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Low Carbon Development Pathways in Indian Agriculture

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Abstract: Indian agriculture sector is a significant emitter of Green House Gas (GHG), which is projected to increase by 47% between 2011 and 2020. In response to this, India has committed itself to voluntarily reduce its emissions intensity (emissions per unit GDP) between 20 to 25 percent below 2005 levels by 2020. This would require rapid and significant scaling up of mitigation efforts including the agriculture sector, which remains a challenge, as mitigation is not a priority in Indian agriculture. The study found out that in-spite of numerous mitigation technologies that are readily available for takeoff, the scale of adoption and deployment is far from sufficient to meet the emission targets set by the Government of India, mainly due to lack of financial incentives, capacity building of farmers, and an enabling policy at different levels. This study identified a suite of feasible interventions for promoting low carbon agriculture such as: low tillage systems as it has negative costs due to savings on tillage and fuel; introduction of superior livestock breeds to reduce numbers (especially unproductive cattle) and increase yield; use of livestock wastes to produce energy for cooking and heating through bio-gas technology can not only reduce methane emission but also save electricity costs for the households and; introduction of carbon credits and exploration of domestic carbon markets. An enabling policy environment must be created for these interventions to take off.

Keywords: agriculture, low carbon, pathways, mitigation

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1 Introduction

Climate change is a serious concern across the globe because of potential impacts on the economy, ecology, and environment [35,29,27,20]. Impacts of climate change are felt in the form of increasing frequency and intensity of extreme weather events and natural disasters. Scientific evidences clearly indicate the role of Green House Gases (GHGs) in global warming that triggers climate change [7]. The global mean air temperature has increased by about 0.74°C over the last century and is projected to rise by 0.3 to 2.5°C in the next fifty years and 1.4 to 6.4°C in the next century [20]. The concentration of CO_2, CH_4, and N_2O has increased by 30%, 145%, and 15%, respectively as result of anthropogenic activities since industrial revolution in the past [20]. The thrust is to decarbonize global economy as quickly as possible to avoid exceeding the 2°C goal set by the global communities [20]. Failure to achieve this would undermine gains made in agriculture, health, and infrastructure, and could impede progress towards meeting the sustainable development goals. Realizing this, world leaders in international forums including the recent Paris Agreement (COP21) have committed to mainstream adaptation and mitigation of climate change into national polices, programs, and projects. Consequently, many countries including India have set up ambitious targets to reduce Green House Gas emissions. For instance, during the Group of 20 Summit in Pittsburgh in 2009, the Indonesian President announced that Indonesia will reduce emissions by 26% by 2020 and mentioned that this could reach as high as 41% if international assistance was forthcoming [39]. Following suit, India during the Copenhagen Climate Summit pledged to voluntarily reduce its emissions intensity (emissions per unit GDP) between 20% to 25% below 2005 levels by 2020 [34,36]. Such historic commitments to undertake mitigations with or without international financial support by developing countries is a clear indication of understanding the magnitude of impacts from climate change which can be averted when each country (industrialized and developing) takes its own responsibility and engage proactively.

McKinseys [28] grouped emissions reduction opportunities into three technical categories namely; energy efficiency, low-carbon energy supply, and terrestrial carbon sequestration. Further they cautioned that delaying actions to reduce emissions even by 10 years to capture these potentials would mean missing the 2°C target set by International Panel Climate Change [20]. However, the implementation of activities to achieve these targets is seriously hindered by technological and economic feasibility at different levels. If we are to achieve sufficient GHG reductions to keep the world below a 2°C increase, there is an urgent need to move beyond business as usual models to prioritize cost effective emission reduction opportunities that should be pursued. Low carbon development pathways offer opportunities for pursuing GHG reductions [14,29,7,35,17]. It is a process through which countries can pursue a balance between controlled greenhouse gas (GHG) emissions and higher living standards and at the same time offers opportunities to achieve the IPCC goals.

Agriculture especially in the developing countries is one of the major contributors of GHGs emitting about 13% of the total global anthropogenic GHG emissions in 2005 [20]. It is estimated that emissions from agricultural sources of CO_2, CH_4, and N_2O accounts for 21% to 25%, 57%, and 65% to 80% [14,37,26]. Agriculture in developing countries contribute about 74% of the global agricultural emissions in 2005 [38]. Globally, India is the 7th largest economy in the world [12] with a GDP of over 1.7 trillion US$. With over 58% of the population dependent on agriculture, agriculture remains as one of India's main economic activity [12]. Agriculture has achieved an overall growth rate of 3.8% in 2010-2011 and contributed about 14.2% to the GDP at 2004-2005 prices [13]. While agriculture is a significant contributor to India's growth, it is also a major contributor of GHGs accounting for 17.6% of the total net CO_2 eq. emissions from India [16]. Fifty percent of India's methane (5 million T) and large amount of nitrous oxide (0.31 million MT). These emissions are expected to grow along with other GHGs with the fast-growing economy and population [12]. India's emissions increased by 65% between 1990 and 2005 and are projected to increase by 47% between 2011 and 2020 [14,35,18]. The major sources of emission in Indian agriculture include, enteric fermentation from livestock, rice cultivation, manure management, agricultural soils and burning of crop residues. The emission from enteric fermentation in livestock was 212 million tons of CO_2 eq. constituting 63.4% of the total emission from agriculture sector in India [37]. Manure management and rice cultivation contribute 2.44 and 69.87 million tons of CO_2 eq. respectively [29]. Total emissions of N_2O from agricultural soils and CH_4 and N_2O from crop residue burning is 50 million tons of CO_2 eq. This is expected to increase temperatures between 2.5°C and 5°C by 2060, resulting in yield losses of many crops [24]. Under this scenario, any increased frequency of extreme events, such as droughts, floods or cyclones due to changing climate will cause significant loss of properties

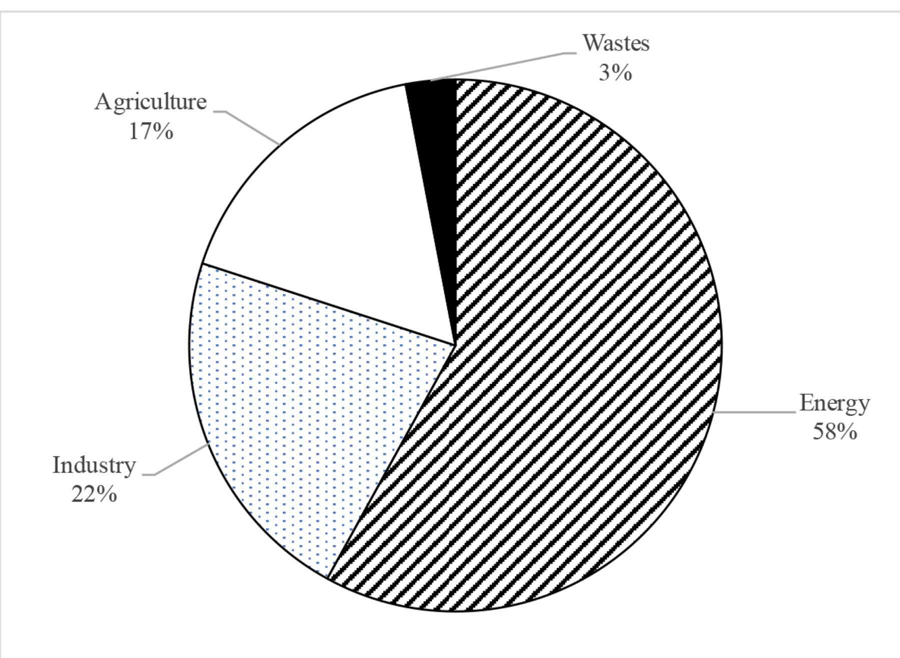

Figure 1. Contribution of Agriculture to GHG emission in India

and lives with the poor being more at risk. Impact will be felt across the country but more severely in the glacier fed Indo-Gangetic Plain (IGP). Melting glaciers will have devastating impact on the IGP, which is the bastion of food and human settlement. On the other hand, in the long run, a meter sea level rise would render millions of people landless and costs to build walls along vulnerable coastal zones are deemed prohibitive [1].

Realizing this escalating challenge of climate change, The Government of India ratified the UNFCCC on November 1, 1993 and the Kyoto Protocol in 2002, which requires developed countries and economies in transition to reduce their GHG emissions by an average of 5.2% below 1990 levels. Article 12 of the Kyoto Protocol also provides for Clean Development Mechanisms (CDM). Consequently, India has developed national level policies and strategies for adaptation and mitigation to climate change, especially targeting industries such as energy, transportation and agriculture in its recent National Climate Change Action Plan [17]. This plan identified 8 core national missions for advancing climate change adaptation and mitigation goals [17]. In the agriculture sector, the need to identify low carbon pathways has been prioritized under the Agriculture Mission. While few studies relating to carbon economy has been published [29], no specific studies have been carried out to identify low carbon pathways in Indian agriculture. This paper attempts to: i) Identify low carbon technologies that are ready to take off; ii) Ascertain the types of support that are required to facilitate the takeoff of these technologies; iii) Identify key barriers and opportunities for low carbon development pathways in Indian Agriculture; and iv) Recommend actions are required to support the adoption and deployment of low carbon technologies including researches.

2 Methods

Secondary information was acquired through review of published articles, Government documents, action plans, etc. Information thus collected was used for baseline analysis of policies, programs, and interventions relating to low carbon in agriculture. This analysis indicated the need to update and identify low carbon pathways, barriers, and opportunities in Indian agriculture. Consequently, CCAFS supported an expert group consultation workshop to both brainstorm on the current state of agriculture and low carbon initiatives under different sectors, identify weaknesses and threats for advancing low carbon initiatives in agriculture. In addition, the work shop also attempted to identify strengths and opportunities that are available for enabling low carbon agriculture in India. The workshop attended by experts from government, civil

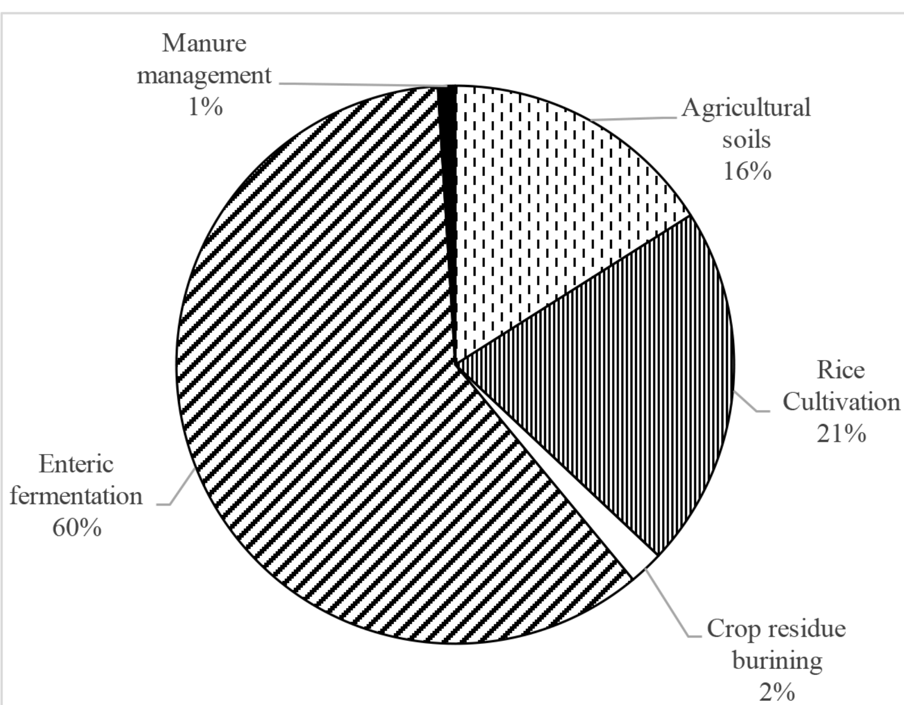

Figure 2. GHG contributions from different agricultural sources.

societies, and international agencies who are involved in policy, program, and plan implementations especially in the field of climate and agricultural sciences.

To deepen our inquiry into the state of low carbon pathways in Indian agriculture, few experts representing different institutions and agricultural sectors were selected for key respondent interview. This consultation allowed for hashing out some of the consultation outputs from the workshop and reaffirm their information and stands. Information collected from the desktop review, consultation workshop, and key information interviews were synthesized to identify state of the art, low cost, and low carbon pathways in Indian agriculture presented in this paper. Second round of literature review was carried out to further cross check and reconfirm the findings especially facts and figures.

3 An assessment of the current status of low carbon agriculture development in India

From the preceding discussion, it is clear that agriculture will continue to be the main stay of Indian economy and will grow in proportions to its economy and population. Low carbon in Indian agriculture would mean striking a balance between increased productivity (which seems to be the focus of the Indian agriculture sector) and sustained GHG emission, i.e. GHG mitigation while meeting the food security needs of the fast growing population of India and their demand for food. The primary sources of GHG emissions are from the large and growing livestock population and paddy cultivation [37]. By 2020, India is expected to have the highest density of cattle in the world (625 million heads) [11]. With 42.3 million hectares of land under paddy cultivation, India has the largest area of land under paddy cultivation yet is food insecure with millions under poverty. These demands exert pressure on food, which is translated into increased demand for land and other resources forcing intensive cultivation practices such as fertilizer applications and irrigation water pumping [11]. This presents opportunities for change in the source and amount of on farm energy consumption, reducing organic matter application, and burning of wastes.

Low carbon agriculture would involve producing sufficient food to meet the food and nutritional security of Indian population without jeopardizing the integrity of its environment and contributing to the climate change [14,4]. However, this challenge is easier said than done especially for large and diverse country like India. It requires judicious approach that is based on careful assessment of current local situation, experiences from pilot projects targeted at reducing emissions, and expert opinions to identify GHG mitigation agro-technologies that do not adversely impact the food production in agriculture and allied sectors [7]. Such an approach should ideally be able to produce multiple benefits such as: i) mitigate GHG emission; ii) increase yield and income; iii) reduce abatement costs; and iv) provide developmental co-benefits. An enabling policy environment must be created to support and scale up such GHG mitigation technologies.

Indian farmers are familiar with low carbon agriculture, since they have been implementing various policies and programs to promote environmental friendly agriculture practices such as low input, organic or water optimization. Main driver for such interventions has been the need to increase productivity and achieve food security and developmental goals rather than climate change. Government of India has allocated about 4,979,090 million Indian Rupees for Agriculture in the 12th five-year plan [15]. As far as the Government Policy is concerned this is likely going to be the case for the coming years, at least through the 12th five-year plan, as revealed during the recent interactions with officials from Department of Agriculture.

Past subsidies, more than often led to fertilizer and pesticide imbalances and associated leaching and hence an emphasis on low inputs. In response to such unsustainable agricultural practices, Government of India invested in programs such as the Systems Rice Intensification (SRI), that is known to save irrigation water, reduced seed rates, bring early crop maturity and significantly increase yields [40]. However, this has received mixed results with lots of farmers reverting to their old ways except in Tripura state, where SRI has been in practice for over 10 years, despite the fact that there is no significant increase in yield.

The Government of India is also advocating green agriculture [12,14,4) but experts at the consultation workshop agreed that low carbon options are full of uncertainties, high transaction costs with no clear modalities for payments in the near future. In addition, a technology such as organic farming can be counterproductive if practiced falsely [29,27,5]. For example, a field flooded continuously after application of organic matter in organic rice production can emit huge amounts of GHGs [30,10,40]. The need to assess the whole carbon cycle of any interventions for low carbon must be carried out to assure that the technology doesn't prove to be counterproductive.

The experts at the recent low carbon workshop [3] identified strengths, weaknesses, opportunities and threats (SWOT) in low carbon agriculture for five major areas for interventions namely: rice; irrigation; soil and land management; agroforestry, and; policies and management. Low carbon systems focused for SWOT were: 1. Rice – low carbon rice production, alternate wetting and drying of irrigated rice, system of rice intensification (SRI); 2. Irrigation – drip irrigation, reduce/cut subsidies to irrigation; 3. Soil and Land Management – conservation of agriculture (zero tillage with residue management, strip cropping, contour farming, nitrogen fixing pants), crop, soil, and moisture management systems; 4. Agro-forestry – promotion of agro-forestry on degraded lands/wasteland, carbon sequestration through agro-forestry models; and 5. General Policies and management practices for low carbon pathways - low carbon policies, best management practices to grow food. The workshop also reported a priority list of policy hurdles, feasible technological options and need for support through policy, financial incentive, research and development, etc. The results are summarized in Table 1.

On the policy front, India seems to be on top of climate issues at the central governmental level and there are opportunities especially in agriculture sector to translate these policies into ground level programs and take advantage of the huge technological innovation that India has, the presence of numerous private environmentally oriented developmental partners to transition from just production oriented goal to one that fulfills both production as well as reduced emission [14,29,5,17]. One thing is certain, that there is no shortage of partners, available technology, and national and international policy support. These findings provide India with an opportunity to evaluate and develop strategic options that addresses a major global and national mitigation issues without compromising, but rather reinforcing its economic goals. Opportunities that exist which can accelerate growth within low carbon are by facilitating additional investments and technology transfer.

4 Low carbon technologies ready to take off in Indian Agriculture

A large number of cost efficient technologies from irrigation to livestock management are now available to help farmers and governments achieve the dual objective of securing food and reducing emissions [22,9,38]. A major challenge that remains for India is to mainstream low carbon pathways as a tool in increasing yield and translate it into activities at the field levels. Due to the urgent nature of climate change impacts, India and other nations must make all out efforts (policy and financial) to adopt the latest and most advanced technologies (technological leapfrogging), so as to save time and save the world. While this is preferred, Tamura and Nishioka [39] cautioned that every new technology must be examined in the context of current systems, infrastructure, values and practices, and capacities for future development.

To mitigate GHG emissions while meeting the food security needs of the growing population, it is important to identify agro-technologies that has proven potentials to: mitigate GHG emission; increase yield and income; lower

Table 1. Strengths, weaknesses, opportunities, and threats of low carbon agricultural systems in India

Strengths/opportunities	Weaknesses/Strengths	Possible solutions
Favorable national and international policies Existence of efficient mitigation technologies that saves water, power, and cost Availability of technical institutional network at government level Subsidies available at varying levels Potential for carbon credits (CDM) Presence of extension network services at local levels Existence of indigenous values and practice to which sustainable livelihoods are anchored	Lack of proper incentives for scaling up low carbon technology Inadequate knowledge amongst policy makers and farmers Financial complications for marginal and small farmers Lack of clarity or technologies or operational technologies Lack of availability of incentives for adoption Inadequate extension system Inadequate access to timely inputs about low carbon policies Contradict values of practices of farmers Fast economic development	Carbon credit for agriculture Marginal abatement cost based decision making Subsidizing targeted low carbon technologies Support Ancillary industries for drip irrigation equipment to provide services in rural areas. Sync modern technology with local values and practices Institute an insurance program to reduce risk and uncertainties associated with adoption of low carbon technologies.

abatement costs; and provide developmental co-benefits. Several technologies with potential to mitigate GHG emission in Agriculture as identified during the low carbon workshop [3] and supplemented from published resources are presented in Table 2.

An analysis of the SWOT (Table 1), agro-technologies (Table 2) and expert opinions indicates that the low tillage systems is the most preferred as it has negative costs due to savings on tillage and fuel. While adoption of SRI technology is challenged by involvement of more efforts including labor, faith towards traditional systems, ignorance and lack of knowledge on scientific water management, it has proven high potential for abatement and restoring soil health and fertility as also indicated from successful trials in Tripura [21,40]. In the livestock sector, introduction of superior livestock breeds to reduce numbers (especially unproductive cattle) and increase yield is an important management tool to keep the livestock population in check [7]. Use of livestock wastes to produce energy for cooking and heating through bio-gas technology can not only reduce methane emission but also save electricity costs for the households [6]. In addition, the households who engage themselves into adoption of this technology have opportunities to market carbon credits [6]. Agro-forestry also provide opportunities for carbon sequestration as well as providing livelihood sources.

While there exist numerous options for low carbon agriculture, success of these innovations can be enhanced by targeting technologies to a specific socio-economic and environmental condition [30,10,40]. It is crucial to understand that the current level of commitment both in-terms of policy and implementation are far short of achieving any significant mitigation target. The major barriers to adopting and expanding low carbon technologies in Indian agriculture have been the lack of proper incentives (financial and market driven) for adoption, scaling up of technologies, and capacity

Table 2. Low carbon agro-technologies that are proven and ready to take off

Technology	Major benefits	Key challenges
Agriculture		
Zero tillage	Saves on fuel (70-90 liters of diesel per ha) Saves water Farmer saves 40-50US$/ha Reduce/eliminate burning of crop residues	Unavailability of good technology Old habits hard to break, especially when ingrained into local cultures
Alternate wetting and drying	Saves water Reduce methane emissions through aerobic decomposition of plant materials	Water use optimization Reduced GHG emission
Drip Irrigation/efficient pump	Saves water Saves energy	High cost Highly technical
Slow Release N-fertilizer	Reduce leaching losses Reduce N use and efficiency of N use Reduce nitrous oxide emission by inhibiting nitrification with use of Neem coated urea/Sulphur	High cost Highly technical application process
System of Rice intensification	Saves irrigation water Higher yields Reduced pest and disease Reduced labor costs and higher income	Precision leveling of fields Construction of water delivery and control structures at canals Labor intensive
Residue management	Reduce methane emission	
Livestock		
Feed and dung management	High protein diets can reduce gas formation Well managed farm yard manure, bio-gas, and compost pits reduce emission of methane	Expensive and tedious Lack of cost effective alternatives
Breed management	Increased yield and decreased cattle heads will reduce emissions	Number of cattle as status and source of manure Pasture availability
Agro-forestry	Carbon sequestration Micro habitats Timber and non-timber resource benefits Benefit from REDD+	Long gestation period Monitoring of illegal activities Government forest rules REDD+ yet to be functional

building of farmers. While pilot efforts have seen successful, Indian population is not forthcoming to adopt these innovations [21,4,24,35]. This can be attributed to the long gestation period of some of the programs (e.g. agro-forestry) and uncertainties. Indian Agriculture experts at the workshop argued for introduction of carbon credits and exploration of domestic carbon markets as such benefits could definitely encourage other farmers to take up low carbon technology options. Islam, et. et., [21], NAAS, [29], and Sharma, et. al., [37] have also supported such initiatives in their studies. However, as of now no major effort has been expended in exploring carbon credits in Indian agriculture or elsewhere. Although similar approaches such as PAT exists in the energy sector. Elsewhere, the British government commission a study to examine the scope and feasibility of a market based mechanism compatible with EU's emissions trading scheme to facilitate trading of GHG reductions from agriculture, forests, and other land management sectors [2]. A study by Rodvo [34] found under a market based system, a large number of relatively low-emitting farms would need to be covered by any scheme in order to ensure that a significant proportion of the sector's GHG emissions were affected. Given the current challenges with small holders [21] this scheme can provide an opportunity for coordinating small holders in India. Increasingly after the Copenhagen agreement, countries have started to use carbon credits from sequestration in the agriculture soils [19]. As far as possible the process of low carbon in agriculture must be developed and transferred keeping in mind the socio-cultural and environmental settings of targeted area [21].

5 Enabling policy environment for adoption and diffusion of low carbon pathways

Policy formulation and priority setting are dependent on political structures, farming systems, agro-climatic conditions and farm household characteristics [30,7]. Policy and financial incentives along with capacity building of farmers and investments in research and development will facilitate rapid deployment of low carbon technologies.

Despite the availability of efficient low carbon technologies in the market [9,10,38], their successful implementation in pilot areas throughout India, and the consensus amongst Indian agriculture experts that low carbon agriculture is the future, these technologies has yet to be adopted and scaled up. There also exists a gap between the national level policy and field level implementation. This gap can be attributed to several deficiencies such as: national level policy not mainstreamed into state and local level plans (as agriculture is a decentralized sector, state governments can choose to or not to support initiatives such as low carbon agriculture); lack of financial incentives for adoption of GHG technologies; high abatement potentials are not equal to high benefits which farmers are after (e.g. SRI).

For adoption and scaling up of low carbon technologies, the national policy on agriculture must balance its focus on increasing yield and mitigating GHG emissions. Policies must focus on: i) defining and outlining technologies and management practices in agriculture that can offset and improve C economy; ii) providing incentive to adopt carbon neutral practices; iii) require farmers to create and maintain C sink and maximize value of carbon offsets at the farm levels; iv) development of clear-cut policy on crop residue management especially discouraging burning. These must then be translated into state and local plans. As benefits are key for farmers coming forth to adopt technologies, carbon credits for agriculture sector must be introduced. Domestic carbon market can be quite effective if demand for carbon reduction is created.

Agriculture policy must rope in economic factors into technologies and involving financial sector across various sectors of the economy. Systematically, integrating carbon finance into public and private investment decisions and participation of public sector and large emitters (large farmers) in the carbon market. A systemic approach (program of investments) rather than piece meal approach (project by project) will contribute significantly towards promoting low carbon agriculture in India.

India has made significant progress in food production to feed its rising population in the last few decades. However, this achievement has to be sustained if India's goal of food and nutritional security, which may undermine potential climate benefits if interventions (policy and technological) are not made to mitigate GHG emissions. India has committed itself to voluntarily reduce its emissions intensity (emissions per unit GDP) between 20 to 25 percent below 2005 levels by 2020 [35]. Agriculture sector can help India in meeting this target by taking a systems approach of "climate smart" agriculture involving application of technologies that would increase productivity and income while reducing GHG emissions in the form that has demand in carbon markets.

Several technologies that are ready to take off are already presented in table 2. Smart agriculture should adopt and scale up these technologies that within farmer's cultural values can achieve the overall goals of climate change and food security through: 1. Increasing productivity; 2. Improving resilience; reducing or removing GHGs, and; 4. Enhancing the achievement of national food security and developmental goals [8].

Policies must also be charted to support future researches into improving the efficiency, effectiveness, and acceptability of low carbo interventions in agriculture. In particular, we suggest researches be prioritized to: i) assess carbon stocks at village, block, district, state, and national levels; ii) develop and pilot appropriate mix of agro-forestry models that can provide optimum benefits to farmers from timber, firewood, NTFP, and also from carbon revenue. Iii) investigate the impact of the allocation of initial credits, considering emission reduction due to business as usual as well as assessing the effect of transaction and enforcement costs.

6 Conclusions

This assessment paper argue that a shift low carbon agriculture is critical not only for reducing emissions but to improve rural living conditions and life on farms. Benefits from low carbon agriculture come in the form of environmental (reduced incidences of soil erosion, improved pest resistance, prevent loss of biodiversity) mitigation, and productivity through sustainable use of water, land, crop rotation, cover cropping, agroforestry, use of organic fertilizer, etc. [25,27].

However, this shift to low carbon agriculture in India is challenged by high transaction costs, enabling policy, affordable technologies, and investments. Some of the most feasible low carbon pathways in India include low tillage systems, SRI, introduction of superior livestock breeds to reduce numbers (especially unproductive cattle) and increase yield, use of livestock wastes to produce energy for cooking and heating through bio-gas technology, Agro-forestry, etc.

To overcome barriers and embrace low carbon options in Indian agriculture, bold policy directives supported by technological innovations and investments are needed so that farmers in India can shift to low carbon agriculture. Agricultural policy and expended market incentives are urgently required to encourage farmers, local governments, and private sectors to invest in and migrate to low carbon agriculture without jeopardizing food security of the small holders. In addition, there has to be a guaranteed easy access to technological innovations that can efficiently assess the mitigation potentials held in agriculture through monitoring of GHG emissions. Low carbon technologies must be developed at low cost and accompanied by subsidy wherever necessary.

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