other schemes: the Modified National Agricultural Insurance Scheme (MNAIS), a modification of the NAIS that is area-based, and the Weather-Based Crop Insurance Scheme (WBCIS), which is based on weather data, with rainfall and temperature being the primary parameters.

NAIS, MNAIS and WBCIS were the three predominant crop insurance schemes being implemented in most states of India. NAIS, MNAIS and WBCIS are AICL-based—government-run. But several private insurance companies, too, have been allowed to operate MNAIS and WBCIS (Bhushan *et al*., 2015) [2].

A new crop insurance scheme named Pradhan Mantri Fasal Bima Yojana (PMFBY) has been launched by the government of India in April 2016. The new scheme will replace NAIS and MNAIS. In the case of WBCIS, the government has declared that premium rates would be rationalized on par with PMFBY.

Concepts of climate smart agriculture (CSA)

The agriculture sector is mostly vulnerable to climate change because different crops and animals thrive in different conditions. This makes agriculture highly dependent on consistent temperature ranges and water availability, which are exactly what climate change threatens to undermine. The relationship between agriculture and climate change is a two-way street: agriculture is not only affected by climate change but has a significant effect on it in return. Globally, agriculture, land-use change and forestry are responsible for 19-29% of greenhouse gas (GHG) emissions. Within the least developed countries, this figure rises to 74% (Vermeulen *et al*. 2012; Funder *et al*. 2009). If agricultural emissions are not reduced, agriculture will account for 70% of the total GHG emissions that can be released if temperature increases are to be limited to 2°C. The mitigation options available within the agricultural sector are one of the three pillars of climate-smart agriculture.

Climate-smart agriculture would ideally invest in and promote innovative, adaptive farming communities working towards restoring and conserving soil health. It will also use land and water optimally, do seed selection (judicially) and adapt to uncertain weather conditions armed with the knowledge of options, choices and resources to use them. Climate-smart agriculture is not an option; it is a necessity for now. The first pillar of climate-smart agriculture is productivity. Farmers need productivity, along with adaptation and mitigation efforts. Climate-smart agriculture should create readiness to deal with extreme weather conditions and weather uncertainties, which are becoming the new normals. Management of water resources cannot be left to governments only. Every citizen and every farmer has a responsibility. Every climate-smart farmer would incorporate practices like farm ponds, bundings, trenching, mulching, micro-irrigation, water harvesting and other practices for conservation of soil moisture, use of appropriate seeds and on-farm inputs to avoid debt situations and to have better access and control over required water resources. Farmers should implement climate-smart practices such as laser-land leveling, alternate wetting and drying in rice, reducing run off, improving soil health for higher returns. Farmers should also be aware about medium range weather forecast agro-advisories issues by concerned AMFUs through ATIC, KVKs, Agriculture/Horticulture Departments, Radio, TV, News Paper, registered E-mails, University web-site, IMD web-site and also can receive SMS on their registered mobile phones, with inputs from meteorological departments, scientists, input dealers and farmers, which allow them to make timely decisions for input application and mid-term mitigation of climate risk. Agricultural Insurance is another option of protecting the farmers against financial losses due to uncertainties that may arise like: extreme weather events pest and diseases etc. arising from named or all unforeseen perils beyond their control (AIC, 2008) [1].

The CSA Approach

CSA is not a set of practices that can be universally applied, but rather an approach that involves different elements embedded in local contexts. CSA relates to actions both on-farm and beyond the farm, and incorporates technologies, policies, institutions and investment.

Different elements of climate-smart agricultural systems include

- Management of farms, crops, livestock, poultry, aquaculture and capture fisheries to balance near-term food security and livelihoods needs with priorities for adaptation and mitigation.
- Ecosystem and landscape management to conserve ecosystem services that are important for food security, agricultural development, adaptation and mitigation.
- Services for farmers and land managers to enable better management of climate risks/impacts and mitigation actions.
- Changes in the wider food system including demand-side measures and value chain interventions that enhance the benefits of CSA.
- Information dissemination and adaptation regarding weather forecast, weather based strategies and activities in agriculture system for benefit of end users.

Weather or climatological events for agricultural risks

Change in the occurrence of temperature extremes has been observed since the mid-20th century, some of which can be attributed to anthropogenic or man-made climate change (IPCC 2013) [9]. Both heat and cold-day extremes have a detrimental impact on crops, but climate change will have different impacts on the probability of the occurrence of these events in a given season. According to the IPCC (2013) [9], the number of cold days and nights has decreased over the past several decades, while globally the number of warm days and nights has increased. Further, extreme minimum temperatures have had a strong increasing trend in each season over the last several decades. Significantly, the frequency of heat waves over a large part of Europe, Asia, and Australia has increased, with the probability of heat wave occurrence more than doubling in some locations (IPCC 2013) [9].

Short-term temperature extremes can be critical for plant growth, especially when coinciding with key stages of plant development. Plant physiology can be significantly altered beyond key temperature thresholds, leading to the potential for severe crop yield impacts from projected climate change (Gornall *et al*. 2010) [7]. For many crops, when a plant enters its flowering stage (including right before and after), just a few days of extreme temperatures (greater than 32°C) can drastically reduce yield (Wheeler *et al*. 2000) [17]. For rice, if temperatures at flowering exceed 35°C for more than just one hour, high percentages of the grains become sterile (Luo 2009). Full day cloud cover (BSSH=0) at the time of anthesis in rice may cause 10-15% sterility each day. In an experiment, soybeans produced nearly one third less in seed yields after experiencing a 10°C temperature increase for 8 days during the late flowering stage and early pod filling (Luo 2009). Short-durations of high temperatures can also impact crops in other ways. Despite being typically produced in high temperatures, groundnuts for instance see severely reduced yields when temperatures exceed 42°C even for short periods of time during post-flowering (Prasad *et al*. 2003) [15]. For maize, short periods above 36°C reduce its pollen's viability. Crop yields are negatively impacted by temperatures above 29°C for corn, 30°C for soybean and 32°C for cotton (Gornall *et al*. 2010) [7].

Droughts arise from combinations of five factors: (1) Delays in the onset of rain or rainy seasons; (2) early cessation of rain or the rainy season; (3) prolonged periods without rainfall resulting in an unusual rainfall distribution; (4) a lack in the volume of cumulative rainfall over the growing season; and (5) water and soil moisture deficits during critical stages of crop growth (for example, flowering). All of these factors are likely to be impacted by climate change. Some areas have already experienced more intense and longer droughts due to climate change, in particular southern Europe and West Africa (IPCC 2011). Arid areas are prone to drought because the amount of rainfall often critically depends on a small number of rainfall events (Dai 2011) [4]. Since the 1960s, major growing areas of barley, maize, rice, sorghum, soybean, and wheat globally have seen an increase in the percentage of area affected by drought, from approximately 5–10 percent to approximately 15–25 percent as defined in terms of the PDSI (Gornall *et al*. 2010) [7].

Increased precipitation events

Rising temperatures generally lead to heavier precipitation events for two reasons. First more evapotranspiration under higher temperatures results in more water vapor present in the atmosphere. Second, simultaneously, a warmer atmosphere can hold a greater amount of moisture (UCSUSA 2011).

Heavy rainfall can severely impact crop production. Overabundant water can result in reduced plant growth due to poor seed distribution, germination and emergence, soil and nutrient erosion, soil water logging, siltation of water storage areas, and floods. For rice, it is especially harmful when heavy rain falls on freshly seeded fields, and is worse if the field has been wet direct seeded. Heavy textured soils tend to have a worse result (IRRI 2009) [11]. Heavy rainfall at the crop maturity stage may be linked to crop lodging, delayed harvest, higher grain moisture content, potentially lower grain quality and increased frequency of fungal disease infections of the grain (Kettlewell *et al*. 1999) [12].

The agricultural regions found most vulnerable to tropical cyclones include the United States, China, Vietnam, India, Bangladesh, Myanmar, and Madagascar. The river deltas of countries along the North Indian Ocean are especially vulnerable because farming in coastal regions most at risk from flooding has increased due to high population growth (Webster 2008) [16].

Hailstorms are an extreme event very frequently associated with risk for agriculture. It is typically considered a localized event.

Indirect effects of climate and weather events—pests and diseases

Climate change will have significant impacts on the occurrence of pests and diseases because weather exerts an influence on all stages of host and pathogen life cycles and the development of disease. Increasing climate variability, higher average temperatures, warmer winter minimum temperatures, changes in precipitation patterns, and water shortages are all climate factors that may favor pest and disease attacks.

Temperature increases may also advance invasion in the growing season, when the crop is at early development and susceptible. Precipitation increases are also likely to favor the development of fungal and bacterial pathogens (Parry 1990). Similar developments are already ongoing, for instance with the coffee berry borer (*Hypothenemus hampei*) having become more prevalent in East Africa due to existing warming (Jaramillo *et al*. 2011) [10].

Aphids may also benefit from increased temperatures, which prevent them from dying in large numbers during the winter and may allow the species to disperse earlier and more widely (Zhou *et al*. 1995) [19]. As a result of rainfall-based migration patterns, precipitation variability due to climate change may affect locust occurrences in sub-Saharan Africa (Cheke and Tratalos 2007) [3].

Risk management strategies

Weather-indexed insurance

Since the new investments are risky, insurance packages help the farmer to try new technologies. The insurance companies allow farmers to get insurance covers for the new technologies such that if they fail, farmers will not get losses as the insurance company compensates them.

Farming or crop production being a biological process, converting input into output carries the greatest risk in farming. This, coupled with market risk, interrupts on the profits expected from farming. Weather-indexed insurance can help farmers protect their overall income rather than the yield of a specific crop, improve their risk profile enhancing access to bank credit, and hence reduce overall vulnerability. Some of pilot schemes and delivery models operated in India are:

1. ICICI Lombard pilot scheme for groundnut in Andhra Pradesh
2. KBS pilot scheme for soya farmers in Ujjain
3. Rajasthan government insurance for orange crop
4. IFFCO-TOKIO monsoon insurance
5. AIC Varsha Bima Yojana (rainfall insurance scheme)
6. AIC Sookha Suraksha Kavach (drought protection shield)
7. AIC coffee rainfall index and area yield insurance
8. ICICI Lombard loan portfolio insurance
9. ICICI-LOMBARD General Insurance Company

10. Reliance General,
11. Oriental Insurance

In India, weather index insurance was introduced to farmers in 2003. In 2007, the national government adopted it as an alternative to crop-yield index insurance. By 2012, up to 12 million farmers, growing 40 different crops over 15 million hectares, were insured against weather-related losses. Despite its potential, weather index insurance can fail to benefit farmers if the information available to the insurance company does not reflect the reality in the fields. CCAFS has played a critical role in improving agricultural insurance products to meet the needs of farmers by enriching the information that the Agriculture Insurance Company of India (AIC) uses for weather index insurance. This involved strategic use of spatial weather, soil and crop management data together with regionally validated crop modelling work to identify critical rainfall thresholds for different crop growth stages. These thresholds are now used by the Agricultural Insurance Company of India (AIC) to develop rainfall index insurance schemes for rice and other crops.
In this context, it is noteworthy that the Pradhan Mantri Fasal Bima Yojana (PMFBY), which is a yield index based crop insurance scheme launched in 2016, has made substantial progress with more ground coverage compared to erstwhile schemes. During Kharif 2016 season 23 States implemented PMFBY and during Rabi 2016-17, 25 States/Union Territories implemented PMFBY. During 2016-17, the target of 30 percent of the Gross Cropped Area (GCA) in the country for PMFBY has been achieved. In 2016-17, for a gross premium of Rs. 22,004 crore, overall coverage was 571 lakh farmer applications and 554 lakh ha area insured for a sum of Rs. 20,2145 crore. As on December 2017, under PMFBY, total claims of Rs. 13,292 crores have been approved for 116 lakh farmers (applications) and Rs. 12,020 crores have been paid (Economic survey, 2017-18) [5].

Table 1: State-wise Insured Area 2014–15 (area in million hectares)

States	2014-15		
	Gross Cropped Area	Area Insured	% of Area Insured
Rajasthan	23.95	11.91	49.70
Bihar	7.78	3.74	48.02
Madhya Pradesh	23.13	10.62	45.91
Maharashtra	21.87	4.87	22.26
Karnataka	11.75	1.44	12.25
Gujarat	12.60	1.39	11.03
Uttar Pradesh	25.82	2.05	7.95
Andhra Pradesh	13.65	0.54	3.96
All India Level	194.4	45.34	23.32

Source: Department of Agriculture, Cooperation and Farmers Welfare

Table 2: Crop-wise Insurance Coverage under All Schemes (Area in Million Hectares)

S. No.	Crops	2014-15		
		Gross Area Sown	Area Insured	Insurance Coverage (%)
1	Paddy	42.76	10.02	23.43
2	Wheat	30.50	7.74	25.39
3	Coarse Grains	25.15	5.95	22.88
4	Sugarcane	5.44	0.15	2.67
5	Cotton	11.90	1.53	12.92
6	Jute and Mesta	0.85	0.07	8.18
7	Oilseeds	29.10	10.43	35.84
8	Pulses	21.96	5.77	26.27
9	Vegetables	5.51	2.09	37.99
10	Fruits	3.77	0.21	5.58
	Grand Total	194.40	45.34	23.32

Source: Department of Agriculture, Cooperation and Farmers Welfare

In view of the limited coverage of existing crop insurance schemes, as shown above and taking note of the financial burden and other difficulties faced by the farmers under these schemes, a new Crop Insurance Scheme namely, Pradhan Mantri Fasal Bima Yojana has been approved by the government in January 2016. The Scheme will replace the ongoing schemes of NAIS/MNAIS from kharif 2016. Salient features of the new Scheme are given

Features of Pradhan Mantri Fasal Bima Yojana (PMFBY)
The Union Cabinet, chaired by the Hon'ble Prime Minister, approved the 'Pradhan Mantri Fasal Bima Yojana' - a path breaking scheme for farmers' welfare on 13th January, 2016. Key features of the Scheme are as follows:

a. For food and oilseeds crops, farmer's share of premium has been reduced to 1.5 per cent for rabi crops and 2.0 per cent for kharif crops. For annual commercial/horticultural crops, the premium has been kept at a maximum of 5 per cent.
b. Provision of capping of actuarial premium rates and reduction in sum insured has been removed.
c. Three indemnity levels – 70 per cent, 80 per cent and 90 per cent.
d. Inundation has been incorporated as a localized calamity for individual farm level assessment.
e. For more effective implementation– cluster approach will be adopted under which a group of districts with variable risk profile will be allotted to an insurance company for a longer duration say 3 years.
f. Use of Remote Sensing Technology and improved technology for planning and assessment of crop losses/yield estimation. g) Better administration of crop insurance through Crop Insurance Portal by linking/coordination with major stakeholders including financial institutions insurance companies, etc.
g. Premiums rates under WBCIS have been rationalized to make it at par with the new scheme.

Table 3: Agricultural Insurance Schemes in Operation

Modified NAIS (since Rabi 2013-14)	Andhra Pradesh (4 districts), Goa, Kerala, Rajasthan, Uttar Pradesh (65 districts) & Uttarakhand.
WBCIS (since Rabi 2013-14)	Assam, Andhra Pradesh (few districts), Himachal Pradesh, Kerala, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan, Telangana, Uttarakhand, Uttar Pradesh (10 districts) & West Bengal.
NAIS (since Rabi 1999-2000)	Assam, Andhra Pradesh, Bihar, Chhattisgarh, Gujarat, Himachal Pradesh, Jharkhand, Karnataka, Maharashtra, Madhya Pradesh, Odisha, Tamil Nadu, Telangana & West Bengal.
No crop insurance	Punjab, Arunachal Pradesh & Nagaland
Occasional	Haryana, Manipur, Meghalaya, Sikkim, Tripura

Protecting smallholder farmers against weather-related risks

Smallholder farming provides a key part of people's income, national GDPs, and global food supply. Vulnerability to climate-related shocks is a constant threat to their food security, income and well-being. Climate change will only exacerbate this vulnerability with more frequent and intense climate hazards, such as floods and droughts. These risks are further compounded by a lack of capacity to manage them. A lack of natural resources, quality inputs and technology, transport and storage, connection to markets, and financial services, make smallholders particularly vulnerable to crop yield gaps and losses, jeopardize their ability to advance beyond the poverty line towards greater prosperity and food security. Strategies for reducing and mitigating risks are therefore essential to overcoming hunger, achieving food security and enhancing resilience.

Integrated Farming system (IFS)

Integrated farming has immense potential to make farmers climate smart through the cultivation of different crops on the same land and using farm resources sustainably [3]:

- CSA involves integrated resource management for maximum productivity
- It involves best utilisation of the growing space through the integrated farming approach
- Nutritional and economic security is ensured for better health of the farm family as they get different fruits, cereals, vegetables, livestock products and cash crops from their own land. It boosts food security through local production and consumption and checks migration
- This improves soil's physical and chemical properties, its nutrient status and biological components. Such interactive systems affect the microclimate and provide a strong base to good agricultural practices for increased productivity

Information Communication technologies (ICTs)

One key role of institutions is the production and dissemination of information, ranging from production and marketing conditions to the development of regulations and standards. Improving the use of climate science data for agricultural planning can reduce the uncertainties generated by climate change, improve early warning systems for drought, flood, pests and disease incidence and thus increase the capacity of farmers and agricultural planners to allocate resources effectively and reduce risks. Farmer Field Schools (FFS) are a participatory approach to farmer education and empowerment. The aim of the FFS should be to build farmers' capacity to analyze their production systems, identify problems, test possible solutions and eventually adopt the practices and technologies most suitable to their farming system. Scientific knowledge and technical capacity building for promotion as eco-friendly and climate resilience techniques may overcome the risks of farming community.

Reducing emissions

Around 41 per cent of GHG come from agriculture, there are a number of practices that can reduce emissions from agriculture. One is alternate wetting and drying of paddy. "By reducing the frequency of irrigation (letting the fields drain periodically), methane emissions from flooded rice production can be cut in half," The livestock sector contributes to about 14.5 per cent of human-induced GHG, much of which is methane produced by ruminant digestion. "Increasing animal and herd productivity means that fewer animals are required to produce the same amount of milk or meat, which also reduces the emissions generated in producing that food."

Weather based agromet advisory bulletin

Climate information services are a powerful tool that live up to their promise of adaptation in agriculture by helping farmers both to protect against drought and take advantage of good climate conditions. Experience in climate services is already out there—the governments of India and Mali have been delivering weather and climate advisory services to their farmers for several decades. Integrating traditional forecasting methods with scientific forecasting can also provide insights into current knowledge gaps at the local level, and increase farmers' trust in scientific forecasting. For communicating seasonal forecast probabilities, face-to-face interaction remains a superior medium for service delivery through training, communication and workshops with farmers, offering an effective way for tailoring information to farmer needs, training to understanding the complexities of information, and planning around historic variability and seasonal prediction. Ministry of earth science (MoES) through India Meteorological Department (IMD) issued medium range forecast twice in a week, district wise and disseminated weather based advisory for end users with the help of 130 AMFUs in all over India for next 5 days on every Tuesday and Friday. Climate smart farmers can use these advisories to avoid risks in their farm which is disseminated through University web-site of concerned state, IMD website, radio, television, news-paper, ATIC, KVKs, NGOs Agriculture Departments, registered E-mails and SMS etc.

Weather Risk Management Facility (WRMF)

The Weather Risk Management Facility (WRMF) is a joint initiative by the World Food Programme (WFP) and the International Fund for Agricultural Development (IFAD) established in 2008 to reduce smallholders' vulnerability to weather and other risks that limit agricultural production. It aims to encourage and protect investments in smallholder agricultural production, and enhance food security.

WRMF Activities

- High quality operational research
- Capacity building in weather risk management for food security and agriculture

- Implementing initiatives for innovative risk management solutions, such as agricultural index insurance (including weather, and remotely-sensed indexes). These solutions can be mainstreamed within WFP's and IFAD's programmes, as well as those of other partners, for an integrated resilience building approach to climate disasters and change.

Risk-Reducing Strategies

Risk-reducing strategies adopted by farmers include crop diversification, inter-cropping / mix cropping, or cultivation of drought or flood resistant crops. Diversification of activities, engaging in nonfarm/ off-farm activities, getting into contractual arrangements such as share cropping, labour hiring, etc. also form a part of risk reducing / risk mitigating strategies.

Since pre-historic times, residents of the Indian subcontinent have made efforts to understand the hydrological cycle, and the behaviour of the Monsoon. About 70 to 90 percent of India's total rainfall occurs in a few days during the Southwest Monsoon, and the amount and timing may vary a great deal from year to year, and from place to place. Therefore, the key to survival has been to build systems to harvest the seasonal rainfall, so that it is available over the remaining period until the next monsoon. Since time immemorial, societies in India have dealt with erratic rainfall and weather extremes by creating a culture of water harvesting. These traditional systems will be valuable resources for people to deal with changing climate.

Climate change poses serious challenges for rice production including: increasing temperature, both daytime and night; changes in rainfall, both total quantity and distribution throughout the growing season; extreme weather hazards, which can damage crops; and sea-level rise, especially affecting the major river deltas. Research on climate change adaptation includes breeding varieties of rice that are tolerant of one or more climate stresses, such as heat, drought, submergence and salinity.

The waterlogged and warm soils of rice paddies make this production system a large emitter of methane. Rice production is and will be affected by changes in climate. Irregular rainfall, drier spells in the wet season (damaging young plants), drought and floods are all having an effect on yields. This has also caused outbreaks of pests and diseases, with large losses of crops and harvested products.

A number of methods and practices are being adopted to address these challenges. For example, production systems have been adapted by altering cropping patterns, planting dates and farm management techniques. For instance, embankments have been built to protect rice farms from floods and new drought and submergence tolerant varieties of rice are being produced and distributed by government institutions and the private sector. System of rice intensification may reduce methane emission and increases production. In addition, many farmers are diversifying their production systems, growing other cereals, vegetables and rearing fish and animals (such as pigs, chickens, mushroom and honeybees). The residues and waste from each system are being composted and used on the land, thereby reducing the need for external inputs. This diversification has increased incomes, improved nutrition, built resilience to shocks and minimized financial risks. The development of advanced modeling techniques, mapping the effect of climate change on rice growing regions and providing crop insurance are other examples of managing risks and reducing vulnerability.

Crops: Conservation Agriculture

Conservation Agriculture (CA) is a term encompassing farming practices which have three key characteristics: 1. minimal mechanical soil disturbance (i.e. no tillage and direct seeding); 2. Maintenance of a mulch of carbon-rich organic matter covering and feeding the soil (e.g. straw and/or other crop residues including cover crops); and 3. Rotations or sequences and associations of crops including trees which could include nitrogen-fixing legumes. They cover all agro-ecologies and range from small to large farms. CA offers climate change adaptation and mitigation solutions while improving food security through sustainable production intensification and enhanced productivity of resource use. They cover all agro-ecologies and range from small to large farms. CA offers climate change adaptation and mitigation solutions while improving food security through sustainable production intensification and enhanced productivity of resource use. Rotations and crop associations that include legumes are capable of hosting nitrogen-fixing bacteria in their roots, which contributes to optimum plant growth without increased GES emissions induced by fertiliser's production.

Agro-forestry

Agro-forestry is the use of trees and shrubs in agricultural crop and/or animal production and land management systems. It is estimated that trees occur on 46 percent of all agricultural lands and support 30 percent of all rural populations (Zomer *et al*., 2009) [18]. Trees are used in many traditional and modern farming and rangeland systems. The use of trees and shrubs in agricultural systems help to tackle the triple challenge of securing food security, mitigation and reducing the vulnerability and increasing the adaptability of agricultural systems to climate change. Trees in the farming system can help increase farm incomes and can help diversify production and thus spread risk against agricultural production or market failures. Agro-forestry systems tend to sequester much greater quantities of carbon than agricultural systems without trees. Planting trees in agricultural lands is relatively efficient and cost effective compared to other mitigation strategies, and provides a range of co-benefits important for improved farm family livelihoods and climate change adaptation.

Fisheries and aquaculture

Production systems and livelihoods, already in crisis from over-fishing, poor management and impacts from other terrestrial anthropogenic influences, are likely to succumb further as the frequency and intensity of storms increase and extreme weather events become more common. Fishers, as well as other community members, will be at greater risk of losing their lives and assets, such as boats, fishing equipment and aquaculture infrastructures. Climate resilient sustainable intensification of aquaculture must occur to meet growing consumption needs and is being achieved by improving management approaches and through the selection of suitable stock (for example through saline resistant species in zones facing sea level rise). Improved energy efficiency and decreased use of fish meal and fish oil feeds are essential mitigation strategies as these inputs are the main carbon footprint in aquaculture systems. Increasing feeding efficiency or switching to herbivorous or omnivorous species, such as carp, greatly reduces the need for fish feed inputs and achieves much higher input/output ratios than other protein sources, such as salmon. The integration of aquaculture within broader farming landscapes provides further opportunities, for example sludge produced during the treatment of aquaculture wastewater or pond sediments can be used to fertilize agricultural crops.

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