Introduction

The basic aim of development is to improve the living standards of the people. In today's inter-dependent world people everywhere have expectations of adequate food, better creature comforts, the possession of consumer durables, such as radios and means of transportation, better education and better health care. Development means all these things to them, but few developing countries today can provide them. They may have difficulties owing to their historical and cultural backgrounds and they must live with their inheritance of natural resources.

In the western world, particularly since World War II, development has been characterized by rapid, technical progress, low rates of population increase and a decline in the demand for farm products in relation to the growth in incomes.

In developing Asia and Latin America similar trends are visible except perhaps for population growth. In the least developing countries, however, and most of them are in Africa, the reverse seems generally to be true; technological change is not occurring, population is increasing rapidly, and the demand for farm products, particularly food, is increasing.

In the 17th and 18th centuries agriculture and farming in the western world meant much the same thing, as it does today in these developing countries. Villages were largely self-contained. The changes whereby farm inputs were made and food processing was carried out in towns and cities started with the Industrial Revolution and accelerated in the 20th century. Today in the industrialised world only a small percentage of the people live on farms but a large percentage is employed in agriculturally-related industry. Growth in agriculture and the production of agricultural products surplus to immediate needs have contributed significantly to growth in all other sectors of the economy.

Developing countries may not wish to follow the same path towards development that has occurred historically in the industrialised world, particularly the decline in the number of people employed on

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the farms and the migration of people to the cities. Unfortunately there is much evidence to show that this is exactly what is happening, particularly in Asia where agricultural growth over the last three decades has been significant and surpluses of agricultural products are already, if temporarily, available. In most of the less developed countries, however, and I refer now to those 40 or more countries of the world where GNP per capita is still below US $500, the production of agricultural goods and particularly food is falling below demand. Greater efforts in food production are required. Can they succeed without damage to the environment?

Most development economists, today, would probably subscribe to the view that increasing agricultural productivity, that is, yields per unit of land or labor, is the surest way to increase food production. But improving productivity impacts directly upon the natural environment.

Changes in soil and water management are needed to achieve increases in productivity. Where arable lands are scarce, trees are cut and wetlands are drained. Where natural rainfall is insufficient, runoff is controlled and soils are irrigated. New and improved types of plants and animals responsive to improved management and the use of manufactured inputs are used. Chemical fertilizers are added to the soil, pesticides are used to protect the improved types from insects and diseases, and more energy is applied to soils through machines or animal drawn implements.

None of these changes are necessarily bad; they are compatible with environmental concerns if they are undertaken wisely. The environmental problems caused by agricultural and industrial development that plague Western Europe are not found in many places in the developing world; where they do exist it is usually because of poverty or ignorance.

The Impact of Poverty

The protection of the environment requires the wise and effective use of soils which cannot always be afforded. People who lack the simple necessities of life may not be able to consider the long term implications of the agricultural practices they use. Their greatest concern is survival; for themselves, their families and their animals.

In parts of Africa, for example, in colonial times, effective programs of soil conservation were established to protect landscapes with highly erodible soils. After independence many of the programs were abandoned and severe soil erosion and landscape deterioration has occurred. In some cases new governments gave low priority to conservation; they allocated their scarce resources elsewhere. But many of the colonial conservation schemes were flawed in that they did not heed the needs, customs or resources of the local people.

Subsistence farmers could not afford to maintain the conservation programs, which in some instances had deprived them of the use of portions of their own lands. Once people were free to make a choice this could not continue. Only when these poor farmers have increased
their incomes will there be any hope of restoring and sustaining erosion control.

The Vertisols of Central India are highly erodible soils. Because early rainfall is erratic and the soils are hard to work when they are wet many farmers leave them fallow in the rainy season and crop them only in the postrainy season on residual moisture. The soils erode, and production and profits are much below what is possible.

ICRISAT has developed a successful watershed-based technology for double cropping these soils. It involves:

- cultivating the land immediately after the previous postrainy season crop when the soil still contains some moisture and is not too hard;
- improved drainage with the aid of field and community channels and the use of graded broadbeds and furrows;
- dry seeding of crops before the monsoon rains arrive;
- the use of improved seeds and moderate amounts of fertilizers;
- improved crop mixtures and row arrangements;
- improved placement of seeds and fertilizers for better crop stands, and
- attention to improved plant protection, particularly for the legume crops.

Over seven years of test at ICRISAT Center the increased annual value of the crops averaged Rs 4000/ha and farmer profits were increased 2-1/2 times. Because the soils are covered by vegetation during the rains erosion is greatly reduced. In adopting the new technology farmers are quick to take up the double cropping systems, the improved seeds and the use of fertilizers. They are slow to take up conservation measures like broadbeds and furrows. Fortunately the most important erosion control measure is to crop the soil during the rains and this the farmer seems willing to do because he can make extra profits. When the broadbeds and furrows are used, they must channel runoff water into natural drainage ways. Farmers must improve the drainage ways and connect them to the community drainage system. This they are willing to do only if the government pays them.

They are not being unreasonable. The community shares the benefits through reduced silting of its reservoirs and reduced flooding in its streets, and so the community, through government programs, should share the costs as well.

It is estimated that there are at least 310 million hectares of Vertisols and associated black soils throughout the developing world. Most are uncultivated or underutilized but all have high potential for
improvement. These soils have unique physical properties that affect their manipulation for use. They occur, often, in climates with high temperatures and variable rainfall. Crop, land and water management are all difficult and need research.

A research network comprising scientists from the national agricultural research systems, and from the IARCs, including the newly-established International Board for Soil Resources and Management (IBSRAM), has recently been established to improve the productivity of these soils and reduce their known susceptibility to erosion. The net effects from the network will be improvement in national agricultural research capabilities, more use of Vertisols, and, most importantly, increased crop and animal production on a sustainable basis to meet the needs of the growing populations of the developing world.

The Impact of Ignorance

Ignorance about how to use agricultural chemicals wisely can also have devastating effects on the environment. In the last 3 to 4 years in the eastern part of the state in which ICRISAT's headquarters are located, that is, the state of Andhra Pradesh in India, farmers have found it profitable to grow cotton. Their biggest problem has been insect attack by white fly and the cotton bollworm, Heliothis armigera, the tropical world's worst insect pest. They controlled the insects initially by the use of insecticides formulated from synthetic forms of pyrethrum, generally amongst the safest and most effective of all such chemicals.

Unfortunately through ignorance, the persuasions of unscrupulous insecticide dealers and in the absence of expert advice, the farmers equated increased profits with increased amounts of chemical and excessive numbers of sprays. This year a catastrophic situation erupted through the combination of a poor cropping season and new generations of insects almost completely resistant not only to the synthetic pyrethroids but to all available pesticides. The crop has been virtually wiped out. Many farmers, at least 20 according to the newspapers, have committed suicide out of desperation and anguish. The resistant insects appear already to be spreading to neighboring districts.

Heliothis armigera also attacks pigeonpea, one of ICRISAT's mandate crops. We have been working for more than ten years to develop pigeonpeas that have natural resistance to its attack. Although cultivars with complete resistance have not been produced, several tolerate Heliothis attack quite well and sustain much less loss than susceptible varieties.

The new resistant forms of Heliothis armigera have been carried on the wind from the cotton growing districts to ICRISAT. We find them 40 times more resistant to pyrethroid insecticides than their local brethren but no more devastating to the tolerant pigeonpea lines.
Developing resistant varieties is the Centers' main approach to integrated pest management, but we also work on alternatives such as biological control through natural parasites of the pests. An interesting and novel line of investigation is being developed with *Heliothis* through cooperation with the Max Planck Institute for Biochemistry at Munich. Professor Rembold and his colleagues have extracted chemicals from pigeonpeas and chickpeas that attract egg-laying *Heliothis* females. A recent formulation combining four chemicals extracted from chickpea has been successfully utilised in field traps at ICRISAT for the first time this year. Although few females were caught in the blank, control traps contained none. By further developing such approaches we hope to limit losses due to insects without the use of pesticides.

The Goals and Strategies of the IARCs

The efforts of the IARCs to intensify food production without adverse effects on the environment are oriented towards small farmers. The Centers are dedicated to the wise and efficient use of both natural and human resources.

The Consultative Group for International Agricultural Research (CGIAR) which supports the Centers also provides guidance on the orientation of Center research and training activities. The most recent goal statement of the CGIAR was adopted in 1986. It reads:

"Through international agricultural research and related activities to contribute to increasing sustainable food production in developing countries in such a way that the nutritional level and general economic well-being of low-income peoples are improved".

Concerns for efficiency, equity and the environment are explicit in the statement. The research strategies of the Centers must take all three into account.

Although technology developed as a result of Center research is generally scale neutral, that is, it can be used equally by small and large farmers, the Centers orient their work towards the crop and animal production systems utilized by small, resource-poor farmers. For them the risks involved in making monetary inputs for fertilizers, feed supplements and pesticides are high. They need stable varieties of crops resistant or tolerant to stresses, with yields that are consistently higher than traditional varieties under traditional management but responsive to whatever improved management farmers can afford.

One serious limitation to increasing yields under harsh conditions is the narrow germplasm base of many traditional crop varieties. Variability can be introduced from the large stocks of germplasm resources that the Centers collect, maintain and distribute. The Centers hold 14% of the world's plant genetic resources collections; they make them available to all users.
The Centers emphasise resistance to major diseases and pests and tolerance of major stresses, in their research. They ensure that these qualities are durable and that yield potential is retained. This involves the use of screening techniques that will identify broad based genetic resistances and tolerances, which can be incorporated into elite breeding material. The resulting improved germplasm is then screened in many situations which include exposure to high levels of stress and contrasting levels of farming.

Improving quality of the mandate crops is also a major goal. Emphasis is usually on nutritional quality, but storability and consumer preferences, particularly for taste and cooking quality, are included. The advanced breeding material produced must be easily incorporated into national breeding programs and yet contain sufficient variability to allow adaptation to local situations. The IARCs spend most of their efforts in producing advanced breeding lines for national programs to use in their own scientific efforts, not in producing finished varieties.

Crop residues are recognized as an important source of fodder for livestock and of fuel in domestic households in the developing world. Research on crop improvement and on resource management both recognize the value of fodder and fuel, the former often ensuring the availability of animal power on small farms, and the return of animal droppings to the soil.

Another important aspect of the work of the Centers is research on improved systems of resource management aimed at attaining balanced production systems at moderately high levels of productivity. A farming systems approach is used to ensure that small farmers have significant input into research planning and that improvements in agricultural systems are relevant to farmers' circumstances and the agricultural policy environments within which they must produce.

A farming systems approach also means the use of systematic ex-ante or prior assessment of technologies in relation to the criteria of efficiency, equity and the environment. Such prior assessment, although still imperfectly performed, is one of the best available means of taking into account the possible long term effects of new innovations.

Policy Guidance

The CGIAR through its goal statement and its regular meetings provides policy guidance to its Centers. It has also established a Technical Advisory Committee (TAC) which looks in detail at each Institute's plans, priorities and strategies. TAC is responsible for ensuring that each Center undergoes an intensive, external review on a 5-6 year cycle. Review panels comprise distinguished scientists and administrators who spend a month or more making an in-depth evaluation of all aspects of the Institute's programs and management. The review reports are discussed within the Centers, between the Centers and TAC, and eventually by the CGIAR. They influence the future directions of research and training and the future contributions that donors make to the Centers.
Where Centers have activities in common, TAC will undertake what is known as a Stripe Review. Such a review examines commonalities in approach, the opportunities for inter-Center cooperation and synergism, and the removal of infructuous overlap. For example, TAC and the IARCs recently undertook a Stripe Review of farming systems research, a subject of great relevance to environmental concerns. A workshop on farming systems research in 1986 was attended by 10 of the 13 centers and by farming systems experts from developing and developed countries. The workshop developed a common terminology for farming systems research so that scientists could communicate more accurately with each other and agreed upon common approaches to the subject. The involvement of the farmer in the research, the need to undertake baseline studies of physical, climatic and biological resources and of socio-economic conditions and the importance of on-farm research were highlighted as essential components of the farming systems approach. The workshop also underlined the importance of cooperation in farming systems research between the Centers and national agricultural research systems.

United Nations agencies, particularly UNEP, FAO, and WMO are often involved in planning and evaluating the work of the International Centers. FAO is one of the cosponsors of the CGIAR and it and UNEP attend all CGIAR meetings. Their representatives also attend many Center workshops and reviews. In 1983 several of the international Centers and national agricultural research systems worked together with UNEP and FAO to develop a set of farming systems principles for improved crop production and the control of soil degradation in arid, semi-arid and humid tropics. The work was a contribution to the development of world soil policy and soil charter statements by the UN agencies involved. It reflected concerns about increasing dangers of soil degradation due to bad agricultural practices.

The outcome of these consultations has been the publication of a set of guidelines which stress the need for national development programs to emphasize the formulation and implementation of environmentally sound agricultural policies and practices. The guidelines recognize the importance of undertaking research that will lead to new and improved technologies, productive and profitable enough to pay for the conservation measures that are needed. We all share a common concern that improvements in production do not lead to degradation of resources. Profits without conservation will not provide lasting benefits. Neither will conservation without profits.

Some Issues

Sustainability: Explicit attention to sustainability is a relatively new aspect of the work of the Centers, although it has been implicit in much that we have always done. TAC and the Centers have worked together in recent years to complete a study on the implications for international agricultural research of sustainable agricultural production.
A dictionary definition of the subject would suggest that agricultural systems are sustainable if production can be maintained at current levels. In that, static, sense many traditional agricultural production systems have been sustainable for centuries. The needs and increasing aspirations of expanding numbers of people force us to a more dynamic view.

Sustainability and concerns for the environment cover much the same ground. If there is a difference between them, it is perhaps that the term "sustainability" conveys the idea of a balance between human needs and environmental concerns. The CGIAR accepts the proposition that human needs will increase and that the environment need not suffer. We do not know that this is true. To make it so we must find ways to make agriculture greatly more productive without increasing the use of external inputs and we will need a much better understanding of the long term implications of change. We do not believe that these subjects can be handled by the CGIAR alone, but it is possible that the Centers can have a disproportionate impact through their ability to influence the nature of research in national institutions.

The exemplary contributions of the international research centers have been specifically recognized in "Our Common Future", the report of the World Commission on Environment and Development. We have asked our donors and other components of the CGIAR system to help in focusing attention on sustainability and encouraging governments and relevant institutions to accord it high priority.

High versus Low-inputs: Much of the public concern in industrialized countries about the sustainability of agriculture has been generated because of the development of high-input agricultural systems. Without them, it is claimed, it would not be possible to meet the food demands of an increasing world population unless more, and less suitable, lands were brought into cultivation. Without a more intensive agriculture, sustainability would be sacrificed, but with it sustainability is certainly not assured. There are many disturbing features about highly intensive agriculture.

The use of high input agriculture in the developing world is increasing and the CGIAR institutes devote time to it. We must work to help prevent the misuse of such technologies. By and large, however, the international centers work towards improving agriculture at a much lower level of productivity using far fewer commercial inputs. Research that emphasizes the recycling of nutrients, the incorporation of crop residues, and the use of intercropping systems—including agroforestry—and the combinations of cereals and legumes, are contributions to the sustainability of low-input agriculture. So too are the development of crop varieties tolerant to environmental stresses, and of animals and crops tolerant or resistant to existing pests and diseases. Farming systems approaches are used to incorporate these components into systems of sustainable agriculture.

In much of West Africa, the soils are extremely deficient in phosphate. It is such an overriding constraint that the improvement of other system components provides little benefit, certainly not
enough to allow farmers in these regions to contribute significantly to increasing food production. Many West African countries, however, have exploitable deposits of phosphate rock. Moving the phosphate from where it is concentrated to where it is needed would transform the agriculture of West Africa over time. It would reverse the trend towards desertification, make other improved components viable and profitable, and contribute substantially to agricultural development.

**Favorable versus Less Favorable Environments:** Many soils are inherently productive. The prairie soils and chestnut soils of temperate regions have long been the breadbaskets of the industrialized world. In the developing world, too, there are favorable regions for intensifying agriculture. The Vertisols and their high potential have already been mentioned. Soils known as rhodustalfs and eutrustox occupy vast areas of the tropics and are equally underexploited. The natural and derived savannas, ecological regions with rainfalls generally between 700 and 1400 mm, have fewer constraints to development than dryer or wetter regions. Intensified agriculture is more sustainable in these places than in others. Higher population densities than currently exist could often be sustained.

The resettlement of people from less to more favorable environments has long been government policy and social practice in many developing countries. Even with good developing planning, however, and almost invariably without it the short-term results have often been disastrous, both in human and environmental terms. When national boundaries are involved, resettlement is both socially and politically unacceptable.

Consequently, no matter how difficult the problems may be, it is not possible to envisage a sustainable worldwide strategy which develops only the favorable environments at the expense of the less favorable. Increased demand for food will have to be met where the demand exists. The CGIAR institutes, CIAT, ICARDA, ICRISAT, IITA and ILCA all have area-related mandates that require them to devote portions of their work to less favored environments in the humid tropics, dry semi-arid tropics and arid regions. They accept the challenge of serving the needs of people in these more difficult regions.

**Conclusions**

If it is agreed that the people in the developing world have a right to live in dignity, then their countries must have the right to grow. The Stockholm Conference, in 1972, recognized that poverty is pollution. The International Agricultural Research Centers are dedicated to removing this form of environmental degradation.

The most important way we can help the poorest people is to help them reduce the costs of their staple foods. To do so we must strive to make agriculture in the developing world more productive and more efficient. The Centers are well aware of environmental concerns. They are targeted to the needs of small, resource-poor farmers and they receive much guidance and advice from the developing nations,
from donors and from the UN agencies. There is no evidence to suggest that the products of their research have led directly to environmental deterioration. If anything, the evidence points in the other direction. In many cases they have succeeded in lifting the least advantaged a few rungs up the ladder of profitability and better living. Only farmers with disposable income have the possibility of investing something in the future.

Sources

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