

**FARMING SYSTEMS RESEARCH
AT THE
INTERNATIONAL AGRICULTURAL
RESEARCH CENTERS**

- I — Analysis by the TAC Review Team of Farming Systems
Research at CIAT, IITA, ICRISAT and IRRI**

- II — Proceedings of the Workshop on Farming Systems
Research, Nairobi, May 29-31, 1978**



FACULTY OF ECONOMIC STUDIES
DEPARTMENT OF AGRICULTURAL ECONOMICS AND BUSINESS MANAGEMENT
THE UNIVERSITY OF NEW ENGLAND

ARMIDALE, N.S.W. 2351. AUSTRALIA

REPLY PLEASE QUOTE

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TELEPHONE: ARMIDALE 72 2911
AREA CODE 067
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14th August, 1978.

Dr. Ralph W. Cummings,
Chairman,
Technical Advisory Committee to the
Consultative Group on International
Agricultural Research,
812 Rosemont Avenue,
RALEIGH. NORTH CAROLINA. 27607
U.S.A.

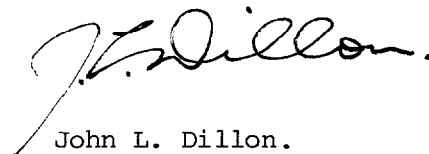
Dear Dr. Cummings,

I have pleasure in formally transmitting to you the report of the Farming Systems Research Review Team entitled "Analysis by the TAC Review Team of Farming Systems Research at CIAT, IITA, ICRISAT and IRRI."

Carrying out this first TAC "Stripe Review" of an IARC activity has been a most stimulating and informative task - not least because of the complex nature of Farming Systems Research and the vigour with which it is being developed in the Centers.

In carrying out its work, the Review Team received every possible assistance and courtesy from the Directors-General and staff of the four Centers whose farming systems research programs were reviewed. I am most grateful for the help and hospitality given to the Team. The Review Team was also greatly assisted in its final drafting of the report by the discussions of the Farming Systems Research Workshop sponsored by TAC in Nairobi in June this year under the Chairmanship of Dr. A.T. Mosher. Finally, I must acknowledge the unstinted work of my fellow team members - Professor D.L. Plucknett and Dr. G. Vallaeys - and of Mr. P.J. Mahler and Dr. E.Z. Arlidge of the TAC Secretariat. Without their unflagging assistance and good humour, the task would have been impossible.

Yours sincerely,


John L. Dillon.

THE CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH
TECHNICAL ADVISORY COMMITTEE

FARMING SYSTEMS RESEARCH
AT THE
INTERNATIONAL AGRICULTURAL RESEARCH CENTERS

- I - Analysis by the TAC Review Team of Farming Systems
Research at CIAT, IITA, ICRISAT and IRRI

John L. Dillon, Team Leader
Donald L. Plucknett
Guy J. Vallaeys

Team Secretariat:
P.J. Mahler
E.Z. Arlidge

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Note from the Secretariat

It will be noted that there is considerable overlap in these two reports. In particular, readers will find that much of the terminology and most of the conclusions and recommendations are the same in both reports. This is due to the following:

- 1) The Workshop generally endorsed the draft report of the TAC FSR Review Team and used it as a basis for the Workshop proceedings.
- 2) The Review Team in drafting the final version of their report, based a number of amendments and additions on the draft report of the Workshop proceedings.

TAC Secretariat
Agriculture Department
Food and Agriculture Organization of the United Nations
Via delle Terme di Caracalla, Rome 00100, Italy

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812 Rosemont Avenue
Raleigh, North Carolina 27607
September 14, 1978

Dr. Warren C. Baum, Chairman
Consultative Group on International
Agricultural Research
The World Bank
Washington, D. C. 20433

Dear Dr. Baum:

I take pleasure in transmitting to you herewith the report of Farming Systems Research at the International Agricultural Research Centers. This includes under the one cover the report of the TAC Review Team on farming systems research (FSR) at CIAT, IITA, ICRISAT, and IRRI, and the report on the TAC Workshop on FSR held in Nairobi, May 29-31, 1978.

The review of FSR at the above four centers carried out by a three-man consultant team under the leadership of Professor John Dillon, University of New England, Armidale, Australia, is the first of the across-center reviews of particular topics (stripe analysis) recommended by the CGIAR Review Committee of 1976. This FSR stripe analysis was carried out during 1977, the visits of the TAC Review Team to two centers (CIAT and IITA) coinciding with the quinquennial reviews. The draft report of the FSR Review Team was first discussed by TAC at its 18th meeting in February of this year. It was not intended at this juncture that TAC should examine the report in depth but more to ascertain the extent to which it met the requirements in relation to the Review Team's terms of reference, and also provide constructive comments to the Team for the finalization of the report. TAC members agreed that the report formed a sound basis for the FSR Workshop.

At this meeting, TAC approved a draft agenda for the FSR Workshop scheduled to be held in Nairobi in the week prior to the 19th TAC meeting. The Committee agreed that the Workshop should be analytical in character and oriented towards the articulation of features of general applicability. The Committee also agreed that the participants (up to some 35 in number) would be drawn from all IARC's either involved in, or interested in FSR, from TAC and its FSR Review Team, the CGIAR co-sponsors, and representatives of a number of national programs.

The Workshop, under the chairmanship of Dr. A. T. Mosher, was a very successful meeting and achieved all that TAC expected of it. One aspect in particular which the Workshop had clearly shown was that across the IARC's and the national institutions, there were a number of workers researching many and varied topics but with a similar basic philosophy. The Workshop

endorsed, with only minor modifications, the conclusions and recommendations of the TAC FSR Review Team. (These modifications have been accepted by the Review Team and incorporated into the text of their final report.)

The final report of the FSR Review Team and the report of the FSR Workshop were discussed at the 19th meeting of TAC, held at ILRAD, Nairobi, June 6-13, 1978. The Committee commended the Review Team for the high quality of their report and generally endorsed the conclusions and recommendations. Center Directors present at the meeting strongly expressed their appreciation of the work done by the Review Team and the excellence of their report. The consensus of the meeting was that TAC's first stripe analysis of a topic common to a number of the IARC's had been a most useful exercise.

In concluding its deliberations, the Committee reached a number of conclusions and brought forward some recommendations with respect to follow up actions and possible alternative mechanisms by which these may be carried out.

Firstly, with respect to need to maintain a continual review of FSR terminology, TAC recommended that recurrent meetings of specialists be convened in which, among other things, the terminology would be updated with the view to compiling an international glossary of terms used in farming systems and research thereon.

Secondly, as regards the important question of methodology in FSR, the Committee believed that the major areas for improvement appeared to be in (a) base data analysis, particularly in the delineation of agro-climatic zones and surveys for socio-economic data collection; (b) procedures to insure the best selection of a limited number of farming systems for study; and, (c) design and analysis of multiple cropping experiments.

On how best to meet the above requirements and organize a significant and sustained effort to further the rapid evolution and refinement of FSR methodology, the Committee concluded that three parallel actions appeared worthy of consideration:

(i) each IARC and regional/national FSR program concerned designate a liaison officer from among their staff to collect and exchange information on developments in FSR methodology;

(ii) FAO be requested to organize the collection, collation, and dissemination of FSR information from international and bilateral organizations and agencies, particularly in base data analysis and multiple cropping; or alternatively, that one IARC could be designated for the purpose; and

(iii) seminars or workshops be organized to discuss FSR methodology in rather specialized fields. These could be organized by FSR liaison officers at IARC's.

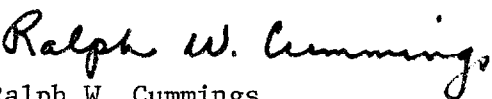
In base data analysis, the Committee underlined the need for improved and increased cooperation between IARC's and other institutions. TAC recognized that FAO, in particular, had a crucial role to play in this field and recommended that FAO be invited to present its opinion on how international cooperation might be further improved and expanded. The Committee also suggested that consideration be given to the future organization of an international data bank serving FSR workers.

Thirdly, as regards the organization of FSR at IARC level, the Committee agreed that flexibility should be maintained. TAC suggested IARC's might explore both possibilities of encouraging the development of national networks of relevant institutions, including universities, and cooperate with this network, and of developing regional networks of cooperating countries. The Committee felt that more use should be made of the research manpower resources in the universities in developing countries. It suggested that the usefulness of private organizations and firms engaged in national programs of FSR, particularly in base data analysis, should not be overlooked.

As a result of this stripe analysis, I believe we have a much better understanding and improved focus of the IARC's activities in FSR. This sentiment was also expressed by Center Directors at the TAC meeting.

TAC will maintain an interest in further developments in FSR in both the IARC's and the international agricultural research arena in general; and the Committee, through its Secretariat, will do whatever is necessary to assist in carrying out the recommendations of the two reports as well as those of TAC itself, which might be endorsed by the Consultative Group at its meeting in November.

Sincerely yours,


Ralph W. Cummings
Chairman, TAC

RWC:nj

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I. INTRODUCTION

(i) Background

1. The activities supported by the Consultative Group on International Agricultural Research (CGIAR) are intended to help alleviate the food problem in the less economically developed countries. This problem is severe and is likely to become more so with the continuing rapid population growth rates in most developing countries.

2. The CGIAR and its Technical Advisory Committee (TAC) clearly recognize that an important element of the solution of this food problem lies in increasing the production of the many millions of small farmers in the developing countries. The typical small farmer in these countries manages a complex farming system which produces a number of commodities, often both crop and animal. Increased productivity may stem either from the use of improved crop varieties and animal breeds or from intensification of land use by better management of land and water resources and other more comprehensive improvements in the farming systems used. However, not until recently has much research been devoted nationally or internationally to intensification via system-wide consideration of the small farming system. The aim of most research to date has been to improve single crop or animal species considered in isolation. The farming system as a whole has not generally been emphasized despite the fact that farmers must operate in the context of their particular farming system and it is within this system that new technology must be implemented.

3. The establishment of the CGIAR and the development of the International Agricultural Research Centers (IARCs) have led to a conscious effort to focus attention on improving farming systems. Both the International Institute for Tropical Agriculture (IITA) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) have significant programs in farming systems research (FSR) comprising 37 and 18.5 percent of the total budget for their research activities in 1977, respectively. The recently established International Center for Agricultural Research in Dry Areas (ICARDA) plans to develop a strong program in FSR and the International Livestock Centre for Africa (ILCA) has adopted a systems-oriented research program. The International Rice Research Institute (IRRI) in 1977 devoted 21 percent of its research budget to its cropping systems program. Significant parts of the current research program of the Centro Internacional de Agricultura Tropical (CIAT) can be regarded as farming systems research activities. Table 1 gives estimates of the expenditures on FSR at these IARCs for the years 1975 to 1980.

4. With the rapid growth of the CGIAR system and consequential expansion of the research programs in the IARCs, there has been some concern expressed at the diversity in objectives, scope and content of their FSR and related cropping research programs.

(ii) The "Stripe" Review Approach

5. TAC at its 13th Meeting in May, 1976, following a discussion on its revised Priorities Paper¹ concluded that there was a need for a critical examination of the role of the IARCs in farming systems research and requested the TAC Secretariat to organize a Working Group to undertake this review.

¹TAC Document DDD/TAC:IAR/76/2 Restricted; Revised 30.5.76.

6. Independently, the CGIAR Review Committee of 1976, in considering the various mechanisms which TAC might employ to evaluate ongoing activities at the IARCs and maintain an overview of the activities of the CGIAR family--particularly with respect to future requirements--made the following recommendation in its final report.¹

"We recommend continuation of the TAC quinquennial reviews for evaluation of scientific quality, scope, and balance of current programs, and to evaluate future plans, including explicit review of center proposals to continue projects of long standing. We also recommend that the TAC give greater emphasis to periodic, across center analysis of particular topics (stripe analysis)."

7. The TAC Quinquennial Review is an enquiry confined to an individual center and only relates to the work of other centers insofar as it examines the cooperative arrangements between the center under review and the other IARCs. In contrast the across-center review, or stripe analysis, is an enquiry on one particular program component at a number of the IARCs and may be expanded, where appropriate, to include an examination of related program elements in national research institutions. By means of a series of stripe analyses of topics such as farming systems research, genetic resources, training, etc., TAC and the CGIAR can obtain an overview of the CGIAR system and thereby identify new needs and would also provide a useful mechanism for IARCs to compare the objectives, scope, content and methodology of their program components. By this means one IARC may benefit from the experience of another. However, it is not intended that the results of a stripe analysis be used to encourage conformity.

(iii) The TAC Review of FSR

8. The TAC Secretariat's proposals² for the review of FSR were discussed at the 14th Meeting of TAC in October, 1976. It was agreed at this meeting that in view of the complexity of this field of research, TAC should take a step-by-step approach. TAC also concluded that because of the divergences in the concepts and programs of the IARCs involved in farming systems research, the review should be confined to IITA, ICRISAT and IRRI, which had on-going programs, and CIAT which had recently discontinued its Small Farm Systems Program. TAC was of the consensus that the scope of the proposed FSR review should not be broadened to include topics such as animal production, agro-forestry and aquaculture which, although recognized as having significant importance in many farming systems, were not covered in the programs of the crop-oriented IARCs. TAC also recognized the reigning confusion in farming systems terminology.

¹Recommendation 15 in: CGIAR, Report of the Review Committee, CGIAR, Washington, January 1977, p.xi.

²TAC Document DD/TAC:IAR/76/18 Restricted.

TABLE 1. Expenditures on Farming Systems Research at CIAT, IITA, ICRISAT and IRRI
for the years 1975 to 1980^{1/} (data compiled by CGIAR Secretariat)

(Costs in '000s US\$)

| | <u>CIAT</u> | | | | <u>IITA</u> | | | | <u>ICRISAT</u> | | | | <u>IRRI</u> | |
|------|----------------|--------------------------|-----------|------------|-------------|------------|-------------|------------|----------------|------------|-------------|------------|-------------|--|
| | (Beef Program) | | | | | | | | | | | | | |
| | <u>M/Y</u> | <u>2/</u> <u>Cost</u> | <u>3/</u> | <u>M/Y</u> | <u>Cost</u> | <u>M/Y</u> | <u>Cost</u> | <u>M/Y</u> | <u>Cost</u> | <u>M/Y</u> | <u>Cost</u> | <u>M/Y</u> | <u>Cost</u> | |
| 1975 | 2 | 173 | 9.0 | 910 | 14 | 1524 | 4 | 488 | 6 | 700 | | | | |
| 1976 | 2 | 199 | 8.1 | 949 | 14.5 | 1820 | 4.5 | 644 | 5.5 | 1270 | | | | |
| 1977 | 2 | 232 | 13.6 | 1918 | 16.5 | 2029 | 7.5 | 941 | 7 | 1479 | | | | |
| 1978 | 3 | 317 | 18.5 | 1940 | 17.0 | 2217 | 8.5 | 1045 | 7 | 1582 | | | | |
| 1979 | 3 | 325 | 19.0 | 2104 | 17.0 | 2470 | 8 | 1101 | 7 | 1652 | | | | |
| 1980 | 3 | 329 | 20.0 | 2297 | 17.0 | 2652 | 8 | 1124 | 7 | 1755 | | | | |

1/ Figures for 1975 and 1976 are actual expenditures; those for 1977-79 are the budgeted expenditures and those for 1980 are projections.

2/ In 1975, 2 M/Y in small farm systems; in 1976, 3 positions for economists in the beef, cassava and bean programs partially filled; positions in these programs filled from 1978 onwards.

3/ Costs pro-rated on total M/Y costs under research activities.

4/ Includes farming systems and economics programs.

5/ Includes the cropping systems program and that part of the economics programs entitled "Constraints on Rice Yields" and "Consequences of New Technology." Three economists from the agricultural economics department and all staff in the cropping systems program have been included.

9. In subsequent consultations between the Secretariat and the Chairman of TAC, it was proposed that the review of the four IARCs be undertaken during 1977 and should be along the following lines:¹

- (1) A desk study by the TAC Secretariat in January with a progress report to the TAC meeting (in February 1977); the main purpose of the desk study being to compile and collate the documentation, attempt to clarify the apparent confusion in the terminology, and make a preliminary comparative analysis of the centers' programs in farming systems or cropping systems so as to identify the main issues for the purpose of providing a provisional list of questions which could be addressed to the IARCs concerned;
- (2) consultants' visits to the IARCs for an on-the-spot review of their programs, the reviews of CIAT and IITA preferably in conjunction with the quinquennial reviews scheduled for April and October/November, 1977, respectively;
- (3) in December 1977 a workshop, at some convenient location, of the IARCs' representatives, review consultants and other invited consultants to further discuss the issues, draw conclusions and prepare a draft report for consideration of TAC at its meeting in February 1978."

10. At its 15th Meeting in February 1977, TAC considered the report² of the preliminary desk study prepared by the Secretariat on the scope and objectives of FSR at CIAT, ICRISAT, IITA and IRRI. This study was seen as providing the basis for the briefing of the Review Team in its proposed visits to these IARCs later in the year. TAC agreed to the review as proposed and reiterated the conclusion of its 14th Meeting that the review should be confined to the above IARCs. TAC was agreeable, however, to the Review Team examining, where feasible, some of the FSR programs in national institutions where these might be seen as complementary to the programs of the IARCs.

11. The composition of the FSR Review Team, its Terms of Reference, and the proposed program of visits to the four IARCs and possibly also to Senegal and Costa Rica, were approved by TAC at its 16th Meeting in May-June 1977.³ This meeting decided to postpone the proposed FSR Workshop until June 1978 to allow more time for preparation of the Review Team's Report.

12. Details of the Review Team's Itinerary and Schedule are given in Annex 1.

¹Progress Report on FSR Review to 15th TAC Meeting. TAC Document DDD/TAC:IAR/77/7.

²Annexed to Progress Report on FSR Review to 15th TAC Meeting; TAC Document DDD/TAC:IAR/77/7.

³Details are given in TAC Document DDD/TAC:IAR/77/14.

(iv) Terms of Reference

13. "The Consultative Group on International Agricultural Research (CGIAR) has charged its Technical Advisory Committee (TAC) with the conduct of periodic across-centre reviews of particular common elements in the programs of the International Agricultural Research Centres (IARCs), to assist TAC and the CGIAR in maintaining an overview of the system and also to provide a useful mechanism for the IARCs to compare their different program components and possibly profit from each other's experience. It is, however, not intended that such reviews be used as a mechanism to encourage conformity.

"It was agreed by TAC at its 14th Meeting, held in November 1976, to organize a mission to carry out an across-centre review of farming systems research at four IARCs, namely: the International Institute for Tropical Agriculture (IITA), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Rice Research Institute (IRRI), and the Centro Internacional de Agricultura Tropical (CIAT), during 1977.

"In pursuance of the main objectives stated above, the review mission is requested to visit the four IARCs, namely IITA, ICRISAT, IRRI and CIAT, and any other institutes as requested by TAC; the visits to CIAT and IITA will be made in conjunction with the TAC quinquennial reviews of these centres which will take place in 1977.

"The mission shall give particular attention to the following aspects of the work of the IARCs:

- "(1) the objectives and scope of farming systems research (or activities which may be considered as such) in relation to:
 - (a) the mandates of the IARCs;
 - (b) national programmes within the geographic mandate of the IARCs;
 - (c) each other;
- "(2) the role of the farming systems research as related to the current overall strategy and the programmes of the IARCs;
- "(3) the relative importance of surveys, data collection and assessment activities, on the one hand, and experimentation, on the other;
- "(4) the balance between on-campus and off-campus activities in farming systems research (or activities which may be considered as such);

- "(5) the relative balance and interactions between the disciplines involved in farming systems research (or activities which may be considered as such).

"The consultants shall present their report to a Workshop involving other consultants and representatives from the IARCs, to be convened in mid-1978 and report the findings of the Workshop to TAC."

(v) Conduct of the Review

14. The FSR Review started with a Desk Study carried out by the TAC Secretariat in the third week of January 1977. The Secretariat was assisted by Dr. S. H. Lok, Senior Agricultural Production Economist, Agricultural Services Division, FAO, and Dr. S. Sarraf, Agroclimatologist, Consultant to the FAO Global Agro-ecological Zones Land Use Project. As mentioned earlier, the purpose of this desk study was to compile and collate the documentation which had been received from CIAT, IITA, ICRISAT and IRRI; attempt to clarify FSR concepts and terminology; and make a preliminary comparative analysis of the IARCs' FSR programs. In the latter an attempt was made to identify the main issues in the form of a list of questions which could be addressed to the IARCs by the FSR Review Team.

15. In the Review Team's visits to the IARCs, the opportunity was taken of arranging those to CIAT and IITA concurrently with the TAC Quinquennial Review of those centers held, respectively, in April and October 1977. Apart from cost savings, it was seen that holding the quinquennial review and FSR stripe review concurrently would minimize the time needed to be devoted by the IARCs' staffs to reviews. From the point of view of the FSR Review Team, this arrangement was found to be distinctly advantageous in that it enabled the Team to obtain both a broader and a deeper perspective of the overall research program of each of these IARCs and particularly of the relationship of FSR with other programs.

16. The FSR Review of CIAT, Cali, Colombia took place during the week of 18-22 April, 1977. The Review Team spent most of this time at CIAT headquarters in discussion with CIAT staff but took the opportunity of joining the Quinquennial Review Panel in visits to Carimagua, Santander de Quilichao, Popayan and Caicedonia, in Colombia, to see experiments and field trials in the beef, bean and cassava programs. In addition, the leader to the Review Team, who was also a member of the Quinquennial Review Panel, visited EMBRAPA headquarters and the Cerrado Region Research Center in Brasilia and the National Research Center for Rice and Beans at Goiania, Brazil.

17. The FSR Review of IITA, Ibadan, Nigeria was undertaken as an integral part of the IITA Quinquennial Review which was held between 17 October and 5 November 1977.¹ This included a survey of IITA's cooperative programs in Sierra Leone, Liberia, Zaire and Nigeria.

¹Dr. G. Vallaeys was not a member of the Quinquennial Review Panel and visited IITA Headquarters only during the week 24-28 October.

18. In the week prior to the IITA review (11-13 October), the FSR Team visited the Institut Sénégalaise de Recherches Agricoles (ISRA), Dakar, Senegal to examine ISRA's farming systems network in the region of Kaolack as well as the work of the Centre Nationale de Recherches Agronomiques at Bambey.

19. Immediately following the IITA review the Review Team visited first, ICRISAT, Hyderabad, India and then IRRI, Los Banos, the Philippines. The visit to ICRISAT (7-10 November) included a visit to Shirapur benchmark village of the FSR/Economics programs and the Mahatma Phule Agricultural University Dry Farming Research Station at Sholapur.

20. The FSR Review Team visited IRRI from 11 to 15 November. Unfortunately, the scheduled visit to Iloilo to examine on-farm cropping systems activities had to be cancelled due to a typhoon.

21. Except for the visit to IRRI, the TAC Executive Secretary accompanied the Review Team as Secretary.

(vi) Nature of the Report

22. Because of the complex nature of farming systems and FSR, and the apparent confusion as to what FSR is and what it should accomplish, the Review Team has found it necessary to devote a portion (Chapter II) of its report to concepts and terminology in FSR. Subsequent chapters provide a conceptual framework covering what the Team considers to be the goals and benefits of FSR (Chapter III), a broad methodology for FSR (Chapter IV), and discussion of how FSR might best be conducted in the IARC context (Chapter V). Chapter VII gives the Review Team's Conclusions and Recommendations.

23. Throughout Chapters III, IV, and V frequent reference is made to the FSR programs and activities in the visited IARCs so as to give an indication of the relevance of each center's FSR to the conceptual framework developed in these chapters. Annexes 2 to 5 respectively present an outline and commentary on FSR at CIAT, IITA, ICRISAT and IRRI, i.e., the visited IARCs. Throughout the report the term IARCs always refers to at least the four centers that were visited. However, depending on the context, it may also refer to additional centers within the CGIAR system.

II. CONCEPTS AND TERMINOLOGY OF FARMING SYSTEMS RESEARCH

24. A variety of terminology has developed around farming systems research (FSR), some of its agricultural and some from systems theory. Between, within, and outside the FSR programs at the IARCs, much of this terminology is used in different ways, often confusingly. As a basis for discussion and understanding, and so as to enable appreciation of the potential role of FSR, it is necessary to specify how the Review Team (a) defines FSR, (b) uses its terminology, and (c) perceives some general implications about farming systems that may be drawn from a broad systems view of agriculture.

(i) What is FSR?

25. There seems to be no end to attempted definition of what constitutes a farming system. The Team suggests the following description:

A farming system (or farm system or whole-farm system) is not simply a collection of crops and animals to which one can apply this input or that and expect immediate results. Rather, it is a complicated interwoven mesh of soils, plants, animals, implements, workers, other inputs and environmental influences with the strands held and manipulated by a person called the farmer who, given his preferences and aspirations, attempts to produce output from the inputs and technology available to him. It is the farmer's unique understanding of his immediate environment, both natural and socioeconomic, that results in his farming system.

26. In such terms, therefore, the Review Team views FSR as research (including training) which:

- (1) is conducted with a recognition of and focus towards the interdependencies and interrelationships that exist among elements of the farm system, and between these elements and the farm environment; and
- (2) is aimed at enhancing the efficacy of farming systems through the better focusing of agricultural research so as to facilitate the generation and testing of improved technology.

In the above definition of FSR, efficacy implies relevance to the objectives of the CGIAR, i.e., to research "benefitting the majority of farmers in low-income countries and on commodities representing important sources of food for the developing countries."¹

The major activities involved in FSR are:

- (a) The collection and analysis of base data;
- (b) The study of existing farming systems;
- (c) The design of new farming systems;
- (d) Farm systems experimentation; and
- (e) The evaluation and monitoring of new farming systems.

¹From condensed summary of CGIAR discussion of its Review Committee's Report, October 27-28, 1976 as presented in: CGIAR, Report of the Review Committee, CGIAR, Washington, January 1977, p.1. The Team notes that this statement (and its associated discussion by the CGIAR) gives no guidance to the acceptable level of trade-off between benefits to small farmers and nonfarm low-income consumers.

(ii) Systems Terminology and Concepts

27. Recent years have seen a burgeoning scientific interest in what has come to be known as General Systems Theory and Systems Analysis.¹ In a farming context, the Review Team interprets the concepts and terminology of this theory as detailed below. While the concepts, approaches and jargon of this generalized systems science are relevant to FSR, they are not essential in themselves to carrying out FSR in the applied research context of the IARCs. However, like all specialist scientific language, they facilitate communication in research.

28. Conceptually, a system is defined as any set of elements or components that are interrelated and interact among themselves. Specification of a system implies a boundary delimiting the system from its environment. Two systems may share a common component or environment, and one system may be a subsystem of another.

29. Systems analysis or the systems approach refers to the holistic approach of studying the system as an entity made up of all its components and their inter-relationships, together with relationships between the system and its environment. Such study may be undertaken by perturbing the real system itself (e.g., via farmer-managed trials or by pre- versus post-adoption studies of new technology) but more generally is carried out via models (e.g., experiments, researcher and/or farmer managed on-farm trials, unit farms, linear programming and other mathematical simulations) which to varying degree simulate the real system.

30. The systems approach to research can be contrasted with and seen as an improvement to the more traditional research approach involving a sequence of: (a) observation; (b) hypothesis development; (c) deductive prediction; and (d) hypothesis testing. This traditional approach is generally disciplinary focused and emphasizes a positive stance of "understanding what is" so as to solve problems. In contrast, the systems approach is more oriented to be conditionally normative. It involves specifying a target and assessing alternative ways of reaching it. This implies both an expansion of knowledge (how to reach the target) and problem solving.

31. The systems approach requires: (i) team effort across disciplines; (ii) clear delineation of the system of interest (e.g., the farm system); (iii) perception of objectives of the system itself (e.g., security of income) and of higher-level systems (e.g., social and economic objectives at national and regional levels); (iv) anticipation of technical and economic restrictions from within the system itself (e.g., labor supply) and from the system's environment (e.g., cultural or credit constraints to new technology); (v) ex ante appraisal of alternative research strategies (e.g., genetic resistance versus pesticides); and (vi) ex ante evaluation of possible gains from the research and their distribution (e.g., as would result from proposed new technology).

¹ See, e.g., articles by R.K. Ackoff (pp.27-38) and L. von Bertalanffy (pp.9-26) in: Couger, J.D. and Knapp, R.W. (eds.), System Analysis Techniques, Wiley, N.Y., 1974.

32. Systems analysis is usually carried out in four sequential (and usually cyclical) stages, as follows:

- (1) Specification of relevant systems, considering objectives of higher-level systems in order to set operational targets.
- (2) Description of system performance and environmental variables in order to assess the payoffs of alternative targets.
- (3) Measurement of the degree and form of relationship among the relevant variables, i.e., screening, experimentation and synthesis.
- (4) Use of simulation and testing (e.g., in field trials) to arrange or redesign system components (e.g., new technological packages) so as to achieve the targeted performance for the system.

Each of the above stages involves the three mutually-dependent research functions of conceptual (i.e. model) development, information collection and information synthesis.

(iii) Farming Systems Terminology

33. Because the IARCs are concerned basically with agricultural production research, their focus must necessarily be towards farm systems as distinct from, e.g., social systems, political systems or ecosystems.

34. A farm is an organized decision-making unit in which crop and/or live-stock production is carried out for the purpose of satisfying the farmer's goals. In doing so, the farm interacts with the uncertain physical, biological and socioeconomic environment in which it has to operate, and may change in structure over time. In this definition, the term "farmer" may mean more than a single decision maker, i.e. it may involve a decision-making group. Also it should be understood that the "farm" does not necessarily imply a distinct or fixed tract of land but may involve a nomadic form of organization. Thus, the farm system may be described in systems terminology as a purposive, multi-goal, open, stochastic (i.e., non-deterministic), dynamic system.

35. A farm system may be specified in terms of subsystems in various ways. A useful approach, for example, is to view it as involving the following subsystems: social (labor, family), biological (soils, plants, animals), technical (tools, machines, inputs) and managerial (knowledge, decision making). To varying degree, these subsystems may overlap and interact with each other. The farm system may also be viewed as a hierarchy of subsystems: soil organisms are a subsystem of the soil system which in turn is a subsystem of the cropping system which is again a subsystem of the farm system. Obviously, whichever way it is viewed, the farm system is an extremely complex one.

36. Any particular farm system will have unique characteristics due to its particular location, work force and management. However, for purposes relative to research, extension, marketing, welfare, etc., it is useful to group farming systems into classes of similar structure, e.g., grazing systems, shifting cultivation systems, etc.; or at a finer level into subclasses, e.g., upland rice systems as distinct from irrigated rice systems. The essence of such classifications is that, in the dimensions of interest, the variance between farm systems in the class be less than the variance between classes, and that the classification be useful.

37. Classification terms have also been developed (and used in different ways) for particular types of crop production.¹ The Team's preferred use of these terms is as follows:

A crop system or crop production system comprises all components required for the production of a particular crop and the interrelationships between them and the environment. These components include all the necessary physical and biological factors, as well as technology, labor and management.

A single crop system is a system in which only one crop is grown on the same plot of land in one year.

A multiple cropping system is a system in which more than one crop is grown on the same plot of land in one year. Some of the main multiple cropping systems are:

- (a) Double (triple) cropping: (also referred to as sequential cropping) growing two (three) crops in sequence, seeding or transplanting one after the harvest of the other.
- (b) Intercropping: (or associated cropping) growing two or more crops simultaneously in the same plot in different but proximate stands. In this system, one crop system is part of the other crop(s) environment.
- (c) Row intercropping: growing two or more crops simultaneously in the same plot in distinct rows.
- (d) Mixed intercropping: growing two or more crops simultaneously intermingled in the same plot with no distinct row arrangement.
- (e) Relay intercropping or relay cropping: growing two or more crops in sequence, seeding or transplanting the succeeding one some weeks before the harvest of the preceding crop.
- (f) Multi-storey (or multi-tiered) cropping: an intercropping system involving crops of significantly different height.

Strip cropping is the growing of two or more crops in distinct strips of several rows with each strip capable of independent cultivation.

Sole cropping is the growing of one crop (cultivar or species) alone in pure stands.

Ratoon cropping, is the development of a new crop -- without replanting -- from buds on the root system, stubble, or stems of the preceding crop. Some ratoon crops may be included in multiple cropping systems.

A crop rotation system implies a time sequence of crop systems, either sole or overlapped in phase, on the same area. While a crop rotation system implies a regular cyclical pattern over time (often involving a cycle of more than a year), this need not be so with multiple cropping.

¹In the course of the review, many and varied farming system terms were encountered by the Team.

The term cropping system refers to the set of crop systems making up the cropping activities of a farm system. If the farm also has non-crop activities, then the cropping system is a subsystem of the farm system. Analogously, we may refer to a farm's livestock system or, for example, its beef system.

38. The term farming systems research is a generic term used to refer to any type of research which views the farm in a holistic manner. Thus it encompasses any research which might more specifically fall under the headings of research on crop systems, cropping systems, livestock systems or whole-farm systems. The Review Team recommends that, whenever possible, research on farm subsystems should be referred to specifically, e.g., as livestock or crop system research; and that FSR directed at the whole farm be termed whole-farm system research. Further, since crop systems, cropping systems and livestock systems can be regarded as components of whole-farm systems, research below the whole-farm level can be referred to as systems component research or simply component research. Of course, this includes research on such system elements as machinery, irrigation, management practices, etc. Accordingly, all research at IARCs -- regardless of its parent program -- could be viewed as systems component research. This, however, would be too broad a view. Hence, in the context of the IARCs -- research program, it would be best not to regard research on individual components as systems research unless either (a) the research is focused on the interaction between the particular component and other system components, or (b) it is undertaken specifically with a systems focus in view.

(iv) Farm System Activities and the Environment¹

39. If farm systems are to be changed and improved, they must be understood -- not least because existing systems have a rational basis. Important to such understanding is an appreciation of system activities and their interrelations with one another and the environment -- both natural and social -- of the system.

40. The boundary separating the farm system from its environment is specified by the span of managerial control exercised by the farmer. Within the farm system, activities are carried out which transform inputs into outputs. Major activities are those concerned with (a) crop production, (b) livestock production, (c) processing and storage of crop and livestock products, (d) maintenance, development and procurement of farm resources, and (e) marketing.

41. Farm system activities are related to one another by their demands on the farmer's managerial capacity. Just as importantly, they are also related inter-and intra-temporally through competition and complementarity in resource use, through intermediate product relationships such as livestock dependence on crop production, and through socioeconomic interdependence in satisfying such farm system goals as risk reduction and dietary foodmix preferences.

42. While the farmer has a direct role in choosing the activities to be pursued by the farm system in the light of his preferences, goals and available resources, the environment of the farm system is also very influential through the effects of:

¹For fuller discussion, see: Ruthenberg, H., Farming Systems in the Tropics, Clarendon Press, Oxford, 2nd edn., 1976.

- natural conditions (soils, climate, diseases) which limit the set of feasible activities;
- institutional, legal, educational and cultural influences affecting the choice of activities and disposition of output; and
- economic parameters bearing on the farmer's choice of input mix, intensity of input use, and types of output.

43. Variation in the environment such as weather fluctuations and changes in prices, land tenure laws, religious custom, available technology, infrastructure or market institutions will lead to farm system response. The elasticity of this response, measured in terms of input demand and output supply, may vary greatly between farm systems; for example, irrigated farming systems are generally far more elastic than shifting cultivation systems. Moreover, insofar as elements of the environment are inherently variable (such as climate in some regions), the farmer may react not only to particular short-term changes but also by adopting strategies or mechanisms of a protective or aggressive nature which allow the system to accommodate the uncertain environmental variation which the farmer knows he must face over time.

(v) Farm System Dynamics

44. Farm systems face two powerful mechanisms for change through general environmental influence. On the one hand, as man-made systems they have to overcome a continual tendency to revert to a low-output steady state as is usually typical of nature. On the other hand, pressure for change to a higher-output dynamic state is continually generated by population pressure and socioeconomic-political-cultural changes in the environment leading to demands for greater and more efficient production aided by advances in knowledge and technology.

45. An important characterization of the state of farm systems is in terms of soil fertility and its maintenance. Farm systems in a steady state may involve a high level of soil fertility and output (as in floodplain rice farming) or, more frequently, a low level of soil fertility and output (as in some semi-arid rainfed farming). Most farm systems are, however, in a dynamic state which may be classified as being "balanced", "improving" or "depleting" over time with respect to soil fertility -- and by appropriate managerial action may be changed from one type to another. Just which type of such system a farmer might best have, of course, depends on his preferences and aspirations together with the environmental influences (climatic, economic and social) that he faces.

46. In the past in developing countries, the farming environment was relatively static except for climatic uncertainty. Available technology and product options, along with socio-cultural and political influence, changed little or slowly over time. Under such relatively static conditions, traditional systems of farming became established. By a process of trial and error over generations, such traditional systems were developed as optimal for their environments. Today, due largely to changing social, political and cultural influences, few farms in developing countries operate under a static environment.

47. Traditional systems are no longer likely to be optimal from either the farmer's or a societal view. Changes, many of which still have to be determined, are needed to adjust the traditional systems to their changed and no longer static environment. In general, these changes are such as to make the farm system become more open, more productive, more dynamic, more dependent on purchased inputs, more vulnerable to changes in the environment and more integrated with the national economic system.

48. It is well known that even when apparently desirable system changes and adjustments have been developed and tested by researchers, such changes may not be feasible or acceptable to farmers because they lack knowledge and experience of the proposed changes, or because of the risks the farmers believe to be involved. In this lies a major challenge for the IARCs. Unless their research leads to applicable technology that is incorporated by the farmer in his farm system, research resources will have been wasted. To this end, it is essential that an appropriate methodology be adopted by the IARCs in FSR and that FSR be allied with activities facilitating the impact of FSR on farmers. These considerations form the focus of the following three chapters.

III. GOALS AND BENEFITS OF FARMING SYSTEMS RESEARCH

(i) FSR as an Activity for the IARCs

49. The basic question for consideration by this report is whether or not FSR is a valid and worthwhile activity of the IARCs relative to the overall objectives of the CGIAR.¹ Of special relevance are the CGIAR's first two objectives, viz. (with underline added):

"(a) On the basis of a review of existing national, regional and international research activities, to examine the needs of developing countries for special effort in agricultural research at the international and regional levels in critical subject sectors unlikely otherwise to be adequately covered by existing research facilities, and to consider how these needs could be met.

"(b) To attempt to ensure maximum complementarity of international and regional efforts with national efforts in financing and undertaking agricultural research in the future and to encourage full exchange of information among national, regional and international agricultural research centres."

50. Further, in reviewing its Review Committee's recommendation that the CGIAR focus primarily on increasing production in food-deficit countries, the Group "noted the need to maintain the emphasis on problem-oriented research that benefitted the majority of farmers in low-income countries and on commodities representing important sources of food for the developing countries."¹

51. Accordingly, assessment of FSR in the IARCs must answer the questions:

- Does it involve critical subject matter not likely to be otherwise covered?
- Is it complementary to national efforts in agricultural research?
- Is it oriented to problems whose resolution would benefit small farmers?
- Is it concerned with important food commodities for the developing countries?

As well, in the context of any particular IARC, there is the question of how well that Center's activity in FSR relates to its mandate -- given the assumption that the mandate meets the objectives of the CGIAR.

52. In attempting to answer the above questions, distinction must be made between the actuality and potential of FSR in the IARCs. As outlined in the Annexes devoted to specific centers and in Chapters IV, V and VI, the actuality is that what is called FSR varies greatly across the centers not only in terms of focus but also, more importantly, in terms of scientific approach.

53. There is little doubt that FSR in the IARCs can satisfy the basic points raised in the questions posed above. FSR aims to deal with an important topic which, given the status of national institutions in most developing countries, would not otherwise be likely to receive adequate attention.

¹ The CGIAR's main objectives are listed in: CGIAR, Report of the Review Committee, Washington, January 1977.

Indeed, some IARCs led in initiating and stimulating research in FSR, and a number of national programs have been initiated as a result of this work. This, in turn, notably through the established IRRI and ICRISAT programs, has led to meaningful collaboration with national programs, especially in efforts to determine methodology and factors having broad applicability (the IARC role) or location-specific characteristics (the national program role).

54. The third requirement -- importance to small farmers -- is a major objective of the FSR program at ICRISAT, IITA, and IRRI. In fact, because multiple cropping is a common feature of small farmer agriculture, IARC research in this area should naturally favor small farmers more than large farmers. An added advantage is that ICRISAT, IITA, IRRI and CIAT all work on major crops or resource problems within their areas of responsibility.

55. Further assessment of how well the FSR programs at IITA, ICRISAT and IRRI meet these four criteria is presented in Annexes 3, 4 and 5 which are, respectively, devoted to these institutes. CIAT's approach is discussed in Annex 2.

(ii) Role of FSR

56. As was pointed out in Chapter II, there appears to be some confusion as to what FSR is and what it should accomplish. This is understandable since it is a relatively new field of endeavor, particularly with its holistic orientation and recognition of the need for a multidisciplinary team approach. In the past, perhaps the field which worked most with FSR was the farm management program in agricultural economics. Today, however, FSR teams generally involve a mixed group with such specialists as agronomists, soil scientists, economists, agro-climatologists, entomologists, agricultural engineers, sociologists, and even geographers or anthropologists.

57. Some basic questions have been raised concerning FSR in general, including:

- Is farming systems a "new science"? If so, what is different or distinctive about it? Or, is it just an approach to integration of research?
- Is it research? Or is it an area of science which can be researched?
- What is FSR supposed to do? Is its basic purpose to innovate and create new systems of production, or to improve old ones?
- What should be its major activities? Its research approach?
- Should FSR be done mostly on experimental stations or should it be done on farms?
- Why can't extension services take care of this work?

Many more questions like these could be or have been raised, but these are examples of some which the Review Team has encountered.

(iii) Opinions of the Review Team on FSR

58. The Review Team considers FSR to be very important in providing a scientific approach to problem identification and technology development aimed at improving agricultural production systems. By its nature, FSR is strongly oriented to the IARC target of producing applicable technology. The Team believes that FSR should be an important integral and identifiable (though not necessarily formally constituted) part of the program of all IARCs. However, in order for FSR to achieve its potential, FSR concepts and principles must be understood by scientists working in the IARCs as well as those in the national research and development institutions who use its results.

59. The goal of FSR is to contribute to the improvement of human welfare through sustainable increased agricultural productivity. The characteristics of FSR transcend those of conventional disciplinary research in that FSR, through multidisciplinary effort, seeks to:

- (1) understand better the problems and needs of the farmer.
- (2) improve the efficiency of the agricultural research process by focusing research on these problems and needs of the farmer so as to develop improved technology.
- (3) take into account both the interactions between technologies themselves and between technologies and the environment, and thereby improve the appropriateness and relevance of the generated technologies.
- (4) ensure that these technologies contribute to the long-term maintenance and enhancement of agricultural productive capacity.
- (5) facilitate the linkages between research, extension, delivery systems and the farmer.
- (6) assist in the formulation of development policies and methods which address the problems of the farmer.

Given the urgent need to increase agricultural production by enhancing the productivity of resources allocated to agriculture in developing countries, it is essential that their agricultural research have an FSR orientation for the following reasons:

- (a) There is need to improve the understanding of most research workers of the skills, preferences, aspirations and existing management practices of the farmer, in particular of small farmers.
- (b) the diversity of the natural conditions of production, in particular in the tropics, and often also the need to use available labour supplies by intensive land use, result in strong interactions among the elements of a farm system and this leads to very complex situations.

- (c) most of the farmers in developing countries do not have the power nor the means to identify and communicate their needs to research agencies.
- (d) the array of agricultural services available in developing countries to farmers is limited; additionally, many technologies made available to them are not adapted to their conditions and their needs.
- (e) there is generally a wide gap between the results achieved on research stations and those obtained by the farmer, and therefore a need to determine why certain practices shown to be highly productive in experimental stations are either not adopted or, if adopted, may not at times be equally productive in the farmer's field.

60. Benefits of FSR could be many, but the major ones appear to be as follows:

- (1) Although development agencies and other groups continuously express a particular interest in the small farmer and his problems, in reality they have little basis for understanding him, his production methods, or his needs. If carried out in the manner suggested in Section (v) of this chapter, FSR can greatly assist in providing the necessary information.
- (2) Most agricultural research in developing countries in the past has been based on narrow disciplinary approaches, and integration and application of new information by the farmer has been difficult. FSR provides a structure within which researchers examine problems in a farm system context, and attempt to achieve solutions which will fit into that farm system given the farmer's capabilities and needs.
- (3) FSR can provide a basis for developing improved technology and its transfer, because it recognizes the need to understand the farmer and his system, to categorize the natural resource base on which the system operates, and to provide a basis for a focused research program on major factors limiting performance of a given system. FSR should also assist in understanding and testing location specificity of certain practices.
- (4) FSR provides a basis for analysis, synthesis and application of a consistent set of practices pertinent to production of a given commodity, whether plant or animal, within a particular farm system. Within this context, FSR can play an important role in facilitating the adoption of available technology.
- (5) By concentrating on crop or animal production systems, rather than discrete factors without regard to their interactions, FSR provides an opportunity to study various crop mixtures, natural resource management practices, or other important components on a larger-scale basis and under conditions which allow more complete technical and economic analysis. However, it should be pointed out that there are limitations in present methodology to accomplish some of the needed analysis (see Chapter IV). Furthermore, good FSR should lead to improved

management assistance to the farmer. In most cases at present, farmers are offered diverse bits of information concerning new management opportunities without the benefit of even experimental trials on these practices at production field level.

61. Although FSR brings considerable benefit as indicated above, there are a number of difficulties and problems with FSR:

- (a) FSR is relatively new and its methodologies are still being developed.
- (b) FSR generally requires research teams involving a wide range of disciplines which may be difficult to coordinate and manage.
- (c) It may not be easy to find research workers who are able and inclined to work in multidisciplinary teams.
- (d) The collection, integration and interpretation of very diverse sets of data and information poses a number of problems.
- (e) FSR requires long-term commitments of resources to comprehensive programs, the results and impact of which are difficult to evaluate.
- (f) In particular, care must be taken (i) to avoid the pitfall of attempting to investigate too many systems at once and (ii) to ensure that available effort is concentrated on only the most important systems and locations.

Thus it is essential for FSR programs to establish clear priorities and objectives and to focus their activities accordingly.

(iv) Where Does FSR Fit?

62. There have been questions as to when and where FSR should be conducted. Some persons see FSR as a "downstream" link in the research chain, taking information gained from the experimental program and finding a place for it in the production system, i.e. at the farm level. Others see an "upstream" role for FSR. Within this concept, FSR is seen as a major asset in constraint determination, problem identification and subsequent analysis, which in turn can both assist research institutions to focus more clearly on key problems currently facing, or likely to face, producers and assist policy makers in the formulation of agricultural development policies.

63. The Review Team considers FSR to be important in both an upstream and a downstream sense. It lays stress on the importance of FSR in the recognition of constraints and in problem identification and analysis, and recommends that IARCs' FSR programs be linked closely with their crop improvement programs. This could be done by ensuring that scientists in commodity or crop improvement programs who work at the crop system (or subsystems) level (e.g., agronomists, economists, pest management specialists) cooperate closely with FSR staff who work at the cropping system or farming system level. Such collaboration, with its two-way information flow, should ensure that component research for FSR could begin early and be strengthened by commodity specialists. In turn, these commodity specialists would be stimulated to follow the component research activity in the FSR program leading to adaption of the component for wider use

or integration with other crop or farm systems. These collaborative efforts could be very important, for example, in providing required plant types for early adoption on the farm, or in integrating specific crop or commodity management requirements into a cropping system or farming system context. As evidenced at some IARCs, similar benefits should result from close collaboration between FSR and other groups, including agricultural engineering, cooperative programs, etc.

64. In such international collaboration with FSR, as described above, the IARCs should aim at early testing and adoption of technology by the farmer, while avoiding narrow program interests which might hamper effective cooperation. The Review Team wishes to point out that upstream activities of FSR could assist IARC commodity programs in achieving impact. This would occur through an improved focus on important problems and better identification of real-world situations where new technology is applicable and acceptable.

65. Downstream activities of FSR should prove to be very important. It is here that research products can be fitted into experimental production systems and studied for adoption by farmers. This is an obvious use of FSR. However, another aspect which should be considered is that of monitoring the adoption of new technology and its short- and long-term aspects. These are areas which are too often neglected. FSR baseline studies on existing farms, which can be considered as upstream activities, can be used in evaluating the actual impact of new technology.

66. Both upstream and downstream FSR activities of IARCs will differ from those of national FSR programs. Because of their nature, IARCs should, so far as possible, limit their concern to FSR activities yielding results (technologies and methodologies) which (a) can be generalized or extrapolated (and are therefore related more to principles and methods rather than location-specific practices), (b) are oriented to specific commodity or resource mandates, and (c) could have potential for wide impact.

67. In contrast, national FSR activities are obliged to deal more with location-specific problems (and are oriented therefore more toward management practices or culture-specific needs), and are designed to have more direct impact on pressing local problems.

68. The Review Team recognizes that some FSR activities at IARCs must be devoted to understanding the nature of location specificity, and to methods of aggregating information on agro-climatic zones to ensure broad application of IARC technology. IITA, ICRISAT and IRRI have all been involved in some activities of this type. IRRI has been especially successful in strengthening its activities through the Asian Cropping Systems Network,¹ which serves both an upstream and a downstream function for IRRI and its national collaborators. ICRISAT has worked out a close relationship with the All-India Coordinated Research Programs in Dryland Farming and jointly they have identified a number of agro-climatic zones where dryland farming is practised. Such work fulfills both an upstream function in providing a basis for planning and setting of

¹Carangal, V.R., Asian Cropping Systems Network, IRRI, Los Banos, September 1976.

research priorities, and a potential downstream function in delineating areas where new technology may be applicable. In doing this, ICRISAT has gained necessary experience which should prove valuable later for application elsewhere (e.g., Africa), while the local Indian program has gained a valuable tool for its internal needs.

(v) An Ideal FSR Program

69. The Review Team considers that it may be useful to outline its conception of the basic ingredients of a well-structured FSR program and to relate these to the role of the IARCs. In general, such a program should aim to meet the following interrelated objectives:

- (1) To understand the land (including climatic) resources and socioeconomic environment within which agricultural production takes place. Areas of concern on the resource side include land suitability, weather and its variation, delineation of agro-climatic (sometimes called agro-ecological) zones, and, where appropriate, identification of agro-climatic analogs which may yield information of value for a particular system and guide the selection of benchmark sites. It would seem fundamental to the success of an IARC's FSR program that accurate and reliable data on the land resources and particularly on factors of soil and climate, are made available and well understood. It is especially important in the selection of benchmark sites to have sufficient data to ensure that the benchmark site is truly representative of the larger area under study. In addition the refinement of agro-climatic mapping in an IARC's geographic mandate has an important bearing on the selection of desirable agronomic characteristics in crop improvement programs. On the socioeconomic side, necessary information will relate to population density, income levels, food consumption patterns, infrastructure provisions and broad cultural characteristics.
- (2) To evaluate existing farming systems in specific physical and socioeconomic environments, in particular the practice and performance of these systems; and to improve our understanding of the farmer, his skills, preferences and aspirations. These studies can be considered as essential baseline studies within benchmark situations. It is not expected that IARCs will understand and address all the problems of all farming systems within their mandates. However, it is important for them to assess farm systems at selected benchmark sites which will yield information of importance to FSR or commodity program responsibilities, and to develop methodologies for evaluation of performance of existing farm systems.

- (3) To improve problem identification (target areas, bottlenecks, etc.) in existing farming systems and thereby to assist in focusing better the research activities and programmes of integrated rural development on specific key problems which limit production or farm income. Again, in the context of the IARC role, emphasis should be placed on developing methodology for study of existing systems and in the training of FSR specialists.
- (4) To enhance the capacity of research organizations to conduct research on priority farming systems' problems so that they are better able to design new and/or improved production systems. The role for IARCs here is in developing research methodology in problem solution, in design and testing of new or improved systems, and in training.
- (5) To conduct research on new or improved practices, principles, system components or subsystems within an FSR context, and to evaluate these for possible testing on farms. Again, the major IARC role is to develop methodology, evaluate possible limits of adaptability and site specificity, and training.
- (6) To evaluate new or improved practices, or systems components, on farms in major production areas. Here the IARC role would be to develop methodology to conduct on-farm studies and to measure farmer reaction to new technology.
- (7) To assess the benefits of improved technology on farms where baseline studies have been conducted, in order to obtain information on the impact of technology, especially on small farms. Again, the main IARC role is to develop techniques and methodology to assess impact of IARC technology, and to identify second or third generation problems, thus providing the necessary feedback to research institutes and policy makers. The concepts of monitoring and continuing assessment of impact can be strengthened by FSR activities of IARCs at benchmark sites.

It should be pointed out that while the above seven objectives imply a full range of FSR activities, not all these objectives would be likely to receive full or equal attention in a given FSR programme. Too, all seven objectives are interrelated and their attainment would automatically involve feedback and feedforward effects between them.

70. In enumerating the above objectives, the Review Team wishes to emphasize that the IARC role in conducting FSR will be strengthened and enhanced by collaboration with national programs and that FSR can provide an important link to national programs through joint activities, training, and problem identification (see Chapter V). Ultimately, success of FSR in the IARCs can only be sustained if there is extensive linkages to national programs since these are the direct clients for such research. Of course, the ultimate client of FSR is the farmer himself.

71. The seven requirements listed above constitute a logical, methodical basis for FSR which, if followed, could extend from an assessment of the natural resource base and an evaluation of representative farm systems, to implementation of a research program which focuses on problems faced, or likely to be faced, by the farmer. The steps can be summarized in three fairly distinct activity areas which may be referred to as Base Data Analysis, On-Farm Studies and Research Station Studies. To some degree these three activities may be sequential and cyclical, but more generally will develop concurrently with joint interaction and feedback effects.

- Base Data Analysis. This involves the collection, collation and understanding of the many factors characterizing the environment of a region. Much such analysis will entail exercises in land resource mapping and evaluation, and in large part can be done at research stations or in head offices mostly relying on secondary data. However, where such data are not available or are considered to be inadequate or unreliable, there will be initially a relatively greater involvement by IARCs in data collection. In addition to the physical resources data there is also a need for socioeconomic data on population, farming systems practised, production and income levels, and various aspects of the infrastructure. The aim of Base Data Analysis is to learn as much as possible about the land and water resources of a region and the variations in those soil and climatic factors which mainly influence agricultural production. The normal end-product is a series of maps depicting agro-climatic zones, land/soil units and land use (farming/commodity systems). Such information can then be used to assist identification of potential target zones for on-site study and to determine the best locations for experimental stations or benchmark sites, as well as providing a basis for later studies on research impact. In general, Base Data Analysis will seldom involve detailed on-site investigations except where larger non-farm units (for example, villages) are the object of study.

- On-Farm Studies. Studies on the farm can be aimed at both upstream and downstream activities of FSR. The major factor in On-Farm Studies which distinguishes it from Base Data Analysis relates both to the location and purpose of the research. Thus surveys of existing farms (an upstream activity) would be considered as an On-Farm Studies activity, and a major output of this work would be information for Base Data Analysis. However, village-level studies aimed at understanding the socioeconomic framework of a given community rather than the farm itself would be considered as a Base Data Analysis activity. In addition to this type of survey activity, On-Farm Studies also involve experimentation (physical, biological or socioeconomic) on the farm. Such research can be considered as a downstream activity and may involve testing of new technology or practices at farm level. On-Farm Studies may involve differing modes and degrees of control and may include research under full

researcher control, joint researcher/farmer control, or full farmer control. On-Farm Studies will also include studies of technology adoption, the monitoring of changes in farming systems, and assessment of the impact of new technology. Further, by their nature, On-Farm Studies must often necessarily involve (and provide a fruitful opportunity for) cooperation with national institutions.

- Research Station Studies. These are seen to involve a focused research program to generate new technology, design components for new systems, or modify existing systems. Such research differs from conventional, on-going disciplinary research in that it is designed to fulfill a need in the context of a given farming system. Sometimes it may be convenient to distinguish different classes of Research Station Studies, for example:
 - exploratory, development research aimed at solving specific problems. Once the problem is defined in an FSR context, its solution may have a largely disciplinary-oriented basis.
 - integrative studies, where component parts are assembled and tested in a holistic framework, i.e. the synthesis of research results into applicable systems and management practices.

72. Subdivision of FSR into three activity areas as listed above can be useful in helping persons to understand just where particular FSR programs or program activities are focused or oriented. For example, many studies of factors affecting multiple cropping, experimental tillage practices, soil and water management, or of principles affecting pest management practices, could be classed as Research Station Studies. However, these same practices or components, when improved, could be evaluated in On-Farm Studies. Indeed, it may be seen in the annexes to this report covering individual IARCs that many of the existing FSR programs are centered mostly on Research Station Studies, with much less resource being devoted to On-Farm Studies. One exception to this is IRRI which has initiated a comprehensive program in On-Farm Studies and some work in Base Data Analysis. IITA has done a great deal of work on land resource evaluation (Base Data Analysis) and systems design (Research Station Studies), but has done less work in On-Farm Studies. ICRISAT has worked on agro-climatic zones (Base Data Analysis), village studies (Base Data Analysis and some On-Farm Studies), and systems design (Research Station Studies).

IV. FARMING SYSTEMS RESEARCH METHODOLOGY

(i) FSR, A Comparatively New Area of Study

73. FSR is relatively new, and in view of its complexity, there has not been time to develop detailed, uniform methodologies to carry out the work. The IARCs have developed or are developing methodologies which are suitable for some studies, but at no one IARC nor at any other institution does the FSR program cover the whole field. In general there is a marked lack of methodology for the structuring and conduct of multidisciplinary, farm-environment conditioned research.

74. FSR methodology problems are not easy to resolve, for they entail much more complexity than more conventional or classical disciplinary research. Added problems are presented by the fact that FSR implies a number of different activity categories or areas of concern (see Chapter III), each with its own level of complexity and need for specificity.

75. Except at IRRI, most existing FSR activities of the IARCs are being carried out at the research center itself or its experiment stations. The scientific approach is usually that of the discipline(s) involved. Hence, the methodology used ranges from a conventional experimental plot approach on research stations to various forms of farm surveys. Few FSR programs have developed specific methodologies to meet the problems faced. Some researchers may not even feel the need to look for alternate research methods, but that does not obviate the methodology issue.

76. Some existing IARC programs in FSR involve farmers directly in the research; others deal mostly with bio-technical or socioeconomic opportunities which are related to one or two major commodities. Only recently have a few FSR programs attempted to understand (as distinct from, to catalog) systems being used by farmers in the region.

(ii) Holistic Approach Versus Reductionism in FSR

77. From a conceptual viewpoint, it might be useful to point out that some of the confusion concerning FSR stems from a misunderstanding of the nature of the work itself.

78. Scientific work has traditionally been based on reductionism, i.e., an attempt to understand physical or biological processes by studying only one or two factors at a time and controlling other factors to the greatest extent possible.¹ Such research does not usually concern itself about use or integration of knowledge gained, leaving these aspects to someone else.

79. In contrast, FSR tends to be holistic in nature, attempting to understand how all significant factors relate and interrelate within the process and with its environment. FSR attempts to integrate factors and information, and

¹Odum, E.P., "The Emergence of Ecology as a New Integrative Discipline", Science 195: 1289-1293, 1977; Dillon, J.L., "The Economics of Systems Research", Agricultural Systems 1:5-22, 1976.

to bring these to bear on actual problems. Therefore, while reductionism aims at precision and detail, holism tends to aim at less precise, even descriptive, measurements and observations which, if considered within a framework of attempting to understand the way a system works so as to enable its purposive manipulation, can be very valuable and useful. Stated another way, it can be said that FSR is more horizontal in nature than traditional research which tends to be vertical.

80. At the same time, FSR in its several activity areas can involve both reductionism and holism; and unless one understands these principles and their roles, methodologies and even philosophies of research approach may differ and even conflict.

81. Base Data Analysis and On-Farm Studies are basically holistic in nature, relying upon a broad background of information and measurement. They attempt to make broad generalizations, classifications or evaluations and then to integrate the information gained through careful, but sometimes somewhat subjective, analyses. On the other hand, Research Station Studies aimed at understanding processes are more reductionist in nature, and therefore are more closely akin to conventional disciplinary research. At the same time, some Research Station Studies (e.g., those dealing with design of cropping patterns or new and improved cropping systems) are holistic, and are therefore more difficult from a methodological point of view. The Review Team considers that there is need for increased work in, and understanding of, the holistic approach of FSR. Most agricultural scientists are trained more in reductionist than holistic thinking, and it may be difficult to acquire staff who can work creatively in a holistic systems analysis and design program.

(iii) The Need for FSR Methodology

82. Calls for a more systematic, rational approach for FSR are not new. As one example, an FAO conference in Africa¹ recommended that "high priority be given . . . to the study of agronomic, economic and sociological conditions existing in farming systems in the Guinea Zone," and ". . . as a primary task of this study, the terminology and methodology of investigation, experimentation and analysis of farming systems should be standardized to permit comparability of results within the Guinea Zone." The Conference also recommended "a training seminar or workshop to organize and to integrate investigations and methods of information dissemination concerning farming systems."

83. A recent study by the U.S. National Academy of Science² suggested that one area of research on FSR which is needed is the "improvement of methodologies used to identify farming systems that are well adapted to the local ecosystem and socioeconomic environment."

¹FAO, FAO Conference on Establishment of Cooperative Agricultural Research Programmes Between Countries with Similar Ecological Conditions in Africa: Guinea Zone, FAO, Rome, August 1971.

²National Research Council, World Food and Nutrition Study: The Potential Contribution of Research, National Academy of Sciences, Washington 1977.

84. Geographers have long been concerned about developing research methods for studying agricultural regions and farming systems. Review of relevant geographical literature emphasizes a major dilemma in farming systems research; that is, most work has been descriptive in nature, and it has been difficult to quantify or evaluate the dynamics of a system.¹

85. Most early farming systems work was done by agricultural economists who specialized in farm management. Surveys were their major tool. Two major types of surveys, case studies and sample surveys, were used. Case studies were done in depth on one or a few farms; sample surveys were conducted -- but not in as much depth on each individual farm -- with the hope that an adequate sample was taken to obtain data over a region or district.

86. Biological and physical scientists in developed countries have seldom become involved in FSR. In part, this is due to the fact that farmers were expected to be the integrators of new information. Also, the emphasis on sole cropping and the tendency toward monoculture (implying relatively simpler farming systems) in many developed countries caused a rather telescopic viewpoint in looking at the farm.

87. Biological and physical scientists did become involved in activities approximating FSR in two major areas, land use (usually done by soil scientists), and range management. Probably range and pasture management scientists come closer to conducting systems research than most other biological or physical science disciplines concerned with agriculture in developed countries. Their methods -- in some cases borrowed or adapted from ecological research -- may be of significant value in the study of farming systems.

(iv) Methodology Used in Selected Regional or National FSR Programs

88. There are several national or regional FSR programs which are noteworthy in their use or development of FSR methodology. In many cases the approaches used are appropriate only for national programs, in that they have been developed to deal with location-specific matters, but are illustrative of the possible nature of some national FSR concerns which the IARCs may need to service. However, some of the methodology used in these programs, if adapted to the needs of the IARCs, may prove useful in a broader context. Two programs, a regional program of the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) in Central America and a national program in Senegal, are outlined below. Other national programs will be referred to, as applicable, under specific topics.

¹See, e.g., Blaut, J.M., "Microgeographic Sampling: A Quantitative Approach to Regional Agricultural Geography", Econ. Geography 35: 79-88, 1959.

(a) CATIE (Costa Rica)

89. CATIE began a small farm production systems program at Turrialba in 1973, involving cropping patterns utilizing the common bean, maize, cassava and sweet potato. Entitled Cropping Systems for Small Farmers, the project links experiment station research (Research Station Studies) with research on farmers' land using simple experiments on improved cropping system technology (On-Farm Studies). The project objective is "to study and quantify the interaction between crops presently cultivated by the small farmer (either as monocultures, polycultures or both) and the environment."¹ The research focus is the farm system. Active farmer participation is a key feature of the project, and a multidisciplinary team works closely together to achieve the major objectives, that of understanding and assisting the farmer.

90. Two related CATIE programs provide assistance to the small farmer cropping systems program. These are the Programa de Información Agropecuaria del Istmo Centroamericano (PIADIC) and a Tropical Soils Project.

91. The PIADIC project focuses on gathering, interpreting, and utilizing agricultural information for Central America, from all sources available, in order to: "upgrade the quality of research results and to orient it to the needs of small farmers, and to create a region-wide system for more effective information management." Types of information gathered are scientific/technical, socio-economic, market trends and trade. The project emphasizes building of national information capacity, training, national and regional coordination, and programmed outputs such as manuals, guides, methodologies, trained personnel, national and regional information centers, packages of technology, market news and crop forecasting, and information exchange. PIADIC provides a key element of Base Data Analysis for the CATIE program in Cropping Systems for Small Farmers.

92. The Tropical Soils Project gathers and analyzes results of past research on soil fertility and soil management. It aims to assemble this information into a framework of land capability zones based on a concept of "soil analogs" (using the U.S. Soil Taxonomy as the basic classification system).

93. The CATIE program has working arrangements with six countries in Central America, and in some cases has staff members assigned to appropriate national institutions in those countries.

(b) ISRA (Senegal)

94. Probably the best-conceived and most-developed national FSR program is in Senegal. The program is under the responsibility of the Institut Sénégalais de Recherches Agricoles (ISRA).

¹CATIE. The CATIE Small Farmer Cropping System Program, CATIE, Turrialba, undated.

95. The basic concept of the program is an integrated system of research to create and diffuse production systems, within a regional framework, in the country. The system provides a structure to gather information, assist in identifying agricultural zones or regions, analyze present production systems, evaluate technically possible new systems, study production factors, and involve the farmer in the design and decision process.

96. The integrated creation-diffusion process for new systems is most distinctive in the Senegal program, for it links traditional research groups (Research Station Studies) with testing and evaluation of production systems at farm and local community level (On-Farm Studies).

97. The creation process involves research station scientists, economists and sociologists to a great degree. It seeks to identify "technically possible systems" through a synthesis of new systems using research results and socioeconomic studies as basic information. These experimental systems are studied at research station, substation and PAPEM¹ (experimental sites located in production areas) level, but under researcher control. Promising systems from these studies are then proposed for evaluation in the diffusion process.

98. The diffusion process begins to deal with "extendable systems" which can be evaluated at farm level within appropriate regions. An important special feature for this type of work is the Unités Expérimentales¹ (EUs), which are defined areas (usually larger than a village and its surrounding farms; more likely a district cooperative and its geographical limits). The EUs provide a location and milieu within which experimental development activities on a farm scale can be carried out and evaluated by agents located in them. It is at EU level (but not only there, for other methods are also used) at which the farmer comes into the picture as a part of the design and decision process. The On-Farm Studies aspects of the Senegal program are very innovative. They provide an important approach to the improvement of existing systems, to introduce new systems, and to measure adoption and impact of new technology. The EU approach, however, is far more suited to and appropriate for national programs than for IARCs.

(v) Status of FSR Methodology and Special Needs

(a) Base Data Analysis

99. Work in this category normally should rely in large part on secondary data sources but if data are not available, measures should be taken so far as is possible to arrange their collection either directly by the IARC itself or via contractual arrangements with other relevant agencies or institutions, or on a cooperative basis. The aim of Base Data Analysis is to analyze existing information in such a way that it can be used, among other purposes, to delineate agro-climatic zones to evaluate resource potentials, to assess present agro-ecosystems from a resource base and land use point of view, to identify target areas for system

¹Tourte, R., "Origin of the Experimental Units", paper given at a Symposium on Experimental Units organized by ISRA and GERDAT, Bambey, Senegal, 16-21 May 1977.

studies, and to identify benchmark research sites.

100. Capacity to conduct Base Data Analysis currently varies widely within the IARCs. IITA has a strong program in soil and land evaluation in the humid tropics. ICRISAT is developing a strong program in analysis of weather data as a basis for planning farming systems component research, management of small watersheds, and in defining agro-climatic zones. CIAT has indicated interest in having a capacity to assess the physical resources of its geographical area, particularly with regard to the beef program. IRRI has cooperated with its Philippine colleagues in developing a rainfall-zones map for the country, has assisted in completing a study on rainfall for Bangladesh, and has stimulated work on agro-climatic zones in the Asian Cropping Systems Network.

101. Secondary data of importance in Base Data Analysis may include weather and climatic records, hydrological information, soil classification maps, land use maps, vegetation maps or analyses, regional economic surveys, local production area or village studies, census records, etc.

102. What is needed in Base Data Analysis are methods of research or analysis that can yield information which can be used to ensure the purposive planning of the Research Station and On-Farm Studies of FSR. Especially, environmental classification needs to be conducted on the basis of an understanding of what aspects of the environment are critical to the adoption of technology and of the size of the changes in environmental conditions that need to be identified. The methods adopted should group important physical resource characteristics in such a way that zones with similar management needs or potential agricultural use can be delineated, i.e., "agro-climatic" or "agro-ecological" zones. The need to define such zones cannot be underestimated, for a successful FSR program must depend heavily upon: (a) a careful analysis of the land and climatic base; (b) an understanding of the extent and importance of major land systems or complexes; (c) an understanding of present land use patterns on given land systems; (d) an understanding of environment-technology interaction; (e) a basis for setting of priorities for FSR work, particularly in relation to the farm systems to be studied and resource use and management issues; and (f) a basis for transfer of technology from research to the farmer, especially where the natural resource base is a major determinant in management systems. In particular, the IARCs should benefit from a better understanding of agro-climatic zones and of the agricultural systems operating in them. Beyond direct benefits to the FSR program, these benefits could include:

- a sharpened focus of commodity programs on problems and opportunities of the zone in question;
- a better understanding of national problems and potentials;
- an analytical framework for problem identification and setting of priorities; and
- a better basis for technology transfer, validation and feedback.

(1) Land Resources

103. Some well-founded systems of natural resource inventory and classification exist, and these should be used as much as possible in FSR. As a corollary, FSR workers should probably avoid attempts to develop new systems of classification, unless established methods are plainly not suitable. In general, it would appear that FSR results will prove to be more widely adaptable and useful if FSR is conducted and presented within an established uniform and internationally applicable system of natural resource analysis or classification. Examples of this are the FAO Land Classification System¹ and the U.S. Soil Taxonomy,² which were designed for wide applicability and utility. If deficiencies do exist in such international systems, then it would appear more profitable to improve those systems than to attempt to develop new systems. This is especially true for the IARCs, whose resources are limited and whose clients are the national research systems. It would appear to be easier to link FSR results into national programs if the results are presented within a framework of a known natural resource classification system. Also, conducting the work and presenting the results within a known classification framework will help to resolve some of the major problems with site specificity, for good land or soil classification should assist in defining the limits of site specificity for a given region or agricultural production system. In the end, FSR will not succeed unless it helps to increase opportunity for technology transfer and improved prediction of performance of given production systems.

(2) Weather and Climate

104. Dealing with factors of climate is not a simple task, but certainly it is necessary for FSR workers to appreciate the weather patterns and possibilities and the climate of a given region. For much FSR work, daily, weekly or monthly weather information and its associated probability distributions may be of more value than long-range climatic studies, but neither topic should be overlooked. ICRISAT has initiated an impressive program of weather analysis for its geographical area of responsibility. It has attempted to specify rainfall patterns and probabilities in relation to crop growing seasons as a basis by which to: (a) delineate zones with similar agro-climatic characteristics; (b) predict the possibility and need for on-farm storage of runoff water; and (c) evaluate the potential cropping patterns.

105. Again, as in the case of soils and land classification efforts, climatic studies in FSR programs should attempt to use existing methods of analysis to the fullest extent possible. This will require close collaboration with international agencies and developed country institutions that have special competence or interest in these fields.

¹FAO, A Framework for Land Evaluation, (Soils Bulletin 32), FAO, Rome, 1976.

²USDA, The U.S. Soil Taxonomy, USDA, Soil Conservation Service, Washington, 1976.

106. A climatic factor often overlooked in physical resource appraisal is irradiance (sunlight). In parts of the humid tropics the amount of sunlight received during the rainy season may be relatively low and constitute a limiting factor in agricultural production.

(3) Socioeconomic Aspects

107. Broad appraisal of data on the economic and social characteristics of relevant regions is also an important aspect of Base Data Analysis. Of particular concern will be information on current levels and likely change in: population density (man/land ratios); crops grown, their level of production and their disposition; income levels; market organization and facilities; infrastructure provision for transport, communication, education and health services; demographic structure; level of education; and, if significant, social structure characteristics and tribal/religious/cultural divisions and boundaries.

108. Within Base Data Analysis, such characteristics as listed above can only be considered in broad aggregate terms, quantitatively where possible but otherwise qualitatively. In addition, judgment must be exercised in deciding the relevance of those socioeconomic characteristics to the classification of zones from Base Data Analysis. With so many dimensions of possible characterization, only the most important should be brought to account. The criterion of what is and what is not important should be the degree of relevance to either the delineation of existing farming systems or to possible system changes. For example, while religion may not generally be relevant, it may sometimes be an important determinant for some livestock systems.

(4) Special Methodology Needs for Base Data Analysis

109. There are several areas where it may be necessary to develop special methodologies or approaches related to Base Data Analysis:

- Selection of benchmark sites and target zones for research, either for On-Farm Studies or Research Station Studies. Especially needed are guideline criteria for the selection of benchmark sites and for limiting targeted systems to a manageable priority set.
- Use of climatic, natural resource and economic data in defining agro-climatic zones.
- Use of secondary information to assess the impact of FSR findings and to measure rates of adoption of new technology and rates of change.

(b) On-Farm Studies

110. Methodology concerns may be greatest for On-Farm Studies, for there is limited past experience to rely upon.¹ In the past, most On-Farm Studies have been conducted using farm management surveys, and biological or physical scientists have seldom been involved.

111. On-Farm Studies become very complex because of the diversity and complexity of the data to be taken, as well as difficulty in analysis of the information obtained. Also, criteria for choosing priority farming systems to receive attention have not been developed. Specification of such criteria should receive immediate attention if FSR is to escape the pitfalls of (a) trying to tackle too many systems and topics at once, and/or (b) investigating systems of academic interest but of little real-world importance.

112. There are three major aspects of On-Farms Studies that must be considered:

- (1) studies to understand existing farming systems (baseline studies) which would be carried out at an early stage and often concurrently with any surveys for Base Data Analysis;
- (2) studies to compare or evaluate new or improved systems; and
- (3) studies to monitor changes in existing systems or to monitor the rate of adoption and impact of new technology. Each of these objectives may require somewhat different methodology and therefore are discussed separately.

113. Of the international centers, IRRI has done most work with FSR On-Farm Studies, and their efforts have yielded important information on research possibilities on small Asian rice farms. As would be expected in a relatively new research area, IRRI's cropping systems methodology has evolved with time and has been modified through the Institute's consultative and collaborative work with the Asian Cropping Systems Network.

(1) The Survey Approach to Existing Farming Systems

114. Farm surveys are an essential mechanism for the study of existing systems on an on-farm basis. Such surveys may be of various types, the major contrasts being between: first, in-depth study of a small sample versus less detailed study of a larger sample; second, single-visit surveys versus multiple-visit or continuous surveys of a panel of farms; and third, surveys emphasizing only socioeconomic data versus an emphasis on biological and physical data. These are the extreme contrasts. In practice, these elements may be combined to varying degree or, as appropriate, different types of surveys may be used at different stages of On-Farm Studies. Too, there may frequently be fruitful opportunities for the survey of existing farming systems to be conducted on a contractual or cooperative basis with national or other relevant institutions.

115. In general, specification of existing farming systems will imply initial survey activities of a broad rather than detailed nature (i.e., across rather than

¹ An example of one approach to On-Farm Studies can be found in: Hildebrand, P.E., "A Multidisciplinary Methodology for Developing New Cropping Systems Technology for Traditional Agriculture" Instituto de Ciencia y Tecnologia Agricolas (ICTA) Guatemala City, undated.

within villages), with single visits to a large rather than small sample, and with an orientation to collecting both agronomic and economic data. As the On-Farm Studies progress, need will develop for more detailed information not only on the specifics of particular systems but also on the changes taking place in them. This could imply the use of multi-visit or continuous panel surveys, or detailed case studies of particular farms.

116. Whatever survey procedures are used, there are likely to be manpower and logistical problems which must be recognized. In particular, survey interviewers must be able to establish rapport with sample farmers if reliable data are to be obtained. Language can be a severe problem.¹ Further, interviewers must be suitably trained to understand the information they are collecting. This is particularly important for the collection of agronomic and other biological information which may involve actual field measurement (e.g., of yields, and disease and pest incidence). For continuous detailed surveys, the ideal is for the interviewer to live in the farm community being studied.

117. Whatever the type of survey, it should be purposive. Data should not be collected without prior knowledge of why it is being collected. Since FSR is an on-going activity, changes in data needs will develop over time. Most often these will best be satisfied from repeated visits to a benchmark site which, as the research activities develop, can be surveyed to gain pertinent information relevant to current hypotheses. In this regard, an excellent example is provided by ICRISAT's continuous survey of farmer samples in its six semi-arid Indian benchmark villages (which were selected after an exhaustive analysis involving the selection and application of a set of 40 criteria).

118. Data to be collected in surveys should be determined by the information needed for hypotheses to be tested in FSR and by the analytical techniques to be used. For economic-type analysis in FSR, relatively strong analytical techniques for handling attitudinal and multivariate data are available (e.g., utility analysis, linear programming and econometric techniques). For multivariate biological data on farm systems, data analysis techniques are not yet well developed. Perhaps ecological methods of multivariate analysis can be adapted to this end, and better integration achieved between economic and biological data analyses.²

119. Implicit in the above discussion is the need for multi-disciplinary participation in the design of farm system surveys. In the past, economists have played a major role in designing and conducting such surveys in the IARCs. The Review Team sees nothing wrong in this so long as other disciplines participate adequately in survey design. However, it would often be advantageous for other

¹The Team was informed that for some IITA contacts with farmers, it has been necessary to use a chain of four translators.

²National Research Council, Supporting Papers: World Food and Nutrition Study, National Academy of Sciences, Washington, 1977, Vol. II, pp.12-51.

disciplinary scientists to be actively involved in the field survey work to some degree so that they thereby obtain (if not in other ways) active contact with real-world farmers and farming systems.

(2) Testing New or Improved Systems

120. The degree of control and management exercised by the farmer or research team are important considerations in choice of methodology in testing new or improved systems on the farm. The number of options to be tested should be quite limited at this point, since most of the variations would have been eliminated in Research Station Studies.

121. For various reasons the FSR team may wish to study certain new or improved practices or systems in the farm environment, but under the control of the research team. For some of this work conventional field plot techniques may be suitable, and few methodology problems may be encountered. However, for more complex studies where packages of practices, intercropping, or mixed farming systems are involved, there may be serious limitations on the use of existing methodology (as noted relative to Research Station Studies, later in this Chapter).

122. When the farmer is expected to manage the fields or plots, especially if he is asked to handle two or more comparisons or a combination of practices, conventional field plot techniques will be limited in effectiveness, and adjustments in methodology may be necessary. These may include: use of larger fields, reduction in number of replications (probably in most cases only one replication of a treatment per farm is manageable), and use of a minimum number of treatments or comparisons. Another factor in methodology for farmer-managed studies is the degree and method of contact of researchers with the farmer. This will vary, depending on circumstances required by the research.

(3) Monitoring Adoption and Impact

123. The study of adoption and impact is analogous to the study of existing systems and implies somewhat similar methodologies. Both are carried out on existing farms and under the management system of the farmer. Both require system measurements within a dynamic, real-world context, and conventional plot techniques are not applicable. Studies of indigenous systems yield baseline data and identify priority problems requiring research attention; while studies to monitor change or to assess impact provide measurements of the systems as they are affected by research results and economic factors, and comparisons with baseline information will be required in order to measure change.

124. Some of the methodology developed by ecologists would appear to be relevant to the study of this type of farming system dynamics, for it is designed to measure physical and biological phenomena within a dynamic space/time/natural resource/plant growth continuum.¹

¹National Research Council, "A Methodology for Farming Systems Research", Supporting Papers: World Food and Nutrition Study, National Academy of Sciences, Washington, 1977, Vol. II, pp.12-51.

(c) Research Station Studies

125. This is the research area with which research workers are most familiar and comfortable. Research methods are more developed and conventional; the research station provides a known, controlled environment for investigations; and data analysis is fairly standardized. However, there are limitations as to the methodologies for FSR which can or should be used, and these should be -- but often are not -- recognized.

(1) Component Research

126. Most research in Research Station Studies is primarily component research. Except for economic studies, it does not usually deal with whole-farm or system-wide problems though it should keep the FSR focus in view. Rather, emphasis is usually restricted to a few factors in the context of a particular problem of production, the resolution of which would be beneficial.

127. Examples of such research include plant breeding, evaluation of tillage practices, pest biology and control, proper fertilizer use, potential new cropping patterns, and animal feed evaluation. Research Station Studies provide new ingredients for components of farming systems for given production zones. Some of this work resembles discipline-oriented research, and may be less dependent on multidisciplinary methodologies than are Base Data Analysis and On-Farm Studies. For those areas where it is more allied to disciplinary research, it is less affected by methodological problems. However, as it begins to focus more on design of alternative or improved systems, or inter-cropping, or other multiple variable topics, methodological problems become more difficult.

(2) Evaluation of Research Station Studies

128. A particular concern with such research is the evaluation of its output (ex ante and ex post) in terms of farm system relevance. Such evaluation must encompass (a) system interactions of a bio-technical and agronomic nature (e.g., maize bred without regard to climbing bean requirements may be of no use for maize/bean systems), as well as (b) economic considerations in terms of resource availability (e.g., is it scale neutral?), expected profitability, income (food) security and external effects (e.g., weedicides could displace and disadvantage poor laborers), and (c) socio-cultural influences to the extent that they are relevant.

129. Important in such evaluation is that there be active cooperation between the biological and social scientists involved in FSR. Of most relevance is the economists' role. The Review Team believes that FSR must include a significant economics component. In contrast, participation by other social scientists (sociologists and anthropologists) might, at least in the initial period, best be on a consultative basis. Otherwise the FSR program may run the danger of losing its agricultural focus and becoming too "rural development" oriented.

130. For the economist's work of economic evaluation to be successful, two ingredients appear necessary: (a) he must understand what the biological scientists are attempting and be able to communicate with them in the context of their language and traditions, so that they recognize (b) the need for the economist to participate in the design of their research. The latter is necessary since, just as with statistical principles, economic principles of analysis cannot be applied to experiments that are not appropriately designed.

(3) Particular Methodology Needs for Research Station Studies

131. There are two major needs in the area of methodology for Research Station Studies:

- Immediate attention must be given to criteria for the selection of research priorities in both farm subsystems and subsystem components. This is essential because of the multitudinous array of possible research topics. Only those which are important and solvable should be researched if scarce research resources are not to be wasted.

- Improved research methods are needed for multiple cropping. This is especially so in the area of experimental design and analysis. Most conventional plot techniques were designed for monoculture. They are generally not suited for use in systems where two or more crops are grown together and where planting dates, growth patterns, harvest dates and other factors differ or are altered by complex interactions. Plot sizes are often too small, and to conduct experiments on a suitable scale and level of replication often leads to prohibitive costs. Further, since the cost and complexity of multiple cropping experiments is generally much greater than for single-crop experiments, attention needs also to be given to the extent to which single-crop research may give guides to a crop's performance under multiple cropping.

132. Other areas of Research Station Studies requiring special methodological attention include the conceptual and integrative aspects of:

- Specifying environment-technology interaction (a methodological area linking Research Station Studies to both Base Data Analysis and On-Farm Studies).
- Designing new or improved systems.
- Testing alternative systems.
- Handling pest management factors, including the biology and ecology of pests in various cropping or production systems, interactions of weeds, insects, diseases and vertebrate pests, etc.

(4) Computer Modelling and Simulation

133. One methodological approach to the four topics listed above is computer modelling and simulation. This has been extremely popular in developed countries in recent years and, to varying degree, some such work has begun in FSR at the IARCs. In the Review Team's opinion, such work has a definite place in the centers, particularly in its linear programming and rainfall/water balance/

crop growth simulation models which can be of real value in helping to define priorities for both Research Station and On-Farm Studies. However, more complicated and nonstandardized modelling should be undertaken cautiously with a full appreciation of its dangers. Stated in extreme terms, these dangers lie in the tendency for such models to become monstrously complex, understandable only to their creators, and inordinately demanding of research resources -- while always giving the appearance that success is just around the corner. Further, as an element of methodology transferable to national programs, such complex models would seem to have limited potential given the shortage of computer skills and facilities in most developing countries.

V. CONDUCT OF FARMING SYSTEMS RESEARCH

134. This chapter will deal more with organization and conduct of FSR than did Chapter IV, although it probably cannot avoid some overlap with methodology questions.

(i) The Comparative Advantages of IARCs in FSR

135. The IARCs have some unique advantages in conducting FSR, including: excellent support staff and facilities, opportunity to travel internationally and to become directly acquainted with the problems in their mandate areas; generally good access to potential cooperators and participants in interested countries; considerable scientific prestige and respect; and international mandates which, compared to national institutions, give them a comparative advantage in the study of environment-technology interactions.

136. Some drawbacks of the IARCs in FSR include: the problem of determining the limits of their FSR programs in relation to the areas of responsibility of national organizations; difficulty in working with individual farmers and farm systems except through national programs, some of which are weak and not very effective; a tendency, because of their close proximity, to concentrate on farming systems of the host country at the expense of farming systems elsewhere; and difficulty in maintaining their focus on critical issues of wide relevance rather than becoming too involved in more location-specific practices and problems.

137. Each IARC has been given a commodity and/or geographical mandate under which to work. In theory, FSR responsibilities for those same commodities or geographical regions would also apply to that center. It follows therefore that a given IARC could be responsible to undertake certain FSR activities (e.g., Base Data Analysis) for the commodity(ies) or area(s) within its mandate. Thus, IRRI could be responsible for mobilizing and using natural resource and economic information (Base Data Analysis) on rice-based systems. In addition, it could conduct On-Farm Studies and Research Station Studies on those systems. The same could be true of CIMMYT for wheat and maize; of CIAT for low elevation tropics and for cassava, beans and beef; and of IITA for the subhumid and humid tropics and for cowpea, yams, and sweet potato. However, it is neither likely nor advisable that a center develop an FSR program covering all its mandate's responsibilities, either commodity or geographical. Rather, it is more likely that FSR at a given center would concentrate on no more than a few major systems. For example, the IRRI Cropping Systems Program has chosen to concentrate on rainfed rice. IITA has concentrated mostly on the subhumid rather than the humid tropics, and has not restricted its work to its mandated crops. It has placed more emphasis on land management systems than on specific commodities, and uses special crops to exploit opportunities presented by the available land resources.

(ii) Organization of FSR

138. The Review Team found that in the IARCs visited, FSR was carried out under quite diverse organizational structures, ranging from a separate farming

systems program with direct budget cover and composed of individuals from distinct disciplines (which at ICRISAT did not include economics) and headed by an Assistant Director (IITA), to a group of individuals from and financed by disciplinary Departments and conducting FSR under the leadership of a program leader (IRRI), to FSR activities being carried out within the structure of commodity programs (CIAT).

139. In terms of organization, the Team agrees that there can be no one perfect structure. Some essential ingredients appear to be that there be: (a) an identifiable structure and that it be led in such a way as to facilitate multidisciplinary research; (b) capacity for skilled disciplinary research within the multidisciplinary framework; (c) adequate recognition for scientists participating in the collaborative program; (d) opportunity for peer review, professional publication (outside of house media and conference proceedings) and career development advice from other center staff in the same discipline for those specialists assigned directly to FSR programs; and (e) flexibility in staffing so that current activity requirements tend to determine staffing rather than the reverse. Further, if there is a separate FSR program, linkages between this program and the crop improvement programs must be ensured (perhaps via joint appointments). Without such linkages, the crop programs may tend to use the existence of an FSR Program as an excuse to ignore the problems of small farmers.

140. As in any research but more so in FSR with its broadranging and multidisciplinary character, leadership is vital. The Review Team believes that it is more pertinent to choose a team leader with scientific leadership capacity in the FSR context of wide disciplinary span than with specific disciplinary or other research background. Other things being equal, the Team would give preference in leadership to a farming systems agronomist. However, the main criteria for selection of a leader should be an ability to perceive problems in a holistic manner and to motivate persons from other disciplines.

141. There appear to be at least three different types of teams which can work in FSR programs. One is a group which does Base Data Analysis and which concentrates on land resources, climate and weather, and socioeconomic factors. Such an analytical group could also be helpful to the Director General of the Center as an intelligence unit collecting, analyzing and categorizing information which could be useful in planning strategy and future programs for that Center. Assuming such responsibilities to the Director General were not too diffuse, or time-consuming, it would seem that this same group could work together to delineate agro-climatic zones, to identify target areas for FSR activities, or to point out new opportunities for commodity research.

142. A second group could focus on On-Farm Studies. Although some members of this group would include scientists also involved in Base Data Analysis, specialists such as entomologists, plant pathologists, economists, and crop physiologists could be drawn, as needed, from the more specialized disciplines involved primarily in Research Station Studies.

143. A third group would be specialists who work on Research Station Studies. They should be leading scientists in their respective disciplinary fields who would be prepared and enthusiastic to work in a multidisciplinary team.

144. Beyond the designation of an identifiable structure and subgroup activities, the Review Team sees an essential requirement for FSR to be programmed or flow-charted through time and across activities. Though this should not necessarily be in terms of precise deadlines, it should at least be in such a way as to recognize the time-phase dependencies between different program elements. This is particularly important in FSR which, by its nature, depends on coordination in the activities of team members. Unless activities are coordinated over time and sequential dependencies recognized, FSR programs are likely to flounder and generate poor morale. Concomitantly, it is important for individual scientists (who will generally have responsibilities across various activities within and outside the FSR program) to know what their responsibilities are, what these responsibilities imply in terms of time allocation, and how they relate to the responsibilities of others.

145. All members of an FSR program should be oriented towards the systems approach, in the sense of seeing their research in a holistic framework and of recognizing the need for consideration of their research from viewpoints beyond that of their own parent disciplines.

(iii) Strategy in FSR

146. The team proposes the following guidelines as the basis of an IARC strategy for FSR, recognizing that the majority of such work will be concerned with farm subsystems (such as cropping systems, watershed systems, livestock-feed systems, etc.):

- Make maximum use of existing secondary or historical data, by using innovative integrating techniques to delineate and to characterize agro-climatic zones (Base Data Analysis).
- Study and evaluate existing farming systems delineated by agro-climatic zone, in order to assess performance; to identify pressing technological, policy or other problems implied by setting targets for systems performance; and to understand the farmer and the major farming systems of relevance. Use such On-Farm Studies as the basis for focusing research programs on real needs of the farm system. Evaluate strengths and weaknesses of existing farming system practices. Where possible, popularize and extend the use of successful farmer practices to similar agro-climatic zones, and if not successful, understand why. These, along with later farm testing of improved systems, are On-Farm Studies activities.

- Postulate, investigate, synthesize and build up improved farming systems via Research Station Studies. Such work can have its origin in Base Data Analysis or On-Farm Studies, or it can arise from ideas and innovations flowing from basic or applied research world-wide or from individual researchers in the IARCs. Once FSR is underway, priority should generally be given to problems identified or refined through On-Farm Studies but without denying opportunity for the consideration of "bold new designs." The purpose of the Research Station Studies activity is to disaggregate various systems or system components into researchable subtopics and then, taking account of interaction effects, to build these into solutions for integration into management systems. Thus, Research Station Studies will likely include detailed analysis of single-factor problems, synthesis and design of components of important cropping systems, and modification of existing systems. The Research Station Studies team will also conduct operational-scale field studies of new or improved systems and, after both preliminary technical and economic evaluation, will recommend the most promising ones for trial in farmers' fields. The Research Station Studies group will interact closely with the On-Farm Studies group in conducting research on the farms. In some cases these teams may consist of many of the same staff members, but On-Farm Studies should be led by a person experienced in on-farm research.

- Limit the number of farming systems to be considered. Unlike crop improvement programs which are relatively tightly defined and can always be rather clearly specified, FSR has a diffuse ambit. Within the mandate of any IARC, a great diversity of farm systems exists due to the influence of agro-climatological, cultural, institutional and socioeconomic factors. But as is clearly recognized, no IARC could possibly handle all the farming systems it confronts. Positive action is still necessary, however, to ensure that FSR is restricted to a range of activities which can be adequately handled within the constraints of staff and budget limitations. To this end, careful selection of priority systems for study and benchmark situations is essential, as is emphasis on research and its associated methodologies which have general rather than only location-specific implications.

147. A further general question of FSR strategy is that of the balance between on-station and off-station work. This is now considered in more detail.

(a) On-Station Research

148. Questions have been raised concerning the types and amounts of FSR which might be carried out on a research station. Such questions are reasonable since the ultimate aim of FSR is to have impact at farm level.

149. Using the Review Team's concept of FSR involving three basic activity areas, Base Data Analysis and Research Station Studies are most appropriate for on-station work. Base Data Analysis, which is essentially an effort to make maximum use of secondary data, is especially well suited to on-station work, although, as noted earlier, this may to some extent necessitate off-station surveys to either obtain, or check the reliability of, resource data. Also, early efforts in Research Station Studies to synthesize and test new or improved systems or system components may be carried out most effectively under the controlled circumstances of the research station. However, as a system or system component approaches readiness for wider testing and evaluation, it should be moved off-station. This should be done through a network of benchmark sites (which may include both research stations as well as on-farm sites), and either in cooperation with national programs, other IARCs, or on sites controlled by the IARC itself.

(b) Off-Station Research

150. It is obvious that all On-Farm Studies, by definition, will be carried out at off-station locations. However, in addition to On-Farm Studies, there may be need for evaluation off-station, but still within a controlled or less visible location. Such testing might occur on experimental stations of the local government or special demonstration farms or unit farms (controlled by a national program or IARC) within given agro-climatic zones or subzones. Such off-station work feeds into and is transitional in nature between detailed Research Station Studies and On-Farm Studies; and may be especially important in cases where technology adjudged potentially useful needs evaluation in a certain agro-climatic situation, but is considered too preliminary or risky for evaluation in On-Farm Studies. So far as possible, of course, it is preferable that such off-station testing and evaluation be conducted at benchmark sites.

(iv) National Programs

151. To be effective, IARCs must work with national programs. Indeed, national programs are the direct clients of the IARCs. The products of the IARCs are methodology, technology and training. In FSR, contact with national programs is of special importance since national or local organizations are needed to provide contact and interaction with farmers for the on-farm testing and evaluation of proposed systems changes. For this reason, when requested, IARCs should be willing to assist national institutions in the planning and organization of national FSR programs.

152. Cooperation in FSR between IARCs and national institutions should be a two-way process aimed at ensuring the relevance of the work of IARCs to the problems faced by the majority of national programs. This cooperation should be based on full reciprocity taking into account the activities of IARCs and the stage of development of national programs.

153. Cooperative activities with national programs would mainly cover the following areas:

- (a) data collection and interpretation and information exchange;
- (b) priority setting and planning of FSR;
- (c) adaption and introduction of new technology within existing farming systems;

- (d) development and introduction of new farming systems; and
- (e) training.

By concentrating IARC FSR on problems of general interest and critical subject sectors unlikely otherwise to be covered adequately by national agencies, such cooperation should achieve maximum complementarity of international, regional, and national FSR efforts.

154. Cooperation in FSR with national institutions should be established on an equal partnership basis and establish communication and dialogue so as to, for example:

- (1) thresh out relevant concepts and terms;
- (2) understand and criticize one another's programs in all their dimensions of research, training and cooperative activities;
- (3) gain an appreciation of alternative forms of organization and planning;
- (4) facilitate the joint development of methodology;
- (5) provide a professional forum for FSR oriented to small farm systems where the more burning questions such as benchmark site selection procedures, criteria for choosing representative systems, and multiple cropping research designs may be argued.

155. Within the cooperative framework, IARCs would be expected to contribute towards the establishment of general principles, basic knowledge and methodologies in FSR, and to develop technologies of wide applicability. It should be pointed out that there are considerable benefits to be gained from cooperative efforts between national programs and IARCs, and that their respective roles in FSR can be complementary. For example, national programs, in addition to meeting their own objectives, could play an important role in an "upstream" sense for the IARCs by identifying priority problems and by suggesting needed improvements in methodology or other outputs of FSR. In some cases national programs may also wish to involve IARCs in some "downstream" activities, especially in the areas of on-farm studies, methodology development, and location specific research.

156. In general, IARCs may not be able to meet all the demands of the many countries which may wish to cooperate with them in the field of FSR. While IARCs may assist a wide range of countries in such aspects as information exchange and training in the field of FSR, the complexity of FSR necessarily limits the scope of cooperation to selected countries. In many cases, however, even if it cannot assist directly, a center may be able to identify and mobilize sources of funding and technical assistance which may contribute towards strengthening national research in this field.

157. Active cooperation with national programs in development of methodology is warranted in the first years of the establishment of FSR at an IARC, even though the center may have no defined program to offer to national institutions. At this stage, it is the center which is expected to benefit most from the cooperation with national programs in that such cooperation can help in setting research priorities for the IARC's FSR program.

158. It should be kept in mind, however, that the scope of cooperation will very much depend on the stage of development of national FSR programs. Some national agricultural research organizations have FSR or other relevant programs of their own. Some of these programs are fairly well established (as in Brazil, Central America, Indonesia and Senegal) while others are just beginning. Close linkages of IARCs with existing or new programs will be important in providing outlets for new technology.

159. There may be some pitfalls ahead of IARCs in dealing with national programs. In particular, IARCs should be cautious in interacting with national programs on politically sensitive issues such as may sometimes arise when assisting in socioeconomic surveys and in contributing to national development programs. Secondly, where FSR programs do not exist in a country, linkages to farms may be limited, and unless some activity or at least appreciation of FSR builds up, adoption and effective use of IARC systems technology may be limited. Also, the specific commodity or natural resource mandates of different IARCs may present problems when more than one IARC works in one country, particularly when the FSR priorities of the national organization differs from that of the IARCs. Accordingly, a center should avoid engaging in cooperative activities in a country where another IARC is already working without prior consultation with this center so as to avoid confusion and competition.

160. The possible modes of cooperation between IARCs and national programs in FSR are necessarily varied. The simplest and often most effective mode of cooperation, as a first step before establishing formal agreements, is between individual scientists in IARCs and in national programs who are engaged in FSR in common areas of interest. Follow-up and backstopping of former trainees by IARC personnel would be another aspect of this type of cooperation.

161. Another mode of cooperation is for the IARC to outpost FSR scientists to work in national programs, share their problems, assist in the planning and implementation of FSR activities, and provide a link and feedback facility for the FSR program at the headquarters of the IARC. Such outposted staff can also play a useful role in identifying candidates for fellowships and training courses at the IARC, and providing in-service training by working with and within a national program. Most IARCs are involved in this type of cooperation.

162. Some IARCs, notably CIAT, ICRISAT, and ILCA, are developing their cooperation with national programs by establishing one or more relay stations at certain benchmark locations for tackling problems which are specific to certain groups of countries. A relay station may also serve as a focal point for establishing programs of cooperation between interested countries.

163. A similar formula is the development of regional programs which play the same role in stimulating cooperation between several countries and an IARC. In this case, however, there is no regional base or focal point (e.g., relay station) for this cooperation. Some of these regional programs are called "networks" when several countries agree to conduct jointly a series of investigations with common objectives and methodologies.

164. IRRI's Asian Cropping Systems Network is an excellent example of a mode of cooperation with national programs. This network operates on a collaborative basis, emphasizing rice-based cropping systems. The program is structured around regular joint planning and conduct of research, annual meetings for planning and evaluation purposes, and strong training linkages which are reinforced through the efforts of a Cropping Systems Network Coordinator.

165. Of course, cooperation within a network will be limited by the possible differences in the stages of development of national FSR programs and in the diversity of their problems as shown by IRRI, when common problems have been identified, networks in FSR can be a very effective means for developing methodologies.

166. In general, cooperation between an IARC and a national program in FSR will usually be with institutions designated by the government for such cooperation. IARCs may play an important role in facilitating the contributions of several national institutions to the national FSR program, in particular that of universities. However, contacts with other institutions such as development agencies, universities, etc., should be made by the IARC through the national institution designated as having official responsibility for agricultural research.

167. Where virtually no national capability in FSR exists, progress will be slower and the seminal role of IARCs, especially in training, could be of great importance. Where little national interest exists or in cases where it cannot be stimulated, IARCs should not be held responsible for lack of progress. In such cases, progress will be necessarily slower, and access by that country to IARC technology may be gained only through specific commodity programs or initiatives. In such cases the crop or livestock system program of Research Station Studies and On-Farm Studies could become important as the vehicle for change.

(v) Training

168. The Review Team considers training to be one of the most important benefits of FSR work at the IARCs. Indeed, the Team considers training to be an integral part of the FSR program, for FSR by its nature is most useful in the context of collaboration between national and international (including IARCs) institutions. Training a cadre of experienced personnel in a cooperating country spreads the philosophy and methodology of FSR to neighboring or interested countries, and provides a basis for FSR networks and cooperative activities. IRRI, ICRISAT and IITA all have FSR training programs, and each has a number of former trainees located in countries within their areas of responsibility. IRRI has been especially effective in selecting trainees who return to specific, identified positions in their home countries, most of which are linked into the Asian Cropping Systems Network.

(vi) Collaboration with International Agencies and
Developed Country Institutions

169. It is clearly recognized that IARCs should not take on the role of development agencies or become directly involved in location-specific problems within their respective geographic mandates or in commodity-based farming systems. It is therefore paramount that they must establish strong cooperative links with national institutions within their constituencies. In addition, they will often need to foster cooperative activities or seek assistance from international development agencies or developed country institutions with specific skills or capabilities. In particular, such cooperation or assistance in national programs may be needed in Base Data Analysis and Research Station Studies programs. For example, help could be sought from FAO on definition of land and agro-climatic zones, from the USDA, CSIRO or FAO on land and soil classification, and from WMO on weather and climatic characterizations.

VI. OVERALL ASSESSMENT OF FARMING SYSTEMS RESEARCH AT THE IARCS

(i) General

170. There are four general categories of IARC involvement in FSR:

- (1) IARCs having little or no FSR activity (e.g., CIP and ILRAD).
- (2) IARCs with FSR activities but no formal subgroup or program (e.g., CIAT in its beef program in particular but also to a degree in its bean and cassava programs, and CIMMYT in its adoption-survey activities).
- (3) IARCs with formal FSR programs as well as Crop Improvement Programs (e.g., ICRISAT, IITA, and IRRI).
- (4) IARCs with a center-wide commitment to following a farming systems philosophy in all program activities (e.g., ILCA and ICARDA).

171. Being a relatively new field of endeavor with all the contingent difficulties of multidisciplinary involvement, it is not surprising that the degree of commitment to FSR and the concepts and approaches used vary widely across the IARCs (as shown by comparing the FSR programs of the four IARCs detailed in Annexes 2 to 5). Such variation is to be expected in the initial growth of a new research field. Further, each of the IARCs can be expected to adopt a somewhat different pattern and style in its approach to FSR according to the obligations of its mandate. For example, the approach to FSR of a center devoted to a specific commodity (e.g., rice) will differ considerably from an IARC where the mandate calls for a geographical focus (e.g., humid tropics).

172. However, there are signs that FSR at the IARCs is entering a stage of consolidation. Improved intra-center organization for FSR is developing, as is inter-center awareness and discussion of differences in approach. From their different starting points, the IARCs visited by the Review Team are all beginning to recognize their FSR deficiencies or needs in terms of the three basic activities of Base Data Analysis, On-Farm Studies or Research Station Studies as the case may be. Concurrently, confidence in FSR is developing as the effects of better organization and farm system understanding enable fruitful co-operation, liaison and complementarity between FSR programs and other center programs in both research and training, and in relation to national programs.

(ii) Potential Role of FSR

173. Crops are the major interest of most of the IARCs. Many view the principal output of the IARCs as improved cultivars generated via a process of germplasm collection, screening and crossing to meet or overcome relevant constraints from either the supply or demand side, and dissemination via national institutions.

174. In such a context, the Review Team would argue that the major potential role of FSR in the IARCs is in better identification and appreciation of the system-wide interdependencies of the relevant constraints on which crop improvement should focus if it is to be acceptable to farmers. Implicit in this major role would be messages to the IARCs on their general program strategy and planning relative to both research (including training) and cooperative activities with national programs. A less important role for FSR would be in guiding farming systems adaptations necessary if full advantage were to be taken of the improved cultivars.

175. Given the limits to further increase in arable land and the rising cost of key inputs (such as oil), the Review Team believes that as the potential for crop genetic improvement diminishes, FSR will assume an increasingly major role in the IARCs, particularly in developing new farming systems mostly independent of seed improvement. Concurrently, as the centers necessarily become more concerned with second and third generation problems, crop programs will increasingly need to consider crop systems. This implies that IARCs will progressively have to take a broader approach to crop production. At one extreme, the approach might be the relatively passive one of acting mainly as a liaison center between national programs. More fruitfully, it could be the active one of FSR based on recognition that farmers use farming systems which are researchable and can be improved at the whole-farm, cropping or crop system levels in multifarious ways beyond seed improvement. At the same time, it should be warned that FSR is not likely to be as startling in its successes as the early exploitations of genetic potential. Rather than "breakthroughs", FSR is far more likely to be characterized by a steady stream of incremental gains arising from myriad system adjustments. This would be expected to be so even under the most efficacious arrangements for transfer, adaptation, development and extension through national agencies. In reality, of course, potential will be lessened by the actuality of national programs being less than the ideal, coupled with the pervasive problem of location specificity for FSR at the IARCs.

176. As emphasized elsewhere in this Report, no IARC could possibly conduct FSR directly relevant to all the systems or locations covered by its mandate. At best, all that is feasible is research on some few key systems at some few key locations. For the potential of IARC FSR to be achieved, it is essential that these systems and locations be chosen such that they are as significant as possible in terms of research output transferability, feasible adaptation and impact through national agencies. However, because of the constraint of location specificity and the newness of FSR, the value of FSR in the IARCs -- at least in the early stages -- will mainly lie not in the direct research results obtained but in the development of FSR methodology for transfer to national programs. It is these national programs which must far more directly meet the problem of location specificity.

177. The immediate need and potential for FSR within the IARCs, as implied above, vary according to both the mandate of a center and relative to its crop responsibilities. Thus it would be poor science for either IITA to be tackling the problem of shifting cultivation or ICRISAT to be considering the semi-arid tropics without a farming systems orientation. Conversely, IRRI's work in FSR appears to reflect an appreciation that rice breeding today needs the guidance of FSR. Likewise CIAT, with its mixed geographical and crop

mandate, has taken a strong systems approach in its "new lands" (i.e. alluvial soil or beef) program for the llanos and cerrado, and within its bean and cassava programs is implicitly using a small farmer systems focus to its research.

178. In summary, therefore, the Review Team sees FSR as being an essential complement to crop improvement and, when improvement possibilities are limited, the major avenue of agricultural research available and appropriate to the CGIAR system. This is particularly so in terms of the CGIAR requirements for IARC activities (as listed in paragraph 49) to involve subject matter (such as FSR methodology and development) not likely to be covered elsewhere, to be complementary to national programs, to benefit small farmers and to enhance production of important food commodities. Further, within this general IARC context, the Review Team considers FSR to be very important in giving a structured and coordinated approach to problem identification, analysis and solution under real-world farm conditions, as well as providing a way to develop appropriate technology for less-understood small farmers.

(iii) Actual Role of FSR

(a) Relative to General Program Strategy and Planning

179. To work effectively in FSR and to ensure early impact, IARCs must concentrate on critical problems and/or promising technological opportunities. Either approach requires good intelligence about the production system(s) and the farmer himself, as well as the constraints under which the farmer has to operate. The required intelligence needs to take into account the existing situation, potential and actual changes in the system, and general future trends. Also, the IARCs need continuing, purposive linkages with national programs and activities. FSR, in the context of its three activity areas, can fulfill a necessary role in measuring and monitoring present farm problems and needs, and in assessing potential future impact and adoption of IARC technology. Also, FSR can provide a "grassroots early warning system" to call attention to necessary changes in IARC strategy or plans.

180. As yet, it does not appear to be the case at any IARC that FSR is playing its full potential role as an influence on general program strategy and planning. Rather, influence appears mainly to have been in the opposite direction. This is not surprising since none of the centers has yet a complete program of basic FSR activities. It would be through the interaction of these activities, when fully established, that major feedback for general center program strategy and planning would be expected.

(b) Relative to Crop Improvement Programs

181. The Review Team considers FSR to be potentially very important in helping to define breeding objectives for new crop cultivars. This complementarity will necessarily strengthen as production increases are achieved more by way of incremental steps based on improved performance of the whole system than by the introduction of a superior cultivar. Thus, if FSR is closely linked to crop improvement programs, a more structured and holistic approach can be taken to breeding, field evaluation, adoption and farmer management of improved IARC cultivars.

182. Across the centers visited, no clear-cut picture emerged of the relationship between the crop improvement and FSR programs. Aspects clouding the picture were the relative difficulty of achieving FSR goals as compared to crop program goals (e.g., as at IITA and ICRISAT), the cautious "outside" attitudes to the new systems approach, the relatively unproven nature of FSR, and the difficulty of assessing its success. Yet it was apparent that fruitful cooperation between programs at the personal level existed at all four centers and that the way is now open and developments are proceeding for strong program interaction and cooperation on a two-way flow basis.

(c) Relative to Understanding the Small Farmer

183. The CGIAR has stressed its desire for IARC work to reach and benefit the small farmer of developing countries. It was notable to the Review Team that at all the centers visited, the FSR Program or orientation provided a very significant and systematic approach to small farmer contact, understanding and appreciation. These benefits, moreover, went not only to FSR but to other center programs and activities as well.

(d) Relative to National Programs

184. For other obvious reasons as well as location specificity, national programs constitute the link between FSR at the IARCs and the farmer. The importance of this linkage can hardly be overstressed.

185. Where on-going national programs exist, it should be relatively easy for IARCs to develop meaningful linkages and mutually agreeable arrangements for cooperation, identify candidates for training, test and adapt new methodology, provide a basis to identify important national problems of specific importance to IARC mandates, etc. Of course, the nature and orientation of national programs may determine or influence the type of interactive or cooperative activities undertaken. Where national programs do not exist or are weak, IARCs will often find it difficult to operate effectively and to find avenues for cooperation and outlets for new technology.

186. National programs are especially important in determining the extent and characteristics of location specificity, a topic of special importance to the IARCs. The Review Team was particularly impressed with the value to IRRI (and national programs also) of the Asian Cropping Systems Network, which appeared to be a truly joint and fruitful mechanism for cooperative planning and decision based on mutual respect and a recognition of partnership between the parties involved. Also significant is ICRISAT's cooperation with Indian Programs. In the case of these two centers they have been cooperating, for the most part, with countries having relatively strong national research programs. Other IARCs are not as fortunate in this respect. The Team emphasizes the importance of training by IARCs as a means of assisting national program development. The real difficulty is where, despite the opportunity of training, no will exists for the establishment or development of national institutions and programs. IARC interest in such situations would appear futile and in the view of the Review Team would be better directed to more fruitful opportunities.

187. The Review Team recognizes the importance of the level of development and nature of national FSR programs. The Team visited only one national FSR program, that in Senegal, and was most impressed with its methodology and approach.

(iv) The FSR Program

188. Because of differences in mandates, approaches and structures across the IARCs, it is difficult to give a coherent overall assessment of the FSR Program as found within the CGIAR system. Assessment and comment are easier on a center by center basis as given in Annexes 2 to 5. Nonetheless, the Review Team has no doubt that, overall, FSR as currently conducted and developing in the centers well meets the CGIAR requirements for an IARC activity as specified in paragraph 49. To date, most FSR in the centers visited by the Review Team has been concerned with the cropping subsystem rather than with the whole-farm system. So far as it has occurred, research on the whole-farm system has largely been restricted to economic analysis. The Review Team expects that FSR in the IARCs will continue to emphasize subsystems rather than the whole-farm system.

(a) Organization and Planning

189. The Review Team recognizes that there is no one perfect FSR program structure. However, there are some principles which the Team sees as being particularly important: (1) that the FSR program be on a team basis and organized in such a way that multidisciplinary research can be conducted with a systems focus; (2) that no one discipline should be considered to have priority in leadership; and (3) that team members should have adequate opportunity for professional development via peer contact, review and professional refereed publication.

190. The latter principle is an aspect of staff relations. If -- as suggested below -- FSR implies flexibility in staffing, then for such work to be attractive it must offer the opportunity for professional development and recognition so as to ensure career prospects for the scientists involved. In large degree, this implies the need to publish in professionally refereed journals. The strong impression gained by the Review Team was that FSR scientists have published too much in sundry conference proceedings and in-house media, and too little in reputable journals. Further, it was commonly implied by scientists that the IARC ambiente was such as to disfavor too big an interest in publication -- rather one should get on with the research and push out the technology, leaving the "publish or perish" syndrome to academics. While this may be an appropriate view for plant breeders, it is not proper for FSR. If the situation is as implied, the Review Team sees it as a short-sighted and scientifically unsound policy.

191. Between centers, the Review Team found the variation in degree of formal organization and planning remarkable, particularly as it believes the need is obvious for FSR to be planned and flowcharted so that team members know what is expected of them and when. In this respect the Review Team considered IRRI's program to be the best organized and planned. IITA, after extensive discussion within the program, has recently established an organizational framework and planning frame (which the Review Team approves), while ICRISAT (with its project-based research administration) had yet to fully consider such possibilities.

192. Closely related to organization and planning is the question of progress in developing methodology and procedures for FSR, e.g., the conduct of the three basic FSR activities (Base Data Analysis, On-Farm Studies, and Research Station Studies). Research has obvious implications for organization and planning. Accordingly, it is not surprising that the Review Team found much the same pattern across centers in the development and appraisal of methodology, and awareness of needs, as for the degree of organizational development and planning. Particular topics on which methodological emphasis is needed are multidisciplinary methods for the study of existing farming systems, methods of on-farm research (both under researcher and farmer control), multiple cropping, benchmark site selection, and selection procedures for priority systems to be studied.

(b) Disciplinary Balance

193. The requirements of disciplinary balance in FSR are not fixed. They should vary depending upon the nature of the program (or center mandate) and its stage of development in terms of basic FSR activities and the amount of on-station and off-station work. What is sure is that a mix is required, that it should vary over time, and that it should generally involve agronomists and economists. At any point in time, guidance on the appropriate mix will be enhanced if the work is programmed and flowcharted so as to show tasks, time tables and responsibilities (with appropriate need, of course, for flexibility as opportunities are seen or dead ends are established).

194. The need for flexibility in balance has implications for staffing policy which may be implemented either via short-term appointments of say 3 months to 3 years or via movements (or adjustable joint responsibilities) between FSR and other programs. Across the centers visited, best appreciation of these possibilities appeared to exist at IITA.

195. So far as balance overall in the FSR program is concerned, changes from that currently existing can be expected as the various centers move towards needed adjustments in the three basic FSR activities. Pointers to such changes are indicated on an individual center basis in Annexes 2 to 5.

196. The Team wishes to emphasize that FSR requires a multidisciplinary team, including physical, biological and social scientists. Historically, the most difficult role to integrate has been that of the social scientists. Of the social scientists, economists are considered essential to FSR, while other social science disciplines may only need to play a consultative role depending on an IARC's particular requirements.

197. Although the Team recognizes the important role that such scientists as rural development economists, sociologists or anthropologists might play in FSR programs at IARCs, it suggests that these disciplinary areas should not be regarded as necessarily having an essential or a permanent status.

198. Economists assigned to FSR should have some background in, and a willingness to work with specialists belonging to, physical and biological sciences. A special partnership is required between agronomists and economists, and both should make special efforts to learn each other's research needs and research approaches in order to carry out meaningful collaborative research. In cases where, for some reason, economists are not formally assigned to FSR programs, arrangements should be such as to ensure their active participation. Overall, the Review Team was most pleased with the contribution of social scientists (largely production economists) to the centers' FSR work. Only at ICRISAT did it detect any hesitancy in the receptivity of some parts of the FSR Program to an economics input, and even this hesitancy appeared to be declining.

(c) Basic Activities

199. As discussed in Chapter IV (v), the Review Team sees Base Data Analysis, On-Farm Studies and Research Station Studies complemented by training and cooperation with national programs, as the basic areas of activity necessary for successful FSR. In these terms the pattern across centers was variable, IRRI coming closest to an adequate balance, CIAT being somewhat short on Base Data Analysis, and ICRISAT and IITA needing more development of On-Farm Studies in their programs.

(d) Benchmark Sites

200. FSR, more so than crop improvement, necessarily needs to be conducted within a specified framework of climate, land, population density, infrastructure, culture, etc., within which the production systems fit. As yet, methodology for delimiting these frames of reference is not well developed or tested. Pending better selection procedures, the agroclimatic zone approach (along the lines developed at IRRI in particular but also to a degree at IITA and ICRISAT) appears fruitful as a basis for demarcating regional areas for FSR purposes. Within such regions, benchmark sites are needed as sample locations for research and testing. Again, just as for the delimitation of regions or situations, methodology is needed for benchmark site selection. Moreover, while only a few benchmark sites can be operated by a center, only a few of all possible system comparisons can be handled at any one site. Hence the selection of benchmark sites and the work to be undertaken on them is most important. Too, benchmark sites may be needed at both the macro (e.g., regional) and micro (e.g., district or village) levels. Micro requirements, however, are likely to vary more over time as particular needs have to be met.

201. Across the centers, IRRI appears to have proceeded furthest in the establishment of benchmark sites; while IRRI and ICRISAT seem best to have considered the problem of choice criteria. Overall, however, the question of benchmark site criteria and location is still very open and in need of attention - particularly since their establishment at the regional level may be relatively permanent and expensive, and choice may depend not just on FSR requirements but also on those of other programs (both center and national).

(e) Balance between On-Station and Off-Station Work

202. Much IARC work in FSR is carried out on the experimental stations, i.e., Research Station Studies. There is currently much less work off-station, especially in On-Farm Studies.

203. The Review Team recognizes that the stage of development of an FSR program will largely determine how much and what type of research will be carried out on or off-station. Generally, surveys (either in Base Data Analysis or On-Farm Studies) and on-farm experiments will be the major types of activity carried out in the early stages of an FSR program. However, as the program develops and benchmark sites (macro or micro-level) are selected, these too will become important. The Team suggests that, while no clear guidelines can be given for balance between on-station and off-station activities, some general principles can be established; namely that (a) IARCs should be involved in both; and (b) IARCs should continually review the balance between these activities relative to the requirements of a changing FSR program.

204. One point which the Review Team wishes to make is that while training may be considered as an on-station activity, it will have significant off-station implications; e.g., in the establishment of networks and the conduct of collaborative research. The Team also emphasizes that the same can be said for on-station development of methodology.

205. Related to the question of on-and off-station activity is the question of balance between surveys (an off-station activity) and experimentation (generally on-station). Both surveys and experimentation are important components of FSR. Without survey information on existing systems, their environment and constraints, FSR will be poorly focused.

206. The balance between surveys and experimentation is mixed across current programs in the four IARCs, particularly when it is recognized that surveys are pertinent to agronomic-type information as well as economic data. Overall, the Review Team judges that somewhat more survey work is required and that there should be a far more purposive orientation in this activity. The exception is ICRISAT where the current balance and purposeful nature of the village level studies appear excellent. At IIRI the balance appears adequate, but more purposeful data collection and analysis would seem to be necessary. Survey activity by IITA must be recognized as a very difficult undertaking due to problems of logistics and language. If these problems could be overcome, the ICRISAT model could be relevant. At the same time, it is a wonder that IITA has been able to do what it has in terms of survey activities.

(f) Work with Non-Mandate Commodities

207. The Review Team recognizes that, in the course of FSR, an IARC will often encounter the need (or possibility) to work or deal with commodities outside of its mandate. Examples might be livestock or fibre crops in some areas, or of tree crops and vegetables in the humid and subhumid tropics. The Team believes that where such commodities are potentially important to farming systems in the area of interest to an IARC, then they should be considered within the center's FSR. However, IARCs should not conduct breeding programs on such crops (as distinct from merely screening existing cultivars if that should be appropriate).

208. Current policy at the centers appears to be largely in line with the above view. On a center basis, perhaps the most burning question is whether IITA should strongly emphasize tree crops as an element of multi-tiered cropping systems for the humid tropics. To the Review Team this would seem a wise development (at least for the future if not immediately) given the substantial body of opinion suggesting that, without tree crops, the problem of shifting cultivation in the humid (as distinct from sub-humid) tropics is unsolvable.

(g) Training

209. The Review Team strongly believes that training must be considered an integral part of FSR programs at the IARCs. Training fulfills functions both in development of individuals as well as in institutional development. Without a training component, FSR work will be strongly disadvantaged in its scope for cooperative activities with national programs and hence in the transfer of its research developments.

210. Of the centers visited, IRRI's training program appeared best developed and in balance with other FSR program activities. Perhaps because of the lack of permanent building facilities, ICRISAT's program seemed least developed in terms of training though, within India, this is probably somewhat compensated for through cooperative field research with national institutions.

(h) Criteria for Assessment

211. A question often raised with the Review Team was how should FSR be assessed. The difficulty is that unlike with genetic improvement, for example, there are no direct measurements available to assess the impact of FSR. However, FSR itself does provide a basis for measuring the adoption or impact of new technology, provided baseline data are available.

212. The outputs of FSR at the IARCs are new methodologies and approaches, new systems and system components, trained personnel and a better basis for both cooperative activities and farmer extension by national agencies.

213. FSR results usually are not specific to one IARC (except in cases such as IRRI when new rice technology is identified closely with the Institute), nor does it carry a name or designation from a particular IARC. In fact, by using a cooperative program approach, FSR benefits will (and should) accrue more to national institutions than IARCs. Therefore, adoption of new technology and methodology by national institutions is one logical criterion for assessment of IARC FSR programs.

214. Beyond this aspect, the Review Team suggests the following list of factors to be used in assessing FSR work at the IARCs:

- potential impact of developed systems;
- degree of adoption of developed systems in their relevant context;
- impact of the FSR approach on national agencies in terms of their research organization, training and planning;
- number of persons trained and their subsequent activities;
- the contribution made to science as recognized by peer review processes.

(v) Cooperation between IARCs in FSR

215. Unlike traditional disciplinary research as in genetic crop improvement, FSR is both young in itself and in its IARC development. Not surprisingly, therefore, there is a need for better inter-center fora providing communication and dialogue in FSR so as to, for example:

- (1) thresh out relevant concepts and terms;
- (2) understand and criticize one another's programs in all their dimensions of research, training and cooperative activities;
- (3) gain an appreciation of alternative forms of organization and planning;
- (4) facilitate the joint development of methodology;
- (5) provide a professional forum for FSR oriented to small farm systems where the more burning questions such as benchmark site selection procedures, criteria for choosing representative systems, and multiple cropping research designs may be argued.

As yet there seems to have been only limited opportunity for such fora, in part because FSR scientists must use some of their travel and conference opportunities to sustain their disciplinary capital.

216. The Review Team sees joint development of methodology as a major goal of cooperation between IARCs. The Team does not consider FSR as a field in which serious overlap may result between IARCs. Joint development of methodology is especially important because of possible confusion which could result if two or more IARCs with different methodologies were to work in the same country on different commodities or problems, but with the same institutions.

VII. SUMMARY OF MAJOR CONCLUSIONS AND RECOMMENDATIONS

217. Only the Review Team's major conclusions and recommendations are summarized in this Chapter. Many other conclusions are noted throughout the prior chapters of this Report. Conclusions and recommendations about FSR at the particular centers visited are given in Annexes 2 to 5.

(i) Terminology in FSR

218. The Review Team found that between, within, and outside the IARCs, much of FSR terminology is used in different ways, often confusingly. In an attempt to improve this situation the Team, in Chapter II of this report, gives its preferred use of terminology in FSR, particularly in relation to crops. The suggested terminology covers such terms as crop or livestock system (or crop or livestock production system), multiple cropping system (of which there may be many specific types such as intercrop or associated cropping system, relay cropping system and sequential cropping system), crop rotation system, and cropping system, all of which can be regarded as subsystems of the whole-farm system of production used by the farmer.

219. The term farming systems research is a generic term used to refer to any type of research which views the farm in a holistic manner. Thus it encompasses any research concerned with farm subsystems or the whole-farm system. The Team recommends that, whenever possible, research on farm subsystems should be referred to specifically, e.g., as crop system research or livestock system research. Further, since crop systems, cropping systems and livestock systems, and their component parts, can be regarded as components of whole-farm systems, research below the whole-farm level should be recognized as systems component research or simply component research. However, the Team believes, in the context of the IARCs' research programs, it would be best not to regard research on individual components as comprising FSR unless either (a) the research is focused on interaction between the particular component and other system components, or (b) it is undertaken specifically with a systems focus in view.

(ii) IARC Involvement in FSR

220. The Review Team is convinced that FSR is both a valid and essential activity for the IARC system. As per CGIAR requirements, FSR involves critical subject matters not likely to be otherwise covered, is complementary to national activities, and is concerned with both important food commodities and small farmers in developing countries. FSR will tend to become increasingly important as the basis of IARC research. Concurrently, as this occurs, crop and livestock improvement will depend increasingly on FSR both as a guide to desired genetic manipulation and as a necessary complement to achieving farmer adoption.

221. A survey of the ongoing programs of the existing IARCs, of which there are nine, reveals that IARC involvement in FSR falls into four categories:

- (1) IARCs having no apparent FSR activities (CIP and ILRAD).
- (2) IARCs with FSR activities but no formal FSR program (CIAT and CIMMYT).
- (3) IARCs with a formal FSR program as well as Crop Improvement Programs (ICRISAT, IITA, IRRI).
- (4) IARCs with a center-wide commitment to following a farming systems philosophy (ICARDA, ILCA).

222. The Review Team recommends that all commodity/regionally oriented IARCs, i.e. all except ILRAD, should have a clearly recognized program in, or orientation to, FSR. Such work, however, should emphasize the production aspects of farming systems in the sense of being primarily oriented to agricultural (including economic) research. The focus should not be broadened to include "rural development" defined in broad social welfare terms relative to farm system improvement.

223. To date most FSR in the IARCs has been concerned with the cropping subsystem rather than the whole-farm system. The Review Team recommends that this emphasis should continue and that research on whole-farm systems should, in general, be confined to (i) the analysis of existing systems and (ii) the monitoring and economic evaluation of proposed new and/or improved systems.

(iii) Role of FSR in IARCs

224. The Review Team believes that FSR has an important role both in a downstream sense (link in the research chain taking information gained from the experimental program and finding a place for it in the farmer's production system) and in an upstream sense (for recognition of constraints and in problem identification and analysis). The Team places particular importance on the latter role of FSR in the IARCs and recommends that crop and/or livestock improvement programs be linked closely with FSR activities in the IARCs.

225. To ensure such linkages it is necessary to devise organizational and work arrangements such that scientists in commodity or crop improvement programs who work at the crop system (or subsystems) level (e.g., agronomists, economists, pest management specialists) cooperate closely with FSR staff who work at the cropping systems or farming system level. One way of fostering wider inter-program cooperation would be for certain key scientists to have joint appointments across the FSR and other programs.

(iv) Limits of FSR in IARCs

226. Both upstream and downstream FSR activities of IARCs will differ from those of national FSR programs. The Review Team recommends that because of their nature IARCs should, so far as possible, limit their concern to FSR activities yielding results (technologies and methodologies) which: (a) can be generalized or extrapolated (and are therefore related more to principles and methods rather than to location-specific practices); (b) are oriented to specific commodity or resource mandates; and (c) have potential for wide impact.

227. In contrast, national FSR programs are obliged to deal more with location-specific problems (and are oriented therefore more toward management practices or culture-specific needs), and are designed to have more direct impact on pressing local problems.

(v) FSR in Relation to IARC Program Strategy and Planning

228. The Review Team recommends that overall IARC program strategy recognize FSR as highly complementary to crop/livestock improvement, particularly in providing a research capability to guide the development and integration of new technology. It is recognized that implementation of this recommendation could take a somewhat different form in each of the IARCs depending on the center's mandate. Further, if advances in genetic improvement become more difficult to achieve, FSR must play an increasing role in guiding a center's research priorities and recognition of research opportunities.

229. It is recommended that the broad strategy for FSR in the IARCs should involve:

- (1) maximum use of existing secondary or historical data.
- (2) study and evaluation of existing farming systems delineated on a purposeful basis.
- (3) postulation, synthesis, investigation and evaluation of improved farming systems.
- (4) purposeful limitation of the number of farming systems to be researched since no center could consider all systems pertinent to its mandate.

230. In carrying out such a strategy, it is recommended that FSR involve the three basic activities of Base Data Analysis, On-Farm Studies and Research Station Studies as described in Chapters III and IV.

231. The current pattern across centers in terms of the three basic FSR activities is very mixed. Overall, on average there is a need for somewhat more Base Data Analysis and On-Farm Studies.

232. Though all FSR activities should contribute to IARC planning, Base Data Analysis may have a particular role to play, either in itself or if complemented by some other "policy secretariat activities", as a source of planning intelligence for overall center management.

(vi) IARCs in Relation to FSR Methodology

233. FSR, with its holistic, multidisciplinary team approach derived from systems analysis, is a relatively new approach to agricultural research. Particularly in terms of small farmer systems (usually involving multiple cropping and of special concern to IARCs), there has not yet been developed a consistent body of methodology. The IARC system has the capacity to develop the required body of methodology. National programs, because of their direct involvement with and responsibilities to farmers in specific locations, have a very strong need for FSR methodology so as to facilitate their research and the eventual acceptance by farmers of improved farming systems. For these reasons it is recommended that the development of FSR methodology be recognized as a major output of IARCs' programs. At the same time, of course, IARCs would also contribute directly to the generation of improved farming systems through their research on certain key systems at benchmark locations.

234. Particular areas of FSR for which it is recommended that methodology needs to be further developed relate to (i) the delineation of agroclimatic or other regions, (ii) the selection of benchmark sites, (iii) the choice of key systems for study, (iv) the design and conduct of multiple crop research and (v) the conduct of on-farm crop and livestock systems research. Especially important are methodologies for the choice of benchmark sites and key farming systems since no IARC could possibly consider all the farming systems relevant to its mandate.

235. A particular aspect of FSR methodology is the possibility of using computer modelling as a surrogate and complement for experimentation. This has many potential advantages. However, the Review Team believes that it is not appropriate at this stage for the IARCs to become heavily involved in research on computer modelling per se, rather they should tend to use adaptations of standard-type models developed elsewhere. Accordingly, the Review Team recommends that IARCs exercise caution in the type of computer modelling they use and their degree of commitment to model development, particularly at the IARCs' current stage of development.

(vii) Organization of FSR

236. Whether as a separate program or as an overriding philosophy to a center's total program, the Review Team recommends that FSR be organized such that there is: (a) an identifiable staff and program structure managed and

led in such a way as to facilitate multidisciplinary team research; (b) capacity for skilled disciplinary research within the multidisciplinary framework; (c) adequate recognition for scientists participating in the collaborative program; (d) opportunity for career development by participating scientists; and (e) flexibility in staffing as necessitated by program development.

237. Other things being equal and recognizing that no particular discipline should be considered as having priority in leadership, the Review Team believes a farming systems agronomist would have the best scientific background for FSR leadership. In any case, the main criteria for selection of a leader should be an ability to perceive problems in a holistic manner and to motivate persons from other disciplines. Within the FSR team, subgroups with overlapping membership might best be organized around the three basic activities of Base Data Analysis, On-Farm Studies, and Research Station Studies as discussed in Chapter V (ii).

238. The Review Team recommends that FSR be programmed or flow-charted through time and across activities, not necessarily in terms of precise deadlines but at least in such a way as to recognize the time-phase dependencies among different program elements and to indicate the interdependent responsibilities among team members. This is particularly important in FSR which, by its nature, depends on coordination in the activities of team members. Unless activities are coordinated over time and sequential dependencies recognized, FSR programs are likely to flounder and generate poor morale.

239. As a matter of organization and planning, the Review Team stresses that FSR at any IARC should be restricted to a range of activities which can be adequately handled within the constraints of staff and budget limitations. To this end, careful selection of priority systems for study and benchmark situations is essential, as is emphasis on research and associated methodologies which have general rather than only location-specific implications.

(viii) Staffing Policy for FSR

240. Because most agricultural scientists are trained more in reductionist than holistic thinking, it may be difficult to acquire staff who can work creatively in the holistic systems analysis and design context of FSR. More so, therefore, than in crop improvement programs, probationary employment may be necessary. Likewise, as FSR programs develop with consequent shifts in emphasis between Base Data Analysis, On-Farm Studies, and Research Station Studies, and between on and off-station work, flexibility in staffing will be needed. Accordingly, the Review Team recommends that staffing of FSR teams be flexible in the sense of staff joining and leaving the team as dictated by program development and requirements.

(ix) Disciplinary Balance in FSR

241. FSR must be multidisciplinary. The balance of disciplines, however, will vary with the stage of program development and the consequent balance between basic activities. The Review Team can make no general recommendations beyond noting that it believes that contributions from agronomy and production economics are essential at all stages of FSR.

(x) Balance between On and Off-Station Work in FSR

242. Like the balance of disciplines, the relative need for on-and off-station work will vary according to the stage of FSR development. In general, however, the Review Team found on-station work somewhat overemphasized. It recommends that, as dictated by program needs, somewhat more emphasis should be given to off-station work. This particularly so for field experimental research as distinct from field survey research, although somewhat enlarged and more purposive survey work is also required at some centers. Too, just as with survey activities, the Review Team recommends that particular care be taken to ensure that off-station experimentation is purposive relative to overall program needs.

(xi) Relations with National Programs

243. National programs constitute the link between IARC work in FSR and the farmer. Cooperation between IARCs and national programs is therefore crucial to IARC success in FSR. The Review Team recommends that cooperation with national programs should always be pursued on joint partnership terms rather than via a hierarchical-directed approach, and preferably with full integration in national research structures; further, within the relevant mandate context, cooperative activities should be organized so far as possible on a network basis rather than on the basis of a series of unrelated bilateral arrangements. The advantage of the network approach is that it gives better opportunity for mutual interaction and joint planning. Of course, a first step towards establishing a network will be to conclude bilateral arrangements between IARCs and national programs.

244. A particular difficulty is the absence or inadequacy of national institutions and programs in some countries. In such situations IARC training activities are a necessary prior step to developing possibilities for cooperation. However, the Review Team recommends that if a country evidences no will towards the development of a research capacity, IARC interest would be better directed to more fruitful opportunities. On the other hand, when requested, IARCs should be willing to assist national institutions in the planning and organization of national FSR programs.

245. Relationships between the IARCs and developed country institutions and programs are also important in FSR. As the need arises, there may often be opportunity for an IARC to use the services of advanced institutions for specific studies, e.g., in the statistical design and analysis of multiple cropping experiments or in farm surveys.

(xii) Training Activities in the FSR Program

246. The necessity for training as an integral element of an IARC's activities in FSR cannot be overstressed. Training is needed to assist in developing and orienting national programs as a basis for cooperative activities. It is a major channel for the transmission of FSR methodology and technology from the IARCs, and is also important as a source of feedback to the IARCs. It is particularly important as the initial step in developing fruitful FSR liaison with countries that as yet have little or no research capacity. Too, because FSR is non-traditional in approach and more complex due to its holistic emphasis, training in FSR is more difficult and demands greater resources than normal disciplinary training. The Review Team believes that somewhat more emphasis is needed overall on training activities within FSR programs. It recommends the strengthening of FSR training activities and suggests IRRI's program with its linked network and training activities be used as a guide. In addition, it is recommended that commodity training programs include consideration of farming system concepts.

(xiii) Cooperation between IARCs in FSR

247. The Review Team does not see FSR as an activity in which serious overlap may occur between IARCs. Because of FSR's relative newness, however, and the need to develop, systematize and improve methodology, the Review Team recommends that effort be devoted towards developing better inter-center communication and awareness of each other's FSR activities.

(xiv) FSR Work with Non-Mandated Commodities

248. It is unavoidable that FSR at any particular center will confront either existing or potential farming systems which include commodities (e.g., vegetables, tree crops, fibre crops, livestock, fish) not mentioned in the center's own mandate. The Review Team recommends that where such commodities are potentially important to the center's FSR, then the center should be entitled to include such commodities in its FSR. However, the center should not conduct breeding programs on such crops or animals (as distinct from merely screening existing cultivars, if appropriate).

ACKNOWLEDGMENTS

The FSR Review Team wishes to express its deep appreciation of the assistance and hospitality offered by the Director-Generals of CIAT, IITA, ICRISAT, IRRI and ISRA and their respective staffs. It also expresses its thanks to the many other persons with whom discussions were held in the countries visited.

Special thanks are due to Messrs. P.J. Mahler and E.Z. Arlidge of the TAC Secretariat for their unstinted assistance at all stages of the Review Team's work. The Team also gratefully acknowledges the assistance of the CGIAR Secretariat, particularly Mrs. Imogene Audifferen, during the preparation of this report.

ITINERARY AND SCHEDULE OF THE
FSR REVIEW TEAM¹

| <u>Date (1977)</u> | <u>Places visited and Team members travelling</u> |
|--------------------|--|
| | 1. <u>CIAT</u> |
| | 1.1 <u>Visits to Brazil and Carimagua, Colombia</u> (as part of TAC Quinquennial Review, J.L. Dillon) |
| 12-13 April | - Visit to EMBRAPA's Cerrado Station near Brasilia. |
| 14 April | - Visit to EMBRAPA's Rice and Bean Resource Center and State Research Farm, and a private farm at Goiania. |
| 15 April | - Visit to EMBRAPA's Tropical Pastures Station at Manaus. |
| 16 April | - Visit to CIAT/ICA cooperative activities at Carimagua, Colombia. |
| | 1.2 <u>CIAT Headquarters</u> (Full Team with P.J. Mahler, Secretary) |
| 17-22 April | - CIAT Headquarters, Cali, Colombia |
| | 2. <u>Senegal</u> (Full Team with P.J. Mahler, Secretary) |
| 9-10 October | - Team assembles in Dakar, Senegal. |
| 11 October (a.m.) | - Contact with FAO Representative and Institut Sénégalais de Recherches Agricoles (ISRA). |
| 11-12 October | - Visit to ISRA's Farming Systems Network substation and "Unité Expérimentale" project at Kaolack. |
| 13 October | - Visit to Centre Nationale de Recherches Agronomiques, Bambey. |
| 14 October | - Dakar. Discussion with ICRISAT's West African Cooperative Program Leader. |

¹Although not part of the TAC FSR review, one of the team (Dr. Plucknett) visited CATIE, Turrialba, Costa Rica on March 15-18, 1977. This was in connection with a joint USAID/Central American Governments' review of the FSR program at CATIE and to attend an FSR seminar.

3. IITA

3.1 Visit to IITA's cooperative activities in Zaire
(D.L. Plucknett and G.J. Vallaeys)

- 16 October - Kinshasa. Discussion with staff of PRONAM (Programme National Manioc).
- 17 October - Kinshasa. Discussion with representatives of the Zaire Ministry of Planning and with USAID Food and Agricultural officers.
- 18-19 October - Visit to PRONAM's team at INERA Research Station, M'Vuazi.
- 19 October (p.m.) - Visit to Centre de Développement Communautaire (CEDECO), Kimpese.
- 20 October - Visit to Vanga Cooperative Projects.

3.2 Visit to IITA's cooperative activities in Nigeria
(J.L. Dillon)

- 17 October - Discussions at Federal Ministry of Agriculture and Forestry, Lagos.
- 18 October - Visit to National Cereals Research Institute, Moor Plantation, Ibadan.
- 19-20 October - Visit to Nigerian Institute for Agricultural Research and the Faculty of Agriculture at University of Ahmadu Bello, Samaru. Also visit to Funta Agricultural Development Project.
- 21 October - Visit to Farm Service Centers of the National Accelerated Food Production Project in the Zaria and Kano districts.

3.3 IITA Headquarters

- 24-28 October - IITA Headquarters, Ibadan.
(Full Team with P.J. Mahler, Secretary)
- 29 October - IITA Headquarters, Ibadan.
(J.L. Dillon, D.L. Plucknett and P.J. Mahler)

4 ICRISAT

(Full Team with P.J. Mahler, Secretary)

- 7 November (a.m.) - Visit to ICRISAT's village level studies at Shirapur.
- " " (p.m.) - Visit to All-India Coordinated Dryland and Agriculture Research network and ICRISAT programs at Sholapur.

- 8-10 November - ICRISAT Headquarters, Hyderabad.
5. IRRI
(Full Team)
- 12-15 November - IRRI Headquarters, Los Banos.
6. Washington
(Full Team with E.Z. Arlidge, Secretary)
- 12-19 December - FAO Liaison Office for North America, Washington, D.C.

ANNEX 2. FARMING SYSTEMS RESEARCH AT CIAT

1. CIAT's Mandate
2. FSR Implications of CIAT's Mandate
3. CIAT's Strategy from the Viewpoint of FSR
 - 3.1 Historical Review
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 - 4.1 General Considerations
 - 4.2 The Commodity Programs
 - 4.3 The Special Studies Unit
 - 4.4 International Cooperation and Training
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ANNEX 2. FARMING SYSTEMS RESEARCH AT CIAT¹

1. CIAT's Mandate

CIAT's By-Laws specify its mandate as being "to accelerate agricultural economic development and increase agricultural production and productivity of the tropics to improve the diets and welfare of the people of the world."

In interpreting this broad goal, CIAT's overall objectives as specified in 1977 by its Director General are:

"To generate and deliver, in collaboration with national institutions, improved technology which will contribute to increased production, productivity and quality of specific basic food commodities in the tropics, principally countries of Latin America and the Caribbean, thereby enabling producers and consumers, especially those with limited resources, to increase their purchasing power and improve their nutrition."²

This statement implies a number of important points:

- (i) CIAT's product is improved technology.
- (ii) Its beneficiaries are to be both producers and consumers, especially those with limited means. Thus CIAT's activities should emphasize commodities which are important to low income consumers; and the technology produced must be relevant to small farmers.
- (iii) CIAT's clients are the national institutions within its region of interest.
- (iv) The geographic scope of CIAT's activities is the tropics, chiefly of Latin America.

To meet its objectives CIAT has chosen to concentrate the majority of its work on three commodities--cassava, dry beans (Phaseolus vulgaris) and beef cattle, the latter with primary emphasis on the infertile acid savanna regions of tropical America. CIAT also has modest programs in rice, maize (by CIMMYT staff assigned to CIAT) and swine. All these commodities meet the criteria of importance to producers and consumers with limited means, particularly within the American tropics.

¹More extensive discussion but not necessarily identical views are to be found in TAC Farming Systems Research Stripe Review: Notes from Visit to CIAT, April 18-22, 1977, a draft report presented to the TAC Secretariat.

²From CIAT's briefing document for its Quinquennial Review.

2. FSR Implications of CIAT's Mandate

From a farming systems research view, there are three major implications to be drawn from CIAT's mandate.

First, orientation to the vast and diverse region of the American tropics implies that it would be infeasible for CIAT to use a direct whole-farm systems approach as the basis of its research. Such an approach may be feasible for IARCs which have a mandate for a specific ecological zone or restricted set of commodities but that is not the case for CIAT. Within CIAT's geographic scope, there is a very wide range of variation in agro-climatic conditions due to differences in rainfall, altitude, soils and latitude. In none of these agro-climatic zones is any one element the major constraining factor on agricultural productivity (as is, for example, moisture availability in ICRISAT's geographic focus). Furthermore, due to this variability no one crop dominates the food economics as does rice in Asia. Thus CIAT's logical choice, given its geographic mandate, has been to focus on a set of commodities important to food production in its region and on which little previous research had been done.

Second, CIAT's mandate has evolved to a commodity focus emphasizing multidisciplinary team research within each commodity, particularly for its three major commodities: beans, beef and cassava. This corresponds to a systems analysis approach focused on (a) the bean and cassava crop systems and the beef production system, (b) associated cropping systems (for beans/maize and cassava-based associations, and (c) system components, (for particular practices such as seed cleaning, planting methods, weed control, etc.).

Third, as for any IARC, farmer use of improved technology generated by CIAT necessarily means the integration of this technology into the farmers' whole-farm systems via national institutions. Especially for CIAT with its wide geographical focus, this implies close interaction, cooperation and liaison with national institutions. Not only does CIAT require such contact to market its product, but also to gain feedback on the types of technology (i.e., whole-farm system components) which it might best produce. Thus, achievement of CIAT's goals will be enhanced: (a) the better the cooperative interface between national institutions and CIAT; and (b) the better the working interface between national institutions and the farmers they serve. Undoubtedly both these interfaces are being fruitfully enhanced by CIAT's training activities and its expanding program of international cooperation.

3. CIAT's Strategy from the Viewpoint of FSR

3.1 Historical Review

To appreciate CIAT's current strategy it is worthwhile to briefly outline its evolution.

CIAT was formally established in 1967 but did not really become operational until 1968. Initially, its program objectives were specified by disciplinary headings within major program elements of animal science, plant science and a miscellaneous set of service disciplines (economics, engineering and biometrics), plus training and communication.

Since the early 1970's there has been a complete move away from a disciplinary-based program to a commodity-based multidisciplinary team approach emphasizing production systems. The first commodity-based programs to be recognized were those for rice, swine and the Beef Production Systems Program. The Cassava Productions Systems Program was initiated in 1971 and the Bean Production Systems Program in 1972/73. In 1977 these program names were shortened to Beef Program, Cassava Program and Bean Program.

By late 1972, concern had grown at CIAT that the Center would not achieve its goals unless efforts were intensified to organize some systems activities so as to be responsive to welfare issues in addition to production goals. This led in 1973 to the establishment of the Agricultural Systems Program, which was constituted with the primary goal of developing a process to identify and analyze farming systems so as to assist in the rapid adoption of improved technology. The title of this program was changed in 1974 to the Small Farm Systems Program so as to more accurately reflect the Program's orientation.

The Small Farm Systems Program aimed at understanding the great diversity of farming systems in tropical Latin America and focused on family farms as integrated systems. It attempted to develop a process whereby limiting factors could be identified and research alternatives selected "to specify the requirements for the introduction of agricultural technology to help achieve farm family and public policy objectives."¹ The scheme for the development of this process consisted of:

- Analysis of family farming systems. In this phase, a number of prototype systems were to be studied.
- Synthesis of prototype farming systems. The insights derived from the analysis were to be tested both on a component basis and a system basis.
- Design of improved technology by specifying the cultural practices, the species mixes, the levels of inputs, etc., to be tested on experiment stations or on family farms, for potential introduction to the rural areas.
- Validation of the process by demonstrating that farm families in relevant areas achieved their objectives through use of the technology selected by the process, and that national agencies adopted the process as a tool to help them achieve their goals.
- Implementation of the process by national agencies in collaboration with CIAT.
- Evaluation via methodology to be developed for assessing the impact of new technology on human welfare.

¹Franklin, D.L. and Scobie, G.M., Small Farm Systems Program: A Program Document. CIAT, Cali, January 1974, p.12.

The Small Farm Systems Program was discontinued in 1975. In the Review Team's judgment, this became inevitable (with hindsight) because of the combined effect of four factors: it was too ambitious in scope; it over-emphasized both formal systems methodology and computer modelling; and its focus was more that of a rural development program than of farming systems. In such terms, the Review Team sees CIAT's decision as correct. Moreover, CIAT's geographical area is so diverse in ecological, institutional, economic and social conditions as to make any widely relevant in-depth study of whole-farm systems on small farms impossible within the scope of reasonable budget limitations. For a center such as CIAT, the comparative advantage obviously lies with a commodity approach aimed at the production of components to be integrated into whole-farm systems via local institutions. This gives the advantages of a multidisciplinary approach within the frame of a focus that is both relevant and achievable. Moreover, it places the concern for small farmer impact within the commodity teams.

Associated with the discontinuance of the Small Farm Systems Program were a number of organizational changes aimed at ensuring CIAT's continued concern with small farmers and the acceptability of its component research at the farm level.

The content of the commodity programs in cassava, beans, beef, rice and maize were respecified "to insure that new production technology developed in CIAT's commodity programs is appropriate under the various production systems used by farmers of all sizes, including those with limited resources, in the many ecological and socioeconomic conditions prevailing in the geographic area of CIAT's influence."¹

For each commodity program, the planned content embraces the following common points:²

- "Work with selected cropping associations involving CIAT commodities to insure that new technology developed at CIAT will be applicable in this common type of production system of special significance to small farmers.
- "On-farm surveys to determine the nature of production systems and factors limiting production of CIAT commodities in selected regions while developing methodology which can be used by local institutions in other areas.
- "Collaboration with national programs in on-farm testing of promising new production technology to insure that it is valid under real farm conditions.

¹Letter of CIAT's Director General to the Executive Secretary of TAC, December 28, 1976.

²Ibid.

- "Ex ante analyses on new CIAT production technology to insure that it is economically viable for farmers of various sizes and under different input/output market situations.
- "Ex post studies on the adoption of new production technology to determine the rate of adoption, the distribution of benefits of such adoption and reasons for non-adoption.
- "Constant effort in all programs to minimize the need for purchased inputs in the new production technology being developed."

A further change was the formulation of a Special Studies Unit (attached to the office of the Associate Director General for Research) with the aim of filling any "small farm" gaps remaining after discontinuance of the Small Farm Systems Program.

Associated with the above reorganizations was the establishment of an Agricultural Production Systems Coordination Group made up of the Associate Directors General for Research and International Cooperation, an outreach production specialist from each commodity program, all of CIAT's economists and senior staff members in the Special Studies Unit. Functions of the group were specified as:¹

- "To overview the commodity programs so as to insure that, so far as possible, the technology they produce is relevant to small farmers, adaptable and pertinent to the various ecological zones of interest to CIAT, and economically viable.
- "To help identify additional activities not appropriate to the commodity programs which should be pursued by the Special Studies Unit.
- "To coordinate inter-program collaboration on research pertaining to mixed cropping and mixed farming."

As well as the above changes on the research side, there has been continuing development of CIAT's activities in the areas of training and conferences, information services and networking with national institutions in terms of research, technical assistance and feedback, all of these being under the aegis of the Associate Director General for International Cooperation.

To summarize all the above changes from a farming systems view, it may be said that CIAT has now placed primary responsibility for the generation of improved technology (i.e., component research) in each of the commodity research teams, complemented by activities in Special Studies and International Cooperation.

¹Memo of Director General to CIAT's Board of Trustees' Program Review Committee, May 9, 1975.

3.2 Current Strategy

CIAT has adopted the strategy of providing improved technology in a number of selected commodity areas to its primary clients, the national organizations. A key element of this strategy is its geographical focus on Latin America.

CIAT has also chosen the strategy of generating technology to bring new land into cultivation as well as to increase yields on existing lands. In the case of new lands, this implies that (1) components will be identified which may be new to the country and people in question; (2) successful adoption of components may be heavily dependent upon infrastructure and policy developments; (3) increased training will be required; and (4) the technology transfer process may become difficult and complex. On the other hand, it may allow for the introduction of new, improved and integrated farming systems which are allowed to develop in the absence of resistance due to tradition, land tenure or scale of operation.

The beef program essentially is following the "new land" strategy, i.e., it is concentrating on the vast infertile acid soil savannas (the Llanos of Colombia and the Cerrado of Brazil) where few people live, but which receive good (though unevenly distributed) rainfall and have excellent topography and soil physical properties. The inherent low chemical fertility of the soil, its remote location and the extensive nature of beef production all point to the development of a low-input, extensive-type grazing system. Such extensive grazing systems--particularly in the Brazilian Cerrado--are likely to be associated with crop production, either as a first step in land development or as a continuing enterprise.

Accompanied development of low-input crop production components (e.g., for cassava) could possibly lead to a more stable and diversified farming system for these infertile acid soils. If upland rice is adopted for more intensive effort, it too would fit into the "new land" strategy.

The other general land-related strategy of CIAT is to increase production on existing lands. Here the bean, cassava, maize and rice programs have a major role. Except for rice (with its largely irrigated focus) and beans which -- although grown mainly on small farms--are readily amenable to production on large farms, CIAT's programs automatically have the small farmer as a major focus. In consequence, the objectives of the research programs for beans, cassava and maize would appear to diverge somewhat from objectives for the medium to larger farms likely to be relevant to the "new land" areas. Also, the natural resource base of most of the small farmers of Latin America--consisting of marginal or sub-marginal, often steep and infertile lands--would seem to imply a somewhat different set of improved components for these lands than for the savanna land areas with better topography.

In terms of experimentation and field testing, CIAT's location at Palmira in the very favorable environment of the Cauca Valley has obvious implications for research strategy. CIAT scientists are well aware of this and have taken steps aimed at ensuring that their component research can be (a) adapted to local (i.e., other) ecological and social conditions on a technical basis and (b) integrated economically with local whole-farm systems.

Thus, because of the overriding importance of the locale specificity problem (in terms of soil type and climatic regime), all the field aspects of the beef program are being conducted in locations (such as Carimagua in the Colombian Llanos and Brasilia in the Brazilian Cerrado) typical of the infertile acid-soil savanna regions.

Likewise with CIAT's two other major commodity programs--beans and cassava--research at Palmira is largely on aspects of technology which are not especially site specific such as, for example, breeding for disease and insect resistance. At the same time, site specificity effects are checked at a variety of locations in Colombia (which offers an extensive variety of site types in terms of altitude, climate, soil and topography) and a number of other countries.

On a crop system basis, problems of location specificity from an ecological and social view are also ameliorated through CIAT's willingness and desire to cooperate with national institutions in conducting field trials and to provide research guidance on problems of local adoption. Such cooperative work is developing strongly. An associated positive influence is the steadily increasing number of commodity specialists throughout CIAT's region who have graduated from CIAT's training program.

The question of economic integration of CIAT's technology into local whole-farm systems is more difficult. CIAT, as it recognizes and as for other IARCs, has neither the resources nor the authority to work at the individual farm level. National institutions, moreover, are much closer to the farmer and do have the responsibility to help him by direct contact. Hence, it is logical that CIAT's strategy for research and technology transfer recognizes the national institutions as its clientele.

On the other hand, the set of enterprises that best constitutes any farming system is sensitive to economic conditions via the prices of outputs and inputs. Output prices, in particular, may vary greatly within and between years. Without allowing its research to be dominated by short-term economic fluctuations, CIAT none the less has to take account of both price and yield risks associated with the technology it produces since these are important aspects of the farmer's choice as to what crop systems he will use. Such considerations are already being investigated by CIAT's economists.

Although CIAT technologies are mostly designed to be scale neutral, the impact of the Center could well continue to be greater on the larger and more advanced farmers (as occurred with rice) who are usually more capable of making technological changes. Certainly, in many countries of Latin America, the access of the small farmer to new technology will continue to be limited by factors on which CIAT has little influence, such as land tenure, credit and marketing facilities.

4. Balance of Activities and Disciplines Involved

4.1 General Considerations

A major task before the Review Team was to examine in each relevant Center "the relative importance of surveys, data collection and assessment activities on the one hand and experimentation on the other" and "the relative balance and interactions between the disciplines involved." Since CIAT does not have a program dealing strictly with farming systems research, it was necessary to consider the whole program of the Center in this context. This includes in particular:

- (i) The commodity programs;
- (ii) special studies; and
- (iii) international cooperation activities.

As to the range of disciplines concerned with farming systems research, their importance obviously varies when considering activities such as: (a) surveys and the identification of problems and priorities; (b) experimentation and trials; and (c) the assessment of changes in farming systems due to improved technologies and other factors. At each stage, however, three groups of disciplines are involved at a varying depth: the natural sciences, the biological sciences and the socioeconomic sciences. In the case of CIAT, it can be noted in general that these three groups of disciplines are well integrated and satisfactorily balanced within each of the commodity programs whereas their involvement in special studies and in international cooperation remains necessarily limited to the needs and circumstances of the case at hand. It is, however, important to examine whether the balance of disciplines and activities so achieved by the Center enables it to meet its objectives, as related to farming systems and within the limits of its mandate.

4.2 The Commodity Programs

Because of the nature of the commodity research team approach at CIAT, most of the work is centered on scientific experimentation. Interdisciplinary teams work together within each commodity program to resolve problems facing the commodity.

The problem identification process, to be effective, should be based on an awareness of the natural and socioeconomic environments within which the commodity is grown, as well as an understanding of the related farming systems or cropping patterns. Surveys are the usual method used by CIAT to obtain such information.

Within each of the major commodity teams (beef, beans, cassava) there is an agricultural economist, part of whose job is to evaluate technology transfer and impact. His techniques include surveys concerned with both base-line economic and technical data with follow-up on micro-economic evaluation of the effectiveness of CIAT technology so as to provide feedback for further component research.

Some of the commodity programs at CIAT have recognized a need to understand the agro-climatic zones within which CIAT commodity systems component technologies must fit. To that end, the Beef Program has arranged an agro-geographical survey of the infertile acid soil savanna areas of South America. Also, the Rice Program plans to survey existing and potential rice land areas of Central America, and the Bean Program team will cooperate in similar studies in at least two countries.

Since CIAT is embarking on an evaluation of production areas for several commodities, it would seem useful and desirable to avoid duplication. For example, surveys of the infertile acid soil savannas should have potential usefulness for the cassava and rice teams; surveys of bean producing areas would be of use for the cassava program, etc. Additionally, the Associate Director General for International Cooperation has also indicated his desire for more information on each of the cooperating countries, as a basis for technology transfer and regional cooperation. For example, selection of sites for regional trials could be expedited and focused more sharply if agro-climatic zones and environmental homologues were delineated.

From an FSR view, particular mention must be made of the Beef Program. In the opinion of the Review Team, this program as it is presently organized and planned appears to be fully congruent with the FSR approach. In part this is the case because, while the major commodity focus of the program is beef, it is delimited to the acid savanna soils in specific well-defined regions and necessarily has to take account of the potentially relevant soil/pasture/beef and crop systems. Beyond this, however, the program is extremely well organized and planned with full recognition of interdependencies between its elements and a successfully working multidisciplinary team.

4.3 The Special Studies Unit

This Unit was started in 1975, in part to provide a mechanism to ensure that certain activities of the former Small Farm Systems Program were not neglected. Its main activity is related to exploratory studies on new production systems involving new crops and crop combinations not covered by the major commodity groups. The Unit has initiated work on minimum tillage, use of living mulches, cycling of nutrients from one crop to another in associated plantings, and unconventional use of nitrogen-fixing trees or shrubs in perennial/annual crop associations. Generally, the Unit has been involved in exploring the possibilities of transfer to Latin America of selected technologies generated by other Centers. While the Special Studies Unit provides for a broadening of CIAT's fields of concern, the Review Team feels its role should remain exploratory rather than intensive.

4.4 International Cooperation and Training

CIAT's training and other cooperative activities with national programs should provide it with essential feedback from cooperating countries on the functioning of farming systems which are relevant to the Center's commodity programs. Provision should be made to this effect in the agreements and projects which CIAT establishes with cooperating countries.

In addition, the Associate Director General for International Cooperation also pointed to his need for more information on each of the cooperating countries, not only on the organization of agricultural research and development, but also on the general agricultural policies and socioeconomic conditions of the countries. The Review Team sees such information, if available, as a valuable complement to the knowledge of farming systems in each country of CIAT's region.

The Review Team agrees with CIAT's judgement that successful development and transfer of its component research output requires strong programs in international cooperation and training. Such programs are essential for CIAT's research output to be successfully integrated into local farming systems.

5. Summary and Conclusions

All CIAT's research can be recognized as being carried out in a systems framework. In beef, research is fully congruent with a whole-farm system focus. For CIAT's other commodity programs, the emphasis is more on crop systems and subsystems.

The potential adoption of CIAT's research output will depend heavily upon the Center's ability to recognize problems, to mobilize and deploy existing information concerning relevant agro-climatic zones and farming systems, to focus its research program on pertinent components of farming systems, and to further strengthen its program of training and cooperation with national institutions.

Currently CIAT appears less strong than it should be in the area of Base Data Analysis. Such capacity is needed to ensure a sharp focus on key farming systems problems and opportunities for commodities for which CIAT has responsibility. The Team believes that such a capacity would enhance both CIAT's research and international cooperation programs.

ANNEX 3. FARMING SYSTEMS RESEARCH AT IITA

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ANNEX 3. FARMING SYSTEMS RESEARCH AT IITA

1. IITA's Mandate

The mandate of IITA has evolved over time and was last modified by the Board in 1977. The modified mandate is: ^{1,2}

"Within the system of cooperating IARCs associated with the CGIAR, IITA will:

- (a) Conduct studies of and research on farming systems in the humid and subhumid tropical zone in order to identify viable alternatives to shifting cultivation which will maintain the productivity of the land under continuous cultivation, with particular reference to food crops;
- (b) Accept worldwide responsibility, covering all climatic zones, for research directed to the improvement of cowpeas, yams and sweet potatoes;
- (c) Conduct studies and research, in the humid and subhumid regions of Africa, for the improvement of crops such as maize, rice, cassava, pigeon pea and soybean, for which other international institutes and organizations have special responsibility, cooperating in whatever ways may be appropriate with those institutes and organizations.
- (d) Conduct research directed to the improvement of other crops which are, or may become, important in the farming systems of the humid and subhumid zones, such as lima bean, winged bean and other grain legumes, cocoyam, taro and other aroids, and plaintain and other forms of Musa³ which contribute substantially to the diets of the people of the zones;
- (e) To make available the results of studies and research carried out in accordance with paragraphs (a) to (d) above to nations and institutions which wish to use them through cooperation with regional and national programs;

¹IITA, Briefing Document for TAC Quinquennial Review Mission, 23 October to 6 November 1977, IITA, Ibadan, 1977.

²CGIAR/TAC. Draft Report of the TAC Quinquennial Review Mission to the International Institute of Tropical Agriculture (IITA), October 1977. This report was used a great deal in preparing this annex. It will not be cited again.

³Several vegetables such as tomato, peppers and Celosia were also included in the FSR program of IITA.

- (f) Take responsibility in collaboration with the International Board for Plant Genetic Resources for the exploration, collection, conservation, documentation and evaluation of genetic materials of food legumes, root and tuber crops and rice in the humid and subhumid regions of Africa in order to make these materials available for use by plant breeders and scholars;
- (g) Respond to requests from appropriate authorities for cooperation with regional and national programs in the humid and subhumid regions of Africa concerned with the improvement of farming competence;
- (h) Respond, in association where appropriate with other international institutes and organizations particularly those associated with the CGIAR, to requests from appropriate authorities for cooperation with regional programs, in countries other than Africa, concerned with the improvement of farming systems and of crops in respect of which IITA has appropriate competence;
- (i) Respond, insofar as it is competent to do so and in cooperation with other institutions where appropriate, to requests from governments in the humid and subhumid regions of Africa for cooperation in developing the agricultural knowledge systems of their countries, including their agricultural research capabilities;
- (j) To provide or organize training, conferences and workshops on topics relevant to the tasks outlined in paragraphs (a) and (i) above with the particular purpose to increase the number of well qualified persons to carry out effective research and development on crops and farming systems;
- (k) Conduct, or take responsibility for, such research or studies on other crops or topics and for such activities concerned with the application of research to rural, agricultural and national development as the Board of Trustees may approve."

Over the years, the Board of Trustees has been concerned with the scope of this mandate in terms of geographical coverage, range of crops, and cooperative activities of the Institute, and the present mandate is therefore the result of a gradual evolution.

2. FSR Implications of IITA's Mandate

A number of the objectives of the IITA mandate are directly related to FSR. These are (a), (d), (e), (g), (h) and (j). In addition, (i) and (k) are indirectly related to FSR, depending upon specific interpretation of these objectives in given situations.

It is noteworthy that FSR is stated as a primary objective of the IITA program.

2.1 Geographical Coverage

The Institute initially concentrated its activities on its main site in trying to develop a sufficiently strong core of research and experience before engaging itself in cooperative work. The Board, however, soon found it necessary to widen the scope of the Institute's programs. The biogeographical scope of responsibilities of the Institute was defined in 1970:

"as including those regions of the earth which lie between the northern and southern desert belts, with particular reference to those parts which are lower than 2,000 feet (600 meters) above sea level and in which precipitation exceeds evaporation for five or more months of the year."¹

Another reason for modification of the ecological orientation of IITA was the location of the Institute itself in the transitional area between the low humid tropical forest and the savannah.

2.2 Cooperation with National Programs

The mandate gives very broad scope to the possible cooperation of IITA with national programs. This may include the distribution of the genetic material collected or developed by IITA, cooperation "in the improvement of farming systems", and "the conduct or responsibility for such research or studies on other crops or topics and for such activities concerned with the application of results of research to rural, agricultural and national developments as the Board of Trustees may approve." The mandate of the Institute appears to be very broad and permits considerable flexibility in cooperating with national programs.

2.3 The Implementation of IITA's Mandate

Research at IITA is considered as a means of finding solutions to problems in order to achieve the real objectives which is to contribute to "the improvement of food crops in the tropics, both as to quantity and quality," by testing and encouraging the application of research results at the farm level. The small farmer in the humid and subhumid tropics is stated by IITA to be the main

¹The exact geographical boundaries of the Institute activities are difficult to delineate and vary with the activity considered. It must be noted that IITA does not intend to engage in farming systems research activities in those regions which, according to ICRISAT's agro-ecological competence, it covers together with this Institute.

target of its research. IITA considers it essential that it finds ways and means through national programs and other collaborating agencies to reach the farmer so as to allow feedback from testing of its research results on farmers' fields.

Because small farmers, particularly in Africa, have few resources or little access to purchased inputs, an objective of IITA's research programs is to try to increase productivity with low levels of cash inputs. This objective is particularly difficult to attain in the subhumid and humid tropics where shifting cultivation forms a stable land use system which has relatively low productivity but which is in equilibrium with the environment at low human population density.¹ With population growth, however, farmers are forced to reduce the length of the fallow period which comprises an important element of the traditional farming systems. In consequence, soil fertility and stability against erosion decreases progressively.

The challenge before IITA as outlined in its mandate is therefore to develop appropriate land use systems which reduce or avoid this fallow period while maintaining the productive capacity of the soil through appropriate land management practices and cropping systems.

The overall strategy of the Institute in attempting to solve these problems is twofold. On the one hand, the Institute aims at introducing significant improvements in some of the key staple food crops of the tropical regions. On the other hand, the Institute is developing integrated land and crop management systems which aim at increasing the productivity of tropical farming systems.

The research programs of the Institute are organized in four main groups of activities, each being carried out by a multi-disciplinary team:

- the Farming Systems Program (FSP)
- the Cereal Improvement Program (CIP)
- the Grain Legume Improvement Program (GLIP)
- the Tuber and Root Crop Improvement Program (TRIP)

IITA recognizes that its main site contains too limited a range of ecological conditions to provide the extensive basic knowledge of subhumid and humid environments which it needs to meet its program objectives. Surveys have been conducted in Nigeria and some other countries of Africa to identify the major problems for research. The need for more comprehensive data on these problems is recognized.

¹Greenland, D.J., "Bringing the Green Revolution to the Shifting Cultivator," Science 190 (5217): 841-844, 1975.

A contrast exists between the conditions of crop production in the subhumid tropics and the humid tropics. Since IITA was located near the transition between these two zones (but definitely within the subhumid tropics), it was felt essential to establish a substation in the high rainfall tropical forest belt where the problems of shifting cultivation are more complex. An 80 ha site was chosen in 1976 at Onne, in southeast Nigeria and the development of the substation has begun.

As a result of the complexity of its mandate, reflecting that of the problems and of the environments in which it works, the Institute has been so far cautious in developing its cooperative programs in FSR since it was essential to develop a sufficient research strength and body of experience at headquarters before sharing activities with national programs.

3. IITA's Approach to FSR

3.1 Historical Review of FSP

The original concept of IITA was an Institute concerned with soil and, to a lesser degree, crop management to overcome the problem of shifting cultivation. Early staff arrivals in 1968/69 -- nematologist, pedologist, soil chemist, soil physicist and soil fertility specialist -- reflected this focus. Until a program approach was initiated in 1971, scientists were largely able to pursue what they regarded as relevant projects with a minimum of integration and direction from above. A proposal to create the three present crop improvement programs and FSP was accepted by the Board of Trustees in early 1972. While it was clear that the soil scientists, agronomists and agricultural economist should belong to FSP, other scientists who had responsibilities across programs (e.g. nematology, microbiology) were also placed in FSP on the basis that they had more identification with FSP than outside of it.

A more purposeful focus within FSP was achieved in mid-1973 when attention was given to devising an FSP structure aimed at facilitating collaborative research within FSP and with other programs. Current concerns are still to develop further a group structure conducive to collaborative research within FSP and with other programs, to ensure that FSP research is carefully programmed and well defined relative to the Program's objective, and real-world evaluation of FSP research results.

In 1977, FSR was restructured to conduct work within project areas.

3.2 Objective of FSP

The objective of the FSP is to develop:

"methods of crop management and land use for the humid and subhumid tropics which will enable more efficient and sustained production of food crops to be technically and economically feasible in these zones. While recognizing the interactions between annual food crops, perennial crops and livestock, FSP concentrates on the food crop components of tropical farming systems."

Specific objectives of the FSP are to:

- " (i) develop crop production systems which will enable good yields on a sustained basis with acceptable input levels;
- (ii) develop methods of land management which which will enable intensive systems of food crop production to replace shifting cultivation where environmentally feasible;
- (iii) dissemination of food crop technologies to national agencies for adaptation to specific areas;
- (iv) provide training in farming systems for researchers and extension workers associated with tropical food-crop production."¹

It is not expected that FSP research will yield location-specific blueprints for improved methods of crop and land management; rather the Program's concern is to develop and make available proven principles and practices for crop and land management. These methods are aimed to serve as foundations for modification by national programs. To this end, FSP research priorities are focused on major agricultural typologies within major agro-climatic zones. At present this typology is based on rainfall (humid; subhumid), soil characteristics (low base status soils; soils derived from basic rocks; high base status soils), soil catenary position (upland, hydromorphic), principal components of the cropping systems used, pressure on the land resource, and major constraints to production.

4. Structure of IITA's FSR Program

4.1 Staffing

With 18 senior scientists, FSP is the largest of IITA's programs. FSP is led by a Program Leader (Assistant Director level). The disciplinary backgrounds of FSP scientists are shown in Table 1, together with a guide of their current time allocation between the six inter-disciplinary project areas designated within FSP, and to other IITA programs. Table 1 illustrates the multi-disciplinary team approach of FSP, with individual scientists having varying degrees of involvement in the six inter-disciplinary project areas within which FSP is organized.

Since IITA's inception in 1969, the approximate man-years of senior staff time (excluding administration) devoted to FSP to date has been as follows, by broad disciplinary area:

¹IITA, Briefing Document for TAC Quinquennial Review Mission, IITA, Ibadan, 1977.

| | Man-years |
|-----------------------------|--------------------|
| - Agricultural economics | 11.2 |
| - Agricultural engineering | 5.5 |
| - Crop management | 23.7 |
| cropping systems | 10.0 |
| pest management | 13.7 |
| - Land management and soils | <u>46.1</u> |
| Total | <u><u>86.5</u></u> |

Table 1 Allocation of FSP Principal Staff Between Project Areas

| Discipline | No. | Regional Analysis | Cropps. Systs. | Pest M'gmt | Land M'gmt | Energy M'gmt | Land Utiliz. | Other Progrs. |
|------------------|----------------|----------------------|-------------------|----------------|---------------|-----------------|-----------------|------------------|
| Ag. Economist | 2 | M | S | L | S | L | M | M |
| Agronomist | 2 | L | M | S | L | | M | |
| Weed Scientist | 1 | S | M | M | S | S | L | S |
| Entomologist | 4 ^a | L | S | M | S | | L | |
| Nematologist | 1 | | S | M | S | | | M |
| Climatologist | 1 | M | | | M | | | S |
| Pedologist | 1 | M | S | | S | | M | S |
| Soil Chemist | 1 | M | S | | M | | | S |
| Soil Fertility | 1 | S | L | | M | | L | |
| Microbiology | 1 | | S | S | M | | | S |
| Soil Physics | 1 | L | L | | M | | | |
| Agr. Engineering | 1 | | S | | S | M | M | S |
| Agr. Eng. Assoc. | 2 | | | | | M | M | |
| FAO Agr. Eng. | 1 ^b | L | | | | M | M | S |
| Other Programs | | | L ^c | L ^d | | | L ^e | |

M = Major involvement

L = Limited involvement

S = Service function

a - On secondment from COPR; project to terminate in April 1978. One of the four is a visiting scientist.

b - Project Leader, FAO African Rural Storage Center.

c - Breeders and physiologists from Crop Improvement Programs.

d - Pathologists from Crop Improvement Programs.

e - Agronomist from Crop Improvement Programs.

4.2 Program Components

As presently specified, the project areas are:

(1) Regional Analysis

The analysis of existing farming systems in relation to soils and climates, economic and social conditions so as to provide basic information for the other project areas.

(2) Cropping Systems

The development and testing of appropriate crop combinations and sequences using cultivators developed in the crop improvement programs, together with other crops--such as plantain and vegetables--important in tropical farming systems.

(3) Pest Management

Development and testing of environment-conscious methods to overcome economically the problems posed by weeds, insects and diseases.

(4) Land Management

The development and testing of methods of land development and soil management to overcome economically the constraints to continuous use of fragile tropical soils.

(5) Energy Management

The development and testing of implements and machinery which can help to relieve labor constraints which exist in relation to land development, crop production and processing.

(6) Land Utilization and Evaluation

The integration and synthesis point of FSR at IITA, in the development, evaluation and adaption of appropriate systems of crop management and land use for different ecologies, drawing on the findings of the Farming Systems and Crop Improvement Programs.

The major multi-disciplinary work of FSP is in problem identification and technology evaluation, i.e., in Regional Analysis and in Land Utilization and Evaluation, the latter providing the point of integration and synthesis of FSR. The four problem-oriented areas of research -- Cropping Systems, Pest Management, Land Management and Energy Management - while supported by a wide multidisciplinary base, tend to have a major input from a narrower set of disciplines.

4.3 Specific Objectives of FSR Project Areas

(1) Regional Analysis

To analyze and develop inventories of resource use and of the biotechnical, physical and socioeconomic environments of farming systems in the humid and subhumid tropics.

Regional analysis works primarily in three major project areas:
(a) Agro-climatological Analysis, (b) Benchmark Soils Project, (c) Studies of Farming Systems.

Agro-climatological Studies involve collection and analysis of data as a basis to characterize agro-climatic zones of the humid and subhumid tropics.

The Benchmark Soils Project describes and classifies carefully chosen soils and then relates their agricultural capability to their morphological, chemical, and mineralogical properties as a basis for technology transfer. The project collaborates with a number of overseas institutions and universities.

Studies of Farming Systems in the tropics are carried out to understand bio-technical and economic factors affecting the farmer and his management system.

(2) Cropping Systems

To develop cropping practices which are productive, biologically stable, and economically viable; to identify systems of crop management adaptable to the conditions and needs of the smallholder in the humid and subhumid tropics.

There are five major projects:

- a) developing and testing combinations and sequences of staple food crops,
- b) investigating the role of vegetables in farming systems and identifying cultivars suitable for improved systems,
- c) identifying and collecting high yielding plantain cultivars and developing productive plantain-based cropping systems,
- d) evaluating the role of grasses and legumes in soil improvement and conservation,
- e) evaluating the potential of planted species as an alternative to natural bush regrowth to increase the efficiency of nutrient recycling.

(3) Pest Management

Objectives can be stated in three sub-project areas:

- a) Weed Science - to develop integrated weed management practices that are economical at low input levels and appropriate for the dominant cropping systems; and to study the impact of land and crop management on weed competition and persistence as a basis for minimizing weed infestation.

- b) Nematology - to increase and stabilize crop yields using minimum farmer input methods such as nematode resistant cultivars, nematode suppressing crop rotations (including live mulches and intercropping) and modifying agronomic practices.
- c) Pest Management - to develop economically and environmentally sound pest management practices appropriate to systems of land and crop management being developed within FSP, with emphasis on maximizing cultural and biological control techniques and the minimum uses of agro-chemicals, and to conduct studies on the pest and associated flora and fauna of indigenous and modified systems to gain a better understanding of the pest regulatory mechanisms which operate in such systems and the background against which agricultural development will take place.

From its inception FSP has had nematology and weed science positions, while entomology and pathology were located within the crop improvement programs. Recently a pest management group, consisting of three COPR entomologists, a residue analyst, the nematologist, and the weed scientist, was formed.

(4) Land Management

To develop systems of land management which will yield long-term, economically and biologically productive, stable returns to the farmer while conserving and maintaining desirable physical and chemical soil properties.

Major projects are:

- a) determining the interaction between ambient climatic, soil and hydrologic parameters and the performance of major food crops.
- b) studies on factors influencing soil erosion and developing methods for its control through soil-conserving tillage systems,
- c) investigations on the maintenance of acceptable nutrient and organic matter levels and the efficient use of fertilizer in low-input cropping systems under different systems of soil and crop management,
- d) microbiological studies aimed primarily at making best use of Rhizobium in biological nitrogen fixation, and of mycorrhizal fungi in phosphate nutrition of major food crops.

(5) Energy Management

To develop low-energy demanding, inexpensive simple farm tools which reduce hardship, increase human productivity and are within the economic and technical range of farmers in the humid tropics and complement the systems of land use being evolved by the Institute.

(6) Land Utilization

To provide a framework to construct and evaluate appropriate systems of foodcrop production and land use. Improved technology is evaluated in a simulated farm environment on selected experiment stations before release to cooperating user agencies.

5. Significant Achievements in FSR at IITA

The Review Team was impressed by the work of the FSP team at IITA. It should be stated that these achievements have been mostly related to on-site research.

5.1 Regional Analysis

Maps have been prepared which broadly define the start, end and duration of the cropping systems of West Africa. Also, a map is being prepared showing erosion-susceptible soils of the humid and subhumid regions of Africa.

Chemical and mineralogical analyses of benchmark soils indicate that percent saturation of exchangeable calcium and magnesium, phosphorus retention capacity and active iron and aluminum oxide content are among the important chemical parameters for agricultural land capability classification in the humid tropics.

Studies of indigenous farming systems have been carried out in Nigeria on low base status soils (root crops and oil palm) and high base status soils (cocoa-cereals and cereal-root crops). A number of important observations which have assisted the Institute in establishing research priorities, and designing and evaluating technology, have been derived from these studies.¹

5.2 Cropping Systems

Eight potentially efficient, two-year, intercropping and rotational

¹Okigbo, B.N. and Greenland D.J., "Intercropping Systems in Tropical Agriculture", in Multiple Cropping, American Society of Agronomy, Madison, Wisconsin, 1976.

sequences suitable for upland conditions on high base status soils under a bi-modal rainfall pattern have been devised. Cropping systems components have been devised for integrated management of valley bottoms and associated upland soils. Crop mixtures include staple crops involved in crop improvement programs and other foodstuffs important in tropical farming systems.

The effect of mulches and covercrops, and their value in soil temperature modification and structure maintenance, erosion control and crop performance have been determined. As mulching may be important in management of upland soils, a range of grasses and legumes as well as food-crop residues have been tested for use as in situ mulches; some have been established using zero tillage. Methods of crop management associated with appropriate land and water management technology are ready for off-site testing and adaptation. FSP seeks willing collaborators in this work, particularly national institutions or development projects. Research on crop mixtures and sequences is often highly location specific; therefore in the future, greater emphasis will be placed on understanding the physiology of crops grown in mixtures and the agronomic principles underlying indigenous cropping systems, and on crop interactions and pest management in intercropping. Coupled with climatological and soil investigations, such studies should provide principles to define crop mixtures for specific locations.

5.3 Pest Management

Nematology studies have contributed to integrated pest and disease management by identification of nematode resistant cultivars; identification of cover crops, crops, and crop sequences with nematode-suppressing potential; and by study of nematode incidence under varying cultural practices, especially in relation to minimum tillage and mulching.

Weed control research has provided basic information on weeds relating to cropping systems and management in the subhumid environment near IITA.¹

Early pest management research efforts indicate that significant information can be obtained through interdisciplinary teams, and that striking differences in pest incidence and spread exist between sole crops and various intercropping patterns.²

5.4 Land Management

This project area has been very productive, and its work has helped to improve knowledge of tropical soils and their management.

¹Moody, K., "Weeds and Shifting Cultivation," PANS 121 (2):188-194, 1975.

²Nickel, J.L., "Pest Situation in Changing Agricultural Systems - A Review," Ento. Soc. Amer. Bul. 19(3):136-142, 1973.

Pedological studies on major soils of West Africa have led to soil groupings of acidic Ultisols and Oxisols, less leached Alfisols and Inceptisols, hydromorphic soils, and of soils developed from basic rocks. A number of typical soils, grouped in toposequences, have been identified as being of major importance -- "benchmark soils" -- and much chemical, pedological, and mineralogical information has been assembled on these. These studies form a framework within which soil fertility of major land areas can be examined as well as adding much to the classification of tropical soils.

Soil physics research is broadly based, focusing on several aspects of the soil physical environment. The present zero tillage work at IITA has developed largely from studies on the erosion and infiltration behavior of soils under cultivation ^{1,2}. Much information has been obtained on the physical, chemical, and biological properties of soils under zero tillage. Such work is basic to extending zero tillage to farm practice. Work is underway on root development and activity in relation to soil composition and structure. Soil temperatures under mulches and covers and their effects on germination, growth and root development have been determined.

Chemical properties of a variety of West African soils have been studied³ and an understanding of the basic physical chemistry has been gained. Much work has been carried out on soil nutrient content and fertilizer response although mainly for soils near Ibadan.⁴

¹Lal, R., Soil Erosion Problems on an Alfisol in Western Nigeria and Their Control, (IITA Monograph 1), IITA, Ibadan, 1976; Lal, R., "Soil Erosion on Alfisols in Western Nigeria, I, II, III, IV, V," Geoderma 16:363-375, 16:377-387, 16:389-401, 16:403-417, 16:419-431, 1976.

²Lal, R., "No-tillage on Soil Conditions and Corn (*Zea mays*) in Western Nigeria," Plant and Soil 40(2):321-331, 1974. Lal, R., "No-tillage Effects on Soil Properties and Crop under Different Crop Rotations in Western Nigeria," Soil Sci.Soc.Amer.Proc., 40:762-768, 1976.

³Juo, A.S.R. and Maduakor H.O., "Hydrolysis and Availability of Phosphate in Tropical Soils," Soil Sci. Soc. Amer. Proc. 37(2):240-242, 1973.

⁴Juo, A.S.R. and Maduakor H.O., "Phosphate Sorption of Some Nigerian Soils and its Effects on Cation Exchange Capacity," Comm. Soils and Plant Analysis, 5(6):479-493, 1974.

Kang, B.T., Corey R.B. Osiname O.A. and Schults E.E., "Zinc Response of Maize Grown on Sandy Inceptisols in Western Nigeria," Agron. J., 65:875-877, 1973.

Kang, B.T. and Okoro E.G., "Response of Flooded Rice Grown on a Vertisol from Northern Nigeria to Zinc Sources and Methods of Application," Plant and Soil 44:15-25, 1976.

5.5 Energy Management

The techniques of CDA (controlled droplet application) have been proven to show promise to reduce energy and logistic inputs for herbicide applications as required if zero tillage techniques are to be applicable for the small farmer. Planters for seeding in zero tillage through mulches or cover crops have also been developed to provide an integrated zero tillage system suitable for small farmers.

5.6 Land Utilization

Zero and minimum tillage techniques have been adapted to minimize soil erosion and to maintain soil fertility in a simulated commercial farming situation. A six-season study on high base low activity soils in a subhumid area has demonstrated that these methods, with crop residues used as surface mulch, have proved effective in controlling erosion and maintaining maize yields, and were more profitable and managerially superior to conventional tillage systems.¹

Hydromorphic valley bottoms, have been shown to be very productive and with improved water and nutrient management are suitable for intensive rice and vegetable production. Five integrated systems of land use, involving the synthesis of the component achievements in crop production and land management are being evaluated in 'model farm' situations.

6. Overview and Comments on FSR at IITA

The Review Team has been impressed by the wide-based, multidisciplinary work of the FSP in this complex field, the considerable contribution to scientific knowledge which this has produced, and the development of farming system components which show promise of making an impact on the problem of shifting cultivation. The Team has noted with approval the present efforts to focus the work of the program more precisely on the collaborative development of new farming techniques.

6.1 Organizational Structure

The present organizational structure of FSP places on the Program Leader the difficult task of providing leadership to a multidisciplinary group of 18 senior scientists. Consideration should be given to ways of providing additional leadership within the Program.

6.2 Staff Balance

The balance between disciplines in the Program does not need any major change. The Review Team believes that increased capability in agronomy is needed

¹Lal, R., Soil Erosion Problems on an Alfisol in Western Nigeria and Their Control, IITA Monograph 1, IITA, Ibadan, 1976.

and suggests that an agronomist with broad crop experience should have some direct responsibility within the Land Utilization area.

6.3 Collaboration with Crop Improvement Programs

Closer collaboration is needed between the Crop Improvement Programs and FSP. Some inter-cropping work is done in the crop programs but this should be jointly planned and monitored. Also the resource evaluation and cropping systems analysis capacities of FSP should be useful to the Crop Improvement Programs in identifying breeding objectives, locating off-station regional trial, etc.

Since 1976, the Cereal Improvement Program has redirected its objectives around the concept of ecosystem balance achieved through the integration of breeding for wide adaptability with pest and crop management approaches. The Team believes that this expansion to ecosystems involving soil problems and cropping practices calls for greatest integration with FSP.

The Team strongly encourages the expansion of agronomic and physiological investigations on cowpea into intercropping systems with the FSP and recommends also close cooperation along the same lines in legume microbiology with the FSP group. Work on the Rhizobium symbiosis with cowpea and soybean should be developed on the basis of an agreed joint program between the FSP and the Grain Legume Improvement Program.

6.4 Research Priority

A number of possibilities and opportunities face FSP, and decisions on them will be required soon. These include:

- the opportunity for off-site testing and evaluation of research methods and results for subhumid areas where FSP has had most experience;
- decisions as to which technological or research opportunities -- zero tillage, soil toposequences, hydromorphic soils, for example -- should be tested off-site;
- relative balance and scope of activities in subhumid and humid areas;
- the pace, direction and location of research in humid areas.

It is suggested that priority should be given to off-site testing of subhumid research results, while exploratory studies on certain soil and climatic factors and simple cropping systems are pursued in humid areas. Also, it might be possible for FSP to collaborate with national agencies in the humid tropics, which would not require substantial IITA investment, but would increase the Institute's experience in this zone. It is probable that much of the technology development for the subhumid zone will not be transferable to the humid zone.

The Team considers that the pursuit and consolidation of the valuable work done within the subhumid climatic zone should have the first priority but within well-defined ecological zones. It notes that the problems in the humid zone are likely to require somewhat different solutions and believes that work within this zone should be developed gradually.

The balance between survey work in economics, climatology, and soil science and more experimentally-oriented work should be kept continually in review. The Team recommends that the work on regional analysis ensure that all relevant existing data pertaining to a region are collected, assessed and utilized.

6.5 Identification of Target Zones and Areas

Through its inter-disciplinary FSP team, IITA has a well-developed capacity to evaluate and assess the natural resources and major farming systems of an area. In doing this, it is understood that field surveys and direct experimental work on-station or in production areas may be required and a balance must be reached between these types of studies. To be effective the Regional Analysis project area should identify target zones giving weight to factors such as land resources, present cropping systems, population, etc. What is needed is a systematic way of guiding selection of target or opportunity zones. It would appear that the same capacity could be used to select sites for off-station testing. Criteria for off-station site selection could include: ecological suitability, technological opportunity, availability of a strong national program, and a commitment for collaboration. The extent and method of control by FSP over off-station research should be carefully considered.

Of the many non-mandated crops within IITA's geographic concern, vegetables can have an important place in many cropping systems. However, the Review Team is of the opinion that breeding of vegetables is not essential to FSR at IITA.

Questions have also been raised as to whether IITA's FSP should include plantain, agroforestry and small animals in its work. Since these commodities would tend to diffuse and dilute the program, the Review Team suggests that caution be exercised and these commodities only included if they are judged crucial to farming system development.

6.6 Specific Comments and Recommendations

(1) Relative to Socioeconomic Studies

The Review Team commends the substantial contribution to FSP made by IITA's economists and agrees that they should focus their activities on the on-farm aspects of farming systems. It also agrees that survey activities, purposefully integrated with other FSP research, are an essential aspect of this work. The move away from broad multi-visit surveys to limited-visit surveys aimed at specific information on particular problems is viewed with approval, and it is hoped that the opportunity will be taken to investigate hypotheses relevant to farmers' choice of crop and land-use systems. Such studies, for example, would include the testing of hypotheses about farmers' motivations and preferences, their conception of risk and attitude towards it, their decision making behavior, and the influence of farm/household/community relationship on their choice of technology.

The Team approves the initiatives taken by FSP in cooperating with national and other agencies in the conduct of field surveys.

(2) Relative to Land Management and Land Utilization

Extensive and thorough studies have been made on the soil environment and on integration of soil management information into land utilization systems which may form viable and dependable alternatives to shifting cultivation under specified soil and climatic conditions. Likewise, valuable work has been done in defining and characterizing important soils in West Africa. The amount of such pedological work should now be assessed. The Review Team recommends no pedology work in addition to this should be undertaken.

In addition the benchmark soils program needs to be assessed and the FSP should decide realistically how many benchmark sites can be investigated in terms of cropping capability.

More effort seems now to be directed to soils outside IITA, and the main thrust of this work should be towards the areas receiving high rainfall, bearing in mind logistic and other constraints.

The Review Team commends the work on zero tillage up to the present, and supports such further testing on the IITA headquarters site as may be necessary to establish the long-term value of the technique. The Team suggests that the work should now concentrate upon off-station sites, selected to cover various ecological zones, and in accordance with a systematic plan. At the same time the research effort should not ignore possible options other than zero tillage.

The Team supports the continuation of the past work on cover crops and mulches in association with the Cropping Systems Studies.

Present studies on crop water requirements, and light requirements and gas exchange in crop canopies are useful, particularly in relation to the study of intercropping. However, there should also be a significant agro-climatological focus towards the delineation and characterization of FSP target areas and agroclimatic zones.

(3) Relative to Cropping Systems

The team has been impressed by the extent of the exploratory work on possible crop associations and combinations. It believes that the time has now come for:

- (a) testing the most promising systems and crop management practices, together with proven land management techniques, within the ecological area of which IITA's site at Ibadan is representative;
- (b) concentrating on more in-depth studies preferably on a limited number of well chosen characteristic crop combinations or sequences. These studies will necessarily require close inter-disciplinary cooperation, involving not only FSP scientists but also the specialists of the Crop Improvement Programs, in order to ensure that the breeding materials developed are adapted to intercropping.

These thorough investigations should be extended by multi-location testing under controlled conditions. The time has come to gather information about farmers' reactions to the proposed systems and practices.

(4) Relative to Weeds, Pests, and Diseases (Pest Management)

The work on nematology and weed science has provided basic information on these pest problems in various cropping patterns and under traditional and improved management systems. The formation of a pest management group to monitor and overcome pest problems in priority cropping systems is commended.

(5) Relative to Agricultural Engineering

Work in agricultural engineering should focus on the design and development of a limited number of implements and machines of direct interest to FSP (such as the jab planter, the hand-pushed sowing machine and the ultra-low volume sprayer).

The Team noted the close cooperation between IITA and the manufacturers of implements and machines in the development of new or adapted implements and machines suited for small and medium-sized farms. It believes that the task of IITA in this cooperation should be limited to the provision of sketches and ideas in most, if not all, cases and that the final design and development should be left to the manufacturers.

7. Conclusions

The Institute has assembled a strong body of knowledge and experience in the very complex field of farming systems research in the humid and sub-humid tropics. The team commends the comprehensive, integrated and purposeful approaches followed by the Institute in this regard and its emphasis on the improvement of the conditions of the small farmers in Africa. Promising techniques of land management and cropping systems are being tested and demonstrated on the main site of the Institute. It is noted that the FSR team will now develop its research and testing methods and practices on other sites while continuing the study on the long-term effects of its proposed farming practices and technologies.

IITA's Farming Systems Program should now give priority to the validation and off-site evaluation of systems presently being developed at IITA for the subhumid zone. It should proceed with research in the humid zone, where feasible, in collaboration with national and regional institutes but limit work at Onne, for the time being, to system components rather than full system analysis.

The Program also should only consider work on vegetables, Musa spp., or tree crops if there is evidence that they are absolutely essential to the viability of the farming systems research of IITA in particular ecological zones. The Review Team recommends that research on animals should be avoided and agro-forestry activities limited to the present project.

The Team also recommends that the discipline of agronomy should be strengthened within the Farming Systems Program in order to facilitate cooperation with the Crop Improvement Programs.

ANNEX 4. FARMING SYSTEMS RESEARCH AT ICRISAT

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 - 5.1 Benchmark Village Level Studies
6. Significant Achievements in FSR at ICRISAT
7. Overview and Comments on FSR at ICRISAT

ANNEX 4. FARMING SYSTEMS RESEARCH AT ICRISAT¹

1. ICRISAT's Mandate

Four objectives are specified by ICRISAT's mandate, viz:

- "(1) To develop farming systems which will help to increase and stabilize agricultural production through better use of natural, human and capital resources in the seasonally dry, semi-arid tropics.
- (2) To serve as a world center to improve the genetic potential for grain yield and nutritional quality of sorghum, pearl millet, pigeonpea, chickpea and groundnut.
- (3) To identify socio-economic and other constraints to agricultural development in the semi-arid tropics and to evaluate alternative means of alleviating them through technological and infrastructural changes.
- (4) To assist national and regional research programs through cooperation and support and contributing further by sponsoring conferences, operating international training programs and assisting extension activities."

Objective 1 is of specific concern to the Farming Systems Research Program; objective 2 relates directly to the Crop Improvement Programs; and objectives 3 and 4 are of concern to the Farming Systems, Crop Improvement and Economic Programs. These major research programs are seen by ICRISAT as intimately related and interdependent. In each program, several disciplines cooperate to attain one common goal: "a better life for the people of the semi-arid tropics." Further, ICRISAT's Board has accepted its mission as being too small (non-irrigated) farmers of limited means without access to large-scale irrigation.

¹The basic document outlining ICRISAT's current FSR program is Krantz, B.A. et al., The Farming Systems Research Program (Document Prepared for the TAC Stripe Review Team), ICRISAT, Begumpet, October 1977. Unless otherwise noted, quotations are from this source.

Since its commencement in mid-1972, ICRISAT has made much progress, indeed surprisingly so given that its permanent buildings will not be available until 1978. Strong activity is underway relative to all four major objectives of the mandate. To date, ICRISAT's overall program emphasis has been to semi-arid areas of the Indian sub-continent but a significant effort is now developing in semi-arid Africa.

2. FSR Implications of ICRISAT's Mandate

Five major implications for her FSR are seen in ICRISAT's mandate. First, the carrying out of FSR is decreed by the mandate. Second, this FSR is to relate to the semi-arid tropics and, third, is "to increase and stabilize agricultural production." Both these requirements portend difficulty. The semi-arid tropics encompass significant parts of the Indian sub-continent, Africa and South America. As for other centers with a significant geographical element to their mandate, ICRISAT can hardly undertake FSR encompassing all the diversity to be found across the semi-arid tropics. While this diversity -- due to the effect of water constraints -- may be less in terms of the number of crops and their combinations used than the diversity faced by CIAT and IITA, it would seem to be greater in terms of the institutional and cultural settings involved. Contrast, for example, the institutional and cultural settings to be found in Northeast Brazil, Mali and India. Such influences are probably more difficult to handle in an agricultural research context than agronomic diversity.

The difficulty with "to increase and stabilize" production under the risky rainfall conditions of semi-arid regions is that increased production may often only be achieved at the expense of stability. As an aim for FSR, the phrasing of the mandate may be satisfactory; but as a criterion for judging FSR results it can hardly be strictly applied.

A fourth implication of the mandate is that through its objective of developing better farming systems, ICRISAT could logically involve itself significantly in the consideration (if not the improvement) of crops and livestock not otherwise mentioned in the mandate. For example, FSR for Northeast Brazil would necessarily involve cotton and beef.

Lastly, through its specification of crop improvement, constraint identification and national cooperative program objectives in addition to FSR, the mandate implicitly recognizes FSR as a key element in the progression from crop improvement to overall agricultural development.

3. ICRISAT's Approach to FSR

3.1 FSR Program Objectives

The Farming Systems Research Program is "resource centered" and "development oriented." Its major objectives are:

- "(a) to generate economically viable, labor-intensive technology for improving and utilizing, while at the same time conserving, the productive potential of natural resources.
- (b) to develop technology for improving land and water management systems which can be implemented and maintained during the extended dry seasons, thus providing additional employment to people and better utilization of available animal power.
- (c) to contribute to raising the economic status and the quality of life for the people in the semi-arid tropics by developing farming systems which increase and stabilize agricultural output."

To these ends, farming systems scientists at ICRISAT are studying the characteristics of the semi-arid tropics (SAT) so as to develop technology emphasizing improved resource management, conservation and utilization. It is envisaged that farming systems research, in close cooperation with programs aimed at the improvement of the genetic potential of specific crops, will result in the rapid development of substantially more productive and economically viable farming systems. The need for a multi-disciplinary systems approach to solve agricultural development problems is recognized. However, the scope and limits of ICRISAT's farming systems research (and its definitions and concepts) are still being delineated.

3.2 FSR Program Activities or Principles

Based on consideration of research productivity and the problems of focusing research and location specificity, together with appraisal of the role of international multilocation cooperative trials, ICRISAT's FSR and Economics Programs have designated a set of seven activities to be encompassed by the Institute's work in FSR.¹ These activities reflect a philosophy and constitute a broad methodology or set of principles for ICRISAT's work in FSR. Overall, they also imply that the Institute's work should complement and not duplicate the research of national agencies.

With intervening discussion, the required activities are listed as (1) to (7) below. Overall, the activities are concurrent rather than sequential.

¹Ibid. and Binswanger, H.P., Krantz, B.A. and Virmani, S.M., The Role of ICRISAT in Farming Systems Research, ICRISAT, Begumpet, August 1976.

Aimed at assisting the focusing of research so that it is purposeful and efficient, the first three activities are:

- "(1) The assembly and interpretation of existing base line data in the areas of climatology, soil science, water management, plant protection and economics.
- (2) The communication of basic and applied research results relating to farming in the SAT to (and from) cooperators.
- (3) The performance of simulation or systems-analytic studies based on climate, soil and cropping systems information so as to predict the potentials of new crops, cropping systems, and soil, water and crop management practices." This involves computer modelling aimed to identify gaps in knowledge and to provide ex ante evaluation of research possibilities.

From base line data analysis guided by research needs, a number of benchmark locations are to be chosen in cooperation with National Programs to represent distinctly different climatic, soil and topographic conditions, aimed at covering the wide spectrum of SAT environments with a minimum of locations. It is planned to develop research at the benchmark locations in cooperation with national institutions so as to develop, test and evaluate information for the area involved.

As well as research at benchmark locations, it is seen as essential that the Institute undertake:

- "(4) The organization of international cooperative trials to rapidly gain information about the performance of a practice, technique or approach over time at the same location and/or across locations."

An assumption of this multilocation trial activity is that "given the climatic variations which are characteristic of the SAT, resource management research can be speeded up significantly by making use of spatial variability in climate."

To date, cooperative research in farming systems has been conducted only in India and mainly via the All India Coordinated Research Project for Dryland Agriculture which involves 23 regional Dryland Research Centers. However, it is hoped that initial contacts in, e.g., Upper Volta, Mali, Tanzania and Brazil, will lead to a strong cooperative network with national programs by 1982. It is envisaged that such co-operative research will involve not only research station testing but also real-world on-farm testing of alternative farming systems. Such a proposal is presently being developed for selected village locations in India by the FSR and Economic Programs in cooperation with relevant National Programs. In such cooperative activities, ICRISAT recognizes that extension and rural action programs are the responsibility of national agencies.

Recognizing that the concepts and approaches of FSR are new, the training of researchers for national agencies is seen as a program activity via:

- "(5) The provision of support and expertise for those ICRISAT training programs involved in all facets of farming systems research."

The research responsibility of the FSR Program is seen as being:

- "(6) The conduct of basic and supportive research in agroclimatology, hydrology, environmental physics, soil fertility and chemistry, farm power and equipment, land and water management, cropping systems, agronomy and weed science." This research, recognizing the problem of location specificity, is to "be concentrated on the development of principles, concepts and methodologies with wide application."

Finally, so as to ensure a real-world orientation in supportive research, a basis for testing and evaluation, and a relevant focus in training, a necessary activity is seen to be:

- "(7) The performance of interdisciplinary research on resource management, crop production and resource conservation at the ICRISAT center and selected benchmark locations" aimed at the development of applicable farming systems for benchmark locations.

3.3 Water - The Major Constraint

In ICRISAT's approach to FSR for the SAT, water is seen as the major constraint. Alleviation of the effects of this barrier is the ultimate aim of the FSR Program and has been the focal point of activities to date. Better usage of precipitation is emphasized so as to overcome the erratic rainfall, low effective rainfall and low water use efficiency characteristic of agriculture in the SAT. Accomplishment is seen to depend on (i) proper management of the soil and of all the precipitation that falls on the land and (ii) better utilization of the improved environment through more productive cropping systems. In many areas, the collection, storage and efficient utilization of runoff water and the use of groundwater, on a watershed basis, to support and stabilize agriculture will also be required. Thus the primary unit in ICRISAT's FSR work is the local watershed and such watershed-based resource utilization is taken as implying that for any given watershed the annual precipitation (used directly or as supplemental water from runoff storage or ground water recovery) is the only source of soil moisture for crop production.

This local watershed approach involving the use of small quantities of runoff or percolated water to back-stop rainfed agriculture, is distinctly different from conventional irrigated agriculture which primarily depends on the transfer of "imported" water from distant catchments or on water lifted by tube wells from deep aquifers. As presently viewed, such irrigated agriculture is outside the focus of ICRISAT's FSR Program.

3.4 Farming System Definition and Research Interpretation

To encompass its resource management and watershed based orientation to FSR, ICRISAT has defined a farming system as (underlining added):

"The entire complex of resource preparations, allocations, decisions and activities which, within an operational farm unit or a combination of such units, results in agricultural production. The harvesting, drying and processing of the products are also directly related to the system that produces them."

In this context, the FSR Program "deals with all components which in combination represent the production process on farms. These include soil and water management technology, cropping systems and methods of planting, power-equipment packages for land development and tillage, plant protection, plant nutrient application, harvesting, threshing, drying and processing" -- and, given the underlined part of the above definition, the inter-farm watershed-based dependencies and arrangements (or lack of) between farms.

Increasingly, the FSR Program is being oriented to study of the biological and physical processes involved in farming systems rather than the study of actual practices since information on these basic processes is seen as less location specific.

ICRISAT's Farming Systems Program is not limited to considering only the crops mentioned in its mandate (sorghum, millet, pigeonpea, chickpea and groundnut) as components of cropping systems. It includes a search for any additional crops (agricultural, horticultural or silvicultural) which have potential in the SAT. It is also seen as requiring research on forage production and the controlled use of livestock, where relevant, as a component of farming systems. In the cooperative research phase with National Programs, the availability of external inputs, the marketing of agricultural produce, socioeconomic constraints and farmers' cooperation and organizations are also to be considered.

The FSR Program recognizes that the final tailoring of farming systems to local conditions and socioeconomic constraints can only be undertaken by national research organizations. However, because of the dearth of agricultural research information in the SAT, ICRISAT sees a greater need for broad-based basic research on principles, concepts and methodologies for the solution of development problems than in most other agroclimatic zones. Thus, the strategy is to concentrate on developing principles of soil and water management, resource conservation and crop technology which will have general application over much of the SAT, and to develop methodologies and approaches which can be used by national organizations to adapt these principles and develop the most effective practices for their locations.

4. Structure of ICRISAT's FSR Program

ICRISAT's FSR Program is structured around interdisciplinary activities within the program itself and cooperative activities with the center's Crop Improvement Programs and, most importantly, the Economic Program, plus cooperative work with national agencies.

Until 1977, the FSR Program was seemingly loosely organized around sub-program areas with no formally designated leader or outwardly obvious organizational linkages or structure within the research program.

4.1 Staffing

The program's senior staff consists of six (soon to be seven) International (or Principal) Scientists spanning the program areas listed below, plus 19 highly trained senior scientists able to conduct research projects with full responsibility. Distinct from the FSR Program, but closely involved in cooperative activities, is the Economics Program which, all told, has an establishment of three International Scientists, one post-doctoral scientist, one senior scientist and four junior scientists. Compared to most other IARCs, ICRISAT is able to recruit excellent local support staff.

4.2 Program Components

Currently the Farming Systems Program consists of five components:

- Research in sub-program areas.
- Operational scale, watershed-based resource utilization research.
- Cooperative research with national and regional organizations.
- Training programs in farming systems.
- Extension and implementation through national programs.

All five of these components are interrelated via focus and staffing, and success is seen as dependent on continuous dissemination and feedback between each of the components. The last three components, as listed, are self-explanatory. The first component, i.e. research in sub-program areas, involves basic or supportive research aimed at specific objectives in the following disciplinary area:

Agroclimatology
Hydrology
Environmental Physics
Soil Fertility and Chemistry
Farm Power and Equipment
Land and Water Management
Cropping Systems
Agronomy and Weed Science.

Much of the research in the various sub-programs or in cooperation with disciplinary specialists from the Crop Improvement and Economics Programs is carried out on a wide spectrum of activities or experiments within the particular disciplines involved. These range from basic investigations to applied studies which may be included in cooperative adaptive projects at an early stage.

The second component, i.e. watershed-based resource utilization research, is conducted on watershed units on both Alfisols and Vertisols at ICRISAT. It is the operational testing ground for principles and leads developed in the various sub-programs where water, power and labor use efficiency, production potential, resource conservation, and economics of alternative farming systems are investigated on an operational scale. Thus, all sub-programs in the Farming Systems Research Program as well as cooperating economists, plant breeders, physiologists, entomologists, pathologists and microbiologists from other ICRISAT programs are involved in some facet of the systems research in the watersheds.

4.3 Specific Objectives of FSR Sub-programs

While ICRISAT has five major research programs (FSR, Economics, Cereals, Pulses, Groundnuts), these titles are largely for administrative and overview purposes. The allocation of research resource is carried out via the Deputy Director (Research) on a research project basis within the programs, each specific research project having a designated team and leader, and usually running for two or three years. Within the FSR Program, such projects are aimed to help achieve the objectives specified for the sub-program areas (which were established in mid-1977), as listed below.¹

¹From Krantz, B. A. et al., op. cit.

Agroclimatology

- (1) To classify the SAT into major climatic zones through the collection, analysis and interpretation of available climatic data.
- (2) To quantify the moisture environment for crop growth in important regions of the SAT through the application of simulation techniques to available rainfall, evapotranspiration and soils data to delineate priority research areas and to determine the probable transferability of agricultural production techniques between similar areas.
- (3) To investigate crop weather interactions to specify crop production relationships and to distinguish production differences due to technology from those due to environmental conditions in order to identify the key variables.
- (4) Investigations of microclimatic elements and influencing the production potential of intercropping and relay cropping systems.

Hydrology

- (1) To contribute to the quantification of runoff probabilities, groundwater hydrology and erosion behavior under alternative management treatments in agricultural watersheds for various agroclimatic zones.
- (2) To assist in the development of hydrologic models and simulation programs for the interpretation and extrapolation of hydrologic research findings to major agroclimatic zones.
- (3) To develop methodology and equipment for hydrologic research.

Environment Physics (from 3 m above ground to 3 m below)

- (1) To characterize, throughout the zone of rooting, the physical properties, (bulk density, moisture characteristic curves, saturated and unsaturated hydraulic conductivity) for major soil groups of the SAT.
- (2) To evaluate alternative methods for in situ measurement of soil moisture and moisture desorption functions.

- (3) To determine detailed seasonal-profile water balances and to quantify the direction and magnitude of moisture flux at various depth and times for Alfisols and Vertisols.
- (4) To derive quantitative relationships between ET/EO and the soil and plant water potentials, dry matter production, L.A.I. and plant height for rainy season and post-rainy season crops.

Soil Fertility and Chemistry

- (1) To determine, in cooperation with National Programs, biologically and economically optimum soil fertility management and fertilization programs for important cropping systems, especially intercropping, in various areas of the SAT.
- (2) To investigate seasonal changes in nutrient status under different management systems and to determine and quantify the processes involved in nutrient transformation and losses so as to develop improved management techniques which will effectively recycle and conserve nutrients.
- (3) To compile the chemical properties of the major soil groups of various regions of the SAT.

Farm Power and Equipment

- (1) To gain an understanding of farmers' motivation and constraints in adopting new equipment and to use this information as feedback into machinery development research. To monitor equipment utilization in Watershed-based Resource Utilization Research, to study the energy inputs required for alternative management levels and to use modelling as a technique to arrive at optimum machinery systems.
- (2) To arrive at improved tillage, fertilizer placement and planting techniques through precise identification of critical physical characteristics for each operation. To select or develop simple and inexpensive instrumentation to quantitatively determine the conditions under which adequate performance is attained.
- (3) To solve the problems of early and quick harvesting of rainy season crops related to intercropping, relay

cropping and sequential cropping systems and also those of post-rainy season crops to facilitate early tillage.

- (4) To improve the utilization of animal and/or mechanical power and energy for field operations and to investigate the applied aspects of other energy forms such as solar heat (crop drying) and wind power (water lifting and electricity generation).
- (5) To design modifications and to construct prototypes based on a selection of alternative materials and components as well as to provide drawings, specifications and cost estimates for equipment production.

Land and Water Management

- (1) To develop land management which results in reduced runoff and erosion, while increasing infiltration of rainfall without causing drainage problems.
- (2) To develop surface drainage techniques which result in a better growth environment for plants and improved workability of the soil during the rainy season without resulting in excessive runoff.
- (3) To develop design criteria for waterway systems which safely convey excess water from the land with minimum interference for agricultural operations.
- (4) To develop alternative technologies for the use of available ground and surface water on rainfed crops, resulting in increased benefits through stabilizing rainfed agriculture and by lengthening the growing season.
- (5) To develop superior systems for runoff collection and reutilization as well as for the use of ground-water to increase the available water resources on a watershed basis.

Cropping Systems

The basic research philosophy of this sub-program is that the intercropping situation, despite its complexity, is still a community of plants, or "crop", which uses growth resources to produce yield. Consequently, the research objectives are similar to those of a crop improvement program but relate to intercropping:

- (1) To achieve a fundamental understanding of growth and resource use as a means of identifying possible ways of improvement.
- (2) To characterize the agronomic relationships and their interactions.
- (3) To produce improved genotypes.
- (4) To identify plant protection problems and their means of control.
- (5) To examine the role of legumes.
- (6) To examine the stability of yields.

Agronomy and Weed Science

- (1) To derive initial guidelines on the agronomy of new pre-release varieties of ICRISAT's five crops.
- (2) To investigate principles of weed management and ecology.
- (3) To evaluate crop residues and forage as sources of animal feed.
- (4) To study the individual and combined effects of several "steps in technology" on crop yields.

4.4 Watershed-based Resource Utilization Research

In line with the FSR Program's view of water as the major constraint and the local watershed as the focal key to improving farming systems in the SAT, a number of local watersheds have been delineated on ICRISAT. Watershed-based resource utilization research is conducted on these station watersheds. This research is aimed at determining "the optimum utilization of the catchment precipitation through improved water, soil and crop management for the improvement and stabilization of agriculture on the watershed."

A number of land and water management techniques are simulated on the ICRISAT watersheds. Alternative cropping systems are superimposed on these treatments, and distinction is made between improved and traditional "levels of management" (i.e. technologies). Thus the station watersheds are operational-scale "pilot plants" where the integrated effect of alternative farming systems can be monitored. All FSR sub-programs cooperate in this research.

The specific objectives of this Watershed-based Resource Utilization Research are:

- (1) To facilitate the development of appropriate technologies for land and water development, soil and water conservation and resource utilization.
- (2) To integrate new information, developed in FSR sub-programs, into viable systems of farming and to rigorously test the improved systems on an operational scale.
- (3) To investigate the water balances of alternative farming systems and to specifically determine the rainfall use efficiencies and yield stability obtained; to generate data for testing hydrologic simulation programs.
- (4) To derive the economics characterizing different farming systems which are prevalent in the Hyderabad region or which seem to have potential for this area; to extrapolate economic results to other areas for identification of priority research areas.
- (5) To provide training to those involved in hydrologic research and natural resource development in different regions of the SAT; to demonstrate a methodology to arrive at viable farming systems for the SAT.

5. Socioeconomic Research in Relation to FSR at ICRISAT

It is noteworthy that the FSR Program's sub-program areas, which are largely disciplinary based, do not include the socioeconomics area. Such work is the responsibility of the Economics Program.

The overall objective of the Economics Program is to help identify constraints to increased food production and agricultural development in the semi-arid tropics, and to evaluate alternative means of alleviating these constraints by technological and/or policy changes.¹

This general philosophy is expressed through the various research projects undertaken in the Program's two major areas of Production Economics and Marketing Economics. Virtually all of the research in the Production Economics Sub-program relates either directly or indirectly to the FSR Program. These projects have been defined and implemented with the collaboration of FSR Program Scientists, and are all designed to be highly

¹Ryan, J.G., Farming Systems Research in the Economics Program, EP Discussion Paper 2, ICRISAT, Begumpet, November 1977.

relevant to FSR Program needs. Work in the Marketing Economics Sub-program, while of direct relevance to the Crop Improvement Programs, is largely only of indirect relevance to FSR. In both a sub-program areas of the Economics Program, work is done of relevance to general agricultural policy which again has indirect relevance to FSR.

Economics projects which relate directly to FSR have as their primary purpose the provision of information and analyses to the Institute's management and to the FSR Program so as: (i) to assist in setting research priorities and strategies; (ii) to help design and implement appropriate experiments; and (iii) to contribute to the testing and evaluation of proposed system changes. Thus, overall, a major function of the Economics Program is to provide data that will help evaluate and ensure that the farming systems being developed are relevant to the actual constraint situations facing SAT farmers and that the potential for payoff is high.

Studies underway or completed of direct relevance to FSR relate to:

- benchmark villages.
- risk in the SAT.
- economics of human, animal and mechanical power sources in the SAT.
- economics of prospective technologies for the SAT.
- "steps in technology" experiments.
- rainfall-runoff modelling.
- history and economics of existing tank irrigation in India.
- group action and organization requirements for the implementation of watershed-based technologies.
- social organization in Indian SAT villages.
- economics of tractors in the South Asian SAT.

5.1 Benchmark Village Level Studies

Because they appear to be the most purposefully designed and fruitful of the sampling studies of existing farming systems reviewed by the Review Team, it is worthwhile outlining the Economics Program's village level studies project.

Aims of the project are to gain a thorough understanding of traditional farming systems in the SAT, to identify constraints to food production and development at the micro-level, and to provide a potential basis for off-station and on-farm testing and evaluation in cooperation with the FSR Program and national agencies.

To date studies have been initiated in India with four villages on Vertisol and two on Alfisols. These benchmark villages were selected with the advice of other Programs and Indian agencies, choice being based on purposeful selection taking into account 40 characteristics (covering climate, soil, location, etc.) judged relevant from a benchmark view. So as to ensure purposeful data collection from the start, a set of eight prior hypotheses about traditional farming practices and farmer behavior were formulated for testing.¹

An investigator has been living in each of the selected villages continuously for the past 2.5 years, following an initial period of intensive training. Each has an M.Sc. in Agricultural Economics, comes from a rural village background in the same region, and speaks the local language. In each village various information schedules have been completed with a stratified random sample of 10 landless laborer and 30 cultivator households (divided equally into small, medium and large family groups) on a regular basis every 15 to 20 days. Data collected cover all farm and non-farm activities, including input-output data, labor utilization and employment, transactions, inventories, prices, kinship relations, etc. In addition to this socioeconomic data, a large number of agrobiological observations and measurements have been made in collaboration with scientists from other ICRISAT Programs. More complete information on the data collected is shown in Tables 1 and 2.

¹Binswanger, H.P. et. al. Hypotheses and Priorities for the Village Level Studies in the SAT of India, ICRISAT, Begumpet, December 1974; Binswanger, H.P. et. al., Approach and Hypotheses for the Village Level Studies of ICRISAT, EP Occasional Paper 15, ICRISAT, Begumpet, May 1977.

TABLE 1

Details of the schedules used for collecting agro-economic data in ICRISAT's benchmark village studies

| Type of schedule | Year and frequency | Schedules completed ^{a/} | Remarks |
|--|---|-----------------------------------|--|
| Household census | May, 1975; once | 1820 | For all resident households; demographic, occupational, landholding and livestock possession detail. |
| Household member schedule | July, 1975 July, 1976 | 480 | More details of above type for sample households; details about each member. |
| Plot and crop rotation schedule | July, 1975, July, 1976; updated during each crop season | 380 | Records physical and ownership status of farm plots; use status (fallow, cropped, double cropped, crop rotation during different seasons). |
| Animal inventory | July, 1975 July, 1976 | 480) | Records sample households' position in terms of fixed assets. |
| | |) | |
| Farm implement inventory | -do- | 480) | |
| | |) | |
| Farm building inventory | -do- | 480) | |
| | |) | |
| Cultivation schedule | Since July 1975; every 15-20 days | over 4600 | Records plotwise input-output details for each crop for each season. |
| Labor, draft animal and machinery utilization schedule | -do- | over 6900 | Records actual utilization of these resources on the day preceding the interview; number of wage employment days, days of involuntary unemployment (for family labor and bullocks) during the period since last interview. |
| Household transactions schedule | -do- | over 6900 | Records type and value of every transaction involving inflow and outflow of cash, goods and services for sample households. |

(Cont'd)

Table 1 - Cont'd.

| Type of schedule | Year and frequency | Schedules completed ^a / | Remarks |
|--|--------------------------------------|--------------------------------------|---|
| 10. Price and Wage schedule | July 1975 to June 1976; once a month | 200 | Records wage rates for labor and bullocks, and price details of major items transacted by villagers in their village or outside for every month. |
| 11. Stock inventory credit and debt schedule | Jan. 1976 and July 1976; once a year | 480 | Records inventory of stocks of food grains, fodder, consumer durables, savings, deposits, debt and credit position of sample households. |
| 12. Kinship and social exchange schedule | Since Dec. '76. every 15-20 days | 2400 | Records details on the social network behind exchange for sample households (Incorporated with household transactions schedule.) |
| 13. Risk investigation schedules | August 1976 to April 1977 | 320 | Records farmers' preferences with respect to suggested decision alternatives with varying degrees of gain and uncertainty of prospects; actual decision and actions about farming; adjustment devices to meet consequences of drought, etc., for sample households. |
| 14. Risk attitude experimentation schedule | April-May 1977 | 295 | Records farmers' actual choices resulting from their participation in 'risk game' designed for the purpose. |
| 15. Time-allocation studies schedule | Since Jan. 1977; once every season | 144 (winter and summer seasons only) | Records actual pattern of activities by all members of households of a sub-sample by constant observation for one day in each of the seasonal rounds. |
| 16. Diet Survey schedule | -do- | 480 | Records through actual measurement and observation the items consumed by each member of the sample households. |

(Cont'd)

Table 1 - concluded

| Type of schedule | Year and frequency | Schedules completed ^{a/} | Remarks |
|---------------------------|------------------------------------|--|---|
| 7. Health status schedule | Since Jan. 1977; once every season | 3036 ^{a/} (for all members of sample households) | Records nutritional deficiencies, disease symptoms and other issues related to health status using methods suggested by health and nutrition experts. |
| 8. Demographic schedule | Oct.-Dec. 1977 | All sample households | Data to determine age-specific fertility of women and to indicate normal completed family sizes. |

^{a/} Completed as of May, 1977.

[/] This excludes the schedules of all school-going children in the villages for whom similar details were collected.

TABLE 2

Details of agro-biological and related data collected through ICRISAT's village level studies during the crop years 1975-76 and 1976-77

| Crop | Description | Minimum No. of plots covered (with 3-5 replicates in each) dur- ing each year | Frequency of obser- vations each year | Crop years covered | Information user ^{a/} |
|---|--|---|--|--------------------------|----------------------------------|
| Sorghum | 1. Shootfly incidence | 6 | 1 | Both yrs | Entomologists |
| | 2. Stem borer count | 6 | 1 | " | " |
| | 3. Midgefly and preharvest assessment | 6 | 1 | " | " |
| | 4. Grain mound counts | 6 | 1 | " | Cereal Pathologists |
| | 5. Striga assessment | 6 | 1 | 1975-76 | Sorghum breeders |
| | 6. Leaf disease incidence | 6 | 1 | 1976-77 | Cereal Pathologists |
| Pigeonpea | 1. Wilt & sterility mosaic | 5 | 3 | Both yrs | Pulse Pathologists |
| | 2. Pod borer counts | 10 | 2 | Both yrs | Entomologists |
| | 3. Nodule counting | 5 | 2 | 1976-77 | Microbiologists |
| | 4. Crop rotation (with pigeonpea) | 30 ^{b/} | 1 | 1975-76 | Farming Systems |
| Chickpea | 1. Wilt incidence | 5 | 3 | Both yrs | Pulse Pathologists |
| | 2. Pod borer counts | 10 | 2 | Both yrs | Entomologists |
| | 3. Germination/crop stand | 5 | 2 | 1976-77 | Pulse Physiologist |
| | 4. Nodule counting | 5 | 3 | " | Microbiologists |
| Pearl Millet | 1. Incidence of downy mildew | 5 | 1 | " | Cereal Pathologists |
| | 2. Incidence of ergot | 5 | 1 | " | " |
| | 3. Incidence of smut | 5 | 1 | " | " |
| | 4. Incidence of rust | 5 | 1 | " | " |
| Groundnut | 1. Nodule counting | 5 | 3 | " | Microbiologists |
| All major ^{c/} crops of the area | 1. Weed counts | 5 (per crop) | 1 | " | Farming Systems |
| | 2. Cropping patterns and crop rotations | 30 ^{b/} | 1 | " | " |
| | 3. Crop cutting | 18 | 1 | " | Economics |
| | 4. Direction of crop planting | 30 ^{b/} | 1 | 1975-76 | Pulse Physiologists |
| | 5. Post-harvest farming practices | 30 ^{b/} | 1 | " | Farming Systems and Economics |
| | 6. Rainfall induced delays in farm operations | 30 ^{b/} | 1 | " | Farming Systems and Economics |
| | 7. Effects of contour bund- ing on crop yields | | 3 | " | Farming Systems |
| | 8. Measurement of inflows/ outflows into tradi- tional paddy tanks | | daily | 1976-77 | Farming Systems |

^{a/} Instructions and pro forms for collecting observations were supplied by the respective scientists who are potential users of these data. They also trained the investigators for making the observations and measurements.

^{b/} Number of households, not plots.

^{c/} Besides the said observations, measurement of plots and sub-plots, weighing of fodder bundles, cart loads of manure, etc., was done on a sample basis.

Since the establishment of the benchmark village studies, they have been found to have increasing potential as a basis for information and hypothesis testing as these needs arise in the Institute's Programs. Thus, for example, they have been highly relevant to FSR Program study of the effects of bunding on crop yields and of traditional paddy tank inflows and outflows. The village studies have also served as an important "full information" base for the study of farmers' risk attitudes and the potential labor-displacement effects of herbicides. Further, they are providing a base for the study of the influence of caste and other socio-anthropological factors on the rate of adoption of improved technology. Most importantly, given the local watershed focus of the FSR Program, the benchmark villages are serving as real-world test sites for testing new watershed-based technologies, as well as for studying the approaches to group action needed for successful implementation of new watershed-based technology.

It is planned to continue the village studies in four of the six sites at the same level of intensity for another year; the study will continue at the other two sites but at reduced intensity. Plans are that analogous studies will commence in the SAT of West Africa in 1978, and a further four villages are proposed for study in India.

6. Significant Achievements in FSR at ICRISAT

Mention is made here of those aspects of ICRISAT's work in FSR which particularly impressed the Review Team:

First, the fact that a significant body of work has been completed, or is in progress after only five years and without permanent buildings, and during which time there appeared to have been only a modicum of formal program structure or flow charting compared to the other IARCs visited.

Second, the recognition that the problem of location specificity has to be met by concentrating IARC work in FSR on methodologies and principles adaptable by national agencies to local situations, complemented by IARC training activities.

Third, the use of Base Data Analysis in both the selection of benchmark village sites and -- especially from a methodological point of view--in the planning of research on farming systems.¹

Fourth, allied with both the emphasis on transferable methodologies and Base Data Analysis, the progress being made in adapting available computerized

¹ Specific reference is made to: Virmani, S.M. The Agricultural Climate of the Hyderabad Region in Relation to Crop Planning (A Sample Analysis), FSR Program, ICRISAT, Begumpet, 1975.

simulation models such as CSIRO's water balance/crop growth model (Watbal) to FSR Program needs via strong multidisciplinary cooperation.

Fifth, the multidisciplinary center-wide committee framework via which the selection of ICRISAT benchmark sites is proceeding in a very thorough fashion.

Sixth, the strong fruitful cooperative activities in both research and training that have been developed with Indian institutions, particularly the All India Coordinated Program on Dry Land Agriculture, the Indian Council of Agricultural Research and a number of universities.

Seventh, the enthusiastic approach to the local watershed as the basic key to improvement of farming systems in the SAT and the multidisciplinary use of the watersheds on ICRISAT for operational testing of system changes.

Eighth, within and across particular sub-programs and often also involving the Economics Program, work related to:

- (a) the measurement and meeting of risk in climate and yields;
- (b) the development of an animal-drawn multipurpose wheeled tool carrier suited to a variety of implements and cultivation practices;
- (c) contour bunding, showing it to give no substantial moisture conservation benefits;
- (d) the development and assessment of broad bed cultivation (and their directioning within the local watershed for run-off manipulation) which has shown broad beds to have quite significant promise for Vertisols of up to moderate slope;
- (e) the assessment of "steps in technology" as distinct from the "package" approach;
- (f) the ex ante appraisal of herbicide use in SAT India¹ taking account of both technical and socioeconomic effects which showed that despite technical advantages, herbicide use would be unprofitable at current and likely wage rates and would adversely affect the income of female laborers who are already one of the most disadvantaged rural groups -- thereby leading to emphasis on non-herbicide weed control in the FSR Program.

¹Binswanger, H.P. and Shetty, S.V.R., Economic Aspects of Weed Control in Semi-Arid Tropical Areas of India, Occasional Paper 13, ICRISAT, Begumpet, March 1977.

- (g) lastly, but certainly not least, the outstanding conceptualization and focusing of the cropping systems work, particularly in intercropping, on a small set of representative systems and the significant development of field methodology for multiple cropping research.

Ninth, the very significant contribution made by the Economics Program, both cooperatively with the FSR Program in research and to the center's management in the determination of priorities as, e.g., with tractor mechanization¹ and herbicide research. Mention has already been made of the village level studies (Section 5.1), the methodology of their selection and use, and their fruitful contribution. Most impressive also is the recent study of farmer attitudes to risk in the Indian SAT² which, in terms of its methodology, is an outstanding contribution. The results of this study, matched with cooperative studies of risks facing farmers in the SAT environment, should be most helpful in guiding and assessing farming system changes. Likewise, the study in progress on approaches to group action for the successful implementation of watershed-wide systems of farming involving multiples of farms is an excellent example of foresight in the recognition of system-wide interdependencies as is essential for the successful conduct of FSR.

7. Overview and Comments on FSR at ICRISAT

FSR at ICRISAT is obviously being conducted with enthusiasm and dedication, and in the five years since establishment of the center a quite substantial output of significant results has been generated. These results include not only SAT system components per se, but also methodologies and guidelines of significance to the conduct of FSR in general and at IARCs in particular. The more important of these have been noted above (particularly in Section 6) and are covered in more detail by the cited references. Suffice to say that the center's work in FSR appears fruitful and to well meet the directions appropriate to an IARC.

Given its favorable overall impression of the center's work in FSR, the Review Team offers the following comments as a basis for discussion and further program development.

- (1) ICRISAT's FSR Program is strong in Base Data Analysis and Research Station Studies but, except for the Economics Program's village level studies, is not yet as involved in On-Farm Studies as would be desirable. However, active steps are being taken to increase activity in this area.

¹ Binswanger, H.P. The Economics of Tractors in the Indiana Subcontinent, ICRISAT, Begumpet, October, 1977.

² Binswanger, H.P., Risk Attitudes of Rural Households in Semi-Arid Tropical India, ICRISAT, Begumpet, 1977, (preliminary draft).

(2) Though there were signs of progress, as evidence by the 1977 specification of program "activities", "components", "sub-program areas" and a leader, the Review Team was disappointed to find that except for the broadest of outlines, there appeared to be no clearcut organizational framework to the FSR Program. Likewise, and no doubt relatedly, there appeared to be no Program-wide programming or flowcharting of activities showing team responsibilities and time dependencies. The Team appreciates, however, that ICRISAT is the youngest of the four IARCs reviewed and has had less time to develop the most appropriate organizational structure for its FSR program. The Team suggests that the problem would be better exposed if there was a program-wide system of programming. In the belief that systems analysis by its multidisciplinary team nature requires more explicit organization and programming than traditional disciplinary research, the Review Team suggests that the FSR Program further consider the question of organizational structure and programming, and how these relate to the project system of research administration employed by the center.

(3) Related to the question of FSR organization is the location of economics. So far as the Review Team can judge, the Economics Program at ICRISAT has been very successful and its existence as a separate program has not hindered its contribution to FSR. In the ICRISAT context, therefore, the Review Team would not recommend upsetting the current organizational structure so as to locate economists within the FSR Program.

(4) Currently, the local watershed rather than the individual farm is seen as the focal key to implementation of ICRISAT's FSR output by national agencies. Whilst the importance of water and local watershed management in the SAT is indisputable, there would seem to be some difficulties with putting too much emphasis on the local watershed rather than the farm unit. Specifically, full implementation on a watershed basis involving a number of farms must overcome the problems of group action arising from questions of tenure, kinship relations, multiple parcels of land, existing structures, loss of independence, hereditary feuds, social caste, etc. The Review Team is pessimistic about such group action difficulties being overcome on any large scale. Accordingly it believes ICRISAT should be careful not to put all its eggs in the watershed basket. As well as ensuring that its watershed technology is divisible across farms in the watershed, additional focus should be given to the farm unit per se. Thus the Review Team would prefer a more even balance between the watershed and farm foci in the FSR Program.

(5) Amongst the objectives of the FSR sub-program areas, simulation modelling is often mentioned as a research procedure. While the Review Team sees the advantages and necessity in some areas for modelling, it believes this should largely be based on the adaptation of models developed elsewhere. It recommends that the construction of complex computer simulation models should not be undertaken de novo within the FSR Program.

(6) As already noted, the FSR sub-programs are a mixture of disciplinary and systems areas. The Review Team believes this set of sub-programs should be assessed for possible respecification. In particular, the Review Team gained the impression that the research being undertaken in the Environmental Physics sub-program, whilst good, was somewhat more akin to what might normally be done in a University or other national research institution, and that it was not as fully integrated to the FSR Program as might be possible.

(7) As yet, ICRISAT has no direct FSR work outside of the Indian sub-continent though some is planned for Africa in 1978. Within India, the modus operandi of cooperating with national agencies and developing methodologies and principles for their adaption of representative systems is progressing very well. However, extension of the FSR Program to other SAT regions will doubtless raise problems of principle as well as logistics. Nonetheless, the Review Team believes that ICRISAT should now begin to extend its FSR Program to West Africa and later Brazil. It approves the steps being taken to select benchmark sites in West Africa, probably one on Ustipsammet and one on Oxisol. It hopes, however, that such extension will not be at the expense of developing On-Farm Research in India so as to capitalize on and assess the progress already made in Research Station Studies.

(8) So far as the question of balance between disciplines and activities in the program is concerned, the Review Team has no comment beyond those made above regarding the watershed approach, environmental physics, computer modelling, On-Farm Studies and international expansion.

(9) The Review Team approves ICRISAT's approach of considering animals (draught stock to date) and non-mandate crops (such as sunflower and various legumes) in its FSR Program so long as they are relevant system activities.

ANNEX 5. FARMING SYSTEMS RESEARCH AT IRRI

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ANNEX 5. FARMING SYSTEMS RESEARCH AT IRRI

1. Objectives of IRRI's Cropping Systems Program¹

Research on cropping systems constitutes one of IRRI's major programs, second only to "Genetic Evaluation and Utilization" (GEU), and absorbing more than one-fifth of the Institute's budget.

The focus of the Cropping Systems Program (CSP) is on the "development of a cropping systems technology to increase cropping intensity on Asia's rice farms, making more efficient use of the available farm resources."

The overall objective of the CSP is:

"To increase food production in South and Southeast Asia through the identification of more productive rice-based cropping systems that are acceptable to typical rice farmers."²

Its specific objectives are:

"to develop research methodology in cropping systems involving rice and to extend that methodology to co-operative programs;

to develop and assemble specific multiple cropping technology for IRRI's target climatic zones;

to feedback appropriate information on basic and developmental research to concerned agencies;

at the national level, to encourage and assist national production programs in the target agro-climatic zones to achieve increased farm production through increased cropping intensity."

Given the limited scope to further increase land area under crops and for major yield advances beyond those now attainable with high inputs, more intensive cropping systems offer the main route to increased food production and the more efficient use of land, labor and capital resources. It is this consideration that has led to the rapid build-up of the cropping systems program at IRRI.

¹IRRI does not refer to its program as "Farming Systems Program," but prefers to call it the Cropping Systems Program. Earlier, it was called the Multiple Cropping Program.

²From briefing papers prepared for the TAC Review Team by the CSP staff.

2. History of the Cropping Systems Program

The program was begun at IRRI many years ago by Professor R. Bradfield, who developed techniques for fitting a variety of legumes and other crops between rice plantings, with the primary objectives of improved human nutrition and soil fertility maintenance. Bradfield's innovative experiments revealed the opportunities available for more intensive and diverse cropping.

After Dr. Bradfield's retirement, emphasis shifted somewhat from determining productivity of new or improved multiple cropping patterns to study of intensive cropping patterns on existing farms where rice was the basic crop. An economist was added to undertake economic studies of existing and improved cropping patterns. In 1974 the program was enlarged to provide a multidisciplinary team, and the Asian Cropping Systems Network began to be organized.

The CSP was the first FSR program at an IARC. It has pioneered in many aspects of FSR, and has been a leader in developing methodology and concepts for multidisciplinary research, notably in On-Farm Studies.

3. IRRI's Approach to FSR

The basic approach of the CSP is to develop improved, intensified cropping patterns on small Asian rice farms. The CSP concentrates on the rainfed lowland and upland rice areas of South and Southeast Asia, where there is potential for increasing the cropping intensity. In this regard, priority is given to areas where it may be possible to increase production during the crop season and increase the cropping intensity from one to two, or from two to three crops.

CSP concentrates on resource utilization on small rice farms. It focuses on crop enterprises of typical rice farmers, and considers physical, biological, and economic factors at farm level, and community factors as they influence the performance of cropping systems. The program depends upon description of the resources available for agriculture and their current use of existing cropping patterns and of economic factors. Efforts are placed both on generation of component technology for cropping patterns, and on farmer management of improved technology. Technology generation, to a large extent, involves both the commodity and disciplinary research programs relying on the FSP to provide the appropriate feedback.

In a large part of the presently single-crop rainfed rice areas, which constitute about half of all the rice grown, the wet season is probably long enough to support two crops of rice. Commonly, however, a single crop is transplanted rather late, and traditional long duration varieties are harvested at the end of the rainy season. Research at IRRI has shown that it is possible to harvest at least two crops of rice in these areas, particularly if the first is sown early in the season by direct seeding, and the second is transplanted after the first crop is harvested, often after zero tillage but

some herbicide treatment. To do this successfully has required some ingenious agronomic research, as well as availability of shorter duration varieties. So convincing are the demonstrations of the major increases in output already obtained in farmers' field by the adoption of these techniques, that the practice is rapidly spreading and the Philippine Department of Agriculture is expanding it on a considerable scale. Many aspects of these techniques require further study, however.

Rice-rice may be the most suitable cropping system on some heavy textured paddy soils, in some cases followed by a legume crop such as mung-bean. On lighter soils and in areas with a shorter wet season, the rice crop may be preceded or more commonly followed by maize, peanuts, cassava, and other crops. Apart from their nutritional advantages, such multiple crop systems are probably also beneficial in terms of fertility maintenance and control of weeds, pests and diseases.

Much cropping systems research must be site or environment specific. It requires detailed examination of the variations in soil and land levels over a farm, and of local climate and local socioeconomic considerations. It also includes a biological description to determine appropriate pest control measures. The extent to which such research can be generalized into the development of principles is one of the concerns of the CSP.

The research strategy of the CSP takes into account the fact that there is much to be learned from an analysis of the reasons for many traditional practices, and that the introduction of new crops, varieties, agronomic techniques and new equipment into an individual farm operation requires careful farm observations and testing. The importance of collaboration at the national level is therefore emphasized.

The cropping systems research methodology developed by IRRI in cooperation with national programs advocates the use of site-related research. This, however, takes a different form in the Philippines, because of the close proximity to IRRI, than in the other cooperating countries.

In Indonesia, Sri Lanka and Thailand, for example, the research process starts with site description followed by cropping pattern design and cropping pattern testing. All experimental work is conducted on farmers' fields and most of it is managed by farmers. The research teams at the sites are supported in aspects of research design, analysis and interpretation by experienced cropping systems researchers of national research institutions. The cooperation between the research team at the site and local extension workers is of great importance, particularly for the baseline survey, the selection of farmer cooperators, and the testing of cropping patterns. It should be stressed that the research team does not establish demonstrations. Rather, it seeks to involve farmers at an early stage in the generation of production methods for the area.

On the other hand, in the Philippines the sites are operated in cooperation with the Bureau of Plant Industry and the research teams are directly supported by IRRI staff. As a result the site research contains several aspects of methodology development that are not envisaged in the research sites operated by national programs in other countries.

4. Structure of the IRRI Cropping Systems Program

4.1 Staffing

The Program is organized as a research team comprising:

- (1) a group of three scientists constituted as the Cropping Systems Group within the Multiple Cropping Department; these three staff are respectively in charge of:
 - leadership of the Program and research work in agronomy,
 - outreach activities in the Philippines,
 - coordination of the Asian Cropping Systems Network,
 - a visiting post-doctoral scientist, temporarily assigned to this group, who is carrying out agro-climatic studies and environmental classification work.
- (2) Three scientists belonging respectively to the Agronomy (Weed science), Economics and Entomology Departments, are assigned to the CSP on a full-time basis.
- (3) A crop production specialist, in charge of the Rice Production Training and Applied Research Program, is practically fully attached to the CSP.
- (4) In addition, some other IRRI scientists (in agronomy and microbiology, for example) contribute a measurable part of their activities to CSP. While noticeable, the contributions of the Statistics Department and the Machinery Development Department are not reflected in the budget.
- (5) About forty Associate Scientists and Research Assistants work within the CSP. About twenty graduate students are attached to this program.
- (6) Three IRRI staff work on cooperative special projects in cropping systems outside the Philippines.

4.2 Program Components

The Cropping Systems Program research activity is composed of the following six program areas (responsible departments are listed in parenthesis¹).

¹ C.S. = Cropping Systems.

- Environmental classification (Multiple Cropping).
- Soil and crop management (Multiple Cropping).
- Weed management (C. S. Agronomy).
- Insect and disease management (C. S. Entomology).
- Cropping systems economics (C. S. Economics).
- Pre-production testing (C. S. Rice Production and Training Program).

Each of the above program areas contribute to the research steps of site description, cropping pattern design and cropping systems testing. Also, each program area works on bottlenecks which constrain cropping systems performance. Such problem solution work also contributes to generation of new component technology.

There are five basic program activities which are the responsibility of the CSP, viz:

- (1) Environmental classification (mainly physical and economic factors).
- (2) Cropping pattern design.
- (3) Cropping pattern testing.
- (4) Evaluation of alternative cropping patterns and management systems.
- (5) Network and Training.

4.3 Specific Objectives of Cropping Systems Program Areas and Activities

- (1) Environmental classification -

"to identify more accurately the relation of physical and socioeconomic environmental variables to cropping pattern performance and to use this information in further development of multiple cropping technology. This objective is pursued by the monitoring of the environment and cropping patterns. At times environmental conditions of particular interest may be induced."

(2) Cropping pattern design -

"to develop techniques for pre-testing evaluation of alternative cropping patterns and management systems. These systems will be evaluated using simulation models that employ results from research on environmental classification and cropping pattern design, as well as by field simulation through actual field trials."

(3) Technology generation -

"to intensify the research on identified management problems associated with basic cropping patterns that have a wide area of adaptation, such as rice-rice-rice; rice-rice (upland crop), rice-upland crop (-upland crop) and upland rice patterns.

(4) Cropping pattern testing -

"to perfect the on-farm research methodology and extend this methodology to include applied research so that cropping systems researchers can provide planners and extension programs with the three essential components of agricultural production technology:

- the technology itself;
- the domain of adaptation of this technology;
- the institutional requirements of this technology."

(5) Network and training -

"to continue the support of cropping systems research in national organizations in South and Southeast Asia. Through the Asian Cropping Systems Network, IRRI provides methodologies, training, information sharing, and varietal testing support."

4.4 Objectives of the Asian Cropping Systems Network

The site-related cropping systems research methodology is now applied on about twenty-five locations in seven countries of South and Southeast Asia. These locations form the Asian Cropping Systems Network. Its objectives are:

- to provide a mechanism for joint program planning and interview between the national programs of the region and IRRI;
- to provide a series of data points on the Asian agro-climatic grid for determining the cropping systems potential in major zones of the region;
- to develop cropping systems technology for the major rice growing regions in Asia;
- to enable IRRI to extend relevant methodology and technology into national programs;
- to provide a mechanism for long-term upgrading of national efforts.

The test sites should represent major agroclimatic zones of the rice growing areas of Asia. At least one test site will be selected from each major rice growing country.

4.5 Methodology in the Cropping Systems Program Activities

(1) Environmental classification

"The relation between physical and socioeconomic environmental variables and cropping pattern performance needs to be understood to enable better extrapolation of research results. This research involves the analysis of the cropping pattern performance as a function of environmental factors. The program is increasingly capable of identifying environmental complexes within which cropping pattern performance is essentially the same. This ability forms the basis for a more rapid extrapolation of research results obtained in any one of the sites of the network. Therefore, a continued substantial input in research that arrives at a classification for climatic, land, and socioeconomic factors that influence cropping pattern performance is foreseen. This classification must satisfy the following:

- (a) The measure of an environmental factor used must relate by identified mechanism in a quantifiable way to cropping pattern performance.
- (b) The measures used must, if at all possible, use existing information.
- (c) The classification should recognize several levels of generality or scale.

- (d) The classification should allow easy retrieval of the information from maps or indexed tables.

The method to arrive at this classification will include the following activities:

- (i) Identification of important determinants of cropping pattern performance from field tests under different natural (farmer's field) or induced (research station) environments.
- (ii) Quantification of pattern performance as a function of environmental factors from surveys and experiments.
- (iii) Tabulation and mapping of environmental factors in a manner that enables easy assessment of cropping pattern performance.
- (iv) Large scale mapping (1:2 million) and the elaboration of diagnostic keys for the identification of cropping pattern adaptation."

(2) Cropping pattern design

"The cropping systems program at IRRI has over time incorporated more and more concepts from systems analysis in the design and execution of its program. The number of environmental complexes in which cropping patterns are being studied, the number of crops and the disciplines involved in their study make it imperative to continuously evaluate the role of each of the research activities and their interactions. The establishment of a systematic framework for this research has already formalized decisions made in the areas of cropping system design and in the identification of research priorities. The program intends to continue with a more formal systems analysis of the research program itself viewing it as a unit responsible for the design and testing of cropping systems in relation to physical and socioeconomic environmental factors.

This analysis will lead to more productive partitioning of research tasks among program staff within a generally agreed upon program structure. It will also provide better understanding of the best sequence of research activities and the times at which results of program components need to be recombined. The analysis will also become the basis for a simulation program for cropping systems design which will generate the input of a second simulation program used to evaluate cropping systems performance. The latter simulation routine is already operational in an initial form. Further refinement of this routine requires definition of many of the technological coefficients related to crop performance. Given these coefficients, the routine will adequately evaluate the economic performance of the pattern under different weather and soil conditions. Both simulation programs will relate cropping systems design and performance to environmental factors. During their development, they will play an important role in identifying research needs and encouraging a multidisciplinary focus on a single problem area."

(3) Technology generation

"This research seeks alternative methods of land preparation (including the bunding and puddling of fields), water management at the field level, crop establishment, fertilization, weed and pest control and time and method of harvesting. The alternatives will be designed to solve clearly described "problem components" of important cropping patterns. The specifications to be satisfied by the alternative management practice is obtained from on-farm field measurements of the performance of the particular pattern under study and is tested in relation to well identified environmental complexes. Alternatives will be evaluated by small plot trials, field simulation trials, and survey methods.

Particular attention is given to crop establishment of the first crop in the monsoon season and of rice and upland crops after rice during and towards the end of the monsoon season respectively. The daily decision about water management at the field level, moving water from paddy to paddy or holding it at certain points along a paddy sequence can strongly affect possibilities and most appropriate methods for subsequent cropping. This subject is to be studied in depth at IRRI, where a simulated toposequence -- from upland fields to rainfed paddy on the side slope to hydromorphic paddy in the lowest part of the sequence -- was completed in 1976.

Already identified management bottlenecks include methods for establishing direct seeded rice (wet-and dry-seeded), with particular concentration on problems of weed management and untimely water accumulation on the paddies. The importance of identifying suitable methods of weed control in upland rice is being borne out by the labor (450 man/days/ha) presently channeled into that task. In addition to this, residual moisture utilization after paddy rice and its relation to tillage and seeding method requires further study. Methods of reducing turn-about times need to be studied. These include the reduction of harvesting and processing times (machinery); methods of rapid establishment of the second rice crop that require little tillage; and for rice-upland crop patterns, upland crop establishment under wet conditions (by shifting labor and cash used for land preparation into moisture conserving and weed controlling activities, e.g., mulching). Continuing identification of insect control techniques is required to enable the introduction of certain crops (particularly legumes) in the predator-rare lowland paddy environment just after rice cultivation. With the right techniques present rates of rainfall utilization (1.5 kg small grain/mm in most of the region) can be increased to 4 or 5 kg small grain/mm at the farm level. Continued efforts on the identification of varieties suited to these methods of crop establishment and to production during a rapidly tapering monsoon are required to increase resource utilization in the dryer agro-climatic regions. To do this the program will be moving towards closer monitoring of the environment and towards relating crop environment more closely to crop performance if need be by using crop performance simulation models."

(4) Cropping pattern testing

"An effective research methodology has been developed through interaction of the Asian Cropping Systems Working Group members among each other. The methodology will, however, require strengthening in the following areas:

(a) A method should be developed to describe environmental complexes in the field and use these subdivisions as a basis of experimental design and the interpretation of research results. The described environments for which a series of cropping patterns is designed should also form the basis for the applied research phase.

- (b) More efficient statistical designs for on-farm cropping pattern testing should be evaluated to better accommodate variations encountered in farmers' fields.
- (c) Data collection should be further streamlined so that baseline surveys, farm records and records for cropping pattern performance are designed in relation to the information required for clearly established criteria of cropping pattern and cropping systems performance. This will provide a closer link between data collection and the analytical and decision-making processes that follow.
- (d) Efficient methods for data handling should be designed. Particular attention needs to be given to the analysis of the research results by personnel at the site responsible for data collection and for the execution of future research. In addition, the scientific information coming from experiments at the site needs to be cumulatively recorded, organized and displayed in a manner that allows the planning of future research.
- (e) The field research methods should be adjusted to handle the measurement of impact of machinery introduction and changes in community level water management on cropping systems potentials.
- (f) Methods need to be designed for a more effective involvement of site personnel in program design.

The cropping systems program expects to give stronger emphasis to the definition of research methodologies. This will continue to be done with active participation of the working group members. Once agreed upon, the research methods will be published as a special report of the working group. The first such report was discussed in the September 1976 working group meeting and dealt with the measurement, analysis, and utilization of socioeconomic data in cropping systems research."

(5) Support of the Asian Cropping Systems Network

"IRRI's support of the network may gradually change its present form in response to the rapidly changing requirements of national programs active in cropping systems research. IRRI's cropping systems program seeks to structure its support of the network in such a way that, in the near future, staff from national programs will increase their participation in network support activities. These activities are:

- (a) The identification of research approaches and methodologies. Methodologies developed at IRRI or anywhere else in the network continue to be discussed and evaluated by the network working group sessions. Where suitable, these new methodologies will be applied in various research programs.
- (b) Training - the IRRI cropping systems program will continue to be the major source for training of cropping systems researchers and trainers. At the postgraduate level, this training will be done in coordination with the UPLB¹ program. Short-course training will continue to support national programs in the network, but the training of trainers will undergo certain changes to improve its efficiency and relevance to the home environment of the trainers.
- (c) Cooperative research between researchers from the network organizational and IRRI staff. The IRRI program will provide facilities for network researchers to complete specific studies related to their own research programs.
- (d) Much of the strength of the cropping systems network depends on its ability to efficiently share and pool the information obtained at different sites in the region. IRRI's cropping systems program will continue to encourage greater uniformity in data collection and data analysis at the network sites. This will be accomplished through the establishment of guidelines for these tasks by the cropping systems network group.

¹University of the Philippines, Los Baños.

The working group will also be encouraged to participate in project monitoring meetings at which research results and research programming for each of the sites will be discussed in detail.

- (e) The support of the network in the area of varietal testing has been based on a close cooperative effort between UPLB and IRRI. The varietal screening program at UPLB will hopefully expand in close cooperation with institutions that provide the basic genetic material, such as ICRISAT, IITA, AVRDC,¹ national programs in the regions and others. Because varietal screening in the Philippines in many cases does not satisfy the needs for regions in which cold temperature and daylight differences become important determinants of crop performance, a screening and distribution program similar to that established in the Los Banos may need to be considered in the future at a site north of the 17° latitude."

5. The Asian Cropping Systems Network (ACSN)

The ACSN is an important part of the CSP, for it provides a structure for cooperative efforts in design and testing of cropping systems production technology throughout the Asian Region. Three basic types of rice cropping patterns have been studied; these are:

- lowland irrigated rice area (Indonesia, Thailand and Bangladesh);
- lowland rainfed and partially irrigated rice area (Philippines, Indonesia, Bangladesh, Thailand and Sri Lanka);
- upland rice area (Philippines and Indonesia).

A number of crops have been included in the research. Most common are corn, sorghum, soybean, peanut, sweet potato, mungbean, cowpea, and cassava.

Methods used are those developed at IRRI or in the network itself; these are modified as necessary to meet the local conditions. Research in

¹Asian Vegetable Research and Development Center, Taiwan.

the network is conducted mostly in farmers' fields and the farmers do contribute to development of technology. Test sites are usually composed of two or more villages. The number of farmer cooperators per site varies according to the environment.

There are two types of farmer cooperators, "economic" and "agronomic". Economic cooperators are involved in farm record keeping, while agronomic cooperators are involved in biological research, mainly cropping pattern trials. Research on component technology factors such as weed control, village practices, fertilizers and pest management is carried out in the farmer's fields, either under the control of the farmer or by research workers from IRRI or national institutions.

A research team at each site is headed by a site coordinator. The research team is usually composed of an agronomist and an economist. The team lives near the site in order to supervise the research program on the farms.

One important factor in the success of the ACSN has been the formulation of a working group which has the following objectives:

- to develop general research plans,
- to review and evaluate research data from the test sites,
- to design research approaches and methodologies to be used in the network,
- to develop standardized methods and measurements,
- to assist IRRI in developing its research program.

The members of the working group are the program leaders from collaborating countries and IRRI, the network coordinator from IRRI, and selected scientists from outside the region. To date they have reviewed research data and plans for the following crop seasons, and the research methodologies to be used. In addition, they have developed:

- a conceptual framework for cropping systems research and development which has been adopted by national programs.
- a varietal testing scheme,
- plans for workshops and a symposium,
- a format for monitoring cropping pattern trials.

The ACSN provides a basis for programmed training of scientists from cooperating countries who are or will be assigned to positions in network programs.

Another important benefit of the ACSN is sharing of research information. The ACSN office at IRRI handles the multiplication and dissemination chores for sharing of relevant information.

6. Significant Achievements in FSR at IRRI

IRRI has been a pioneer in the multidisciplinary approach of FSR, and its contributions have been significant and numerous, too numerous to be recorded here in detail.

The Review Team would like to point out some of what it feels are especially noteworthy accomplishments of IRRI's CSP.

(i) The CSP has played a major role in stimulating interest in, and pointing out the importance of, multiple cropping and intercropping. There can be little doubt that the IRRI Program has helped to make research in intercropping and multiple cropping respectable and, in some cases, a major research activity.

(ii) The CSP has developed a sound basis for multidisciplinary research to assist small farmers.

(iii) IRRI has pioneered in developing methodologies for conducting FSR on small farms, both under farmer control and research control.

(iv) The CSP has led in developing methods and approaches to use of climatic and physical environment data in defining agro-climatic zones. Especially noteworthy are the rainfall pattern map of the Philippines¹ and the book on agro-climatic zones of Bangladesh.² In the opinion of the Review Team, the formation of the Asian Cropping Systems Network has been the most significant development in cooperative programs between an IARC and its constituent countries. The collegial, collaborative mode of the ACSN -- especially as regards program planning, development of methodology and program evaluation -- is a key factor in the success of the network. It should be pointed out that IRRI played the leading role in establishment of the network.

(v) CSP has developed important new approaches and methodologies to the development of component technology and to the development and testing of improved cropping systems.

¹IRRI, "Rainfall Patterns of the Philippines", IRRI, Los Baños, undated.

²Monala, E.B., Agro-Climatic Survey of Bangladesh, Bangladesh Rice Res. Inst. and IRRI, undated.

(vi) IRRI has developed and hosted workshops and symposia in cropping systems technology. These meetings and the CSP itself have generated significant information on cropping systems research and technology.

(vii) The IRRI training program has developed a core of cropping systems specialists in a number of Asian countries. These specialists are now engaged in conducting location-specific research in their own countries, and their results are being used to feed back into the IRRI program.

(viii) IRRI now carries out about 80 percent of its activities in FSR off-site. This is the highest percentage of off-site FSR of any IARC.

7. Overview and Comments on FSR at IRRI

FSR at IRRI is conducted with imagination and committed leadership. The program, a pioneering effort, has led in defining new concepts and approaches to FSR and in organizing FSR research. Much thought has gone into the development and execution of the program, and other FSR programs could benefit from a sharing of the IRRI experience and conceptual framework.

The Review Team was very impressed by the research work of the CSP and its focus. Clearly, the decision to concentrate on rainfed lowland and upland rice farms has been wise and has provided a clear focus for technology development. Also, the decision to concentrate on cropping systems, rather than farming systems, has probably helped to maintain a direct emphasis on rice and its associated crops.

IRRI has seen development of methodology as a major output of its program. In the opinion of the Review Team, this emphasis on methodology is appropriate and correct. The Review Team wishes to point out that other IARCs could benefit from the methodology development work at IRRI. Especially outstanding are the methodologies for On-Farm Studies in the Asian Cropping Systems Network.

The Review Team would like to point out that the CSP has had an interesting development history, as regards the types of activities. Originally the program concentrated on Research Station Studies (intensive multiple cropping research). Then, in order to understand more of systems used by the farmers, it initiated On-Farm Studies. Later, in order to define agroclimatic zones, CSP began to conduct Base Data Analysis.

The CSP is strong in On-Farm Studies and Research Station Studies, and has developed some capacity in certain aspects of Base Data Analysis where it has acquired temporary or part-time services in land capability evaluation and climatology.

The CSP program areas provide a logical basis for organization and conduct of multidisciplinary FSR activities. The organizational scheme is interesting in that it combines a permanent FSR department (Multiple Cropping) with staff members of disciplinary departments (Agronomy, Economics, Entomology) who are assigned to CSP. Leadership for CSP is provided by the head of the Multiple Cropping Department. The Review Team was impressed with the multidisciplinary structure of the CSP.

The Review Team highly commends the formation of the Asian Cropping Systems Network and the role which the CSP has played in its development. The ACSN provides a vital framework for cooperative research and a point of entry for IRRI technology to the cooperating countries. Also, it provides a mechanism for exchange of research information and feedback from farmers.

IRRI so far has not taken its CSP work outside of Asia. The Review Team wonders if the Institute will continue to focus on Asia, or if in the future it will decide to give more emphasis to other rice growing regions.

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THE CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

TECHNICAL ADVISORY COMMITTEE

FARMING SYSTEMS RESEARCH

AT THE

INTERNATIONAL AGRICULTURAL RESEARCH CENTERS

II - Proceedings of the Workshop on Farming Systems Research,
Nairobi, May 29-31, 1978

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I. INTRODUCTION

(i) Opening of the Workshop

1. The meeting was opened at 9.30 a.m. on Monday, 29th May 1978 at the newly established Conference Centre of ILRAD, Nairobi. Dr. A.T. Mosher was in the Chair. A list of participants is given in Annex 1.

2. Dr. P. Nderito, Associate Director, Administration, ILRAD, welcomed the participants on behalf of Dr. J. Henson, Director-General, who was on a mission overseas.

(ii) Background

3. Dr. R.W. Cummings, Chairman of the Technical Advisory Committee, in providing the background to this Workshop first reviewed the developments of the programmes of the IARCs in relation to farming systems research (FSR). He recalled that the older centres, IRRI and CIMMYT, had been essentially given the mandate to improve specific commodities. However, as their programmes developed and other IARCs were established with regional mandates, it was felt necessary for the CGIAR system to give increased attention to the problems of the adoption and combination of improved technologies within the broader context of farming systems. Also it was felt that emphasis should be placed on the problem of intensification of resource use, in particular under the conditions of the small farmer. Several IARCs had therefore been established with specific reference to farming systems research in their mandates in addition to their responsibility for selected commodities. More recently two IARCs had been established with mandates which have established systems concepts as the overall framework and purpose for their research programmes.

4. The CGIAR members had therefore expressed growing interest in these developments, but due to the diversity of IARCs' endeavours in this field, they had requested TAC to examine this question further.

5. TAC had been conducting quinquennial reviews of the individual IARCs. In addition, the CGIAR Review Committee requested that TAC undertake across-centre reviews (stripe analysis) of common facets of IARCs' programmes. The purpose of such analysis was to furnish TAC and the CGIAR with an overview of the activities of the CGIAR system in a certain field of research and to identify new needs and provide a basis for closer exchange and cooperation among centres.

6. Following a desk study by its Secretariat, TAC appointed in February 1977 a three-consultant team (the composition of the team is given in Annex 1) to review FSR activities at CIAT, IITA, ICRISAT and IRRI. The visit of the Review Team to CIAT and IITA was arranged to coincide with their quinquennial reviews in June 1977 and October-November 1977, respectively.

7. The draft report of the FSR Review Team was discussed by TAC at its 18th meeting in February 1978. The report was generally well received by the committee which recommended it for further consideration by an FSR Workshop with participants covering a wide range of FSR workers including representatives of all IARCs concerned and of national programmes.

8. The Chairman of TAC, concluding his introductory statement, commended the Review Team for the quality of their work.

9. The Executive Secretary, TAC, briefly described the next steps which were expected to be taken as a follow-up to the Workshop. He anticipated that the report of the Workshop would consist of a summary of the Consultant's report incorporating the conclusions and recommendations based on the discussions by the Workshop. The Workshop report, to which the Review Team report would be appended, would be submitted to TAC at its meeting in the following week. It was expected that IAC would then forward the two reports with its comments to the Consultative Group for its meeting in November 1978.

(iii) Adoption of the Workshop Agenda

10. The Chairman, introducing the discussion on the Workshop agenda, pointed to the wide range of activities in FSR carried out by the IARCs. He believed that apart from the crop improvement programmes, FSR activities at the IARCs could be classified generally under three major headings: (a) characterisation and delineation of agro-climatic zones; (b) resource management research, and (c) enterprise combinations research. In the former could be included base data collection and analysis which helped IARCs in planning their research, and in facilitating the dissemination of the new technologies they develop. The second aimed at finding better ways of managing soil, water and other resources to increase and sustain agricultural production, while the latter embraced such aspects as multiple cropping and also included livestock enterprises at the farm level. Within this framework different types of FSR activities could be listed, some of which involved on-station research and on-farm trials. These could be considered as intrinsically serving the purpose of FSR. Others were seen as having a more complementary nature related not only to FSR but also to crop improvement programmes.

11. Although appreciating the Chairman's attempt to provide a practicable agenda, the Workshop recognised the difficulty of categorising the activities of the IARCs within a detailed and fairly rigid matrix. It was decided however, to address this problem during the course of the Workshop under the relevant items of the agenda.

12. The Workshop adopted an agenda along the lines of the major topics dealt with by the Review Team in their report. These included the following:

- (1) Terminology in FSR
- (2) Goals, objectives and benefits of FSR
- (3) FSR methodology
- (4) Relations between IARCs and national programmes
- (5) Organisation of FSR
- (6) Training
- (7) Conclusions and recommendations.

13. In order to maximise participation by all present in the discussion of these agenda items, the Workshop split up into three groups which held simultaneous sessions. In addition, the Workshop appointed three special ad hoc committees: (1) to examine the detailed terminology in FSR; (2) to determine the goals, objectives and benefits of FSR; and (3) to draft the conclusions and recommendations. These groups and committees subsequently reported to the Workshop in its plenary sessions.

II. TERMINOLOGY IN FSR

14. The Workshop, after considering the report of the ad hoc Committee on FSR terminology, found that it was in general agreement with the views expressed, and the definitions proposed by the TAC FSR Review Team in its report (paragraphs 25 to 38).

15. The concepts and definitions given below relate to systems, systems analysis and systems approach, a farm, a farm (or farming) system, and farming systems research. In addition, a list of terms agreed on by the Workshop, in relation to crop production systems is given in Annex 2 of this report. The Workshop recommended that this terminology should not be considered as final but kept continually under review.

16. The Workshop recognised that there were a great many other definitions relating to the various types of agricultural production systems which differed both in scale and in the combination of activities and elements involved.

(i) Systems Terminology and Concepts

17. Conceptually, a system is defined as any set of elements or components that are interrelated and interact among themselves. Specification of a system implies a boundary delimiting the system from the environment with which it interacts. Two systems may share a common component or environment, and one system may be a subsystem of another.

18. Systems analysis or the systems approach refers to the holistic approach of studying the system as an entity made up of all its components and their interrelationships, together with relationships between the system and its environment. Such study may be undertaken by studying changes to the real system itself (e.g., via farmer-managed trials or by pre- versus post- adoption studies of new technology) but more generally is carried out via models (e.g., experiments, researcher- and/or farmer- managed on-farm trials, unit farms, linear programming and other mathematical simulations) which to varying degree simulate the real system.

19. The systems approach to research may be seen as complementary to the more traditional research approach involving a sequence of: (a) observation; (b) hypothesis development; (c) deductive prediction; and (d) hypothesis testing. This traditional approach is generally disciplinary focused and emphasises a positive stance of "understanding what is" so as to solve problems. In contrast, the systems approach is more oriented to the conditionally normative. It involves specifying a target and assessing alternative ways of reaching it. This implies both an expansion of knowledge (how to reach the target) and problem solving. (Reference is invited to paragraphs 31 and 32 of the TAC FSR Review Team's report for more details of the systems approach and analysis.)

20. As noted by the TAC FSR Review Team, while the above concepts, approaches and jargon drawn from generalised systems science are not essential in themselves to carrying out FSR in the applied research field, like all specialist scientific language they facilitate communication in research.

(ii) Farming Systems Terminology

21. Because the IARCs are concerned basically with agricultural production research, their focus must necessarily be towards farm systems as distinct from, e.g., social systems, political systems or ecosystems.

22. A farm is an organised decision making unit in which crop and/or live-stock production is carried out for the purpose of satisfying the farmer's goals. In doing so, the farm interacts with the physical, biological and socio-economic environment in which it has to operate, and may change in structure over time. Thus, the farm system may be described in systems terminology as a purposive, multi-goal, open, stochastic, (i.e. non-deterministic), dynamic system.

23. In this definition, the term "farmer" may mean more than one decision maker, that is, it may involve a decision-making group. Also it should be understood that the "farm" does not necessarily imply a distinct tract of land but may involve a nomadic form of organisation.

24. A farm system or whole-farm system (commonly referred to as a farming system¹) is not simply a collection of crops and animals to which one can apply this input or that and expect immediate results. Rather, it is a complicated interwoven mesh of soils, plants, animals, implements, workers, other inputs and environmental influences with the strands held and manipulated by a person called the farmer who, given his preferences and aspirations, attempts to produce output from the inputs and technology available to him. It is the farmer's awareness of his immediate environment, both natural and socioeconomic, that results in his farm system.

25. For purposes of description it is useful to group farming systems into classes of similar structure, e.g., crop production systems, grazing systems, etc. There are also a number of distinctive terms which are widely used to classify various types of crop production systems. The full list of terms and definitions agreed on by the Workshop is given in Annex 2 of this report.

(iii) Farming Systems Research Terminology

26. The term farming systems research is a generic term used to refer to any type of research which views the farm in a holistic manner. Thus it encompasses any research which might more specifically fall under the headings of research on crop systems, cropping systems, livestock systems or whole-farm systems. Farming systems research can be defined as research which:

- (1) is conducted with a recognition of a focus towards the interdependencies and interrelationships that exist among elements of the farm system, and between these elements and the farm environment;
- (2) is aimed at enhancing the efficiency of farming systems;

¹The term "farming system" narrowly used, specifies a class of farms, for example, bush fallow farm systems, maize - beef systems, etc. It is, however, often used in the broader sense and this usage should be adopted.

- (3) focuses on enhancing the relevancy of agricultural research;
- (4) facilitates the generation of innovations; and,
- (5) facilitates the testing of innovations for their applicability to the farm.

For these above purposes, which are further elaborated in Chapter III, FSR utilises such activities as:

- (a) base data collection and analysis;
- (b) the study of existing farming systems;
- (c) the design of farming systems;
- (d) farm systems experimentation; and,
- (e) the monitoring of farming systems.

27. The Workshop agreed with the recommendation of the Review Team that research on farm subsystems should be referred to more specifically, e.g., as livestock or crop system research. The term farming systems research could then be reserved to research on whole-farm systems. Further, as suggested by the Review Team, since crop systems, cropping systems and livestock systems can be regarded as components of whole-farm systems, research below the whole-farm level can be referred to as systems component research or simply component research. Of course, this includes research on such system elements as machinery, irrigation, management practices, etc. Accordingly, much of the research at an IARC - regardless of its parent programme - could be viewed as systems component research. This, however, would be too broad a view. Hence, in the context of an IARC's research programme, the Workshop supported the Review Team in the belief that it would be best not to regard research on individual components as systems research unless either (a) the research is focused on the interaction between the particular component and the other system components, or (b) it is undertaken specifically with a systems focus in view.

III. GOALS, OBJECTIVES AND BENEFITS OF FSR

(i) Rationale and Overall Objectives

28. The Workshop clearly recognized that the general goal of FSR is to generate technology on the management of limited resources that will improve farm productivity and, thereby, the socio-economic well-being of the farmer. The characteristics of FSR transcend those of conventional disciplinary research in that FSR, through multidisciplinary effort, seeks to:

- (1) understand better the problems and needs of the farmer;
- (2) improve the efficiency of the agricultural research process by focusing research on these problems and needs of the farmer so as to develop improved technology;
- (3) take into account both the interactions between technologies themselves and between technologies and the environment and thereby improve the appropriateness and relevance of the generated technologies;
- (4) ensure that these technologies contribute to the long-term maintenance and enhancement of agricultural productive capacity;
- (5) facilitate the linkages between research, extension, delivery systems and the farmer;
- (6) assist in the formulation of development policies and methods which address the problems of the farmer.

While developed countries devote relatively minor resources to farming systems research, it is essential that FSR assumes a particular role in developing countries for the following reasons:

- (a) There is an urgent need to increase agricultural production by enhancing the productivity of resources allocated to agriculture in developing countries.
- (b) There is need to improve the understanding of most research workers of the skills, preferences, aspirations and existing management practices of the farmer, in particular of small farmers.
- (c) The diversity of the natural conditions of production, particularly in the tropics, and often also the need to use available labour supplies by intensive land use, result in strong interactions among the elements of a farm system and this leads to very complex situations. The farm system approach greatly facilitates decision making under such circumstances.
- (d) Most of the farmers in developing countries do not have the power nor the means to identify and communicate their needs to research systems.

- (e) The array of agricultural services available to the farmers is limited. Additionally, many technologies made available to them are not adapted to their conditions and their needs.
- (f) There is a lack of personnel trained in the concepts and methodologies of FSR.
- (g) There is generally a wide gap between the results demonstrated at the research stations and those obtained by the farmer, and therefore a need to determine why certain practices shown to be highly productive in experimental stations are either not adopted or, if adopted, may not at times be equally productive in the farmer's field.

(ii) Specific Objectives

29. The Workshop recognised that an FSR programme may include any one or a combination of the following specific objectives:

- (1) to understand the resource context within which agricultural production takes place;
- (2) to evaluate existing farming systems operated by the farmers in specific physical and socio-economic environments, in particular the practice and performance of these systems, and to improve our understanding of the farmer, his skills, preferences and aspirations. These studies can be considered as essential baseline studies within benchmark situations. However, it is not expected that FSR programmes will understand and address all the problems related to all farming systems within their mandates;
- (3) to improve problem identification (target areas, bottlenecks, etc.) in existing farming systems and thereby to assist in focusing better the research activities and programmes of integrated rural development on specific key problems which limit production or farm income;
- (4) to enhance the capacity of research organisations to conduct research on priority farming systems problems so that they are better able to design new and/or improved production systems;
- (5) to conduct research on new or improved practices, principles, systems components or subsystems within an FSR context, and to evaluate these for possible testing on farms;
- (6) to evaluate new or improved practices, or system components, on farms in major production areas; and,
- (7) to assess the benefits of improved technology where baseline studies have been conducted, in order to obtain information on the impact of technology, especially on small farms, and identifying second or third generation problems by monitoring and continuing assessment, thus providing the necessary feedback to research institutes and policy makers.

In a given FSR programme, not all the above objectives which imply a full range of FSR would be likely to receive attention.

(iii) Benefits

30. The Workshop realized that the benefits expected from FSR could be many, but the major ones would appear to be as follows:

- (1) FSR can greatly assist in providing necessary information on the farmer and his problems, and provide a basis for understanding him, his production methods, or his needs.
- (2) FSR provides a structure within which researchers examine farm problems at a whole-farm level, and attempt to achieve solutions which will fit into that farm system and farmer's capabilities and needs. Most research in the past has been based on narrow disciplinary approaches, and integration and application of new information by the farmer on his farm have been difficult.
- (3) FSR provides a basis for analysis, synthesis and application of a consistent set of practices pertinent to production of a given commodity whether plant or animal, within a particular farm system.
- (4) FSR can provide a basis for developing improved technology and its transfer, because it recognises the need to understand the farmer and his system, to categorise the natural resource base on which the system operates, and to provide a basis for a research programme focused on major factors limiting performance of a given system. FSR should also assist in understanding and testing location specificity of certain practices.

Thus, by concentrating on crop and/or animal production systems, rather than discrete factors without regard to their interactions, FSR can be seen as providing an opportunity to study various crop mixtures, natural resource management practices, or other important components on a larger-scale basis and under conditions which allow more complete technical and economic analysis.

(iv) Difficulties and Problems

31. Although it was seen that FSR could bring considerable benefit as indicated above, there are a number of intrinsic difficulties and problems:

- (1) FSR is relatively new and methodologies are still being developed.
- (2) FSR generally requires large teams involving a wide range of disciplines which are difficult to coordinate and manage.
- (3) It is not easy to find research workers who are able and inclined to work in multi-disciplinary teams.

- (4) The collection, integration and interpretation of very diverse sets of data and information pose a number of problems.
- (5) FSR requires long-term commitments of resources to comprehensive programmes, the results and impact of which are difficult to evaluate.

In the light of these the Workshop stressed the need for FSR programmes to establish clear priorities and objectives and to focus their activities accordingly.

IV. FARMING SYSTEMS RESEARCH METHODOLOGY

32. The Workshop generally agreed with the conclusions and recommendations of the TAC Review Team with respect to FSR methodology as given in their draft report. However, the Workshop made a number of suggestions for the elaboration and clarification of several points and recommended some amendments and additions. A summary of the conclusions is presented below. Reference is invited to the Review Team's report for more details on the subject of FSR methodology (Chapter IV).

(i) A Methodological Framework for FSR

33. The Workshop concluded that FSR, whether carried out by IARCs, regional centres, or national programmes, be recognized as comprising three major types of activity areas which are generally conducted concurrently with joint interaction and feed-back efforts:

- (1) Base Data Analysis: involving the collection, compilation, and understanding of information related to the physical factors and natural resources, the biological and socio-economic environment, and inventory of present land use. The analysis of data should be conducted in a selective and purposeful manner to assist in the identification of potential target zones, selection of benchmark sites, and suitable locations for Research Station Studies and On-Farm Studies. Base Data Analysis provides a basis for identifying potentials, key constraints, and problems including those which require research or application of existing technologies. It should also provide a framework for later studies on monitoring and assessing the impact of new technologies.
- (2) Research Station Studies: These involve problem-oriented research to modify existing systems, design system components, and generate new technology. Besides conventional crop improvement programmes, which should benefit from an overall farming system approach, Research Station Studies in the field of farming system research may include two major interrelated categories of investigation: natural resources management research, and enterprise combinations research.
- (3) On Farm Studies: These involve (a) initially the study of existing farming systems as managed by the farmer which adds to the overall data collection and analysis referred to in (1) above, and (b) later evaluation of improved systems at the farm level with varying degrees of supervision by research workers. Follow-up survey and studies of farming systems and monitoring of ongoing development projects involving new packages of technology should be conducted on a continuing basis since these provide effective feedback for determining research effectiveness and priorities. The above studies should, whenever possible, be conducted in full cooperation with extension personnel so that the necessary dialogue between researchers and extension workers can take place.

34. The Workshop, while recognising the general value of the above methodological framework for FSR both at international and national level, stressed that methodologies in FSR were far from being firmly established and would require further improvement in the three activity areas listed above. More exchange of information was required on methodological advances between IARCs and national programmes. It was felt, however, that the IARCs should not concentrate their efforts on the development of methodologies only, but rather continue to develop appropriate technologies which may have significant impact in improving existing farming systems. Nevertheless, the Workshop was strongly of the opinion that the IARCs seek ways and means of publishing and disseminating information on their methodologies to a wider audience. IARCs also should continue to enlist the assistance of universities and visiting scientists to bring solutions to some specific methodological problems, such as the design of experiments in multiple cropping and the interpretation of data from these.

35. The Workshop appreciated the fact that the relative importance of the three categories of activities noted above was expected to change with time. Some activities were of a more permanent nature while others could be considered as temporary. For example, within Base Data Analysis, the identification of major climatic zones and soil areas was essentially a one-time operation, required when an FSR programme was being established. On the contrary, socio-economic data at both macro and micro levels would require continual updating.

36. Similarly some basic Research Station Studies assessing the major constraints of farming systems in a given region, as for example, the maintenance of soil fertility in the tropics, would be considered as almost permanent and continuing undertakings, whereas some technological improvements in resource management practices might only need to be studied for a more limited time.

37. On-Farm Studies were considered as a most important facet of FSR. It was recognised that while most national programmes had established Research Station Studies, the On-Farm Studies were often neglected for lack of methodology and lack of adequately trained personnel. IARCs contribution in these fields was considered essential.

38. The Workshop generally recognised the inadequacy of data available on the physical and socio-economic environments and on the existing farming systems. It acknowledged that a considerable amount of data was available at national and international level on soils, climate, production factors, etc., although records were often incomplete. The major problem was due to the fact that data had not been collected to serve the objectives and requirements of FSR, and that methodologies to use existing data to assist FSR have not been developed and refined. There was therefore a need for additional surveys specially conducted for the purposes of FSR.

39. Reference was made also to the possibility of IARCs contracting out some of the survey work and base data collection required for their programmes. The role of other international institutions was stressed in this context, and the need was recognised to reduce overlaps and to achieve maximum complementarity in the ongoing works of IARCs, national programmes and international institutions in Base Data Analysis and surveys of existing farming systems.

V. RELATIONS BETWEEN IARCS AND NATIONAL PROGRAMMES

40. The Workshop generally agreed with the views expressed in the Review Team's report on the cooperation between IARCs and national programmes in the field of FSR. It was felt necessary, however, to address this important subject in more detail, in particular by stressing the role of national programmes. After discussions in working groups, the Workshop reached the following conclusions:

(i) Scope of Cooperation

41. The cooperation between IARCs and national programmes was seen as a two-way process aimed at ensuring the relevance of the FSR work of IARCs to the problems faced by the majority of national programmes. The Workshop recognised that any cooperation should be based on full reciprocity taking into account the activities of IARCs and the stage of development of national programmes.

Cooperative activities would mainly cover the following areas:

- (a) data collection and interpretation, information exchange;
- (b) priority setting and planning of FSR;
- (c) adaptation and introduction of new technology within existing farming systems;
- (d) development and introduction of new farming systems; and,
- (e) training.

42. Concentrating FSR at international and regional levels on problems of general interest and critical subject sectors unlikely otherwise to be covered adequately by national research facilities, should lead to maximum complementarity of international, regional, and national efforts. The cooperation should be established on an equal partnership basis and establish communication and dialogue so as to, for example:

- (1) thresh out relevant concepts and terms;
- (2) understand and criticise one another's programmes in all their dimensions of research, training and cooperative activities;
- (3) gain an appreciation of alternative forms of organisation and planning;
- (4) facilitate the joint development of methodology; and,
- (5) provide a professional forum for FSR oriented to small farm systems where the more burning questions such as benchmark site selection procedures, criteria for choosing representative systems, and multiple cropping research designs may be argued.

43. The Workshop agreed that within the cooperative framework, IARCs would be expected to contribute towards the establishment of general principles, basic knowledge and methodologies in FSR and to develop technologies of wide applicability. It was recognised that there were considerable benefits to be gained from cooperative efforts between national programmes and IARCs, and that their respective roles in FSR could be complementary. For example, national programmes, in addition to meeting their own objectives, could play an important role in an "upstream" sense for the IARCs by identifying priority problems and by suggesting needed improvements in methodology or other outputs of FSR. In some cases national programmes might also wish to involve IARCs in some "downstream" activities, especially in on-farm studies, development of methodology, and in location-specific research.

44. In general, it was clearly seen that IARCs would not be able to meet all the demands of the many countries which might wish to cooperate with them in the field of FSR. While IARCs could assist a wide range of countries in such aspects as information exchange and training in the field of FSR, the complexity of this type of research necessarily limited the scope of cooperation to selected countries. In many cases, however, the centres would at least be able to identify and mobilize sources of funding and technical assistance which could contribute towards strengthening national research in this field.

45. The Workshop held the view that active cooperation in development of methodology was warranted in the first years of the establishment of FSR at an IARC, even though the centre might have no defined programme to offer national institutions. At this stage, it was the IARC which could benefit most from the cooperation with national programmes, particularly insofar as helping set the research priorities of an IARC's FSR programme.

46. In general, it was considered that cooperation in on-farm surveys and village level studies, as well as in related training activities, might be considered as a suitable starting point for cooperation between national programmes and an IARC in the field of FSR.

47. As early as possible in the cooperation, national programmes should take major responsibilities in data collection and on-farm trials. In addition as national FSR programmes strengthened and yielded results, training should increasingly be conducted by national institutions.

48. The Workshop clearly recognised, however, that the scope of cooperation would very much depend on the stage of development of the national FSR programme. Whereas some countries might well be ahead of IARCs in this field, others had no FSR as yet. In some areas of interaction with national programmes, IARCs would need to exercise prudence, especially on politically sensitive issues which might arise when assisting in socio-economic surveys and in monitoring national development programmes.

(ii) Modes of Cooperation

49. The Workshop acknowledged that the modes of cooperation between IARCs and national programmes in this field were necessarily varied. The simplest and often most effective mode of cooperation, as a first step before establishing formal agreements, was between individual scientists in IARCs and in national

programmes, who were engaged in common areas of interest of FSR. The follow-up and back-stopping of former trainees by IARC personnel was one important aspect of this type of cooperation.

50. Another mode of cooperation was for the IARC to outpost FSR scientists to work in national programmes, share their problems, assist in the planning and implementation of FSR activities, and provide a link and feedback facility for the FSR programme at the headquarters of the IARC. These outposted staff would also play a useful role in identifying candidates for fellowships and training courses at the IARC, and providing in-service training themselves by working with and within a national programme.

51. Several IARCs were developing their cooperation with national programmes by establishing relay stations at certain benchmark locations for tackling problems which were specific to certain groups of countries. Such relay stations might also serve as focal points for establishing programmes of cooperation between interested countries.

52. Another formula was the development of regional programmes which played a similar role in stimulating cooperation but in this case between several countries and the IARC. Usually, however, there was no regional base or focal point (e.g. relay station) for this cooperation. Such regional programmes were called "networks" when several countries agree to conduct jointly, a series of investigations with common objectives and methodologies. Of course, cooperation within a network would be limited by the possible differences in the stages of development of national FSR programmes and in the diversity of their problems. When common problems had been identified, networks in FSR could be an effective means of developing methodologies.

53. It was agreed that the location specificity of most FSR would be to some extent, a limitation to the possibilities of establishing regional cooperation in this field, and most national programmes would prefer to establish bilateral arrangements with each IARC for specific purposes and needs.

54. The Workshop concluded that, in general, cooperation between an IARC and a national programme in FSR would usually be with institutions designated by the government for such cooperation. IARCs might play an important role in facilitating the contributions of several institutions to the national FSR programme, in particular the contribution of universities to agricultural research. However, contacts with other institutions, development agencies, universities, etc., should be made by the IARC through the national agricultural research institution.

(iii) Inter-IARC Cooperation Relative to National Programmes

55. Several examples were given during the Workshop of the procedures whereby several IARCs might work together with a national programme. IARCs had established joint offices in some countries. Some on-farm surveys and on-farm studies had been conducted by a national programme jointly with two or more centres. Several centres might, for example, establish common research protocols, or survey questionnaires and training programmes at national level could involve personnel from several centres. All these arrangements were aimed at avoiding duplication or conflict of objectives in the cooperation of IARCs with a national programme.

56. The responsibility for requesting and coordinating contributions of several IARCs to a national programme obviously would lie with the government institution responsible for agricultural research in the country. Some countries had established a focal point unit to deal with the cooperation with IARCs and, in particular, with their participation in several cooperative networks.

57. In addition to these arrangements, the Workshop believed that inter-IARC cooperation should be fostered by consultations between the senior staff of the IARCs and agreements between their Directors General. Considerable flexibility should be maintained in this regard. However, in principle, an IARC should avoid engaging in cooperative activities in a country where another was already working without prior consultation so as to avoid confusion and competition. It was suggested that the annual Centre Directors' meetings could provide opportunities for these consultations.

58. Further to the above, the Workshop recommended that cooperative agreements and arrangements should also be developed between IARCs and other international and regional institutions which were involved in FSR, and rural development in general, at national level, such as for example FAO, World Bank and CATIE.

VI. ORGANISATION OF FSR AT THE IARCS

59. The Workshop recognised that FSR at the IARCS was organised in quite diverse structures which reflected both differences in the mandates and in the historical development of the centres. The Workshop supported the views of the Review Team in that there was no perfect structure of FSR. It also agreed that, in general, several essential ingredients were necessary for proper organisation and functioning of FSR such as:

- (a) an identifiable staff and programme structure operated in such a way as to facilitate multidisciplinary research;
- (b) capacity for skilled disciplinary research within the multidisciplinary framework;
- (c) adequate recognition for scientists participating in the collaborative programme;
- (d) opportunity for peer review, professional publication (outside of house media and conference proceedings) and career development advice from other centre staff in the same discipline for those specialists assigned directly to FSR programmes; and
- (e) flexibility in staffing so that current activity requirements tended to determine staffing rather than the reverse.

The Workshop, while agreeing generally with the conceptual methodological framework proposed by the review team, stressed that this framework should not be meant as suggesting a common structure and organisation for all FSR at the IARCS. The major categories of substantive activities presented in the introduction also would not lend themselves to providing a common organisation or programmatic framework for all IARCS. These classifications were seen rather as a means of referring ongoing programmes and existing structures to a wider matrix which encompassed a whole range of FSR activities which might not necessarily be undertaken and organised by all IARCS in the same way.

60. The difficulty of organising and managing FSR programmes was generally recognised. Capacity of leadership and the goodwill of research personnel to work in interdisciplinary teams, and to contribute to several research projects concurrently, were seen as more important than the organisational structures themselves in achieving the objectives of FSR. The multiple objectives and avenues of FSR in increasing productivity would make it more difficult for an IARC to organise FSR than it would to organise crop improvement programmes which were focusing on the basic objective of producing improved seed material.

61. A minimum requirement for staffing an FSR programme was to establish a team with capability in base data analysis, resource management and agricultural production. Understanding of interdisciplinary work, capacity for coordination, and leadership, were considered important criteria in selecting the leader of an FSR programme.

62. Participants in the Workshop generally agreed that IARCs should further exchange experience in the organisation and conduct of FSR programmes. While there might be advantages for CGIAR and TAC members to have the FSR programmes of the centres presented with similar formats, it was stressed that it would be most impractical and perhaps detrimental to the commonly accepted need for diversity in IARCs' endeavours. In fact, the diversity of the organisation and programme structures reflected the differences in the problems addressed by the centres.

63. It was expected, however, that the progress made at this Workshop in developing a common understanding in terminology and methodology would assist CGIAR members and TAC in having an overview of the total effort of IARCs in this field and facilitate communication between them and the centres, and among centres themselves, as indicated in the objectives set for stripe analysis. Mention was also made of the experience gained in national programmes in this respect and it was suggested that this be also taken into account in furthering the organisation and structure of FSR at the IARCs.

64. Reference is invited to the recommendation of the Workshop (Chapter VIII, paragraph 83) with regard to organisation of FSR. This is in agreement with that made by the TAC FSR Review Team.

VII. TRAINING

65. The Workshop generally agreed with the views expressed by the Review Team stressing the growing importance which training should take in FSR at the IARCs. Several representatives of national programmes emphasised the magnitude of their country needs in the field of training personnel in FSR.

66. FSR being a relatively new field of activity at the IARCs, it was clear that centres were still developing their training strategies and programmes in this area. Several centres were actually only starting their FSR training programmes and concentrating their main effort on training their own personnel. Such programmes would have the benefit of inculcating an appreciation and awareness of the importance of the FSR approach.

67. But it was not clear as yet how training in FSR could be best achieved, i.e. whether at national level or at the IARCs. In fact, most of the training provided by the IARCs in FSR was concentrating on systems component research, and on training of research personnel as future collaborators. There was a broader demand for training national FSR workers in aspects which may go beyond the most immediate requirements of the cooperative programmes of the IARCs, and several centres were attempting to meet this broader demand in countries where there was no established structure and programme for FSR to make use of, and employ personnel trained in this field. Moreover, as for other fields of research, the present policies of the IARCs of concentrating their training efforts in areas where they have a comparative advantage were considered as basically sound.

68. There was general agreement that IARCs be requested to develop training programmes in FSR which accommodated both the three basic activity areas and research advances, but that it would be difficult to develop all aspects of such a training programme concurrently.

69. The Workshop recognised that other categories of personnel (decision makers, project development managers, extension workers) would benefit from an exposure to FSR, and some centres were devoting attention to this demand by organising seminars, workshops and study tours for these categories of national personnel, so as to give them a better understanding of farming system approaches and research methodologies.

70. Participants described the different types and categories of training in FSR, ranging from training of field personnel involved in data collection, to the training of research workers in selecting priorities, designing and organising FSR programmes, and interpreting research results.

71. The Workshop concluded that IARCs should concentrate on training highly qualified personnel who could conduct training in their own countries, although recognising there was also a need for IARCs to assist in the training of personnel not so highly qualified.

VIII. CONCLUSIONS AND RECOMMENDATIONS

72. Except for some minor modifications, the Workshop endorsed the conclusions and recommendations as set out in Chapter VII of the report of the TAC FSR Review Team. These modifications are incorporated into the recommendations of the Workshop as given below. Other recommendations of the Review Team not referred to below were also endorsed by the Workshop.

73. The Workshop hoped that the body of the Review Team's report would be made freely available to all those involved or interested in FSR.

(i) Terminology in FSR

74. Reference is invited to the definitions of single and multiple cropping in Annex 2. The Workshop draws attention to workers in FSR to the use of this terminology in cropping systems. However, it recommends that this terminology should not be considered as final but be kept continually under review. The Workshop further recommends that a document containing this basic terminology be provided to all users and updated as necessary, particularly to include definitions of livestock production and other systems.

(ii) IARC Involvement in FSR

75. The Workshop is convinced that FSR is both a valid and essential activity for the IARC system. In line with established policies, FSR at the IARCs involves critical subject matters not likely to be otherwise covered, is complementary to national activities, and is concerned with both important food commodities and small farmers in developing countries. FSR will tend to become increasingly important as the basis of IARC research. Concurrently, as this occurs, crop improvement will depend increasingly on FSR both as a guide to desired genetic manipulation and as a necessary complement in achieving farmer adoption.

76. The Workshop recommends that all commodity/regionally oriented IARCs, that is all except ILRAD, should have a clearly recognised orientation to, and/or programme in FSR. Such work, however, should emphasise the on-farm aspects of farming systems in the sense of being primarily oriented to agricultural (including economic) research. The focus should not be broadened to include rural development activities.

(iii) Role of FSR in IARCs

77. The Workshop believes that FSR has an important role both in a downstream sense (link in the research chain taking information gained from the experimental programme and finding a place for it in the farmer's production system) and in an upstream sense (for recognition of constraints and in problem identification and analysis).

78. The Workshop recommends that IARCs crop and/or livestock improvement programmes be closely linked with FSR activities.

(iv) Limits of FSR in IARCs

79. The Workshop recommends that because of their nature IARCs should, so far as possible, limit their concern to FSR activities yielding results (technologies and methodologies) which:

- (a) can be generalised or extrapolated (and are therefore related more to principles and methods rather than to location-specific practices);
- (b) are oriented to specific commodity or resource mandates; and,
- (c) have potential for wide impact.

(v) FSR in Relation to IARC Programme Strategy and Planning

80. The Workshop recommends that overall IARC programme strategy recognise FSR as a highly complementary activity to crop/livestock improvement, particularly in providing a research capability to guide the development and integration of new technology. Implementation of this recommendation can take a somewhat different form in each of the IARCs depending on the centre's mandate. Further, if advances in genetic improvement become more difficult to achieve, FSR can play an increasing role in guiding a centre's research priorities and recognition of research opportunities. It also recommends that the broad strategy for FSR in the IARCs should involve:

- (a) maximum use of existing secondary or historical data;
- (b) study and evaluation of existing farming systems delineated on a purposeful basis;
- (c) postulation, synthesis, investigation and evaluation of improved farming systems and components;
- (d) purposeful limitation of the number of farming systems to be researched since no centre could consider all systems pertinent to its mandate.

In the carrying out of such a strategy, the Workshop further recommends that FSR involve the basic activities of base data collection and analysis, on-farm studies, on-station research, on-farm evaluation and feedback.

(vi) IARCs in Relation to FSR Methodology

81. FSR, with its holistic, multidisciplinary team approach derived from systems analysis, is a relatively new approach to agricultural research. Particularly in terms of small farmer systems (usually involving multiple cropping and of special concern to IARCs), there has not yet been developed a consistent body of methodology. The IARC system has the capacity to develop the required body of methodology. National programmes, because of their direct involvement with and responsibilities to farmers in specific locations, have a very strong need for FSR methodology so as to facilitate their research and the eventual acceptance by farmers of improved farming systems.

82. The Workshop, therefore, recommends that the development of FSR methodology be recognised as having major importance in an IARC's FSR programme. It also recommends that the IARCs exercise caution in the type of computer modelling they use and their degree of commitment to model development, particularly in the early stages.

(vii) Organisation of FSR

83. The Workshop recommends that FSR, whether as a separate programme or as an overriding philosophy to an IARC's total programme, be organised so that there will be:

- (a) an identifiable staff and programme structure operated in such a way as to facilitate multidisciplinary team research;
- (b) capacity for skilled disciplinary research within an interdisciplinary framework;
- (c) adequate recognition for scientists participating in the collaborative programme;
- (d) opportunity for career development by participating scientists;
- (e) flexibility in staffing as necessitated by programme development.

(viii) Staffing Policy for FSR

84. The Workshop recommends that the staffing of FSR teams be flexible in the sense of staff joining and leaving the team as dictated by programme development and requirements.

(ix) Disciplinary Balance in FSR

85. FSR must be multidisciplinary. The balance of disciplines, however, will vary with the stage of programme development and the consequent balance between basic activities. The Workshop recommends that in FSR relevant to crop production, agronomy and production, economics are essential at all stages.

(x) Balance between On and Off-Station Work in FSR

86. Like the balance of disciplines, the relative need for on- and off-station work will vary according to the stage of FSR development. The Workshop recommends that, as dictated by programme needs, more emphasis be given to off-station work.

87. It further recommends that in off-station experimentation particular care be taken to ensure that the research is purposive relative to overall FSR programme needs.

(xi) Relations with National Programmes

88. National programmes constitute the link between IARC work in FSR and the farmer. Cooperation between IARCs and national programmes is therefore crucial to IARC success in FSR. The Workshop recommends that cooperation with national programmes should always be pursued on joint partnership terms within the relevant mandate context. The mode of cooperation may include, first, a series of bilateral arrangements and, second, a series of activities arranged on a network basis, as deemed appropriate.

(xii) Training

89. The Workshop recommends that training programmes at the IARCs contain a strong element of FSR. It further recommends that the commodity training programmes include consideration of farming system concepts.

(xiii) Cooperation with Other International/Regional Institutions

90. The Workshop recommends that, whenever appropriate, cooperative arrangements and agreements be developed between IARCs and other international and regional institutions which are involved in FSR and rural development, in general, at the national level.

LIST OF PARTICIPANTS

Dr. H.O. Ademehin

Research Fellow

Institute of Agricultural Research and Training

University of Ife

P.M.B. 5029

Ibadan, Negeria

Dr. D.R. Bhumbla

Deputy Director General

Indian Council of Agricultural Research

Ministry of Agriculture & Irrigation

Krishi Bhavan, Dr. Rajendra Prasad Road

New Delhi, India

Dr. A. Blumenschein¹

Executive Director

Empresa Brasileira de Pesquisa

Agropecuaria

Palacio do Desenvolvimento

9º Andar

Brasilia-DF 70 000, Brasil

Dr. N.C. Brady

Director General

International Rice Research Institute (IRRI)

P.O. Box 933

Manila, Philippines

Dr. Ahmed Burhan

Director General

Agricultural Research Corporation

Wad Medani, Sudan

Dr. V.R. Carangal

Croppings Systems Network Coordinator

International Rice Research Institute (IRRI)

P.O. Box 933

Manila, Philippines

Dr. M.P. Collinson

Economist

International Maize and Wheat Improvement Centre (CIMMYT)

P.O. Box 25171

Nairobi, Kenya

¹Dr. Blumenschein attended the last day of the Workshop as a replacement for Dr. Palma Valderrama.

Dr. J.K. Coulter
Scientific Adviser
CGIAR Secretariat
The World Bank
1818 I Street, Northwest
Washington, D.C. 20433
U.S.A.

Dr. R.W. Cummings (Chairman, TAC)
North Carolina State University
P.O. Box 5428
Raleigh, N.C. 27607
U.S.A.

Dr. H.S. Darling
Director General
International Centre for Agricultural Research
in the Dry Areas (ICARDA)
P.O. Box 114/5055
Beirut, Lebanon

Dr. C. de Haan
Senior Animal Husbandman
International Livestock Centre for Africa (ILCA)
P.O. Box 5689
Addis Ababa, Ethiopia

Professor John L. Dillon (FSR Review Team Leader)
Department of Agricultural Economics and Business Management
University of New England
Armidale, N.S.W. 2351
Australia

Dr. D. Franklin
Leader, CIAT Biometrics Group
c/o Box 5368
North Carolina State University
Raleigh, N.C. 27607
U.S.A.

Dr. J.C. Flinn
Economist
Leader Farming Systems Programme
International Institute of Tropical Agriculture (IITA)
Oyo Road P.O. Box 5320
Ibadan, Nigeria

Dr. Astolfo Fumagalli
Deputy General Manager
Instituto de Ciencia y Tecnologia Agricolas (ICTA)
5a, Av. 12-31, Zona 9
Edificio "El Cortez", 20 y 3er Niveles
Guatemala City, Guatemala

Dr. D. Gibbon
International Centre for Agricultural Research
in the Dry Areas (ICARDA)
P.O. Box 5466
Aleppo, Syria

Dr. Arturo Gomez
Philippine Council for Agricultural and
Resources Research (PCARR)
College, Los Banos, Laguna
Philippines

Dr. B. Gora
C.N.R.A. de Bambey
Senegal, W. Africa

Dr. H. Hanson
Director General
The International Maize and Wheat Improvement
Centre (CIMMYT)
P.O. Box 25171
Nairobi, Kenya

Dr. A.B. Joshi (TAC member)
Vice-Chancellor
Mahatma Phule Agricultural University
Rahuri-413 722, Dist. Ahmednagar
Maharashtra State, India

Dr. J.S. Kanwar
Associate Director
International Crops Research Institute for the Semi-Arid
Tropics (ICRISAT)
1-11-256, Begumpet
Hyderabad 16, India

Dr. Raul Moreno
Centro Agronomico Tropical de Investigacion
y Ensenanza (CATIE)
Turrialba
Costa Rica

Dr. A.T. Mosher (Workshop Chairman)
Interim President
Agricultural Development Council Inc. (A/D/C)
1290 Avenue of the Americas
New York, NY 10019
USA

Dr. Hector Munoz
Centro Agronomico Tropical de Investigacion
y Ensenanza (CATIE)
Turrialba
Costa Rica

Mr. S.N. Muturi
Science Secretary
National Council for Science and Technology
P.O. Box 30623
Nairobi, Kenya

Dr. J.L. Nickel
Director General
International Centre for Tropical Agriculture (CIAT)
Apartado Aereo 67-13
Cali, Valle
Colombia

Dr. B.N. Okigbo
Deputy Director General
International Institute of Tropical Agriculture (IITA)
Oyo Road P.O. Box 5320
Ibadan, Nigeria

Professor Donald L. Plucknett (FSR Review Team)
Department of Agronomy and Soil Science
College of Tropical Agriculture
University of Hawaii
3190 Maile Way
Honolulu, Hawaii 96822

Dr. R. Rowe
Head, Breeding and Genetic Department
International Potato Centre (CIP)
Apartado 5969
Lima, Peru

Dr. H. Ruthenberg
FSR Consultant
c/o ILCA
P.O. Box 47098
Nairobi, Kenya

Dr. J.C. Ryan
Economist
Economics Program
International Crops Research Institute for the
Semi-Arid Tropics (ICRISAT)
1-11-256 Begumpet
Hyderabad, India

Dr. S.V.S. Shastry

Director of Research
International Institute of Tropical Agriculture (IITA)
Oyo Road P.O. Box 5320
Ibadan, Nigeria

Dr. C.C. Thomsen (TAC member)

Professor in Agricultural Policy
Royal Veterinary and Agricultural University
Thorvaldsenvej 40
DK-1871 Copenhagen V, Denmark

Dr. Guy Vallaeys (FSR Review Team)

Deputy Director General
Institut de Recherches Agronomiques
Tropicales et cultures vivrieres
110, rue de l'Universite
75340 Paris, France

Dr. S.M. Virmani

Agroclimatologist
International Crops Research Institute for the
Semi-Arid Tropics (ICRISAT)
1-11-256 Begumpet
Hyderabad 16, India

Dr. H.G. Zandstra

Agronomist
Multiple Cropping Systems Programme
International Rice Research Institute (IRRI)
P.O. Box 933
Manila, Philippines

Observers

Dr. Floyd Williams

Associate Director Research
Office of Agriculture
Bureau for Technical Assistance
Agency for International Development
Washington, D.C.

Mr. N.R. Carpenter

Chief, Farm Management Unit
Agricultural Services Division (AGS)
FAO
Rome, Italy

Ir. H. Toxopeus

Secr, Farming Systems Group
S.V.P. "de Haaf"
Wageningen, The Netherlands

Secretariat

Mr. P.J. Mahler

Executive Secretary, TAC
FAO
Rome

Dr. E.Z. Arlidge

Assistant Secretary, TAC
FAO
Washington

CLASSIFICATION TERMS IN FSR RELATING TO CROP PRODUCTION SYSTEMS

A crop system or crop production system¹ comprises all components required for the production of a particular crop and the inter-relationships between them and the environment. These components include all the necessary physical and biological factors, as well as technology, labour and management.

Single cropping: growing only one crop on a plot of land within one year.

A multiple cropping system is a system in which more than one crop is grown on the same plot of land on one year. There are various multiple cropping possibilities in time and space. Some of the more important are:

- (a) double cropping: growing two crops in sequence, seeding or transplanting one after the harvest of the other. Similarly triple cropping is the growing of three crops in sequence one after the other in one year.
- (b) intercropping: growing two or more crops simultaneously in the same plot in different but proximate stands.
- (c) row intercropping: growing two or more crops simultaneously in the same plot in distinct rows.
- (d) mixed intercropping: growing two or more crops simultaneously intermingled in the same plot with no distinct row arrangement.
- (e) relay intercropping or relay cropping: growing two or more crops in sequence, seeding or transplanting the succeeding one some weeks before the harvest of the preceding crop.

Strip cropping: growing two or more crops in distinct strips of several rows with each strip capable of independent cultivation.

Sole cropping: growing one crop (variety or species) alone in pure stands, either as a single crop or as a sequence of single crops within the year.

A crop rotation system implies a time sequence of crop systems, either sole or overlapped in phase, on the same area. While a crop rotation system implies a regular cyclical pattern over time (often involving a cycle of more than a year) this need not be so with multiple cropping.

The term cropping system refers to the set of crop systems making up the cropping activities of a farm system. If the farm also has non-crop activities, then the cropping system is a subsystem of the farm system.

¹Analogously, we may refer to a farm's livestock system, or livestock production system, for example its beef system.