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A REVIEW

Strategies towards climate resilient agriculture

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ABSTRACT : The climatic changes have solid impacts on agricultural production system posing a great challenge for the global food security. Thus, the current situation demands knowledge about the unpredictable climatic events and the actions to be taken up. Basically, the three pillars of climate change mitigation, adaptation and resilience can be adopted. The techniques and technologies need to reach every sector of the society, especially to the farmers. Primarily, the changes can be brought up mainly at farmers mind set, at farmers field level and at policy makings. Hence, the knowledge horizon of the farmers must be enlarged and new techniques and technologies are to be deployed at farmers filed level. The existing developments and policies need to well utilized by the farmers. In addition to that, new policies and technologies are to constructed. However, National Initiative on Climate Resilient Agriculture (NICRA) was launched by the Indian Council of Agricultural Research (ICAR), New Delhi, during 2010-11, in 100 vulnerable districts. Indeed, the fight against climate change is a future win for our both food and financial security.

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Key Words :
Climate change, Climate resilient agriculture, Climate adaptation, Climate mitigation, Agriculture, agricultural production system, NIC

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The elevated rate of climate change makes the environment adaptation difficult (Lamboll *et al.*, 2017). However, the Intergovernmental Panel on Climate Change (IPCC) defines Climate Change as 'any change in climate over time, whether due to natural variability or as a result of human activity'. Interestingly, one of the major contributors of climate change is agriculture. The anthropogenic activities such as, burning biomass, use of organic and synthetic fertilizers, swamp rice production and maintenance of live stock production etc. contribute to global warming (Lamboll *et al.*, 2017) and thereby the climate change. The result of climate change are extreme and unpredictable weather conditions such as high temperature, rise in sea level. Over the past century there is an increased temperature extremes all over Asian continent (Pound *et al*., 2018). By the mid of twenty first century the global temperature could increase more than 2^0C (IPCC, 2014a). However, agriculture is the major sector which is highly influenced by the effect of climate change. This implies that the actions and reactions of are intertwined. In addition to that, the global sustainable goals are ultimately under threat.

In India, the climate change can cause a huge loss to the agriculture due to multiple reasons such as vagaries of rainfall, drought, flood, cyclone, heat wave, cold wave, rise in sea water, saline water intrusion, decreased quality of irrigation water, declined soil fertility, pests, weeds and disease incidences. The rain fed area covers almost 60 per cent of India's

cultivating land. The risk associated with rain fed cultivation is accelerated with climatic aberrations. The farmers are at risk in terms of physical, financial and social capital (Jasna *et al*., 2014).

Now, understanding the vulnerability of agricultural sector towards climate change highly important. However, vulnerability is referred to as the ability of a community, group or individual to cope with the impacts of a hazard and to recover. The vulnerability can be measured in terms of degree of exposure towards climatic changes, the extent to which one has been directly or indirectly affected and also the ability to cope up, recover and adjust towards the climate change impacts. Not only that, the technological developments, prevailing culture and tradition, gender and governance also determines the sensitivity to the impacts of climate change (Swaminathan and Kesavan, 2012). Thus it is clear that, the developing and under developed countries are more prone to the climate change hazards. Such is the case with India, where a large population depend on agriculture, huge pressure on natural resources along with poor mechanization.

Thus the current scenario demands all the possible ways to tackle the effects of climatic changes. The efforts need be initiated from grass root level. A well planned and organized strategies must be implemented both at national and international levels. Of course there are schemes and policies implemented by different organizations and governments all over the world. Still the knowledge horizon of farmers and citizens must be enhanced regarding the impact of the climate change on the food security and the steps to be taken in order to dilute or eradicate the situation. Therefore it is significant to understand and implement the strategies such as adaptation, mitigation and climate resilience in agricultural practices.

With the objective of enhancing resilience of Indian agriculture, to climate change and vulnerability the Govt. of India has announced National Innovations on Climate Resilient Agriculture (NICRA) in February, 2011. The project was implemented in 100 districts of India (Pise *et al*., 2018). In addition to that, Climate Resilient Agriculture (CRA) which is one of the four pillars of Action on Climate Today (ACT) programme is funded by UK Department for International Development.

It is high time to understand and implement climate resilient agriculture as climate change is one of the major challenge to be faced globally. This paper aims to review about the strategies towards climate resilient agriculture whose adoption is a serious matter of concern for the current and future generation.

Climate change and agriculture: Interrelation:

Indeed, climate change and agriculture are interlinked with each other. Anthropogenic activities which include both agricultural inputs and practices are a major contributor of green house gas emission and thereby the climate change. The impact of climate change influence the potential of current agricultural scenario. The events of climate change are change in pattern of precipitation, extreme temperature variation, unpredictable climatic events. Climate change negatively influence the biodiversity and agriculture, live stocks, human lives and settlements and also the financial status of people specially the framers. Interestingly 31 per cent of total green house emission is contributed by forestry and agriculture (17.4% and13.5%, respectively) (IPPC, 2007). However, the sources of other proportion (69%) of green house gas emission are transport, industry, buildings, energy, waste water and waste. Which clearly reflects that, forestry, agriculture and land use sectors contribute to nearly one third of the global green house gas emission. More over, livestock system accord for 18 per cent of human generated green house gases. From the livestock system about 25 per cent of methane (CH_4) is generated from the belching of animals, 32 per cent of carbon dioxide (CO_2) is produced from the decomposition of organic substances and 31 per cent of nitrous oxide (N_2O) is released from spread out manure and slurry over land (Swaminathan and Kesavan, 2012).

The agricultural production is adversely interrupted by the saline water intrusion by the rise in sea water level (Pound *et al*., 2018). Also, there is a chance of shifting crop production towards northwards, where the cooler regions are likely to benefit from the warmer temperatures and thereby an increase in their arable area (Altdorff *et al*., 2018). The pattern of monsoon is also changing such that, end of the year receives monsoon rain accompanied by longer dry spells within the monsoon period. This results in late harvest of *Kharif* (wet) season crops and hence late sowing of the preceding *Rabi* (dry) crops (Pound *et al*., 2018). The crop productivity is expected to fall off in many part of South Asia unless there is a change in crop varieties and management

practices (Ban *et al*., 2008). IFPRI reported that, Asia will be highly influenced by climatic aberrations and there will be a significant reduction in the crop yield (Meehl *et al*., 2009). Climate change may enhance the out break of pests and diseases which can severely reduce the production (Chakraborty and Newton, 2011). The existing hybrids may not be able to adapt with the climatic variations. In India, there are evidence of poor yield of wheat and paddy with the increased temperature, reduced number of rainy days and water stress. The impact of medium term (2010-2039) climate change estimates an yield reduction of 4.5 to 9 per cent on agriculture according to the variation on magnitude and distribution of warming. Hence in India, the cost of climate change per year accounts for about 1.5 per cent of Gross Domestic Product (Kumar *et al*., 2018). There fore, enhancing the agricultural productivity is critical for ensuring food cum nutritional security to the resource poor farmers.

The impact of climate change also influence the human settlement. Floods and cyclones are the most significant hazards faced by the Asian cities (Adhikari *et al*., 2010). In case of floods, the highest lost of lives and property is seen in India, Bangladesh and Pakistan. In addition to that, the coastal communities are more prone to cyclone as a result of rise in sea level of Indian Ocean (IPCC, 2014b).

The submergence of low laying areas of Sundarbans in turn resulted in the displacement of thousands of people (Aalst *et al*., 2003). In 2007, the flooding along the coast of Ganges and Brahmaputra rivers has severely affected more than 13 million people in Bangladesh. In 2010, more than 20 million people in Pakistan was affected due to flooding. The flood of 2007 in Bangladesh caused a loss of worth over $1 billion while in Pakistan it was about $10 billion (IWMI, 2011). It is estimated that, in Bangladesh the climate change can cause a net increment of poverty of about 15 per cent by 2030 (CDKN, 2014).

Need for technological adaptation towards climate change:

The current scenario demands a deep understanding of the impact of climate change along with all the possible ways to win the situation. Such understanding and actions must carried out through both the top down and bottom up approaches. The knowledge base of farmers must be spread out to the policy makers inter linked with the making and adoption of new schemes and policies by the governments all around the world. If agricultural production falls under treat, it directly influence food security and lively hood of billions of people around the globe. Different techniques and measures can be done in order to tackle the situation. Mitigation, resilience and adaptation are three interacting ways to address the climate change (Pound *et al*., 2018). Climate change mitigation refers to efforts to reduce or prevent emission of green house gases. Mitigation means using new technologies and renewable energies, making older equipment more energy efficient, or changing management practices or consumer behaviour. Whereas, resilience can be defined as 'the capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation'. Adaptation is the process of deliberate adjustment to actual or expected climate and its effects (IPCC, 2014b). The ways to improve the capabilities of households, communities and countries to cope up with the impacts of climate change are well described by resilience and adaptation.

However, resilience deals with uncertainty, surprise and recovery from unexpected events whereas adaptation engages with specific, anticipated risks to mitigate their impact. Adaptive change can be both incremental and transformational. Changes are brought out in present practices and structures in *incremental* changes while present practices and structures are replaced by better ones in transformational changes (Pound *et al*., 2018). But, adaptation measures often fail to address interactable and persistent vulnerabilities thus limiting its success. Whereas, resilience provides clear understanding of how a system can be organized around different stable states, according to the circumstances of the people involved (Nelson *et al*., 2007).

All the ways of climate change mitigation, adaptation and resilience are equally important. Here we emphasis more on climate resilient agriculture. Techniques and technologies have to be adopted farmers field level along with expanded knowledge horizon and enhanced decision making capabilities must be inculcated to the farming community. New schemes and policies need to be brought out in accordance with the vagaries of climatic events.

Interestingly, the duel concepts of resilience and adaptation comes under the umbrella of Climate Smart

Agriculture (CSA) approach which is promoted by the Food and Agriculture Organization (FAO), the CGIAR Climate Change, Agriculture and Food Security (CCAFS) Research Programme and the World Bank. Climate Smart Agriculture is an approach to transform and reorient agricultural systems to safeguard food security under the new realities of climate change. The resilience cannot be restricted only to the agricultural production system rather need to deployed to the whole value chain of agricultural commodities to get rid of disasters. Thus, farming community need to exploit social networks such as, cash loans, shelter, moral support etc. and commercial opportunities such as sale of assets, petty trading, paid labour. Sometimes the situation demands for the temporary or permanent migration. The extremity to which climate change affects a community or household [their resilience and, conversely, their vulnerability (ADB, 2012b)] depends on their adaptive capacity, sensitivity to particular aspects of climate change and their exposure to the impacts (Lankao, 2005). The stability is determined by the resilience in agricultural production systems and value chains. In addition to that, safety and waste interlinked with the processing and food chains come under utilization. Climate resilient agriculture is a sub set of climate smart agriculture interventions with the specific objective of enhancing the agricultural and social systems. Under agricultural systems, off farm options such as livelihood diversification is also considered by the climate resilient agriculture which can be a viable option for many people. Sustainable agriculture is a common factor of climate resilient and climate smart agriculture, which encourages farming without depleting natural resources over long term and is based on ecological principles. Whereas, sustainable livelihoods is a holistic approach different household assets (natural, physical, financial, social and human) and external forces acting on them are brought together. The yields are enhanced in sustainable agricultural intensification without cultivating more land and without environmental impacts (Garnett and Godfray, 2012).

Considering the agricultural production systems, changes must be brought up at farmers mind set, farmers field and at policy generation level.

Components of resilience : Enriching farmer's mind set:

Climate change resilience requires flexibility, multifaceted skill set, redundancy, collaborative multi-sector approaches, planning and foresight, diversity and decentralization and plans for failure.

Flexibility at individual, organizational and systemic levels are needed wherein, each level react and contribute to every situation, and also to changing and unpredictable circumstances. A multi-faceted skill set reflects the abilities which help in thorough preparation such as, comprehensiveness and detail-orientation. Survival ability, such as quick decision making capability and resourcefulness. In addition to that, innovation and diligence helps in rapid recovery. Redundancy of processes, capacities and responses within an institution, community or system, to allow for partial failure within a system or institution avoiding complete collapse. Collaborative multi-sector approaches towards planning, execution and recovery, as no one sector has monopoly over a particular impact and thus understanding the overlaps and gaps between sectors is critical. Planning and foresight to get prepared for identified impacts and risks. Sometimes it is impossible to plan for every possible set of impacts, also in majority of cases the cumulative effect of impacts is unknown, the process of planning brings learning, builds skills, and helps to generate resilience. Diversity and decentralization of planning, response and recovery activities. Diverse options have greater potential to reciprocate the particular scenario of impacts that occurs, whereas, decentralization allows for portion of the system to continue operations even if other portion of the system are down. Plans for failure are necessary so that break-downs happen gracefully, not catastrophically. For example, during severe floods, the flood waters are channeled towards uninhabited flood zones protecting human lives and damaging only properties. Incremental failures and planning for failures will allow for timely response and revision and will reduce social, environmental and economic costs. However, total system failure limits response options and results in greater suffering (Kumar *et al*., 2018).

Technological approaches towards climate resilient agriculture :

Nourishing farmer's field :

At field level, potential adaptation strategies are modifying crop management practices, crop diversification, improving water and pest management, introducing new farm techniques like resource conserving

technologies (RCTs), better weather forecasting and crop insurance and harnessing the indigenous technical knowledge of farmers. Moreover, developing new cultivars which are tolerant to heat and salinity stress, resistant to flood and drought are also important. The adaptation strategies in turn help in enhancing the resilience of the agriculture production system (Jasna *et al*., 2014). The following approaches can be utilized at farmer's field.

– Building resilience in soil
– Adapted cultivars and cropping systems
– Rainwater harvesting and recycling
– Water saving technologies
– Farm machinery (custom hiring) centers
– Crop contingency plans
– Weather based agro advisories
– Village Climate Risk Management Committee (VCRMC)

(Source: Kumar *et al*., 2018)

Building resilience in soil:

Building resilience in soil carbon can be done by improving soil carbon, controlling soil erosion and by enhancing water holding capacity. The soil carbon can be build up with sources like, green manuring, organic manure addition, brown manuring, inter-cropping with legume sequester carbon, crop rotation or biochar. Biochar is a fine-grained, carbon-rich, porous product remaining after plant biomass has been subjected to thermo-chemical conversion process (pyrolysis) at low temperatures (~350–600°C) in an environment with little or no oxygen (Chandran *et al*., 2013). Cover cropping, mulching, strip cropping, use of wind breaks and shelter belts etc. can be adopted alone or in combination according to the land configuration and need. Under Tillage management conservation tillage is more advocated. Improved method of fertilizer application include soil test based fertilizer application and also use of new techniques such as SSNM and Leaf colour chart for rice, use of slow release fertilizer (coated urea), deep placement of urea, fertigation and INM.

Adapted cultivars and cropping systems:

Climate resilient agriculture needs use of improved, early duration drought, heat and flood tolerant varieties which obtains optimum yields despite climatic stresses. In addition to that, selection of cropping sequence is also highly important. Shallow rooted and deep rooted crops are be sequenced along with inclusion of leguminous crops are also needed. Crop diversification is yet another solution for climate change. Higher diversity of crops and live stocks helps in improving the resilience.

Rainwater harvesting and recycling:

Rainwater harvesting and recycling through farm ponds and restoration of old rainwater harvesting structures in dryland / rainfed areas can be taken up. Percolation ponds can be used for recharging of open wells, bore wells and injection wells and thereby recharging ground water. In fields, inter-row water harvesting can be done through crop residue mulches, coir pith which improves water holding capacity. Extra rain water which runs through the passage or furrows between the plots raising crop on the level land which is known as inter-plot or micro plot water harvesting.

Water saving techniques:

Water saving techniques such as direct seeded and drum seeded method of rice cultivation, zero tillage, micro irrigation can be employed. Improved plating techniques like BBF, FIRB, tied ridges, tied furrows which arrest water.

Farm mechanization:

Machines used for common resilient practices include: chisel plough, para plough, bund former, channel former, laser leveler transplanters, harvesters and intercultivators.

Crop contingency plans:

District level contingency plans are developed by ICAR or CRIDA to cope up with climate variability. Some of these plans are seed village and community nursery, community pond, pulse panchayat, use of community land for livestock and fishery interventions.

Weather based agro advisories:

Automatic weather stations are established at KVK experimental farms and mini-weather observatories in project villages to record real time weather parameters.

Village climate risk management committee (VCRMC):

A village committee is formed, representing all group of farmers including women and the land less, with the

approval of Gram Sabha for the decision making regarding interventions, promote farmers participation and convergence with ongoing Government schemes relevant to climate change adaptation.

Redefined policy making:

Much can be done by the policy and decision makers towards climate change adaptation, resilience and mitigation. While making such approaches, the different roles, rights, responsibilities and representation of women and men need to be recognized and included (Nelson and Huyer, 2016 and World Bank *et al*., 2015). National Initiative on Climate Resilient Agriculture (NICRA) was launched by the Indian Council of Agricultural Research (ICAR), New Delhi, during 2010-11, in 100 vulnerable districts to deploy strategic research on adaptation and mitigation, fill critical research gaps, technological demonstrations on farmers' fields to cope with current climate variability and capacity building of different stakeholders. There is need for reconstruction and redefining of policies and governmental schemes.

Climate change is a not a new phenomenon, but the elevated rate is posing a treat not only to the human kind but also to the biodiversity of nature. However, anthropogenic activities are active contributors of climate change. Therefore, those activities need to be controlled and eliminated. Need not to say, agriculture is the prime sector which is highly prone to climatic vagaries, thereby challenging the global food security. Thus, different strategies need to be deployed in order to win the impact of climate change. Different approaches can be deployed either alone or in combination with one another. The strategies of climate resilience, adaptation and mitigation are significant. Mitigation means using new technologies and renewable energies, making older equipment more energy efficient, or changing management practices or consumer behaviour. Whereas, resilience can be defined as 'the capacity of a social-ecological system to cope with a hazardous event or disturbance, responding or reorganizing in ways that maintain its essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation'. However adaptation is the process of deliberate adjustment to actual or expected climate and its effects (IPCC, 2014b). Nowadays, adoption of climate resilient agriculture is more pronounced. Considering the agricultural production systems, changes must be brought up at farmers mind set, farmers field and at policy generation level. Hence, the knowledge horizon of the farmers must be enlarged and new techniques and technologies are to be deployed at farmers filed level. The cultivation practices should aim at building resilience in soil interlinked with use of adapted cultivars and cropping systems, rainwater harvesting and recycling etc. can be adopted at farmers filed level. The existing developments and policies need to be well utilized by the farmers. In addition to that, new policies and technologies are to constructed. Given that, National Initiative on Climate Resilient Agriculture (NICRA) was launched by the Indian Council of Agricultural Research (ICAR), New Delhi, during 2010-11, in 100 vulnerable districts to deploy strategic research on adaptation and mitigation, fill critical research gaps, technological demonstrations on farmers' fields to cope with current climate variability and capacity building of different stakeholders. The current scenario demands creation and adoption of new techniques, technologies and governmental policies to fight against the impact of climate change thereby, protecting the global food and financial security.

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