CIMMYT MR
International Maize and Wheat Improvement Center

Cereal Crops: Food and Nutritional Security for a Changing World

The Facts

- Seventy percent of the world's poorest people live in rural areas. Many depend on rice-, maize- and wheat-based farming systems for food and income.
- According to the Food and Agriculture Organization (FAO) of the United Nations, maize and wheat account for about 40 percent of the world's food and 25 percent of the calories consumed in developing countries.
- Billions of poor people – including poor people in urban areas – get more than half their daily calories from rice-, maize- and wheat-based foods.
- Maize and wheat are farmed on nearly 200 million hectares (ha) in developing countries. While CIMMYT is a strong advocate that these crops be grown in more environmentally responsible ways, their importance cannot be overstated.
- Developing countries currently need about 700 million tons of maize and wheat to meet their food needs. By 2020, these countries will need an additional 368 million tons of maize and wheat.

The Importance of Maize, Wheat and Rice

There are those who believe that research and funding should be further diverted from rice, wheat and maize. While funding should be available for a wide variety of crops, these three cereals have been – and will continue to be – the world's staple crops and are of critical importance to both developed and developing nations. In fact, these staples have only grown in importance to the world over the past 100 years and no other crops can replace them in terms of feeding the world's growing population between now and 2050 (and likely beyond).

Rather than divert funding and research from these staples, the reverse should occur. Additional funding should be focused on: how to grow these cereals more efficiently and effectively (through sustainable intensification techniques such as conservation and precision agriculture); how to increase their yields (in order to save land, water, labor, nutrients, etc.); how to adapt them to changing climatic conditions (through climate-smart agriculture); how to ensure that as much produce as possible moves from farmers' fields to consumers (by decreasing post-harvest losses); how to add vitamins and micronutrients to these cereals while they are in the fields (through biofortification, nutrient-infused fertilizer or other means); and how to increase farmers' incomes and improve their livelihoods (through better value chains and more vibrant markets).

CIMMYT and the International Rice Research Institute (IRRI) have been and are effectively addressing each of these challenges. The crops the two Centers focus on are the world's most important. CGIAR and donors should more fully support CIMMYT and IRRI and the CRPs they lead (WHEAT, MAIZE and the Global Rice Science Partnership, or GRiSP) – the Centers and CRPs that can have the most immediate, positive impacts on food and nutritional security.

According to the CGIAR Framework, the Centers "will contribute to: less rural poverty; better food security; better nutrition and health; and sustainably managed resources." More effective wheat, maize and rice production systems can make greater contributions to those four goals than the other 7,000 crops combined.

Why Maize, Wheat and Rice Are Important for the World

While there are 7,000 known edible crop varieties, wheat, rice and maize provide 48 percent of all calories and 42 percent of all protein in developing countries. Shiferaw and other authors in *Food Security/Crops that Feed the World* (Springer, Netherlands. 3: 307-327, 2011) state, "Maize is one of the most important food crops in the world and, together with rice and wheat, provides at least 30 percent of the food calories to more than 4.5 billion people in 94 developing countries." Maize-, rice- and wheat-based systems are the primary source of protein in 12 of the 15 poorest farming systems worldwide.

Breakthroughs in improving the protein quality and amounts of micronutrients in these three staple crops have had a

positive impact on human nutrition. This is not meant to belittle the importance of diversification, but the billions who live on less than $2 per day need affordable food in sufficient quantities and quality. Wheat, maize and rice are not the complete solution for these people, but the importance and impact of these crops is so great that they must be major components in the fight to eradicate hunger.

Wheat, rice and maize are extensively traded and there are functioning markets for these crops nearly everywhere they are grown. Are there/would there be robust markets for other crops? Of course, no one knows for sure, but can the billions of food-insecure take a chance? For example, cereal-legume cropping systems have been recommended extensively (including by CIMMYT), but have not been fully implemented because smallholder farmers realize that there is not always a market for their excess legume production. Any introduction of a new crop into an existing farming environment requires careful value chain analysis.

How many of the 7,000 crops have a better nutrient balance than wheat? While roots, tubers and legumes are important crops, they often contain less protein and fewer nutrients than the staples. 'Orphan crops' are defined as "neglected and/or underused crops that have been used for centuries or even millennia for their food, fiber, fodder, oil or medicinal properties, but have been reduced in importance over time owing to particular supply and/or use constraints such as a lack of secure markets, low yields and difficulties in growing them." How many of these crops can be economically produced today in the quantities needed to feed billions?

Malnutrition, so prevalent in far too many developing regions of the world, is often related to poverty, lack of income opportunities and small land holdings. While crop diversification can occur when additional income is relatively certain, farmers are risk-averse. And farmers who are both risk-adverse and at-risk are more likely to rely on cereals before taking a chance on other crops.

While dietary diversification is desirable (and fully supported by CIMMYT), a more in-depth look at the continued relevance of carbohydrate sources such as rice, wheat and maize in food is critical. Based on an expert consultation organized by FAO and the World Health Organization (WHO) in 1997, "Carbohydrates in human nutrition" was published. The publication's findings on the role of carbohydrates in nutrition and the role of carbohydrates in human health includes "...the experts felt it was necessary to emphasize that carbohydrate foods provide more than energy alone. Although high carbohydrate foods provide the full range of vitamin and mineral nutrients, some are also particularly rich in phytochemicals, many of which are antioxidants. There is increasing evidence of the role of such substances in the protection of health." In essence, there is nothing "black" or "white" regarding carbohydrates as a food source!

The critically important priority in many parts of the world is still to produce enough calories for human consumption. We have begun the process to also meet the need for proper nutrition. While the lack of proper nutritional health is often referred to as "hidden hunger," spikes in cereal prices over the past several years and associated social unrest show the impact of "real hunger."

From CIMMYT's Perspective:

The Importance of Cereals

The importance of cereals – the world's staple crops – to both developed and developing countries has not diminished. The following provides relevant information about these critically important crops. CIMMYT is working across the world to increase food and nutritional security, improve livelihoods and protect the environment.

Effective Maize and Wheat Farming Systems – the CIMMYT Mandate

Maize and wheat are two of the three most important food crops, feeding approximately 3.4 billion resource-poor consumers who earn less than $2 a day. Wheat is the "staff of life" for 2.5 billion consumers and a vital income source for 30 million resource-poor wheat producers and their families. In addition, 900 million consumers and 120 to 140 million resource-poor farmers and their families depend on maize for both their diet and livelihoods.

CIMMYT is the global leader in wheat and maize agronomy and agricultural innovation systems for the developing world. Sustainability is central to the CIMMYT mission, so a combination of improved breeding and agronomy are essential to achieve the necessary increases in productivity of these two staple crops. And while often lumped together, maize and wheat are very different crops that face very different challenges.

Wheat

Except for potatoes, wheat is the food crop most affected by climate change – with each 1 degree celsius (°C) increase in temperature, productivity is projected to decrease 10 percent. This challenge is further exacerbated by diseases such as Fusarium head blight and wheat rusts. Demand for wheat is also increasing. In South Asia alone – where 25 percent of the world's population is projected to live by 2050 – demand for wheat is expected to rise by 40 percent. Traditionally not a major wheat-growing region (despite its potential), Sub-Saharan Africa (SSA) currently spends about $12 billion to import around 40 million tons of wheat annually, constituting more than one-fourth of Africa's total food import expenditures of $40 billion. Despite this demand, wheat and wheat-farming systems research only receive meager funding in Africa.

Wheat is the leading source of vegetable protein in developing countries (and most developed countries as well) – about 20 percent of all protein in the human diet comes from wheat. This is often overlooked when the impact of the Green Revolution is referenced. Since the mid-1960s, wheat has improved both the calorie and protein status of its consumers.

According to Shiferaw, B., et al. (2013) "Crops that feed the world: Past successes and future challenges to the role played by wheat in global food security," *Food Security* 5(3), **"Wheat is fundamental to human civilization and has played an outstanding role in feeding a hungry world and improving global food security. The crop contributes about 20 percent of the total dietary calories and proteins worldwide.** Food (wheat) demand in the developing regions is growing by 1 percent annually and consumption varies from 170 kilograms (kg) in Central Asia to 27 kg in East and Southern Africa. The developing regions (including China and Central Asia) account for roughly 53 percent of the total harvested area and 50 percent of the production. Unprecedented productivity growth from the Green Revolution since the 1960s dramatically transformed world wheat production, benefiting both producers and consumers through low production costs and low food prices. Modern wheat varieties were adopted more rapidly than any other technological innovation in the history of agriculture, recently reaching about 90 percent of the area in developing regions. One of the key challenges today is to replace these varieties with new ones for better sustainability. While the Green Revolution 'spared' essential ecosystems from conversion to agriculture, it

also generated its own environmental problems. Also, productivity increase is now slow or static. Achieving the productivity gains needed to ensure food security will therefore require more than a repeat performance of the Green Revolution of the past. **Future demand will need to be achieved through sustainable intensification that combines better crop resistance to diseases and pests, adaptation to warmer climates, and reduced use of water, fertilizer, labor and fuel. Meeting these challenges will require concerted efforts in research and innovation to develop and deploy viable solutions. Substantive investment will be required to realize sustainable productivity growth through better technologies and policy and institutional innovations that facilitate farmer adoption and adaptation.** The enduring lessons from the Green Revolution and the recent efforts for sustainable intensification of cereal systems in South Asia and other regions provide useful insights for the future."

CIMMYT is working with HarvestPlus, which is developing micronutrient-dense crops (wheat, maize and golden rice). The bio-fortification of maize, wheat and rice is a key effort to improve diets in the developing world, particularly for the rural poor. In wheat, the current bio-fortification target is to increase the zinc content by 25 percent over currently grown varieties (at whatever those levels are). Wheat is the second-most prevalent staple (after rice) in South Asia – where more micronutrient-deficient people live than in the rest of the world. Therefore, bio-fortified wheat could improve nutrition for millions of zinc-deficient people. Among children, it could help reduce stunting.

In regard to wheat production many forget, ignore or are unaware that there is simply no biological or economic alternative to wheat. Why? Wheat covers around 220 million ha globally, and with the exception of high latitudes (United States, Canada, Western Europe, Kazakhstan and Siberia) most wheat is grown during winter – fall-sown winter wheat and fall-sown spring wheat. Wheat is one of the few crops that can be produced on large areas and has the tolerance to cold temperatures to grow during winter. Even if all wheat production stopped, there are no broad-scale alternatives to fill the free area. While there are some winter vegetables and oil seed crops like canola, how much does the world need? Some legumes like fava beans have winter hardiness but yields are not high enough to feed the global population. Currently there is no crop that could be grown at scale in winter wheat-growing areas, nor is there a crop that has the market capacity to be produced and ability to feed the same amount of people that wheat does (nor provide an equivelant level of protein).

A wheat crop matures in a field.

Although there are developed markets for each of the three key staples, wheat is the most traded crop – more than rice and maize combined. When famines or failed harvests occur in the world, wheat is usually the staple of choice that is used to bridge the food gap. Reasons for this include wheat's long-term storage and transport capacity and the few post-harvest diseases or toxins that can impact the crop. However, large-scale reductions in wheat stocks will make price fluctuations more likely in years with major weather-related issues, natural disasters or political disturbances. Moreover, sufficient stocks are needed, since rice, wheat and maize prices are interdependent.

Maize

According to Shiferaw, B., et al. (2011), "Crops that feed the world: Past successes and future challenges to the role played by maize in global food security," *Food Security* 6 (3), **"In parts of Africa and Mesoamerica, maize alone contributes over 20 percent of food calories. Maize is also a key ingredient in animal feed and is used extensively in industrial products, including the production of biofuels.** Increasing demand and production shortfalls in global maize supplies have worsened market volatility and contributed to surging global maize prices. Climatic variability and change, and the consequent rise in abiotic and biotic stresses, further confound the problem. Unless concerted and vigorous measures are taken to address these challenges and accelerate yield growth, the outcome will be hunger and food insecurity for millions of poor consumers. We review the research challenges of ensuring global food security in maize, particularly in the context of climate change. The paper summarizes the importance of maize for food, nutrition and livelihood security and details the historical productivity of maize, consumption patterns and future trends. We show how crop breeding to overcome biotic and abiotic stresses will play a key role in meeting future maize demand. Attention needs to be directed at the generation of high-yielding, stress-tolerant and widely adapted maize varieties through judicious combination of conventional and molecular breeding approaches. **The use of improved germplasm per se will not, however, be enough to raise yields and enhance adaptation to climate change, and will need to be complemented by improved crop and agronomic practices.** Faced with emasculated state extension provision and imperfect markets, new extension approaches and institutional innovations are required that enhance farmers' access to information, seeds, other inputs, finance and output markets. Over the long-term, **large public and private sector investment and sustained political commitment and policy support for technology generation and delivery are needed to overcome hunger, raise the incomes of smallholder farmers and meet the challenges of growing demand for maize at the global level."**

"Today, maize is the most important food crop in SSA and Latin America, and is a key Asian crop."

Maize is a major source of calories in the diets of millions of inhabitants of SSA, South Asia and Latin America. Annual per capita maize consumption averages 36, 10 and 23 kg, respectively, in these regions, but this masks significant variation and per capita food consumption of maize. In Mesoamerica, annual maize consumption exceeds 80 kg per capita in Guatemala, Honduras and El Salvador, rising to 125 kg in Mexico. Maize is also the most important cereal food crop in SSA, consumed by 50 percent of the population. Consumption levels exceed 130 kg per capita per year in Lesotho, Malawi and Zambia. The highest amounts of maize are consumed in southern Africa (85 kg/capita/year) compared with 27 kg/capita/year in East Africa and 25 kg/capita/year in West and central Africa.

Maize is often consumed indirectly in the form of eggs, corn syrup, milk and cheese products, beef and pork. In developing countries, maize is more commonly consumed directly as a food staple and accounts for up to 56 percent of total caloric intake. Today, maize is the most important food crop in SSA and Latin America, and is a key Asian crop. As the world's population increases and more people begin to add higher amounts of meat, poultry and dairy to their diets, demand for maize is expected to rise. By 2025, maize will be the developing world's largest crop and between now and 2050 the demand for maize in the developing world is expected to double. While consumption is expected to increase, yields are expected to decline – leading to higher food prices. Production increases are threatened by emerging diseases like maize lethal necrosis and by post-harvest losses.

The importance of maize as feed, which becomes meat protein, is huge and growing (an example is the projection of demand versus supply of maize in China over the coming

decades). While the number of people who will eat maize may decline in some regions, increasing numbers want to eat eggs, chicken, dairy products, pork and beef. All are sources of protein and micronutrients that are 'fed' by maize. Moreover, maize is the most efficient way to produce these proteins. The world needs more maize, and this is congruent with promoting more balanced, nutritious diets.

Sustainable Intensification

Reduced investment in research to improve the productivity of wheat, maize and rice would be a serious mistake since only the increased productivity of these staples will sustain global food security. Poor farmers are risk-averse and will only diversify to vegetables and other crops if they are convinced that they will be profitable.

An additional reason why cereals are important for the world is the land-sparing effect from yield and yield stability increases in smallholder maize- and wheat-based systems. Using the sustainable intensification techniques of conservation agriculture (CA) and precision agriculture, farmers use less land to produce the same amount of calories from cereals. In many systems these techniques give farmers opportunities to diversify their production (for example, into legumes, livestock and/or cash crops) and therefore improve both their diets and income.

The relationship between agriculture and nutrition is not a simple one – increasing the income of farmers through increased cereal production often provides rural families options to diversify their diets through expanded food purchases.

CIMMYT's Future

Across the world, CIMMYT staff members are working steadily and resolutely to fulfill the Center's mission to "sustainably increase the productivity of maize and wheat systems to ensure global food security and reduce poverty." Using the fruits of AR4D, they are working with hundreds of partner organizations (and through them millions of individuals) to improve agricultural productivity, the effectiveness of agricultural value chains and the agriculture sector as a whole.

In the coming years, CIMMYT will increase its agricultural research for development efforts and its partnerships to improve agriculture's benefit to mankind. Improving global agriculture is among the most complex issues facing the world. While certainly not the full answer, staple crops are the foundation of sustainable global food and nutritional security.

(Above): A maize crop matures in a field in Pakistan.

(Left): A Bangladeshi smallholder farmer stands amid his young rice crop.

The CIMMYT Mission

CIMMYT's mission is to "sustainably increase the productivity of maize and wheat systems to ensure global food security and reduce poverty."

CIMMYT's dedicated staff continued a tradition of excellence in agricultural research for development (AR4D) that stretches back to CIMMYT's predecessor organization (the Office of Special Studies) in the 1940s and to the founding of CIMMYT in 1966 – working to improve the food and nutritional security and livelihoods of those the Center serves.

This work is as important now as it has been for the past 70 years – perhaps more so as the world faces an ever-increasing population, climate fluctuations, less arable land and declining amounts of water for agricultural purposes. The critical work that CIMMYT does would not be possible without CIMMYT's partners and donors. Hundreds of partners work with CIMMYT to improve lives across the developing world, and CIMMYT's accomplishments are shared with them. The dedication of CIMMYT's donors to similar goals and their generous funding make CIMMYT's work possible, and all CIMMYT employees are proud and thankful for their support and assistance.

During 2013 CIMMYT's Board of Trustees, staff, partners and donors continued to work together to deliver on CIMMYT's mission. New projects began and others continued to meet or exceed the goals set for them. CIMMYT staff members are working to improve all areas of operations across the world – to be ever more efficient and effective in reaching the Center's goals.

CIMMYT is having an impact across the world, but much more needs to be done – and will be through these collective efforts and partnerships.

The following are representative examples of CIMMYT's work to carry out its mission:

- **Recent estimates indicate that wheat varieties developed by CIMMYT and its partners are planted on more than 64 million hectares (ha) in developing countries, representing more than 75 percent of the area planted to modern wheat varieties in those countries.**

- **Maize varieties developed by CIMMYT and its partners are planted on nearly half of the area sown to improved varieties in non-temperate areas of the developing world.**

- **Two CIMMYT scientists who developed more nutritious maize varieties received the 2000 World Food Prize. In 2014, Dr. Sanjaya Rajaram, who succeeded Dr. Norman Borlaug in leading CIMMYT's wheat breeding program, received the World Food Prize for his work in developing 480 improved wheat varieties that today are grown on 58 million hectares across six continents.**

As reported in *Science* magazine, in the absence of CGIAR Centers such as CIMMYT, with their many partners in the developing world, crop yields in developing countries would have been 19.5 to 23.5 percent lower; prices for food crops would have been 35 to 66 percent higher; imports would be 27 to 30 percent higher; calorie intake would have been 13.3 to 14.4 percent lower; and 32 to 42 million more children would have been malnourished. The area planted to crops would be 4 percent higher for wheat and 2 percent for maize.

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