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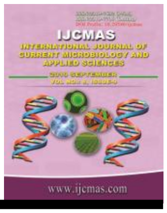

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Smart Strategies for Enhanced Agricultural Resilience and Food Security under a Changing Climate in Irrigated Agro-ecosystem of North West IGP: A Review

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ABSTRACT

Keywords

Adaptation strategies, Climate-resilience, Climate change, Food security

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Agriculture will face significant challenges in the 21st century, largely due to the need to increase global food supply under the declining availability of soil and water resources and increasing threats from climate change. Nonetheless, these challenges also offer opportunities to develop and promote food and livelihood systems that have greater environmental, economic and social resilience to risk. It is clear that success in meeting these challenges will require both the application of current multidisciplinary knowledge, and the development of a range of technical and institutional innovations.During last two decades, the atmospheric greenhouse gases (GHGs) concentrations have increased markedly. Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have increased from 280 ppm, 715 ppb and 270ppb during pre-industrial era (1750 AD) to 385 ppm, 1797 ppb and 322 ppb, respectively in 2008. As on today, The CO_2 concentration has exceeded 400 ppm. Increase in temperature can increase crop evapotranspiration and soil nutrient mineralization and salinity, reduce crop duration, fertilizer use efficiency and may affect survival and distribution of pests. Already scarce water resources will be further stressed under expected climatic changes. In the scenario of sea-level rise, the saline area under sea inundation will also extend and influence the crop production. Thus, changing climate is likely to have a significant influence on agriculture and eventually the food security and livelihoods of a large rural population. This paper identifies possible climate change responses that address agricultural production at the plant, and farm, regional scales. Critical components required for the strategic assessment of adaptation capacity and anticipatory adaptive planning is identified and examples of adaptive strategies for a number of key agricultural sectors are provided. Adaptation must be fully consistent with agricultural rural development activities that safeguard food security and increase the provision of sustainable ecosystem services, particularly where opportunities for additional financial flows may exist, such as payments for carbon sequestration and ecosystem conservation. Climate change will affect agriculture and forestry systems through higher temperatures, elevated CO_2 concentration, precipitation changes, increased weeds, pests, and disease pressure, and increased vulnerability of organic carbon pools. Benefits of adaptation vary with crop species, temperature and rainfall changes. Useful synergies for adaptation and mitigation in agriculture, relevant to food security exist and should be incorporated into development, and climate policy. Synergistic adaptation strategies to enhance agro-ecosystem and livelihood resilience, including in the face of increased climatic pressures. Ensuring food security without compromising sustainability of land resources under a rapidly growing population and changing climate is among the major challenges of this era. Smart strategies individually offers a magic bullet solution to the foregoing challenges and most of the promising technologies are founded on local knowledge, local and scientific knowledge must be integrated when choosing the most suitable climate-smart technologies and practices for any given agro-ecology.

Introduction

End hunger, achieve food security and improve nutrition is at the heart of the sustainable development goals. At the same time, climate change is already impacting agriculture1 and food security and will make the challenge of ending hunger and malnutrition even more difficult. The effects of climate change on our ecosystems are already severe and widespread, and ensuring food security in the face of climate change is among the most daunting challenges facing humankind. While some of the problems associated with climate change are emerging gradually, action is urgently needed now in order to allow enough time to build resilience into agricultural production systems.

Climate change pertains to increase in atmospheric concentration of carbon dioxide (CO_2) and global warming. Present day atmospheric CO_2 level hovers around 397 ppm which is a significant increase over the pre-industrial level of 280 ppm. It is anticipated that the concentration level will double by the end of this century (IPCC, 2007).The good news is that agriculture can be integrated into the solution to reduce the pace of climate change by sequestering carbon in the soil instead of emitting it into the atmosphere. It is possible to achieve what the World Bank (2010) terms “climate-smart agriculture” or “triple wins”: attaining higher yields, placing more carbon in the soil, and achieving greater resilience to heat and drought. A consequence of increased greenhouse gas (GHG) emissions is the entrapment of heat within the earth's atmosphere leading to an alarming rate of global warming. Global average increase in mean annual temperatures is estimated at 0.8°C till now. An increasing rate of warming has taken place across sampling areas spread across the globe over the last 25 years. Global mean temperatures are likely to witness significant increase towards the end of this century. Between seasons, warming in the rainy season will be less pronounced than in the winter months in India (IMD, 2010). Another climate change feature significantly influencing agro-ecosystems is the change in seasonal rainfall patterns. Increased frequencies in occurrence of extreme weather events such as heat wave, cold wave and hail storm over short periods exert adverse influence on crop performance. Rainfall is predicted to be highly erratic with fewer rainy days but with greater intensity. A combination of higher average annual temperatures and water stress can have serious implications for crop production in the tropics. Farmers need to intelligently adapt to the changing climate in order to sustain crop yields and farm income. Enhancing resilience of agriculture to climate risk is of paramount importance for protecting livelihoods of small and marginal farmers. Traditionally, technology transfer in agriculture has aimed at enhancing farm productivity. However, in the context of climate change and variability, farmers need to adapt quickly to enhance their resilience to increasing threats of climatic variability such as droughts, floods and other extreme climatic events. Over the years, an array of practices and technologies has been developed by researchers towards fostering stability in agricultural production against the onslaught of seasonal variations. Adoption of such resilient practices and technologies by farmers appears to be more a necessity than an option. Therefore, a reorientation in technology transfer approach is necessary. Efficiency in resource-use, environmental and social safeguards, sustainability and long-term development of agriculture assume greater importance.

Crop yield studies focusing on India have found that global warming has reduced wheat yield by 5.2% from 1981 to 2009, despite adaptation (Gupta *et al.*, 2017). It is projected that climate change would reduce rain-fed maize yield by an average of 3.3–6.4% in 2030 and 5.2–12.2% in 2050 and irrigated yield by 3–8% in 2030 and 5–14% in 2050 if current varieties were grown (Tesfaye *et al.*, 2017). Despite variability in input use and crop management, there is a negative effect of both season-long and terminal heat stress on rice and wheat, though wheat is considerably more sensitive than rice (Arshad *et al.*, 2017).Besides its impact on crop yields and production, climate change also affects the natural resources, primarily land and water that are fundamental to agricultural production. Water availability is expected to decline due to climate change, while agricultural water consumption is predicted to increase by 19% in 2050 (UN-Water 2013). For instance, growing reliance of Indian farmers on groundwater to cope with climate-induced drought has led to a rapid decline in the groundwater table, and it may worsen further due to increased climatic variability in future (Fishman 2018).It is projected that food price changes between 2000 and 2050 are 2.5 times higher for major food crops and 1.5 times for livestock products with climate change (Nelson *et al.*, 2009). Therefore, in the absence of adaptation measures to climate change, North West IGP could lose an equivalent of 1.8% of its annual gross domestic product (GDP) by 2050 and 8.8% by 2100 (Ahmed and Suphachalasai, 2014). The average total economic losses are projected to be 8.7%.Since agriculture provides livelihood to over 70% of the people, employs almost 60% of the labor force, and contributes 22% of the regional gross domestic product (GDP) (Wang *et al.*, 2017), these losses of GDP will have major consequences in agriculture-dependent communities in the region (Ahmed and Suphachalasai, 2014). Therefore, improved understanding of impacts of climate change in agriculture and the adaptation practices to cope with these impacts are essential to enhance the sustainability of agriculture and to design the policies that reduce poor farmers' vulnerability to climate change in North West IGP.

Adaptation to climate change involves any activity designed to reduce vulnerability and enhance the resilience of the system (Vogel and Meyer 2018), and therefore, the actual impacts of climate change largely depend on the adaptive capacity (Vermeulen *et al.*, 2012). Adaptation is particularly fundamental to North West IGP agriculture for the following reasons: (1) agriculture is a primary source of livelihood; (2) fragmented and small land size—less than a hectare—reducing farmers' capacity to adapt to climate change; (3) increased population and high economic growth has further exacerbated the adverse impacts of climate change due to increased demand for land and water from other sectors of the economy mainly driven by search for alternative farm practices; (4) less developed risk and insurance market to promote adaptation to climate change; and (5) to sustain local food security, especially of the poor and small farmers against the high food price fluctuation under extreme climatic variability. On this backdrop, this review paper examines the prospects of the smallholder production system in North West IGP to adapt to climatic variability to minimize the negative impacts of climate change on food systems. We also discuss why farmers use few adaptation measures, if any, despite the prevalence of several measures in light of the existing barriers and policy setup. Moreover, documents the impact of climate change on agriculture and multiple adaptation measures applied in the agricultural sector in North West IGP. The climate change adaptation policies and future prospects of agriculture in North West IGP with a due focus on existing barriers.

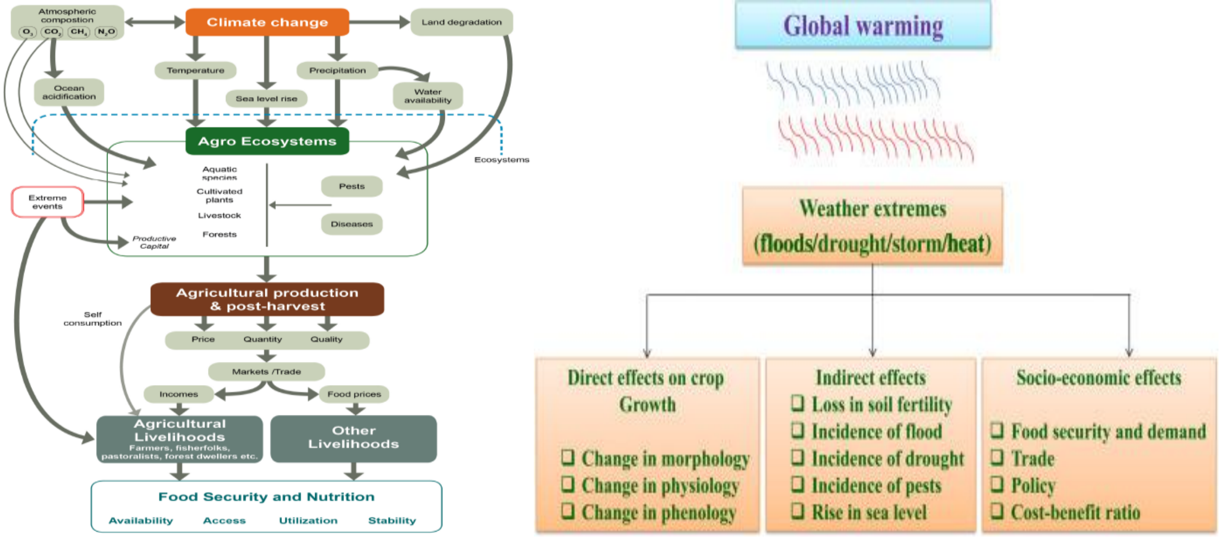
"What is of the greatest importance in our present condition – on the one hand, bring home to the commercial community the inestimable value of science as an essential factor of industrial regeneration, and, on the other hand, make the landed aristocracy realize that science enables us to solve difficult agricultural problems and thereby revolutionize agricultural methods."Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life (World Food Summit, 1996). There are four dimensions of food security: availability of food, accessibility (economically and physically), utilization (the way it is used and assimilated by the human body) and stability of these three dimensions. What is needed is not only enough food being produced globally –enough food is produced globally now but there are still almost 800 million hungry people – but that everybody has access to it, in the right quantity and quality, all the time and established direct consequences to food security:

Loss of rural livelihoods and income
Loss of marine and coastal ecosystems, and livelihoods
Loss of terrestrial and inland water ecosystems, and livelihoods
Food insecurity and breakdown of food system

The aim of this review paper is to provide an overview of the effects of climate change on food security and nutrition, intended as its four dimensions, and to explore ways to reduce negative impacts through adaptation and resilience.

Church *et al.*, (2013) revealed that as seawater continues to warm and glaciers and ice sheets are lost, global average sea level will rise during the twenty-first century faster than the past decades. In 2046–2065 (relative to 1986–2005), global average sea-level rise is likely in the range of 0.17 to 0.32 m and 0.22 to 0.38 m for the lowest and highest GHG concentration pathways, respectively [Fig.1].Ocean acidification in the surface ocean will follow the rise of atmospheric CO_2 concentration. It is also likely that salinity will increase in the tropical and subtropical and a decrease in the western tropical Pacific is predicted over the next few decades.

Fig.1 Schematic representation of the cascading effects of climate change impacts on food security and nutrition



Kirtman *et al.,* (2013) also found that the projected change in global average temperature will likely be from 0.3 °C to 0.7 °C for the period 2016–2035 relative to the reference period 1986–2005.The increase in temperature will be larger on the land than over the ocean and larger than the mean. It will be larger in the Arctic (IPCC, 2014a). There will be more frequent hot-temperature extreme episodes over most land areas (IPCC, 2014b). Average precipitation will very likely increase in high- and parts of the mid-latitudes, and the frequency and intensity of heavy precipitation will also likely increase on average. The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase. Short-duration precipitation events will shift to more intense individual storms and fewer weak storms are likely as temperature rises. Shetty *et al.,* (2013) reported that climate change is projected to reduce timely sown irrigated wheat production by about 6% by 2020. In the case of late sown wheat, the projected levels are alarmingly high, to the extent of 18%. Similarly, a 4% fall in the yield of irrigated rice crop and a 6% fall in rain-fed rice are foreseen by 2020 due to climate changes. The warming trend in India over the past 100 years is estimated at 0.60°C. The projected impacts are likely to further aggravate yield fluctuations of may crops with impact on food security. It requires a serious attention on adaptation and mitigation strategies to overcome the problems of climate change.

Müller and Elliott, (2015) reported that by 2100 the impact of climate change on crop yields for high-emission climate scenarios ranges between –20 and –45 percent for maize, between –5 and –50 per-cent for wheat, between –20 and –30 per-cent for rice, and between –30 and –60 per-cent for soybean. Assuming full effectiveness of CO_2 fertilization, climate change impacts would then range between –10 and –35 per-cent for maize, between +5 and –15 per-cent for wheat, between –5 and –20 per-cent for rice, and between 0 and –30 per-cents for soybean. If nitrogen limitations are explicitly considered, crops show less profit from CO_2 fertilization and amplified negative climate impacts. Uleberg *et al.,* (2014) noted that, despite challenges such as unstable winters, increased autumn precipitation and possibly more weeds and diseases, a prolongation of the current short growth season together with higher growth temperatures can give new opportunities for agriculture in the region, but that it will require tailored adaptive strategies, breeding of new plant varieties, changes in sowing calendar and crop rotation, etc. – adaptive changes that seem feasible given the agronomical knowledge base in the region. Adaptive changes in crop management – especially planting dates, cultivar choice and sometimes increased irrigation – have been studied to varying extents, and in many regions farmers are already adapting to changing conditions, many of them being changes made to existing climate risk management practices. Müller and Elliott (2015) found that adaptive changes in crop management have the potential to increase yields by about 7–15 per-cent on average, though these results depend strongly on the region and crop being considered: for instance, according to IPCC (2007), responses are dissimilar between wheat, maize and rice, with temperate wheat and tropical rice showing greater potential benefits of adaptation.

As agro-climatic zones may shift pole-ward, cropping might be feasible in previously unsuitable places, such as in parts of the Russian Federation, Canada or of the Scandinavian region, albeit with other constraints due to climate extremes, water limitations or other barriers. This might only compensate for some of the losses in tropical latitude areas. Developing cultivars with appropriate thermal tolerance characteristics, or resistant to drought, can be a solution

(Ziska *et al.*, 2012). Increasing the efficiency of scarce resources, particularly water, is an important aspect of building resilient livelihoods. One of the main effects of climate change is altering rainfall and water availability patterns, and thus a capacity to deal with water scarcity will be important in order to maintain productivity levels. Adapting to increasing drought conditions and water scarcity can be enabled by enhanced water management in agriculture (HLPE 2015) with water storage and improved access to irrigation water, improved irrigation technologies and techniques. Agronomy practices that enhance soil water retention should also be considered, such as minimum tillage, agro forestry or increase in soil carbon and organic matter, among others. New tillage practices can reduce the exposure of topsoil to the air, reducing evaporation, improving soil moisture characteristics and reducing sensitivity to drought and heat. Breeding can lead to new cultivars that send roots down faster and deeper, increasing access to water in the soil profile, or that are more robust to underwater submergence conditions that could become more common in a future climate.

An essential aspect of adaptation to climate change will be that of increasing the diversity within production systems. This can take many forms: combining different types of production in different ways; increasing the numbers of different species, populations, varieties or breeds; and increasing the use of materials that are themselves genetically diverse such as crop multiline. These different approaches will help provide the complementarity, option values and risk minimizing strategies that will become increasingly important in the future. Finding ways to combine diversity-rich strategies with the production demands of the future is one of the major challenges for the future and the improved maintenance and use of genetic resources for food and agriculture will lie at the heart of meeting this challenge (FAO, 2015c).

Agricultural adaptation strategies to climate change impacts

Adapting to climate change entails taking the right measures to reduce the negative effects of climate change by making the appropriate adjustments and changes. Adaptation has three possible objectives: to reduce exposure to the risk of damage; to develop the capacity to cope with unavoidable damages; and to take advantage of new opportunities.

Crop adaptation strategies

Planting of drought resistant varieties of crops

Emphasis on more drought resistant crops in drought-prone areas could help in reducing vulnerability to climate change. For example, wheat requires significantly less irrigation water compared to dry season rice. The uses of drought-resistant crop varieties have been tried by smallholder farmers as adaptation methods to climate change in Agro-ecosystem of North West IGP (Ngigi, 2009).

Change in cropping pattern and calendar of planting

Climate change adversely affects crop production through long-term alterations in rainfall resulting in changes in cropping pattern and calendar of operations.

Enabling in-farm and off-farm diversification

For most farming families, agriculture is only one of several sources of income and smaller size households often have higher shares of non-agricultural incomes than larger ones. It is also important to recognize that an important strategy for increasing resilience among agricultural based populations is to diversify to non-agricultural sources of income and in many cases to exit from agriculture for employment opportunities in other sectors. In many micro-level studies of agricultural household welfare, the access to off-farm income sources from labour diversification is generally positively associated with welfare levels. For example, labour migration is a common strategy in the face of climate risk and environmental degradation, and remuneration from these migrants plays an important role in maintaining household resilience. Of course, there is considerable variation in how well these strategies actually do contribute to livelihood resilience. In addition, evidence indicates that the poor and most vulnerable to climate risks are the least capable to undertake effective migration, since they lack the assets and social networks required. Non-agriculture-based livelihoods are likely to play an increasingly important role in building resilience among agricultural populations due to projected population growth patterns as well as potential climate change impacts.

Thus it is important agriculture and non-agriculture sectors to access resilient livelihoods. Diversification, both on-farms with increased number of varieties, species and breeds, including through mixed systems such as crop/livestock, crop/fish or processing products, and off-farm, by getting a non-agricultural job, is an important element of climate change adaptation (Thornton and Herrero, 2014). It is, however, very context-dependent, operates at farm level and requires overcoming constraints of access to information and initial cost of investment. Household income diversification is not restricted to developing economies (Kurukulasuriya and Rosenthal, 2013).

Mixed cropping

Mixed cropping involves growing two or more crops in proximity in the same field. The system is commonly practice where cereals, legumes (beans) and nuts (groundnuts) are grown together. The advantages of mixing crops with varying attributes are in terms of maturity period (e.g. maize and beans), drought tolerance (maize and sorghum), input requirements (cereals and legumes) and end users of the product (e.g. maize as food and sunflower for cash).

Improved irrigation efficiency

Success of climate change adaptation depends on availability of fresh water in drought-prone areas. It should be emphasized that most adaptation methods provide benefits even with the lower end of climate change scenarios, such as improved irrigation efficiency. As water becomes a limiting factor, improved irrigation efficiency will become an important adaptation tool, especially in dry season, because irrigation practices the for dry area are water intensive. Climate change is expected to result in decreased fresh water availability (surface and groundwater) and reduced soil moisture during the dry season, while the crop water demand is expected to increase because of increased evapo-transpiration caused by climate change and the continuous introduction of high-yielding varieties and intensive agriculture (Selvaraju *et al.*, 2006).As temperature increases, farmers tend to irrigate more frequently. Irrigation is clearly an adaptation strategy to warming. When precipitation increases, they tend to irrigate less often and resort to natural rainfall more often.

Adopting soil conservation measures that conserve soil moisture

Soil conservation techniques are increasingly practiced in North West IGP. Nyong *et al.,* (2007) noted that local farmers in Western U.P., India, conserve carbon in soils through the use of zero tilling practices in cultivation, mulching and other soil management techniques. Natural mulches moderate soil temperatures and extremes, suppress diseases and harmful pests, and conserve soil moisture. Before the advent of chemical fertilizers, local farmers largely depended on organic farming, which also is capable of reducing GHG emissions.

Planting of trees (afforestation) and agroforestry

Tree planting is the process of transplanting tree seedlings, generally for forestry, land reclamation, or landscaping purposes. It differs from the transplantation of larger trees in arboriculture, and from the lower cost but slower and less reliable distribution of tree seeds. In silviculture the activity is known as reforestation, or afforestation, depending on whether the area being planted has or has not recently been forested.

It involves planting seedlings over an area of land where the forest has been harvested or damaged by fire or disease or insects. Agro forestry is a rational land-use planning system that tries to find some balance in the raising of food crops and forests (Adesina *et al.,* 1999).In addition to the fact that agroforestry techniques can be perfected to cope with the new conditions that are anticipated under a drier condition and a higher population density, they lead to an increase in the amount of organic matter in the soil thereby improving agricultural productivity and reducing the pressure exerted on forests.

Other adaptation strategies

Labour migration

Migration is a dominant mode of labour (seasonal migration), providing a critical livelihood source. The role of remittances derived from migration provides a key coping mechanism in drought and non-drought years but is one that can be dramatically affected by periods of climate shock, when adjustments to basic goods, such as food prices are impacted by food aid and other interventions (Devereux and Maxwell, 2001). Migration is an important mechanism to deal with climate stress. Temporary migration as an adaptive response to climate stress is already apparent in many areas. But the picture is nuanced; the ability to migrate is a function of mobility and resources (both financial and social). In other words, the people most vulnerable to climate change are not necessarily the ones most likely to migrate.

Vulnerability assessment and tools

Impacts on agricultural productivity and other aspects of the sector can lead to different repercussions in household income and food security. Vulnerability of livelihoods depends on the capacity of local communities to substitute a negatively affected production system with an alternative that could prevent losses in agricultural income, provide subsistence production, or supply food to urban markets. Vulnerability assessments characterize and identify areas, households or subpopulations that have particularly low livelihood resilience. This helps adaptation planners prioritize their actions and target vulnerable communities. Vulnerability assessments also provide the basis for the development of strategies to increase the resilience of systems and livelihoods to climate change. The bottom-up approach, on the other hand, focuses more on collecting different indicators that would characterize the vulnerability of agriculture sectors to various risks, including climate change. There are a wide variety of possible indicators, including socio-economic resources, technology, infrastructure, information and skills, institutions, biophysical conditions and equity (Brugère and De Young, 2015). Climate change is one among many risks and drivers of change for food insecurity and may be an amplifier of existing vulnerabilities. Vulnerability to climate change should be seen in the context of existing broader socio-economic and environmental conditions. Contextual conditions of the society and environment clarify their adaptive capacity and vulnerability to potential threats.

Integrate climate change concerns in all agricultural and food security strategies and policies

Numerous instruments and policies need to be mobilized for adaptation, to build resilience of agriculture and food systems to climate change. This requires the elaboration of an integrated strategy covering, first of all, agriculture and food security policies and measures, as well as those related to water management, land and natural resource management, rural development and social protection, among others. Such an approach can be part of broad, economy-wide adaptation strategies and plans at national or subnational levels. It calls for holistic approaches considering agricultural development for food security and nutrition in the context of climate change, combining practices, enabling policies and institutions as well as financial resources. It is with such objectives that FAO proposed in 2010 the concept of climate-smart agriculture an approach than can help decision-makers in the agriculture sectors, from farm to national authorities, integrate food security and climate change concerns in their actions and policies.

Constraints in production

The various constraints or limitations are responsible for poor performance in yield in some of the states. Among the states where there the highest yield levels had been achieved, a yield plateau could possibly be foreseen. Both the situations however need to be addressed as the former situation is an opportunity whereas the latter situation is a threat. Thus the limitations to harness the yield potential are many. One can delineate such constraints as resource, technology and policy based. The resource based including land and irrigation limits the scale of operation in the country. As the area sown more than once has increased from 34.63 million hectares (1980-81) to 53.74 million hectares, it resulted in an increase of cropping intensity from 123 per cent to 138 per cent. With reference to irrigation coverage, the country's net irrigated area has increased from 38.72 million hectares to 63.20 million hectares during the above period. However, the percentage of irrigation coverage to the net area sown has increased from 28 per cent to 44.71 per cent. About 55 per cent of the gross cropped area is still not covered under irrigation inducing severe pressure on land. Besides, differences do occur in irrigation coverage among the various crops. The declining average size of holding is another major threat and limits the scale of operation. The average size of operational holding in India has come down steadily from 2.28 hectare in 1970-71 to 1.16 hectare in 2010-11. Such marginal size of holding with marginal rise in operational area would add more number of marginal and small farmers implying that there are nearly twice as many farms as four decades ago. Developments in molecular biology, bio technology, nano technology etc. are expected to provide significant new opportunities for yield enhancement of various crops. These technical developments also pose new challenges like increased adaptation, capacity building, and policy changes, regional and global cooperation.

Innovations, technologies and strategies

Several categories of innovations have been introduced to increase agricultural production and productivity in the country. The categories include mechanical innovations (tractors and farm implements), biological innovations (new varieties, hybrids, seeds etc.,), chemical innovations (fertilizers and pesticides), agronomic innovations (new management practices), biotechnological innovations and informational innovations that rely mainly on computer technologies. In crop improvement, biotechnology plays key role in improving agronomic traits and quality of food crops. Tools like genetic engineering, marker assisted selection, genomics etc., help us to improve many of the complex traits in plants. One of the important applications of genetic engineering is to improve plant traits by over-expressing or suppressing specific genes associated with the phenotypic trait. Examples include improved yield, reduced vulnerability of crops to environmental stresses, enriching nutrient content in grains, development of “Golden rice” possessing increased beta-carotene accumulation in rice grains and rice grains possessing enriched iron content by over-expressing “Ferritin” gene(s). Few technologies are helping the farmers to have reduced dependency on fertilizers, pesticides and other agrochemicals. For example, *Bacillus thuringiensis* (Bt) is a soil bacterium that produces a protein with insecticidal qualities (Bt toxin). Crop plants have now been engineered to contain and express the genes for Bt toxin, to impart resistance against lepidopteran pests.

Besides in the farmer’s field through extension support many technologies have been developed and practiced. System of Rice Intensification (SRI) is a synergistic management technique involving four components of rice farming such as planting, irrigation, weed and nutrient management strategies. Besides, few more packages namely preparation of mat nursery, transplanting and weeding are also introduced. Modified mat nursery technique, mechanized planter and weeder are also developed. Mechanization of rice crop production in irrigated eco-system, integration of herbicidal and mechanical weed management for different rice ecosystems and rice production technologies for protected agriculture (precision agriculture, conservation agriculture) are the future strategies for improvement of productivity of rice in the country. Improving the efficiency of water use through the use of sprinkler and drip technology for improving the yield and quality of maize, water logging during the rainy season is the major problem for which adequate drainage facilities should be arranged since the crop is highly sensitive to water logging. Moisture conservation measures for rain-fed maize cultivation, providing supplemental irrigation through farm ponds and mobile sprinklers, skill manpower for hybrid maize development and seed production, technical and investment support to private enterprises to establish maize seed industry, technological interventions on low cost and efficient management practices would lead to substantial increase in maize production.

In conclusion, climate changes are alarming the world by hampering agriculture and its products. Industrialization and poisonous gases cause global warming, which ultimately disturbs the world’s environment. Climate change has devastating effects on plant growth and yield. Abiotic stresses are the major type of stresses that plants suffer. To understand the plant responses under different abiotic conditions the most pressing current need is to explore the genetic basis underlying these mechanisms. Some bottleneck molecular and physiological challenges present in plants need to be resolved for better plant adaptation under abiotic conditions. Temperature fluctuations and variations in rainfall spells are very crucial indicators of environmental stresses. Weather variations collectively have positive and negative outcomes but the negative effects are more thought-provoking. It is very difficult to overcome the imbalance in agriculture by climate change. How to tackle this problem and what strategies we should apply are still ambiguous. Hence, researchers need to focus on optimizing plant growth and development in abiotic stresses. For crop resistance against biotic and abiotic stresses, propagating novel cultural methods, implementing various cropping schemes and different conventional and non-conventional approaches will be adopted to save agriculture in the future.

Besides developing technologies for promoting intensification, the country needs to emphasize development of technologies that will facilitate agricultural diversification particularly towards production of fruits, vegetables, flowers and other high value crops that are expected to increase income growth and generate effective demand for food. Thus identification of need-based productive programs is very critical which can be explored through characterization of production environment which are so diverse. We have to develop demand-driven and location-specific programs to meet the requirements of different regions to meet the targeted growth in agriculture. Besides, because of the high variability in agro-climatic conditions, research has to become increasingly location-specific with greater participation or interaction with farmers.

Increasing resilience of food security in the face of climate change calls for multiple interventions, from social protection to agricultural practices and risk management. The changes on the ground needed for adaptation to climate change in agriculture and food systems for food security and nutrition will require to be enabled by investments, policies and institutions in various areas. The people who are projected to suffer the earlier and the worst impacts from climate change are the most vulnerable populations, with livelihoods depending on agriculture sectors in areas vulnerable to climate change. Understanding the cascade of risks, as well as the vulnerabilities to these risks, is key to frame ways to adapt. Reducing vulnerabilities is key to reducing the net impacts on food security and nutrition and also to reducing long-term effects.

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