Water-smart farming: review of strategies, technologies, and practices for smallholders Farming Areas in a changing climate

ABSTRACT

Increases in human population and world temperatures, which have risen by 1.1°C in the last ten years, are already making it more difficult for agriculture to get water in areas where it is limited. The concept of "water-smart farming" was created to solve issues related to the accessibility, availability, and usage of agricultural water. In climate-smart agriculture, it supports aims and practices pertaining to agricultural water. It includes several water-saving techniques, tools, and technology for growing food sustainably, as well as cropping systems that adapt to changing climate conditions. The urgent problem of agricultural water competition can be lessened with the successful application of water-smart farming. Therefore, this review introduces the conceptual framework of water-smart farming and its main components or ideology. In situations when water is more scarce than land and other resources used in production, increasing crop water productivity is an important response strategy. A growing, wealthier, and more urbanized population places increasing demands on food, which can be met with improvements in agricultural water productivity. However, there is also a pressing need to achieve improvements in agricultural water management because of pressure to reallocate water from agriculture to cities and to increase the amount of water available for environmental purposes. Water clearly has a role in reducing poverty and promoting economic progress. The review also briefly shows the contribution of some of these best practices and adaptive technologies of water-smart cropping toward promoting water-saving methods used for crops and vegetables.

***Keywords*:** Climate change, Food security, Greenhouse gas emission, Water smart farming

INTRODUCTION

For adequate living standard as in westernand industrialized nation, a renewable water supply of at least 2000 m^3 per personper annum is necessary. If only 1000-2000 m^3 per person per annum is available, thecountry is 'water stressed', while the value comes below 500 m^3 per person per year,the country is called 'water scarce' (Kumar and Kar, 2013). The demand for water will only rise due to the growing population and improving standards of living in competing industries such as agriculture, industry, and home use. In addition, an increasing amount of water will be needed for environmental issues like aquatic life, wildlife refuges, and leisure. Sustainable water management in agriculture is a major concern in India due to shifting global climate patterns and decreasing per capita availability of surface and ground water resources. Future agricultural water use in India will confront fierce competition for limited water resources due to growing water demand from other industries. Therefore, the availablewater resources would be inadequate utilizable to meet the future water needs for allsectors unless the utilizable quantity is raised by all possible means and water isused more efficiently. Adoption of the suitable agro-techniques for cultivation of crop is need ofhour to produce more crops with less water utilized so as to check the reduction of ground and surfacewater

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resources in India. Recognizing the importance of above fact,the country has developed water smart agriculturefor achieve 'more productivity per drop water.

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Efficient management of water resources is essential to guaranteeing fair distribution and maximum use. Fundamentally, this means utilizing every drop of water to maximize food production while minimizing losses, or, to put it more concisely, understanding the widely recognized definition of water usage efficiency, which is "the amount of carbon assimilated as biomass or grain produced per unit of water used by the crop" (Hooveret *al*., 2023). A wide range of techniques are included in water-smart cropping solutions, such as the development of drought-tolerant maize varieties, cover crops, intercropping legumes with food crops, system rice intensification, alternate wetting and drying, and farmer-led reduced irrigation. It is imperative that these methods be widely used in conjunction with good agricultural practices. Smallholder farmers, who remain dominant in global agricultural landscape, must be empowered to spearhead adaptation efforts ofclimate change (Mushi *et al*., 2023; Ndhlovu and Mhlanga, 2023). This empowerment necessitates agronomic management encompassing fertilization, cropping patterns, irrigation, and plant protection, along with addressing external factors that is input supply, post-harvest facilities and policy regulations (Islam *et al*., 2022).

Over the past few decades, it has become clear that freshwater shortage is posing a danger to the sustainable development of human society due to a continually rising demand. Water crises are the worldwide risk with the greatest potential impact, according to the World Economic Forum's most recent annual risk assessment (World Economic Forum, worldwide Risks 2015). The primary causes of the rising worldwide demand for water include the growing world population, rising living standards, shifting consumption patterns, and the growth of irrigated agriculture (Vörösmarty *et al*., 2000; Ercinand Hoekstra, 2014). There is enough freshwater available annually and globally to meet this need. However, there are significant seasonal and geographical changes in the demand and availability of water, which causes water scarcity in a number of regions of the world at certain periods of the year. The fundamental cause of global water shortage is the spatial and temporal mismatch between freshwater availability and demand (Savenije, 2000). This mismatch can be quantified physically or in terms of the consequences for society or the economy depending on the ability to adjust (Rijsberman, 2006; Wolfe and Brooks, 2003). This paper aims to address two topics: (i) the potential contribution of agricultural research to enhance the productivity of small farmers and their capacity to cope with and lessen the effects of climate change; and (ii) the most effective way to improve productivity under near-normal or slightly below-normal rainfall conditions using smaller-scale water management systems. and (iii) to describe how muchimprovements in water and land management, canincrease productivity of water in the agriculture.

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Water scarcity facing by people

When assessing water scarcity annually, one or a few months of extreme shortage won't be noticeable because they will average out with the other, less scarce months. We discover that 1.8 to 2.9 billion people—the range given by previous estimates—have been severely lacking in water for at least 4 to 6 months. Consequently, we demonstrate that quantifying the fluctuations in water shortage over the course of a year helps to illuminate the realities faced by The assumptions made about the degree of environmental flow requirements do not significantly affect the outcomes. With the present

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assumption of flow requirements environmentalat 80% of natural runoff, we find 4.3 billionpeople living in areas with WS > 1.0 at least one month in a year. If wewould assume flow of environmental requirements at 60% of natural runoff,this number would be still 4.0 billion.The results are also sensitive to uncertainties in blue water footprintand blue water availability. We tested sensitivity of the estimated number of person facing severe water scarcity to change in blue water footprint and blue water availability. When we increase water availability worldwide estimates and for each month by 20%, number of people facing severe water scarcity during at least one month of year reduces by 2% (from 4.0 to 3.9 billion).Reducing water availability by 20% gives 4.1 billion. Changing water footprints 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. Due to a significant temporal mismatch between water availability and demand, sensitivity is low: Generally speaking, availability is higher than demand, or the reverse is true. Changes in one or the other can only cause the situation to shift from one level of shortage to another when the demand and availability of water are of equal size.

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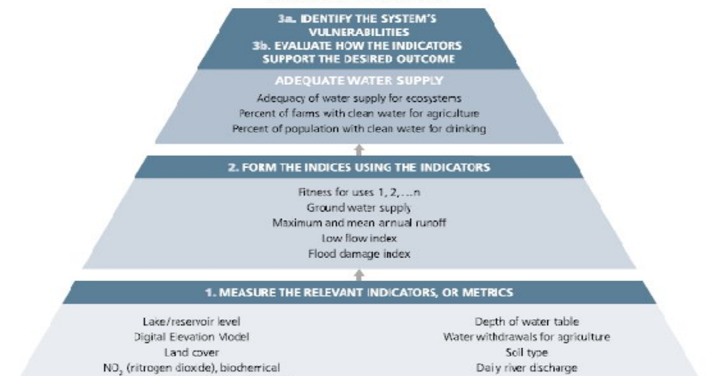

Fig.1:Water security thread from Vital Signs. The pyramid of the water security thread depicts the integration of metrics (1) that buildthe desired indices (2) with the outcomes of interest (3a and 3b). Adapted with permission from the Vital Signsprogramme (~~S~~Barbour, personal communication, 2014).

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The future of food production and water-smart agriculture

Global food systems differ greatly, as do the ways in which various consumers obtain food. The majority of the world's poorest rural communities still depend heavily on locally grown food and poorly linked local economies to survive and make a living.Barrett (2007). Cross-country econometric data provided by the World Bank (2008) demonstrates that investments in agriculture, where smallholder farmers are involved as managers and laborers, have double the impact on reducing poverty as investments in any other sector. The difficulty lies in reducing these emissions without jeopardizing the security of food and livelihood, especially for the impoverished rural population. Hence, research on climate change, agriculture, and food systems is especially needed to address extremely local contexts while also paying the necessary attention to larger institutional mechanisms

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for disseminating solutions, creating common future visions, and negotiating disparate roles and responsibilities. All of this will require a sincere dedication to fostering collaboration, building capacity, and resolving societal disparities.

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Regional effects of climate change are probably going to be significant and uneven, with some areas benefiting from a changed environment and others suffering negative effects. In most important places (such as subtropical and tropical areas), food production is generally expected to drop; but, when technology is more readily available and proper adaptive modifications are made, agriculture in industrialized countries may actually gain. Parvatha (2014). Accordingly, it is predicted that crop productivity will rise marginally at mid-to high-latitudes for local mean temperature increases of up to 1-3°C, depending on the crop, and then decline in some places after that. Crop productivity is predicted to decline at lower latitudes, particularly in seasonally dry and tropical areas, with even modest local temperature rises (1-2°C), which would raise the risk of hunger OECD (2015). Warmer weather expected to bring longergrowing seasons in northern areas, and plants every places weregive benefit from carbon fertilization Vuren *et al*. (2008).

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Farm-scale Management Practices to Improve Productivity

Enhancing water production is crucial to lessening the demand on water supplies. Even with an assumed increase in water productivity from 1,800 m3 to 1,200 m3 per ton of grain produced, there would still be a significant increase in water demand to fulfill the MDG by 2015. According to Jacob*et al*. (2009), the projected increased water requirements, including for increases in water productivity, range from 1,850 m3 y-1 in 2015 to over 3,000 m3 y-1 in 2030 and 2050. When we also take into account the obligation to allocate water resources for purposes other than agricultural output, this extra requirement poses an enormous difficulty. As per Thornton and Lipper (2013), agriculture alone contributes30-40% of anthropogenic GHG emissions. Three-quarters ofagricultural in developing countries, GHG emissions occur and thisshare may increase above 80% by 2050. Livestock dung and fertilized agricultural soils are the sources of direct emissions. IPCC (2014) states that indirect emissions are caused by fertilizer leaching and runoff, changes in land use, and the use of fossil fuels for transportation, mechanization, and the manufacturing of agrochemicals and fertilizers. Changes in conventional land use and natural vegetation, such as deforestation and soil degradation, account for the majority of indirect emissions. Another traditional land use strategy that involves constantly disturbing the land is intensive tillage. Due to soil erosion and SOM breakdown, this method raises CO2 emissionYibekal*et al*., (2013).

Reduction of Greenhouse Gases by adopting conservation agriculture

Positive changes under agronomic practices like manuring,tillage, and irrigation can help reduce the release of greenhouse gases intoatmosphere Table1.Adoption of controlled irrigation and zero tillage can reduce the evolution of N_2O andCO_2.Reduction in burning crop residues reduces the generation of CO_2, CH_4 and$N_2O$to the significant extent. Saving on diesel by judicious use of water pumps and reduced tillage can have play major role. Changing to zero tillage would save 98 litres diesel per hectare Naresh *et al*., 2013.With each litre of diesel generating 2.62 kg,about 3.21 Mt CO_2annum^{-1} (about 0.80 MMTCE) can be reduced through zero-tillage in 12 million ha under rice-wheat cropping systems in Indo-Genetic Plains alone. Intermittent irrigation and drainage will be further reducing CH_4 emission from paddies by 28% to 30% as per findings at~~at~~PantnagarandIARI (Delhi). Enhancing plant uptake and decreasing N2O emission can be achieved by applying nitrogenous fertilizers deeply rather than topically and by substituting calcium nitrate or urea for ammonium sulphate. Through changes in soil parameters (such as soil porosity, soil temperature, and soil moisture, among others), tillage and crop residue retention have a significant impact on CH4 and N2O emission [Yao etal., 2009]. According to certain studies, switching from conventional tillage (CT) to no-till (NT) can drastically cut emissions of CH4 and N2O [Estavillo *et al*., 2002]. According to Wang *et al*. (1998), the primary variations in the CH4 production zone were caused by the tillage methods' disturbance of the soil at different depths. Consequently, depending on the tillage technique used, the CH4 production zone may change. Regina *et al*., 2007revealed that CH_4 oxidation rate were higher when there were fewer micro-pores or more macro-pores in the soil.

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

Tillage method	Cumulative CO_2 Loss (t/ha)
Moldboard plough	9.21
Disk harrow	3.79
Chisel plough	3.59
No- tillage	1.91

Source: Reicosky, 1998

Agricultural technology for changingclimate resilience and mitigation

Investing in agricultural water management systems is just one way to lessen sensitivity to mild changes in rainfall; other alternatives include diversification and breeding for drought stress. The majority of crop germplasm development aimed in subtropical regions is concentrated on increasing tolerance to stressors like drought. There is also debate over whether increasing yields during dry spells must come at the expense of yields during seasons with adequate rainfall, even if the production of drought-resistant germplasm is generally well-established and supported in comparison to some of the more recent developments in climate risk management. Diversifying one's sources of income can help one become more resilient to the unpredictable nature of the climate if the diversified portfolio does not significantly reduce average income and (a) there is no significant correlation between the various income sources and seasonal rainfall. Diverse rural economies, combinations of farm and non-farm businesses within the household, and cultivars with staggered phenology at the field scale are examples of opportunities for diversification. Additionally, these studies can be used to customize the creation of germplasm for small-scale water management practices like conservation agriculture and for cultivar combinations that are more resilient to dry spells than individual cultivars (Brown and Hansen 2008).

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Climate variability and the frequency, severity, spatial extent, length, and timing of extreme weather and climate events are inextricably linked to climate change (IPCC, 2012). Extreme weather and climate fluctuation can also have an impact on yield quality. It has been demonstrated that the protein content of wheat grain is sensitive to variations in rainfall and temperature variability (Porter &Semenov, 2005); in particular, large temperature extremes during grain filling can impact the protein

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Comment [L18]: Don't found in references content of wheat grain (Hurkman*et al*., 2009). More fundamental alterations may arise in circumstances where climate unpredictability and variations are greater, especially if crucial thresholds for rainfall and/or temperature are crossed (Gornall *et al*., 2010).Changes in nature and timing of growing seasonmay be inducing smallholders to grow shorter durationand/or more heat and drought tolerant varieties and crops.

Climate risks management

"Reducing water-related risks posed by high rainfall variability rather than coping with an absolute lack of water" is the fundamental problem in subtropical India, where a large portion of the remaining hunger and poverty are concentrated (AWMA, 2007). However, the most promising avenues for enhancing agricultural water management provide little control. To address the residual risk that water control alone cannot minimize, a comprehensive approach to investing in pro-poor agricultural water management necessitates concurrent investment in other climate risk management measures.

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Agricultural climate risk management entails:

- Systematic use of climateknowledge and climate information in strategic planningand adaptive decision-making;
- Climate informed technologies andmanagement strategies that decline vulnerability to climate-variability;
- Climate informed policy and market basedinterventions that transfer riskfrom vulnerable of rural populations.

Climate risk management must be address in full range ofvariability, balancing protection against impacts ofthe climatic extremes such as floods and droughts with effort to capitalize on the opportunities arisingfrom average and favorable climatic-seasons (roughly 2/3 ofthe area toward right, Figure2).

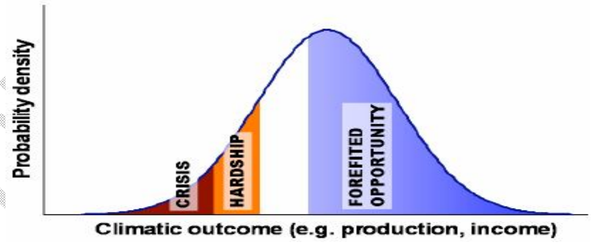

Fig. 2. Idealized representation of the impact ofclimatic risk associated with different portions of distribution of some climate sensitive outcome.

CONCLUSION

To sum up, this review has clarified a thorough framework for improving agricultural water management and developing water-smart cropping systems that are sustainable. Several important conclusions have been highlighted by us during the investigation. As a natural approach to agriculture's adaptation to climate change, we have highlighted the critical role that water-smart cropping plays and highlighted how it can protect water supplies for coming generations. We have emphasized the variety of water-saving methods, technical advancements, and climate-responsive food cropping systems that make up the foundation of water-smart farming. Together, these tactics support the production of food in a sustainable manner. Furthermore, when it comes to water, adaption solutions that rely on energy to provide water are in opposition to mitigation. Consequently, increase greenhouse gas emissions. In order to ensure that short-term activities in a particular area do not increase vulnerability to climate change in the long run, 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. National, regional, and international policy harmonization of climate change, agricultural, and food security is required. Therefore, a variety of tactics should be used to adapt, such as increasing the use of water and soil conservation techniques, crop diversification, planting dates that are adjusted, crop diversification, and a shift from farm to non-farm activities. Nonetheless, the review study suggests that these safeguards should be reinforced.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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