

Climate-smart agriculture for greenhouse mitigation

sustainable intensification and ensuring farmers' income

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The climate smart agriculture is an approach that aids to guide actions needed to transform and reorient agricultural systems to effectively support the development and ensure food security in a changing climate. Climate-Smart Agriculture aims to tackle three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible. Climate-smart agriculture includes already demonstrated/established practical techniques such as mulching, intercropping, conservation agriculture, crop rotation, integrated crop-livestock management, agroforestry, improved grazing, and improved water management coupled with innovative practices such as better weather forecasting, more resilient food crops, and risk insurance.

Key words: Agriculture, Climate, Farmer, Greenhouse, Income, Mitigation

WORLD'S population will reach 9.1 billion by 2050, to feed this growing population will require additional 60% increase in total agricultural production. With many of the natural resources needed for sustainable food security already exhausted, the challenges to provide adequate food to all are huge. At the same time climate change is already negatively impacting agricultural production globally and locally (Fig. 1). Climate risks to cropping, livestock, and fisheries are expected to increase in falling decades, particularly in low-income countries where adaptive capacity is weaker. Impacts on agriculture threatens both food security and agriculture's pivotal role in rural livelihoods and broad-based development. Also, the agricultural sector, if emissions from land use change are also included, generates about one-quarter of global greenhouse gas emissions (<https://ccafs.cgiar.org>). Therefore, farmers

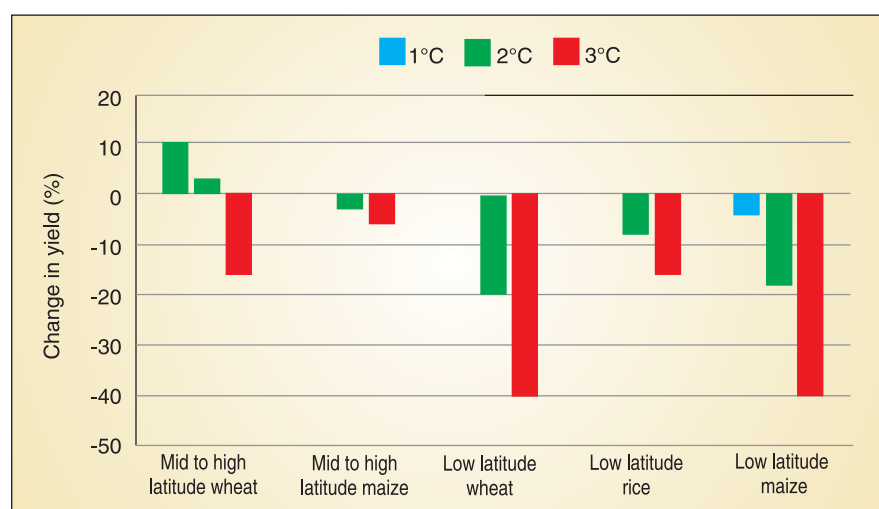


Fig. 1. Crop yield variation due to climate change at various latitudes (Redrawn from US NRC, 2011).

need to adopt climate-smart agriculture technologies to increase sustainable productivity, strengthen their resilience, reduce greenhouse gas emissions and increase carbon (C) sequestration, which in turns strengthens food security and delivers

environmental benefits.

The climate-smart agriculture is an approach to developing the technical, policy and investment conditions to achieve sustainable agricultural development for food security under climate change. The magnitude,

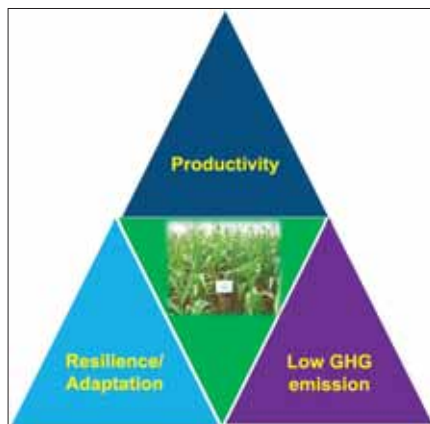


Fig 2. Component of climate-smart agriculture

immediacy and broad scope of the effects of climate change on agricultural systems create a compelling need to ensure comprehensive integration of these effects into national agricultural planning, investments, and programmes. The climate-smart agriculture approach is designed to identify and operationalize sustainable agricultural development within the explicit parameters of climate change (Fig. 2, FAO 2013). This approach also aims to strengthen livelihoods and food security, especially of small holders, by improving the management and use of natural resources and adopting appropriate management practices and technologies for the production, processing, and marketing of agricultural goods. To maximize the benefits and minimize the trade-offs, climate-smart agriculture takes into consideration the social, economic, and environmental context where it will be applied.

Execution of climate-smart agriculture

The climate-smart agriculture can be executed as follows:

(a) *Sustainable crop production intensification*: In recent times, crop production has increased significantly, providing more food for a growing global population. The best known and documented example of this is the Green Revolution, which flourished through much of the developing world during the 1960s. The Green Revolution was characterized by the planting of high-yielding crop varieties, with high input farming such as fertilizer and

irrigation. As a result, farmers increased cereal food production from 800 million tonne to over 2.2 billion tonne between 1961 and 2000. While an estimated 1 billion people were saved from famine, this has come with a high price tag in the long-term (FAO 2013).

In many countries, practising of intensive cropping for many decades have degraded top-fertile land, depleted groundwater, triggered an increase in pests, eroded biodiversity and polluted air, water, and soil. Intensive crop production is no longer considered sustainable system; therefore, a new paradigm is required – Save and Grow i.e. sustainable crop production intensification (FAO, 2011). It means a productive agriculture that conserves and enhances natural resources through an ecosystem approach that capitalizes on natural biological inputs and processes. It also reduces the negative impacts on the environment and enhances natural capital and better flow of ecosystem services. Sustainable crop production intensification also contributes to increasing systems' resilience – a critical factor, particularly in the climate change scenario. Sustainable crop production intensification can be achieved through good farming practices that are based on improving efficiencies and managing biological processes. It is based on agricultural production systems and management practices that include:

- maintaining healthy soil to enhance soil-related ecosystem services and crop nutrition;
- cultivating a wider range of species and varieties in associations, rotations, and sequences;
- using quality seeds and planting materials of well adapted, high-yielding varieties; and
- adopting the integrated management of nutrients, pests, diseases, weeds and water and managing inputs efficiently.

(b) *Agricultural approaches and practices to climate change adaptation*: Different approaches and practices for sustainable crop production can contribute to climate change adaptation. They provide options for location-specific contexts and should

be adapted with local farmers/ farming communities. For example, ecosystem-based approaches, conservation agriculture, integrated nutrient and soil management, mulch cropping, cover cropping, alterations in cropping patterns and rotations, crop diversification, using high quality seeds and planting materials of adapted varieties, integrated pest management, integrated weed management, grasslands management, water and irrigation management, landscape-level pollination management and organic agriculture (World Bank, 2010).

(c) *Conservation agriculture*: Conservation agriculture, an approach to farming that seeks to increase food security, alleviate poverty, conserve biodiversity and safeguard ecosystem services, can also contribute to making the agricultural system more resilient to climate change. The conservation agriculture principles comprises of minimum soil disturbances, maximum soil cover and diversified cropping system (Fig. 3). The conservation agriculture is based on the integration of management of soil, water and agricultural resources that can assure more sustainable agricultural production. The conservation agriculture is aimed to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water, and biological resources combined with external inputs.

Stocking more organic C in soil with the adoption of conservation agriculture practices of no-tillage and residue retention (Fig. 4) was proposed as a potential way to slow down the rising atmospheric CO₂ concentration resulting from the accelerated use of fossil fuel as a source of energy (Fig. 5a, b, c) and food production by conventional soil cultivation methods. One goal of soil C-sequestration is to increase the mass of C-stored in agricultural soils so as to check its increasing concentration in the atmosphere and prevent global warming and climate change effects of this greenhouse gas. Increasing soil organic carbon improves both efficiency and resilience. It improves nutrient and



Fig. 3. Principles of Conservation Agriculture, swiftly cope-up with floodsal tillage wihtoutue retention under soybean-wheat

water intake by plants, which increases yields and resource efficiency of land, nutrients, and water. It also reduces soil erosion and increases water retention, especially as it is often combined with added soil cover, as in conservation agriculture. This combination makes the system more resilient to the variability of precipitation and to extreme events. Increasing carbon sinks in the soils also capture carbon (C), which contributes to climate change mitigation.

(d) *Soil and nutrient management:* The availability of nitrogen (N) and other nutrients is essential to increase crop yields. Therefore, managing fertilizer nutrient and increasing its efficiency is also comes under climate-smart agriculture. The urea deep placement technique, developed by the International Fertilizer Development Centre, is a good example of a climate smart solution for rice systems. The usual technique for applying urea, the main nitrogen (N) fertilizer for rice, is through a broadcast application. This is a very inefficient practice, with 60 to 70% N losses contributing to greenhouse gas (GHG) emissions and water pollution. In the urea deep placement technique, urea is made into 'briquettes' of 1 to 3 g that are placed at 7 to 10 cm soil depth after

the paddy is transplanted. This technique decreases nitrogen losses by 40% and increases urea efficiency to 50%. It increases yields by 25% with an average 25% decrease in urea use. Besides, the use of ammonium sulphate $(\text{NH}_4)_2\text{SO}_4$, supplements was also used to promote soil microbial activity and reduce methanogens. Sometimes, skipping of basal dose of nitrogen (N) application to crops and applying those amounts during critical crop growth stages was proved beneficial in getting higher yield and also minimizing N losses.

Another way of managing nutrients in the soil is through integrated nutrient management. This can be done through organic manure, composting manure and crop residues, more precise matching of nutrients with plant needs, slow/controlled release and deep placement technologies or using legumes for natural nitrogen-fixation. Using methods and practices that increase organic

nutrient inputs, retention and use are therefore fundamental and reduces the need of synthetic fertilizers which, due to cost and access, are often unavailable to small holders and through their production and transport, contribute to greenhouse gas (GHG) emissions.

(e) *Water harvesting and use:* Improved water harvesting and retention (such as check-dams, farm pond/pits, retaining ridges etc.) and water-use efficiency (irrigation systems) are fundamental for increasing production and addressing increasing irregularity of rainfall patterns. Now-a-days, irrigation is practised on 20% of the agricultural land in developing countries but can generate 130% more yields than rainfed systems. The expansion of efficient management technologies and methods, particularly those appropriate to smallholders is essential.

(f) *Pest and disease control:* The climate change is altering the distribution, incidence, and intensity of animal and plant pests and diseases as well as invasive and alien species. The recent emergence in several regions of multi-virulent, aggressive strains of wheat yellow rust adapted to high temperatures is a good indication of the risks associated with pathogen adaptation to climate change. These new aggressive strains have spread at unprecedented rate in five continents resulting in epidemics in new cropping areas, previously not favorable for yellow rust and where well-adapted, resistant varieties are not yet available. The wheat disease Spot Blotch, caused by *Cochliobolus sativus*, is another example, causing heavy losses in Southern Brazil,

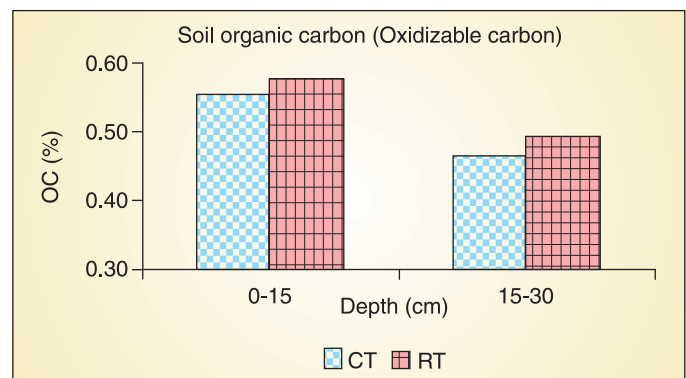


Fig 4. Effect of different tillage on soil organic carbon



Fig. 5. (a) Conservation tillage with crop residue retention under soybean-wheat, (b) maize-gram system, and (c) conventional tillage without residue

Bolivia, Paraguay, and Eastern India, due to a lack of resistance to the disease. As wheat growing areas of Asia become warmer, the pathogen is likely to spread even faster and may eventually cause more losses.

(g) *Genetic resources*: Genetic make-up determines a plants and animals tolerance to shocks such as temperature extremes, drought, flooding and pests, and diseases. It also regulates the length of growing season/production cycle and the response to inputs such as fertilizer, water, and feed. The preservation of genetic resources of crops and breeds and their wild relatives is therefore fundamental in developing resilience to shocks, improving the efficient use of resources, shortening production cycles and generating higher yields and quality and nutritional content per area of land. Generating varieties and breeds which are tailored to ecosystems and the needs of farmers is crucial.

Greenhouse gas mitigation technologies for climate-smart agriculture

A number of methods and practices were adopted to address these challenges. For example, production systems adapted by altering cropping patterns, planting dates and farm management techniques. The embankments built to protect rice farms from floods and new drought and submergence-tolerant varieties of rice were produced and distributed by the government institutions and the private sector.

Besides farmers were diversifying their production systems, growing other cereals, vegetables and rearing fishes and animals (such as pigs and chickens). The residues and waste

from each system were converted into composted and used as manure, thereby reducing the need for external inputs. This diversification enhanced incomes, improved nutrition, built resilience to shocks and minimized financial risks. The development of advanced modeling techniques, mapping the effect of climate change on rice-growing regions and providing crop insurance were other examples of managing risks and reducing vulnerability. Research on rice cultivation identified that emissions mainly occur in the few months of the year when the ground was waterlogged. A more integrated approach to rice paddy irrigation and fertilizer application was found to substantially reduce emissions.

Rice is fundamental for food security with approximately 3 billion people, about half of the world population, eating rice every day. Approximately 144 million ha of land is cultivated under rice each year. The waterlogged and warm soils of rice paddies make this production system a large emitter of methane (CH_4). Rice production will be affected by changes in climate. Irregular rainfall pattern, drier spells in the wet season (damaging young plants), drought and floods showed adverse effect on yields. This has also caused outbreaks of pests and diseases, with large losses of crops and harvested products. Peng *et al.* (2004) analyzed 6 years of data from 227 irrigated rice farms in six major rice-growing countries in Asia, which produced more than 90% of the world's rice. They found that rising temperatures especially in night had a severe effect on yields causing losses of 10 to 20% of harvests in some locations. Globally

agriculture accounts for 50% and 60% of totally anthropogenic CH_4 and N_2O emissions respectively. Within agriculture, intensified rice production system is one of the major anthropogenic sources of atmospheric CH_4 and N_2O . Emissions are predicted to increase by 35 to 60% by 2030 as result of the increasing application of chemical fertilizers (FAO, 2003).

(a) *Azolla, green manure application technology to mitigate greenhouse gas emission*: Green manures are widely used in rice production and may influence methane (CH_4) efflux. Influence of application of *Azolla* (*A. caroliniana*), a widely used biofertilizer for rice (*Oryza sativa* L.), on CH_4 efflux from a flooded alluvial soil planted to rice, and select soil and plant variables were investigated in a field experiment at Cuttack, India. *Azolla* was either incorporated as green manure at the beginning of the experiment or grown as a dual crop in the standing water along with the rice crop. Dual cropping of *Azolla* (equivalent to 30 kg N ha^{-1}) in conjunction with urea (30 kg N ha^{-1}) effected lowest CH_4 flux ($89.29 \text{ kg CH}_4 \text{ ha}^{-1}$). Cumulative CH_4 flux followed the order of urea > *Azolla* (incorporated) + urea > *Azolla* (incorporated + dual crop) > no N control > urea + *Azolla* (dual crop). The dual cropping of *Azolla* in conjunction with urea considerably reduced CH_4 efflux without affecting the rice yields and can be used as a practical mitigation option for minimizing CH_4 flux from flooded paddy. The study showed that dual cropping of *Azolla* reduced CH_4 flux and yet increased grain yield similar to that of urea application. The

decrease in CH_4 efflux in plots with a dual crop of *Azolla* could be related to the release of oxygen in the standing water by the growing *Azolla* leading to less reduced conditions in the soil. This suggested the possibility of practising *Azolla* dual cropping for sustaining higher yields and protecting the environment by minimizing the CH_4 flux from flooded rice paddies.

(b) *Water management strategies to mitigate greenhouse gas emission from paddies:* Both soil types and water regimes play important roles in the process of methanogenesis and methane emission from rice soils. In view of wide spatial and seasonal variability and the importance of moisture on the process of methane emission, it is pertinent to evaluate the role of soil type and moisture interaction on methane efflux from soils planted to rice. In a study, CH_4 flux from alluvial and laterite soils planted to rice (cv. CR 749-20-2) was monitored under non-flooded and flooded conditions. CH_4 flux from continuously non-flooded pots was always lower than from pots maintained under flooded conditions. The cumulative CH_4 flux was 150 and 880 mg pot^{-1} in laterite and 105 and 405 mg pot^{-1} in alluvial soils under non-flooded and flooded conditions, respectively. Therefore, this study showed necessity of a systematic investigation of CH_4 flux from a variety of rice ecologies including dryland rice which occupies 16% of the total rice cultivation in India.

(c) *Use of agrochemicals to mitigate greenhouse gas emission from rice paddy ecosystem:* Agrochemicals including pesticides were widely used as agronomic practices to enhance crop productivity, however, their influences on soil microbial mediated greenhouse gas emission are not well understood. Pesticides like Tridemorph, butachlor applied to rice fields can significantly inhibit greenhouse gas production. Tridemorph even at field application rate could influence CH_4 production while the herbicide butachlor inhibits CH_4 production and emission by 20% from paddy ecosystem. Thus,

use of such agrochemicals enhanced crop growth and productivity simultaneously mitigated greenhouse gas emission from rice fields. In an experiment influence of herbicide on greenhouse gas emission from paddy studied. A commercial formulation of the herbicide butachlor applied @ 1 kg a.i. ha^{-1} to an alluvial soil planted with direct-seeded flooded rice (cv. Annada), significantly inhibited both crop-mediated emission and ebullition fluxes of methane (CH_4). Over a cropping period of 110 days, the crop-mediated cumulative emission flux of CH_4 was lowered by F 20% in butachlor-treated field plots compared with that of an untreated control. Concurrently, ebullition flux of CH_4 was also retarded in butachlor-treated field plots by about 81% compared with that of control plots. Significant relationships existed between CH_4 emission and biogeochemical processes like redox potential (Eh) and Fe_2 content of the flooded soil. Methanogenic bacterial population, counted at the maturity stage of the crop, was also low in butachlor-treated plots, indicating both direct and indirect inhibitory effects of butachlor on methanogenic bacterial populations and their activity. Results indicated that butachlor, even at field-application level, can effectively abate CH_4 emission and ebullition from flooded soils planted to rice whilst maintaining grain yield.

(d) *Biochar accounting and emission trading for climate-smart agriculture:* It is possible to combat greenhouse gases emissions and reinvigorate rural and agricultural communities simultaneously through the use of biochar, (name given to charcoal produced for agronomic and other ecosystem applications). Besides, stably sequestering the carbon in the biochar for periods of time estimated to be several hundred to several thousand years biochars can be applied to cropland to increase crop yields, decrease runoff, decrease fertilizer and lime use, increase soil fertility and minimize nitrous oxide and methane emissions, which are also potent greenhouse gas. Biochar

acted as an absorber of NH_3 and water-soluble NH_4^+ and might, therefore, reduce losses of N during composting of manure. Biochar's porous structure allowed oxygen (O_2) to move through the material, and maintaining these air passageways enhanced microbial activity and provides for a faster and odor-free decomposition. Studies showed a significant reduction in N-P-K loss during the decomposition process as nutrients and minerals bond to the biochar. In using biochar, commercial composters find the reduction in greenhouse gas emissions and ability to sell their compost as an enhanced N-P-K fertilizer quite significant.

SUMMARY

The climate-smart agriculture aims to improve food security, help communities adapt to climate change and also contributes to mitigation of climate change effects by adopting appropriate practices, developing enabling policies and institutions and mobilizing needed finances. It also strengthened food security and delivered environmental benefits. Moreover, ecosystem-based approaches such as conservation agriculture, integrated nutrient and soil management, mulch cropping, cover cropping, alterations in cropping patterns and rotations, crop diversification, using high quality seeds and planting materials of adapted varieties, integrated pest and weed management, grasslands management, water and irrigation management, and organic agriculture. Besides, climate-smart agriculture helped to overcome as well as cope-up with climatic vulnerabilities such as drought, prolonged dry-spell, water-logging, floods etc. The climate-smart agriculture related interventions helped farmers to face the climate vulnerability—more 'smartly, swiftly and successfully' in minimize losses due to climate aberration.

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