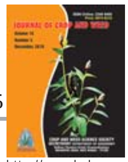
Journal of Crop and Weed, 15(3): 59-64 (2019)

ISSN- O : 2349 9400 ; P : 0974 6315



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Climate smart agriculture for sustaining food production

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Received : 20.11.2019 ; Revised : 25.11.2019 ; Accepted : 02.12.2020
DOI: https://dx.doi.org/10.22271/09746315.2019.v15.i3.1238

ABSTRACT

The most exposed sector influenced by climate change is agriculture because of its reliance on climatic parameters like soil health, temperature, rainfall, etc. In developing countries, agriculture must undergo a significant transformation such that it can overcome the related challenges of achieving food security and responding to climate change. In most of the estimations, it has indicated that climate change is likely to decrease agricultural productivity, production and incomes in some areas that already have high food insecurity levels. It is the need of the hour for agriculture to become 'climate smart' so as to alleviate these challenges posed by climate change. Climate smart agriculture means sustainably increase agricultural productivity, production and income, adapt and build resilience to climate change and reduce greenhouse gases emissions in every possible way. Therefore, to achieve climate change goals and food security, there is a significant need to develop climate smart agriculture.

***Keywords*:** Agriculture, climate change, climate smart, food security

Climate change is a serious threat to fight against hunger, disease, malnutrition and poverty in the world. Based on populations' growth and food consumption patterns, projections indicated that atleast 60 per cent of agricultural production need to increase in order to meet the demands by 2050. It is indeed a special challenge to address climate change which impacts agriculture. In many ways, climate change and agriculture are correlated with each other as climate change is the chief reason of biotic and abiotic stresses, which in turn have adverse effects on agriculture of an area. The multiple negative impacts of climate change on the land and its agriculture are due to variations in global change of atmospheric CO_2 or ozone level, ûuctuating sea level, annual rainfall, average temperature, heat waves and modiûcations in weeds, pests or microbes. Climate change is adversely affecting agriculture activity. In today's scenario, food security and resilient ecosystem are the most discussed topics worldwide. With alarming changes in environmental conditions, the severe effects on productivity of plant are proceeding intensely in large due to abiotic stresses. Because of the never ending deforestation and over exploitation of fossil fuels, CO_2 concentration has intensified from 280 μmol^{-1} to 400 μmol^{-1} in the atmosphere. Already the Intergovernmental Panel on Climate Change (IPCC) has postulated that a small increase in temperature of 1-2°C could lower even upto 50% yield of crop in rainfed agriculture. Therefore, it is time for us to change our priority from estimating its expected impact on agriculture to in fact finding solutions based on science and management to achieve sustainable food production by adapting and mitigating to climate change and pressures of natural resource. These challenges need to be addressed together as they are interlinked. Climate Smart Agriculture (CSA) integrates social, economic and environmental aspects which is seems address various effects of climate change broadly.

Climate Smart Agriculture is tactics to assist those people who run agricultural systems to counter climate change effectively. Keeping a strong focus on food security and adaptation to climate change, the concept of CSA was developed for the present and the times ahead. CSA merges both agricultural technologies and practices to achieve food security goals while at the same time adapting and mitigating climate change, for instance, using crop varieties and livestock breeds that are suited to climate change; improved water management techniques for more efficient water use; and improved grazing to conserve soil carbon and water. CSA also centres on improved weather forecasting, early warning systems, and crop insurance to farmers so as to reduce their risk. Adoption of CSA technologies and practices increases agricultural productivity, adapt to climate change, reduce green house gas emissions, and builds farmers' resilience especially for small holders farmers (Paul and Kumar, 2016).

FAO has acknowledged the pressing fact that agriculture needs to become 'climate smart' in order to feed the whole world in a sustainable manner. CSA concept was developed by the Food and Agriculture Organization (FAO) in an integrated aim to address climate change challenges. Many other international institutions such as the United Nations (UN), The International Fund for Agricultural Development (IFAD), the World Bank and The Consortium of International Agricultural Research Centres (CGIAR) accepted the definition of climate smart agriculture which integrates

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the social, economic and environmental of sustainable development to address food security and climate change. Climate smart agriculture is a consolidated approach to tackle the interconnected challenges of food security and climate change, which actually aims for three main objectives:

1. ***Productivity*** **:** Climate smart agriculture aims to sustainably increase agricultural productivity, to support equitable increase in farm incomes from crops, livestock and fisheries, food security and development. It is aimed at increasing productivity through sustainable intensification without harming the environment.

2. ***Adaptation*** **:** Climate smart agriculture aims to adapt and build resilience of agricultural and food security systems to climate change at multiple levels, that is, from farm to national level. The farmers are prevented from taking short term risk due to unexpected change in weather parameters. The farmers' resilience are strengthened through capacity building to adapt and rise when there is an abrupt change in weather.

3. ***Mitigation*** **:** To reduce and remove greenhouse gas emissions from agriculture (including crops, livestock and fisheries) whenever and wherever possible. This denotes that we can lower green house gas emissions for each calorie or kilo of food, fibre and fuel that we produce. Deforestations should be ward off from agriculture. Soil can be managed to maximize their potential to act as carbon sink and trees to absorb water from the atmosphere.

Main features of climate smart agriculture

1. ***It addresses climate change*** **:** Unlike conventional agricultural intensification development, climate smart agriculture includes climate change into the planning and development of sustainable agricultural systems in a systematic manner.

2. ***It combines two or more goals*** **:** Many times it is not possible to accomplish all the three ideal goals at the same time- increasing productivity, building resilience and reducing greenhouse gas emissions. Based on their objectives, the stakeholders with the assistance of participatory approach estimates the cost and advantages of integrated climate smart agriculture options before it is put into action.

3. ***It maintains ecosystems*** **:** It is crucial that the technologies and practices options used in climate smart agriculture do not deteriorate the natural ecosystem which provides the farmers with food, water, air, etc.

4. ***It has many entry points at different levels*** **:** Climate smart agriculture has many entry points varying from the developing technologies and practices to amplifying climate change models, strengthening institutional and political, etc. Initially at farm level, there is single use of technology and as the level goes higher up such as in the food system, landscape, value chain, policy level, etc. a combinations of technologies and practices are involved.

5. ***It is location specific*** **:** The result from integration of climate smart technologies and practices may differ from location to location wise. Climate smart agriculture is set of practices that cannot be universally applied. For example, a combination of agricultural practices may be climate smart in one particular location but those same integration of agricultural practices may not be climate smart in another location.

6. ***It involves both women and marginalised groups*** **:** Climate smart agriculture approach must engage poor and vulnerable groups in order to accomplish food security goals and adapt to sudden changes. Many times these groups dwell on marginal lands which are affected by harsh climatic events like drought and floods. Women are also given focus in climate smart agriculture. Generally woman have less legal rights and access to land which would actually assist them to build coping mechanism when faced with weather aberrations like floods and droughts.

7. Climate smart agriculture strives to include all local, regional and national stakeholders in decision-making process. In this way, the most suitable climate smart interventions can be identified and selected.

Climate smart agriculture indicators

The three main theme or pillars for technical indicators of Climate Smart Agriculture are classified as productivity, resilience and mitigation (The World Bank Group, 2016).

The sub-theme of productivity is categorized into crop system, water use and energy. The indicator crop system includes increase in yield, risk reduction of wind or water erosion and augmentation of soil fertility. For water use, the indicator includes increase in water productivity, total water withdrawal reduction and increase in irrigated land area. The indicators for energy include increase in usage of renewable energy and reduction in agricultural energy use.

The sub-theme for resilience is categorized into robustness, cropping system and livestock system. The indicators of robustness are increase in production stability, promote diversification of income, and integrate site-specific knowledge. For cropping system and livestock system the indicator is higher resilience to drought.

The sub-theme of mitigation is divided into - emissions intensity and sequesters carbon. The indicator for emission intensity is reduce greenhouse gases emissions whereas the indicator for sequesters carbon is higher carbon sequestration.

Characteristic differences between climate smart agriculture and conventional agricultural intensification

The differences between climate smart agriculture and conventional agricultural intensification are highlighted herewith in terms of energy, inputs, land use, system and varieties.

Conventional agricultural intensification **:** In conventional agricultural intensification, the conversion of energy sources from human to fossil is dependent on machinery. The inputs include increase use of fertilizer, herbicides and pesticides which are generally having lower application efficiency. Deforestation is done for expansion of agricultural land. It also includes conversion from grasslands to cropland. There is increased specialization in agriculture production and marketing systems. Improved and hybrid crop varieties are given emphasis in this conventional agriculture intensification.

Climate smart agriculture **:** It involves use of energy efficient technologies for agricultural power for example-tillage and irrigation purposes. The inputs used in climate smart agriculture have increased inputs/fertilizer efficiency and incorporates use of organic fertilizer. Unlike conventional agriculture intensification, there is no expansion to new areas in climate smart agriculture. Instead, there is intensification on the existing land area for main source of production. There is greater diversification in input. Production and output market systems. There is great value given to the resilience of traditional varieties.

Climate smart agriculture technologies and practices

There are several studies that identified large number of climate smart agricultural practices which have the capability to reduce emission of greenhouse gases, sustainably increase agricultural productivity and build resilience to climate change (Soussana *et al.,* 2010; Smith *et al*., 2013; Herrero *et al*., 2010). CSA technologies and practices confer advantages for addressing climate change challenges, economic growth and development of agriculture sector. There are hundreds of agricultural practices and technologies around the world which fall under Climate Smart Agriculture. When at least one pillar of climate smart agriculture is obtained, the agricultural practices and technologies can be taken into account as 'climate-smart'. Some of the climate smart technologies and practices are categorized below :

I. Water-Smart technology/ practices
II. Energy-Smart technology/ practices
III. Nutrient-Smart technology/ practices
IV. Carbon-Smart technology/ practices
V. Weather-Smart technology/ practices
VI. Knowledge-Smart technology/ practices

Information sources: Erenstein and Laxmi, 2008; CIMMYT, 2015; FAO, 2016 Rupan *et al.*, 2018

I. Water-Smart technology/ practices: These includes technologies/practices that minimize water requirements, improve yields and increase water use efficiency.

Some selected water-smart agriculture technologies and practices are as follows**:**

Rainwater Management (Rainwater Harvesting): It involves increase of water availability by collecting and managing rainwater run-off. Hence, the water is used for domestic purposes and in agriculture land especially in dry areas or rainfed areas.

Drip irrigation: It involves the application of water in the rootzone of crops such as to minimize the loss of water.

Laser land levelling **:** At higher areas, soil water deficit may occur and in low lying areas, water logging may occur. Therefore, a guided laser beam is used to level the field to a desired slope so as to ensure uniform distribution of water in the field, lower the water loss and improves the nutrient use efficiency.

Drainage management **:** This method involves water control structures for removing the excess water.

Furrow irrigated bed planting **:** The crops are grown on ridges or beds and irrigation are given through the furrows. During monsoon, this method provides more effective control over irrigation, drainage management as well as rainwater management.

Cover crops method **:** In this method, the soil health and water retention is maintained in crops such as wheat and mustard. There is reduction in soil water evaporation loss.

Clay pot **:** Indigenous unglazed earthen pot with micropores in its wall is used for subsurface irrigation.

Crop rotation **:** This method contributes in improving the soil fertility and productivity and conserve water.

Green manure **:** Green manure crops such as cowpea, mustard, soybean, etc. are incorporated into the soil when still green or after flowering.

Aerobic rice **:** Crops can be dry or transplanted and soil is kept aerobic throughout the growing season. Varieties mostly planted where irrigation water is scarce and rainfall is low. The concept is to try and combine the drought resistant characteristics of lowland varieties.

System of rice intensification **:** Here the productivity of rice is increased by managing the plants, soil, water, and nutrients. This technology is also practiced in other crops such as wheat, millet, sugarcane and pulses.

Other water smart practices include intercropping, crop diversification, agroforestry (alley cropping, field wind breaks, riparian forest buffer), direct seeded rice drought-tolerant varieties, conservation agriculture, etc.

II. Energy-Smart technology/ practices: These include technologies and practices which improves water use efficiency and save energy by reducing tillage and inputs.

Some selected energy-smart agriculture technologies and practices are as follows:

Zero tillage or minimum tillage: It is also known as zero-till or no-till. Here the main goal is to minimize the manipulation of soil. Seed are directly sown into the unploughed fields with a single pass of tractor. This practice reduces the amount of energy used in land preparation. It also improves the water infiltration and organic retention.

Energy savings in zero tillage occur predominantly through savings in land preparation and cost establishment (*i.e*., a decrease in tillage and savings in irrigation). Findings on savings in energy for the various studies are provided below in the table 1.

Renewable energy for irrigation **:** Renewable source of energy such as solar energy, biogas and wind are used for operating the irrigation pumps.

Direct-seeded rice **:** The dry seeds are drilled into non-puddled soil. It is cost-effective establishment practice. Proper land levelling and effective weed control measures are practiced in this method.

Other energy smart practices include residue management, legume-catch cropping, etc.

III.Nutrient-Smart technology/ practices : The technologies and practices under this category increase the nutrient use efficiency by minimizing the inputs and improving the nutrient cycle management.

Some selected nutrient-smart agriculture technologies and practices are as follows:

Green manuring **:** This practice helps in increasing the nitrogen supply as well as improves the soil quality.

Residue management **:** In this practice, the incorporation of crop into the field increases the soil nutrient and soil carbon.

Leaf color chart **:** The leaf color chart helps in detecting nitrogen deficiency and thereby shows the required amount of nitrogen based on the greenness of the crops such as rice.

Nutrient expert decision tools **:** This software application estimates the balance quantity of fertilizer required by crops.

Intercropping with legumes **:** This practice improves the nitrogen supply and soil quality.

Other important nutrient smart practices includes conservation agriculture, site specific integrated management, green seeker crop sensor, etc.

IV. Carbon-Smart technology/practices : The technologies and practices under this category helps in reducing the greenhouse gas emissions, increase the soil carbon and save energy.

Some selected carbon-smart agriculture technologies and practices are as follows:

Agroforestry **:** This practice helps in promoting both carbon sequestration as well as sustainable land use management.

Concentrated feeding for livestock **:** This method lessens the nutrient loss, thereby low quantity of livestock feed is needed.

Other categories of carbon smart agriculture technologies and practices include residue management, fodder management, integrated pest management, legume-catch cropping, etc.

Conservation agriculture **:** In this practice, especially no till or zero tillage has been given importance due to their ability to reduce climate change. Here, carbon sequestration is achieved by integrating no till with residue retention as this practice contributes in increasing the soil biomass inputs. Combination of crop residues or mulch with constant soil cover leaves a source of fresh organic material constantly, out of which some are transformed into stable carbon fractions which are left in the soil for a long period of time. The crop residue cover also contributes in preventing soil and wind erosion. The crop residues' carbon-nitrogen ratio is maintained by rotating crop with leguminous crops thereby, the nitrogen present in decaying surface residues are released slowly and hence it is offers as a source of nitrogen for the next crop. The higher availability of soil carbon contributes in mitigating climate if only there is an additional atmospheric net carbon transfer to the soil.

V. Weather-Smart technology/ practices : Weather related advisories are given to farmers through weather smart technology and practices. The technologies and practices under this category helps in reducing the weather related risks as well as providing better weather management.

Some selected weather-smart agriculture technologies and practices are as follows :

Agronomical weather services **:** The weather forecasting information is disseminated from the respective local weather stations.

Climate smart housing for livestock **:** This particular climate smart practice provides shelters to the livestock from extreme heat stress, cold stress and other climatic factors.

Table 1: Energy savings for zero tillage

Country	Crops	Energy savings in percentage change	Authors
India	Wheat	81 % savings in energy costs	Erenstein and Laxmi (2008)
Haryana, India	Wheat	46% savings in machine labour costs	Tripathi *et al.* (2013)
Haryana, India	Wheat	63%-77% savings in machinery costs	Krishna and Veettil (2014)
Rupandehi, Nepal	Wheat	63% savings in land preparation cost compared to conventional tillage	Tripathi (2013)
Haryana, India; and Punjab province, Pakistan	Wheat	80% savings in diesel consumption for tillage operations	Erenstein *et al.* (2008)

(Source: Chowdhury and Bajracharya, 2018)

***Weather based crop agro-advisory* :** Weather based information are disseminated to the general made especially for farmers as it also provides value added agro-advisories.

Various weather smart technologies and practices include stress tolerant varieties, agroforestry, irrigation schedule for wheat, crop insurance, etc.

VI. Knowledge-Smart technology/ practices : The technology and knowledge under this category employs both local knowledge and science.

Some selected knowledge-smart agriculture technologies and practices are as follows :

***ICTs* :** Information and Communication Technologies (ICTs) is an effective tool used in climate smart agriculture. Through this tool huge numbers of people are reached out in a very short span of time. This tool is used for keeping the farmers alarm and alert in times of critical weather emergencies/situations.

***Contingent crop planning* :** This provides plans on climatic risk management inorder to deal with unexpected and unpredictable major weather conditions such as high rainfall intensity, hailstorms, frost, pest and disease outbreaks drought, flood, heat stress, cold stress during the crop growing period or season. This contingent crop planning reduces the possibility of crop failure and thus improves the income of farmers.

***Improved crop varieties* :** Use of improved crop and fodder seed varieties helps in managing the adverse climatic events.

***Seed and fodder banks* :** Here, the crop and fodder seeds are conserved inorder to manage the adverse climatic weather conditions.

Some examples of knowledge smart app developed are listed below :

i. ***Agro climate* :** This web resource interactive tool was developed by the Southeast Climate Consortium (SECC). Its maintenance is presently done by the University of Florida. It provides decision support and learning by providing climate related information in order to enhance crop management decisions, decrease the risks involved in the process of crop production.

ii. ***Plantix* :** This app was developed by PEAT GmbH and cooperates with ICRISAT, CIMMYT AND CABI. It is a crop advisory mobile app useful especially for farmers and extension workers. Initially, this app helps in diagnosing crop or plant diseases, damages done by pests and nutrient deficiencies, and then it provides treatment measures to be performed.

iii. ***IFFCO kisan agriculture* :** This app is handled by IFFCO Kisan. According to the needs of the Indian farmers, this app provides them with customized information such as to make informed decisions. Through this app, diverse informative modules in the form of text, image, audio, videos can be obtained. The informative modules included in this app are agricultural advisory, weather, market prices, and agriculture information. Kisan Call Centre services helpline numbers are also provided in this app.

iv. ***Agri market* :** This app was launched by the Government of India with the aim to keep the farmers updated with crop prices in the markets within 50 km of their device location and hence prevent them from going distress sale.

Difficulties in Adopting Climate Smart Agriculture Practices And Technologies by farmers

Farmers embracing the climate smart agriculture technologies and practices may not ensure achieving the target productivity and mitigation objectives every time. The reason may be due to variation of region to region characteristics such as soil and climate. Moreover farmers embracing these technologies and practices may imply some implementation risks. For example, poor implementation of the technologies or practices due to lack of knowledge fails to facilitate in accomplishing the climate smart agriculture objectives. It also reduces the productivity and net income of the farm. The mentioned risk implication tends for farmers to reject the adoption of climate smart innovative technologies and practices. Therefore, demonstration sites and extension services act as an important agent for farmers to take up the climate smart technologies and practices (García de Jalón *et al*., 2017). Farmers pointed out difficulties faced by them when exercising the technology. Farmers also reported resource limitation issues such as land availability, water availability, machinery availability, fuel competition, and livestock feed competition *etc*. Farmers not only lack full knowledge of new technologies and practices but also lack skills to run new machinery. Small farmers often tends to lack weather related information as there is less dissemination of weather information to them and reports show that they usually lack strong market links (Mertz *et al*., 2009). Other constraints faced by small scale farmers includes limited credit availability, lack of new technologies and practices dissemination to farmers due to fewer extension agents *etc*.

Presently, the dissemination of the significant benefits of climate smart agriculture technologies and practices is still in progress and the process of taking up the technologies and practices is challenging. The widespread dissemination of climate smart practices and technologies is at critical juncture. In local areas, adapting the climate smart technologies and practices is difficult. It is also challenging to promote joint learning among farmers, researchers and extension workers. There is an utmost need for inter institutional support. The policies made for climate, agriculture, food and nutrition needs to be adjusted and coordinated. Identification of appropriate climate smart technologies and practices in particular region is necessary which is possible through site-specific assessments (Rupan *et al*., 2018). Climate smart agriculture should not be a choice for the farmers instead they should aim to become progressively more climate smart.

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