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Climate Resilient Agriculture an Approach to Reduce the Ill-Effect of Climate Change

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***Abstract*: Climate resilient agriculture (CRA) is a sustainable approach for converting and reorienting agricultural systems to support food security under the new realities of climate change through different adaptation and mitigation mechanisms. Agricultural systems are extremely vulnerable to climate change, given their sensitivity to variations in different threats like temperature, precipitation and incidence of natural events and disasters such as droughts and floods with this on an average the extreme weather patterns can impact farm incomes in the range of 15-18 %. Threats can be reduced by increasing the adaptive capacity of farmers as well as increasing resilience and resource use efficiency in agricultural production systems. CRA promotes synchronized actions by farmers, government, scientist, private sector, and policy-makers through three main action areas: (1) Building the capacity to identify the threats; (2) Curing the threats through adaptation and mitigation process (3) Sustain their adaptive mechanisms over a long time. The vulnerability of existing conditions of poverty, malnutrition and increasing populations puts intense pressure on finite natural resources, especially land, water and energy – all of which are integral to agricultural systems. In this context, it becomes imperative to adopt Climate-Resilient Agriculture (CRA) measures at co-operative scale to address the impending impact of climate change on agriculture.**

***Keywords*: Climate Change, Climate Resilient Agriculture, Finite Natural Resources, Food Security, Malnutrition, Threats.**

1. Introduction

Climate change is long-lasting change (i.e., over the decades) in the statistical distribution of weather pattern which pose a great problem towards ecology and persist for long periods with its toxic level. It is well established fact that climate change is supported by greenhouse gas (GHG) emission. Agriculture is both a target of and a contributor to climate change. Agriculture was the second highest source of GSGs emission (19.6% of total emissions) (FAOSTAT), among this India's total GHGs emissions in 2014 were 3,202 million metric tons of carbon dioxide equivalent (MtCO2e), totaling 6.55% of global GHG (www.climatelinks.org), mainly due to the use of chemical fertilizers, low nutrient use-efficiency pesticides, enteric fermentation, transplanted rice cultivation etc. Additionally, 1/3 of food produced globally is either lost or wasted (www.worldbank.org). Resilience is the ability of a system and its component to anticipate, absorb, accommodate or recover from the effect of hazardous event in a timely and efficient manner (IPCC, 2012). Adverse influences of global warming include reduced crop quantity and quality due to the reduced growth period following high levels of temperature rise, reduced sugar content, and reduced storage stability in fruits, increase of weeds, blights, and harmful insects in agricultural crops, reduced land. Climate resilient agriculture increase the capacity of the system to bounce back and it changes in such a way that it doesn't go back to the previous situation. For us Climate resilient agriculture is a new term but this adaptation and mitigation mechanism is already present in the nature from immortal, but the problem is rapidity of the climate change, it changes too fast that nature can't synchronize with this. Climate change can be natural (i.e., due to continental drift, volcanos, earth's tilt, ocean current) or anthropogenical (i.e., due to urbanization, industrialization, burning of fossil fuel, deforestation, unscientific agricultural practices); natural climate change can be synchronizing with the nature but the anthropogenically caused climate change dominate over the nature's synchronization power, but with some mitigation and adaptive green technologies ,nature also combat the human induced or anthropogenically caused climate changes.

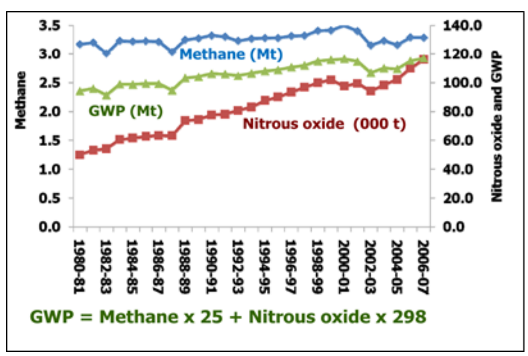

Fig. 1. Trends of greenhouse gas emission from Indian agriculture soil (source: online).

2. Effect of Climate Change on Agriculture

Climate change and agriculture are interlinked, both of which take place on a global scale. Agriculture is particularly vulnerable to climate change. There is different type of threats governed by the climate change, among them temperature,

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CO_2, rainfall affect directly to the plant growth and indirectly by land availability, irrigation, weed growth, pest and diseases outbreak etc. The climatic potential yield, which depends mainly on the climatic condition get reduced due to the vagaries of the threats. Since 1970 the global average temperature has been rising at a rate of 1.7°C per century (Marcott et al., 2013). High temperature will tend to reduce quality and yield of crops, it also encourages the weed and pest proliferation. In general, the temperate regions appear to be less vulnerable to climate change than the tropical regions due to the fact that higher temperatures in temperate areas shift biological process rates toward optima, and beneficial effects are likely to ensure (Rosenzweig, C., et all.1992). Increases in temperature will also extend the frost-free season in temperate regions, allowing for longer duration crop varieties to be grown and offering the possibility of growing successive crops. In tropical locations where increased temperatures may move beyond optima, negative consequences may dominate over benefits. A 1°c increase in mean temperature resulted in considerable decrease in grain yield of C3 plant like rice by 6% (Saseendran., 2000) and in wheat, soybean, mustard, groundnut, potato by 3 to 7 % (Dagar et all., 2012). In north-western India specially in wheat every 1°c increase in temperature reduce yield by 4 Mt (Reddy., 2019). But in elevated CO_2 Level, C3 plant get benefited more than C4 plant due to the fact that C4 plant close their stomata early then C3 as C4 plant have less CO_2 compensation point (0-10 ppm) and high PEP carboxylase activity thus reduce the transpiration and induce the leaf temperature lead to temperature stress within leaf level. Increase in CO_2 to 550 ppm increase the yield C3 plants like rice, wheat, legumes, and oil seed by 10-20% (Venkateswarlu., 2014). The combined effect of temperature and CO_2 is complex but the negative effect of temperature is more prominent over positive effect of CO_2, as high temperature induce respiration, mineralization, reduce nutrient use efficiency, net assimilation in crop. Due to terminal heat stress, plant lead to forced maturity thus reduction in crop yield. In general, vegetative growth is positively co-related with elevated CO_2 level but the reproductive stage of the crop is more linked with an optimum temperature, thus the economic yield reduced with increasing in temperature as it not gets the particular temperature at the critical stages and increased vegetative growth resulted by elevated CO_2 use the all-residual soil moisture quickly so reproductive stages faces two stresses i.e., temperature and water as well. Change in precipitation pattern increase the Probability of short-run crop failures and long-run production letdowns. Erratic rainfall with high CV% lead to erosion loss and waterlogged situation. A trend of increasing monsoon seasonal rainfall has been found along west coast, norther Andhra Pradesh, and north-western India (+10 to +12% over the last 100 years) while a trend of decreasing monsoon seasonal rainfall has been observed over eastern, north-eastern India and some Gujrat and Kerala (-6 to -7% over the last 100 years) (Reddy., 2019). Changes in precipitation pattern alter the interaction between insect-pest and their host crop, changes in the pattern of rainfall will cause the alteration of water availability, which ultimately lead to weed shift thus application rate of agricultural chemicals increased copiously lead to environmental pollution. Farmers always prefer a production system with less variation in yield over the year but increased drought and flood are likely to increase production variability. Drought reduce the quality of forage available for grazing livestock. Increased temperature in sea and river temperature are likely to affect fish breeding and migration. Increasing acidity of world's ocean, could harm shellfish by weakening their shell which is made up of Ca.

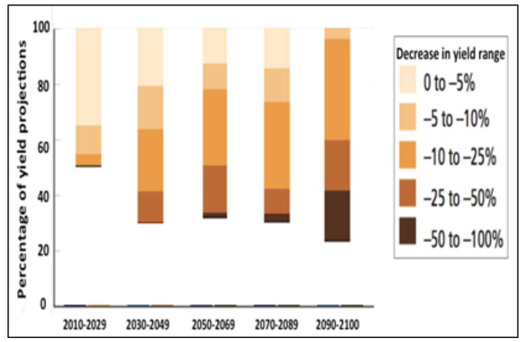

Fig. 2. Studies show that a decrease in crop yield under global climate change (Source; Climate change and Food Security IPCC 2014 5th assessment)

3. How does Climate Resilient Agriculture Works

Climate-resilient agriculture (CRA) is an approach that includes sustainability with existing natural resources through crop and livestock production systems to achieve long-term higher productivity and farm incomes under climate variabilities, it differs from climate smart agriculture (CSA) that, climate smart agriculture (CSA) is too advanced and smart that it doesn't allow any adverse situation of climate change over ecology as well as productivity, but climate resilient agriculture(CRA) is an inbuilt mechanism of the system to recognition the threats that need to be responded to, with effectiveness. Climate smart means anything which is planned effectively in advance to encounter vagaries of climate change so that its effect may be minimized. This may involve avoiding stress or tolerating stress with any set of procedures. However, climate resilient is something which is capable of tolerating the stress arising out of a set of conditions.

Climate-resilient agriculture (CRA) include 3 phases, i.e.,

- *Recognition Phase*: "System recognize its adverse threats quickly". Such threats include event such as erratic rainfall, cyclone, drought, flood, heat or cold wave, long dry spell, frost, insect and pest outbreaks and other threats caused by climate change.it is also known as initial phase of CRA.
- *Curing Phase*: "System cure itself through different adaptive and mitigative mechanisms". Such mechanism includes conservation agriculture, cover crops, integrated farming system, carbon sequestration, direct seeded rice, precision farming, site specific nutrient management. It is the intermediate phase of CRA.
- *Sustaining Phase*: "System should sustain their adaptive mechanisms over a long time". CRA with these mechanisms building itself in such a way that it

can break through any hurdle that would come its way. It is the final phase of CRA.

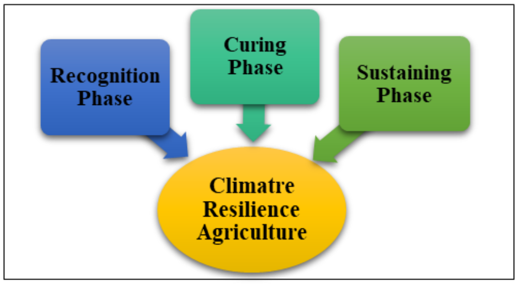

Fig. 3. Recognition Phase, Curing Phase, Sustaining Phase, act together to bring the climate resilient agriculture

4. Recognition of Threats in Agriculture

In recognition phase, system (i.e., agricultural system) recognize its threats, but now as rapidity of climate change is increased so human intervention is required for recognition of threats. Threats can be 2 types, i.e., long term threats and short-term threats. Long-term threats include ground water depletion, crop burning, pattern change in rainfall, soil organic carbon degradation, atmosphere and groundwater pollution, urbanization, industrialization, etc. Short-term threats include flood, drought (early-season, mid-season and terminal drought), frost, heat/cold wave, cyclone, hail-storm, insect pest attack etc. Scientist community play an important role in detection of long-term threats by their extensive research, it is now possible to figure out the long-term threats. Here for the first time, ground water depletion was reported in regional-scale basis through long-term study (1996–2014, using more than 19000 observation locations) in situ and decadal (2003–2014) satellite-based groundwater storage measurements in western and southern parts of India (Bhanja, S. N et al, 2017). Extension workers creates awareness to these threats to the farmers. Over the time being the short-term threats create problems which is resultant of the long-term threats, is more devastating and erratic in nature. If we aware with these long-term threats and act accordingly then the vulnerable effect of short-term threats are not be there. Recognition of long-term threats act like a prevention mechanism, and always prevention is better than cure. For short-term threats weather forecasting play a significant role. Medium range weather forecast is for a period of 3 to 4 days to two weeks, which is more significant in relation to agricultural purpose.

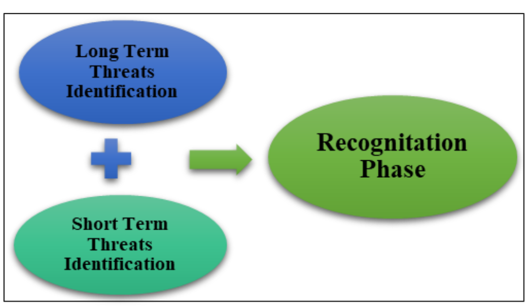

Fig. 4. Both long- and short-term threats identification help to CRA

5. Curing of the Threats to Reduce the Effect of Climate Change

Adaptation and mitigation are two important strategies to bring resilience to the effect of climate change. Adaptation is referring to "adjustment in ecological, social, or economic system in response to actual or expected stimuli and their effects or impact. The term refers to change in process practice and structure to moderate potential damages or to benefit from opportunities associated with climate change" (IPCC. 2001). Mitigation means using new technologies and renewable energies to making older equipment more energy efficient or changing management practices or consumer behavior (Chary et al., 2008). Mitigation mainly focused in the use efficiency of that system to reduce the greenhouse gas effect. By reducing GHG emission and enhancing removals from atmosphere increase the efficiency of mitigation of climate change.

A. Improved techniques for adaptation to climate change

Adverse effect of climate change can be reduced by implanting program like weather based agro-advisories, crop and variety selection, efficient cropping system, water harvesting for conserving water resources, Custom hiring of farm machineries, contingency planning etc.

1) Weather based agro-advisories

Programmed weather stations at KVK and mini-weather observatories in village level are established to record real time weather parameters such as rainfall, temperature, relative humidity and wind speed etc. And to increase the customized agro-advisories and improve weather literacy among farmers. The agro advisory based on this is then presented in respective languages in the form of a wallpaper at public places such as Panchayat Buildings or Schools or any favorable place from where all farmers get information. Mobile phones are being used to give the personal message to the farmer for short coming weather condition and it is now ever-increasing appeal to rural users. Weather based agro advisory helps to the farmer to act accordingly, thus the upcoming ill-effect of the weather can be reduced in farmer's level.

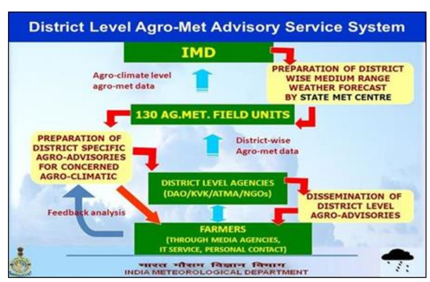

Fig. 5. Flow chart of agromet advisory (source: IMD)

2) Smart Crop and Variety selection

Selection of a climate-smart crop variety is the best adaptation option, crop which have more sowing windows can be sown in broad sowing dates. Different weather calamities like heat/cold wave, flood, cyclone, frost, hail storm, reduce the potential climatic yield of a particular zone. So based on the weather forecasting and long-term research data, we have to select a crop which is suitable for this particular region.

Sometime reallocation of crop in alternatives areas can also be a great option against climate change, for example in basmati rice, tea, coffee, are sensitive to temperature increases as temperature reduce the quality, so alternative areas that become suitable for this crop from quality point of view need to be allocated. In rice-wheat cropping system introduction of a short duration summer legume like moong bean as break crop or catch crop after wheat harvesting maintain the soil quality as well as it adds some organic matter and reduce the N20 emission from the field as the residual nitrogen can be used by moong bean after wheat.

3) Efficient climate-based cropping system

Efficient cropping system means a location specific cropping system which can fulfil the market demand, soil health, consumer choice, as well as control weed and minimize the pest outbreaks. Mixed cropping, intercropping, relay cropping reduces the climatic vulnerabilities. Farmers can get at least one crop if any adverse situation is there. Pigeonpea either as a base crop or inter crop performed better, particularly in the sorghum, cotton, pearl millet-based cropping system (AICPRDA,2013). Inclusion of a legume in cropping system add sustainability to this system through soil cover, addition of biological nitrogen. Cultivating of a legume, usually after the principal cereals crop, is a well-known strategy under rainfed agriculture. An efficient cropping system always meet the climatic requirement based on the particular region.

Table 1
Potential cropping systems in relation to rain fall and soil type in India.

Rainfall (mm)	Soil type	Effective Growing Season (week)	Suggested cropping systems
350-650	Alfisols and shallow vertisols	20	Single rainy season cropping
350-600	Deep aridisols and Entisols	20	Single cropping either in kharif and rabi
350-600	Deep Entisols	20	Single post rainy season cropping
600-750	Alfisols, Vertisols, and Entisols	20 -30	Intercropping
750-900	Entisols, Deep Vertisols, Deep Alfisols, and Inceptisols.	30	Double cropping with monitoring
More than 900	Entisols, Deep Vertisols, Deep Alfisols and inceptisols	More than 30	Double cropping assured.

4) Water harvesting

According to World Bank, India with the geographical area of 3.29-million-km2, supports more than 18% of world's population but has only 4.2% of fresh water resource. Climate change shall have implication on water resources and agriculture. An increase in temperature will increased demand for water for evapotranspiration by crops and natural vegetation and will lead to more rapid depletion of soil moisture. According to one projection, a rise in 1°c will increase the crop water demand by 2%. Climate change significantly affect sea level with potential impacts on the salinity of the surface and groundwater in coastal areas. The rising levels of CO2 concentration, warmer atmosphere and more intense precipitation may have significant effects on the hydrological and Regional Water source availability. Cyclone which is now more often, created by oceanic temperature rising above 26.5°c lead to devastating loss in the coastal areas. Increased precipitation induces run off, whereas increase in temperature may enhance the evapotranspiration demand So, water harvesting shall be a boon for the resource saving adaptation programme in water management. During the rainy season in dry and dryland farming areas, a rain harvesting system (water tank, dug well, percolation tank, farm pond) is used to catch and collect rainwater. The rain harvesting system reducing the electricity that would otherwise be needed for pumping in lift irrigation. This water is then available for people to use and consume during the dry season when there is a shortage of clean water. Likewise, micro-catchments (around 1000 sq. m), small farm reservoirs (1000 to 500,000 cu.m), rooftop systems, water spreaders, inter row harvesting, runoff farming On-farm systems (Contour ridges, Semi-circular and trapezoidal bunds, small pits, small runoff basins, run-off strips, macro-catchments and flood water system, may reduce the water stress to the crop. 1-2 supplemental irrigations from this water harvesting structures sometime give reasonable yield to the growers.

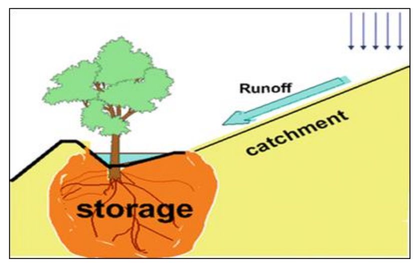

Fig. 6. Collection, accumulation, or storing of stormwater for its eventual reuse

5) Balanced fertilization

Balanced Fertilization is the proper supply of all nutrients (macros and micros) throughout the growth of a crop for optimum growth, yield and quality. Applying of fertilizer in optimum ratio and adequate amounts is called "Balanced Fertilization". Nitrogen is required for protein synthesis, for this plant required optimum amount of energy and enzyme which is provided through phosphorus and potassium. So, application in balanced amount reduce the losses of nutrient from the system. Balanced fertilization provides optimum plant growth, with highly efficient nutrient use, thus less adverse effect on environment. Balanced fertilization reduces the N2O-N emission by controlled use of nitrogen fertilizer.

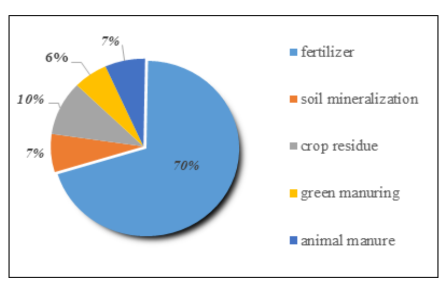

Fig. 7. Emission of N20-N from different sources of agriculture soil (Pathak et al. 2010)

6) Custom hiring of farm machineries

In a village level, land fragmentation is great problem, so community nurseries, community farm machinery hiring reduce environmental pressure due to reduced use for cultivation practices. The Community managed custom hiring centres are setup in each village to access farm machinery for timely sowing/planting. This is an important intervening to contract with variable climate like delay in monsoon, inadequate rains needing replanting of crops.

7) Contingency planning

Contingency crop planning for reverent rainfall refers to planning for alternate, crop and cultivator to suite the resource endowments of rainfall and soil in a given location (Reddy., 2019). In rain fed areas as a general rule, early showing of crop with the onset of monsoon is the best-bet practises for obtaining maximum yield. Generally resowing, thinning the crop, removing the alternate crop, dead furrow, 2% urea or KNO3 or DAP application, growing storm resisting crop (e.g., ginger, pineapple etc) are some promising contingency cultivation practices to combat the climate change.

B. Improved techniques to mitigate climate change

Mitigation process acts from the base, its effort to reduce or prevent the emission of greenhouse gas which is the main culprit. The adverse impact of climate change can be mitigated by reduction of food losses and waste, improved crop management practices, recarbonization of soil, No-Till farming, site specific nutrient management, integrated farming system etc.

1) Reduction of food losses and waste

In 2011, FAO presented the estimate that around 1/3 of the world's food was lost or wasted every year. We generally concerned about how to increase the food production, but if we reduce the food losses then it improves efficiency in the use of resources as less pressure of food production on farmer, and food production industries. In the home, one of the best ways to reduce food waste is to plan meals ahead, rotate time-sensitive foods in the fridge and cupboards and freeze surplus garden vegetables. Process or dehydrate surplus or damaged fruit, produce and meats. Compost kitchen waste which is at least increase the soil health.

2) Improved crop management practices

Carefully managed crop land offers many opportunities to induce the sustainability in crop production. In India rice majorly grown as a transplanted, which not only harm the groundwater resources but also possess some sentimental related problem also. Intermittent irrigation reduces the CH4 production by 40%, but increase the N20-N emission by 6% due to more water filled pore space, low bulk density in surface reduces the diffusion of O2 into the soil, however the total carbon flux is reduced by this process. In rice CH4 emission peak in the tillering to reproductive stage and in this stage 90% of the CH4 passes through the aerenchyma tissue. To reduce this CH4 production from rice field our system has to be resilient one like direct seeded rice (DSR), alternate wetting and drying (AWD). DSR and AWD reduce the CH4 emission about 80-90% and 30-40% respectively (Bhatia et al.,2010). Along with this DSR reduce 30-40% water with an advantage of early sowing.

3) Recarbonization of soils

Soil organic carbon management is the key for achieving the soil resilience to climate change. Increasing soil carbon storage can increase infiltration, increase fertility and nutrient cycling, decrease wind and water erosion, minimize compaction, enhance water quality, and generally enhance environmental quality. Enhancing the carbon sequestration through best management practices (BMPs) like residue management, eliminating fallow period by permanent plant cover in soil, diversified crop rotation with legume, agroforestry etc. Retention of crop residue without burning lead to add some carbon to the soil, 1 tonne of rice residue burning emit 1515 kg CO2, 0.4kg SO2, 2.5kg CH4, 92kg CO, 3.83 kg NOX and non-methane volatile organic compound (Andreae and Merlet., 2001) which can increase the vagaries of the climate change. For retention of CO2 in the soil, ratio of C:N is so much important so the N source from the legume play an important role to control the C-sequestration. Agroforestry is a great option for recarbonization through global carbon sequestration generally involved in carbon capture and the long-term storage of atmospheric carbon dioxide. In agroforestry system the carbon stored in soil ranges from 30 to 300 Mg C/ha up to 1m (Nair et al., 2010).

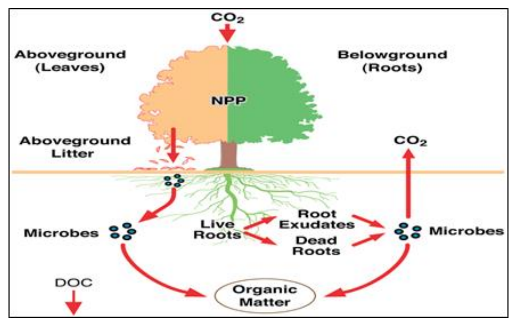

Fig. 8. Forest carbon sequestration

4) No-Till system

Soil tillage practices have a profound influence on the physical properties of soil and the greenhouse gas (GHG) balance. By not tilling their fields, farmers can save labor and fuel costs, reduce soil erosion and preserve precious nutrients. No-till also increases the accumulation of soil organic carbon, thereby resulting in sequestration of atmospheric carbon dioxide. It has been recorded that a significantly higher net global warming potential under conventional tillage systems which is 6–31% higher than zero tillage systems (Mangalassery., et al,2014). According to the environmental protection agency, 2009, in no-till system we can save 35 liters for land preparation, one liter diesel contains 0.74 kg C and emit 2.67 kg, so through this no-till system, global worming potential of a particular system can be reduced.

5) Site specific nutrient management

Agriculture contributes 70-90% of nitrous oxide (N2O) emissions, mostly from N fertilizer (cgiar.org). Site Specific Nutrient Management (SSNM) is an approach of supplying plants with nutrients to optimally match their inherent spatial and temporal needs for supplemental nutrients by using of SSNM through right amount, right source, right rate of application, right time, and right method. It is a dynamics system by which we can optimise the production. SSNM should be prescriptive type and corrective type. In prescriptive type we add nutrient through soil test, crop, and climate basis. And in curative type, means on field management, some of the examples are chlorophyll meter (SPAD meter), leaf colour chart (LCC), Nutrient expert. Though SSNM approach does not specifically aim to either reduce or increase fertilizer use, it aims at applying nutrients at optimal rate and times to achieve the high nutrient use efficiency, yield as well as low cost and also low environmental pressure. Efficient N management can help in adaptation and mitigation while reducing other environmental threats such as eutrophication, acidification, air quality and human health. SSNM reduces N2O emissions by reducing total N application and/or timing applications to crop needs, thus avoiding N losses to volatilization, leaching and runoff.

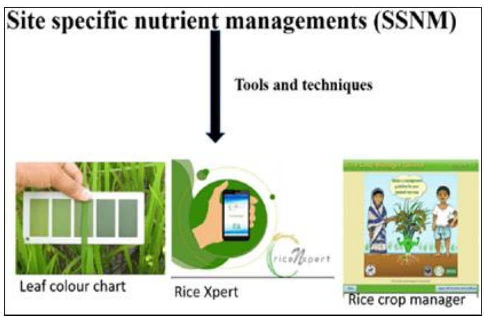

Fig. 9. Some prominent SSNM tools for CRA

6) Integrated farming system (IFS)

Integrated farming has enormous potential to make farmers climate resilient through the cultivation of different crops on the same land and using farm resources sustainably. IFS is often less risky, because it managed the farm more efficiently, thus reduce the dependence of output. IFS benefited by the synergisms among enterprise, and it is environmentally sound. Intermittent use of farm produces proper recycling on by-products, crop residue, weed, an all-other farm waste combined with Conservation of farm resource have been found to reduce chemical load in the form of inorganic fertiliser by 36% (Gangwar et al., 2014).

7) National programmes to mitigate climate change:

The National Mission of Sustainable Agriculture was implemented in 2010 under the National Action Plan on Climate Change (NAPCC) to promote the effective utilisation of existing resources and this was one of the eight missions under NAPCC. In 2015 the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) was launched to address the issues of water resources and provide a permanent solution that envisages Per Drop More Crop by promoting micro / drip irrigation for the conservation of maximum water. GREEN INDIA Mission was launched by the GOI in 2014 under the umbrella of NAPCC with the primary objective of protecting, restoring and enhancing India's diminishing forest covers, thereby reducing the deleterious effects of climate change. Additionally, Neem-Coated Urea was also introduced to minimise the excess addition of urea fertilizers, thereby protecting soil health and supplying plant nitrogen.

6. Sustaining or Maintaining the Measures to Reduce the Effect of Climate Change.

Effect of climate change is very much frequent, to combat this situation CRA should always be prepared with their best adaptive and mitigative mechanisms. Climate resilient agriculture not only to be implemented, it should be sustained or maintained over the time being through different village level awareness programme. Government plays an important through different schemes, subsidies. Technology demonstrations under the National Initiative on Climate Resilient Agriculture are currently in operation in 100 vulnerable districts identified based on their exposure to repeated climatic vulnerability. The goal of technology demonstration component under NICRA is to mainstream some of the successful practices and technologies that promote resilience to climate risk under the National Mission on Sustainable Agriculture (NMSA), other National Missions and on-going government schemes such as Rashtriya Krishi Vikas Yojana (RKVY), Mahatma Gandhi National Rural Employment Guarantee Programme (MGNREGP) and National Food Security Mission (NFSM). The aim is to up-scale the proven practices in all the vulnerable districts in the country by the end of XII five-year plan to make Indian agriculture more resilient to climate variability.

7. Conclusion

Enhancing the resilience of Indian agriculture to cope with climatic variability and climate change is boon for the livelihood security of millions of small and marginal farmers in the country. Climate-resilient agriculture (CRA) achieve long-term higher productivity and farm incomes under different climate variabilities through improved crop and livestocks management. It is a way for farmers to cope with the climate change, but despite the superficial benefits, rates of adoption by smallholder farmers are highly variable, if government and other responsible organizations step forward to encourage the practice of CRA then it is easier to reduce the effect of climate change.

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