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Water-Smart-Agriculture to Cope With Changing Climate in Smallholders Farming Areas of Subtropical India: A Review

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ABSTRACT

Agriculture affects climate through emissions of greenhouse gases (GHGs) such as carbon dioxide, methane and nitrous oxide. These emissions come directly from use of fossil fuels, tillage practices, fertilized agricultural soils and livestock manure in large proportion. Conversely, agriculture could be a solution for climate change by the widespread adoption of mitigation and adaptation actions. This happens with the help of conservation agriculture practices. Reducing emissions of agricultural greenhouse gases (GHGs), such as methane and nitrous oxide, and sequestering carbon in the soil or in living biomass can help reduce the impact of agriculture on climate change while improving productivity and reducing resource use. Globally, the water requirement to feed the world in 2050 would be an increase of ~4500 km^3/yr from the current ~7000 km^3/yr. Water productivity improvements could save up to 2200 km^3/yr reducing the future additional needs to ~2300 km^3/yr. This saving is larger than the world's current total consumption of water in irrigated agriculture. In India the availability of water for agriculture is expected to decline from 84% in 2010 to 74% by 2050.

Under the scenario of producing 350 million tones food grain from shrinking water resources, this will put tremendous pressure on the existing water sources. This challenge can be met either by inter basin water transfer or by enhancing irrigation efficiency and water productivity or both. Increasing crop water productivity is a key response option where water is scarce compared with land and other resources involved in production. Improvements to agricultural water productivity help to meet rising demands for food from a growing, wealthier, and increasingly urbanized population, when at the same time there are pressures to reallocate water from agriculture to cities and to make more water available for environmental uses contribute to the urgency for achieving gains in agricultural water management. There is a clear link between water, poverty reduction and economic growth. For the rural poor more productive use of water can mean better nutrition for families, more income, and productive employment.

Key words: *Climate change, Food security, Livelihoods, Greenhouse gas emission*

INTRODUCTION

Shrinking water resources owing to over exploitation of ground water in Western Uttar Pradesh threatens the maintenance of agricultural productivity. As a result, the water table is falling in 60% area of the state. Most of this area falls in the Western part of the state. With the inception of green revolution in the sixties, the water table started declining and the area having water table below 30 feet. Depth has increased from 3% in 1973 to 60% in 2006. During 1993-2006, the average fall of water table in the Western Uttar Pradesh was 50 cm per annum. However, in some of the areas, the fall of water table is even more than 80- 100 cm per annum. Out of 819 blocks, there are 85 dark block, 214 grey blocks in the state, of which 67 dark and 86 grey blocks are in western region, 15 dark and 38 grey blocks in central region 12 dark and 90 grey block in eastern region and 1 dark block in Bundelkhand region. In Western Uttar Pradesh out of 70 blocks, the water table in 40 blocks has gone down below 50 cm depth and in these blocks; submersible pumps are being installed to replace centrifugal pumps. It is projected by 2025 in Western Uttar Pradesh the water table depth will be below 90 cm in 66% area, below 100 cm in 34% area and below 130 cm in 7% area. Correspondingly in each district, the per cent area below 70 cm depth will be 90% in Agra and Mathura, 80 % in Ghaziabad, 70 % in Baghpat, 60% in Aligarh and Saharanpur. To arrest this dangerous trend of ground water exploitation, there is an urgent need to conserve irrigation water through water smart agriculture.

As per studies, a significant (20-25%) amount of irrigation water is lost during its application at the farm due to poor farm designing and unevenness of the fields. This problem is more pronounced in the case of rice fields. Fields that are not level, have uneven crop stands, increased weed burden and uneven maturing of crops. All these factors lead to reduced yield and poor grain quality[44]. The water resources potential of India which occurs as natural runoff in the rivers is estimated at about 186.9 M ha-m. Considering both uneven distribution of water resource over space and time about 112.2 Mha-m of the total potential can be put to beneficial use, 69 M ha-m through surface water resources and 43.2 M ha-m by groundwater. India experiences high degree of spatial variability of annual rainfall, highest annual rainfall of 11,690 mm is recorded at Mousinram near Cherrapunji, Meghalaya, and lowest of 150 mm at Jaisalmer of Rajasthan. Average 75% precipitation of the country occurs during southwest monsoon season (June to September) only. The country's vast cultivated area (82 M ha) is still rainfed.

For adequate living standards as in western and industrialized countries, a renewable water supply of at least 2000 m^3 per person per year is necessary. If only 1000-2000 m^3 per person per year is available, the country is 'water stressed', while the value comes below 500 m^3 per person per year, the country is called 'water scarce'. With rapid population growth and rising expectation of better life, there will be ever increasing demand of water for various competing sectors like domestic, industrial and agricultural needs. Also more and more water will be required for environmental concerns such as aquatic life, wildlife refuges and recreation. With changing global climatic patterns coupled with declining per capita availability of surface and ground water resources, sustainable water management in agriculture is a great challenge in India. With increasing water demand from other sectors, agricultural water use in India will face stiff competition for scarce water resource in future.

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Therefore, the available utilizable water resources would be inadequate to meet the future water needs of all sectors unless the utilizable quantity is increased by all possible means and water is used efficiently. Adoption of suitable agro-techniques for crop cultivation is need of the hour to produce more crops with less water so as to check the decline of surface and ground water resources in India. Recognizing the importance of the above fact, the country has developed water smart agriculture to achieve 'more productivity per drop'.

There are 115 million operational holdings in the country and about 80 % are marginal and small farmers. The growth rate of agriculture in the recent past is very slow in spite of the rapid economic growth in India. According to the Economic Survey of India, 2008, the growth rate of food grain production decelerated to 1.2% during 1990-2007, lower than the population growth of 1.9%. It is projected that in our country population will touch 1370 million by 2030 and to 1600 million by 2050. To meet the demand, we have to produce 289 and 349 MT of food grains during the respective periods. The current scenario in the country indicates that area under cultivation may further dwindle and more than 20% of current cultivable area will be converted for non-agricultural purposes by 2030[16].The operational farm holding in India is declining and over 85 million out of 105 million are below the size of 1 ha. Due to ever increasing population and decline in per capita availability of land in the country, practically there is no scope for horizontal expansion of land for agriculture. Only vertical expansion is possible by integrating farming components requiring lesser space and time and ensuring reasonable returns to farm families.

Globally, climate change (CC) is the most serious environmental threat that adversely affects agricultural productivity[10]. According to inter-governmental panel on climate change[28] report, climate change refers to any change in climate over time, due to natural variability or as a result of human activity. This climate change mainly caused by greenhouse gases (GHGs) accumulation in the atmosphere, which results in increased greenhouse effect. Climate change and agriculture are interrelated processes, both of which take place on a global scale and their relationship is of particular importance as the imbalance between world population and world food production increases. Based on some projections, changes in temperature, rainfall and severe weather events are expected to reduce crop yield in many regions of the developing world, particularly subtropical India[18]. The impact and consequences of climate change for agriculture tend to be more severe for countries with higher initial temperatures, areas with marginal or already degraded lands and lower levels of development with little adaptation capacity[32].

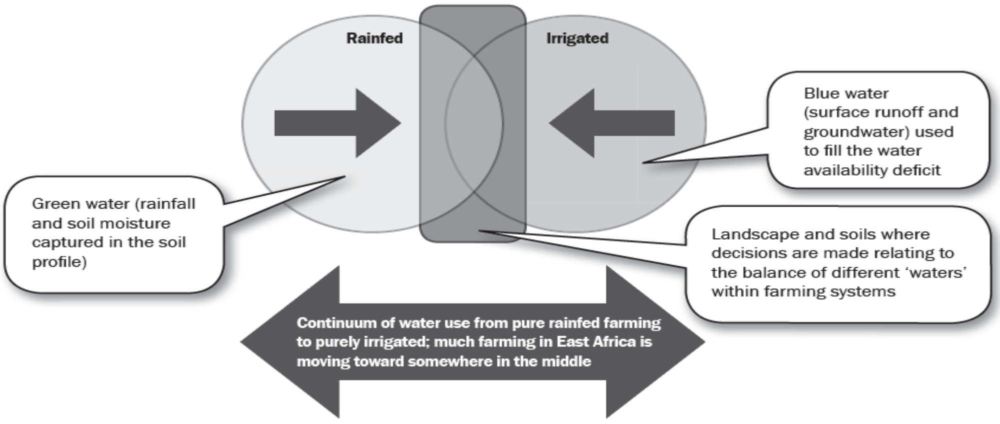

Fig. 1: Water-smart agriculture conceptual model

On the other hand, various studies indicate that current agricultural activities are a significant source of GHGs that aggravate climate disruption[47]. The practice of agriculture is very different between developing and developed counties, which results in variation of agricultural contribution to climate change. In developing countries, GHG emission from agriculture sector is much more because of large number of cattle and inadequate manure management, improper use of agro-chemicals and mismanagement of the land. In turn, CC impact becomes more serious in developing countries due to their dependence is on agriculture. Conservation agriculture and organic agricultural systems can help reduce agricultural GHG emissions through energy conservation, lower levels of carbon-based inputs, lower use of synthetic fertilizer and other features that minimize GHG emissions and sequester carbon in the soil. In general, agricultural activity could be a source of GHGs as well as a sink, notably through the storage of carbon in the soil organic matter and in biomass and influenced by CC Hoffmann[24].

Agricultural producers, in particular the smallholder farmers of subtropical India, are facing unprecedented challenges in the 21st century. With an estimated 9.2 billion people to feed by 2050 – of whom 8 billion will be in developing countries – and increasing scarcity of land and water, productivity gains will have to be the main source of growth in agriculture and the primary means to satisfy increasing demand for food and other agricultural products[35]. With globalization and new supply chains, farmers will need to continuously innovate to respond to changing market demands and remain competitive. Moreover, "climate change has the potential to irreversibly damage the natural resource base on which agriculture depends." Climate change is increasing production risks in many farming systems and reducing the ability of farmers and rural communities to manage these risks on their own. Around the world, resource-poor farmers and pastoralists are trying to adapt to the effects of climate change, which affect them disproportionately: (i) dwindling crop yields; (ii) exacerbated by changes in rainfall patterns; (iii) diminishing natural resource productivity; and (iv) in some areas, irreversible loss of biodiversity.Water Smart Agriculture (WaSA) as a subset of Climate Smart Agriculture (CSA)—and in some ways a more practical and tangible starting point to implementation. Many of the challenges facing farmers to adapt and increase resilience to a changing climate within landscapes either directly or indirectly are water-related, from capturing and storing uncertain rainfall and managing declining aquifers to supporting better soil moisture retention and crop use efficiency. Many choices relate to the range of storage and use options presented in Figure 2.

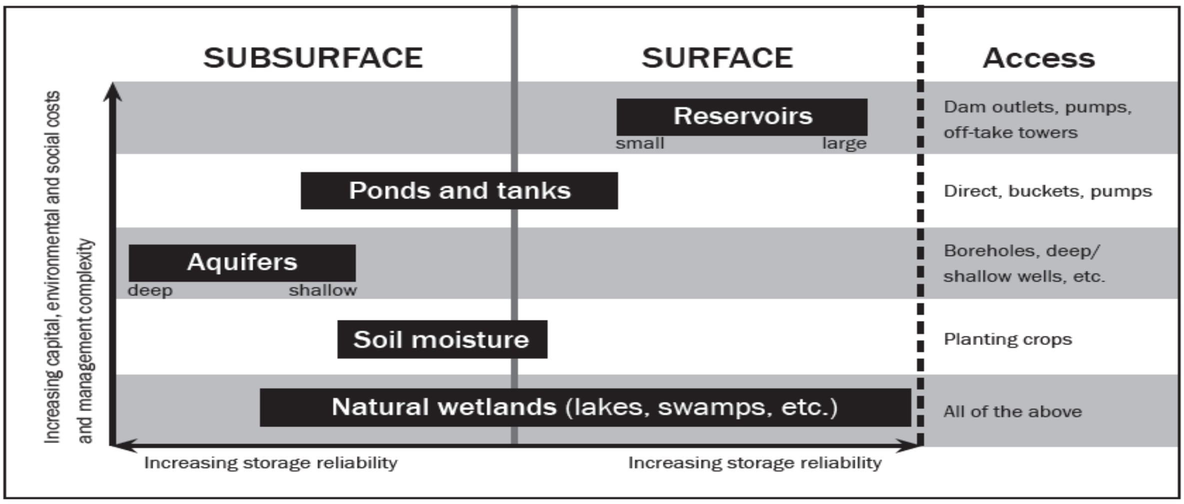

Fig. 2: A continuum of water storage options[41].

The agricultural sector offers opportunities for mitigating climate change. Agriculture has strong potential to reduce greenhouse gas (GHG) emissions by promoting clean and efficient energy, reducing deforestation and promoting sustainable agricultural practices such as the rehabilitation of degraded lands, water conservation and management, and increased biomass production. Since rural people manage vast areas of land, they are important players in natural resource management and carbon sequestration. However, they are not usually compensated for their efforts in any significant way. In the second half of the last century, agricultural research played a major role in rapidly increasing agricultural production and reducing rural poverty in Asia. But after 20 years of disengagement, progress in productivity gains has slowed, environmental damage has increased, global warming has accelerated and the number of hungry people is on the rise.

During the last few decades, it has become evident that because of a steadily increasing demand, freshwater scarcity is becoming a threat to sustainable development of human society. In its most recent annual risk report, the World Economic Forum lists water crises as the largest global risk in terms of potential impact[69]. The increasing world population, improving living standards, changing consumption patterns, and expansion of irrigated agriculture are the main driving forces for the rising global demand for water[11,62]. At the global level and on an annual basis, enough freshwater is available to meet such demand, but spatial and temporal variations of water demand and availability are large, leading to water scarcity in several parts of the world during specific times of the year. The essence of global water scarcity is the geographic and temporal mismatch between freshwater demand and availability[57], which can be measured in physical terms or in terms of social or economic implications based on adaptation capability[54,65]. The purpose of this paper is to discuss: (i) the potential role of agricultural research in improving small farmers' productivity and ability to adapt to and mitigate climate change; (ii) how smaller-scale water management systems are best prospect for improving productivity under near-normal or moderately below normal rainfall conditions and (iii) to describe how improvements in water and land management can increase the productivity of water in agriculture.

People facing different levels of water scarcity

The number of people facing low, moderate, significant, and severe water scarcity during a given number of months per year at the global level about 71% of the global population (4.3 billion people) lives under conditions of moderate to severe water scarcity (WS > 1.0) at least 1 month of the year. About 66% (4.0 billion people) lives under severe water scarcity (WS > 2.0) at least 1 month of the year. Of these 4.0 billion people, 1.0 billion live in India and another 0.9 billion live in China. Significant populations facing severe water scarcity during at least part of the year further live in Bangladesh (130 million), the United States (130 million, mostly in western states such as California and southern states), Pakistan (120 million, of which 85% are in the Indus basin), Nigeria (110 million), and Mexico (90 million). The number of people facing severe water scarcity for at least 4 to 6 months per year is 1.8 to 2.9 billion. Half a billion people face severe water scarcity all year round. Of those half-billion people, 180 million live in India, 73 million in Pakistan, 27 million in Egypt, 20 million in Mexico, 20 million in Saudi Arabia, and 18 million in Yemen. In the latter two countries, it concerns all people in the country, which puts those countries in an extremely vulnerable position. Other countries in which a very large fraction of the population experiences severe water scarcity year-round are Libya and Somalia (80 to 90% of the population) and Pakistan, Morocco, Niger, and Jordan (50 to 55% of the population).

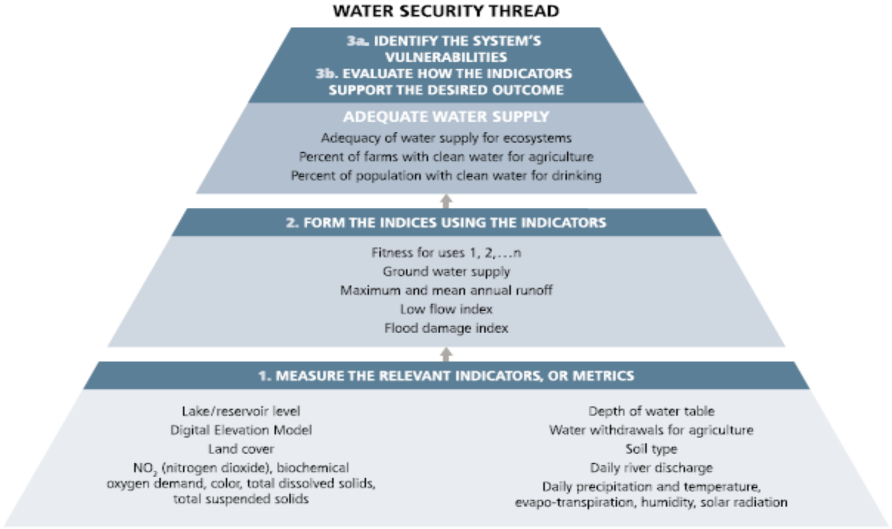

Fig. 3: Water security thread from Vital Signs. The pyramid of the water security thread depicts the integration of metrics (1) that build the desired indices (2) with the outcomes of interest (3a and 3b). Adapted with permission from the Vital Signs programme.

One or a few months of severe water scarcity will not be visible when measuring water scarcity annually, because of averaging out with the other, less scarce months. We find that the number of people facing severe water scarcity for at least 4 to 6 months is 1.8 to 2.9 billion, which the range is provided by earlier estimates. Thus, we show that measuring the variability of water scarcity within the year helps to reveal what is actually experienced by the results are not very sensitive to the assumption on the level of environmental flow requirements. With the current assumption of environmental flow requirements at 80% of natural runoff, we find 4.3 billion people living in areas with WS > 1.0 at least 1 month in a year. If we would assume environmental flow requirements at 60% of natural runoff, this number would still be 4.0 billion. The results are also barely sensitive to uncertainties in blue water availability and blue water footprint. We tested the sensitivity of the estimated number of people facing severe water scarcity to changes in blue water availability and blue water footprint. When we increase water availability estimates worldwide and for each month by 20%, the number of people facing severe water scarcity during at least 1month of the year reduces by 2% (from 4.0 to 3.9 billion).Reducing water availability by 20% gives 4.1 billion. Changing water foot prints in the ±20% range results in the number of people facing severe water scarcity to be between 3.9 and 4.1 billion as well. Changing water availability in the ±50% range yields 3.8 to 4.3 billion people facing severe water scarcity during at least part of the year, whereas changing water footprints in the ±50% range yields 3.6 to 4.2 billion people. The reason for the low sensitivity is the huge temporal mismatch between water demand and availability: Demand is generally much lower than availability or the other way around. Only in times wherein water demand and availability are of the same magnitude can changes in one or the other flip the situation from one scarcity level to another.

Water-smart agriculture and the future of food production

Food systems vary enormously around the world and different consumer's access food differently. Many of the world's poorest rural populations continue to rely for their sustenance and livelihoods primarily on local food and local economies that are poorly integrated into global markets Barrett[3]. The World Bank presents cross-country econometric evidence to show that investment in agriculture, in which smallholder farmers participate as managers and labourers, has double the impact on poverty reduction as investment in any other sector[68]. Future impacts of climate change on the incomes and food security of poor households will very much depend on whether resultant losses in agricultural yields are local or widespread[23]. Moreover, climate is not the only determinant of food security: rapid environmental, economic and political changes may be connected globally but have disparate impacts in different locales[27]. Agriculture is also a major contributor to greenhouse gas emissions both directly[2] and as a proximate driver of land use change[22]. The challenge is to mitigate these emissions without compromising food and livelihood security, particularly of the poor rural majority. Therefore there is a particular call for research in climate, agriculture and food systems to address highly local contexts while also giving the requisite attention to wider scale institutional mechanisms for spreading solutions, developing shared visions of the future and negotiating differential roles and responsibilities. All this will necessitate serious commitment to working in partnership, enhancing capacity and addressing societal differences.

Climate change affects agriculture in a number of ways; including through changes in average temperatures; rainfall and climate extremes with an important impact on soil erosion (i.e. floods, drought, etc): changes in pests and diseases, changes in atmospheric carbon dioxide, changes in the nutritional quality of some foods, changes in growing season, and changes in sea level[66]. Crop yields show a strong correlation with temperature change and with the duration of heat or cold waves, and differ based on plant maturity stages during extreme weather events[24]. Modified precipitation patterns will enhance water scarcity and associated drought stress for crops and alter irrigation water supplies. They also reduce the predictability for farmers' planning[46]. In an indirect way, a change in temperature and moisture levels may lead to a change in the absorption rate of fertilizers and other minerals, which determine yield output. In short, the rise in temperature along with the reduction in rainfall reduces agricultural productivity if both are beyond the threshold that is suitable for crop production[61]. According to Ignaciuk and Mason-D'Croz[26] climate changes currently decreases the yield of maize, rice, wheat, potatoes and vegetables and continue to reduce seriously by 2050 globally.

Climate change regional impacts are likely to be substantial and variable, with some regions benefiting from an altered climate and other regions adversely affected. Generally, food production is likely to decline in most critical regions (e.g. subtropical and tropical areas), whereas agriculture in developed countries may actually benefit where technology is more available and if appropriate adaptive adjustments are employed[47]. In relation, crop productivity is projected to increase slightly at mid to high latitudes for local mean temperature increases of up to 1-3°C depending on the crop, and then decrease beyond that in some regions. At lower latitudes, especially seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2°C), which would increase risk of hunger[45]. Warmer weather was expected to bring longer growing seasons in northern areas, and plants everywhere were expected to benefit from carbon fertilization.

Agriculture is central to the survival of millions of people in subtropical India many. It is the number one provider of employment and livelihood in country[28]. The impacts of climate change on agriculture have significant consequences on livelihoods, food production, and the overall economy of countries, particularly those with agriculture-based economies in the developing world because agriculture contributing 29 percent of developing countries' GDP and 65 percent of developing countries' populations[7]. As Lobell *et al*[39]., study in 12 food-insecure regions of the world reported that climate change could significantly impact agricultural production and food security up to 2030 particularly for South Asia due to both changes in mean temperatures and rainfall as well as increased variability associated with both.

Farm-scale Management Practices to Improve Productivity and Resilience

Water productivity improvements are essential to reduce pressure on water resources. If we assume improved water productivity from 1,800 m^3 to 1,200 m^3 per ton of grain produced, the corresponding required water for meeting MDG by 2015 is still a considerable additional water demand. The estimated additional water requirements, allowing for water productivity improvements, are of the order of 1,850 m^3 y^{-1} in 2015, to about 3,000 m^3 y^{-1} in 2030, and in 2050[30]. This additional requirement presents a great challenge, when we also consider the need to allocate water resources for other things than agricultural production. According to Thornton and Lipper[60] agriculture contributes 30-40% of anthropogenic GHG emissions. Three-quarters of agricultural GHG emissions occur in developing countries, and this share may rise above 80% by 2050[59]. According to FAO [13] report in developing countries there is a significant increase in GHGs emission from 2001-2011 (14%), the increase occurred, due to an emission from agriculture accounts about 80% FAO[13]. As the global population and the demand for food continue to grow, total GHG emissions from the agricultural sector are projected to increase over time Marius[40]. Agriculture creates both direct and indirect emissions. Direct emissions come from fertilized agricultural soils and livestock manure. While indirect emissions come from runoff and leaching of fertilizers, emission from land-use changes, use of fossil fuels for mechanization, transport and agro-chemical and fertilizer production[29]. The most significant indirect emissions are changes in natural vegetation and traditional land use, including deforestation and soil degradation. Intensive tillage is also one of traditional land use practices which involve continuously disturb the land. This practice increases CO_2 emissions by causing decomposition of SOM and soil erosion[71].

Globally, agriculture contributes to 58 percent of total N_2O emission[67]. It creates 4.5 million tons of nitrous oxide annually[34]. Various management practices in the agricultural land can lead to production and emission of nitrous oxide, range from fertilizer application to methods of irrigation, tillage and cattle and feedlots. The use of synthetic fertilizer for agriculture is a major source of nitrous oxide emissions. Apart from this, large quantities of natural gas are used to make synthetic fertilizers because it is the main ingredient. The production process also takes a lot of energy so their impact on climate change is actually larger when we factor this in. Industrialized farming practices have worsened this loss and the result has been increased emissions. Continuous cropping may result in using of large chemical fertilizer[6]. Increasing the control of water resources available for agriculture reduces vulnerability to climate variability and leads to greater agricultural productivity[34,53].

Reduction of Greenhouse Gases through conservation agriculture

Positive changes in agronomic practices like tillage, manuring and irrigation can help reduce greatly the release of greenhouse gases into the atmosphere. Adoption of zero tillage and controlled irrigation can drastically reduce the evolution of CO_2 and N_2O. Reduction in burning of crop residues reduces the generation of CO_2, N_2O and CH_4 to a significant extent. Saving on diesel by reduced tillage and judicious use of water pumps can have a major role to play. Changing to zero tillage would save 98 litres diesel per hectare[43]. With each litre of diesel generating 2.6 kg,about 3.2 Mt CO_2 $annum^{-1}$ (about 0.8 MMTCE) can be reduced by zero-tillage in the 12 million ha under rice-wheat systems in the Indo-Genetic Plains alone. Intermittent irrigation and drainage will further reduce CH_4 emission from rice paddies by 28% to 30% as per the findings at IARI (Delhi) and at Pantnagar. Use of calcium nitrate or urea instead of ammonium sulphate and deep placement instead of surface application of nitrogenous fertilizers can increase its efficiency and plant uptake thereby reducing N_2O emission. Tillage and crop residues retention have a great influence on CH_4 and

N_2O emission through the changes of soil properties (e.g., soil porosity, soil temperature and soil moisture, etc.)[70]. In some experiments, conversion of conventional tillage (CT) to no-till (NT) can significantly reduce CH_4 and N_2Oemission[12]. Wang *et al*[63]., indicated that the major differences in CH_4 production zone resulted from the disturbed depth by the different tillage methods. Therefore, the CH_4 production zone may vary according to the adopted tillage method. Regina *et al*[51]., indicated that CH_4 oxidation rate was higher when there were more macro-pores or fewer micro-pores in the soil.

Table 1: Carbon dioxide emissions over a 19-day period after tilling wheat stubble with different methods

Tillage method	Cumulative CO_2 Loss (t/ha)
Mouldboard plough	9.13
Disk harrow	3.88
Chisel plough	3.65
No- tillage	1.84

Source: Reicosky[52]

Maintenance of mulch under conservation tillage systems increases the ability of soil to sequestrate CO_2 and reduces emissions, protecting the atmosphere. In some soils, following several years under a conservation tillage system, organic matter content has been shown to increase by as much as 2000 $kgha^{-1}yr^{-1}$. Increased organic matter also improves the soil's nutrient and water holding capacity. As shown Table 1, tillage increases oxidation of soil organic matter content releasing large quantities of CO_2, whereas conservation tillage can reduce CO_2 emission by up to 80%. Conservation tillage has an even more direct impact on greenhouse gas levels. It can reduce the number of trips needed to produce a crop and lowering the horsepower requirement for crop production; it reduces the amount of fuel used in farming. Mulch tillage light to moderate tillage passes that leave more than 30 percent residue cover after planting saves approximately 2.0 gallons per acre[31]. Across the 46.7 million acres of mulch-tilled cropland, that represents a savings of 93.4 million gallons of diesel. Extrapolating that out over the nation's 65 million acres of no-till crops, a savings of 253.5 million gallons of diesel is realized. Combining those two figures, conservation tillage saves 353.8 million gallons of diesel per year. Kern and Johnson[33] determined no-till could reduce fuel consumption by 3.5 to 5.7 gallons per acre, depending on the number and type of tillage trips eliminated the soil type and moisture content.

Crop inputs, no-till emitted less CO_2 from agricultural operations than did conventional tillage, with 137 and 168 kg C $ha^{-1}yr^{-1}$, respectively[50]. Larney *et al*[37]., suggested that although relative increases in soil organic matter were small, increases due to adoption of NT were greater and occurred much faster in continuously cropped than in fallow-based rotations. Hence intensification of cropping practices, by elimination of fallow and moving toward continuous cropping is the first step toward increased C sequestration. Reducing tillage intensity, by the adoption of NT, enhances the cropping intensity effect. Changing from conventional tillage to no-till is therefore estimated to both enhance C sequestration and decrease CO_2 emissions[64]. The benefits of NT systems on carbon sequestration may be soil/site specific, and the improvement in soil organic matter may be inconsistent in fine textured and poorly drained soils. Studies conducted in Europe, based on EU 15th implementation report provided that 70% of the farmland was under direct seeding and minimum tillage, leading to a reduction in CO_2 emissions of more than 135 MT per year. This amount represents almost 40% of the annual CO_2 emission reduction target until 2012, which was established at 346

MT CO_2 yr^{-1}.This study assumes that the sequestration of 1 ton of carbon is equivalent to 3.7 tons of CO_2 and that the consumption of 100 litres of fuel produces an emission of 303 kg of CO_2. It is also assumed that direct seeding results in an increase of soil carbon of 0.77 t ha^{-1} yr^{1} and minimum tillage of 0.5 t ha^{-1} yr^{-1}. In total, conservation agriculture reduces energy consumption between 15%-50%, reduces the working time by over 50%, and increases energy efficiency between 25% - 100%.

Saharawat *et al*[56]., reported that the Simulated CH_4 emission in rice ranged from 25 to 59 kg ha^{-1}, and the transplanted rice after conventional puddling FP (T_1) had the largest emission followed by unpuddled transplanting (T_2). Emission of N_2O from soil in rice as well as in wheat varied between 0.10 and 0.12kg N_2O-N ha^{-1}.Fertilizer contributed 0.24 and 0.37 kg N_2O-N ha^{-1} in rice while it was between 0.42 and 0.54 kg N_2O-N ha^{-1} in wheat. Farm machinery including pump used for irrigation emitted 389 to 507 kg CO_2-C ha^{-1} in rice and 58 to 81 kg CO_2-C ha^{-1} in wheat. Off-farm practices such as production of fertilizer contributed 117 to 199 kg CO_2-C ha^{-1} in rice and 222 to 252 kg CO_2-C ha^{-1} in wheat. Production of biocides contributed 47 to 82CO_2-Cha^{-1} in rice, while its contribution was negligible in wheat. Application of fertilizer and biocide contributed about 40 kg CO_2-C ha^{-1} in rice-wheat system. Flooded rice (with the practice of puddling the soil) is a large contributor of CH_4 emissions from agriculture. Reduced or NT is currently being promoted in the IGP in rice-wheat systems[15]. With this system, direct-drill seeded rice does not require continuous soil submergence, thereby could either reduce or eliminate CH_4 emissions for lowland rice when it is grown as an aerobic crop[48].

Grace *et al*[19]., estimated an average of 29.3 $Mgha^{-1}$of GHGs emitted over 20 years in conventional rice-wheat systems across the IGP; this decreased by only 3% with the wide spread implementation of CA. Ladha *et al*[36]., indicated that different RCTs in rice-wheat system had pronounced effects on the GWP, which varied between 2799 kg CO_2 equivalent ha^{-1} in raised-bed system (T_3) and 3286 CO_2 equivalent ha^{-1} in FP (T_1). Compared to the FP (T_1) all the technologies reduced the GWP by 3 to 28%. Ahmad *et al*[1]., revealed that on an average, there was 87.2% and 82.3% lower emission of CH_4 in DSR treatments, as compared to TPR treatments, in first and second years respectively. IWD reduced CH_4 emission by 32.4% and 28% as compared to the TPR treatments, in the first and second years, respectively. Gaihre *et al*[14]., reported that in China farmers who drain their irrigated rice fields mid season reduce methane emissions by up to 50% and water needs by up to 30% without compromising yields. Pathak *et al*[49]., reported that the global warming potential (GWP CH_4 + N_2O) of wheat–rice systems varied from 944 to 1891 kg CO_2 eq. ha^{-1} and 1167–2233 kg CO_2 eq. ha^{-1} in the first and second years of wheat–rice cropping respectively. Gupta et al[20]., 2016 observed that ZTW-DSR and ZTW + RR-DSR showed the lowest global warming potential (GWP) and GHG intensity during experimentation. Adoption of these systems in the Indian-IGP can reduce GWP of the conventional RWCS (CTW-TPR) by 44–47% without any significant loss in the system yield. This was mainly due to significantly low CH_4 emission (82.3–87.2%) in DSR as compared to TPR due to prolonged aerobic condition under DSR.

Agricultural innovation for climate change resilience and mitigation

In addition to investment in agricultural water management technologies, breeding for drought stress and diversification strategies can reduce vulnerability to moderate fluctuations in rainfall. Much of crop germplasm improvement targeting the subtropical areas is focused on resistance to drought and associated stresses. While drought-resistant germplasm development is fairly well established and supported relative to some of the emerging areas of climate risk management, there is still controversy about whether improving yields under drought must come at the expense of yields in seasons when rainfall is favorable. Livelihood diversification can be an effective means to increase resilience in the face of climate variability if (a) the different income streams are not strongly correlated with each other or with seasonal rainfall, and (b) the diversified portfolio does not sacrifice substantial average income. Opportunities for diversification can range from mixes of cultivars with staggered phenology at the field scale, to mixes of farm and non-farm enterprises across the household, to more diverse rural economies. There is also scope for such analyses to tailor germplasm development to small-scale water management such as conservation agriculture, and to mixes of cultivars that are less susceptible to dry spells than single cultivars[4].

Climate change adaptation is a continuous process requiring location-specific response. Adaptation should enable agricultural systems to be more resilient to the consequences of climate change. Farming systems and farmers will differ enormously in their capacities to respond to climate change. Differentiated adaptation strategies and enhanced climate risk management support to agriculture and farming households are critical to counter the impacts of climate change[28]. These adaptation measures could include in particular the choice and change of species and varieties, the adaptation of the field works to the calendar (more flexibility), the adaptation of plant production practices (i.e. fertilization, plant protection, irrigation, etc.) or the adoption of plant production practices that increase the soil organic matter content. In relation, improved cropland management (lower use of synthetic fertilizers, reduced tillage etc), Restoration of organic soils and degraded lands to increase soil carbon sinks, Improved water and crop management, and Land-use change Increasing efficiency in fertilizer production and behavioral changes of food consumers could also be main climate change mitigation measures in agriculture sector[55].

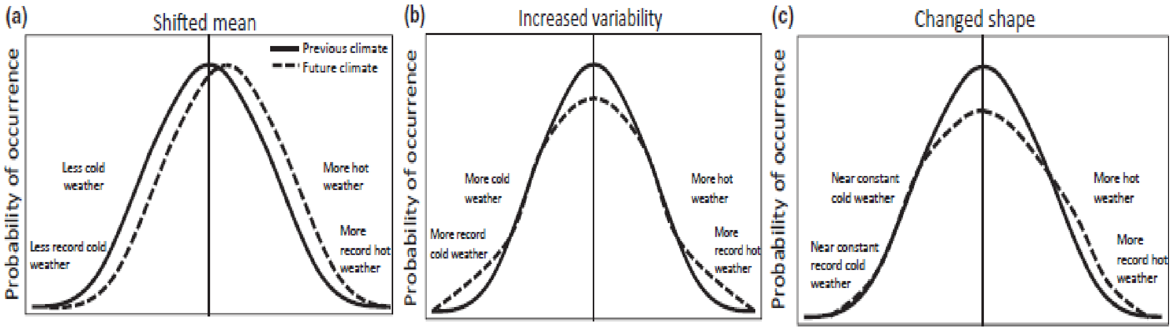

Fig .4: The effect of changes in temperature distribution on extremes. Different changes of temperature distributions between present and future climate and their effects on extreme values of the distributions: (a) Effects of a simple shift of the entire distribution towards a warmer climate; (b) effects of an increase in temperature variability with no shift of the mean; (c) effects of an altered shape of the distribution, in this example a change in asymmetry towards the hotter part of the distribution. Source[29].

Climate change is inevitably resulting in changes in climate variability and in the frequency, intensity, spatial extent, duration, and timing of extreme weather and climate events[29]. Changes in climate variability and extremes can be visualized in relation to changes in probability distributions, shown in Figure 4. Earlier flowering and maturity of several crops have been documented in recent decades, often associated with higher temperatures[9]. Increases in maximum temperatures (as climate or weather) can lead to severe yield reductions and reproductive failure in many crops. In maize, each degree day spent above 30 °C can reduce yield by 1.7% under drought conditions[38]. Impacts of temperature extremes may also be felt at night, with rice yields reduced by 90% with night temperatures of 32 compared with 27 °C[42]. Climate variability and extreme events can also be important for yield quality. Protein content of wheat grain has been shown to respond to changes in the mean and variability of temperature and rainfall; specifically, high-temperature extremes during grain filling can affect the protein content of wheat grain[25]. In situations where changes in climate and climate variability may be larger, more fundamental changes may occur, particularly if critical thresholds in temperature and/or rainfall are reached[18]. Changes in the nature and timing of the growing season may induce smallholders to grow shorter duration and/or more heat- and drought-tolerant varieties and crops.

Managing climate risks

In the subtropical India, where much of the remaining hunger and poverty are concentrated, "the key challenge is to reduce water-related risks posed by high rainfall variability rather than coping with an absolute lack of water[8]". Yet the most viable opportunities for improving agricultural water management offer only incomplete control. A holistic strategy for investing in pro-poor agricultural water management requires parallel investment in other climate risk management measures to deal with the residual risk that water control alone cannot mitigate.

Climate risk management for agriculture includes:

- Systematic use of climate information and climate knowledge in strategic planning and adaptive decision making;
- Climate-informed technologies and management strategies that reduce vulnerability to climate variability;
- Climate-informed policy and market-based interventions that transfer risk from vulnerable rural populations.

Climate risk management must address the full range of variability, balancing protection against the impacts of climatic extremes such as droughts and floods (extreme left tail, Figure 5) with effort to capitalize on opportunities arising from average and favorable climatic seasons (roughly 2/3 of the area toward the right, Figure 5).

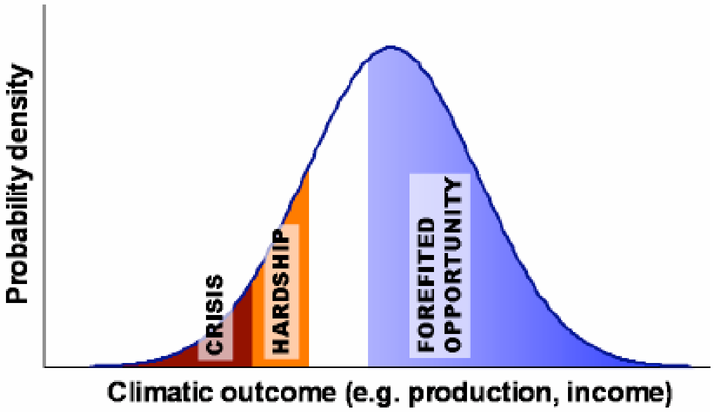

Fig. 5: Idealized representation of impact of climatic risk associated with different portions of the distribution of some climate-sensitive outcome.

While improved water management is a crucial element, a portfolio of synergistic interventions is the most promising approach to covering the full spectrum of climate risks that confront farmers and impede the investment needed to realize the potential benefits of water management. Several options are available for managing the risk that feasible water management strategies cannot cover. A few –new ways to use new types of climate information, climate informed livelihood strategies, innovations in financial risk transfer products – have not yet been fully explored or exploited[21]. Godfray *et al*[17]., also revealed that agricultural practices such as these, which maintain or increase productivity while enhancing livelihood resilience and reducing emissions, can help meet the demand for 70% more food by 2050 while also minimizing impacts on the climate. Silva-Olaya *et al*[58]., and Burzaco *et al*[5]., indicated that integrated measures that track changes in emissions or removals relative to yields, often called 'intensity' or efficiency measures', can help integrate information relevant to managing for multiple objectives—productivity, resilience and mitigation.

CONCLUSION

From this extensive review, it is concluded that water smart agriculture and climate change has relationship with agriculture in one or another way. This relationship becomes strong in subtropical India because their livelihood depends on agricultural activities and these activities mostly depend on climatic condition. In relation, the impact of climate change is very serious in small farming areas of subtropical India due to their limited adaptive capacity and lack of technology and also they are the main emitter of non carbon GHGs from their cattle and farm management mainly from use of synesthetic fertilizers. Those are the main direct emitters. There are also indirect emitters such as land use change; from runoff and leaching of fertilizers; use of fossil fuels for mechanization and agro-chemical and fertilizer production.

A number of adaptation options in agriculture face a dilemma. Increasing water availability and increasing the reliability of water in agriculture, is one of the preferred options to increase productivity and contribute to poverty reduction. However, as a result of the predicted climate change, semiarid subtropical areas that would greatly benefit from increased irrigation may see water availability changing temporally and spatially and rainfall not only declining, but also being more erratic and unfavorably distributed over the growing season, so that irrigation in the long term might not be a viable option. In addition, the interrelations between adaptation and mitigation need to be carefully considered. At best, adaptation and mitigation strategies exhibit synergies. Include many carbon-sequestration practices involving reduced tillage, increased crop cover and use of improved rotation systems. These lead to production systems that are more resilient to climate variability, thus providing good adaptation in view of increased pressure on water and soil resources.

In relation to water the adaptation strategies that run counter to mitigation are those that depend on energy to deliver water and, therefore, produce additional greenhouse gas emissions. Short-term plans to address food insecurity provide access to water resources, or encourage economic growth must be placed in the context of future climate change to ensure that short-term activities in a particular area do not increase vulnerability to climate change in the long term and harmonization of climate change, agricultural, and food security policies is required at the national, regional, and international levels. So to use a combination of strategies to adapt: proper timing of agricultural operations, crop diversification, use of different crop varieties, changing the planting dates, increased use of water and soil conservation techniques and diversifying from farm to nonfarm activities. However, this review study recommends that such measures need to be strengthened.

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