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Climate resilient farming system for enhancing farmers' income: A review

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Abstract
Challenges before the governments is to build systems to sustain focus and integrate activities aligned to sustainable agriculture practices as climate change poses new risk to yields and quality of food crops. The growth story of Indian agriculture since food scarcity to self Sufficiency has been very impressive. In these efforts, land degradation and environmental challenges have however emerged to thwart sustainability of agrifood system. As per reports, climate change could reduce annual agricultural incomes in the range of 15 % to 18 % on an average, and up to 20 % to 25 % for unirrigated areas. The low level of farmers' income and year to year fluctuations in it are a major source of agrarian distress. Doubling farmers' income by 2022 is quite challenging but it is needed and is attainable through development initiative, technology, and policy reforms in agriculture. Holistic approach may further encourage the farmers' to mitigate the negative impact of climate change and to move towards resilient farming system for increasing own farm income as well as nations' income in general.

Keywords: climate, resilience, farming, sustainability, income

Introduction

Agriculture and its allied sectors still remain an important sector because of its continued role in employment, income and most importantly in national food security. Its contribution to national income has gradually declined from 18.2 per cent in 2014-15 to 16.5 in 2019-20 (Govt. of India, 2019-20), compared with much lower rate of decline in its share in total employment from 63% to 57% over the years. Declines in the share of agriculture in GDP have resulted in fragmentation and decline in the size of land holdings which leads to agronomic inefficiency, a rise in unemployment, a low volume of marketable surplus. These factors could contribute to increase vulnerability to global environmental change (Aggarwal *et al*., 2004). Small-holder producers across the world have always faced the vagaries of nature. However, their capacity to cope with the speed and intensity of current climate events is of concern (IFAD, 2011). With over 60 percent of Indian agriculture being rain-fed and more than 80percent farmers being small-holder producers, the need for a climate-resilient approach to agriculture is critical.

Animal husbandry, dairying and fisheries activities, along with agriculture, continue to be an integral part of Indian farming system. Livestock income has become an important secondary source of income for millions of rural families and has assumed an important role in achieving the goal of doubling farmers' income. Livestock sector has grown at a compound annual growth rate of nearly 8 per cent over the last five years, as it assumes an important role in Indian farming system income, employment and nutritional security. It plays a critical role in providing draught power for agriculture and transportation, biodiversity regeneration and maintenance, and most importantly, manure for agriculture (Govt. of India, 2019-20).

With the implementation of the National Food Security Act from July 2013, the food subsidy bill has increased from Rs.113171.2 crore in 2014-15 to Rs.171127.5 crore in 2018-19. India's food management should focus on rationalisation of food subsidy while addressing the challenges of food security under changing climate scenario, especially of the most vulnerable sections. The growth of GVA of agriculture and allied sectors has witnessed a fluctuating trend. GVA at constant (2011-12) prices for 2019-20 from 'Agriculture, Forestry and Fishing' sector is estimated to grow by 2.8 per cent as compared to growth of 2.9 per cent in 2018-19. Agriculture mechanization is an essential input to modern agriculture to increase the productivity and profitability of Indian farming system by making use of other inputs and natural resources judiciously. However, overall farm mechanization in India has rather been lower (40-45 per cent) compared to other countries such as USA (95 per cent), Brazil (75 per cent) and China (57 per cent). Focus on water use efficiency at farm level through precision or micro Irrigation (drip and sprinkler irrigation) has become a farm imperative to ensure a sustainable agricultural practice. Considering this, the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) was launched on 1st July, 2015 with the motto of 'Har Khet Ko Paani' for providing end-to end solutions in irrigation supply chain, Per Drop More Crop component of PMKSY (PMKSY-PDMC) is also operational from 2015-16 in the country focussing on water use efficiency at farm level. These type of articulation will give a great thrust to Indian economy as well as farming system under changing climatic conditions.

Under the umbrella of National Agriculture Research Management System (NARS), the 716 Krishi Vigyan Kendras

(KVKs) of the country have been linked with 3.37 lakh common service centers to enhance the reach of the KVKs amongst the farmers and provide the demand driven services and information (Govt. of India, 2019-20). Sectoral developments of Indian agriculture are the steel pillars of Indian economy like India continues to be the largest producer of milk in the world with 187.7 million tonnes milk in 2018-19; fisheries sector provides livelihood to about 16 million fishers and fish farmers; processing industrial sector provides employment to almost 18.54 lakhs (2016-17) etc. The realisation of the objective of doubling farmers' income necessitate addressal of some of the basic challenges of agriculture and allied sectors such as investment in agriculture, water conservation, improved yields through better farming practices, access to market, availability of institutional credit etc. Changes in the climate have led to an increase in irregular weather events such as extreme drought and severe floods, storms, cyclones and heat waves, which have had a significant impact on agricultural production (Cline, 2008) [7]. One rational and cost-effective method may be the implementation of increased agricultural crop diversification. Diversification is change in product (or enterprise) choice and input use decisions based on market forces and the principles of profit maximization (Pingali and Rosegrant, 1995) [24]. Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value added crops with complementary marketing opportunities. Efforts, therefore, need to be made by governments to explore the full potential and prospects of crop diversification to forge congruence of enhanced productivity, profitability and sustainability.

2. Climate Change and Resilience

There is now clear evidence for an observed increase in global average temperature and change in rainfall rates during the 20th century (Easterling, 1999; IPCC, 2001; Jung *et al*., 2002; Balling Jr and Cerveny, 2003 [3]; Fauchereau *et al*., 2003) [13] around the world. In recent years, with the growing recognition of the possibility of global climate change, an increasing emphasis on world food security in general and its regional impacts in particular have come to forefront of the scientific community. Changes in temperature and in precipitation patterns and amount will influence soil water content, run-off and erosion, salinisation, biodiversity, and organic carbon and nitrogen content. The increase in temperature would also leads to increased evapotranspiration. There is need to quantify the specific regional soil-related problems and that affect the global environmental change will have on soil fertility and its functioning for crop growth and production (Mall *et al*., 2007) [23]. Estimating the effect of a changing climate on crop production in the India is difficult due to the variety of cropping systems and levels of technology used. However, the use of crop growth models is one way in which these effects can be studied, and probably representing the best method we have at present for doing so.

Environmental changes may affect many different aspects of agricultural production. With greater climate variability, shifting temperature and precipitation patterns, and other global change components, we expect to see a range of crop and ecosystem responses that will affect integral agricultural processes, all of which will greatly influence food production and food security (Fuhrer, 2003 [14]; Jones and Thornton, 2003) [20]. Keeping facts of climate change and vulnerable impacts due to it, climate resilience agriculture (Table 1) is one of the best suited ways to cop up the severity of it in the coming years to come. Resilience, as defined by Holling (1973) [17], is the magnitude of disturbance that can be experienced before a system moves into a different state and different sets of controls. Crop diversification can improve resilience in a variety of ways: by engendering a greater ability to suppress pest outbreaks and dampen pathogen transmission, which may worsen under future climate scenarios, as well as by buffering crop production from the effects of greater climate variability and extreme events.

Table 1: Climate-Resilient Agriculture: An Approach Encompassing Food Security, Markets and Economic Resilience

Methodology	Key Essentials	Cross-Cutting Components
Diversified cropping	Low external input farming	Energy efficiency
Integrated farming systems	Weather-based agro-advisories	Enterprise development
Integrated livestock development	Water budgeting	Capacity building
	Contingent crop planning	

Vijayan and Viswanathan (2018) [28]. Critically observed that both implementation of advanced technologies and appropriate policies may help the agriculture sector become more resilient. Incidentally, there also exist sample traditional wisdom and proven practices amongst the farmers to manage the climate variations, which are not widely appreciated in the existing agriculture development planning in the country. To overcome the agrarian impasse caused by the climate change induced risks, the Government of India had launched a major National Initiative on Climate Resilient Agriculture (NICRA) in February 2011 under the auspices of the Indian Council of Agricultural Research (ICAR) with support from the Ministry of Agriculture. The NICRA has three key priority areas that include demonstration of technology, building of capacity and strategic research. Developing technologies for climate resilient agriculture becomes important to enhance farm production and productivity, taking into consideration of the natural resources that are also scanty and highly varying in quality and quantity across regions.

2.1 Climate Change Impacts on Agriculture

1. If temperatures rise by 4°C, vast areas of drylands will have their growing season's cut by more than 20 percent.
2. Temperature and water stress affects leaf formation, flowering, and growth.
3. Temperature increase of 3.5°C by 2050 will lead to a decline of yield in water-intensive crops such as rice by 8–9 percent and wheat yields by 2–6 percent.
4. There will be negative impacts on sorghum productivity due to reduced crop durations, if temperatures increase by 3°C.
5. As the climate becomes warmer, the response of crops to added fertilisers will be lower.

6. Increase in temperature affects the quality of cotton, fruits, vegetables, tea, coffee, and medicinal plants.
7. Increased temperature leads to loss of moisture from the soil and soil organic matter which will affect soil fertility and decrease yields.
8. If rainfall reduces by 10 percent, there will be decrease in yield of groundnut.
9. There will be increased risk of pests and diseases due to change in the pattern of host and pathogen interaction.

3. Crop Diversification Strategies

On-farm diversification is a promising strategy for farmers to adapt to climate change while also contributing to diverse food production, healthier diets, and a better use of agricultural biodiversity (Vermeulen *et al*., 2012 [27]; Waha *et al*., 2018 [29]; Willett *et al*., 2019) [31]. This decision-making framework is intended for practitioners and researchers in agricultural development. The framework can be used to establish a dialogue with individual farmers or farmer groups to develop on-farm diversification strategies with the use of participatory research approaches, which have proved to be successful approaches in the selection and adoption of new agricultural technologies (Carberry *et al*., 2002 [6]; Grothmann and Patt, 2005 [27]; Urwin and Jordan, 2008) [26].

Farmer perceptions of weather cycles and climate change are a good starting point for identifying climate risks. Their knowledge may need to be combined with formal predictions to reduce bias from their recent experiences and to reflect long term climate trends. Once climate risks are identified, crops, varieties, and management practices can be selected to manage these risks. Climate models with projections in climate change under different economic and climatic scenarios allow for predictions of climate change impact on crop production for the next decades (Lobell *et al*., 2008 [22]; Baca *et al*., 2014 [2]; de Sousa *et al*., 2019) [9]. Diversification of farm systems in space and time can foster ecological functions, such as climate regulation, water storage, nutrient cycling, and pest regulation. Farmers may find it useful to use a straightforward checklist of management practices, which foster ecological functions to improve their farm systems. Microclimates can be regulated by tree shade, which buffers against high temperatures above ground and in some cases prevent frost damage (Barradas and Fanjul, 1986 [4]; Caramori *et al*., 1996) [].

On-farm diversification with cover crops and green manures can improve and conserve soil by building up organic matter, adding nitrogen, improving soil structure, and reducing soil erosion (Cong *et al*., 2014) [8]. As a consequence, soil fertility, infiltration, water holding capacity, and soil moisture can increase, and with that the crops' ability to cope with drought (Erenstein, 2003; Waraich *et al*., 2011) [30]. However, under humid conditions and on poorly drained soils, mulching can cause waterlogging resulting in lower yields (Giller *et al*., 2009) [15]. Some cover crops are competitive for water, and if intercropped, they can reduce the yields of the main crop under water limiting conditions. Therefore, selection of soil-improving inter crops or relay crops, which are water efficient, is important in drought-prone environments. Therefore, On-farm diversification is a key component of a range of climate change adaptation and mitigations practices and technologies known collectively as climate-smart agriculture.

3.1 Constraints in Crop Diversification

The major problems and constraints in crop diversification are primarily due to the following reasons with varied degrees of influence:

- Over 117 m/ha (63 percent) of the cropped area in the country is completely dependent on rainfall.
- Sub-optimal and over-use of resources like land and water resources, causing a negative impact on the environment and sustainability of agriculture.
- Inadequate supply of seeds and plants of improved cultivars.
- Fragmentation of land holding less favouring modernization and mechanization of agriculture.
- Poor basic infrastructure like rural roads, power, transport, communications etc.
- Inadequate post-harvest technologies and inadequate infrastructure for post-harvest handling of perishable horticultural produce.
- Very weak agro-based industry.
- Weak research - extension - farmer linkages.
- Inadequately trained human resources together with persistent and large scale illiteracy amongst farmers.
- Host of diseases and pests affecting most crop plants.
- Poor database for horticultural crops.
- Decreased investments in the agricultural sector over the years.

The Way Forward

India being a hotspot for climate change and having 15 broad agro-climatic zones and 127sub-zones, the presentation of climate change and its effects will vary from region to region. Hence a 'one size fits all' approach will be detrimental to the agriculture and food security of the country. Given the multiplicity and interconnectedness of possible solutions, these will necessarily have to be selected and tailored to fit the geographic and socio-economic characteristics and needs of the local community. Solutions should address the twin challenges: adaptation to climate variations and sustainability of the resource base with increase in productivity, to meet future food security demands. When dependence of farmers for their sustenance is solely on agriculture, they will use any and all means to earn for their survival, even if it means extracting every drop of water, or increasing the application of chemicals, cultivating cash-pulling monocrops, and taking huge loans for agriculture. Therefore, diversification of crops (SAPPLPP, 2012) agri allied activities, and alternate livelihoods are imperative for increasing resilience, ensuring economic security, and protecting the natural resource base. It thus, reduces the burden of productivity from agriculture, particularly in a climate change context.

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