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Developing a suitable technology for small farmers

Any technology, no matter how beneficial, is useless if the farmer is unwilling to adopt it. The farming-systems approach assesses a technology's compatibility with the farmer's existing goals, methods, and infrastructure.

by Dr. David W. Norman and Dr. Henry M. Hays

TO MEET the world's future food and fiber production requirements, most farmers in developing countries will have to adopt some kind of improved farming technology which enables their present resources to be used more productively. The question remains, however, as to what makes a technology suitable for these farmers and how it can be developed.

Thinking on this subject has evolved through four stages. The extractive philosophy of colonial times was replaced by the idea that the developing countries would benefit from a transference of technology from the developed countries. Later the concept of developing the technology within these countries evolved. This "top-down" approach used the same elements that had made technological changes successful in the developed countries. But recently this approach for developing a suitable technology has been supplemented, but not replaced, by a "bottom-up" approach known as the farming-system approach.

There are a number of reasons for the changes in thinking that preceded the development of the farming-system approach. The first was the repeated failure, particularly of the first two strategies, in improving the livelihood of small farmers. Policies and technologies were advocated that were incompatible from both a technical and human viewpoint. The second reason is that where improvements in the well-being of small farmers have taken place, it often has not been equitably distributed and sometimes has not been as great as anticipated. A third reason has been the rising costs of fossil energy coupled with an increasing realization of the value of many of the traditional practices used by small farmers in the developing countries.

There is a need to concentrate on the problem of developing suitable technology for these farmers so that achievements are more continuous, equitable, and occur in a systemic way. For only with a better understanding of these problems can public policies be created that will lead to the establishment of the institutions and programs necessary for an effective rural development strategy.

The farming system and the environment

The farming systems that presently exist in many developing countries are a result of attempts over long periods of time to modify the environment. Generally the farming systems are well adapted to the environment in which they are operating, but improvement is still possible. However, since man uses farming systems to fulfill particular objectives, what actually evolves is only a portion of what is technically feasible.

A farmer has certain specified quantities of the four factors of production (e.g., land, capital,

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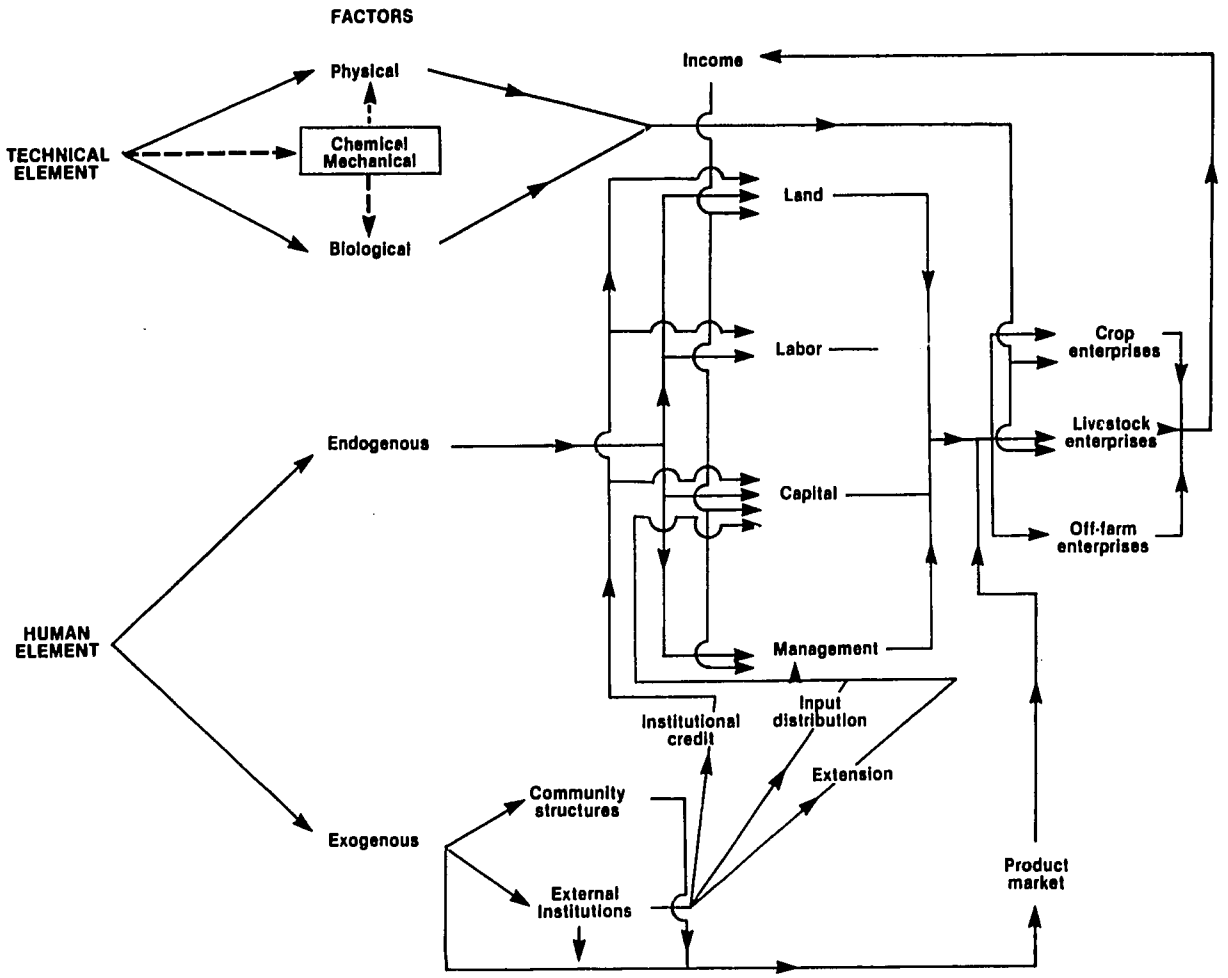

Figure 1. *Some determinants of the farming system*

labor, and managerial ability) at his disposal. With these he can undertake a variety of farming enterprises. The skill of the farmer lies in combining these factors to produce a mix of farming enterprises that enable him to reach a goal. Therefore, the farming systems that usually evolve are complex and go beyond physical and biological elements to encompass economic, social, and sometimes political elements.

Figure 1 shows some basic determinants of the farming system. The total environment can be divided into two parts:

1. *The technical element.* This reflects in the farming system's potential, and therefore, provides the necessary condition for the presence of a particular farming system.

2. *The human element.* This reflects what the farming system will actually be, and is a portion of the systems that are technically possible.

The technical element

In the past the technical element received the greatest attention, particularly, as might be expected, from the technical scientists. They have, within certain limits, been able to modify the technical element and improve the potential farming system by developing technologies that partially alleviate the deficiencies of one of the technical factors.

At this point it is important to explain that the technical element can be divided into two factors: physical and biological. Physical factors are water, soil, solar radiation, temperature, etc. Technical scientists, for example, can enhance water availability through irrigation (i.e., through the use of mechanical techniques), or soil quality through fertilizer application (i.e., through the use of chemical techniques). Biological factors are crop and animal physiology, disease, insect attack, etc. Examples of limited intervention of technical scientists in this area would

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include breeding early maturing varieties of crops and varieties that resist disease.

The human element

In the past the human element received little attention in "traditional" agricultural research. However, it has now been recognized that the relevancy lacked by many improved technologies is caused by a disregard of the human element. This element can also be divided into two factors: exogenous (external) and endogenous (internal).

Exogenous factors are those that the individual farmer cannot control, but which still influence what he can do. Simplistically these can be considered in two broad groups:

- Community structures such as customs of the community, the way the society is organized at the village level, etc.
- Infrastructure, which in developing countries is usually financed and manned by the government, and, therefore, reflects governmental policies.

Infrastructure factors may include efforts by an extension staff to convince the farmer and, perhaps the explicit provision of market support by government. And since most improved technologies are expensive, it also includes insuring that farmers have the necessary resources at the time they are required in order to purchase the technology (i.e., perhaps a credit program will be required). The infrastructure factors may also include ensuring that the inputs required for the adoption of the improved technology are distributed in sufficient quantities to the right place at the right time.

Endogenous factors are those that the individual farmer can influence. As previously stated, a farmer initially has access to certain specified quantities and qualities of the four factors of production. These may, depending on the circumstances and the farmer's wishes, be complemented and supplemented in quantitative or qualitative terms through the provision of exogenous inputs, such as capital via a credit program and management via an extension input. Depending on his constraints and attitudes the farmer then allocates the factors of production he has through three possible processes—cropping enterprises, livestock enterprises, and other non-farming enterprises—in order to establish a farming system that attains his goals.

The farming system obviously is complex, which explains why so often technology thought to be relevant has not been adopted, or when it has, why it varies widely in the degree of adoption.

Requirements for a suitable technology

Technology for agriculture is usually thought of as the application of biological, chemical, and mechanical sciences in order to increase productivity and thus create higher output levels. In most cases, this application is usually the responsibility of technical scientists. A suitable technology, however, is one that provides for increases in productivity in a way that is useful and usable by the small farmer, given his farming system, resources, and constraints.

Therefore, judging whether a given technology is suitable is usually the responsibility of the social scientist, and it is in the researching and making of this judgment that problems arise. This is not a criticism of the social scientist; it is a criticism of the way in which most "improved technologies" have been developed and introduced to the small farmer. To date, little effort has been put by both social and technical scientists into determining the requirements and assessing the suitability of a technology.

Specifically a suitable technology must meet the following requirements:

1. *Technical feasibility.* It must be capable of increasing productivity given the technical elements.
2. *Economic feasibility, dependability, and compatibility with the farming system.* It must be profitable and have a risk level that the farmer can accept as well as have requirements which enable the technology to fit into the existing farm system.
3. *Social acceptability.* It must be compatible with community structures, norms, and beliefs.
4. *Infrastructure compatibility.* It must have requirements which can be accommodated by the present level of infrastructure.

To develop a suitable technology, it is important to understand and analyze all of the existing farming systems. It is then necessary to compare the results of the improved technology (including the four requirements previously mentioned) with the results the farmer is achieving under the existing system. If properly researched, an improved technology will go through several evaluating stages: experiment station trials, trials at the farm level, and farmers' testing. But the final test is the result the farmer is able to obtain using the available infrastructure.

It is vital when considering a new technology to understand the infrastructural deficiencies of the present farming system relative to what the new technology will require if it is to be adopted. Pro-

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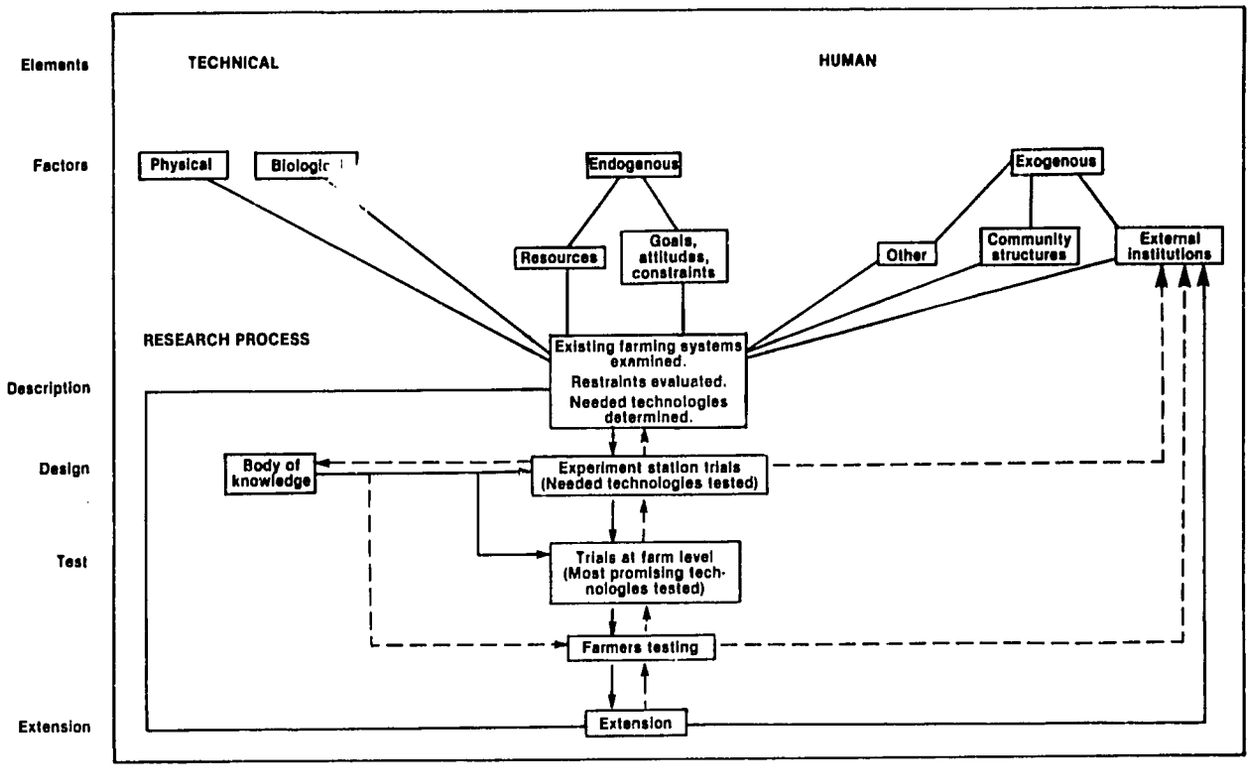

Figure 2. *Schematic framework for farming systems research*

grams will be needed to remedy these deficiencies if changes are to be successfully adopted. The suitability of technology and infrastructure will, to a great extent, be location specific. In other words, the necessary elements of infrastructural support systems (e.g., market for product, convincing or extension input, need for credit, distribution system for inputs, etc.) will vary according to the location and technology being advocated.

See the accompanying box for an assessment of the suitability of an improved technology.

Farming-system approach

Improved technologies often fail because policymakers do not recognize the interdependencies between the existing farming systems, the requirements of the proposed improved technology, and the necessary infrastructural support systems. The farming-system approach recognizes these interdependencies. A farming system approach assesses the technical feasibility of the improved technology, its value to the farmer, and its compatibility with his goals and farming-system, as well as its compatibility with community structures, local beliefs, and the available infrastructural support.

The schematic framework for farming-system research as shown in figure 2 provides a simplistic approximation of the farming-system approach. As can be seen, emphasis is on developing an understanding of the farmer's traditional system by studying the interaction of the technical and human elements. Obviously, participation is necessary by both the technical and social scientists. The four stages of research using this approach are:

1. The descriptive stage in which the existing farming system is examined to determine the real restrictions of farmers, and, therefore, what technologies will be required to overcome them.
2. The design stage in which a range of technologies thought suitable to overcome the restraints arising from the descriptive stage are tested under experiment station conditions.
3. The testing stage in which a small number of the more promising technologies arising from the design stage are evaluated first by trials on farmer's fields and then by the farmer himself.
4. The extension stage in which the technologies found during the design and testing stages to best overcome the constraints set forth in the descriptive phase are introduced to the farmers.

It is not possible to discuss in de-

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One can't wait until new technology is ready for consulting the neighbors.

Assessing the suitability of an improved technology

Assessing the suitability of an improved technological package is a complex process. It involves assessing the compatibility of the package with the technical element as well as with the endogenous and exogenous factors that make up the human element. Consider the following example.

In 1973 and 1974, improved technology packages for sole cropped sorghum, maize, and cotton were tested in the Daudawa area of northern Nigeria. (It should be noted that 1973 was not a typical year for Daudawa, as it was during the Sahelian drought.) The study involved farmers with oxen and farmers whose only power source was hand labor. The actual performance achieved by the farmers using the three improved technology packages are given in table 1. In table 2 the results of a suitability assessment of the three improved technology packages are given, based upon how well the packages met both the technical and human element requirements.

This discussion concentrates on the situation where the technology was not considered suitable or where it was questionable.

With reference to technical feasibility the SK 5912 sorghum variety with a 160 day growing season experienced difficulties in the dry year of 1973; the yield was substantially below the 1974 yield (table 1). It is apparent then that the sorghum variety does not adapt well to the environment in the Daudawa area in any year with a shorter-than-normal growing season. (It should be noted that this area is slightly north of the zone recommended by the Institute for Agricultural Research.)

Obviously. the SK 5912 variety is somewhat unsuitable; therefore, it must be used in areas where the growing season is longer, or it should perhaps be used in crop mixtures, or the biological composition be altered, or a shorter season hybrid might be recommended (table 2). On the other hand, the S 123 composite maize with a growing season of 120 days fitted well into this area's growing season.

With the cotton crop two problems of a technical nature arose. First, the cotton variety recommended at the time required farmers to plant in June instead of July; this conflicted with the endogenous factor of work on food crops. Therefore, the June planting did not fit into the farmers' system (table 2), implying that to improve suitability a cotton crop variety and a set of recommended practices should be used that enable July planting. The second problem which pertains to cotton and is not apparent from the figures presented is use of the ultra low volume (ULV) system of spraying rather than the traditional water-based methods. The elimination of the need for water, the reduction in the time required for spraying, and the lower cost and easy operation of the ULV spraying machine makes this technology more technically feasible for the small farmer.

Assessing compatibility

In assessing the compatibility of these improved technology packages with the endogenous factors the two main considerations are the economic feasibility as determined by profits and the dependability (or risk level) associated with obtaining a certain yield or profit and how well it fits into the farming systems. In terms of yields and profitability the improved packages for all the crops were substantially higher the crops were higher than under indigenous conditions (table 1).

In addition, the co-efficient of variation in yield on the average was only slightly greater for sorghum and it was less for cotton, indicating little difference from a risk standpoint. Except for cotton in 1973, farmers always achieved a yield in excess of that needed to cover all costs of production; again this indicates a dependable return. The results indicated that on the average the improved technology for sorghum was more profitable than for cotton, while neither compared favorably with maize which is not a traditional crop in the area. Thus, from the perspective of a land intensification technology these packages meet the suitability requirements.

It must be remembered, however, that economic feasibility and dependability are only part of the suitability requirements. In terms of fitting into the system there were problems with cotton and a potential problem with maize. As mentioned earlier the requirement of the recommended practices to plant cotton in June instead of July made extra demands on labor that could not fit into the existing farming system. Therefore, suitability can be increased by focusing developmental research on a later planted variety of cotton plant. The extra yield in the maize crop created a problem with threshing. However, the problem was solved by making small hand driven mechanical shellers available to the project.

An additional point of concern regarding the suitability of the improved technology packages is that there is an increase in total labor requirements (harvesting, fertilizer application, weeding, cotton spraying) as compared with indigenous practices. This could create a labor bottleneck.

In regard to social acceptability, it is important to assess how the improved technology package relates to the farming family's personal beliefs and norms as well as to those of the community structure. In this case, there were no problems with sorghum or cotton. However, there was a problem of personal preferences with maize. The variety introduced had hard kernels and grinding it into flour was more difficult than for sorghum. In addition, the hull on the maize kernel was more difficult to remove. Consequently, the mechanical grinder operator charged more for grinding it, and wives did not like to grind it by hand. Collectively, from a consumer's viewpoint, these factors made maize less acceptable than sorghum. Increasing the suitability for a maize crop, therefore, will require a different variety, different methods of food preparation, or better grinding machines.

Exogenous factors are important in the introduction of improved technology packages; this includes the development of an adequate infrastructural support system to deliver the services required to the farmers. The large number of "no" and questionable responses given in table 2 under infrastructure compatibility indicate numerous suitability problems. In developing product markets the main problem is the maize package. Although the yield and profitability of maize is potentially high, human consumption is low and the feed grain market is undeveloped. Therefore, to increase the suitability of the maize package some overt participation by government in the product marketing system may be necessary.

Adopting the package

Maize also presents a problem in that it requires purchase of a substantial quantity of improved inputs, which the present input distribution system cannot provide. The ability of the input distribution system to provide these inputs in smaller quantities for cotton and sorghum is also questionable. In addition to the problem of input distribution, purchasing the inputs requires a larger investment than the farmer is likely to have. So if the packages are to be successful, it may be necessary to establish a credit program.

Finally, the availability of an adequate extension input, which is a necessary infrastructural support, is questionable. This area of Nigeria, prior to the recent implementation of a World Bank project, had a low extension concentration (i.e., one extension agent for 2500 to 3000 farmers). Extension input is necessary because, with the exception of maize, the adoption of the improved technology involves a drastic change from mixed to sole cropping. The adoption also involves changes in operation which affect timing and, in the case of cotton, use of spraying techniques. Both the operations and spraying require expert management which can be imparted, to some extent, through the extension worker.

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Table 1. **Results of the performance of three improved technology packages in Daudawa**

Crop	Level of practice	Year	Yield (kg/hectare) Average[a]	Minimum	Maximum	Coefficient of variation in yield %	Yield necessary to cover all costs kg hectare	% achieving	Net return costing all labour N/hectare
Sorghum (SK 5912)	Improved	1973	1161±385	350	3266	69	302	100	80.77
		1974	1530±245	866	3184	38	648	100	82.46
	Indigenous	1973	436±172	128	960	55	180	83	37.95
		1974	845±112	263	1324	40	267	89	52.07
Maize (S 123)	Improved (Advanced)	1973	2867±516	1133	5031	37	575	100	193.96
		1974	2927±589	1118	5694	43	962	100	186.75
	Improved (Intermediate)	1974	2284±703	1310	3328	37	775	100	152.75
Cotton	Improved	1973	658±125	257	1212	40	462	79	16.60
		1974	784±127	403	1276	37	301	100	80.18
	Indigenous	1973	454±122	200	594	32	236	88	16.72
		1974	364±128	173	695	55	149	100	38.83

[a]*Including 95% confidence limits.*

Table 2. **Results of an assessment of the relevancy of three improved technology packages in Daudawa**

Improved technology package	RELEVANT TECHNOLOGY REQUIREMENTS: Technical Elements – Technical factors: Technical feasibility		Human Elements – Endogenous factors: Economic feasibility dependability, & farming system compatibility			Exogenous factors: Social acceptability		Infrastructure compatibility			
	Physical	Biological	Profit level	Risk[a] level	Farming[b] system	Community structures	Norms and benefits	Product market	Input market	Credit input	Extension input
Sole cropped sorghum (SK 5912)	N	N	Y	Y	Y	Y	Y	Y	Q	Q	Q
Sole cropped maize (S 123)	Y	Y	Y	Y	Y	Y	N	N	N	N	Q
Sole cropped cotton (June/sown)	N		Y	Y	N	Y	Y	Y	Q	Q	Q

[a] The level of risk is measured by examining the variation (coefficient of variation) of the yield. Dependability implies that the variation in yield with the improved technology is not significantly more and, hopefully, less than with indigenous practices.
[b] Given the present state of investigations, this assessment is subjective. There needs to be more rigorous analysis to conform this response, (e.g., linear programming).

Y = yes, N = no, Q = questionable, Indicates whether the improved technology package meets relevant technology requirements.

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Obviously there is considerable scope for increasing production if the requirements for suitable technology can be achieved. But to ensure that these improved technologies have some chance of adoption, it would appear that a costly infrastructural commitment has to be made by the government. But in this case, as in most cases, it is impossible for the government to provide equal infrastructural development in all areas of the country. Therefore, pleasare increasingly being made for the development of improved technologies that accept limitations. These improved technologies can be termed intermediate, rather than advanced.

Suitable intermediate technologies would be types that:

- Do not involve a concentration of extension workers. They would not involve radical changes in the present farming system, and would be simple to adopt, flexible as to timing, and involve little risk.
- Do not involve high improved input investments, necessitating low levels of such inputs.

Admittedly, these constraints make it unlikely that the research worker will develop technological improvements that result in spectacular payoffs. A farmer, however, is more apt to adopt a technology with a lower profit, if it has the characteristics just mentioned.

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tail here the problems and procedures for undertaking each stage. But a number of brief points can be made concerning the schematic framework of the farming-system research given in figure 2.

First, to develop a suitable improved technology it is necessary to recognize the interaction of the technical and human elements. This can best be ensured by the "bottom-up" approach characteristic of farming-system research. This necessitates the establishment of a group of technical and social scientists actively contributing to the research rather than waiting to study the outcome.

Second, there is recognition of the locational specificity or differences between the technical and human elements in any given location. The farming-system research approach recognizes the necessity of assimilating these factors into subgroups and developing appropriate improved technologies for each subgroup. Then an analysis is made to determine the restraints in the existing farming system of the different subgroups. This becomes the focal point for developing strategies that will overcome the restraints or at least prevent them from becoming worse.

The third point is that the farming-system approach recognizes the farmer as a central figure in the research process. It also recognizes that his experience, knowledge, and traditional experimentation can contribute to the improvement of the farming system. At the same time his involvement increases the possibility of developing improved systems that will address the constraints he faces, and by utilizing the positive parts of the existing system will result in a greater response by the farmers to the improved technology.

Thus many of the changes envisioned in farming-system research involve small adjustments rather than dramatic changes. As figure 2 shows, to maximize the role of the farmer and to ensure reality in the research process, work on the experiment station is minimized while work on the farmer's fields is maximized. Initially the managerial input is provided by the research worker (trials at the farmers level) and then later, in most cases, by the farmer (farmer testing).

The fourth point is that this approach by recognizing the farming system creates an appreciation of the multi-utilization of resources. In addition, the farmer's involvement ensures the use of suitable evaluation criteria (i.e., the four requirements for a suitable technology) rather than just the traditional net return per unit of land so often used in experimentation.

The next point is that this approach recognizes that the research process is a dynamic, repetitive process with backward linkage between the farmer and the research worker, rather than forward linkages characteristic of the "top-down" approach.

Finally, the farming-system approach does not seek to replace other basic and applied research (i.e., body of knowledge in figure 2) but integrates the results from such research whenever possible, and sometimes assists by setting priorities.

Too often the resources of both international and national agencies have been wasted in developing technologies that were, from either a technical or human viewpoint, unsuitable for the small farmer. The result is failure in increasing production and in improving individual farmer and societal welfare. Farming-system research with its "bottom-up" approach may help in developing a more suitable technology. Although it is still in the developmental stage and has yet to be shown as an efficient means of improving the livelihood of the small farmer, it does meet the four requirements necessary for a suitable technology. □

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