

# Global Food Security and Declining Agricultural Productivity

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## Article Info

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## ABSTRACT

The world's farmlands must take the lead in the fight to feed the world's anticipated 9 billion people. Broad-based economic development, especially increased agricultural investment for better land, water, and nutrient use, might mitigate the negative consequences of climate change on food security. Benefits include increased food security, livelihoods, and environmental security will result from better crop, soil, and water management techniques as well as stress-tolerant cultivars that will withstand the negative effects of climate change. The dryland tropics, where the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is mandated, are among the agricultural systems most vulnerable to climate change. In order to help farmers escape poverty, ICRISAT's new Strategy to 2020 places a strong emphasis on inclusive market-oriented development (IMOD), which connects farmers to markets and raises incomes through strategic partnerships and a systems perspective. Through its research focus on lowering vulnerability to heat, drought, and other climate change scenarios, ICRISAT seeks to create resilient dryland systems. ICRISAT's short-duration chickpea varieties, which have made it possible to expand the crop into tropical latitudes in Asia and Africa, sustainable soil management techniques like microdosing, conservation agriculture, and projects like the Sahelian Eco-Farm, as well as knowledge-based and people-centric entry-point activities in its community-based watersheds, have all been significant turning points on its path toward climate responsibility.

**KEYWORDS:** Global food security, sustainable agriculture, rain-fed agriculture, climate change impact

## INTRODUCTION

Managing climate change and eradicating poverty and food insecurity are the three defining and interconnected concerns of the twenty-first century, elevating them to the top of the global agenda. The world saw food riots, a jump in food prices, and political upheaval in a number of nations in 2008. 40% to 50% of India's kharif harvest was lost due to the monsoon failure in 2009; the food crisis was made worse by the heavy rains. Unprecedented floods devastated Pakistan, severely affecting food production and agriculture. Over half of Niger's 14 million people are at risk of starvation due to drought and poor harvests.

Within the next fifty years, the planet is expected to get warmer due to climate change. According to all predictions, the average temperature will rise by about 1°C by 2050. They then

drastically diverge, ranging from 2°C to 4°C by 2100. At that point, many more crops' yields will be seriously jeopardised. The impact of rising temperatures on rainfall distribution patterns in Africa and Asia, however, is still far less certain, according to the Intergovernmental Panel on Climate Change (IPCC); in some regions of the world, the frequency of extreme rainfall events and droughts appears to be significant. Therefore, most people will find it difficult or impossible to adjust to future climate change unless the livelihood resilience and adaptive capacity of vulnerable groups can be significantly strengthened.

## CLIMATE CHANGE: SEVERITY AND IMPACT

The issue of feeding nine billion people by 2050 is enormous, since two billion people now reside in the world's driest regions, where climate change is predicted to drastically diminish yields! This implies that by then, the world's agricultural output must increase by 70% to 100%. And what does that mean for the 1.5 billion people who work in agriculture—nearly 60% of the labour force in developing countries? Even a small percentage loss in agricultural productivity could result in a larger proportionate income loss for developing countries than for industrialised ones, since agriculture accounts for a far larger portion of GDP in developing countries than in developed ones. Without intervention, food prices could increase by up to 131% for maize, 78% for rice, and 67% for wheat by 2050, according to the most recent data from the International Food Policy Institute (IFPRI).

There are 450 million undernourished people spread throughout more than 40 developing nations with a total population of 2 billion. 42% of undernourished children live in Asian drylands, whereas 27% live in sub-Saharan African drylands. Their numbers could rise sharply as a result of production losses brought on by climate change, seriously impeding efforts to combat food insecurity.

Because the impoverished directly depend on already delicate ecosystems for their well-being and livelihoods, climate change also poses a threat to efforts to reduce poverty. More significantly, their voices are not sufficiently heard in international conversations, especially in climate change agreements, and they lack the means to effectively defend themselves or quickly adjust to changing conditions. Conflict over resources may increase as a result of climate change-related environmental consequences including desertification and rising sea levels.

Agriculture contributes significantly to greenhouse gas (GHG) emissions, accounting for 14% of world emissions, despite being extremely susceptible to climate change. Due to population growth and dietary changes, agricultural emissions in developing nations rose by 32% between 1990 and 2005 and are predicted to climb further (Food and Agriculture Organization 2009). Since 1961, improved yields have prevented emissions of up to 161 gigatons of carbon (GtC), despite an increase in emissions from variables like fertiliser production and application. According to estimates, every dollar invested in agricultural yields has prevented 3.6 GtC annually and resulted in 68 fewer kgC emissions compared to 1961 technology (Burney, Davis, & Lobell 2010).

Therefore, agriculture has the capacity to adapt to and lessen the effects of climate change, with developing nations potentially realising 70% of its high technical mitigation potential. Adopting sustainable practices, like better soil, crop, and water management, makes this feasible. Additionally, agriculture can operate as a potential carbon sink and help smallholder farmers become more resilient so they can withstand and adapt to the effects of climate change. Broad-based economic growth, especially increased agricultural productivity, strong

international commerce in agricultural products that can offset regional shortages, and investments in agricultural production, might mitigate the detrimental consequences of climate change on food security. For example, a 2% annual improvement in maize production until 2050 would result in a 12% price increase and a 3% to 5% decrease in the proportion of undernourished children.

It is well known that the tropics are far more vulnerable than the temperate regions due to increased heat stress, monsoon shifts, and drier soils. Since the majority of developing nations are found in tropical regions and mostly rely on agriculture for both food and revenue, relatively impoverished nations with limited resources must deal with the expensive and

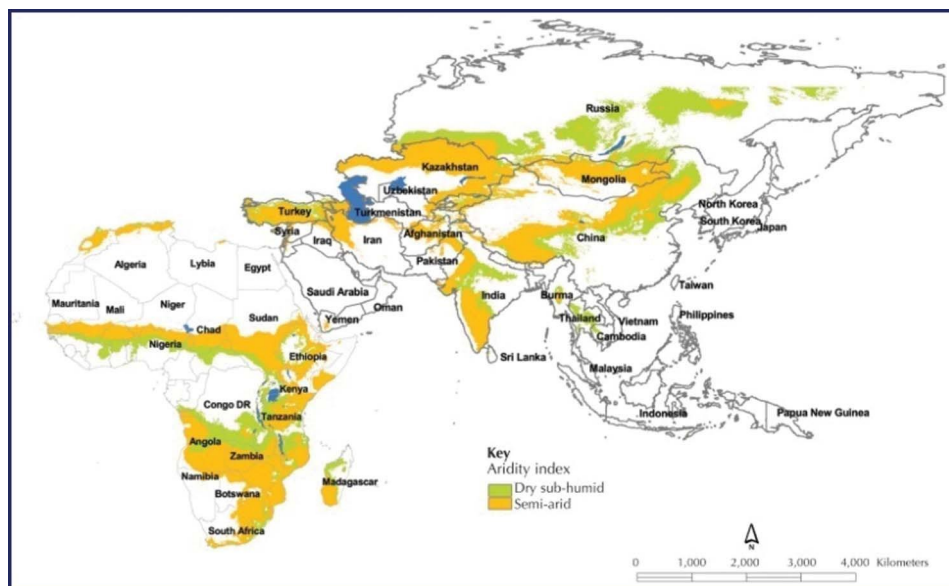


**FIGURE 1** Projected tropical drylands of Africa and Asia in the year 2050, based on climate change models. The dryland tropics were delineated using the Aridity Index of the FAO and UNESCO (color figure available online).

difficult challenge of climate change adaptation. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) focuses on the semi-arid tropics, also known as tropical drylands, which are home to more than 2 billion people and cover an area of 6.5 million square kilometres over more than 55 nations. Agriculture is dangerous in the difficult and hostile terrain of the tropical drylands. Based on climate change simulations, Figure 1 depicts one of the numerous scenarios of tropical drylands in Asia and Africa in 2050. The maps were created using data from the CRU-TS 3.0 Climate Database for the year 2000 and the HADCM3 result of the A2a scenario for the year 2050. The FAO and UNESCO Aridity Index was used to define the dryland tropics.

Extreme rainfall variability, frequent and unpredictable droughts, flooding, high temperatures, and a delicate natural resource base with naturally low fertility soils are all characteristics of the drylands. The rising perfect storm, which combines climate change, desertification, biodiversity loss, rising prices, and growing poverty and population, further threatens to disrupt the lives of the impoverished in the drylands who rely on agriculture for

survival.

An approach to environmental protection based on the "ecosystem services" that nature offers to humanity is gaining traction on a global scale. Nature's services to humans will essentially be reduced to zero as long as the market considers them as free items. By setting prices for these services,

All of the lakes, seashores, streams, and woods would suddenly become valuable economically. After that, people will be motivated to protect them.

## STRATEGIES TO ALLEVIATE THE EFFECTS OF CLIMATE CHANGE

Adaptation and mitigation methods must be immediately incorporated into national and regional development projects since climate change is a threat multiplier. Developing nations must take part in a globally integrated solution to this issue. Adaptive plant breeding and crop husbandry technology, pest forecasting and management technologies, irrigation infrastructure, water storage, and water management are some examples of adaptation policies. Improved crop and livestock management techniques, such as increased input-use efficiencies (such as fertiliser microdosing and need-based pesticide application for pest control), cropping system diversification, enhanced water management, and improved forecasting and early warning systems, are examples of mitigation strategies.

### CLIMATE CHANGE-READY CROPS

Crops that are acclimated to high soil and air temperatures, knowledge and comprehension of flowering maturities, information on genetic variation for water-use efficiency, short-duration varieties that avoid terminal drought, and high-yielding and disease-resistant varieties are already available to ICRISAT. For example, we have created super-early chickpea and pigeon pea lines that mature in roughly 65 to 75 days; short-duration ground-nut cultivar ICGV 91114 that avoids terminal dryness (Figure 2); and short-duration chickpea cultivars ICCV 2 (Shweta), ICCC 37 (Kranti), JG 11, and KAK 2. The crop has been able to spread into tropical latitudes in Asia and Africa because to short-duration chickpea varieties.

Pearl millet hybrids 9444 and 86 M 64, developed by ICRISAT and the private sector, blossom and set seed at temperatures as high as 44 °C. At temperatures higher than 40°C, ICRISAT-bred sorghum hybrid seed parents exhibit consistent seed set. Even in situations with inadequate water or moisture stress, sorghum genotypes possessing the stay-green trait continue to fill their grains regularly (Borrell, Hammer, & Douglas 2000). The sorghum hybrid parents created by ICRISAT, ICSR 21002, ICSV 21011, and ICSB 371, have good yields and the drought-tolerant stay-green trait (Reddy et al. 2007).

By cultivating the crop throughout the summer, we were able to screen chickpeas for heat tolerance, and the results showed significant diversity. ICCV 92944, formerly known as Yezin 6 in Myanmar, was one of the finest heat-tolerant lines found.



**FIGURE 2** ICRISAT's climate-smart short-duration groundnut cultivar 'ICGV 91114' escapes terminal drought (color figure available online).

What we need to better understand is the physiological mechanism underlying heat tolerance, and to identify wider gene pools to develop crops with wider adaptability and to develop more effective germplasm-screening techniques for desired traits. ICRISAT's gene bank holds more than 119,000 accessions from 144 countries that will help safeguard and exploit genetic diversity to enhance adaptation.

## CLIMATE-SMART PRODUCTION SYSTEMS

### Water Management

While increased temperatures will result in an increase in crop water demand, climate change will alter rainfall, evaporation, runoff, and soil-moisture storage. In such a situation, improving soil moisture issues through greater rainfall collection and storage as well as increased use efficiency will be crucial to increasing crop productivity. Seasonal rainfall is typically sufficient in tropical drylands to significantly increase yields, but controlling the great rainfall variability in time and place is extremely difficult. The primary factors influencing yield are water management and effective use.

In Andhra Pradesh, Gujarat, Madhya Pradesh, Rajasthan, and other Indian states as well as portions of southern China, northern Vietnam, and northeast Thailand, ICRISAT's participatory and knowledge-based watershed development programs have demonstrated that public and farmer investment can yield attractive social returns that reduce poverty. Farmers, legislators, and development investors have been drawn to Kothapally in Andhra Pradesh, India, due to the Adarsha Watershed model's success. Options for creating income for women and the landless in Kothapally and other comparable watersheds have included establishing village seed banks through self-help organisations; adding value through seed material; processing products like dals, grading, and marketing; raising chickens to produce meat and eggs; and vermi-composting. Crop diversification and other systems in the watershed produced an average household income of US\$1,066, compared to US\$734 in the non-watershed areas. This is a 45% gain that may be attributed to watershed interventions.

In a similar vein, the Luchebe watershed in Guizhou province, China, experienced increased productivity as a result of the implementation of economical water-harvesting structures, the diversification and intensification of farming systems from rice and rapeseed to caring cattle and horticulture crops. Farmers' average income tripled from US\$462 (before to the interventions) to US\$1,538 after the initiatives, which primarily involved cultivating vegetables and other varied tasks like caring for chicks and pigs. In China and India, the creation of community watersheds has led to a four-fold increase in crop production and a 45% and 77% increase in revenues, respectively.

## **Crop Management Practices**

Finding more suitable crop-management techniques is essential for climate change adaptation; many of these techniques are expansions of those presently employed or encouraged to boost crop productivity. Rapid plant growth brought on by warmer temperatures significantly lowers plant biomass and yield. Redeploying and retargeting existing germplasm can help offset the effects of climate change, and better varieties of most crops that are adaptable to a wide variety of climatic circumstances are available.

Promising and financially feasible technologies include reduced tillage, conservation agriculture, microdosing fertilisers, need-based pesticide treatment, and using legumes in crop rotations. Under varying climatic conditions, these technologies can lower risk, increase soil fertility, and boost yield.

## **Integrated Pest Management**

Increased climate variability will result in more variation in pest incidence. Many of the pests that are currently only found in tropical climates have the potential to spread northward to temperate regions in North America and Europe. Because the dispersion of a pest is also dependent on the availability of a host, changes in the range of host crops will have a significant impact on changes in insect pest distribution.

Creating cultivars with long-lasting or stable pest resistance will offer an efficient method for managing pests. In Kenya, stem borer severity rises during drought, but resistance to sorghum midge (*Stenodiplosis sorghicola*) disintegrates under high humidity and moderate temperatures (Sharma et al. 1999). Consequently, it's critical to recognise



**FIGURE 3** A farmer shows off his downy mildew-free crop of pearl millet hybrid 'HHB 67-Improved' (color figure available online).

and create cultivars that exhibit consistent resistance to the target pests in a range of climates. Global warming will alter the relationships between pests and their natural enemies, leading to both rises and losses in the status of individual species. Future pest management initiatives will focus heavily on quantifying the impact of climate change on natural enemies' activity and efficacy.

Crop cultivars resistant to diseases and pests have been created by ICRISAT. For instance, wilt-resistant high-yielding pigeonpea ICEAP 00040 in Tanzania, Malawi, and Mozambique; rosette-resistant groundnuts in Uganda; and downy mildew-resistant pearl millet hybrid "HHB 67-Improved" (Figure 3) in India.

## INTEGRATED NUTRIENT MANAGEMENT

Micronutrient deficiencies are thought to affect more than 815 million families globally. Our primary goal is to use both conventional and biotechnological breeding to improve the bioavailability of beta-carotene and the minerals zinc and iron in the grains of ICRISAT-mandated crops. Using high-Fe seed parents and restorers, ICRISAT is conducting multilocation trials to investigate the viability of creating pearl millet hybrids that combine high grain yield and high Fe content. Results have demonstrated that there are good opportunities to create high-Fe hybrids with grain yield competitive to commercial hybrids, even if current hybrid parents that had not previously been developed for greater Fe content are exploited.

In order to lower the danger of food and feed contamination, ICRISAT is creating mycotoxin-tolerant cultivars, especially ground-nut, as well as suitable pre- and post-harvest technology. Both traditional plant breeding and technological applications, as well as straightforward and

inexpensive mycotoxin detection instruments, are used to achieve this.

## **ECONOMIC DIVERSIFICATION, CAPACITY BUILDING, AND COLLECTIVE ACTION**

In the semi-arid tropics, diversifying the crops grown by smallholder farmers has the potential to boost household income, produce a more nutrient-dense diet, offer lucrative employment possibilities, and produce useful byproducts like fibre, firewood, and fodder. In the Indo-Gangetic plains of South Asia, crop diversification through the introduction of legumes into rice/wheat fallows, the cultivation of aromatic and medicinal plants in collaboration with private sector businesses, and systems diversification through mixed crop-livestock systems have all been used as risk-reduction and income-boosting strategies. Chickpea, peanut, pigeon pea, sorghum, and millet crop wastes are significant sources of animal feed all year long, especially during the dry months when other feed resources are limited. Particularly in South Asia, increasing the digestibility of such crop residues can have a big impact on milk output. For instance, in Andhra Pradesh, farmers who used the improved groundnut variety's haulm or stems saw a 20% increase in the milk production of their dairy cows.

Fruit, vegetables, and trees may be commercially integrated in the arid Sahel thanks to the African Market Gardens (AMGs) idea, which blends low-pressure drip irrigation systems with high-value product variety. These tiny "market gardens" can be tended by women's organisations to boost their earnings and vary their family's nutrition, increasing their earnings by many times—in some cases, more than tenfold to US\$1,500 from a mere 500 square meters.

## **WEATHER FORECASTING AND CROP MODELING**

When creating adaptation solutions, weather and climate services and goods play a critical role. The biggest obstacle to rainfed farming in the semi-arid tropics is managing temperature and humidity extremes, as well as rainfall variability within and between seasons, which will significantly impact crop growth, insect incidence, and crop yield.

Climate projections are still not widely used in farm-level decision-making. For farmers and other agri-cultural decision makers to reap the potential benefits of using climate forecasts appropriately, a number of prerequisites must be met, such as decision-maker awareness of vulnerability and motivation; feasible decision options that benefit from forecast information; prediction of the components of climate variability that are relevant to decisions; adequate communication and understanding of pertinent information by the right audience at the right time; and, in the long run, appropriate institutional commitment and policy support (Hansen 2002). More regionally accurate climate-change assessment tools are required, as well as tools that are more helpful for reviewing agricultural policies, programs, and scenarios and that more clearly take into account the biophysical limitations that impact agricultural production. Tools like INSTAT and GENSTAT, MARKSIM, and APSIM/DSAT, which analyse climate data and generate high-quality information and products suited for agricultural applications and quantify the linkages between climate, crop, soil, and water resources, serve as a guide for crop adaptation efforts.

## **CLIMATE CHANGE: HOPE FOR THE SEMI-ARID TROPICS**

In order to test the premise that, in the medium term (2010–2050), we are well-positioned to assist farmers in mitigating the problems and taking advantage of the opportunities presented by climate change, ICRISAT's scientists have started research using a variety of meteorological data-driven methods. According to yield gap analyses, farmers can significantly reduce the adverse effects of climate change by implementing more innovative crop, soil, and water management techniques as well as more focused crop improvement strategies that explicitly address climate change adaptation.

Since other factors will continue to impose overwhelming limits to crop growth and yield, the influence of climate change on yields under low-input agriculture is probably going to be negligible. Even in the face of climate change, the adoption of currently advised, better crop, soil, water, and pest management techniques would give far higher yields than farmers are already getting under low-input systems. Adoption of improved "temperature-adapted" cultivars may completely mitigate the consequences of climate change brought on by rising temperatures.

### INCLUSIVE MARKET-ORIENTED DEVELOPMENT (IMOD)

In contrast to the previous product-oriented supply chains, consumer-driven supply chains will play a major role in the fundamental transition in agriculture that developing nations in Asia and Africa are experiencing from farming for household consumption to a more market-oriented output. Contract farming, bulk marketing through producers' associations, direct marketing, marketing through cooperatives or specialised middlemen, and ICT-enabled supply chains that directly connect the producer to the end user are examples of institutional innovations in the procurement and marketing of agricultural commodities.

Market access is essential for escaping poverty, according to World Bank and ICRISAT analyses. Based on strategic studies, long-term village-level research, and our extensive knowledge base spanning 38 years in collaboration with institutions, we have discovered that changes have taken place in several dryland communities in Asia and Africa over the course of three decades. Improved access to urban markets that bought agricultural products and provided more job opportunities has been a major factor in areas where poverty is decreasing. With the help of strategic alliances, ICRISAT's new Strategy to 2020 focuses on using markets to accomplish our four mission goals: to lift the impoverished out of poverty, hunger, malnutrition, and environmental degradation throughout the dry tropics of the developing world. Three straightforward phrases may be used to sum up the plan, which is based on inclusive market-oriented development, or IMOD for short: innovate, grow, and flourish (Figure 4).

A new degree of resource access, stability, and productivity for low-income small-holder farmers will be attained through the IMOD, a socioeconomic process that is a dynamic transition from subsistence to market-oriented agriculture. By lowering their susceptibility to drought and climate change while boosting diversity and value, ICRISAT's contribution to IMOD through its Strategic Thrust on Resilient Dryland Systems seeks to assist the impoverished in navigating the path out of poverty. Women, who make up the majority of the impoverished and hungry, are given more attention by the IMOD since their children represent the future of the dryland and they run the risk of being left behind by markets. Additionally, it focuses on developing resilience—the capacity to endure and bounce back from

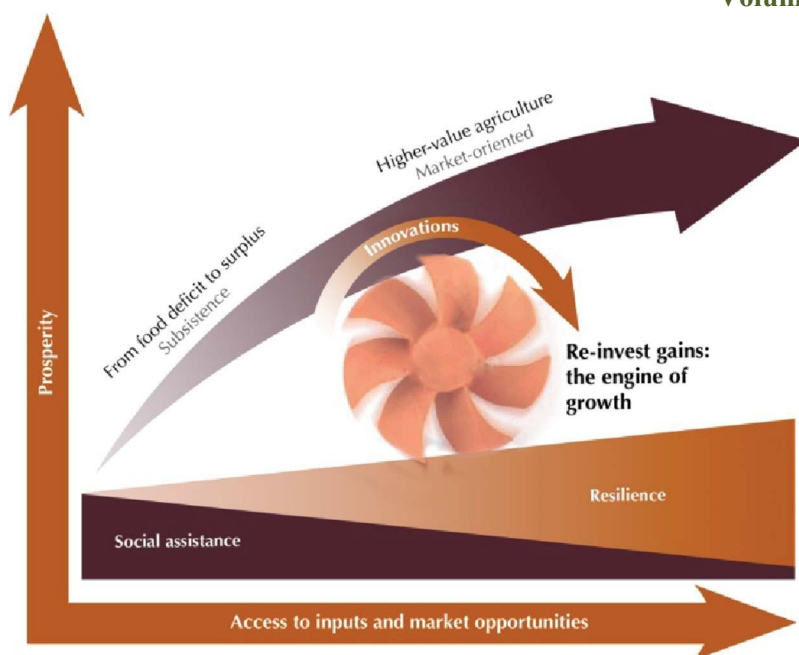


**FIGURE 4** Inclusive market-oriented development: The conceptual framework for ICRISAT’s Strategic Plan to 2020 (color figure available online).

stress, which in the drylands includes human, social, physical, natural, and financial stresses.

## CONCLUSION

Everyone agrees that rising greenhouse gas concentrations in the atmosphere are having shocking effects on Earth’s climate, weather patterns, and global temperatures. If the rural poor in emerging nations are to experience less strain from climate change, high food costs, and environmental and energy challenges, new understanding and technical and policy solutions are essential. Adaptation and mitigation methods are essential given the negative effects of climate change on crop productivity and production as well as the geographic distribution of pests. Programs that are implemented locally, are adapted to local conditions and ecosystems, are community-managed with immediate benefits for the communities and long-term benefits for future generations, are based on sound science, are enabled by effective policy at all levels, and are built on the current wealth of knowledge and new research directions can provide a better understanding of how climate change affects food production, forests, and natural resources in order to target and prioritise both adaptation and mitigation measures.

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