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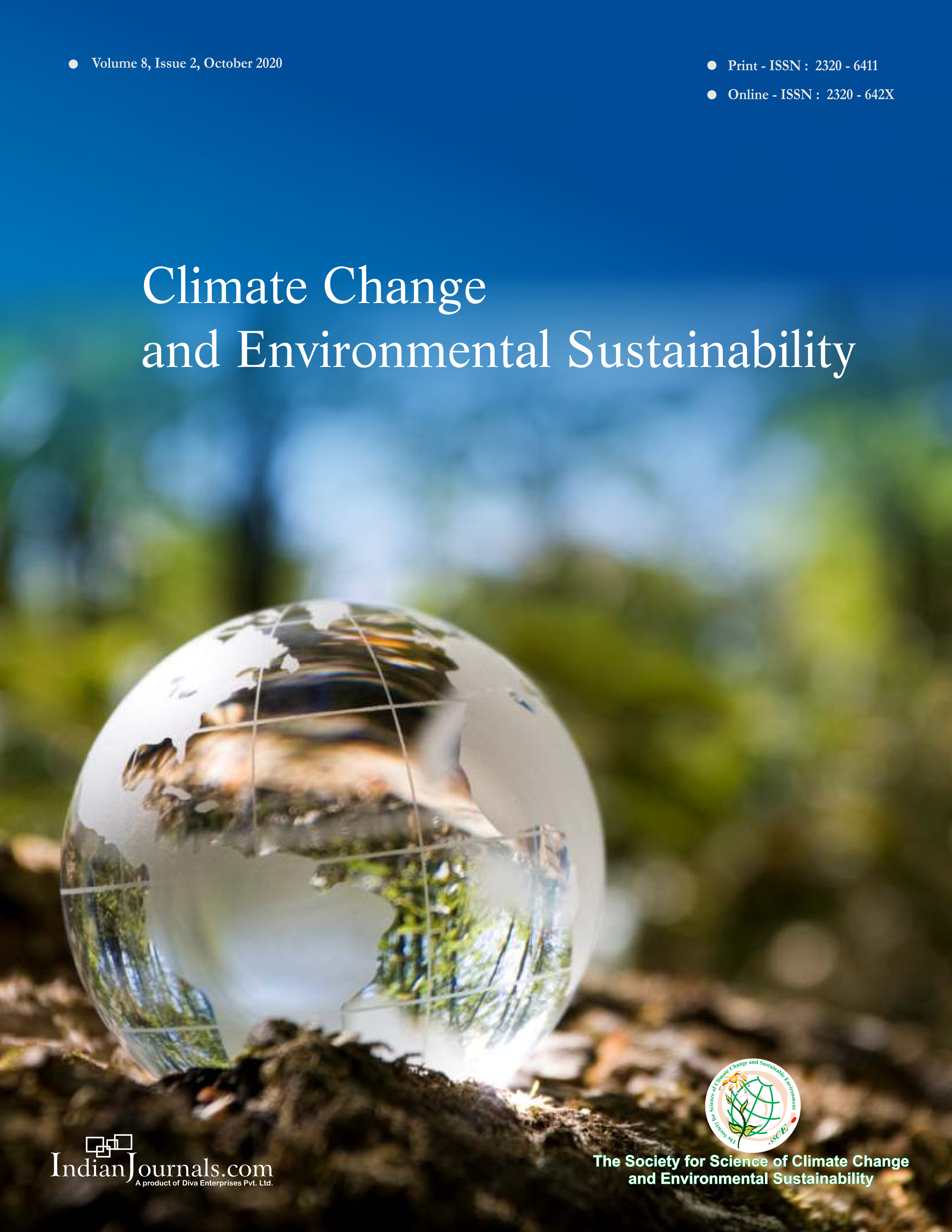

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REVIEW ARTICLE

Mainstreaming Climate Resilient Villages in National Programmes towards Sustainability of Agriculture and Environment in India

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Abstract Climate change and variability are the major challenges globally and India in particular. Intergovernmental Panel on Climate Change (IPCC) in its 5th report said that the climate change seriously impacts agriculture, natural resources, water and food security. India is more vulnerable in view of the large population dependent on agriculture. During the last 2 decades, several weather-related extreme events occurred like drought of 2002; cold wave in 2002–2003; heat wave in 2003; high temperatures in 2004; droughts, cyclones of 2014; and floods in 2015, 2018 and 2019, etc. in one or the other parts of India severely impacting agriculture production. Marginal and small land holders of rainfed areas are more affected because of less resilient mechanisms. For effectively dealing these climate change issues ICAR (Indian Council of Agricultural Research) has started NICRA (National Initiative on Climate Resilient Agriculture) for site specific technology demonstrations for increasing the resilience of the 151 climatically vulnerable districts of the country. This approach ensures food security, build resilience of agricultural systems and increase the adaptive capacities of farming groups. Strengthening various support systems in the village or initiation of new ones like VCRMC (Village Climate Risk Management Committee), CHCs (Custom Hiring Centres), commodity groups, seed banks and fodder banks were given importance. The promising resilient technologies can be mainstreamed in to the developmental programmes for enhancing adaptive capacities of communities and villages.

Keywords: Agriculture, Climate change, Resilience, Villages

1. Indian Agriculture

Agriculture plays a prominent role in India's economy. The total workforce of about 54.6% in the country is involved in agricultural and related sectors (Census, 2011) and at current prices, agriculture adds 16.5% share to the country's Gross value added (GVA) for the year 2019–2020. According to the report of 2014–2015, given by Land use statistics (LUS) the total geographical area of India is 328.7 MH, out of this the net sown area is 140.1 MH, that is, 43% of the total geographical area and the gross cropped area is about 198.4 MH with a production intensity of 142%. The net irrigated area is about 68.4 MH (Annual Report, 2019–2020).

According to the estimates given by the Central Statistics Office (CSO), Ministry of statistics and programme implementation, the agriculture and associated activities have given roughly to India's GVA at existing rates is about 16.1% during 2018–2019. The contribution to GVA from agriculture and related activities and its part in total GVA of the country according to existing rates from the previous 5 years is shown in Figure 1.

There was a continuous decline in the share of agriculture and related activities from about 18.2% in 2014–

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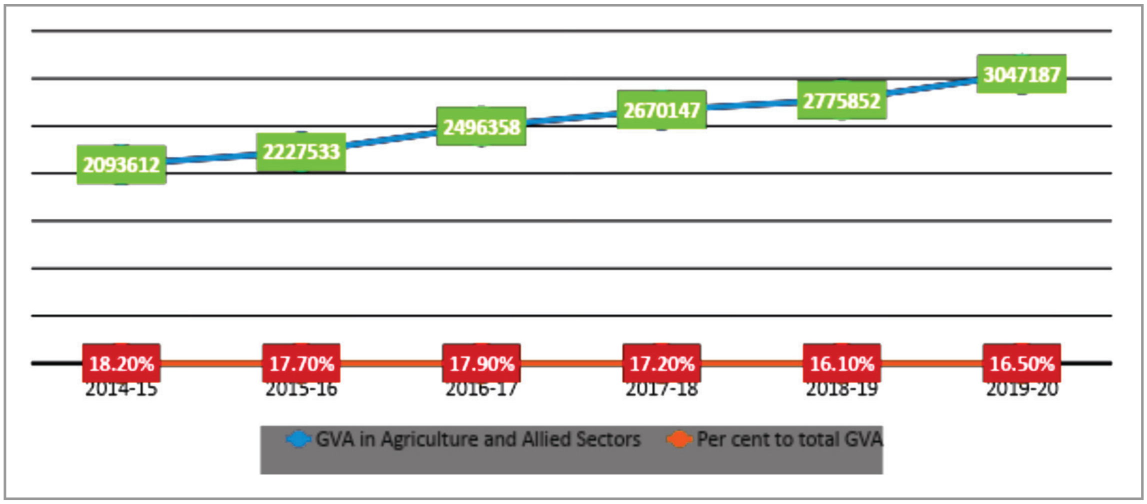

Figure 1. GVA (Gross Value Added) of agriculture and related fields and share in percent
Source: Annual report 2019-20, Department of Agriculture Cooperation & Farmers' Welfare, Ministry of Agriculture & Farmers' Welfare

2015 to 16.5% in 2019–2020 in the total GVA to India. In a rapidly growing and structurally changing country, the decline in share from crop production and its related farm activities to GVA is expected but also a concern as it sustains large population.

1.1 Ecosystems

India is bestowed with diverse agro-ecosystems, with varied climate, edaphic and geographic features which permits cultivation of diversified crops. In India, there are greater than 800 crop types, each with greater variability, for instance, rice has about 50,000 varieties and sorghum has about 5,000 varieties. The National Bureau of Soil Survey and Land Use Planning (NBSS & LUP) delineated twenty agro ecological zones (Table 1), based on multiple criteria with varied characteristics and growing environments (Singh and Chaturvedi, 2017).

Irrigated areas are homogenous and more suitable to raise the crops intensively, whereas the dry weather regions are heterogenous and more varied in nature. The latitude and climate of the rainfed or dryland areas of India allows varied biodiversity. In India, farmers are still practicing the traditional practices for growing crops in several rainfed regions notwithstanding the practice of mono cropping in several green revolution regions of irrigated agriculture.

Rainfed agriculture in India frequently experience droughts and floods. Considerable fall in production of food crops occurs with increase in severity or expanded periods of drought. The extent of crop losses vary based on the incidence, intensity and duration of drought. Impact of droughts are profound, seen on food production, food security and national economy. In arid regions of the country, drought is inevitable as the average annual rainfall is less than 500 mm. Frequency of concurrence of drought of 40–60% is reported in semi-arid regions with mean annual rainfall of 500–750 mm because of low seasonal rainfall or low availability of soil moisture. In dry sub humid regions, with an annual rainfall of 750–1,200 mm, occurrence of drought is mostly because of withdrawal of monsoon in the middle or early (Srinivasarao *et al*., 2015).

1.2 Farmer's Constraints

1.2.1 Social Problems

- Unexpected natural calamities and drought
- Primarily agriculture based
- In sufficient incomes

1. Disorganised agriculture: There is no systematic institutional and organisational planning in production, irrigation, harvesting and marketing. Minimum purchase price fixed by the government do not reach to the poorest farmers.
2. Declining size of holdings: After independence, land is divided into small bits because of more members in the family. So, production in such small area is not feasible economically. Farmers are becoming vulnerable in this situation. In some cases, farmers are not the

Table 1. Agro-Ecological Regions in India

Agro-ecological regions	Characters	Majorly grown crops
Arid Ecosystem		
Western Himalayas	Cold, hyper-arid, shallow skeletal soils length of growing period (GP) < 90 days	Wheat, barley and millets
Western plain, Kachchh and part of Kathiawar Peninsula	Hyper-arid, hot, saline and desert soils, GP < 90 days	Pulses and millets
Deccan Plateau (Karnataka Plateau)	Hot arid, red and black soils, GP < 90 days	Cotton, oil seeds and millets
Semi-arid Ecosystem		
Northern Plains and Central Highlands	Moist semi-arid, alluvium derived soils, GP 90–150 days	Cotton, sugarcane, maize, pulses, millets and wheat
Central Highlands, Kathiawar Peninsula and Gujarat plains	Hot dry or moist semi-arid, medium and deep black soils GP 90–150 days	Pulses, wheat and pulses
Deccan Plateau	Hot dry or moist semi-arid or dry sub-humid, shallow and medium black soils GP 90–150 days	Pulses, millets, cotton and sugarcane
Deccan Plateau (Telangana) and Eastern Ghats (North and South Telangana Plateau, Eastern Ghat)	Hot dry or moist, semi-arid or dry sub-humid, red and black soils, GP 90–150 days	Cotton, sugarcane, millets, oilseeds and rice
Sub-humid Ecosystem		
Northern Plain (Punjab, Rohilkhand, Avadh and south Bihar Plains)	Hot dry or moist sub-humid, alluvium-derived soils, GP 150–180 days	Pulses and sugarcane
Eastern Plain (North Bihar and Avadh Plains, Foothills of Central Himalayas)	Hot or warm, dry or moist sub-humid, alluvium-derived soils, GP 180–210 days	Rice, wheat and sugarcane
Humid-perhumid Ecosystem		
Assam and Bengal Plain (Middle, Lower and Upper Brahmaputra Plain, Bengal basin, North Bihar Plain, Teesta, Barak Valley)	Hot or warm moist, sub-humid or humid, alluvium-derived soils, GP 210 + days	Rice, jute and plantation crops
North-eastern Hills (Purvachal) (Meghalaya Plateau, Nagaland Hill, Purvachal)	Warm to hot moist humid to per- humid, red and lateritic soils, GP 210 + days	Forest and rice in patches
Coastal Ecosystem		
Eastern Coastal Plain (South and North Tamil Nadu Plains (Coastal), Andhra Plain, Utkal Plain, East Godavari Delta, Gangetic Delta	Hot dry or moist semi-arid or sub-humid or humid, coastal alluvium-derived soils, GP 90–210 + days	Rice, pulses and millets
Island Ecosystem		
Islands of Andaman-Nicobar and Lakshadweep (Andaman and Nicobar group of Islands, Lakshadweep and group of Island)	Hot per-humid or humid, red loamy and sandy soils, GP 210 + days	Forest, coconut and rice

Source: Adapted from Singh and Chaturvedi (2017) original land owners and the earnings of them goes in payment of lease for the land owner.

3. Illiteracy and little knowledge about the latest technological developments: Most of the marginal farmers have little knowledge and they are totally unaware of new improvements or techniques in farming.
4. Lack of irrigation facilities: Only a small part is under irrigation or seasonal irrigation. So, most of the land is under rainfed. Assured crop production and income is not possible under such condition.
5. Government Schemes: The programmes or schemes implemented by various State and Central Governments do not reach the needy.
6. Rural unemployment: Seasonal employment in agriculture, more family members in a joint family, lack of supporting occupation, etc. are the reasons for unemployment (Sonowane, 2016).

1.3 Production Constraints

- Unscientific methods of cultivation
- Less remunerative prices of agricultural products
- Poverty
- Hunger
- Malnutrition
- Lack of infrastructure facilities
- Adoption of traditional technology
- Rainfed agriculture
- Low productivity
- Land tenancy
- Constraint to get machine in time on hire basis for crop production (Divya *et al*., 2019)

1.4 Markets

In India, the agricultural markets are controlled by the state Agricultural Produce Marketing Committee (APMC) laws. Producers will sell their produce on their own at designated mandis under these state acts. APMC mandis presently charge fee from producers for vending of their produce at mandis. This leads to increase in the cost of production. Further, farmers have to bring their produce from farm to the nearest mandi which poses additional burden of transport and fuel. Several brokers are involved in transportation of produce from farm to mandi. In majority of the cases, the rate received by the producer is less than the rate of the same produce when sold to a retailer.

Central government in 2003, formulated a APMC model act. Through this reform, there is a provision for direct selling of produce. This act gives scope for the private people, consumers and farmers to form agricultural markets. A single market fee is charged for selling of their produce and replaces licenses with enrolment of market agencies through which they sell in more markets. As of now only eighteen states and Union Territories (UTs) are following the regimes of the act, four states have not started till now and the rest of them are at different levels of implementation.

Economic survey in 2014–2015 recommended a National Agricultural Market (NAM) to give a country wide electronic medium where farmers can vend their commodities. In this market, farmers get a reasonable rate for the commodity and also permits farmers to vend their product throughout India. Indian government in the year 2016, started the NAM in districts of eight states and linked wholesale mandis to form a common venue.

2. Climate Change and Indian Agriculture

Both agriculture and climate are interrelated. A very small change in climate affects agriculture production. Increase in average atmospheric temperature causes global warming phenomenon which leads to climate change. The World Meteorological Organisation (WMO) and United Nations Environment Programme (UNEP) reported that the Carbon Dioxide (CO_2) is the main cause of climate change due to its higher percentage in global warming. The club of Rome Report in the year 1972, officially said that the global warming is an international issue. Estimation of the effects of global climate change is essential in agriculture to adapt farming to enhance agricultural production (Fraser *et al.*, 2008).

By 2100 the earth temperature would be warmer by 3.2°. Reduction in emission of GHG by 7.6% per year from 2020 to 2030 may achieve the goal of reducing the global temperature. However, due to the population explosion and the consequent pressure for demand of food the GHG emissions are increasing.

The main greenhouse gas contributing to global warming is CO_2, even though there are other gases like methane and nitrous oxide. There are several forms of emission of CO_2 when fossil fuels are burnt from regular uncovered coal burnings to emissions from power generators. In the earth's carbon cycle, the CO_2 in the atmosphere is partially absorbed by seas and different stagnated water places and by flora on land. Not only fossil fuel burnings, some amounts of CO_2 is taken by surface water bodies and returned back to ecosystem and the rotting and decay of plants also emits carbon as methane. There is a difference in net amount of CO_2 present in the atmosphere and the total amount of emitted CO_2. But, these aspects of net and gross stock of CO_2 released to the environment are important in the study of climate change (Jayaraman, 2011).

2.1 Impacts

Indian sub-continent and other continents are highly vulnerable to weather abnormalities and its effects on different activities. In India on 16th August, 2018 in Kerala severe floods occurred due to heavy rainfall during the monsoon season. It was the worst and severe flood in this state nearly in a century. The Government of India has declared it as the calamity of severe nature or level 3 calamity. In early December 2015, heavy rains caused severe flooding in Tamil Nadu. This is due to a heavy tropical depression hit the south-Indian coast of India and Sri Lanka during November 16–19, which came from Bay of Bengal as a result for 9 days there was rain about 30–37 cm. Around 500 people lost their lives during these devastating floods. The Government of India declared Chennai as a National disaster zone (NDZ) and National Disaster Response Force (NDRF) taken up the remedies in the city. The rains and subsequent overflow from the rivers caused intense flooding and evacuations from the city and surrounding areas and considerable damage occurred to homes and farm fields. (Vishnu and Sridharan, 2016). Similarly, in the year 2019, the same city Chennai was affected with severe floods causing drinking water crisis which lead to large scale migration of people. In future, the sea levels are going to increase in the range of 10–100 cm by 2,100, which leads to submergence of Maldives Island. Arid regions in India, including dry regions are facing severe drought. 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). About 42% of India's land area is affected by extreme droughts. India's cultivable land area of about 68% is prone to drought (NIDM, 2010). Indian agriculture is monsoon dependent and drought effects crop production. In the year 2016–2017, in Maharashtra the sugarcane industry recorded low sugarcane crushing and production due to severe drought. The sugarcane cultivating areas has dropped down from 10.3 lakhs ha to 6.3 lakhs ha (2014–2015 and 2015–2016, respectively) (Jain, 2017). In the same way, the pulses production also declined during drought years of 2016 which is about 12% compared with non-drought year of 2013–2014. (Verma, 2016). Cyclone, storms and landslide are the other climate change disturbances. Hudhud was one of the two strongest tropical cyclones of 2014 in Bay of Bengal which evacuated many and damaged the properties in Andhra Pradesh. Farmers are affected severely due to these storms and cyclones. During the last 10 years, different cyclones affected India are Laila (2010); Hudhud (2014); Kyant (2016) in Andhra Pradesh; Titli (2017) and Fani (2019) in West Bengal and Odisha; Ockhi (2017), Gaja (2018) in Tamil Nadu severely affected the coastal population. In the month of October 2019, two back to back cyclones (Maha and Kyarr) right at the peak of harvesting have left kharif crops (groundnut, cotton and paddy) massively damaged in Saurashtra and South Gujarat. Approximately 45 lakh hectares of kharif area is affected due to Maha and Kyarr cyclone unseasonal rains (Vora, 2019).

Agricultural production and productivity is completely dependent on climatic conditions (Srinivasarao *et al*., 2016; Bal and Minhas, 2017). Weather disruptions, like changes in temperature, precipitation and solar radiation, affect the agriculture including livestock, arable and hydrology sectors. In India an increase in rainfall of 2 mm and temperature by 1.5°C, projected to decrease the rice yields by 3% – 15% (Ahluwalia and Malhotra, 2006). Impacts of global warming and its effects on yield and productivity of crops vary from region to region. Uneven rainfall and high temperature have significant effects on horticultural production and productivity. For example, banana crop suffers from high temperature, water logging or flooding and soil moisture stress. Higher temperature and moisture stress at maturity causes fruit cracking and sun burn in litchi. In perennial crops like mango and guava phenology of flowering is influenced due to increase in temperatures.

Fruit set in tomato is impacted by variable temperature and formation of inferior sized fruits occur at higher temperatures. Flooding in tomato crop damages the crop due to endogenous accumulation of ethylene. Continuous drought reduce production and productivity of coconut with a loss of 3,500 nuts/hectare/year in India. Drying of flowers as a result reduction in yields are reported in cashew due to low Relative Humidity (RH) of less than 20% and high temperature of greater than 34.4°C.

Climate change impact spice crops severely especially black pepper, small cardamom and seed spices. Area under pepper cultivation has decreased by 24% in last 9 years and its production has come down to nearly half due to decrease in productivity. Chilling and frost injury are seen in seed spices like coriander, ajwain, nigella and cumin which are very sensitive to frost and ultimately reduction in yields. In Jasmine, low temperatures (< 19°C) reduces flowering as a result there is a reduction in size of flower. For orchids of tropical grown, at temperature of 15°C flowers do not open completely. But, under high temperatures (> 35°C) flower bud drops and unmarketable spikes are formed (Hirpo and Gebeheu, 2019). Climate change affects the different processes like production, reproduction, health and habitat of animals. Increased temperatures abruptly change the animal's body physiology (Pereira *et al*., 2008) such as rise in rate of respiration, that is, greater than 70–80 beats per minute, blood flow and body heat of greater than 102.5°F. Unexpected climatic variations affect the production level of animal by 58% and reproduction by 63.3% (Singh *et al*., 2012). An increase in metabolic heat production in higher milk producing breeds leads to higher prone to high temperature pressures; while the dairy animals are resistant (Dash *et al*., 2016). Poultry is severely affected due to heat stress which leads to less intake of feed by birds (Deng *et al*., 2012) which leads to less body weight, egg production and quality of meat. Methane emissions from livestock can be reduced by giving feed of good quality. Soil carbon status of soil can be improved by manure application as a result increases the soil fertility and structure along with soil carbon and nutrient pools. An equitable application of fertilisers, organic sources of nutrients and cultivation of pulse crops in the system will increase carbon storage (Srinivasarao *et al*., 2015).

3. Strategies for Climate Change Adaptation

Technology is the critical input for driving adaptation to climate change. For climate change adaptation, it is necessary to increase awareness and capacity building is critical for all the stakeholders from farmers to policy makers. Instead of individual action it is important to engage communities, community driven programmes and village level institutions to adapt to climate change. There is a requirement for merging the multi-ministries events or programmes at village or mandal level for taking up the benefits of national or state-level climate adaptation programmes.

To reduce the harmful effects of climate change, there is a need to follow the improved or farming techniques/ practices along with adaptation strategies. Climate change adaptation technologies have multiple advantages of mitigation by removing, decreasing or replacing the release of atmospheric CO_2, CH_4 and N_2O with some additional benefits (FAO, 2012). In India and other places for overall climate change adaptation, water management is an essential factor. Whenever water is limited, the order of preference should be given as first to livestock then horticulture and finally to field crops. Since, more than half of the Indian agriculture is dependent on rainfall it is vital for conservation of rain water both in-situ and ex-situ through various methods like community ponds or farm ponds is highly recommended as an adaptation strategy for climate change. For conservation of water resources, efficient cultivation systems of rice, wheat and sugarcane is very important. Several land treatments for in-situ rain water conservations, location-specific designs of farm ponds for harvesting of runoff under high intensity rains were developed by the ICAR and there is a need to scale-up these technologies.

It is evident that in India and other developing countries livestock is critical for secured livelihoods of small and marginal farmers. For sustainable livestock production ICAR recommended a three-tier strategy like better breed, feed and shelter management. Combination of these strategies could not only contribute to productivity enhancement, climate change adaptation but also reduce GHG's emissions particularly methane. Modifying the feeding habits of livestock by improving forage quality, using of fodder grasses, specific dietary additives can enhance the digestion and reduces the emission of gases through enteric fermentation. There are reports that by giving fresh tree leaves as feed emits less amount of methane (< 2 ml/100 mg) from digested substrate in comparison to dry straw which liberates huge quantity of methane (6 ml/100 mg) followed by food grains (Bhatta *et al*., 2015). Combination of various feed additives have a synergetic effect in controlling methane emissions.

Greenhouse gases emissions can be reduced by improved management practices like diversified crop rotation, cover cropping, reduced tillage, increased cropping severity and reduction in N fertiliser application. Tillage needs consumption of fossil fuel which leads to emission of GHG. Reduction of tillage intensity can be an effective strategy for reduction of GHG emission in crop production. Zero till or reduced tillage systems could be potential technologies for reducing the consequences on agriculture on the ecosystem by avoiding burning of crop left overs (Pratibha *et al*., 2016).

Experimental studies were conducted to find out the energy use efficiency and greenhouse gas release from soil disturbance operations like regular conventional tillage, decreased tillage and no tillage and crop left overs levels (harvesting heights resulting in 0, 10 and 30 cm anchored residue) under semi-arid rainfed regions of India in pigeonpea-castor systems. Conventional tillage has utilised 30% and 31% higher energy inputs compared to zero tillage in red gram and castor, respectively. Consumption of energy in zero tillage was 58% and 81% less against conventional tillage in pigeonpea and castor, respectively, which reduced the emission of greenhouse gas emissions by 21% and 23% than conventional tillage. Zero tillage recorded maximum energy use efficiency and energy productivity with 10 cm anchored residue (Pratibha *et al*., 2015).

To maintain stability of yields, it is important to develop novel crop cultivars with high yield and ability to tolerate to various abiotic pressures like floods, dry weather, coastal salinity, etc. One of the important goals of the breeding programme should be to develop cultivars of main crops for high temperature tolerance. Growers should be provided with varieties having broad genetic base. To strengthen the adaptation process of farmers, make availability of new cultivars which are tolerant to heat-stress, drought and salinity so that the impact of climatic variability can be reduced. During high temperature and moisture stress conditions, crop diversification and resilient varieties which are tolerant to drought and heat stress can increase the productivity. There is a huge and increasing popularity for high value produce like fruits, vegetables, dairy, meat, eggs and fish due to rise in income and urbanisation. Another strategy for adaptation to reduce the effects of climatic aberrations is change in land use practices by rotation of crops and by integration of livestock, diversifying with appropriate land use for marginal areas, minimising the amount of chemicals and capital and labour inputs. Sustainable intensification of cropping systems by growing of suitable cultivars, planting different types of crops and sequential cropping, that is, the number of continuous crops grown in a year per unit area should be increased. Growers have to adjust to altered hydrological systems by diversifying crops. Field studies reported that the resource conservation technologies (RCTs) are increasingly applied by farming communities in Indo-Gangetic plains for cultivation of rice-wheat due to many benefits like saving of water, man days and pre-planting of wheat. Another advantage of RCTs in rice-wheat system is mitigation of greenhouse gas emission and climate change adaptation. (Pathak *et al*., 2012).

India plays a key role in international climate discussions. Further, in India the state and central government schemes have started focusing adaptation to climate change in government programmes due to efforts of National Action Plan on Climate Change (NAPCC), which in turn is functional through State Action Plans on Climate Change (SAPCC). With the assistance of Indo-German cooperation project on Climate Change Adaptation in Rural Areas of India (CCA RAI) , climate proofing government schemes and estimation of vulnerability is being piloted at state level. Many government initiatives are examined and assessed at district and community levels, to know the potential to contribute to adaptation. The leaders in these activities are Indian Government NGOs, communities and scientific institutions.

4. Climate Resilient Villages in India

Potential of the sector to reduce the effect of climatic variability involves efficient utilisation of existing natural resources viz., land, soil, water and genetic resources via improved technological practices.. Social and ecological systems of resilience of agricultural systems is important and the knowledge on vulnerability of the agricultural systems is essential for deployment of technologies which can enhance resilience. Social systems of resilience consists of farmers, regions and communities, the level of which depends both on the property and techniques the farmers can share and the welfare given by institutions and governments. Climate Resilient Agriculture (CRA) essentially consists of introduction and deployment of various technologies which can minimise the impact of variability and helps in quick recovery of the agriculture systems (Srinivasarao *et al*., 2018).

4.1 Concept

CRA essentially aims at enhancing the capacity of the system to tackle various climate associated risks like floods, drought, heat or cold wave, uneven rains, dry weather, insect-pest population outbreak, etc. and minimise the impact due to them and builds the capacity of the systems for quick recovery from such events (NAAS, 2013). CRA is the ability of the system which can respond to the climatic threats and tolerates the impact and responds quickly with the favourable conditions in such a way that minimises the harmful impacts and makes effective use of the available resources such as soil and water through implementation of safest practices (Venkateswarlu and Shanker, 2009; Srinivasarao *et al*., 2016). CRA technologies are location, crop dependent and on the resources in a given region and can be manipulated in such a way to meet the economic conditions and preferences of farming communities (Rosenstock *et al*., 2015). CRA essentially focuses on minimising the impact of climatic variability in less resource endowed regions where variability in rainfall seriously impacts the crop growth and production and can potentially leads to complete crop failure and aims at minimising the impact of such events so that communities can realise acceptable yields and can sustain livelihoods.

Climate Smart Agriculture (CSA) is an integrated approach essentially consists of 3 objectives: (a) sustainable increase in production of crops and income (b) resilience building and adaptation to multiple variations of climate in agriculture and food security and (c) reduction in emission of greenhouse gases in crop production (production, animals and fisheries) to the maximum degree (FAO, 2013). Climate smart agriculture essentially aims at enhancing resource use efficiency such as water, fertilisers, labour and aims at maximising the production with the available inputs particularly in better resource endowed regions such as irrigated regions where assured supply of water exists and the focus is to use the available water and other resources efficiently. Often the focus is on minimising the emissions from the agriculture systems by way of utilising the available resources efficiently (Aryal *et al*., 2015; Scherr *et al*., 2012).

Climate Resilient Village essentially consists of deploying technological practices at a larger scale such as a village, bigger than the individual farm by way of deployment of technologies depending on the resource endowments in such a way to minimise the adverse impact of rainfall variability. Rural areas contains adjacent cultivated fields, with naturally formed landscapes and various habitations. Village is a landscape, varies approximately from 500 ha–1,500 ha in size. Identification of resilient technologies aiming at the predominant crops, animal systems and resource conservation systems and utilisation are important and taken up at such a scale to minimise the impact of variability. Taking technologies to scale is one of the important components of CRV (Scherr *et al*., 2012).

4.2 Components of Climate Resilient Villages, Technologies

In India, as part of NICRA in the identified 151 vulnerable districts, extensive farmers' participatory location specific resilient technologies were demonstrated in farmer's fields to minimise the impact of weather and to increase the resilience of agriculture systems. On the basis of scientific analysis of climate, variability, sensitivity, exposure to future climate, adaptive capacity of communities, the vulnerable districts were identified (Rama Rao *et al.*, 2013). The main objective of this project is not only to demonstrate the resilient technologies for agriculture at the village level but also to institutionalise mechanisms for long term adoption of resilient practices (Srinivasarao *et al*., 2016).

4.2.1 Resilient Crops and Stress Tolerant Varieties

Climate variation like drought is a situation where the availability of water is scarce which leads to soil moisture deficit, impact crops, animal sector and livelihoods. The occurrence and severity of drought is different in various soils, crop stages and under various management conditions and affects crop growth differently. Various management practices are needed to minimise the impact of drought (Srinivasarao and Gopinath, 2016). Improved cultivars plays a vital role in stabilising productivity in rainfed environments and to minimise the impact of climatic variability (Reddy *et al*., 2014).

Late maturing cultivars of red gram which comes to harvest in 220 to 250 days face the dry weather period at various growth stages because of uneven rainfall pattern and also frost in the month of December–January, in certain areas of North India. Whereas, the early maturing cultivars of red gram which matures in 130 to 140 days escapes the drought and frost and also creates situation for taking up the post-rainy season crop (December–April) in several regions of North India. Increase in crop intensity by planting two short-duration crop cultivars is an effective resilient measure as it ensures income from the second crop even if one of the crops fails due to variable climatic (Campbell *et al*., 2014).

4.2.2 In-situ Moisture Conservation

Water harvesting in-situ by simple technologies enables greater water infiltration, extends the availability of moisture to the crop, temporarily stops the water on the surface of the soil to enhance the rate of infiltration and helps the crops to withstand rainfall variability (Srinivasarao and Gopinath, 2016). In areas receiving high rainfall, moisture saving through covering the soil with plastic are live materials exclusively in vegetable crops to escape dry weather and helps in growing of second crop using residual moisture and conserved water in post-rainy season. For example, in high rainfall areas like Khagribari village in West Bengal of Cooch Behar district which gets a rainfall of 2,983 mm, cucumber production on raised bed with artificial mulching gave increased yield (29.1 t/ha) against flatbed production (26.2 t/ha) because of suitable temperature in the atmosphere and soil moisture conditions.

In India, 55% of the total sown area is rainfed which is arable, conservation and efficient usage of received rainfall is important for sustained income generation and resilience. In rainfed agriculture the success depends on the conservation of soil moisture in-situ or harvesting the excess runoff in specialised structures and using it in adverse situations as a supplement source of irrigation. In recent years, rainwater harvesting technologies got importance in rural and agricultural development programmes of India due to frequent climatic aberrations. Water use efficiency of harvested water can be enhanced by using customised drip and sprinkler systems in the cultivation of high value crops and cultivars. Under various government schemes, different types and sizes of rain water harvesting structures are built on farms of small-holders like tanka, percolation pond and farm pond. In light or red soils rainwater harvesting structures has lining to control seepage losses of harvested water. These linings are done with less thick polyethylene or more thick polyethylene sheet or any other usable material for control of seepage losses and utilisation of preserved water during dry weather. Whereas, in black soils the seepage losses are very less. The benefits of water harvesting was not realised in Anantapur and Bangalore because of water loss through seepage except some ponds having lining which gives source of supplemental irrigation. Thus, any government schemes on rainwater harvesting structures in the light or red soil areas consists of lining of the structures (Shalander *et al*., 2016).

4.2.3 Natural Resource Management

Soil health improvement can enhance resilience of agriculture systems in changed climates Numerous practices were initiated to enhance soil carbon, increase water holding capacity, reduce soil erosion, which can potentially enhance resilience of soil. Analysis of soil was conducted in farmers' fields to recommend location specific nutrient management practices, correct deficiencies to lower N_2O release and also to rationalise fertiliser application (Srinivasarao *et al*., 2013b). For instance, in paddy and wheat systems of cultivation in some parts of North India, where huge amounts of left-over crop residue is commonly burnt after paddy harvest extensive frontline demonstrations conducted in farmers' fields to recycle the left-over crop residues of paddy and wheat sowing was done by using zero tiller. This intervention of crop residue recycling and zero till planting of wheat has numerous benefits like reduction of CO_2 release into the atmosphere due to crop residue burning, decreases soil till and conserves water and energy (Hobbs and Gupta, 2003; Sapkota *et al*., 2015).

A long term (18 years) experiment carried out to study the influence of synthetic fertilisers and organic sources of nutrients on carbon storage in comparison to raising of crop and carbon capturing in entisol of western India. The results reported that the application of 33.5Mg ha^{-1} carbon along with farm yard manure did not met the loss of soil organic carbon through oxidation and net loss of 4.4 Mg C ha^{-1} occurred in 18 years. The loss of soil organic carbon non-fertilised plot was even more, that is, 12 Mg C ha^{-1}. Higher agronomic yields and reduction in rate of soil organic carbon depletion due to integral use of chemical fertilisers with farm yard manure. In six cropping seasons the optimum yields of seeds in pearl millet (809 kg ha^{-1}), cluster bean (576 kg ha^{-1}) and castor (827 kg ha^{-1}) were obtained by combined use of fertilisers and manure. There was a proportional increase in soil organic carbon stock and yield. An increase of 0.46 Mg of crop yield is reported for every Mg rise in profile soil organic carbon stock. (Srinivasarao *et al*., 2014).

4.2.4 Horticultural Systems

Horticultural crops like fruit trees which are perennial are more tolerant to rainfall variability compared with annual crops due to the presence of deep root systems. Adoption of fruit tree-based cultivation ensures higher income to producer and provides way for value addition and a platform for generation of jobs in the rural areas (Dhyani *et al*., 2013).

4.2.5 Poultry and Fishery

The important intervention in poultry sector during variations in climate is to introduce improved breeds which can tolerate high rainfall conditions. To bear the high temperatures during the day and protection from night, poultry is provided with improved shelters. For fisheries, interventions like production of quality fingerlings, reduction in cost of production of fingerlings by engaging various groups in mass developing of fingerlings, release of fish into the filled water reservoirs especially in high rainfall areas, establish village institutions for day to day operations, management, building potential and sharing of benefits are some of the practices which can potentially contribute to resilience in fisheries sector.

2.5.6 Livestock and Fodder

In arid areas of India, animal-based farming is important for income generation and sustaining livelihoods. Though drylands are not suitable for intensive cultivation, drought tolerant crops and cultivars which are also valued for fodder are preferred. In low rainfall regions, interventions like enhancing fodder production and availability, improved shelter for livestock for minimising heat stress, improved breeds of small animals and livestock and improved health of animals and saving the fodder during rainy season for using it in dry periods are some of the promising interventions for improving resilience (Kinyangi *et al*., 2015).

4.3 Institutions in CRV

Developing support systems in the village either by nurturing the already established institutes or inaugurating new ones like Village Climate Risk Management Committee (VCRMC), establishment and management of Custom Hiring Centre (CHC) for farm implements, seed bank for procuring seed at emergencies, fodder bank, creation of commodity wise groups, water sharing groups are to be taken up for developing CRV. Initiation of collective marketing by strengthening value links, village level group nursery, and provision of weather index-based insurance and providing climate information and advisory services using data from automatic weather station and village level manual weather station were taken up to synergise the efforts (Srinivasarao *et al*., 2016).

4.4 VCRMC

In all the CRVs an institution known as VCRMC was established involving all the categories of farmers and also by involving the democratically elected representatives of the village. This institute consist of villagers (12–20 members) with president, secretary and treasurer chosen between them unanimously with one female member. This group supports the adoption and the spread of the resilient practices in the village. VCRMC engages in all issues like deciding the involvement and their execution, and gives community point of view about the place of water harvesting structures, especially choosing of farmers for enhancing the spread of technologies and coordinates with village head. For raising the fund and for all financial transactions to done, an account on VCRMC was opened in a bank at each CRV and all the farmer's contributions are credited to this account for conducting various programmes. The cost is shared between the project and the farmer for implementation of different interventions in the village. For instance, a producer should contribute to 25% – 50% of the cost of the intervention and the received amount is credited in the VCRMC account. Committee takes the decisions unanimously and utilises the money received in the account. Other contributory share of farmers for purchase of best performing animal breeds, fertiliser, etc. is also credited in the VCRMC account. The expenses and income gains are periodically discussed with the head of operations. At village level and in research institutes capacity building was done for the office bearers with regards to interventions, their implementation and resources handling (Srinivasarao *et al*., 2016; Venkateswarlu *et al*., 2012).

4.5 CHCs

In rain fed agroecosystems agricultural operations should be done in time to utilise sowing window effectively mainly for planting and weeding operations as the low or higher availability of moisture in soil limits the area to be brought under cultivation in the season. (Reddy *et al*., 2015). For ensuring average plant population and crop growth in the field, it is important to sow timely and to schedule other operations depending on the moisture status in the soil. Small farmers cannot go for timely sowing due to lack of implements as their availability and access to small farmers is very less (Mehta *et al*., 2014).

NICRA established CHCs in the villages for acquiring of required farm equipment's to utilise during adverse climate events (Srinivasarao *et al*., 2013). As the small farmers cannot afford for costly machinery, about 151 CHCs were started in various ecological regions of the country as part of NICRA. Their main focus was on small farm mechanisation as per the location. At country level Central Research Institute for Dryland Agriculture (CRIDA) took the lead in planning and execution of the programme. Zonal Project Directorates (ZPDs) presently known as ATARIs (11) and concerned State Agricultural Universities (SAUs) were implementing the programme in their specific zones. Whereas, at the village level, KVKs are implementing the project through farmer's participatory approach (Srinivas *et al*., 2017).

CHC gives access to required implements and tools at the village under the control and management of committee for providing access to farmers for performing various farm operations in different agroecosystem. These implements can be used on rent basis by paying user charges by any farmer. The number of tools and machines and the type were decided in consultation with the village level extension officers and VCRMC. The rent for the equipment's and machinery were shown on board and the charges gathered is collected by the VCRMC. The raised money from custom hiring is used for maintenance, wear and tear of machines and instruments and the left-over money used as circular fund for necessary activities at village level. Most of the equipment's bought are related to planting, intercultural operations, protection, harvesting and post-harvest operations and unique equipment's like transplanting of rice seedlings, breaking of hard pan under plough layer, etc. Farm implements widely used in CHCs are rotavator for seed bed preparation, power weeder, multi-crop planter, for sowing of paddy zero till drill and drum seeder and chaff cutter.

A study was conducted in Raichur of Karnataka state on access to farm machinery for small and marginal farmers from CHCs has enabled them to perform their farm operations timely at low cost (Hiremath *et al*., 2015). The income of these small and marginal farmers have increased from 10% to 15% due to increase in productivity with the assistance taken from CHCs for farm machinery. Hence, the CHCs have much scope for the betterment of small and marginal farmers and for taking up timely operations which can enhance resilience.

4.5.1 Village Seed Banks

To give resilience against climate variability, farmers should be supplied with improved and stress tolerant seeds, which is an important intervention. The main role of seed bank in a village is to supply the seed during emergencies like non-availability of seeds, where there is a chance of resowing. These community seed banks serve as beneficial tools for preserving indigenous cultivars and accessibility of quality seeds and provision for lower cost of seed compared with seed vendors. These banks guarantee sufficient quantity of seed at correct time at reasonable cost which increases seed availability (Boef *et al*., 2010). They also helps in sharing seed informally and they educate the farm groups and village organisations and for easy access to seed availability and food security.

A seed bank at village level is an important village institution which strengthens the local farmers' for providing access to diversified crop genetic resources besides on farm conservation of agrobiodiversity (Maharjan *et al*., 2011). Small land holder farmers are present not only in Latin America, Asia, and Africa and also in other developing countries depends mostly on farm saved seeds for sowing and informal system to get new seeds (Louwaars and de Boef, 2012).

For seed production of 2–4 important crops varieties, a group of 20–25 farmers were selected in the village. These farmers group was given training, guidance and then seed for multiplication of the seed. In the beginning the group was given with breeder/foundation seed then they are trained on production of seed, seed processing and finally storage of seed. Demonstrations were given on seed production of flood and drought tolerant and short duration varieties at village level with the help of farm science centres in rice, moong, finger millet, groundnut, soybean, red gram and foxtail millet. The improved and tolerant cultivars are raised, multiplied on the farms, then taken for processing and finally stored for easy availability to village farmers by the communities. Seeds taken from the farmers are carefully chosen and stored based on the existing conditions of storage facilities of the area. Storage at community seed banks may be of different types like in pots in shed or mud pots on the plain surface.

4.5.2 Community based Fodder Banks

In developing nations like India small farm land holders takes up mixed cropping and livestock where animals are vital for their income, food and nutritional security of their household, which supports diverse activities such as draft power, transportation, spread risk and are the vital role for income generation and savings (de Hann *et al*., 1997). Feed for the livestock is met through different ways like left over crop residues, cultivable fallows, private and community lands for grazing, crop lands after harvest and a small area of cultivation of forage crops. The climate change events like temperature change, rainfall patterns, CO_2 concentrations will impact production of grass crops, fodder crops, etc. which leads to change in diets and decrease in access to food for animals (Izaurralde *et al*., 2011; Thornton and Herrero, 2014). During hotter months of the year the fodder obtained is less in quantity and quality and also low in nutrition compared with wet season and the animals grown on dry lands are less productive.

For ensuring high quality diet to animals during dry season, supplements is an option but the limitations are of low in availability, high cost and the small farmers cannot afford for buying. The other way is to form a fodder bank in village, if the area under pasture is significant. These fodder banks helps in high quality fodder production which gives huge biomass in less time which is beneficial for use in dry season and at scarcity (Bayala *et al*., 2014). Growing of high biomass producing and rapid growing grasses and shrubs enhances the availability of fodder, decreases soil erosion in these areas. Other benefits of establishing of fodder banks at village level are storage of excess fodder, supply of nutritious fodder during off-season, and increase the nutrient content of crop leftovers and other plant waste for livestock food (Dhyani *et al*., 2013). Even though these banks do not provide cent percent requirement still they add forage during dry season. Villages which are prone to severe shortage of fodder during dry seasons, community fodder banks are formed.

4.5.3 Automatic Weather Stations

Indian rainfed agriculture is largely rely on monsoon and is affected by its variability. Real-time information on weather helps farmers to reduce the risk. This is possible only if they have access to best network of weather observatory with fast communication facilities. From crop sowing to post-harvest and marketings the information on weather and climate plays a key role and if this is known in advance can helps the growers to set the available sources to take the advantages by complete use of high value fertilisers. For real-time access to weather data a network of automatic weather stations (AWS) is the good one, which benefits the researchers to know site-specific estimates and helps in avoiding adverse weather based impacts. Along with real-time weather data, agrometeorological advisories and weather forecast helps to sustain crop yields by management of agro-climatic resources and other inputs like irrigation, pesticides and fertiliser (Rathore, 2013).

For recording real-time weather parameters like temperature, wind speed, rainfall and sunshine hours, AWS were established at farm science centres and small weather station in villages of project implementation. This weather data is saved, archived and given to the people. Capacity building programmes on environmental data collection and its use as agro advisories are initiated.

4.6 Impacts of Climate Resilient Interventions

From NARS various agricultural practices were developed which can mitigate the effect of climatic aberrations on crop production and helps in adjustment to variations of climate. Additionally, adjustments in practices can reduce the variation of yields and increase the production under natural calamities and climate variation which gives to resilience (Mall *et al*., 2007; Singh *et al*., 2012). It is important in choosing of better cultivars and crops on the basis of prevailing climatic problems of the area. For rain fed areas, selection of suitable crop cultivars like early maturing, drought bearing and the potential to give profitable output even at low soil moisture situations is to be taken up (Webber *et al*., 2014). Early maturing cultivars comes to harvest within short time, can avoid drought even the monsoon is for few months and can also be cultivated if the monsoon is not on time as an adaptation strategy. A study was conducted in Aurangabad district of Maharashtra to face the challenges of low rainfall conditions by early maturing and drought tolerant cultivars of red gram (BDN–708), moong dal (BM 2002–1), and chick pea (Digvijay and Vijay) were cultivated which resulted in 20%–25% higher yields than local varieties. In another study taken up in a village Chamua of Lakhimpur district with various land conditions to find out the interventions suitable to face the dry weather which occurs seasonally in Sali rice. Effect of dry weather on late maturing cultivars was low on plains but the yield of these cultivars was decreased to 43.07% when they are sown after 23rd of June. Yields of the late sown cultivars were low, when they were affected with dry weathers in the later stages of crop growth. The problem can be overcome in low lands and hills through the use of early maturing and medium maturing high yielding cultivars and adjusting the sowing dates of late maturing cultivars for plains (Neog *et al*., 2019).

Cyclones along with intense rains leads to flooding situation impacting rice cultivation in India. Cultivation of flood tolerant cultivars can lower the loss (Dar *et al*., 2013). Rice varieties, MTU-1001, MTU-1140, Swarna-sub1 and MTU-1010, can do well in excess water conditions. By utilising inter spaces of foxtail millet with pigeonpea sown in the ratio of 5:1 during late onset of rainy situations resulted that the system was more profitable with high benefit cost ratio of 5:1 against 1.5–2.6 in mono cropping system in all the consecutive three seasons of study and can also endure drought up to 25 days without affecting the yields. In a study which receives an annual rainfall of 645 mm in Aurangabad, Maharashtra intercropping of pigeonpea + moong dal (1:2), pearl millet + pigeonpea (3:3), cotton+ moong dal (1:1) and soybean + pigeonpea (4:2), performed significantly better than respective sole crops (Prasad *et al*., 2015).

Soil and water conservation practices like ridge and furrow system, low lying and raised bed system, paired row planting, mulching, conservation furrow, contour farming, broad bed and furrow system, etc. can minimise the impact of dry spells and drought which occur frequently in rainfed areas of the country. But, the success of any practice depends on the location specific factors (Srinivasarao *et al*., 2014). *In-situ* soil and water conservation practices has many benefits like improving soil hydraulic conductivity and porosity, increased rate of infiltration, enhancing soil water retention capacity and eventually minimising the impact of drought (Srinivasarao *et al*., 2016a). It is important to combine different farm services such as, livestock, dairy, duckery, honeybees rearing, horticultural crops and field crops, etc. within the available physical and biological resources to reduce the risk in farming and to increase income under small-scale land holder conditions (Das *et al*., 2014; Shanwad *et al*., 2015). An IFS model with a farm pond was demonstrated in some low rainfall areas of Datia in Madhya Pradesh, by way of integration of crops, short duration vegetables and fish production.

Sustainability of livestock production is depended on the availability of natural resources which impacts the productivity of livestock. Livestock based systems minimises risk to variable climate. For example, the productivity of local breeds is low and they can tolerate extremities in climate better than the exotics and high productive local breeds were used for enhancing the productivity (Kinyangi *et al*., 2015). During offseason

(December–May) In rainfed areas sufficient availability of fodder, that is, fresh or dried was one of the constraints for increasing livestock production (Sati and Singh, 2010). In a case study conducted at Baramati district, Maharashtra in salt affected areas, salinity tolerant *Dichanthium annulatum* (Forssk.) (marvel grass) Phule Govardhan produced 29% higher green biomass in comparison to fodder sorghum under low rainfall conditions.(Prasad *et al*., 2015). Making available of green fodder during dry season (December–May) in an important intervention for sustainable livestock production which is an important component of CRA. Livestock should be fed with harvested green fodder from maize in silage bags with a capacity of 500 kg is best to give food to one milch animal at the rate of 5 kg per day resulted in 15.5% enhancement in milk production over the regular farmer's practice of giving only dry fodder in Yaganti Palli village of Kurnool district (Prasad *et al*., 2015).

4.7 Mainstreaming CRV into Programmes and Policies

India is a developing country and climate change is a major concern due to its impact on economy especially on farming sector for food availability. Agriculture is an important component of the economy of the country with a share in employment of about 53%. As agriculture is vital for the economy, several programmes were initiated by the government to affectively address the impacts of climate change since the last 6 decades.

India is playing a key role in the United Nations Framework Convention on Climate Change (UNFCCC). In 2003, it has established the National Clean Development Mechanism Authority (NCDMA). The prime minister of India in the year 2007 has set up the board to coordinate the country's action for estimate, adjustments and reducing the effect of climate aberrations. In 2008, to solve weather extremities and to address the growth concerns of the economy, NAPCC was launched. Out of the eight National Missions, sustainable agriculture is the centre of the NAPCC, which indicates 'multipronged, sustainable and combined decisions for reaching the aims of changes in climate'. To support climate change adaptation in agriculture the National Mission on Sustainable Agriculture (NMSA) was formulated which aims at development of climate adversities tolerant crop cultivars, agricultural practices and spreading weather-based insurance and to minimise the impact of climate change on the agriculture sector. SAPCC are also formed by all Indian states in accordance with the NAPCC to bring the integration of adaptation and mitigation practices into the ongoing schemes and policies of the government.

ICAR has emerged as the nodal organisation in agricultural research, innovation of technologies and dissemination of technology. ICAR started an interlinked programme on variations of climate in 2004 with fifteen centres and subsequently extended to 23 centres. This project aims at assessing the impacts of climatic variation on agriculture and allied sectors and to develop management practices which can minimise them. NICRA was started by the ICAR in the year 2011 with the objective of developing technologies, demonstrating proven practices to farmers and to build capacities of stake holders. The proven resilient practices are demonstrated so as to enhance their adoption by the farming community. The technologies demonstrated can be divided in to 4 modules (1) natural resource management (2) crop production improvement (3) innovations of institutions and 4)improving livestock and fisheries. The main objective of this mega project is to develop climate resilient village in 151 districts of the country which faces various climatic extremities such as drought, cyclones, famines, heat waves, hailstorm, cold waves, seawater intrusion, frost, etc. so as to stabilise agricultural production and livelihoods, and reduce emission of greenhouse gases and carbon enrichment practices. CRVs acts as a model for adjacent villages, blocks and districts for dissemination of knowledge on climate change adaptation and expansion. For further upscaling of CRVs there is a need to integrate proven resilient technologies with that of the development programmes like soil health card, water mission, National Agricultural Development Programme (NADP), National Mission for Sustainable Agriculture (NMSA), Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA), Pradhan Mantri Krishi Sinchai Yojana (PMKSY) and green climate fund, etc.

In 2014, India started National Agroforestry Policy to combat the extreme weather-related events and to support and extend the planting programme in a combined way with conventional crops, forest trees and animal sector to better the production, income generation, job creation in villages and livelihood security of rural people to save and encourage resilience in cropping systems. The programme also aims at production of required raw material by various industries like timber based and for small timber for village and tribal farmers and leads to reduction in pressure on forests for timber. Various other schemes like MGNREGA and National Afforestation Programme also takes part in afforestation, drought related programmes and natural resource management. Green India Mission (GIM) takes up in promotion of restoration of forests, agroforestry, afforestation and urban forestry

5. Conclusions

Climate change and variability is impacting agricultural production throughout the world but a developing country like India is more affected due to more people are dependent on agriculture, exhaustion of natural resources and poor recovery processes. Short term and long-term variations in climate are impacting agriculture, livestock, poultry and fishery sectors. A developing country like India, it is important to stabilise production and livelihoods under variable climates which is important for sufficient food and nutritional security especially to resource poor small and marginal farmers. In the year 2011, ICAR started NICRA project with an aim to build model CRVs to stabilise production and income of the farmer, in spite of extreme weather events and natural disturbances in weather through adjustment to various climatic aberrations. About 151 villages chosen are in regions prone to climatic stresses like drought, floods, cyclone, heat or cold wave, seawater intrusion, etc. Suitable climate resilient involvements are identified and demonstrated in participation with farmers as well as village level technology transfer extension workers. Institutional interventions such as, formation of VCRMCs, CHCs for procuring of tools, machinery, seed storage banks for access to new better varieties of crops, and fodder giving banks were encouraged via combined way to develop to resilience between groups of farming communities. Conducting of on-site demonstrations for capacity building on new technologies, practices, demonstrations, and exposure tours supported farmers to get access to information and built capacities of farmers to face harmful weather aberrations. At several places, demonstration of resilient technologies, institutional and policy interventions and convergence with the development departments resulted in the spread of technologies to majority of the households in the village. Significant increase in productivity and livelihoods and adaptation to climate extremes as well as mitigation co-benefits are seen. Some of the promising technologies are being integrated in to central and state governmental schemes for their up scaling. The formed CRVs have become an example for affectively addressing the concerns of climate change. The approach is effective for production of food through various technological interventions and to address climate adversities in addition to ecosystem services by means of reduction of greenhouse gases emission.

6. Way Forward

To meet the food and, livelihood security at the household level it is important to address the climate change and variability. It is urgent due to enhanced occurrence of cyclones, dry weather of various degree, cyclones, storms and terminal heat in post-rainy months and water inundations in various parts of the nation. The approach of climate resilient villages can enhance the capacity to adjust to variations of climate. Different practices can enhance resilience and adaptive capacity of communities are *in situ* soil moisture conservation, incorporation of crop residue avoiding burning, build up soil organic carbon, rainwater harvesting, use of flood and drought resisting cultivars, water conserving methods, site related cultivation practices, enriched feed for animals and ways of giving feed can helps in reduction of greenhouse gases emissions. In addition to the technologies the following approaches can further build the capacities of communities for effectively facing the climatic extremes:

- For the development of CRVs, requires a strong government policy, a well-framed institutional help and integration among different institutions.
- At village level promote ITKs in collecting germplasm, saving natural resources, etc.
- Technological inputs for CRVs were obtained from NARS. For upscaling and out scaling of CRVs can be done through NAPCC, policy of national agroforestry, district contingency plans, SAPCC, and with various schemes and central programmes such as, PMKSY, Water Mission, RKVY, NMSA, National Afforestation Mission, MGNREGA, etc.

- Develop and disperse crop cultivars which are tolerant to flood, drought and heat. Form rural level seed storage banks for meeting the requirements.
- Increase the number of weather observatories and set up rain gauges at village level. Through weather based agro-advisories manage the climate adversities.
- Improve the knowledge dissemination services and information transfer like improved ICT modules to increase the potential of villagers or producers to tackle the weather stresses.
- For adoption of climate resilient agricultural practices and resource conservation technologies farmers should be provided with incentives and credits.
- Continuous support for the development of climate resilient technologies.
- For diversification in income of vulnerable areas support for off-farm activities and for sustaining their livelihoods.
- Initiate institutional mechanisms at village level such as SHGs, CHCs, seed material availability, climate risk management committees, farmers' cooperative societies and provide enabling environment for continuous sharing of information.
- Capacity building programmes to all the stakeholders like farmers,' village youth, technology transfer persons.

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