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Unfolding government policies towards the development of climate smart agriculture in India

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Abstract The main aim of this paper is to map agricultural policies and programmes, with components of climate smart agriculture, implemented by the Government of India (GoI). Although climate resilience is not the explicit goal of these, our analysis shows that the GoI has been spending 15% of the total expenditure for agriculture towards enhancing resilience on agriculture to climate change. This expenditure has been made through micro-irrigation, watershed development and conservation agriculture under National Food Security Mission (NFSM), National Mission for Sustainable Agriculture (NMSA), National Horticulture Mission (NHM), Rasthrya Krishi Vikas Yojana (RKVY), crop insurance, neem coated urea, and weather advisory systems. Moreover, the government of India is committed to invest Rs 838 billion towards development of climate smart agriculture in the coming five years. We can argue that the increase in public expenditure will also attract significant additional investments from farmers, private sectors and state governments. This large resource commitment by the central and state governments and the farmers of India will have a greater impact on agrarian economy and environment only if there is a greater convergence among different programmes and more farmers' participation in these.

Keywords Climate smart agriculture, Climate change, Agriculture, Government policies, India

JEL classification Q18, Q28, Q15, R53, Q54

1 Introduction

Agriculture in India is highly vulnerable to climate change. Rise in temperature, changes in rainfall patterns and increase in the frequency of extreme weather events pose challenges to agricultural growth and food security (Mall et al. 2006). Despite its shrinking share in gross domestic product (GDP), agriculture is still the main livelihood source of nearly half of the population. The negative shocks to agricultural output, therefore, threaten not only food security, but also slow down the pace of poverty reduction (Kishore et al. 2015) and rural development. Two consecutive droughts in 2014 and 2015, interspersed by unseasonal rainfalls around *Rabi* harvests, have highlighted the impact of climate change on India's agriculture. Growth in agricultural GDP has stagnated and there is major rural distress in large parts of the country. A slowdown in agriculture has wider effects on overall economic growth. Smallholder farmers and farm laborers, who constitute most of India's rural poor, are the most vulnerable to the impacts of climate change.

The agriculture sector is also a significant contributor to greenhouse gas (GHG) emissions. In India, the total GHG emissions from the agriculture sector in the year 2007 was 334.41 million tons of CO_2 equivalent, which was 17.6% of the net GHG emissions (MOEF, 2010). However, this figure does not include the additional emission of 34 million tons of CO_2 equivalent emitted from the energy-use in agriculture (MOEF, 2010). Within the agricultural sector, the enteric fermentation in livestock, followed by methane (CH_4) emission from rice cultivation, Nitrous Oxide (N_2O) emission from

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agricultural soils, Carbon Dioxide (CO_2) emissions from crop residue burning, energy use in agriculture and fisheries are the major contributors of GHG emissions.

Therefore, there exists a two-way relationship between climate change and agriculture. Scientists predict even deeper impacts of climate change in India in the years to come if we do not take necessary steps to mitigate and adapt to the changing climate. Consequently, making agriculture climate-smart is a developmental and environmental imperative.

The Food and Agriculture Organization (FAO) coined the term Climate Smart Agriculture (CSA) in its background document prepared for the 2010 Hague Conference on Food Security, Agriculture and Climate Change (FAO, 2013). CSA is an integrative approach to address the interlinked challenges of food security and climate change that aims at three objectives: (i) sustainably increasing agricultural productivity to support equitable increase in farm incomes, food security and development; (ii) adapting and building resilience of agricultural and food security systems to climate change; (iii) and reducing GHG emissions from agriculture.

What distinguishes CSA from other approaches to increase agricultural productivity and sustainability is its explicit consideration of climatic risks that are emerging more rapidly and with greater intensity than in the past, coupled with an emphasis on addressing adaptation and mitigation challenges. The CSA approaches entail higher investments in (i) managing climate risks; (ii) understanding and planning for adaptive transitions that may be needed and iii) exploiting opportunities for reducing or mitigating GHG emissions, where feasible.

Like other emerging economies, India also faces the challenges of rapid economic growth reconciliation and climate change mitigation. On 1st October 2015, in its submission of the Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCC), India committed to reducing GHG emissions intensity by 33-35% of its 2005 levels by 2030. Earlier, in 2010, India had committed to reduce the GHG emissions intensity by 20-25% below the 2005 levels by 2020 (GOI, 2015). While India's commitment to reducing GHG emission intensity is voluntary and not mandatory and India's INDC does not bind it to any sector-specific mitigation obligation or action, including the agriculture sector. In spite of that, the GoI has launched a series of policy initiatives in the past few years with significant budgetary allocations to fulfill its commitment at COP 21.

Although most of these policies were implemented in the past and did not give special consideration to climate change adaptation and mitigation, a few of them are directly or indirectly address this issue. On the other hand, the government has launched a slew of ambitious programmes in recent years to directly address the impact of climate challenge on agriculture. This paper reviews some of the biggest such programmes launched by the GoI in the past years and unfolds their implications for both adaptation to climate change and mitigation of GHG emissions in case of agriculture sector.

The rest of this paper is organized as follows. Section 2 describes the approach and methodology followed and Section 3 describes the mapping of selected government interventions in accordance with the key pillars of climate smart agriculture. Section 4 describes each intervention and quantifies its implications for water use, energy use, nitrogen use, farmers' income and GHG emissions from the agriculture sector. Finally, Section 5 concludes this paper with key recommendations for achieving climate smart agriculture in India.

2 Approach and methodology

Agriculture is under the state list of the Constitution of India and therefore, all agriculture-related policies and programmes are implemented by the state governments. The GoI can, however, influence policies and programmes it wants the states to adopt by extending financial support for their implementation. Thus, we have two types of agricultural programmes in India. Firstly, some programmes are implemented across all the states with partial or full financial support from the central government. Secondly, states may have their own programmes for agriculture funded by their own budgetary resources. In this study, we limit our analysis to the agricultural interventions launched and sponsored by the central government i.e. GoI.

In this study, the selected government interventions have been reviewed in accordance with the 6 key pillars of CSA, namely, water smart, energy smart, nitrogen smart, crop smart, knowledge smart and weather smart. An intervention is said to be water/energy/nitrogen smart if it promotes improvement in efficiency in water use/fossil fuel use/nitrogen use respectively in the farmers' fields. The crop smart interventions focus on the adoption of improved varieties of seeds which are productive and tolerant to various climatic stresses. Additionally, interventions for crop diversification are also considered as crop smart. The interventions to strengthen the extension services for the agriculture sector to adapt to climate change are called knowledge smart interventions. Finally, agricultural insurance schemes and information and communication technology (ICT) based weather advisory are considered as weather smart interventions.

In this study, we follow both qualitative and quantitative approaches to map the government interventions with the above-mentioned pillars of CSA. In the qualitative approach, we map the components of each intervention with the CSA pillars. This qualitative information is converted to quantitative by estimating government expenditure associated with the intervention during the 5 years' period between 2012 and 2017.

We further estimate the possible implications of these selected policies for savings in water use, energy use, fertilizer use, farmers' income and GHG emissions from the agriculture sector. To do so we review scholarly articles, government reports and case studies on the impacts of these policies. We first estimate the possible implications of an individual intervention on the above-mentioned indicators with the assumption that other interventions are not in place. Later, we estimate the combined effect of all these interventions by using the weighted average of individual effects on water use, energy use, nitrogen use, farmers' income and GHG emissions. The share of government expenditure on each intervention is considered as a weight for this purpose. The detailed review of the government interventions and their implication on various components of climate smart agriculture is described in the subsequent sections of this study.

3 Unfolding government policies towards climate smart agriculture

Table 1 and table 2 describe the selected interventions implemented by the Government of India, their mapping with the 6 pillars of climate smart agriculture and the cumulative government expenditure made between the year 2012 and 2017. As described in table 1, few components exist in the past and present policies which have direct implications towards the development of CSA. Subsequently, it is observed from table 2 that 15% of average public expenditure on agriculture (including subsidy and investment) in India has been spent on CSA. Of the total government expenditure towards the development of climate smart agriculture i, 54% has been spent for nitrogen smart, 15% for weather smart, 11% for water smart, 11% for knowledge smart, 9% for crop smart and rest 1% for energy smart agriculture.

We notice that the expenditure on nitrogen smart component is the highest. The expenditure on fertilizer subsidy alone (Rs 70,000 crores in 2016-17) is equivalent to the cumulative expenditure on other components during the last 5 years. As the fertilizer subsidy results in excessive use of chemical fertilizer and thereby N_2O emissions, this expenditure is not considered as climate smart. However, in 2016, the GoI mandated the use of neem coated urea for fertilizer subsidy to minimize the N_2O emissions and improve the quality of the soil. Therefore, we consider only the expenditure on fertilizer subsidy in the year 2016-17, as opposed to the expenditure over the last five years, as part of the nitrogen smart component of climate smart agriculture.

4 Implications of government policies for achieving climate smart agriculture in India

In this section, we discuss each policy and its contribution to climate smart agriculture. In addition, we review existing literature to assess and quantify the implications of the policies for water use, energy use, nitrogen use, farmer's income and GHG emissions. Table 3 presents the implications of each policy on key input use for agriculture, farmers' income and GHG emissions.

a. Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)

Irrigation or water management is considered as the best measure against droughts (Fishman 2011). It also helps moderate the effect of high temperatures on crop

Table 1. Central government policies/programmes and their map of concordance with various components of climate smart agriculture

	Mapping of policies with different components of climate-smart agriculture					
Government policy/program	Water smart interventions	Energy smart	Nitrogen smart	Crop smart	Knowledge smart	Weather smart
Prime Minster Agriculture Irrigation Plan (PMKSY)	Micro irrigation (Drip & sprinkler)				Capacity building	
	Water conservation & harvesting					
	Irrigation infrastructure through MGNREGA					
National Mission for Micro Irrigation (NMMI)	Micro irrigation (2005-06 to 2013-14)					
National Mission for Sustainable Agriculture (NMSA)	On-farm water management 2014-15 Rainfed Area		Soil Health Card & Management			
	Development					
Rashtriya Krishi Vikas Yojna(RKVY)	Micro irrigation		Integrated Nutrient Management	Crop diversifi-cation & development		
	Natural Resource Management					
National Food Security Mission (NFSM)	Conservation Agriculture	Resource conservation machines	Integrated Nutrient Management		Farmers' training	
	Micro irrigation					
National Mission for Horticulture	Micro irrigation			Area rejuvenation		
Renewable Power Program		Solar pump sets				
National Mission on Agriculture Extension and Technology (NMAET)		Farm mechani-zation			Training on improved agronomic practices	
Agriculture insurance						Pradhan Mantri Fasal Bima Yojona
Weather advisory						Agro metrology

Source: Authors' creation

Note: We have taken the components of each policy/program which directly focuses on resource conservation/ emission reduction.

Table 2. Cumulative expenditure of the Government of India on different policies and Programmes (2012-2017, 12th Five Year Plan period) (Unit: in Crore Rupees)

Government program	Water smart	Energy smart	Nitrogen smart	Crop smart	Knowledge smart	Weather smart	Total
Prime Minster Agriculture Irrigation Plan (PMKSY)	5088	0	0	0	6	0	5094
National Mission for Micro Irrigation (NMMI)	3129	0	0	0	0	0	3129
National Mission for Sustainable Agriculture (NMSA)	1779	0	372	0	0	0	2151
Rashtriya Krishi Vikas Yojna (RKVY)	4318	0	394	11071	1097	0	16881
National Food Security Mission (NFSM)	310	92	81	59	39	0	581
National Mission for Horticulture	134	0	0	288	0	0	422
Neem coated Urea	0	0	70000	0	0	0	70000
Renewable Power Program	0	400	0	0	0	0	400
National Mission on Agriculture Extension and Technology (NMAET)	0	481	0	0	13073	0	13554
Agriculture Insurance						18943	18943
Weather Advisory						265	265
Cumulative expenditure during (2012-17)	14758	973	70848	11418	14215	19208	131420
% of total expenditure	11	1	54	9	11	15	100
Average investment expenditure for CSA (Rs Crore/ year)							26284
Average public expenditure for Agriculture sector (Rs. Crore/year) (Development + non-development)							169635
The share of climate smart expenditure in public expenditure on GFCF (%)							15

Source: Authors' estimates based on various MIS reports from websites of government departments, National Accounts Statistics (NAS) of Central Statistical Organization (CSO), and public finance statistics of GoI.

production, besides raising productivity and cropping intensity. After decades of massive investments in irrigation projects, more than 40% of India's net sown area is still rainfed[1]. At the same time, large parts of India are facing increasing water scarcity and unsustainable use of water in agriculture. In the face of this dual challenge, the GoI launched the Pradhan Mantri Krishi Sinchayee Yojana (Prime Minister Agriculture Irrigation Plan, PMKSY) with the vision of extending irrigation to every field while improving water-use efficiency in agriculture. The governments have been implementing several irrigation schemes since independence. However, the PMKSY is different from earlier schemes as it emphasizes on increasing the irrigated area (*har khet ko paani* or water to every plot of land), recharging aquifers, increasing water-use efficiency (More Crop Per Drop) and promoting sustainable water conservation practices[2].

As mentioned in table 3, we have obtained the implication of PMKSY by reviewing the study by Sharma et al. (2010). This study has been undertaken in 604 districts spread over various agro-climatic regions across states in India to estimate the efficiency of regional rain water use and incremental production due to supplementary irrigation for different crops.

[1] According to the Agricultural Census 2010-11, about 58 million out of India's 138.3 million farm holdings are 'wholly unirrigated.

[2] Although micro-Irrigation is part of PMKSY, we have analysed that separately in the subsequent section to understand special significance of micro irrigation in India.

Table 3. Possible implications of polices on input-use, farmers' income and GHG emission

Government program	Savings in input-use and GHG emission					Sources of information
	Savings in water use (%)	Savings in fuel- use (%)	Savings in fertilizer use (%)	Increase in farmers' income (%)	The decline in GHG emissions (%)	
Prime Minister Agriculture Irrigation (PMKSY)	20.0%	5.0%		5.0%	3.2%	Sharma et al. (2010)
National Mission for Micro Irrigation (NMMI)	25.0%	15.0%	15.0%	21.0%	7.5%	Global AgriSystem (2014)
National Mission for Sustainable Agriculture (NAMSA)			7.0%	5.0%	10.6%	Makadia et al. (2015), Makadia, D.J.J (2012). Fishman et al. (2016)
Rashtriya Krishi Vikas Yojana (RKVY)	12.0%	3.0%	17.0%	11.0%	5.5%	Kumar et.al (2013)
National Food Security Mission (NFSM)	8.0%	20.0%	0.0%	6.0%	8.0%	Joshi (2011)
National Mission for Horticulture					4.7%	Malhotra. (2017)Kumar (2013)
Neem Coated Urea (2017). Ramappa et al. (2017)			6.0%	5.0%	2.3%	PIB (Press Information Bureau).
Renewable Power Program		25.0%		19.0%	5.5%	MNRE (2011),
National Mission on Agriculture Extension and Technology (NMAET)		17.0%	15.0%	30.0%	8.0%	Kulkarni (2005)Grant Thornton India LLP. & FICCI. (2015)
Agriculture Insurance	-5.1%	1.6%	-8.9%	2.5%	-2.2%	Das et al. (2009)Varadan et al. (2012).
Weather Advisory		2.0%	5.0%	10.0%	1.3%	Maini et al. (2011)
Overall Impact	2.2%	3.1%	6.1%	8.4%	3.0%	

[Note: 1. the percentage values in this table are relative to the traditional practices. Since INCCA provides GHG emissions data for the year 2007 and most of the above-mentioned interventions were implemented during post-2007 period, we have considered the year 2007 as the base year. 2. The share of various sources of GHG emissions from the agriculture sector has been taken as weights to estimate percentage reduction in GHG emissions. 3. Policies/program-wise expenditure share is taken as weights to estimate the overall impact on resource-use efficiency and reduction in GHG emission]

Since the key focus of PMKSY is to promote watershed development, rain water harvesting and water conservation, we found this study relevant to understand the implication of PMKSY for Indian agriculture. Sharma et al. (2010) find that the rain water used in supplemental irrigation increases productivity in rainfed areas by 12% and generates 40% increase in net benefits for pulses and oilseeds. Pulses and oilseeds together contributed to 12% of the total value of output from the agriculture sector in India in the year 2015-16 (CSO 2016). Here, we use this information as a weight to obtain a possible increase in farmers' income at the national level. Therefore, we assume here that once the watershed development for rain water harvesting is scaled up across all the rain-fed areas, it will improve the income of the farmers by 5% in India. Sharma et. al (2010) also estimated that an additional 114 billion cubic meter rain water is available in India for harvesting and this can irrigate up to 21mha with a depth of 100mm, which is 45% of rain-fed areas in India. As groundwater contributes to 60% of irrigation water supply, an additional 66 billion cubic meter groundwater will be exploited which is 20% of annual groundwater use for irrigation as on date. Therefore, we argue that once the PMKSY will be scaled up with its desired vision, 20% of additional groundwater use can be saved and water accessibility can be improved across the agricultural plots.

b. National Mission on Micro Irrigation (NMMI)

The National Mission on Micro Irrigation was subsumed under the PMKSY program in 2015. However, we have analyzed the implication of micro-irrigation separately. To do that, we have taken away the budget allocated for NMMI from the PMKSY budget for the 2015-16 and 2016-17 so that double counting in estimating possible implication of PMKSY can be avoided.

The micro-irrigation systems help to minimize conveyance loss, evaporation and runoff that are associated with common irrigation methods. It leads to more efficient water-usage and better irrigation of marginal land. To understand the implications of micro-irrigation on the input-output relationship in agriculture we have reviewed the latest report on micro-irrigation prepared by Grant Thornton India, Irrigation Association of India (IAI), and Federation of Indian Chambers of Commerce and Industry (FICCI) (Grant Thornton.,IAI., &FICCI. (2016)). This report has cited 50%-90% savings in water, 31% savings in energy use, 29% savings in fertilizer consumption and 42% increase in farmers' income. This report also cited that the micro irrigation system can be scaled up to 69 Mha in India which is 50% of the net sown area in India. In this study, we have used this 50% as a weight to estimate the national level impact on water use, energy use, fertilizer use, and farmers' income. Therefore, the data presented in table 3 can be explained in the way that once micro irrigation system is scaled up it will result in improved water, energy and nitrogen use by 25%, 15%, and 15%, respectively.

c. National Mission for Sustainable Agriculture (NMSA)

The National Mission for Sustainable Agriculture (NMSA), was formulated in 2008 for enhancing agricultural productivity and minimizing climatic risks with a special focus on rainfed areas through its Rainfed Area Development Program (RADP). The program aimed to improve water-use efficiency and nutrient management by shifting to environment-friendly technologies, adoption of energy-efficient equipment, and conservation of water resources in an integrated farming system (IFS) approach.

The world celebrated 2015 as the International Year of Soils to raise awareness about the importance of soils for food security (Lal & Stewart 2010) and essential ecosystem functions (Kibblewhite et al. 2008), and to promote sustainable use and preservation of this valuable natural resource. In India, the International Year of Soils was celebrated with the launch of a massive and ambitious programme that aims to provide Soil Health Cards (SHCs) to all the farmers of the nation. This programme promises to conduct laboratory tests of soil composition for each farmer's land and provide a detailed analysis of the availability of various nutrients and other compounds in the soil as well as crop-specific recommendations for fertilizer application based on a target yield. The farmers will receive these cards every three years. However, the available studies by Fishman et al. (2016) and Makadia et al. (2015) did not find any significant impact of SHCs on fertilizer use at the farmers' field level.

The latest impact evaluation conducted by the Ministry of Agriculture & Farmers' Welfare reports that the integrated nutrient management practice is an effective intervention to save fertilize and thereby increase farmers' income (Ramappa et al. 2017; PIB, 2017). Another study by Wani et al. (2017) has found an average increment of cereals' yield by 20%, legume yield by 40% and oilseeds yield by 35% due to the adoption of soil testing based integrated crop and nutrient management. This study also found an increase in farmers' income by 35%. As soil health management is one of the major components under NMSA, we review these reports to estimate the possible implication of NMSA on fertilizer savings and farmers' income. Thus, it has been estimated that almost 7% chemical fertilizers can be saved, and 5% income of the farmers can be increased by scaling up soil testing based integrated nutrient management in India (see table 3).

Also, the promotion of agroforestry through NMSA is an effective intervention for GHG mitigation. Nair (1979) defines agroforestry as a land use system that integrates trees, crops, and animals in a way that is scientifically sound, ecologically desirable, practically feasible, and socially acceptable to the farmers. Improved soil structure and fertility, enhanced the productivity of land in an environmentally sustainable manner and the creation of better climatic opportunity for the growth of agricultural crops, are some of the ways in which agroforestry will benefit the agriculture. The study by Jha et al. as cited in Murthy et al. (2013) showed that agro-forestry in India has the potential to increase carbon sequestration by at least 26% as compared to seasonal crop cultivation practices. As the GoI is planning to adopt agro-forestry in 33% of agricultural land, we have considered this share as a weight to estimate GHG emission mitigation for agriculture at the national level.

d. Rashtriya Krishi Vikas Yojana (RKVY)

The implication sof RKVY have been analyzed by reviewing the all India report on impact evaluation of RKVY conducted by Institute for Social and Economic Change in collaboration with the Department of Agriculture, GoI (Kumar et al. 2013). As mentioned in table 2, promotion of micro-irrigation, on-farm water management through watersheds, nutrient management by promoting micro nutrient and bio-fertilizer are key climate smart interventions under this program. As reported in the impact evaluation study, most of the beneficiary farmers observed 10% to 20% increment in farmers' income and around 44% savings in water and 36% savings in fertilizer due to the adoption of various water management practices under RKVY. In the case of nutrient management, the impact evaluation study has found that most of the beneficiaries obtained almost a 10% increase in productivity. In this study, we have used this information as a proxy to estimate the implication of RKVY for water savings, nitrogen savings and farmer's income. For example, we have considered the mid-value (10-20%) of the percentage increase in farmers' income due to water management practices. On the other hand, the percentage increase in productivity due to nutrient management is assumed as savings in fertilizer use for crop cultivation. Further, to combine all these impacts to estimate the impact of RKVY, we have applied the share of expenditure on these climate smart interventions as weights corresponding to the benefits derived from each intervention. For example, benefits due to water management is given 25% weight (as 27% of total climate smart expenditure under RKVY is on water smart) and benefits from nutrient management is given 73% weights (i.e. a combination of integrated nutrient management and crop development). Although we have considered the expenditure for farmers training under RKVY as knowledge smart intervention of CSA (see table 2), while calculating the above-mentioned weights, we have included this expenditure with water smart, nutrient smart and crop smart interventions proportionately. In this way, we have obtained 12% savings in water, 17% savings in fertilizer, and 11% increase in income of the farmers due to the promotion of climate smart interventions under RKVY. It is also evident that the energy use for irrigation is directly proportional to the water use for irrigation. Therefore, it can be assumed that 12% savings in water will lead to an equal percentage reduction in energy use for irrigation. Again, it is evident from the available evidence that irrigation energy demand accounts for 25% share of the total energy use for the agriculture. Thus, we have obtained 3% (25%* 12%) savings in energy use due to savings in irrigation water use by adopting improved water management practices through RKVY.

e. National Food Security Mission (NFSM)

The Government of India launched the National Food Security Mission (NFSM) in 2007 to increase production of rice, wheat, and pulses. In recent years, the programme has been up-scaled to include coarse cereals and commercial crops. To address the growing challenges of adaptation and mitigation of climate change, the current focus of the programme is on increasing production and on productivity enhancement in a sustainable manner through agro-climatic zone wise planning. Components of the programme include Integrated Nutrient Management (INM), production and distribution of HYVs and hybrid seeds, Accelerated Crop Production Program (ACPP), Crop Diversification Program (CDP), Direct Seeded Rice (DSR), Alternate Wet and Dry (AWD) method of water management for rice cultivation, and zero-tillage for wheat cultivation. Agricultural productivity can be increased through crop nutrient management and adopting crop species that can give higher yields under area-specific environmental conditions. These are the most effective climate smart interventions in rice-wheat cropping systems in India (Bhan & Behera 2014; Kumar & Ladha 2011; Olaf 2009).

The Indo-Gangetic Plain (IGP) in India occupies almost 27% of the total net sown area of India and rice-wheat cropping system is dominant in this region. Various studies have observed benefits of different types of conservation agricultural practices on water use, energy use and nitrogen use for rice and wheat cultivation (RWC- CIMMYT, 2003; Jat, et al. 2005, Erenstein & Pandey 2006). However, the study by Joshi (2011) summarizes the benefits from conservation agriculture in India as 20-35% savings in water, 60-90% savings in energy use, 5-10% decrease in cost of production and 10 – 17% increase in yield. Therefore, under the ceteris paribus condition, the fall in the cost of cultivation and increase in yield would increase farmer incomes by 15-27% by adopting CSA. To estimate the implication of NFSM at the national level we have assumed IGP in India as a highly potential region to scale up conservation agriculture and hence we have applied 27% weights on the mid -values of these benefits. In this way, we have obtained, 8% savings in water, 20% savings in energy use, and 6% increase in income of the farmers at the national level (see table 3).

f. National Mission for Horticulture (NHM)

The NMH aims to promote the holistic growth of horticulture to create a potential alternative livelihood for farmers and will enhance the nutritional security. Of total expenditure under this scheme, Rs 288 Crores have been spent annually for horticulture area rejuvenation which is considered as crop smart intervention for climate smart agriculture. The Mission also focusses on building water-use efficiency through dissemination of micro-irrigation. Apart from adaptation, these crop smart policies will also contribute to mitigating climate change by reducing greenhouse gas (GHG) emissions, for example, by reducing the dependency on inorganic fertilizers, by offering a possibility of sequestering carbon (specially by planting more perennial crops), and by reducing methane emissions from the rice-growing areas (FAO 2013).

The implication of the National Mission for Horticulture (NHM) on climate smart agriculture is two-fold – savings in fertilizer through integrated nutrient management and carbon sequestration through horticulture based agro-forestry (Malhotra 2017). We have assumed similar kind of implication on GHG mitigation as we observed in case of the agro-forestry component under NMSA. Again, as 18% of the net sown area in India is covered by horticulture crops, we have applied this share as the weight to estimate the possible GHG mitigation. We have reviewed all India study on impact evaluation of the National Horticulture Mission (Kumar 2013) to assess the implication of this program on farmers' income. It is observed from this study that, NHM results in an increase in area under horticulture crops but fails to enhance the yield significantly. Therefore, we have assumed no impact on farmers' income and confined our estimate in estimating GHG mitigation due to area expansion of horticulture crops. Thus, we have obtained a 4.7% reduction in GHG emission at the national level by promoting horticulture crops.

g. Neem coated urea

The nitrogenous fertilizer, urea, is heavily subsidized in India (Rs 268 per 50 kg) for user-farmers, irrespective of changes in the production costs[3]. Thus, farmers often apply too much urea to their fields while seldom, if ever, apply secondary nutrients (sulfur, calcium, and magnesium) and micronutrients (zinc, iron, copper, boron, molybdenum, and manganese).

[3] Diammonium phosphate (DAP) and murate of potash (MoP), the two other key macro-nutrients, are also subsidized in India, by Rs 12,350 per metric ton and Rs 9300 per metric ton, respectively, but unlike urea, their prices are not fixed.

Over-application of urea has resulted in a highly skewed NPK ratio of 8.2:3.2:1, compared the recommended ratio of 4:2:1. This imbalance in fertilizer application is thought to have affected soil fertility, and crop productivity, and even farmers' net profits, resulting in diminishing biodiversity, increasing pollution of water resources and global warming.

In January 2015, the Government of India made it mandatory for the urea manufacturers to neem-coat the urea up to a minimum of 75% of their total production of subsidized urea, up from 35% earlier, and allowed them to go even up to 100%. In the use of conventional urea, about half the applied nitrogen is not assimilated by the plants and it leaches into the soil, causing extensive groundwater contamination. Spraying urea with neem oil slows the release of nitrogen, by about 10-15%, reducing consumption of the fertilizer and increasing crop yields.

In the context of a reduction in GHG emissions from the agricultural system, the neem coated urea initiative by the Government of India is an important step. The impact assessment study conducted by Ramappa & Manjunatha (2017) has shown a reduction in fertilizer use by 6% during the Kharif season 2016-17 (Ramappa & Manjunatha 2017). The same study also reveals an increase in crop productivity by 5% (Press Information Bureau, 2017, 25 March). Therefore, we have assumed these values to estimate the implication of neem coated urea towards the development of climate smart agriculture.

h. Renewable Power Programme

In India, the farmers pump an estimated 230-250 billion m^3 of groundwater every year to irrigate 60-70 million hectares of land using nearly 25 million diesel and electric pump sets. In the process, they use 5-8 billion liters of diesel and 0.12 million gigawatt-hours (GWh) of heavily subsidized electricity, emitting approximately 110-120 million tons of CO_2 into the atmosphere.

In 2014, the Government of India launched 'the solar pumping program' with the goal to install 1 million solar pumps for irrigation and drinking water. The program provides capital subsidy on solar pumps. The government expects that by the year 2020-2021, at least 1 million solar pumps will be deployed for irrigation and drinking water purposes. Research conducted by the International Food Policy Research Institute (IFPRI) shows that affordable irrigation using solar pumps helps to increase crop yields, crop quality, and farmers' net returns while providing effective drought-proofing (Kishore et al. 2015).

A study by KPMG has shown that the replacement of 1 million diesel pump sets with solar would result in savings of diesel use by 9 billion liters and CO2 emission mitigation by 25.3 million tonnes during the entire life period (average 7 years) of the pump set. On the other hand, it is observed Indian agriculture consumes almost 8 billion liters of diesel for irrigation and land preparation (CSO, 2016). Moreover, the study by AC Nielsen and MoPNG, GoI shows that 25% of the total diesel consumption in agriculture is accounted for by irrigation pump sets, almost around 2 billion liters per year. Therefore, promotion of solar pump sets would save 25% diesel energy used in agriculture. The same study has also reported a 19% internal rate of return (IRR) to the farmers through the entire life years of the pump sets. We assumed this IRR as income benefit of the farmers due to the adoption of solar pump sets.

i. National Mission on Agriculture Extension and Technology (NMAET)

The National Mission on Agriculture Extension and Technology (NAMET) plays an important role in achieving climate smart agriculture in India mainly through farm mechanization. Farm mechanization helps to increase crop productivity, cropping intensity, and profitability from agriculture, besides reducing the drudgery due to many farm operations. Equipment like happy-seeders, laser land levelers, multi-crop planters, and power threshers are critical for the adoption of resource conservation oriented agricultural practices that make agriculture more sustainable and resilient to droughts and unseasonal rains. The efficient farm equipment would be more affordable to farmers and would help reduce the emission intensity of mechanized farm operations.

The study by Kulkarni (2009) shows that the adoption of modern equipment (seed-cum- fertilizer drill and zero tillage machines) results in 12-34% increase in productivity, 15-20% savings in fertilizer, and 29-49% increase in income of farmers. On the other hand, Indian agriculture has achieved 40-45% mechanized area and states like Punjab, Haryana and western Uttar Pradesh are highly mechanized. The promotion of mechanization reduces the time for land preparation and reduces the consumption of seeds, thereby reducing the cost of cultivation. Since seed-cum-fertilizer drill machine is highly feasible across all types of agro-ecological conditions, we have taken the mid-values of these benefits to obtain the national level implication of this program.

j. Agricultural Insurance - Pradhan Mantri Fasal Bima Yojana (PMFBY)

Agriculture is vulnerable to weather fluctuations. Access to assured irrigation and use of stress-tolerant crop varieties can reduce the risk, but do not eliminate it. Even in the agriculturally developed states like Punjab and Haryana, where nearly entire sown area is irrigated, crops have suffered considerably due to unseasonal rains or a spike in temperature or pest attacks in recent years. Even advanced technologies cannot fully secure agricultural output from abiotic and biotic stresses. Farmers need agricultural insurance to protect themselves from possible crop losses due to various factors that are not in their control.

On 13th January 2016, The Government of India launched a new crop insurance scheme called the Pradhan Mantri Fasal Bima Yojana (PMFBY) to extend the insurance coverage to 50% of the total cropped area in three years. To encourage and enable more farmers to insure their crops, premium rates have been substantially reduced to 2% of the sum assured for Kharif crops, 1.5% for Rabi crops and 5% for the commercial and horticultural crops. The scheme has come into effect from Kharif 2016. Under the previous crop insurance schemes, the coverage was capped, that is farmers could, at best, recover a fraction of their losses. This cap has been removed under PMFBY. Now there will no upper limit on government subsidy. Even if the balance premium is 90%, the government will bear it.

Apart from providing generous subsidies on crop insurance premium, the government will set up 5,000 automated weather stations across the country under the public-private partnership model for the successful implementation of the scheme. Smart phones, drones, and remote sensing images will be used to assess the yields and avoid delays in payment of claims to farmers. Further, whereas in earlier schemes, blocks were taken as a unit of assessment and individual farmers got paid if crops were damaged across a wide area, in the new scheme, either a village panchayat or individual farmer's field (in case of localized calamities such as hailstorms) will be the unit of assessment. The PMFBY will also cover post-harvest losses.

Agricultural insurance and weather advisory schemes are important adaptation strategies to cope with the climate variability and extreme events. However, limited studies are available to assess the implication of these two programmes at the national level. On the other hand, the available studies are focused either at the sample state or region within the state. For example, the study by Varadan & Kumar (2012) on the impact of agricultural insurance on rice farming in Tamil Nadu. As the rice crop in India is highly vulnerable to climate change and occupies 23% of the gross cropped area, if the entire rice area is covered under insurance, it will minimize the risk of farmers in India. We have used the results from the above-mentioned study to estimate the implication of agriculture insurance on input use and farmers' income. Thus, we used 23% as the weight for the national level. To estimate the implication of agro-advisory in Indian agricultural system, we have reviewed the study by (Maini & Rathore 2008).

5 Implications for greenhouse gas emissions

In Table 3 (6th column), we also assess the possible implications of each policy for GHG emissions. To do this, we have taken into consideration the INCCA report which provides source specific GHG emissions. It is observed from the INCCA report that 22% of GHG emissions from agriculture (including energy use for agriculture but excluding livestock) is due to energy use for land preparation and irrigation, 28% of emission is due to fertilizer consumption, 45% due to rice cultivation and rest due to crop residue burning. We have assumed a direct relationship between water use, fertilizer use, energy use and GHG emissions. For example, savings in fertilizer use will directly reduce GHG emissions and the similar logic is also assumed for energy and water use. Therefore, we have considered the share of water and fertilizer use in GHG emissions as the weights and applied these weights to the values associated with the water and fertilizer savings corresponding to each intervention. This is how we obtain values for GHG emissions reductions in table

3.

Additionally, we estimated the overall impact of these interventions on savings in water, energy and nitrogen use for agriculture and on income enhancement of the farmers along with the possible GHG mitigation. As presented in the last row of Table 3, the selected interventions together save almost 2% of irrigation water, 3% fossil fuel, 6% fertilizer and increase farmers' income by 8.4%. The combined effect of these polices results in reducing GHG emissions by 3%.

6 Conclusions and the way ahead

India is a global hotspot for climate change. Agriculture, the refuge of the bulk of India's poorest, is highly vulnerable to weather shocks. A negative shock to agriculture has an economy-wide impact. Poor smallholder farmers and landless laborers suffer the most as the rate of poverty reduction slows down with the weather-induced recession in the agrarian economy. Agriculture is not only affected by climate change but is also a significant source of GHG emissions. However, the agriculture sector in India offers cost-effective options to mitigate GHG emissions.

In the past two years, the Government of India has launched several new agricultural policies and programmes that capture potential synergies between the three goals of climate-smart agriculture: increasing farm productivity and farmers' income; adapting agriculture to changing weather patterns; and capitalizing on mitigation options available in the agricultural sector. This investment by the Government of India will surely attract further investments from the state governments, agribusiness companies, and farmers in the development of climate smart agriculture.

However, if the experience is any guide, large budgetary allocations alone do not guarantee successful implementation of any program. The recent investments on canal irrigation in Andhra Pradesh and Maharashtra provide an example. Even after spending nearly Rs 1483 billion over a decade, these states did not realize any significant increase in canal irrigated area (Shah 2016). Therefore, a question that arises is what should the Government of India do to ensure that its financial commitments to secure agriculture against climate change and to make it more remunerative lead to maximum impact?

We suggest the following five steps to ensure that the recently announced agricultural policies and programmes have the desired impact.

(i) The central and state governments are implementing many programmes in the agriculture sector. The scarce human and financial resources will be used much more effectively and efficiently if we develop institutional mechanisms to explore and establish synergies between various programmes for agricultural and rural development. The central government may have to offer incentives, by way of additional funds, to the implementing institution to achieve convergence. In this regard, the PMKSY has made a good beginning in trying to converge different programmes related to irrigation, water conservation, and recharge and recycling of wastewater. It also has the provision of state-level coordination committees to facilitate convergence.

(ii) The government should invest in agricultural research and development, and education to ensure that resources are utilized for scientifically sound and locally suitable interventions. Rigorous pilot tests should be conducted to learn about the needed interventions before the launch of mega programmes. Monitoring and evaluation of programmes can offer useful lessons for course correction in ongoing interventions.

(iii) The macro policies and mega programmes for climate-smart agriculture will have a greater impact at the micro-level on farmers and the farming community if the state and central governments implement them in partnership with farmers. These programmes should strengthen farmers' institutions and should be flexible enough to adapt to the regional socio-ecological conditions and address the regional needs. Ensuring local participation will increase the ownership of these programmes and make them more effective.

(iv) The projects that create positive externalities merit subsidies, but sometimes badly-designed subsidies can crowd out private investments and discourage farmers and agribusiness firms from investing their resources and building new and innovative products, services or business models. The public policies and programmes to promote climate-smart agriculture should enable and incentivize farmers and agribusinesses to invest more resources and efforts to promote climate smart agriculture.

(v) Climate change is an ongoing challenge that will require significant investments of resources for decades, not years. The Government of India has announced policies for the promotion of climate-smart agriculture with a financial commitment of up to Rs 838 billion over the next five to ten years. An even higher financial commitment may be required in the future as the climate-change situation worsens. More resources could be generated to expand, or at least sustain, the current level of financial commitment to promote climate-smart agriculture by rationalizing the existing distortionary subsidies for agricultural sector. Many of the largest subsidies for the agriculture sector, like the fertilizer subsidy (Rs 70,000 crore) or power subsidy for agriculture (Rs 15,000 crore) or the irrigation subsidy (Rs 15,000 crore) encourage over-exploitation of resources and emissions of more greenhouse gases. Rationalizing some of these subsidies through better targeting and shifting to direct benefit transfer regime will not only release resources for climate-smart agriculture, but also offer the double dividend of reducing GHG emissions and increasing the sustainability of agriculture.

Last but not the least, it is imperative to mention that this study follows an ex-ante assessment of the government policies to understand their likely impact on climate change adaptation and mitigation efforts. Moreover, this study follows an optimistic approach that all the policy targets will be accomplished within the desired time frame.

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