8 APPROPRIATE TECHNOLOGY FOR SUSTAINABLE FOOD SECURITY*

By **Dr. William D. Dar**
Director General,
International Crops Research Institute for
Semi-Arid Tropics, Patancheru, Hyderabad, India

PRELOGUE

Food security, which essentially means food production, its affordability, accessibility and nutrition, is a critical concern worldwide, especially against a background of rapid population growth. In most developing countries it is the resource poor small-scale farmers who contribute substantially to food production. We cannot achieve food security without improving agricultural productivity and sustainability in the small-scale sector. To achieve this, we need to empower these farmers with 'appropriate technology'.

Modern science has made tremendous progress in the last century. It has opened up new opportunities, but not all of them are relevant to the needs and circumstances of poor farmers. This paper discusses some key technologies that have the potential to uplift poor farmers by improving economic conditions and agricultural productivity. These appropriate technologies seek to harness farmers' knowledge base and skills to develop new varieties and better options to manage soil, water and other natural resources, and control pests and diseases; and better food processing and storage methods. We must fully exploit new science such as biotechnology, information and communication technologies, and alternative energy sources. To be truly effective in ensuring food security for the poor, development of appropriate technology should focus their problems and provide flexibility for farmers to design, choose and implement their own options.

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The International Crop Research Institute for Semi-Arid Tropies (ICRISAT), is one of 16 Future Harvest Centers that are part of the Consultative Group on International Agricultural Research (CGIAR). It has global responsibility for agricultural research in the Semi-Arid Tropics, or SAT. The SAT covers parts of 48 developing countries in Africa and Asia, and is home to one-sixth of the world's population. Many of these people are poor by any standards. Half of them lack access to even basic health and nutrition. The farming environment is characterized by poverty, frequent drought, infertile soils, growing desertification, and overall environmental degradation. Farming is mostly subsistence-level, and agricultural production is struggling to keep pace with population growth.

It is against this backdrop that ICRISAT began its work 30 years ago. ICRISAT has five mandate crops — sorghum, pearl millet, chickpea, pigeonpea, and groundnut. The mission is to conduct research that will help increase production and improve management of natural resources; and ultimately to achieve food security through sustainable farming practices. ICRISAT has research facilities in India and at seven locations in Africa, and this geographical spread has allowed to get closer to the problems, and work with farmers to find appropriate solutions.

To days presentation reflects the way ICRISAT trys to reach out to the poor farmers in these regions, and empower them to grow their way out of poverty. ICRISAT works on staple food crops, but this approach is equally relevant for scientists who are working on vegetables.

To billions of poor people who struggle for survival in the developing world, food security means food availability, affordability, accessibility and nutrition. No country has developed successfully without first ensuring a high level of food security for its people. There are over 800 million hungry people in the world today. Every day around 24,000 people die of starvation or hunger-related causes. By 2020, the world will have 2 billion new mouths, largely in the developing countries, which means food production will have to increase by 40% from current levels. Most developing countries, particularly those in the semi-arid tropics, will need a 2-4 % of growth rate in agricultural production to feed their growing population. To attain such growth rates, we should not only strive just to improve agriculture, but to transform it.

When we speak of targets for agricultural growth rates for ensuring food security, we must remember that in developing countries, substantial part of food production comes from small and marginal farmers. For example, 80% of the farmers in India have less than 2 ha of land per family. These small holder farmers produce 41% of India's food grains. Whether food is easily and cheaply available, whether nutrition levels can be improved, whether our ecosystems remain healthy and diverse — all these will depend on whether or not these small-scale farmers can sustainably manage the limited natural resources they have. To help poor farmers achieve food security, we need to empower them with appropriate technology, suitable for their needs and circumstances.

WHAT IS APPROPRIATE TECHNOLOGY ?

Appropriate technology is technology that fits the needs of small-scale (grass roots) and people-centered economic activities. It is a bottom-up approach that addresses the problems identified by the local people themselves, and provides solutions that fit it into their operating environment, be it a new production package or a new crop or variety, or watershed development. Appropriate technology must appreciate the needs of poor farmers, and should not lead to over exploitation of natural resources. For example, it should not lead to excessive withdrawal of underground water as is happening in many places. Appropriate technologies encourage farmers to achieve the same (or better) results even with reduced use of inputs; it treats resources the same way we treat gold, recycling to avoid wastage. Most importantly, it provides poor people with alternative options, after careful debate of the potential benefits and associated risks, in the context well-being and food security. Thus, appropriate technology is a philosophy in itself, a way of seeing things.

What technology is "appropriate" for small and marginal farmers? Modern science offers tremendous opportunities for improving the livelihood of poor farmers as well as protecting the environment. There are skeptics who may question the benefits of modern science, and even blame science for many of our current problems. They are opposed to poor farmers using purchased inputs such as improved seeds, fertilizers and chemical pesticides since it makes them dependent on markets and private suppliers, and less self-reliant. We must remember, however, that modern science can serve poor farmers only if scientists focus on the interests of the under privileged and small holder farmers. Call this Science with a Human Face, and it is the guiding mantra of ICRISAT. Work has to be designed to solve poor people's food and nutrition problems through good science in tandem with appropriate policies and institutions. Technology development must be demand driven i.e., based on the socio-economic and environmental needs and circumstances of resource-poor farmers. In many cases, existing institutions and policies are biased against the poor – the technologies may be too costly, and other enabling factors like information and communication technologies (ICT), farm credits and inputs may not be available to the poor.

APPROPRIATE TECHNOLOGIES FOR POOR FARMERS

Examples of appropriate technology options that have relevance to poor farmers are given below. The case studies provide evidence of benefits and risks, and the implications for sustainable food security. There is a need to continuously build upon these ideas and move forward to implement them.

Farmer-Innovated Agro-Ecological Technology

Farmers in third world countries have developed their knowledge base over many generations, to integrate natural resources as functional inputs into agriculture. For example, farmers have long practiced soil fertility management by recycling organic residue, green manuring, crop rotations, watershed management and pest control. But can these farmers still benefit from their traditional knowledge base and social capital to produce large amounts of food? To answer this central question, the University of Essex conducted a social audit of sustainable agriculture in 52 developing countries. It suggests that farmers are benefiting substantially from their own innovations – for example home gardening with vegetables and fruit trees, adding new productive elements to existing production systems such as fish in rice paddies, better use of water, and improvement in yield through integrated pest management into the system (Pretty and Hine, 2000). The study also found that farmers require more information on relationships between pests and predators, plant growth and soil moisture, and crop and livestock; and those farmers who experiment new technologies are better innovators. Social learning contributes significantly to sustainable agriculture as well as to innovation and adoption of new ideas.

Farmer-led innovations have played a major role in increasing food production in Asia. For example, water harvesting, conservation and recycling to produce additional dry land crops or increase supply of water for an irrigated crop. There is a need to support and encourage more of these innovations. For example, soil improvement brought about by zero-tillage combined with use of green manures and/or herbicides, are being adopted in millions of hectares in Brazil and Argentina (Huang et al., 2002). In Bangladesh, thousands of farmers practicing IPM in rice no longer use pesticides — and by eliminating pesticide residues they have been able to incorporate fish, shrimps and crabs in their rice fields. In Kenya, a large number of farmers are using 'push-pull' pest management systems (pushing the pests out and pulling the predators in) resulting in 60 to 70% increase in maize yields.

Conventional Research-Based Technologies

A classic example of conventional research-based technology is the Green Revolution catalyzed by CIMMYT and IRRI. More than 70% of the world's rice land is now planted to cultivars from breeding materials or the progenies of IRRI-bred materials. National rice improvement programs throughout the world have released more than 300 varieties of rice initially developed by IRRI. We are more food secure today largely as a result of development and promotion of high yielding crop varieties, fertilizers and irrigation. The high yields of the Green Revolution also had a dramatic conservation effect: saving millions of acres of forest land all over the Third World from being cleared for cultivation. If the world's crop and livestock yields were at the level of 1950, at least half of today's 40 million square kilometers of forest would already have been plowed down, and the rest would be scheduled for destruction in the next three decades. The science that made the Green Revolution happen is still relevant today and will continue to play a crucial role in the future, along with advances in molecular biology (Huang et al. 2002; Evans 2001). Further, substantial increases in yield are possible. What is needed is that it should be made more pro-poor so that its impact will go beyond that of the Green Revolution that has primarily benefited only a select group of farmers who had access to subsidized electricity, credits and fertilizers. Indeed it is already beginning to happen.

For example, in Africa, NERICA, the New Rice for Africa combines the ruggedness of local African rice species (*Oryza glaberima*) with the high productivity traits of Asian rice (*Oryza sativa*) that was the mainstay of the Green Revolution. The new rice is transforming agriculture in the humid West Africa region where rice imports top 3.5 million tons. In Guinea alone, NERICA is planted on 90,000 ha saving $13 million in rice import bills.

Most of us are aware of benefits from conventional, Green Revolution type research. It is also commonly known that Green Revolution productivity gains have been slowing down due to a variety of stresses imposed on the resource base by intensive cereal monocropping. Researchers are now trying to make the Green Revolution more sustainable by introducing resource conservation technologies and greater diversification in rice-wheat systems. For example, ICRISAT is working to diversify cereal-based systems in South Asia with pigeon pea and other legumes. We also need to develop varieties adapted to semi-arid and marginal areas that have been by passed by the Green Revolution. Farmers in these areas are unwilling to risk using fertilizer to the same extent as in irrigated areas. One alternative is "natural" fertilizer in the form of nitrogen-fixing legume species. The introduction of short-duration pigeon pea developed at ICRISAT has helped increase or maintain soil fertility by including legumes in crop rotations in Central India (Bantilan and Parthasarathy 1999). In this case the widespread adoption of short-duration pigeon pea, which is an excellent cash crop, has made farming profitable in the short term – via cultivation of a second crop in the post rainy season – and farmers expect to sustain productivity in the long run through crop rotation to maintain soil fertility.

Productivity gains achievable through conventional technologies have not been fully exploited. There is a large yield gap – as high as four t/ha – between potential and actual yield, especially in less-favorable (rainfed) environments. These areas often referred to as marginal; yields are usually below one t/ha, and droughts occur frequently. One main problem in these areas is that research and promotion of improved crop management technologies has lagged behind variety development research. We need to adapt technology to the environment, and not the other way round. Adapting the crop to the environment will allow farmers to get more out of their natural resources, and manage these resources more efficiently and sustainably. They can turn adversity into opportunity and change the marginal grey areas to green. This 'Grey-to-Green Revolution' must be our aim. For example, affordable micro doses of fertilizers (only one Coca Cola capful per plant) has led to large yield increases of pearl millet in highly variable, drought-prone areas in West Africa.

In 2002, the world grain output is likely to fall 83 million tons from last year's levels. The decrease is largely due to acute drought in both developing and developed countries. In India, rice output is likely to decrease from 90 million to 80 million tons, with similar reductions in other irrigated grain and vegetable crops. There is need to develop water use efficient rainfed crops that provide assured high incomes and withstand drought. We must therefore promote the use of crops such as sorghum, millet, and legumes such as pigeonpea, chickpea and groundnut, which require less water and can tolerate high temperatures. Simultaneously, we need to improve technology for rain water harvesting and rain water management through the development of watersheds. This will improve both crop productivity and ground water recharge. Unfortunately, farmers in marginal areas do not have enough cash incomes to support this kind of investment. However, if supplemented with the government support – similar to the support provided for developing watersheds in irrigated areas – it could be a way to sustainably improve the lives of poor farmers, ensure food security, and convert more grey areas to green.

HARNESSING BIOTECHNOLOGY TO ENHANCE FOOD SECURITY

Conventional approaches to germplasm enhancement and crop breeding have had dramatic impacts on food productivity, particularly in systems with high inputs of fertilizer, water and pesticides. However, these approaches not been able to satisfactorily control pests, diseases and weeds, which according to two surveys done in 1967 and 1994 accounted for 40% world wide losses in crop yields (Cramer 1967, Oerke et al. 1994). We have high hopes that the new biotechnology methods will prove more effective. These tools can be used to develop new varieties that are drought-tolerant, resistant to insects and diseases, and able to capture nitrogen from the air. Biotechnology can be used even to increase vitamin A and micronutrients (such as iron, zinc) in the edible portion of the plant. For sub-Saharan Africa, biotechnology could be used to develop virus-resistant sweet potatoes, groundnut, cassava and maize, improve productivity of banana, vegetables, and develop crops that tolerate drought, soil acidity and salt.

Unfortunately, modern biotechnology, especially genetic modification, is getting mired in controversy; this has affected its full scale exploitation and delayed the benefits. In China, many low-income farmers are producing more cotton with less pesticide through the use of Bt cotton. But in other developing countries, skeptics are turning farmers against the cultivation of GM crops. Of course, developing countries could try to follow the examples set by Argentina, China, and the United States, where genetically modified agricultural products (such as soybeans and maize) are already widespread. About half of the soybean area in the United States and more than one-third of the maize area is now sown with genetically modified seeds, and GM crops are used in many processed food. Of course food safety issues should be adequately addressed before popularizing such foods, but one must work harder to exploit the potential of biotechnology.

Biotechnology has enhanced the efficiency, effectiveness, speed and precision of plant breeding across the world, but progress has been slow in developing countries. Transgenic crops are grown on over 45 million ha worldwide, but the area in the developing countries is very small. Except for a few countries like Brazil, China, Egypt, India, and South Africa, there is little biotechnology research on food and agriculture in the developing world. One reasons is that much of the research is conducted by the private sector, which finds it unprofitable to work on crops that are important for subsistence farmers. International institutes such as ICRISAT and others do conduct this research, but a handful of institutes cannot meet the needs of small farmers in developing countries. Many developing countries are shying away from biotech research for the fear of IPR restrictions imposed by developed countries. Clearly, policy and institutional arrangements must be strengthened to improve access to technologies needed by developing countries.

INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT)

ICT represents the newest tools that store, process, share, and disseminate information. The use of computers and the internet is increasing at a fantastic speed, especially in Asia. The World Wide Web is now increasingly being used for scouting information and online marketing of goods. But it has not been used on any significant scale to improve the livelihoods of poor farmers and make their agriculture profitable. ICT can spur the growth of agricultural markets by providing timely information on marketing cycles for various produce. For example, in hundreds of villages in Bangladesh, people are investing in cell phones for profit. They rent phone time to neighbors, who in turn obtain higher prices for their crops with the availability of real-time market information. In both Ghana and India, coastal fisherman, while still at sea, have used cell phones to obtain the latest information about markets prices.

In India, spread of ICT and its advantages to rural communities is becoming increasingly evident. Fishermen are beginning to learn how to access the web for weather forecasts before venturing into the sea. The India Tobacco Company is setting up 'e-chaupals' where soybean and coffee farmers can sell, reducing the role of middlemen, and ensuring that farmers receive a much higher share of the final consumer price. The days of farmers hanging around market yards and waiting for traders and agents to examine their stocks and dictate prices are numbered. As these poor farmers begin to use ICT on a wider scale this will develop into a new type of marketing arrangement. ICT can also help in modernizing agriculture and providing just-in-time market and storage information of agricultural produce, timely data on prices of farm inputs, agricultural implements, new agricultural options, labour supply situation, climate forecasts and opportunities for diversification of income sources. ICT can thus help foster a safe, healthy, tightly coordinated, demand and supply system based on accurate information.

Technologies are continuously being developed that will fuel the rapid spread of ICT in creating a rural awakening. For example, the Indian Institute of Technology in Madras has pioneered the use of a brand new digital wireless technology for rural areas in Tamil Nadu, Madhya Pradesh, Jharkhand and Uttaranchal. This is based on CDMA technology that allows simultaneous data transmission and will greatly facilitate communications in rural areas. Another example is the low cost access use of satellite connectivity that many rural development organizations can share. ICRISAT is using this for its project in India.

Farmers can also get email advice from experts about their agricultural problems. Computer aided and internet connected Virtual Colleges linking scientists and rural poor can be established at local, national and global levels. Together, these initiatives can launch a knowledge and skill revolution. ICT-based agricultural extension will create knowledge services in rural areas in ways that are unprecedented. Combined with open and distance learning, this will bring about fundamental changes in the way agriculture is practiced. This was the import of the statement on virtual colleges that was independently mentioned by Dr MS Swaminathan. In other words, ICT promises new opportunities direct to farm families as well as to development administrators in rural areas.

Simulation modeling and Geographical Information System (GIS) are more specialized ICT tools that will take longer to provide direct benefits to rural poor than the inexpensive mobile phone. However, their potential is already being demonstrated. Simulation modeling can accurately provide farmers with reliable information on sowing date, timing and quantity of irrigation or fertilizer, extent of pest damage, etc. It can simulate scenarios to identify alternative cropping systems, and if combined with real time economic indicators, it can help farmers choose alternative cropping options. Insurance companies can determine the extent of crop compensation to farmers in the event of crop failures and settle claims quickly and efficiently.

GIS technology provides means for visualizing physical, social, economic factors, extent of land degradation, and cropping patterns. Villagers can relate easily to a geographic representation of their environment. So one direct application of GIS is in participatory mapping to create inventories of natural resources and property status, land use rights and perceived problems. Detailed information about these can enable better targeting of appropriate technology to the environment. Preparation of poverty maps can sensitize planners to target interventions.

Lack of literacy, social and physical capital, or even electrical power, will make it much harder to bring ICT to the door steps of the poor, but with a strong will, one can make ICT an integral part of agriculture. In India, ICRISAT is pioneering the use of ICT at grassroots level to enhance drought-preparedness among rural communities. ICRISAT is working in partnership with a number of ICAR institutes and open universities and hope to include institutions such as the IITs.

ALTERNATIVE ENERGY SOURCES

Shortage of energy is both a consequence and a cause of poverty. Time which could be spent on other activities is wasted in gathering fuel wood, crop residue and animal dung. Animal dung provides about 75% of rural energy needs. However, this inappropriate use is causing not only loss of vital manure, but also indoor pollution that eventually affects women.

A number of alternative sources of fuel have been suggested for rural areas for ecological sustainability that remains to ensure food security. This includes for example, harnessing renewable energy sources (wind, solar, and biomass) through biogas plants, solar lighting and heating systems, improved cooking stoves, improved kerosene lanterns and water mills. These alternative energy sources are effective, sustainable, and can transform the lives of poor people. In many rural areas in South Asia, electrification is still a distant dream. An alternative such as biogas can provide a sustainable supply of fuel, and protect the environment by reducing the dependence on forest wood for fuel. It is especially beneficial to women and children as it reduces their drudgery and save them from the hazardous consequences of pollution. Unfortunately, most of these technologies are highly capital intensive in spite of the decline in prices in recent years. They have not been able to benefit the poor substantially beyond a pilot scale. The possibility of diverting some of the subsidies from polluting fuels (such as kerosene and thermal power plants) towards alternative energy sources should be explored.

FOOD PROCESSING AND STORAGE

Other examples of appropriate technology include food preservation and post harvest processing. Lack of proper processing and preservation technologies forces farmers to sell their produce in raw form. Lack of sanitation causes food contamination that results in poor health and illness. Many farmers cannot store their food grains and horticultural produce and are forced to sell them immediately after the harvest when prices are low. A number of options have been developed for product processing that increases both longevity and nutrition, so that the products could be marketed at higher prices as well as consumed at home. This largely applies to fruit and vegetables, which are more perishable than grains. Food preservation through safe irradiation practices is one way to reduce perishability at a relatively low cost.

IMPORTANCE OF VEGETABLES

In this presentation, I did not discuss a great deal on vegetables on which the International Conference on vegetables is focused. Vegetables are important source of vitamins and nutrients and therefore require important consideration while devising strategies for sustainable food security. Also, vegetable production is as an important source of livelihood for the rural poor as it provides alternative sources of income and increases opportunity for on-farm employment. In many developing countries returns from vegetable production are twice the returns from rice crop. According to an FAO estimate, average world's annual vegetable production during the 1985-95 periods was 489 million tones. There is about 3.2 % increase in vegetable production per year. The estimated annual production value for vegetables over the period 1993-1995 amounted to an average of US$ 159 billion. The largest vegetable production area in the world is in Asia with 61% of the total production and an annual growth rate of 5.1% per year. The two largest vegetable producing developing countries are India (19.4%) and China (48%). The vegetable production in Sub Saharan Africa is <4% of the world. ICRISAT has initiated projects on African Market Gardens to increase vegetable production and revitalize farm economy in the region. ICRISAT has also devised gravity fed irrigation systems that are becoming popular among farmers. Many of the problems, which affect crop production in these countries, also affect vegetable production. In addition, vegetables due to perishable nature also have problems of storage and transportation. While developing appropriate technology vegetable production should also receive adequate attention for it provides excellent options for diversification and in creating employment opportunities for the rural poor. A careful integration of the crop and vegetable production systems will be of critical importance for ensuring sustainable food security.

EPILOGUE

The Green Revolution resulted from science-led appropriate technology. It has been extremely successful, but needs to be replicated elsewhere. Success stories of this kind should not be a rare event. One should strive to use science to generate such technologies more often and for the benefit of communities that the Green Revolution has by passed, especially for those living in semi-arid regions. I have tried to describe broad areas where appropriate technology can ensure food security and alleviate poverty. Many more examples can be given; the basic message is that the value of a technology depends on how much it can benefit poor farmers.

Development of more such appropriate technologies will require continuous investments in research, especially in publicly funded institutions. Unfortunately, budgets for agricultural research are falling, which means we are being forced to scale down research when the need is for more expanded research programs. Luckily, the recently concluded World Summit on Sustainable Development (WSSD) has put agriculture back on the world's development agenda. Many developed countries, which have made generous contributions to research, are willing to increase or maintain funding and in some instances specifically to the CGIAR that has helped many developing countries in Asia achieve food security.

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