Rationality of New Technology for Small Farmers in the Tropics

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Summary

Small farm systems in the third world are complex in part because of the many physical, biological, economic, and social factors which interact in the total environment. The farmer and family are also faced with a multiplicity of objectives including providing food and income, avoiding a large investment in production, minimizing risk, and sustaining a food and income supply through as much of the year as possible. A limited land and capital resource base are part of the reality of the small farm, and these factors must be considered in design of appropriate technology. There are many reasons why the "green revolution" technology has not reached most of these farmers. The development of low-input alternatives which lead not only to sustainable food and income, but also to a regeneration of the production resource base are badly needed for these farmers. This rationale has led us to seek new technologies which are "management-intensive" and "information-intensive," in contrast to those which are fossil fuel energy intensive, as a new direction for development in the Third World.

"In designing a technology for small farmers and especially low-income farmers in the tropics, with limited resources, the key problem seems to lie in adapting existing know-how to meet their needs, suited to their environment, and making use of the resources available to them . . . Our goal should be to generate diversified production systems where farmers may make efficient use of existing resources to meet their needs."

Jose Emilio G. Araujo
Director General, IICA
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The complexity of small farm systems is due in large degree to the interactions among physical, biological, economic, and social factors which make up the total environment of the farmer. The rationality which farmers follow in confronting this complex situation is highly influenced by the objectives of the farmer and family. For this reason it is often difficult for the outsider to put some order or degree of reason into an analysis of decision making on the small farm, especially if this outsider comes from another culture, an urban environment, and/or has been trained in a specific academic discipline. This paper explores the complex factors which influence decision making on the small farm in the third world, and the directions which new technology must explore to improve the economic situation and nutrition of the farm family.

The words of Director Araujo focus on the limited resource base of the small farmer, and on the need to promote diversified production systems which depend on existing resources. This approach is different from the emphasis on "green revolution" technical packages, those farming practices which are modeled after successful systems in developed countries and which are highly dependent on fossil fuel-derived fertilizers and pesticides. In contrast, the need of low-resource farmers is the development of low-input systems which meet the objectives of sustainability of production and reduction of risk, while providing a nutritious source of food for the family (Francis, 1981).

Considering the land resource available to most small farmers, there is a critical need to search out methods of improving the fertility and production potential of that limited resource. This has led Robert Rodale (1983) to stress the need for "regenerative" production systems, or those which are highly productive for the farmer while at the same time developing the physical, biological, and human resource base on which production will depend in the future. The focus of this paper will extend to consider the small farmer's objectives in meeting the current needs of the farm family. This is also a long-term strategy for improving the resource base. According to Richard Harwood (1984), adding the long-term time dimension to agricultural production and the regenerative philosophy to the exploitation of the farming environment will lead to a new paradigm in development. New information on biological structuring of cropping systems and a better understanding of the complex interactions among crop, soil, micro-organisms, and physical factors in the environment will move our emphasis away from a "dominance approach" farming which controls the environment but depends on high levels of outside inputs of chemical fertilizers and pesticides. In the future, cropping systems will be characterized by a careful management of interacting physical and biological factors, in what could be called "information-intensive" or "management-intensive" farming systems (Francis and Harwood, 1985). These systems have obvious and immediate importance to low-resource farmers of the Third World. There is no doubt that large farmers will also adopt more energy-efficient and cost-effective practices, and many of these will be regenerative. Many will adopt more quickly than small farmers. However, the constraints facing the large operator are different, as the following sections point out.

Physical Environment

The most important factors in the physical and climatic environment which influence small farm production include soil, topography, air, water, plant nutrients, and excesses or deficiencies of any of these. Examples of the extremes include floods or droughts, excessive cold temperature or frost and prolonged hot drying winds. Often located on the least fertile soils in a region, the small farmer operates at an immediate disadvantage and has little if any control over the factors listed. The physical location and size of the small farm may have been determined by historical, political, social, or economic factors. Whatever the cause, this soil resource is one of the current realities of small farm agriculture. There is little opportunity to move the farm, but there is potential to improve this resource.

Soil fertility is often a limiting constraint to production on the small farm. Unlike a commercial farmer who dominates the soil environment by applications of chemical fertilizer, the small farmer must depend on a different series of strategies. These include rotation of cereals with legumes; mixtures of crops in an intercrop, relay, or double crop pattern; overseeding of legumes into a cereal crop; and a mixture of animal and crop enterprises on the farm. These are all ways to maintain and even improve the soil organic matter and the sustainable productive capacity on marginal lands.

Lack of control over soil moisture may be the most serious constraint in many areas, especially if the small farm is located on a hillside under completely rain-fed conditions. Compared to the commercial farm which is more likely to occupy flat, mechanizable areas and may have access to irrigation, the small farmer must adopt a strategy to optimize the use of rainfall. If this is a lowland area with a monsoon rainfall pattern, the farmer may plant rice during the rainy season and an upland crop with the residual moisture in the dry season. These may be relay or double-planted patterns which take advantage of the short growing cycle of beans, cowpeas, mung beans, or sorghum which complete their growth rapidly and can fill grain on limited residual moisture. The farmer is rational in this choice of a range of crops which diversify the potential crop output and sources of food and income. The pattern makes best use of all available moisture. A similar situation exists for an upland farmer who takes advantage of a single or bimodal rainfall cycle through careful design of the planting pattern and diversity in the crops included. Use of a range in planting dates also spreads the risk of failure of the several crops. These methods of increasing the efficiency of using limited fertility and water are rational ways to deal with a rigorous and uncontrolled physical environment.

It is important for the development planner to consider the effect that different management strategies have on the long-term productivity of this marginal land resource. Heavy use of soluble chemical fertilizers would promote high crop yields in the short run, but could lead to leaching of some nutrients through the soil and into groundwater reserves. Monoculture of mechanized single crops without rotation, a current recommendation in some countries based on projected economic returns, can lead to serious soil erosion which further depletes an already deficient soil resource. In contrast, the intercropping, rotation, and judicious integration of animals into the system can lead to an improvement in organic matter and the development of a more productive long-term soil resource for future production.

Biological Interactions

There are similarities between small-farm agriculture and large farms with high levels of technology. Both involve a series of crop species, the insects and diseases which cause crop loss, and the weeds which compete for water and nutrients. The principle differences are those of scale, where a large commercial farm is focused on one or a few crops with high levels of inputs to control the production environment, and output is measured only in kilograms per hectare or economic return. The small farm is characterized by a greater level of diversity in crops, an integration of small and/or large animals, and a series of other objectives such as food supply, yield stability, or minimizing risk. Savings may be measured by the small farmer in terms of numbers of cattle owned or amount of food or feed stored for the coming dry season.

The multiple cropping systems often found on small farms have a different biology in the cropping environment than a high-tech mechanized farm. Intensive multiple crop systems have evolved to meet specific farmer demands in specific micro-climatic areas. They often maximize use of light, rainfall, and soil nutrients to produce food for the family and for sale, and feed for animals. These systems suppress weed germination and growth, and buffer the system against crop-specific insect or disease problems. This buffering is a function of both diversity in the planting each season and the mixing of crops in the field. When two plant species are dissimilar in growth habit, in root exploration patterns, or in maturity there is a potential for greater total use of nutrients, water and light available on the farm. There is also potential for greater total dry matter production, useful for feeding animals and for returning organic matter to the soil. Since these patterns are labor and management intensive, some of them are uniquely suited to the small farm. It is important to consider that many small farmers must work off farm, and that there are peak labor demands during the cropping cycle when there may not be an excess of labor available. Thus, not all cropping systems which depend on greater labor or management demands may be appropriate to small farmers. Biological systems which spread the demand for labor through more of the year, however, would help the farmer to meet demands for on-farm activities and off-farm income. These are some of the characteristics of the biological environment of the small farm, and how this differs from a large, mechanized agricultural activity. It is difficult to separate some of these characteristics from the economic constraints faced by the small farmer.

Economic Challenges

The tenuous economic environment in which the small farmer and family exist must be considered as a factor in the adoption of new technology. Thus, a consideration of economic constraints and risk must be central to the design of new technology. The prototype small farmer has a limited land and capital resource, and little equity to qualify for agricultural credit under the traditional rules. With marginal participation in the commercial economy and a strong aversion to risk, it is doubtful whether the small farmer should be interested in credit under most circumstances even if it were available. It should not be surprising that the farmer is unable or unwilling to accept a new technology requiring additional investment or perceived risk compared to the present system.

If farm size is small, there is no margin for experimentation or chance to take a part of the farm to try out a new practice. In small farm communities, extension and research specialists may have difficulty finding fields large enough to plant their demonstrations or experiments, as well as trouble finding someone who is willing to cooperate unless risk is covered in some other way. Costs of mechanization, new equipment for application of fertilizer or pesticide, or water control may be beyond the reach of small farm clients, and this is one reason why many of the recommendations which have come from experiment stations through the traditional extension channels have not found acceptance.

There are unique resources on the small farm. Labor availability in the family may help to make scale-specific activities in the intensive multiple cropping area especially suited to a limited land area. Methods of composting or using animal or green manure can take advantage of a labor resource. Value of labor depends on the opportunity cost of this labor vis-a-vis other activities in the area. The fact that the farm is small means that it can be managed intensively, with unique cropping sequences put in practice in each small field and soil situation. This type of scale specificity favors the small farm, and makes it possible to take advantage of the biological potentials outlined above. Farming systems research methods are well suited to understanding the complexity of these farming situations, and participation of the farmer in the design and testing of new technology gives a promising approach toward improving productivity in a way which is perceived as adoptable on the part of the farmer (Norman, 1980).

Social Structure and Influence

The most complex area of concern, and that least understood by the agronomist or animal scientist, is the social, cultural, educational, and political environment in which the small farm family operates. Factors which are important are local culture, educational and other experience of the family, and the social interactions among families in the community. In the broader context, regional and national politics and the degree of national concern with agriculture and the small farm situation can have direct bearing on decisions on the farm. The design of new technology must take into account these factors.

The rise and fall of opaque-2 maize in Colombia illustrates the complexity of how these factors may interact. Developed in the late 1960s, two hybrids with enhanced protein quality were released in 1969 and seed was produced by the national center. A large number of regional trials and demonstrations, plus a national promotional campaign, was instrumental in bringing to the farmer an understanding of the quality of this new maize and how it could help in family nutrition as well as improve feeds for small animals. This valuable new technology appeared to scientists, planners, and extension specialists to be an ideal way to improve nutrition of small farm families. One year after the wide demonstration of the new hybrids, the program was discontinued. Farmers rejected the technology because of insect problems in the field and in storage, cost of hybrid seed needed each season, need to isolate the maize from other normal types, and lack of a market for the new product. There were also changes in the cooking time needed for this new maize. None of these problems was anticipated by the research team, and the farmer was rational in what was perceived as an inappropriate new technology.

Although the green revolution technology has made great changes in the agricultural methods and levels of production in some favored areas of the Third World, there are many farmers who have not been touched by this revolution. It is this challenging sector which development planners and research specialists need to explore. A limited land resource, lack of access to credit, low educational level, and inability to access the new technology may have many social and political roots in addition to the obvious economic differences between large and small farms. To date, the development of technology which has been accessible only to farmers with land and resources has essentially bypassed the majority of small farmers who badly need to improve productivity. It is this need which must be addressed in development of the agricultural technology for tomorrow.

Tomorrow's Technology

In order to make an impact in the complex environment outlined above, we need to seek new approaches in developing technology and in focusing on the rural sector. The easy problems have been solved, and a substantial part of the food in most countries will continue to come from the large and successful farms for some time. Although this production is expensive and somewhat tenuous, the green revolution will help us to buy time while we search for the solutions to a sustainable agriculture, and one which depends on regenerative rather than exploitative techniques.

Sustaining and improving the soil fertility resource can be encouraged by using techniques which add organic matter to the soil, which keep cover over the land during as much of the year as possible, and which minimize or eliminate erosion during intense and sustained rainy periods. Rotation of cereals with legumes, interplanting low-growing legumes in a cereal stand or in the stubble, and intercropping of two or more crops can all help in this process. Use of mixtures of annual and perennial crops can help to cycle nutrients upward in the system, to better explore lower soil strata and reverse or at least balance the usual downward leaching of nutrients. Removal of chemical inputs from the system appears to promote greater biological activity and stimulate the breakdown of organic matter to provide more available nitrogen. Agroforestry methods are being perfected which can lead to regeneration of marginal soils or those which have been completely lost due to intensive crop production.

Pest control through some of the same rotations and intentional diversity in cropping patterns can lead to more economical control as well as a better environment for the farm family and higher quality food without pesticide residues. Since many of the pesticide approaches to control are not available or are too expensive to the small farmer, it is logical to concentrate on control measures which are understood and are compatible with the resource base. Genetic resistance to major insect and pathogen problems can provide control along with the seed, a solution which is economical for the farmer and relatively easy to introduce if the new varieties are acceptable in grain type. Improved varieties have been used as an entry point to stimulate adoption of other technologies such as fertilizer and improved cropping practices. As production increases, this could improve income or farm family nutrition, if appropriate crops are used. Manipulations of crop density, interplanting of several crops, and mixtures of animals and perennials all have potential in controlling weeds. These are all realistic methods of sustaining economic control of pests without complex and expensive technology from outside the farm.

The integration of crops and animals in farming systems has been described. When there are crop residues or products which cannot be consumed or sold, it is logical to feed these to large or small animals and then return the manure to the fields, either directly or after composting. Animals provide a source of draft or transport in some parts of the world and this is a realistic and regenerative way to integrate systems without dependence on fossil fuels. The potential for sale of meat or animal products adds to the diversity of the total system and to its stability. Animals can provide emergency income or ready assets which are available any time for needed cash or barter potential.

The practices of technological alternatives listed all stress self-reliance of the farm family. Although this is contrary to conventional economics which teaches the advantages of specialization and comparative advantage in production, it is realistic to think of a high degree of self-reliance in food and energy on the small farm. The U.S. food system, for example, has a very high proportion of the energy tied up in processing, transport, and sale of agricultural commodities. Not only does this remove the income from the farm family and place the value added somewhere else in the system, it creates an incredible drain on energy which most developing countries cannot afford to sustain. In the macrostructure of agriculture, there is a need for each country to seek a high degree of self-sufficiency in basic food and in principal energy needs as well. Given the uncertainty of world commerce, the influence of political alliances on trade, and the sheer cost of importing food and energy into most countries in the third world where debt has already reached staggering proportions, it is realistic to set policies and development directions which encourage a high degree of self-reliance. These policies must address challenges on the farm, in the region, and in the entire rural food sector.

Conclusions

The discussion of physical, biological, economic, and social factors related to decisions on the small farm was designed to demonstrate the complexity of the small farm environment. This complexity also influences the decisions which are made on the farm and determines in part the strategy which must be employed in the design of new technology. Many of the easy problems have been solved, and there will be a reliance on large farms and green revolution technology to provide food to urban populations for the near future. These systems are highly dependent on fossil fuels, however, and their potential sustainability is in question. For this reason, large farmers will also be concerned about the applicability of energy-efficient and cost-effective alternatives to the current practices. National government decision makers will have to chart a course which includes both the short-term goals of food production and the long term necessity of conserving the environment and regenerating the production resource. It is important for them to realize the unique situation of the small farmer, and the potential contribution which can be made by this sector to national food production.

A new set of objectives and an approach to developing technology which is scale specific for the small farmer has been outlined. This grew in part from farming systems methodology, takes into account the limited resource base including information which is available to the small farmer, and includes some new biological approaches which can lead to other management options. These systems for tomorrow's agriculture may be called "information-intensive" or "management-intensive" farming systems (Francis and Harwood, 1985), as compared to those which are fossil fuel input intensive. We hope that some of this philosophy can begin to permeate the agricultural research efforts of those who are working in collaboration with scientists in the Third World and who have a direct stake in increasing food production for their countries. As important as this concept is to the research and extension specialist, we think it even more crucial to sell this new approach to technology to the decision makers who determine the direction of agricultural research and development. The ultimate impact will be on the farm families which are faced with a need for food and income, and a need to avoid a large investment in production and increased risk as a result of any change in farming practices. Sustained food and income are essential, and some cushion against an uncertain climate. The food crisis in Africa today is just one example of the problems which face an unsustainable food production system. However, the crisis is not without solution. A concentration on the fundamentals of good farming and efficient use of existing indigenous resources, and especially an emphasis on regenerative agricultural techniques, can lead to long-term solutions of food production which will help alleviate or eliminate these problems in the future.

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