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An Economic Justification for the Farming Systems Approach

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I. What is the consensus on the farming systems approach?

Not everyone agrees as to what is the exact nature of the farming systems approach, a technique for improving farm welfare in LDC's. There are several questions which can be asked. Why is it necessary? What does it purport to do? Is it not just a convenient way to attract new resources for carrying out what farmer programs were designed to do but never accomplished? To answer these questions, one must look at how farming systems as an approach arrived on the scene, and try to define what are its premises, how it works and what is the economic justification for doing it this way.

In the early 70's several research organizations began to realize that experimental results emanating from research stations were not acceptable to limited resource farmers in their target areas. Initial responses from the point-of-view of the researchers were that the farmers lacked the necessary resources to appropriately use these results. This led to great support for credit and extension programs. However, credit and extension were not enough. The results from the stations could not be matched by either extension agents on demonstration plots or on "good" farmer's fields with

all the inputs. Some agronomists began thinking that maybe the soils and environments found at the research stations were so modified over time that farm conditions were not being simulated. Hence, the idea of research trials on farmer's fields and under common farm conditions were introduced in Asia, Latin America, Central America and East and West Africa. With these advents farming systems as a practice was born.

In the late 70's, these activities had been practiced enough so as to attract a relatively large following. Successes were seen in Latin America and Asia, as well as some instances in Africa. The essence of the approach was to develop and test agronomic recommendations under the farmer's local conditions by running researcher and farmer managed trials in the farmer's own fields. Once results from these farm trials were generated the agronomists had to decide how widespread these results could be applied in the local area. This led to defining regions and conditions that would validate the trial results. They quickly realized, however, that many of these conditions were socio-economic conditions as well as bio-physical. Agro-economic zoning, just as that used in upstate New York to halt the urban spread into good dairy land, soon became an important element amongst farming systems practitioners. How often must the field trials be repeated to adequately cover an entire region and what were all the variables that needed to be considered?

These last questions led to the need for refining the diagnostic survey. Initially, based on these survey results, agronomists realized that "expensive" recommendations could not possibly be applied by poor farmers. Often they simply recommended only 1/2 to 2/3rds of the maximum points identified in their production functions, even assuming they used economic maxima and not physical maxima. But then they found out that simple diagnostic surveys recording farmers' asset levels and farm quality measurements--soils, climate, rainfall, etc.--could not adequately detect true pictures of farm resource limitations. Since then several techniques have been developed for diagnostic purposes.

Some field practitioners did not believe one needed a full-blown diagnostic study before they designed research strategies for on-farm trials. This author remembers the early maize-in-sole-stand trials in the hills of Colombia when cropping pattern surveys showed less than 1% of the area dedicated to sole stand staple crops. The same problem occurred in Puebla, Mexico. Hence, eventually the research design process had to relate on-farm trials to the findings of the diagnostic survey work.

The last observation to make in this historical overview is in regard to how new recommendations are diffused. If researchers develop the packages by themselves, extension agents will remain skeptical. Early inclusion of extension agent staff into the development process is imperative. How

this unfolds is not something to be dictated, but suffice it to say that it needs direct attention when designing farming systems activities.

Five Steps in the Farming Systems Process

The above review suggests that general consensus exists around the world that the farming systems approach involves five basic steps. The first is site selection, either through agro-economic zoning or by delineating recommendation domains or by identifying various dominant cropping patterns. The second step is the diagnostic survey. Several techniques can be employed, by varying time and budget requirements. The quality of the results are not so much a function of effort but of the appropriateness of data collected and its initial analysis. This refers mainly to the degree of variance encountered when mean regional values for asset levels are being developed. The third step in this process is the design of on-farm trials. The true complexity of this phase in the farming systems development process has not yet been recognized. On-farm trials can be researcher-managed, farmer-managed, run as extension pilot plots or demonstrations. The variables chosen for inclusion and the experimental format must be considered. All of this is still in its formative stage. Once the design has been agreed upon, on-farm trials can begin. But as Barker from Cornell noted at the Kansas State Symposium, we perhaps think we know a lot more about how to do this than we actually do in fact.

Nevertheless, we have a lot of experience in this area with several good results. The last step is extension, or perhaps more appropriately diffusion. But anyone who has worked and studied diffusion knows that this is an iterative process. When a recommendation is released, farmers are free to play with it, alter it, choose components appropriate to them, and use it as they see fit given their resource limitations. Extension agents must be astute enough to determine when a recommendation (or part-thereof) is appropriate and when it needs modification. That modification may be required through further on-farm trials or it may be required of the existing set of supporting institutions or policies. And the extension agent, public or private, must ascertain whether to act (interventionist approach) or react (submissive approach) to those constraints which arise to prohibit immediate adoption.

Types of Farming Systems Programs

Much has been written on the different types of farming systems programs. A short review and classification will appear here. Norman (1982) and Hildebrand (1983) have used terminology that divides FSR/E (Farming Systems Research and Extension) from FSIP (Farming Systems Infrastructure and Policies). In the Shaner, et al, Guidelines (1982), two extreme approaches are described, to reflect technology development within the institutional and policy constraints existing in the area and technology development which considers institutional and policy change in the environment as

complementary to the technical changes being developed. Most programs are a mixture of the two, but more has been written about the former rather than the latter in the farming systems literature.

Gilbert, et. al, (1980) wrote about "upstream" and "downstream" farming systems work, describing the "upstream" as the development of prototype solutions for productivity increases, and "downstream" as more of a testing and adaptation process to fit the technologies into the farmers environment and to create the conditions under which they can use the technologies generated. Most of the current reports on farming systems projects refer to "downstream" FSR.

Fresco has recently (1983) written an article which attempts to compare the Francophone approach with the Anglophone technique employed in East Africa. The essence of her article centers on two issues. First, the Francophone approach recognizes the historical evolution of the local society and the institutional constraints which have evolved, and, second, it allows for comparison of the benefits which could be generated by not only productivity increases of existing crops but also from a wholesale change to/or introduction of new activities. The Anglophone approach is more incremental given existing production activities.

It seems, however, that the West African Anglophone approach is much closer to the Francophone, than it is to that practiced in East Africa. The East African system may be

constrained by the fact that it is promoted by CIMMYT, an international research institution without a station based in the area and constrained to a commodity base in maize.

The Latin American model incorporates both the FSR and FSIP activities. In some programs there is more emphasis on FSIP, such as the Desarrollo Rural Integral-Integrated Rural Development (DRI) models of Ecuador, Colombia ad Mexico, whereas the CATIE and CIMMYT models are more FSR with farm validation trials. In Asia, cropping systems techniques are well-developed, emanating from multiple cropping programs at IRRI and Bogor, Indonesia.

All of these approaches use the basic five steps outlined in the first section, but apply them in different ways and orderings, and with varying emphasis. Other systems may exist as well. They are all part of the emerging philosophy of farming systems. Representatives from each school were present at last month's symposium at Kansas State.

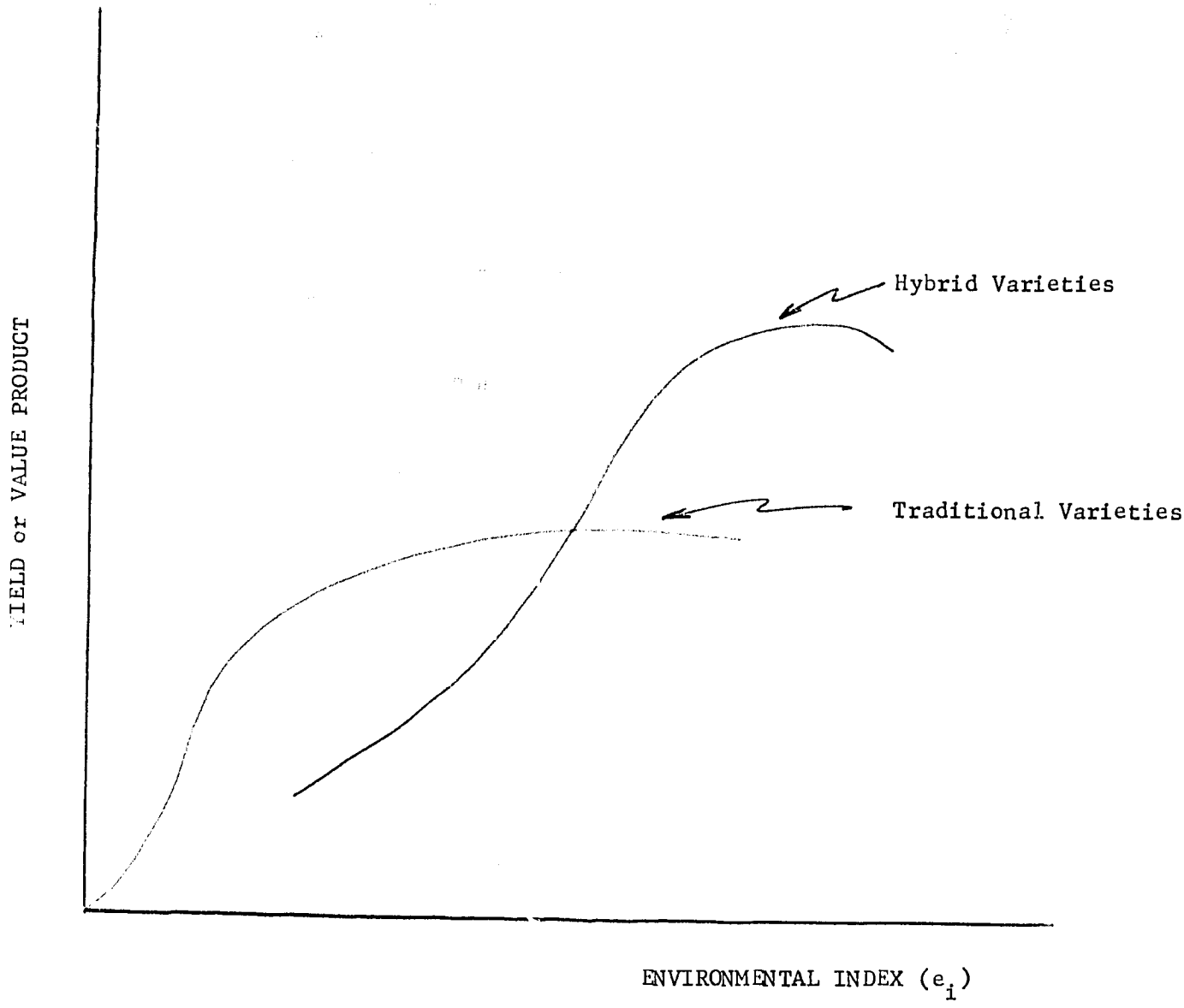
But <u>what</u> makes this approach really unique compared to the way new agricultural technologies have been developed in the past, either in the old days of farm management in the U.S. or the component research approaches practiced by the International Agricultural Research Centers, or the National Research Centers modeled after the colonial interests?

II. Economics of Technology Generation

I submit that there is a very clear, precise economic justification for the farming systems approach to technology

generation for limited resource farmers. It is based on the notion of the stability index developed in plant breeding a few decades ago. When new seeds were developed they had to be subjected to varying environments in order to prove their stability in terms of yields before they could be released. Using this concept as a base, Hildebrand has developed the idea of an environmental index for identifying the degree of spread to which each recommendation can be applied.

Using the production function concept, visualize two crossing functions, with yield on the vertical axis and inputs or resources on the horizontal (Figure 1). When inputs are high, one technology (usually improved varieties) is superior, but when inputs are low, the traditional technology is better. Hildebrand uses environments (farm level test locations) for these input levels and uses a surrogate of treatment yields for all inputs. Hence, individual yields per treatment are measured against average yield per site, i.e., the environmental index. But since ei, the environmental index, is the average yield of all treatments per site, where yield is a function of all inputs, we really have yield as a function of inputs, the traditional production function. If all input variables could be measured, we would not need the environmental index. However, management techniques, input timing, and micro-climatic variations are difficult to detect and defining the structural form of such an equation to catch all of the interactions is virtually impossible. To



FIGUE I. Modified Stability Index (Yield-Environment Index Relationship)

cover these problems, economists often revert to multiplicative forms like the Cobb-Douglas, CES, or Spillman functions in order to avoid these definitional questions. We end up lumping variables together and not measuring individual effects, variable by variable. This causes problems when we attempt to make recommendations. An easier approach is to use partial budgeting with mean input and yield levels, together with input variance measures. T-tests can then be used to determine differences in input effects between environments. But it is difficult to accurately measure marginality with partial budgets.

In light of these specification and measurement difficulties, it appears that the concept of the environmental index can be quite useful.

Let $Y_i = f(e_i)$

Where Y_i = yield per treatment i;

e_l = average yield for all treatments at location l,

and

l refers to each site where trials are run.

Then, $e_l = f(Z_t)$

Where Z_t = inputs $X_1, X_2, X_3 \ldots\ldots X_n$

and X_1 = fertilizer

X_2 = seed quantity (seed type becomes a multiplier or slope intercept shifter)

X_3 = soil fertility

X_4 = climate (same as above for seed type)

X_5 = capital used or access to capital

X_6 = labor used or available

X_7 = management techniques (time of planting, weeding, fertilizer application) probably in error thru or indexed once again wealth, risk levels, etc.)

When a researcher wants to test fertilizer and seed, with some kind of randomized block design or any other format, there is an assumption that all other variables are constant. However, in the real world they are not, and hence, the design is misspecified. Using the environmental index, however, in conjunction with seed type and fertilizer, one can specify the following:

$$Y_i = f(X_1, X_2, [e_1-(X_1,X_2)])$$

$$\text{or } Y_i = A+BX_1+BX_1+B(\text{Farmer})$$

$$\text{where the farmer} = e_1-(X_1,X_2)$$

This specification will allow the the interactions of all other variables. (This, in essence, is what Hildebrand's article in the Agronomy Journal (1984) has done.) To make the partitioning of the crossing production functions effective, some of the remaining X's need to be measured. But this can be done in a stepwise procedure, that is, run the trials first, look at the groups that emerge, (to the right, center, and left) and try to detect outstanding environmental characteristics that place each farm in each environmental group, including variables such as asset levels and access potential. Once these key variables are detected, further regression analysis can be done, drawing them out of e_1 as was done for the X_1 and X_2 inputs, using continuous or dummy variables, and then testing for significant differences of the group levels of each.

Generating Technologies For Stress Conditions

This procedure will allow us to generate the "best" technologies that can tolerate the most stress, as described by our limited resource farmers located on the left hand side of our production function. Presumably, those technologies with the largest area under the curve for each partition will be the recommended technologies. It is easy to partition and select the best technology when only two functions cross in the middle.

However, usually more than two varieties are tested. With a set of crossing curves over the range of environments, the area under the curve becomes the measurement for determining the best technology.

So far, variance has not been mentioned. Partitioning for environmental differences can only be valid if the superior technology as measured by mean or area, is also of relatively equal risk. When risks increase significantly, gains due to the mean may not be relevant in decision-making practice. Several forms of risk measurement techniques exist; many may be appropriate. There is a whole set of safety-first techniques, as well as the stochastic dominance approach. Much more research is required in this area. How do farmers react when recommendations are made for superior technologies in stressed environments when risks (variance) are high? Do they adopt anyway? Or must there be some absorptive activity introduced first? Some farming systems practitioners have addressed this issue with some initial success, but more focused attention and research must be directed towards this concept.

First Stage of the Production Function

If farmers are producing with limited resources, they may find themselves actually operating in the first stage of the production function. Although it is extremely difficult to prove this point with field data, it is worth considering for a moment for the sake of argument. It could also be that some resources are limited to stage I levels of input whereas others

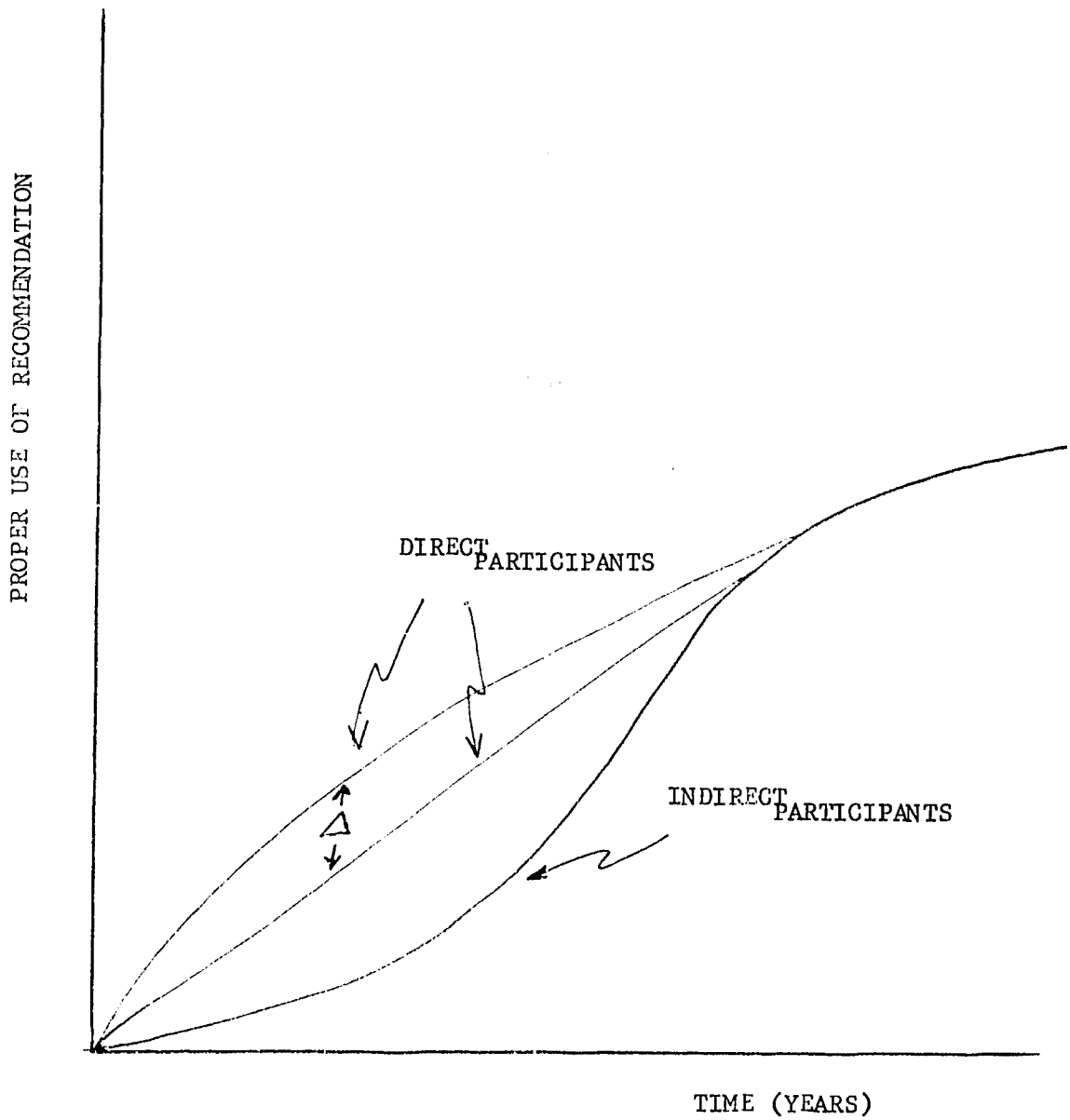
are simultaneously at stages II or even III. It may be that fertilizer is applied under stage I conditions, land at stage II and labor in stage III. If this is the case for an input, we have a problem. If there is a choice between or among enterprises for allocating this resource, the stage I notion causes the following to occur. The production possibilities frontier curve turns convex to the origin rather than remaining concave outward. As the budget or resource limitation line is brought in to tangency it touches each activity along its axis. This leads to specialization, not diversification, as we so often see. But what is actually happening?

The budget curve is not linear for limited resource farmers. It is elliptical because of the shape of their utility functions. As the elliptical curve is brought down to the convex possibilities frontier curve, it becomes tangent somewhere in the middle, thereby allocating resources between the two enterprises, supporting diversification. However, the dynamics of this phenomena are such that equilibrium is not pursued where marginal products equal input prices, but instead, the system drives towards the origin or out of farming. Only with a basic shift in one of the parameters, which could allow for the constrained resources to be applied in stage II of producton, can efficiency in production be achieved. Such shifts could be introduced as subsidized inputs, to raise the quantity available at existing cost levels, (subsidized credit does not achieve this goal because

it only deals with the price of the credit itself, not the value of the principle), the availability of credit to allow for mortgaging the crop, absorbing the risks inherent in the systems so that given asset levels can accept more costly production activities, or generating new technologies which can reach stage II production with existing resource levels.

The Learning Curve

New ways of carrying out agricultural tasks cannot be learned and adopted overnight. Generally, farmers adopt new ideas according to their perception of their costs and risks. The most costly or least remunerative activities are adopted last. This has led some field practitioners to arbitrarily reduce recommendation levels rather than adjust them according to economic principles. It also gives support to the incremental approach, saying that the farmers can only handle small changes. Neither of these conclusions seem to hold given our economic frame of analysis and our knowledge of adoption rates. When costs are reduced, by technology changes or risk reductions, adoption rates jump upwards. Nevertheless, there is a learning process involved. Learning production probabilities for how new crops or techniques produce under varying environmental conditions takes time. Applications of these new techniques or levels of investment will lag as this learning process goes forward in time (Figure II). However, this curve can be shifted to the left with different kinds of training programs or programs to reduce the risks involved as



Δ = Adoption Rate shift caused by Government Intervention

FIGURE II. Learning/Adoption Curves

perceived by the farmer. If the curve is shifted far enough to the left it will also help those farmers functioning in stage I of production to move into stage II.

It is obvious from the above discussions that a great deal of knowledge on farmer's conditions, enterprise activities, asset levels, access to resources, perceptions of risk and uncertainty, market availability, etc. is necessary in order to develop design and transfer technologies and properly design institutional supports. Data collection systems often gather lots of information but fail to adequately measure induced response rates to the changes introduced or to capture the historical dynamics of weather, markets and institutions. Much more work is needed in this area.

Economics of Cropping Patterns

Farming systems research has emerged from cropping systems research, which views how farmers mix their crops within fields and throughout the year. Agronomic field trials on different combinations of crops can determine the spacing and timing criteria which will lead to maximum yields. When resource constraints are added to this effort, different solutions can be proposed to farmers for their trial and error testing. However, economic criteria are strangely absent as a technical tool for choosing the best mix. Partial budgeting is often used to determine costs and gross margins, but value product evaluations are based on "a price" at harvest rather than on real world conditions which say that prices vary on a

daily basis. The question which needs to be studied for different cropping patterns is whether yield variation by date is greater than price variation by date. There may be instances where changing the seeding date of a relay crop may lead to greater returns when real price variations are considered than seeding at the physical optimum would yield. This needs to be developed in detail with good price and market information.

III. Conclusions

Several authors claim justification for the farming systems approach because it incorporates the goals and inter-relationships found within the limited resource farm family, and takes a holistic approach to defining solutions. Nevertheless, in practice, most programs are concentrated on the crop production subsystem, and on introducing new bio-technical modifications to the cropping system. Recognition is slowly emerging that socio-economic constraints may be binding when new bio-physical technologies are developed, and hence, they are now being addressed directly. However, this paper goes one step further and shows that the farming systems approach is a unique application of research methodology designed to develop new and improved technologies which automatically fit within the constraints binding on limited resource farmers. The paper also demonstrates why support programs may be necessary to move these farmers out of the low-productivity trap and into "rational" production

behavior. This author believes that such an interpretation gives a clearer focus as to what farming systems can contribute and what it can hope to accomplish.

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