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REVIEW OF THE SWAZILAND PROJECT "CROPPING SYSTEMS RESEARCH AND EXTENSION TRAINING" (645-0212)

A. COLIN McCLUNG AND KRISTIAN OLAND

October 9, 1980

TELEPHONE (212) 869-8500 TELEX 224862 via RCA or 421824 via ITT CABLE: IADSERVIS, NEW YORK

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20 October 1980

Ms. Lucretia Taylor
Assistant Desk Officer, Swaziland
USAID, AFR/SA
Department of State, Room 6847
Washington, D.C. 20023

Dear Ms. Taylor:

As per our phone conversation today, I am enclosing five copies of the "Review of the Swaziland Project: Cropping Systems Research and Extension Training (645-0212)", prepared by A. Colin McClung and Kristian Oland.

If I can be of further assistance to you, please do not hesitate to contact me.

Sincerely yours,

Claudia A. Gentile

Claudia A. Gentile
Secretary to Dr. McClung

TELEPHONE (212) 869-8500

CABLE IADSERVIS, NEW YORK

FOREWORD

This review was prepared by a team of two persons provided by the International Agriculture Development Service. They were asked to review the Project Implementation Document (PID) with regard to general approach, technical assistance requirements, staff development, physical facilities, and related matters. They discussed the issues with Swazi officials, USAID staff, and other persons. They referred to the documents (Annex A) relating specifically to Swaziland and discussed Swaziland-specific problems and needs.

Annex B provides some background on the increasing interest in cropping systems research in relation to small farm development.

The scope of work for the review did not call for recommendations on specific actions and objectives that the cropping systems project might address. It did, however, touch on the subject and the reviewers developed a number of ideas of an immediately researchable nature. These are recorded in Annex C. While the proposals must be modified and refined by the design team, it seemed that they would provide a basis to get underway promptly with an action-oriented program in Swaziland.

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REVIEW OF THE SWAZILAND PROJECT "CROPPING SYSTEMS RESEARCH AND EXTENSION TRAINING" (645-0212)

A. COLIN McCLUNG AND KRISTIAN OLAND

General

1. The general approach of the project is sound. The indicated goal of improving the economic status of the farmer on Swazi Nation Land (SNL) can best be met by a systems approach in which the whole farm enterprise is the unit of study and action.

2. The program envisioned in the PID and in the design study on which it is based is too experiment-station-oriented. Work on cropping systems should be 80-90 percent done in farmers' fields. The substantial amount of basic crop and soil data already available in Swaziland needs to be tested in on-farm systems experiments.

3. We recommend that the animal production aspects of the farming system not be ignored in the project design. During the initial 5-year phase, it may not be possible to substantially influence animal production. We believe, however, that it is important to evaluate and monitor the animal production sector from the start. This will provide a rational basis for subsequently including animal production aspects in an adequate farming systems research program. We recommend further that some exploratory work be started, even during the third year of the project, on milk production as a means of improving the economic return on SNL farms.

4. The cropping systems research project must be regarded as a full partnership involving the farmer and the extension and research services. The research and extension services must participate in all phases.

5. Major support will be required from institutions which provide training in agriculture at all levels. Support of the Faculty of Agriculture will be particularly critical.

The research division

1. The state of substantially suspended activity which now prevails in the National Agricultural Research Division could seriously hamper the development of this project for cropping systems research must be based on sound technology. However, the establishment of the cropping systems project at a time when the Research Center is being re-staffed and re-structured offers a unique institution-building opportunity.

2. The gazetted posts in the research division should be examined for relevance, and some re-orientation made. New posts may be needed. Specifically, we recommend that posts be created for:

(a) an agricultural production economist;
(b) a soil and water engineer;
(c) a cropping system specialist.

Some of these changes might be achieved by dropping certain specialities from the current list. (For example, a soil and water engineer might be substituted for "soil physics.")

3. Every effort should be made to fill, with qualified personnel, the agreed upon posts in the research service. When qualified Swazis are not available, Swazi training candidates should be identified and appropriate training arranged.

4. While Swazis are being trained, members of the project team might fill certain of the gazetted posts. But this should not (a) alter the project's orientation to working directly with farmers; or (b) delay the training of Swazis to take over the posts on a regular basis, first with counterparts and then on their own.

Research procedures in cropping systems*

1. We recommend that the project enter promptly into an active research program, at the same time making every effort to train local staff through participation in the research and in formal training programs.

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*Please refer to Annex B.

2. The research should be carried out by research teams which are posted in target areas throughout the Swazi Nation Lands. These teams will be integral parts of the project effort. Senior technicians and their counterparts should be based at the Malkerns station.

A typical team would include one technical research officer, one field extension officer, and a selectively recruited young expatriate B.Sc. holder from a volunteer organization. The latter would add a broader base in agricultural sciences which would complement the talents and experience of the Swazi team members.

3. The first cropping season following the initiation of the project should be devoted to:

(a) forming research teams and enabling them to gain direct personal experiences with Swazi cropping systems by conducting observational trials on one or more of the research stations and/or on private farms;
(b) carrying out experiments on aspects of the system to test promising modifications of the systems;
(c) conducting surveys of systems in use in selected target areas.

Selected farmers from the target areas might be brought in to observe and participate in the experimental work.

4. During the second season, the research teams should be placed in residence in the target areas in which they are to work. The general strategy would be for these teams to carry out collaborative experiments with farmers in easy reach of this base of operation. Bicycles and motor bikes could facilitate this travel. The teams should establish a number of simple experiments containing three or four variables that would appear to have a good chance of successful impact.

5. In subsequent seasons the team would modify and expand its experimental work and at the same time would work with interested farmers who wish to try out some of the more promising results from earlier work. New teams should be formed to establish similar centers of research and diffusion in other areas. Work in farmers' fields may vary in complexity but each team should have a target for collaborative work

which might be of the magnitude of 30 to 50 farmers' field activities each year for which records are kept.

6. Because of the scarcity of trained manpower it will be necessary to staff research teams with persons whose training may be less than optimum. These teams will draw on Diploma holders for work that would be more appropriately done by individuals with more advanced training. The greatest challenge of the project will be to develop a viable program under these circumstances. Not only is qualified staff going to be scarce but outstanding individuals will have to be taken out of the on-going program and sent for advanced training as soon as they can be identified. New participants will be brought in to take their places. This means that the regional teams will require constant high quality backstopping from other project staff.

Systems research on small farms is more difficult than traditional work on experiment stations under controlled conditions. To get the job done with few experienced local staff will place heavy demands on the expatriate staff. They will have to be prepared to travel a great deal to support the field teams and trouble shoot problems.

Staff development

1. Lack of Swazis trained in agricultural sciences is the most serious problem facing this project. Further, there are at this time few Swazis with the necessary qualifications to undertake advanced training abroad. The question of what proportion of project resources should be used for training is somewhat academic so long as training candidates are not available.

2. One can only be pessimistic about the availability of Swazi graduates for training for the research officer positions. Projections that the design study team extracted from the University Bulletin of Statistics should be re-examined. For instance, instead of 10 Swazi B.Sc. graduates in 1982-83 there will be none, and in 1983-84 the number is 3 instead of 14.

On the other hand, Diploma holders are coming out of the University in an adequate number. Many will have to be assigned to the project as Technical Officers. Some of these will be good material to be trained as farming systems research officers. Therefore, staff

development for long-term farming systems research should have its major thrust in taking Diploma holders through the B.Sc. and some subsequently to the M.Sc. We recommend that project funds be reserved for advanced degree candidates, but that the alternative of using some resources to support B.Sc. degree candidates not be discarded.

3. The cropping systems project can have an important training function. The research teams which carry out the work in farmers' fields will consist of research and extension personnel. Each season additional research and extension staff can be added to each team to learn the procedures as well as to carry out the work of the project. In subsequent seasons they could become regular members of new teams being provided, or they could return to regular service as field extension officers. At the Malkerns Research Station, diploma and certificate candidates, as well as field extension officers, should be included as trainee members of the cropping systems research project. Specialists from the Crop Production Center at Manzini should be brought into this joint undertaking to facilitate the achievement of their responsibility for giving practical orientation to prospective extension officers.

4. Modest funding should be available throughout the project to permit Swazi scientists to travel to international agricultural research centers and to visit on-going programs in other parts of the world.

Physical facilities and equipment

1. Construction plans should be revised to conform to a highly regionalized program.

2. The proposed new office/laboratory block will not be required during the first 5 years of the project and should be omitted. Funds should be included for refurbishing and adding to existing buildings to provide additional office space for project and gazetted staff.

3. The proposed greenhouses and head house will not be needed to support the cropping systems research program and should not be constructed at this time.

4. No more than one or two new storage sheds will be needed at the central research station. However, some facilities probably will be needed in outlying regions to support cropping systems research.

5. Needs of regional cropping systems research teams should be carefully evaluated. The savings in construction costs as recommended in items "1" to "4" would permit construction of simple utility buildings for the use of cropping systems research teams in outlying regions. These would be used to store supplies, tools, equipment, etc., and to hold meetings with farmers. At some locations sleeping rooms might be included for use of team members.

6. The number of vehicles proposed for the cropping systems project is too low. All that are listed in the PID will be needed but there should be 5 ¼-ton pickup trucks instead of one as given in the PID. Provisions should be made to replace 20 percent of the fleet by the third or fourth year, as well as for spare parts. Some light motorcycles should be provided to extend the range of operation of the regionally-based cropping systems research teams.

7. Review of physical facilities and equipment related to the Faculty of Agriculture was outside the scope of work of the review team.

Proposed technical assistance

1. We agree with the proposals in the PID regarding:

(a) cropping/farming systems specialist (COP);
(b) cropping systems agronomist;
(c) cropping systems horticulturist;
(d) agricultural production economist.

All are to be 5-year assignments. Specific terms of reference, when drawn, should reflect that the focus of the work is the farmers' fields and not the experiment station. Also, it would be desirable for the COP to be experienced with mixed farming systems which include an animal component.

2. The "irrigation specialist" should be re-described as a soil and water engineer. The incumbent should be highly qualified in basic soil and water engineering with orientation to the use of irrigation by small farmers in a tropical/subtropical environment. He must be cognizant of social as well as engineering factors. (In the engineering area, consultants should be used to support evaluation of farming implements research.)

3. The rural sociologist will not be required because a person with these qualifications is being supplied by FAO. (If there is any doubt about FAO continuing this post beyond 2 years, then contingency funding should be kept in the project budget. This post is important to the project.) It is urgent that a Swazi counterpart be recruited and/or trained to take on this work on a regular basis.

4. We recommend that during the first 2 years of the project a second economist be added to study alternative employment opportunities for small holders, to assess current incomes for small holders from these sources, and to participate in establishing income targets for the average small holder following the farming systems which are to be researched.

5. Starting with the third year, an animal production specialist should be added. He should conduct farming systems research on improving the animal production component. Beef, dairy, small ruminants, poultry and other elements should be potential parts of the research program. The assignment of this specialist should be preceded by the baseline surveys of the animal sector. Short-term consultants should be used in developing these surveys.

6. We recommend that 10 Diploma or B.Sc. holders be assigned to the project initially and that this number be increased to 15 in the second year and 20 in the third. Five or six of these would be based at the Research Center to work directly with the expatriate staff as counterparts. B.Sc. holders would fill these posts to the extent available. Diplomates would be assigned to regional systems research teams which would number 4 or 5 in the first and second years and up to 10 in the third year and beyond. In a few cases experienced certificate holders may be assigned in place of diplomates. Certificate holders should be considered particularly for use by the economist in collecting survey data.

7. We recommend that the selected Title XII institution hold a workshop on cropping systems research to review recent innovations in this relatively new approach to dealing with small farm development. Four or five experienced people should be invited to review recent work with particular regard to methodology.

8. Before they start their design work, the project design team should visit one or more on-going farming systems projects in the developing countries. Perhaps they could visit these projects while enroute to Swaziland.

9. Two or three key Swazi officers should participate in "7" and "8" above.

10. Up to five volunteers should be selectively recruited for assignment to the regional research teams. These might be replaced with the same or a larger number at the end of the first 2 years.

11. Review of the posts of lecturers in agronomy and anima. production and of agricultural education and information were outside the scope of work of the review team.

Cropping systems research and the Swazi marketing structure

The review team was not able to investigate marketing problems in sufficient depth to make specific recommendations. Among the people whom we interviewed we encountered a great deal of concern about the marketing mechanism. Although marketing procedures need substantial improvement, we find no reason to delay cropping systems research because of this. Instead we recommend that the project team interact with marketing persons and agencies in Swaziland as it plans and carries out the cropping systems project.

Research proposals and recommendations for the design team*

1. The project should establish income targets for the average small holder particularly through studies of opportunity costs of remaining in agriculture. Small holder incomes from outside the researched systems should be assessed, and the income targets which the systems must reach should be estimated.

Contact by farmers prior to project design will of necessity be limited. Project targets and emphasis should be formulated with general Government policy, self-sufficiency in basic food commodities, etc., in mind. When farmer contact is adequate, it could well be that

*Please refer to Annex C.

diversificaton will prove to be their strongest interest. Farming/cropping systems research should therefore make economic assessments of a number of potentially high profit products for possible introduction into the farming systems. These assessments would be in preparation for intelligent discussions of diversification proposals with farmers. The project may subsequently be broadened to include a range of diversification elements and/or establish lines of cooperation to other agricultural development projects in Swaziland.

2. The project should carry out research for the development and improvement of three systems:

(a) a dryland food crops system with a small element of non-food cash crops;
(b) a mixed farming system with food crops, fodder crops, and milk production;
(c) an irrigated system which could be in support of either (a) or (b) above, or independent.

3. The project design team should consider for inclusion in its paper outlines of immediately researchable systems components, as follows:

(a) <u>Dryland food crops system</u>
  (1) land preparation and establishment of the crop
  (2) intercropping
  (3) building up of soil fertility
  (4) crop rotation
  (5) implements introduction
(b) <u>Mixed farming system</u>
  (1) silage and crop residues as basic fodder
  (2) coarse grasses and fodder trees for stall feeding
  (3) established pastures and hay and crop residues
(c) <u>Irrigated agriculture</u>
  (1) agronomic and economic data for vegetable crops
  (2) cropping sequences on irrigated land.

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COMMENTS ON "SYSTEMS" RESEARCH IN SMALL FARM DEVELOPMENT

The process of improving the technology of agriculture is an ancient undertaking of mankind. It was a natural process which accompanied (perhaps led) the development of society. Only within about the past two centuries have there been attempts to organize this process, and only for a little more than a century has there been a serious effort to base agriculture on a systematized knowledge of natural laws and processes. Thus most of the farming systems of the world are based on tradition that is largely the result of trial and error and shrewd observation by generations of farmers.

Research within scientific disciplines

The first agricultural researchers were generally broadly based and tended to look at the whole farming enterprise as they carried out their investigations. The nature of their undertaking dictated, however, that there would be increasing specialization. This resulted in the proliferation of a range of scientific disciplines that focused on specific aspects of agricultural sciences such as genetics, plant pathology, and soils. Even within disciplines there was a tendency to concentrate on specialities such as soil chemistry, soil physics, or other subdivisions.

The disciplinary approach led to rapid development of the understanding of the natural phenomena. It tended, however, to isolate scientists from the problems of farmers. To counteract this, integrative disciplines such as agronomy came to be recognized, and subject matter specialists or extension specialists came on the scene to help the farmer pick and choose among the various findings which might improve his farming performance.

Commodity-oriented research

To further encourage the utility of research output and to identify gaps in the technology and resolve them, a number of research units around the world formed multidisciplinary research teams charged with looking into all aspects of the production of a given commodity. Almost invariably large-scale plantation operations followed this procedure. They were often highly successful in improving production. From the

1920's to the present such teams in the U.S., Japan, and elsewhere developed technology for non-plantation crops. When widely adopted by farmers, this technology resulted in national average production as much as four or five times as high as at the start. The most highly developed examples of the commodity-oriented approach are probably the international centers such as the International Rice Research Institute.

Farming systems research

The multidisciplinary commodity team leaves much ground untouched, and it is largely up to the farmer to integrate the various commodities into his own farming system. While interaction with the farmer may bring research attention to inter-commodity problems, the process is not closely organized in most western countries.

Within the past decade, and particularly within the developing countries, steps have been taken to make the unit of study not the single discipline nor the single commodity, but the whole farming enterprise or system. This approach is seen as especially needed to encourage rapid improvement of agricultural production and rural standards of living, taking into account environmental constraints, scarce supplies of inputs, the need to conserve soil and water, and a host of other factors.

Terminology is not completely established but generally research on "farming" systems is seen as including all farm operations and the ways in which they impinge upon the farm family. "Cropping" systems research attempts to separate out those portions of the total farm enterprise which relate to crops and crop production. This is a somewhat arbitrary separation and although it may have practical utility, it can give problems in systems with a substantial animal component.

"Agricultural" systems include inputs supplies, agribusiness, and other off-farm elements that interact with the farm and farm family. Sometimes the term is used even more broadly.

Methodology of farming systems research

Scientists responsible for farming systems research have to develop much of the methodology as they go along. It is a sufficiently new field that there is little guidance from prior work about how to go about investigating and improving traditional farming systems of small

farmers. However, researchers working in Africa, Asia, and Latin America have demonstrated some promising approaches.

In skeletal form an approach which has proven particularly successful has been as follows:

(a) Analyze the existing farming system(s) in the target area from the standpoint of what the farmer is doing and why he is doing it. What are his objectives as regards his farming operations and himself and his family?

(b) Look for bottlenecks or gaps which appear to exist in the on-going operations as based on current production knowledge coming from research or from farming practices elsewhere. For example, would the use of a shorter growth duration variety permit him to grow an extra crop? Could the use of appropriate animal-drawn implements allow better seedbed preparation? Could he extend the cropping season by simple soil and water conservation procedures?

(c) Select the more promising of these possible innovations and plan a simple experiment where they will be compared with current farm practice in the farmer's field. The farmer participates in planning and carrying out the work. However, the researcher is involved at each step. An appropriately trained research assistant lives in the community or near enough so that he can visit the farm regularly and know exactly what is going on. He collects weather data and records crop performance so that the results of the trial can be better evaluated and extended to other locations. Where there are failures he attempts to know the factors responsible and feeds the information to the experiment station and laboratory for further study.

(d) Encourage the cooperating farmer to try the best procedures in a part of his own production area. When the results of the on-farm trial are favorable, the farming system research team fosters diffusion of the new procedure. Again, the researcher works with the farmer in applying

the new technology. This not only favors successful diffusion but provides useful insights to the researcher as to how the new technology might be further modified for easier farm use.*

Relationship to extension and/or rural development action programs

The extension service must come in as an equal partner with the farmer and the research service in planning and carrying out farming systems research. To a considerable degree the lines between research and extension are eliminated or blurred. The research worker is extending as he carries out his research, and the extension agent is experimenting when he helps the farmer try out new technology on a pilot basis. When special rural development programs exist, as they do in Swaziland, the cropping systems research program can work with them on a partnership basis.

Role of the experiment station in farming systems research

Farming systems research in no way takes the place of the experiment station. The selection of varieties and the development of pest control procedures and other cultural practices must be carried out under the more controlled conditions of the experiment station.

Before establishing on-farm trials of intercropping, minimum tillage, bedding, and other possible innovations, the farming systems team will want to try them out at the experiment station. However, the researcher cannot assume that the results he gets there will be the same as under farm conditions. This is particularly true when the procedures in question interact with a range of environmental factors. For example,

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*The Director of Agriculture in Swaziland, Mr. Victor Pungwayo, comments that the first research work done in Swaziland was on a basis similar to that described in this section. There was no research station in the country at the time, and the first research was carried out entirely in farmers' fields. The extension service participated in this work and frequently followed up with demonstration plots. Unfortunately, this tie to the farmer was substantially weakened when an experiment station was established. The station produced much sound information but research was less closely tied to the farm, particularly the small farm, than it had been previously.

an intercropping procedure which works well on the experiment station where there is good seedbed preparation, good weed control, etc., may prove hard to manage on the farm.

Most scientists who work principally on the experiment station frequently conduct traditional plot research in farmers' fields to test their results under a wider environmental range. These may include varietal comparisons, N-P-K factorial experiments, or tests of almost any factor under study. They may contribute substantially to the understanding of important aspects of agriculture. However, this is not farming systems research but rather a regionalization of regular experiment station work.

The farming systems team depends upon the experiment station (and also on advanced basic research laboratories) for its store of knowledge. It must often call on them to solve problems encountered at the farm level. Its chance of succeeding without these resources is slim. Farming systems research integrates technology into the farmers' regular practice. It brings science more sharply to bear on traditional agriculture. It is not a panacea, and it is not a substitute for other elements of the research system.

PROPOSED FARMING/CROPPING SYSTEMS INNOVATIONS FOR SWAZILAND

Swaziland is well on its way with rapid development of economy and welfare. Employment opportunities outside the small holder sector are good. There are more than 80,000 wage earners out of a total population of around 600,000. Many of those we have had discussions with do fear, however, that employment opportunities may not remain as favorable as they are at the moment.

The need for the small holder sector to be economically competitive with wage employment is more apparent in Swaziland than in any developing country we know. The problem of the economic competitiveness of the SNL farms is aggravated by the small areas of land the individual family holds. The size of the average holding may decrease as population increases.

There is a need for economic studies that would not normally be part of a farming/cropping systems project.

Further, the systems to be developed must have at least some high profit margin components, and the prospects of sustained growth in productivity must be good.

ECONOMICS STUDIES FOR SYSTEMS DEVELOPMENT

Economists and sociologists in a systems research team would normally begin by assembling information and surveying present agriculture, on-farm resources, farmer attitudes, etc.

In Swaziland economic study priorities should be:

(a) Income targets for SNL farmers

Whether small holder farming is economically sufficiently attractive can best be measured against family economy and welfare obtained by unskilled laborers. We were told that the pineapple industry pays E1.47 per man-day for unskilled labor, the sugar industry pays E1.72, while the rate for those employed by Government is around E2.50 per man-day for similar work.

Assessment of the opportunity cost of remaining in agriculture does, however, require much more study than merely finding out what the wages are. The costs of housing, food, fuel, etc., would be quite different for a family living from wage employment as compared to the family on a small holding. Housing and food subsidies may be paid to some of the wage earners, etc.

This study would set minimum targets for small holder income, which would be partly in cash and partly in kind. A rainfed cropping system on the average size land holding may not reach the minimum goal, and high profit margin elements such as milk production and irrigated vegetable production have to be introduced. Some of these innovations are available for immediate introduction, and the project should be oriented to a dynamic diversification program.

(b) Assessment of potentially high-profit-margin products for introduction into the farming systems

Swaziland has a favorable atmosphere for the introduction of new commodities into small holder agriculture, with both small holders and extension workers actively seeking new high-profit-margin innovations.

Cropping/farming systems research should join forces with this trend, cooperate with other projects, and in particular carry out a set of economic studies of potential innovations. The study should prepare estimates and show expected profit margins for such potential new activities as a number of fruit crops, Angora goats, modernized poultry production, and possibly fish farming. Resource requirements in terms of skills, training, and advisory services should be assessed, and investment capital needs estimated.

The project may not initially take an active part in the introduction into the small holder systems of more than milk and vegetable production. But there is a limit to the number of small holders that may beneficially be

involved in, say, vegetable production. The assessments proposed here are in preparation for the continuous diversification of the systems.

(c) Study of present agriculture

The project would follow the general pattern for such studies, with adjustments to Swazi conditions as deemed necessary. But since we propose the possibly novel approach for a developing country of working towards an income target for small holder farming systems, it seems desirable to mention that the economic and social studies must also include the traditional animal production sector. Modernization in this sector is, however, outside the initial scope of the project.

(d) Economic studies of systems components

For irrigated vegetable production it has been specifically outlined that economic baseline data for individual crops and cropping programs should be project outputs. It is equally important that cost of inputs, labor use, profit margins, etc., be presented for, say, intercropping and many other systems components. Data processing programs should be available to deal with these requirements.

SYSTEMS TO BE DEVELOPED

The PID document proposes that the project under review be limited to cropping systems research. We fear, however, that particularly a rainfed cropping system on the average small holding could fail to reach the minimum income target. Many of those with whom we had discussions would share this view. We have concluded that it would be meaningful to research and develop three systems:

1. A dryland food crops system with a small element of non-food cash crops (say, tobacco and cotton).
2. A mixed farming system with food crops, fodder crops, and milk production.
3. An irrigated agricultural system, either as a separate system or in support of (1) or (2) above.

IMMEDIATELY RESEARCHABLE SYSTEMS COMPONENTS

For project efficiency in general the design document should outline systems components on which research may start as soon as the staff arrives in Swaziland, and for all team members.

According to textbook knowledge about systems development, research must progress in a rather fixed sequential arrangement, with the surveying of present farming activities preceding on-farm technical research. But the "logical" sequence argument omits that farming systems development needs to be a collaborative effort, with farmer and researcher collaborating. While the researcher is interested in present agriculture, on-farm resources, farmer attitudes, etc., the farmer is equally interested in how the researcher can help him. Potential contributions from the researcher should be demonstrated at an early stage and may best be done by bringing selected technical innovations to rural areas.

Also, systems to be developed and components to be researched are not selected merely on the basis of socio-economic surveys. In this selection/decision making process it is equally important to draw arguments from such sources as:

- Statements of government development goals and policies,
- Inventories of the natural resources for agriculture and knowledge about the suitability of the environment for various types of agricultural production,
- Research results and general agricultural know-how on which rapid farming/cropping systems innovations can be based.

The following immediately researchable components are suggested for serious consideration by the design team.

1. Dryland food crops system

   a. Land preparation and establishment of the crop

Research in Swaziland suggests that there would be considerable yield responses to modification of the present method of land preparation. The project should select for initial testing in farmers' fields the bed land preparation method developed at ICRISAT. Land is prepared in 1.5m wide beds, with furrows in between in which the oxen walk. The bed is

shallowly tilled and some crop residue is incorporated into the top layer, giving a mulching effect. The soil and water conservation benefits would be particularly attractive to Swaziland.

Simple ox-drawn equipment (tool carriers) for this method of land preparation are available from India and possibly also from the National Institute of Agricultural Engineering, Silsloe, England, and elsewhere.

The method has a low draft power requirement. Two oxen could be sufficient, possibly after an initial establishment of the beds by tractor.

Establishment of a larger number of plants per hectare than is at present achieved (for maize the average for Swaziland may be 8,800 plants per hectare as against recommended 40,000), should also receive attention. Guidelines for selection of planters and their adjustment and use needs to be firmly established. Some of the units now in use give poor stands because they damage the seeds and also because the fertilizer and seeds are placed together and salt injury may occur.

b. Intercropping

Mixed cropping has been commonly used in small holder agriculture. Research on experiment stations has concentrated on monocropping. In systems research, intercropping should be a prominent element. Intercropping is growing of usually two crops in row arrangements in the same field. It is a modernization of mixed cropping, giving the advantages of monocropping in operations such as weed control.

Research has by now provided a solid body of evidence showing that intercropping gives a higher return per hectare as compared to monocropping. Crop failure (the return falling below an acceptable limit) is drastically reduced through intercropping as compared to the growing of the same crops separately.

Maize will continue to be the dominant crop on farms adopting intercropping. Therefore the advantages of different hybrids and open pollinated varieties should be determined. As indicated by research at the Faculty of Agriculture, maize, if carefully selected, may in the early part of the growing season be intercropped with pumpkins; a legume, as a second intercrop, may be planted late in the growing season. Legumes to be tested in intercropping with maize, at least in the initial phase, may be limited to groundnuts, beans, and cowpea.

c. Soil fertility in SNL farms

Appropriately used fertilizers are potent in the modernization of agriculture all over the world, and small holder agriculture in Swaziland will be no exception. Yet, fertilizer response data available to us indicated a complex response situation (Jones, several papers). How fertilzer use should progress may best be resolved by including response studies in the cropping systems development project. Initially only manure and N- and P- fertilizers should be included in the systems work. Nitrogen top dressing should receive particular attention. Research should also be concerned with the longer term building up of soil fertility.

The soil acidity problem will have to be resolved in the course of the building of a desirable level of soil fertility. Liming may be required; introduction of maize and other crop varieties that will produce well on acid soil may contribute to the resolution of the acidity problem.

d. Crop rotation

The effects of crop rotation are so complex to analyze that research has a long way to go before we can rationally argue what systematic crop rotations may be beneficially employed in the SNL farming systems. For Swaziland in particular, there is conflicting evidence as to whether a crop rotation would be generally beneficial to the small farmers.

To fallow a part of the arable land seems to be a common feature of present agriculture, probably after unacceptable decreases in yields have been experienced. (There are some suggestions however that part of the fallowing done in Swaziland results from labor shortages.) The Swaziland extension handbook lists maize, cotton, and pastures as major crops which may be grown on the same land year after year. The same source indicates that success with other crops such as beans, groundnuts, potatoes, tobacco, and tomatoes depends on them being grown in rotation. but little if any o this information was acquired on the small SNL farms and thus is little indication of how cropping systems should be modified to take advantage of crop rotation benefits.

We conclude that where cash crops play a significant role, systematic rotation should be researched for inclusion in the cropping system. Know-how commonly used in Zimbabwe and the Republic of South

Africa may be particularly valuable for the designing of appropriate crop rotation work.

e. Implements introduction

As indicated under (a), Land Preparation, ox-drawn implements which are not yet known by the Swazi farmers could prove attractive by allowing for improved agronomic practices as well as for reducing draft power requirements. Farming/cropping systems research should test selected types of new ox-drawn implements in a range of farming operations, not only in land preparation. Similarly, testing of selected hand tools for weeding, and hand powered machinery for threshing/shelling of crops should be considered for inclusion in the project.

2. Mixed Farming System

The crop production part of mixed farming will have the same elements as in the system for farming units with crop production only. But the mixed farming system will have greater opportunities for benefitting from use of manure and from a crop rotation which includes pasture and fodder crops.

The major difference between the mixed farming system and the cropping system will be the far greater cash earning potential which milk production introduces. With an easily achievable level of management, a milking cow on half a hectare of land in the middleveld should give a gross return in excess of E500 per year.

Cooperation with the Dairy Board is essential in development of milk production. The Board will establish the milk collection centers, and provide facilities for acquisition of either grade or purebred milking cows.

The systems project should concentrate on provision of fodder for milking animals. Three alternatives should be investigated:

(a) Silage and crop residues as basic fodder

Silage in trench silos with millet and/or maize as raw material would start off from high production per hectare. The investment would be mainly in the form of on-farm labor, and the risk factor would be low. Crop residues, partly or fully substituting for hay, would be maize stover and groundnut and bean residues.

(b) Coarse grasses and fodder trees for stall feeding

Pennisetum purpureum, Napier grass, could be the coarse grass, and *Leucena leucocephala* the fodder tree. For Napier grass the technology would be easily available from Kenya, while Malawi would be a good source for Leucena technology. Fodder trees could advantageously be grown on the soil conservation strips which have been instituted in the Swaziland Rural Development Area Program.

(c) Established pastures plus hay and crop residues

This may be an attractive alternative to the farmers in an initial phase of milk production. Pasture recommendations are available from research in Swaziland. Frequent rainfall may discourage hay production.

3. Irrigated agriculture

It is quite obvious that there exists in Swaziland experiences which strongly suggest that irrigated land can rapidly increase cash earnings in agriculture. Rainfall in the rainy season is rather adequate for considerable improvements of dryland yields. Nevertheless, the arguments in favor of development of irrigated agriculture are strong:

- The length and severity of the dry season, while temperatures remain favorable for crop production.
- A relative abundance of irrigation water, distributed in such a way that opportunities for irrigation schemes at all levels of sophistication are easily seen.
- Scarcity of land, rapidly growing population, considerable and rapidly increasing internal demand for many of the potential products.

Gross return to a hectare of irrigated land under small holder management may be in excess of E1500.

There may be a tendency towards underestimating the need for investment capital when irrigated land is developed by government support. But irrespective of how the costs are covered, it is expensive to develop land for irrigation. An average figure in Swaziland may at the moment

be E1500 per hectare for schemes planned by engineers. Low cost dams or low cost channels of water from streams may, however, be developed on individual holdings. Such facilities could be highly profitable.

Irrigated agriculture could develop as an integrated part of dryland agriculture. Whether this be the case or whether irrigated agriculture develops mainly as an independent system, the project should see its main objectives in two areas, as follows:

(a) Agronomic and economic data for vegetable crops

The data should be collected on farmers' plots, with the constraints under which the farmer operates. Information is needed about land preparation and irrigation practices, suitable varieties, pest and disease control, harvesting and marketing, etc. Data collected should include yield, preferably quality (grading), cost of purchased inputs, labor use, and profit margin. Major horticultural crops at present are green maize, cabbage, onions, potatoes, and tomatoes. Risk and profit margins vary widely with season. All of these crops are subject to overproduction in the present marketing situation.

(b) Research results available from outside Swaziland

Results from research in Swaziland on variety selection, pest and disease control, etc., of considerable value to vegetable production, are already available. However, there are many new or untapped sources of genetic materials with disease resistance, tropical adaptation, and other desirable features. The vegetable production aspects of the cropping systems project should look into this.

(c) Cropping sequences on irrigated land

While profit margins for individual crops are basic to systems design, optimal utilization of resources would also depend on working out cropping sequences. These sequences would depend on requirements of individual crops relative to the seasonal characteristics of the environment, the need to rotate crops because of disease

and pest problems, labor availability, marketing and price prospects, etc. Farmer and researcher should collaborate in the working out of a cropping plan for all of the irrigated land held by the farmer. Record keeping would form the basis for assessment of the cropping plan, and subsequent modifications to the plan.