The technology challenge

THE CHALLENGE

Global food production needs to increase by 70 percent by 2050 in order to feed an additional 2.3 billion people. Food production in developing countries needs to almost double. Production will not need to grow as fast as in previous decades because of the slowdown in population growth rates, but incomes are growing, and the volume requirements are still remarkable: for instance an additional one billion tonnes of cereals and 200 million tonnes of meat will need to be produced annually by 2050. In developing countries, 80 percent of the production increases are projected to come from increases in yields and cropping intensity and only 20 percent from expansion of arable land. In land-scarce countries, almost the whole of the production increases would be achieved through yield improvement. But the fact is that globally the rate of growth in yields of the major cereal crops has been steadily declining. The rate of growth in global cereal yields, for example, dropped from 3.2 percent per year in 1960 to 1.5 percent in 2000. The challenge for technology is to reverse this decline, given that a continuous linear increase in yields at a global level following the pattern established over the past five decades would not be sufficient to meet food needs.

The challenge is made more pressing by climate change, which is projected to have a significant impact on agricultural production. According to the Intergovernmental Panel on Climate Change (IPCC), if temperatures rise by more than 20 °C, global food production potential is expected to contract severely and yields of major crops like maize may fall globally. The declines will be particularly pronounced in lower-latitude regions. In Africa, Asia and Latin America, for instance, yields could decline by between 20 and 40 percent if no effective adaptation measures are taken. In addition, extreme weather events such as droughts and floods are becoming more frequent, causing greater crop and livestock losses. Also an increasing demand for biofuel feedstock may put additional pressures on global agricultural production. New technologies will be needed to address the problem of rapidly increasing water scarcity, and also to reduce post-harvest losses. Addressing these challenges will require pushing the technology frontier outwards, including in marginal areas. This could be achieved by developing and disseminating new technologies and crop management techniques but also by making already existing technology available to small farmers in developing countries. In order to ensure a wide uptake of modern technologies, it is indispensable that resource-poor smallholder farmers are not bypassed by technological progress.

THE ISSUES

CLOSING YIELD GAPS

Yield gaps exist mainly because known technologies that can be applied at a local experiment station are not applied in farmers' fields having the same natural resource and ecological characteristics. One main reason why yield gaps exist is that farmers do not have sufficient economic incentives to adopt yield enhancing seeds or cropping techniques. This may be explained by numerous factors, including lack of access to information, extension services and technical skills. Poor infrastructure, weak institutions and unfavourable farm policies can also create huge obstacles to the adoption of improved technologies at farm-level. Other factors can be that available technologies have not been adapted to local conditions. Solutions lie with public sector investments in institutions and infrastructure, better research-extension-farmer linkages and sound policies to stimulate adoption of technologies that improve productivity and reduce costs, thus increasing agricultural incomes. Changes in crop management techniques can also help closing yield gaps. Plant breeding plays an important role in closing yield gaps by adapting varieties to local conditions and by making them more resilient to biotic (e.g. insects, diseases, viruses) and abiotic stresses (e.g. droughts, floods). Studies estimate that the global yield loss due to biotic stresses averages over 23 percent of the estimated attainable yield across major cereals.

INCREASING INPUT USE EFFICIENCIES

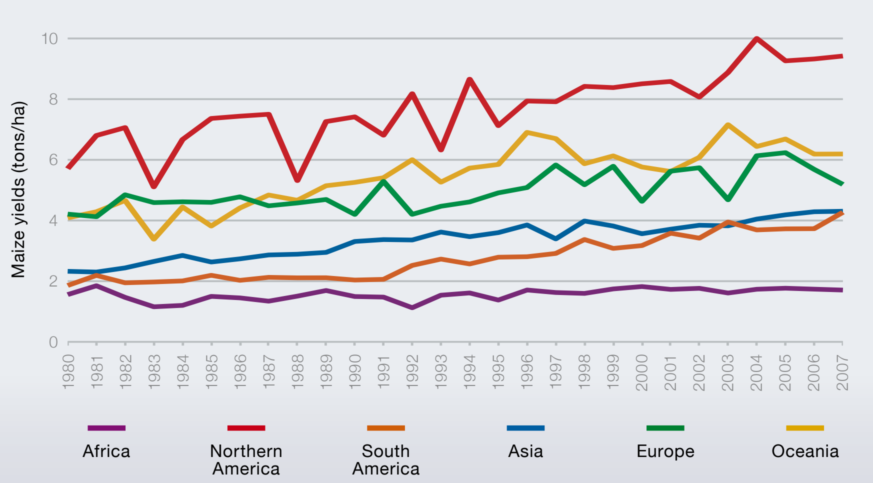
Increasing input use efficiencies in agricultural production will be essential as natural resources are getting scarcer, and prices of non-renewable resources like fossil fuels, nitrogen, and phosphorus are expected to increase over the next decades.

- *Conservation farming* using zero tillage offers a major opportunity to reduce fuel use in agriculture by an average of 66 to 75 percent as well as sequester soil carbon. Conservation agriculture (CA) can improve crop yields and farm profitability, improve soil productivity and make agriculture more sustainable, providing greater resilience against drought and other stresses. Yields are less variable from year to year, while labour and fuel costs are lower. However, CA is knowledge intensive and location specific and will require sharply increased investments in research on suitable varieties, management practices, appropriate machinery etc. CA is currently practised on about 10 percent of global crop land, mainly in Latin America. Payments for soil carbon sequestration could provide additional incentives to adopt conservation agriculture.

- *Fertilizer consumption* is expected to rise in developing countries. Nitrogen represents 90 percent of fertilizer consumption. Fossil energy accounts for 70–80 percent of the cost of manufacturing nitrogen fertilizer. Because major efficiency gains in manufacturing nitrogen have already been made, it is likely that fertilizer prices will in the future rise in line with energy prices. Increasing the on-farm use of nitrogen and the supply of biologically fixed nitrogen are good options for efficiently using fertilizers. Precision agriculture and integrated plant nutrient management systems provide new tools for further improving efficiency.

- *Integrated pest management* (IPM) aims to minimize the amount of pesticides applied by farmers by using other control methods more effectively. Pest incidences are monitored and action is taken only when the crop damage exceeds certain tolerable limits. Many countries (e.g. Niger, Mali, Jordan, India, Bangladesh, and Viet Nam) have introduced IPM and have experienced increased production accompanied by lower financial, environmental and human health costs.

Figure 1: Historical development of maize yields, by geographic region



Source: FAOStat

- *Irrigation water.* FAO estimates that some 1.2 billion people live in countries and regions defined as “water-scarce”, and the situation is projected to worsen rapidly, with the number rising to 1.8 billion by 2025, partly as a result of population growth. Yet the benefits of irrigation are immense, with a productivity differential between irrigated and rainfed areas of about 130 percent. Over the past decade, irrigation alone accounted for about 0.2 percent out of overall annual yield growth for cereals of 1.1 percent. Experts estimate that at present in developing countries, irrigated agriculture, with about 20 percent of all arable land, accounts for 47 percent of all crop production and almost 60 percent of cereal production.

SOME BASIC FACTS

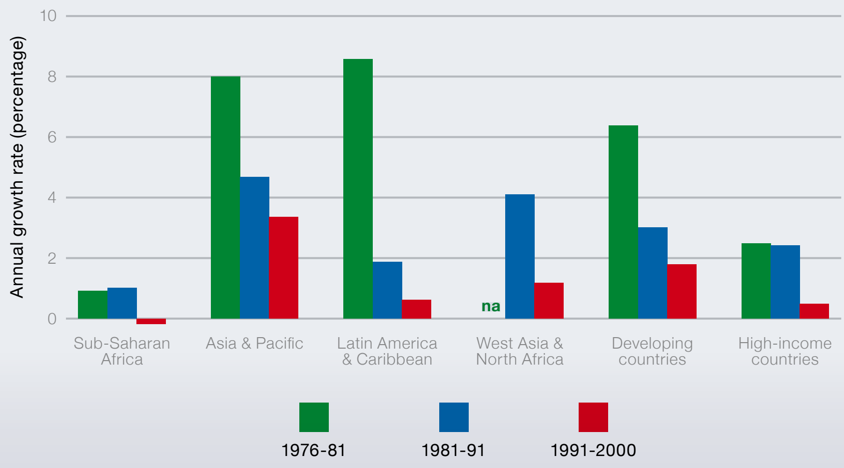
- **The Green Revolution played a key role in raising agricultural production over the past 40 years. Yield increases for major cereals (wheat, rice, maize) amounted to 100 to 200 percent since the late 1960s. However, yield growth rates were unequally distributed across crops and regions: despite the successes in cereal crops, yield growth for millet, sorghum, and pulses – which are major staples for resource-poor farmers and rural households – was slow.**
- **Large and economically exploitable yield gaps remain in many places, especially in the developing world and nowhere more so than in sub-Saharan Africa (see figure 1, for maize yields).**
- **Increased and timely access to modern inputs and information, improved rural infrastructures, and better access to credit markets may facilitate the exploitation of yield gaps by farmers.**
- **Total global investment in agricultural R&D totalled US$41 billion in the year 2000. The public sector accounted for 59 percent and the private sector 41 percent. Most private sector research was**

Addressing the yield challenge may require the expansion of irrigated areas as well as the wider use of management practices that will improve the efficiency of water use, e.g. water "harvesting" techniques and conservation of soil moisture. In severe water scarce regions, the effort should focus on getting more "crop per drop".

PLANT BREEDING

Plant breeding techniques, and particularly modern biotechnology, have aroused large public debates in the last decade. Technically speaking, modern biotechnology has the potential to speed up the development of improved crops, which may increase yields and/or decrease crop losses. For instance, marker-assisted selection increases the efficiency of conventional plant breeding by allowing rapid laboratory-based analysis of thousands of seedlings without the need to grow plants to maturity in the field. Tissue culture techniques allow the rapid multiplication of clean planting materials of vegetatively propagated species for distribution to farmers. Genetic engineering can help to transfer desired traits between plants more quickly and accurately than it is possible with conventional plant breeding. Genetic engineering for biotic stress and herbicide resistance has been shown to be successful in some cases: it has permitted to reduce pesticide applications and has lifted yield of crops subject to insect attack. Engineered herbicide tolerance in soybeans, maize and canola has facilitated conservation tillage and permitted more timely planting with modest benefits for yields. Further yield improvements by using genetically modified crops that are stress resistant are seen by some experts as a good possibility for bridging yield gaps. Some experts also predict that by 2050 genetically modified technologies would be cheaper, far more widely available and used to a much greater extent to improve potential yields and yield stability of staple food crops. Nonetheless, it has to be recognized that genetically modified crops, and particularly transgenic modification, carry risks and arouse widespread public concerns in many countries. These include ethical misgivings, anxieties about possible negative effects on human, plant and animal health and concerns about the impact on the environment and threats to biodiversity. There are also strong concerns about the concentration of economic power in the hands of just a few large trans-national companies and consequent technological dependence on those companies as well as increasing costs of seeds. Other barriers that prevent poor farmers from accessing modern biotechnology include inadequate regulatory procedures, complex intellectual property issues, poorly functioning markets and weak domestic plant breeding capacity. In view of these constraints, only some farmers in a few developing countries may be able to reap the possible benefits of transgenic crops.

Figure 2: Annual growth rates in agricultural R&D, by geographic area



Source: Beintema & Elliott (2009)

INVESTMENTS IN AGRICULTURAL RESEARCH AND DEVELOPMENT

In low-income countries, agricultural R&D continues to be the most productive investment in support of the agricultural sector, followed by investments in education, infrastructure, and input credits. Investments in R&D have very high rates of return

carried out in developed countries and tended to be focused on the requirements of commercial farmers in well-developed regions. Public sector R&D still dominates in developing countries and is more focused on basic research and the improvement of staple food and minor crops.

- **Public investments in agricultural R&D worldwide grew from US$16 billion in 1981 to US$23 billion in 2000, with large inter- and intra-regional differences. While public investments in the Asia-Pacific region (driven by China and India) more than doubled over this period, investments in sub-Saharan Africa only grew at an annual average rate of 0.6 percent from 1981 to 2000 and actually fell during the 1990s (see figure 2). Agricultural R&D investments are increasingly concentrated in a few leading countries in each region.**
- **In 2008, genetically modified crops worldwide were cultivated on 800 million hectares in 25 countries (15 developing and 10 developed countries). Herbicide tolerant soybeans are the major genetically modified crop, occupying 53 percent of the total area under genetically modified crops, followed by maize (30 percent), cotton (12 percent) and canola (5 percent).**

DISCUSSION POINTS

1. Do we have the right technologies in place to raise agricultural production sustainably and equitably? Why are many already existing technologies not used by small rural farmers?
2. What incentive structures are required to improve the adoption and diffusion of modern technologies and cropping techniques by all farmers, including resource-poor farmers?
3. How can we make sure that relevant technologies and knowledge on how to use them reach women farmers, who constitute the majority in developing countries?
4. How can the funding for agricultural R&D be mobilized in order to ensure that the right technologies are in place to address the challenges of the future, in particular helping agriculture to adapt to and mitigate the potential impacts of climate change? What will be the role of the CGIAR system in addressing these future challenges?
5. How can research on modern plant breeding techniques be stimulated? What kind of regulatory and approval systems are needed to ensure full use of the many technologies that are in their early stages of adoption that promise a win-win combination of enhancing productivity and sustainably managing natural resources? What role do public-private partnerships play in this context?
6. How can national public institutions and farmers' organizations help in the diffusion and adoption of technologies, particularly among smallholder farmers and women?
7. Is a second Green Revolution possible? What should be its characteristics to ensure its wide dissemination and achieve the required increase in food production by 2050?

(between 30 and 75 percent) and long-term benefits. Massive public and private investments in R&D are required today in order for agriculture to benefit from effective technologies in the future given that benefits from agricultural research tend to materialize after a considerable time lag. In 2002, FAO estimated that an incremental US$1.1 billion (at 2002 prices) would have to be invested every year into strengthening the capacity for knowledge generation and dissemination in order to reduce hunger effectively. The need for more investments in agricultural R&D will increase to address the emerging challenges of climate change adaptation and water scarcity. Many countries will also need to invest in their human and institutional capacity to enable them to tackle the broadening agricultural research agenda. This includes the development of more effective public agricultural research systems, more effective financing mechanisms and increased investments in agricultural education. Currently, agricultural R&D in developing countries, which is essential to meet the needs of low-income farmers in agricultural based economies, is mostly funded by the public sector and is likely to remain so while the private sector perceives that the potential rates of returns are low. Increasing private sector involvement in agricultural R&D also means addressing issues of intellectual property rights (IPRs) and ensuring that a balance is struck so that access of poor farmers to new technologies is not actually reduced. Appropriate regulatory systems that are adapted to a country's needs and effectively enforce IPRs will be essential to stimulate private sector investments. The actual level of private investments will critically depend, among other things, on favourable policy and business environments, good rural infrastructures and well functioning markets (input, output and credit).

DISSEMINATION

Spreading knowledge, skills and technology is a major challenge. In many countries, extension services have been cut in line with the reforms of public institutions, in others the knowledge base and extension services have been hard hit by HIV-AIDS. Agricultural extension programmes are meant to ensure that information on new technologies, plant varieties and cultural practices reaches farmers. In many regions of the developing world, women form the majority of farmers, which means particular efforts need to be made to factor the needs of women into dissemination and capacity development programmes. However, in the developing world it is common practice to direct extension and training services primarily toward men. A recent FAO survey showed that female farmers receive only five percent of all agricultural extension services worldwide and that only 15 percent of the world's extension agents are women. Policies have been based on the assumption – proved wrong by studies – that information conveyed to the male head of a household would be passed on to its female members. Apart from extension services, Farmer Field Schools are proving an effective means for spreading knowledge, while information and communication technologies (ICTs) also look very promising tools for information dissemination. Rebuilding public institutional capacity in developing countries and empowering farmers' organizations and women will help in this endeavour.

For further information

HOW TO FEED THE WORLD 2050

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