FARMING SYSTEMS ANALYSIS

an introduction

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The Netherlands   September 1988

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I WHY FARMING SYSTEMS ANALYSIS?

Farming provides a livelihood to a great number of people in developing countries. To them, it is not only a source of food, but very often also a source of feed, of fuel, of fiber, of pharmaceutical products, of cash income, and last but not least, a source of pride. Although any farmer knows that farm households have multiple goals, this fact has been relatively ignored by agricultural researchers and planners. It has important implications, however, for the way in which research and extension are conducted. Until the mid seventies, the development of improved agricultural technology has been concentrated on raising outputs per unit of land area of certain crops. This so-called commodity approach has had a tremendous impact on food production, in particular in the case of rice, wheat and maize. While increased yield has been a necessary condition to improve the lot of farmers in many countries, it has also become very clear that production increase per se is not sufficient to alleviate rural poverty.
Indeed, many farmers have not been able to benefit from the new technology developed by agricultural scientists. The reasons why the impact of technology differs so widely between farmers and regions has been the subject of many studies. To put it simply, farmers have missed out either because the technology did not address their most important constraints, or because it implied changes in the allocation of resources that conflicted with their other activities. Over the last decade, agricultural researchers have been increasingly aware of the need to design technology that is more appropriate to the needs and constraints of farm households in the tropics and subtropics. A multitude of different research approaches has been the result, and these are commonly referred to as farming systems research (or farming systems research and development, or cropping systems , or on-farm research - the debate on terminology is far from completed). This volume deals mainly with farming systems analysis or FSA, i.e. the understanding of the structures and functions of farming systems, the analysis of constraints on agricultural production at the farm level and ways to translate this understanding into adaptive research programmes.
These farming systems approaches have a number of features in common. They are nearly exclusively concerned with developing agricultural

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technology for small farmers, i.e. farmers who undertake a variety of cropping and/or livestock activities, often on fields of limited sizes, use family labour and relatively few externally purchased inputs. Mostly, farming systems analysis does not only focus on raising yields of one crop, but aims to increase the long-term stability of yields and reduce risks, for example through diversification of crops or crop varieties. Farming systems analysis has drawn attention to the importance of farmer practices such as multiple cropping, and to the unique understanding that many farmers have of their ecological environment. Emphasis has also been put on crop and livestock species that have hitherto been rather neglected by the mainstream of agricultural research, such as cassava, sweet potato, yam, millet, beans, goats and buffalo.

With respect to methodology, farming systems analysis advocates the careful planning of research to include a "diagnostic phase" prior to the actual technology design and testing. Also, the testing of technology, i.e. technical improvements that change input/output ratios, should not only take place in research stations but mainly on farmer fields, and ultimately by farmers themselves.

The most distinguishing feature of farming systems analysis in contrast to most classical research in agriculture is its interdisciplinarity. Since farmers face ecological as well as socio-economic problems, research cannot afford to limit itself to a single discipline, but needs to integrate the results of various disciplines. The physical, biological and socio-economic aspects of a farm are closely interlinked, so much even that a farm can be considered as a system, i.e. an arrangement of components (or subsystems) which process inputs into outputs. Hence the term farming system, meaning a decision-making and land-use unit comprising the farm household, cropping and livestock systems (the subsystems), that produces crop and animal products for consumption and sale.

It goes without saying that farming systems analysis can only exist if good disciplinary research is carried out. Rather than a replacement, or a new discipline, farming systems analysis is an essential addition to the agricultural and biological work carried out in research stations. Farming systems analysis is also primarily a research approach, and not a development strategy, although its results may have implications for development planning. In other words, the scope of farming systems analysis is necessarily limited and its contribution to alleviating rural poverty cannot be but modest.

While the emergence of farming systems analysis as a new approach in thinking about agricultural technology is significant, we have to remain aware of its limitations. As in all new fields of science,

both farming systems analysis and its terminology are subject to heated debates. For example, farming systems analysis has been accused of being too qualitative and descriptive, of downplaying the role of livestock and trees in the farming system, of neglecting the role of women and the intrahousehold division of resources, and of ignoring political issues. Over the past years, however, the theoretical basis has been clarified considerably, while exaggerated expectations of the role of farming systems analysis have also been toned down.

This volume intends to provide students with an overview of the concepts, methodology and applications of farming systems analysis of FSA. Its primary focus is on the analysis of farming systems: on methods to acquire data for analysing the constraints and potentials of farmers, and on conceptual frameworks to integrate the data in a meaningful way. It also discusses the implications of farming systems analysis for agricultural research. A companion volume of selected readings is also available at the Department of Tropical Crop Science of Wageningen Agricultural University.

II A THEORETICAL FRAMEWORK TO ANALYSE FARMING SYSTEMS

1. The concept of a system

Agriculture in general can be described as the human activity that transforms solar energy at the earth's surface into useful (edible) chemical energy by means of plants and animals. It involves variables and parameters with very diverse characteristics and complicated interactions. The study of agriculture requires not only the contribution of many disciplines but also unifying concepts. Systems theory provides such theoretical framework, that helps to understand and predict complex phenomena by describing them as systems. A system can be defined in many ways, but all systems involve an arrangement of parts (components or subsystems) that interact according to some process (transform inputs into outputs). What matters, however, is not the definition but the concept of a system.

Systems display special properties that emerge from the interaction of components: a whole is different from and often more than the sum of its parts. Knowing only the parts, therefore, does not adequately predict the behaviour of the system as a whole. In all systems five elements are distinguished: components, interactions between components, boundaries, inputs and outputs. The structure of a system is defined by the quantitative and qualitative characteristics of the components and the interactions between them. The way in which inputs

are processed into outputs determines the _function_ of a system. Within the boundaries all relevant interactions and feedbacks are included, so that all those components that are capable of reacting as a whole to external stimuli form a system.

Systems theory, and also FSA, makes use of models. A model is, per definition, a simplification of reality in accordance to the purpose one has in mind. Many authors use a simplified, standard model of the farming system/cropping system/livestock system to analyse input/output flows. Two types of models are used. Structural models represent the components of the farming system, while functional models provide qualitative and where possible quantitative flows between the components. Often the two are combined, but a structural model can be helpful in determining the flows that need to be investigated (for an example see fig 1).

2. A hierarchy of agricultural systems

Systems theory is increasingly applied to agriculture. The best way to do this is to describe agriculture as a hierarchy. At the lowest levels, one finds the cell and the plant organs, followed by the plant itself. Plants combine into crops, and crops into fields that may carry crop populations of various species and variety, weeds and pathogens. The farm is situated at the next higher level. Groups of farms combine into villages or land use units. These in turn combine into regions, which may cover a part of a country, an entire country or even a group of countries.

It appears immediately that the higher levels in the agricultural hierarchy are less easily defined than the lower levels. At the lower levels, there is a clear analogy with ecology. The plant corresponds to the level of the individual, and the crop to the population, and the field to the community. The farm can be considered an ecosystem composed of interacting human, animal and plant populations. Farms, however, can be grouped in diverse ways, because they display many different facets. Depending on whether socio-economic or biological and physical aspects are studied, a model of the higher levels of the agricultural hierarchy includes farms combined into socio-economic, e.g. village units or into physical land use units, such as watersheds. At an even larger scale, for example of the region or country, ecosystems are increasingly complex and more difficult to map.

Figure 2 presents a qualitative model of the agricultural hierarchy. It identifies levels of analysis, systems, system components, inputs and outputs as well as units of observation.

The lowest level that is usually considered in FSA is the crop system, with crops, i.e. the plant subsystems and their interactions, as

the main component. The crop system may involve plant populations of varying species and variety. At this level, one is interested in interactions between plants rather than in individual plants.

The next higher system level is the cropping system, with the field as the corresponding unit of observation. The cropping system is a land use unit that transforms plant material and soil nutrients into useful biomass. Cropping system components are the crop system (crops, weeds, pathogens, insects) and land. Land refers here to the soil and landscape characteristics of the field on which the crops are grown. The cropping system corresponds to the community level in ecology. Apart from solar energy, water and nutrients that are processed by crops, the most important inputs are labour and management. Labour and management are inputs provided by the next higher level in the hierarchy, the farming system. The cropping system may involve complex spatial and time arrangements of various crop species and varieties according to micro-variations in the soil. Trees found in the field or around the homestead are included in the cropping system insofar as they interact with crops. Fields belong to the same cropping system if they are managed in the same way. The output of the cropping system is useful biomass that can be used by humans as food, feed, fiber (including thatch) and fuel.

The livestock system comprises the grazing lands and other feed sources (hedge rows, crop residue) as well as the animals involved. A hierarchy of animal production would involve animals, herds and livestock systems as levels. The next higher level in the hierarchy is the farm. If the farm is studied as a system, it is usually called farming or farm system. The farming system is a decision-making and land use unit comprising the farm household, cropping and livestock systems, that transforms land, capital (and external inputs), labour (including genetic resources and knowledge) into useful products that can be consumed or sold. The farming system comprises the cropping system(s), the livestock system(s) and the farm household. Each of these constitutes a complex subsystem by itself. In the tropics, nearly all farms have more than one cropping and/or livestock system, e.g. upland crops as well as irrigated paddy fields as well as home gardens, in addition to farm yard animals or herds of small ruminants. Cropping and livestock systems frequently interact, e.g. if crop residue is fed to animals or manure and animal traction are applied to crops. The role of perennials and trees is also analysed at this level.

The farm household consists of a group of people, often related, who, individually or jointly, provide the management, labour, capital, land and other inputs for the production of crops and livestock, and who consume at least part of the farm produce. The farm household is thus

the centre of consumption, resource allocation, management and labour, and can consist of more or less autonomous subsystems. Management, of course, is one of the crucial variables here. Management implies decisions on objectives (e.g. cash or food crops), on the way these are to be reached (e.g. cassava or other crops), and on how deviations from standards have to be corrected during implementation (e.g. replacing plants after pest attacks). Off-farm activities can be an important separate element in the farm household system. A study of farming systems must also involve money and information exchanges.

Farming systems are components of higher level systems that for simplicity sake are called land-use systems here and may be a village, a watershed, a valley or another landscape or geographical unit. These systems in turn are part of a regional system. The regional system is a complex large scale land utilization unit which produces and transforms primary products and involves a large service sector, including urban centres. The regional system can be analysed from an ecological or socio-economic perspective. Ecologically speaking, it consists of climate, land and vegetation and human resources. In the economic sense, regional systems comprise a primary production sector, a secondary sector (processing of agricultural products) and a tertiary sector (services, marketing and urban). The primary production (agricultural) sector comprises all the farms in the region.

In figure 2 only a simple graphical representation is given of the hierarchy of systems (from crop/livestock to regional system). The dotted lines indicate how systems at each level are made up of components that become systems with their own components/subsystems at the next lower level. Only a single system is shown at each level, but in reality, of course, many systems exist at each level. Moving upwards from the plant system to the regional system, the number of units decreases. In other words, there are many plants in a crop population, several crops in a field, only one or two fields in a cropping system, and perhaps only two cropping systems in each farming system. The same applies to the higher levels in the hierarchy. In one single region, there may be a few subregions (or villages or watersheds), but each of these consists of a multitude of farms.

Systems interact both vertically, with systems at higher or lower levels, and horizontally, with systems at the same level. Farming systems, for example, interact with the regional system through flows of produce and money, as well as with one another, through exchanges of labour or goods.

Systems can be considered similar if they are similar in structure, i.e. the characteristics of their components and component inter-

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actions, and in function, i.e. the way inputs are transformed into outputs. Similarity and degrees of similarity between systems provides the basis for a <u>classification</u> of systems. In the agricultural hierarchy, systems can be classified into types at each level. At the plant system level, a distinction is made between C3 and C4 plants according to photosynthesis pathways. Types of crop systems may be defined according to the dominant population, e.g. the cassava crop system. Cropping systems can be classified in many ways, for example according to the degree of land use intensity. ˉFarming systems are usually distinguished with respect to the interaction of animal and crop production, but it may be equally important to consider access to resources and degree of market integration. The classification of farming systems can never reflect all aspects, and depends to a great extent on the purpose one has in mind. FSA aims at defining similarities between farming or cropping systems that are relevant to agricultural research.

3 <u>Exogenous</u> <u>and</u> <u>endogenous</u> <u>constraints</u> <u>on</u> <u>systems</u>

System output is limited by exogenous factors as well as by endogenous factors. <u>Exogenous</u> <u>factors</u> are those occurring at levels higher than that of the system involved. The cropping system, i.e. the combination of crops, land, management, weeds and so on, sets limits on crop system outputs, for example. Higher level constraints will affect all lower level systems, because the hierarchy is comprehensive (each system is included in the next higher level).
Climate, prices and infrastructure are examples of factors at the regional system that may be constraining the outputs of all lower level systems. Higher level constraints may be subject to changes at lower levels, however. The limitations imposed by rainfall, a constraint in the regional system, may be modified at lower levels such as in the cropping systems by soils and farmer management. Consequently, even if one is only interested in lower level systems, as in the case of crop physiologists and geneticists, who mainly work at plant and crop systems, constraints at higher levels must be acknowledged, such as soil nutrient limitations (cropping system level) and constraints imposed by labour peaks (farming system level) or consumer preferences (regional system).
<u>Endogenous</u> <u>factors</u> are set by subsystems within the system or by lower level systems. Farming system outputs, for example, are limited by labour inputs provided by the farm household (a subsystem) as well as by the genetic potential of crop varieties (crop system). The distinction between exogenous and endogenous factors is essential in

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understanding system performance.

Yet FSA is not limited to an analysis of constraining factors, but focusses on the options that farmers have within the context of these constraints. On the one hand, it looks at individual variations between farmers in similar conditions, and on the other it suggests opportunities for improving input-output relations within these conditions. Combinations of exogenous and endogenous constraints obviously set limits to potential production, but do not entirely fix the ways in which the farming system deals with the environment. In the same agro-ecological and economic environment very different systems may be operational. In the savanna region of Central Africa, for example, hoe and ox farming exist side by side. What farming system prevails in a given case depends on household resources, access to inputs, the division of labour and cultural factors.

There are various ways to analyse systems. In general, understanding a system at any level involves:

a. observing the system in reality;
b. identifying the system's components;
c. describing, in qualitative, and where possible in quantitative terms the component interactions, input-output flows and their variations;
d. assessing opportunities for changing input-output relations in the system;
e. formulating testable hypotheses for bringing about these changes;
f. testing these hypotheses and, when necessary, adjusting the description of the system and the assessment of changes (i.e. reverting to steps c an d).

With this framework in mind, systems can be studied in numerous ways. It is crucial to determine the relevant characteristics that need further study, in order to limit data collection efforts. In farming systems analysis, four important features of farming and higher level systems are:

- productivity: the ratio between unit of output and unit of (scarce) input, e.g. yield, income per labour day;
- stability: the degree to which productivity remains constant in the face of fluctuations in external circumstances;
- sustainability: the degree to which a system can maintain its productivity and manage its resources successfully to satisfy changing human needs while safeguarding its environment;
- equitability: the degree to which a system's outputs are evenly distributed among the human beings involved in it.

These features can be used to assess the current situation and as criteria for predicting the impact of future changes.

III THE SEQUENCE OF FARMING SYSTEMS ANALYSIS

FSA has adapted methods from systems ecology to develop a series of
research procedures to fit its own, particular purpose: analysing the
constraints of resource-poor farmers in less favourable environments
and developing adapted technology for them. FSA involves three basic
steps that are each divided into a number of activities. This entire
sequence is iterative, since all or only a few of the steps may be
repeated according to need. While the steps are described chronologi-
cally, it is not uncommon to find that some activities are carried
out simultaneously. For example, exploratory on-farm experiments may
be initiated before the diagnosis and planning are fully completed,
if they are thought to throw light on a central issue in the analysis
of constraints. However, this can lead to a proliferation of ill-
designed experiments that are a burden to the farmer and the resear-
cher alike. It is always necessary to define the objectives of each
activity in the FSA sequence with great care and to ascertain that
all data are adequately analysed, before moving on to a next step.

The basic steps or phases in FSA are:
1. Diagnosis, i.e. the analysis of farming systems and the identifi-
    cation of constraints.
2. Design, i.e. the step from diagnosis to research, both on- and
    off-station.
3. Experimentation, i.e. the testing of technology designed to meet
    the constraints.
These steps are summarized in table 1. They are followed by a phase
of dissemination of results, through extension to other farmers in
similar environments, but also to research stations with a view to
setting priorities for further component or commodity research. This
last phase must also involve the monitoring of the farmers who were
originally involved in FSA, to ascertain what changes they are making
to the new technology. Most of the work in the dissemination phase,
however, is not FSA in the strict sense, and requires major inputs
from extension and other rural organisations, for example credit pro-
grammes. The following section discusses the basic FSA sequence and
highlights the main methodological concepts involved.

IV DIAGNOSIS

The diagnostic phase has the following, interrelated objectives:
- to describe and analyse the physical, biological and socio-economic environment in which farmers operate;
- to understand the skills and knowledge, the constraints and aspirations of farm households;
- to evaluate existing systems, i.e. their performance in terms of the processing of inputs (labour, seeds, fertilizer, management etc.) into outputs (crop and livestock products for cash, food, fiber, fuel etc.);
- to identify the most constraining factors that research should focus on.

The diagnosis itself consists of several stages, depending on the degree of detail required and the quality of data available prior to the diagnosis. Very often diagnosis is a reiterative process which becomes increasingly focussed on particular types of farming systems or their components. Thematic studies, e.g. on particular commodities (crops, livestock) or on components (soil fertility, marketing) will be conducted later during the diagnostic phase. In fact, diagnosis follows the levels of the hierarchy described previously. It usually starts with a broad overview of the regional system, and then gradually the lower level systems of the hierarchy are explored. Since different processes and components are involved at each level of the agricultural systems hierarchy, a specific set of data is required of each level.

The level of the hierarchy at which diagnosis is carried out therefore determines to a great extent the data collection process. Most data on the regional system stem from secondary sources (rainfall and agricultural production statistics, maps, government reports etc.). Direct observation becomes increasingly important at lower levels of the system such as the cropping system. Because changes occur more rapidly at lower levels (e.g. annual crops are harvested each season, plant growth rates can be monitored daily), the need for long-term time series of data decreases with system level. A full understanding, for example, of nutrient flows at regional level requires climatic, crop production and fertilizer data of several decades. While these may not always be available, all FSA must involve an attempt to understand the historical factors that have shaped agriculture in the region under study.

While direct observation cannot be substituted entirely, other sources of data can be very helpful, esp. to gain information on aspects of the farming system that cannot be observed directly during the diagnosis (such as what happens in other seasons, what happened in

the past, what happens in other villages). In this context, interviews with key informants, e.g. district agricultural officers, leaders of a farmer cooperative, development workers with extensive experience in the area, as well as case studies of particular farms, are very useful.

In contrast to regular agricultural research, FSA starts with an area approach rather than a thematic one: it concentrates on a given area and analyses the problems faced by agriculturists in that area, usually without determining in advance which problems are to be tackled. During the diagnostic phase the interdisciplinary FSA team collaborates closely with farmers. The outcome of the diagnostic phase consists of possible solutions and opportunities to alleviate constraints. Some of these constraints may be addressed through on-farm experimentation, while others will need interventions by regional or national development agencies, or even changes in policy.

Activities carried out during diagnosis

An overview of the typical activities during diagnosis follows below. Usually, but by no means always, these are undertaken in the chronological order indicated here. However, many practitioners of FSA have developed their own diagnostic sequence, so the order given here must not be interpreted rigidly. Some authors prefer to wait with the definition of recommendation domains until the end of the formal survey, rather than determining them in advance of the survey. In other cases, the formal survey is replaced by a series of increasingly focussed rapid appraisals and exploratory surveys. The way in which the activities are carried out is also flexible in the sense that it depends on the availability of prior information, the composition of the FSA team and the general rural development objectives in which the FSA work fits. For example, if the area has already been studied by other (FSA) teams and if the FSA team works within the context of a commodity program, diagnosis may be limited to case studies and perhaps a formal survey on the constraints faced by farmers with respect to that particular commodity.
The typical diagnostic activities are described as follows:

1. Characterization of the research area: through a study of secondary sources an initial impression of the problems and potential of the regional system and the farming systems in the region is obtained. Depending on the size of the area and the available amount of information, this may take one to three months. This period is often combined with short visits to the area and with

the training of field assistants. It results in the selection of representative pilot area(s) for further study. Pilot areas must reflect the significant differences within the region, e.g. valley and hilly zones, and must be internally homogeneous to limit variations of climate, soils, landscape, population density, infrastructure, ethnic groups. Micro variations that are typical of the farming systems in the region, such as toposequences, must of course be included. The size of the pilot areas may vary from a single village to a subdistrict.

2. Rapid appraisal of the pilot areas: rapid appraisals, exploratory surveys or sondeos are by now classical techniques in FSA that aim to provide, in a relatively short period of time, a first analysis of field data collected through observations and interviews with farmers and other key informants with a view to formulating hypotheses about possible interventions.
   While interviewing procedures are highly dependent on the social context, a few guidelines are the following. Initial contact must be made through the village authorities, and the purpose of the team's visit must be stated very clearly. Interviews with farmers should be conducted preferably by two interviewers and care should be taken to obtain answers from the entire farm family, not only from the male head. Interviews are best conducted in the fields, rather than at the homestead, so that the situation of the fields can be discussed as well. When the rapid appraisal team consists of a rather large group, it is useful to rotate the team members daily to facilitate exchanges. When the interviews for a particular pilot area or village are completed, the team should spend at least a few days to evaluate the results, draw conclusions and to formulate tentative hypotheses. This can also guide the remainder of the appraisal work.
   The rapid appraisal may take one or even a few months, and may be repeated several times throughout the agricultural seasons. Its outcome consists of a physical, biological and socio-economic description of the pilot area, or land-use/village system in the hierarchy, and an analysis of issues that need further study and/or can be used for the design of on-farm trials. Leading questions are usually: why do farmers do what they do? Are there unidentified opportunities in the farming system? What constraints do farmers face? Are there great differences between farmers? If so, to what can they be attributed?
   Case studies (of individual farms) and thematic studies (e.g. of seed storage facilities or food crop marketing) are very important tools during this phase, and may continue through the other

phases of FSA.

Rapid appraisals have been criticized as "quick and dirty" because of their superficial treatment of many subjects. It must be realized, however, that they constitute an essential step in the process of FSA enabling researchers to communicate among themselves and with farmers. It goes without saying that quantitative data, esp. of longer time series can only be obtained through formal surveys. Rapid surveys allow the latter to be cost-effective and better focussed through the definition of recommendation domains.

3. The definition of recommendation domains: farmers within a pilot area, even if it is relatively homogeneous, may face different problems. It is therefore essential to group farmers within the same pilot area according to a range of agro-ecological and socio-economic criteria. A more or less homogeneous group of farmers with similar circumstances for whom similar recommendations can be made is called a recommendation domain. For example, within the same pilot area, some farmers may have access to irrigation, others may own draught animals and rent them out, and others again may rely heavily on off-farm employment. The farming systems of each of these three groups are likely to be very different. The categorization of farmers into recommendation domains may be further refined during the FSA. Initially it helps to identify similar groups, and later, during the on-farm testing stage, it helps to identify sites for on-farm tests and to tailor recommendations to the specific circumstances of different farmer groups. Recommendation domains relate to the farming system level of the hierarchy, but in some cases cropping systems may also be classified into recommendation domains.

The difficulty with recommendation domains is that farmers classified in different domains may farm adjacent areas, and farmers belonging to the same domain may live at considerable distance but share similar characteristics. It is therefore shortsighted to use a single criterion, such as the growing of hybrid maize, to define recommendation domains because that might exclude other important characteristics (e.g. the presence of animal traction). In hierarchical societies, class differences may form the basis of recommendation domains.

It can be argued that each farming system constitutes a unique constellation of components and could be considered a recommendation domain by itself. This would of course be very impractical, and overlooks the fact that recommendation domains are based on relevant differences between groups and similarities within

groups. During the definition of recommendation domains, case studies of typical farms may be conducted to obtain a thorough qualitative understanding of the linkages between the system components. In some cases, the definition of recommendation domains follows from the formal survey, so that more detailed (statistical) methods can be used to determine the correlation between different farmer characteristics.

4. Formal surveys: formal surveys are a way to obtain primary (i.e. new) quantitative data on the farming systems, cropping systems and livestock systems in the pilot areas. Formal surveys are intended to verify the hypotheses formulated during the rapid appraisal. Because they are without exception very demanding in terms of time and costs, they must be as focussed as possible. These are methods that are clearly complementary to other forms of diagnosis. This means that it is only useful to conduct a formal survey when one knows exactly what information one is looking for and that that (quantitative) information will make a significant difference to the understanding of the situation. Formal surveys require the use of formal (often random) sampling procedures, pre-tested and standardized questionnaires and other methods that allow the statistical treatment of data. In other words, they demand well-trained personnel both in conducting the survey and in the analysis. Usually surveys are limited to single visit interviews, and need to be complemented by case studies and other informal methods. In others, farmers are asked to keep weekly records, so that more detailed data are acquired.
Designing interview guidelines is an art. Some things that must be taken into account are: questions should deal with only one subject (e.g. one crop or one field or one activity) at the time; be phrased in terms that farmers are likely to use themselves; and specify the time period (weekly, monthly, annually). Formal surveys may take from six months to over two years including pretesting and data analysis (or more if multi-annual data are required).

5. Analysing and presenting the results of the diagnostic phase: once all the information has been collected, the most pressing problem is the processing of the large amounts of data. Preferably processing should already take place after each of the preceding phases. If processing and analysis take too long, the data may already be outdated by the time the field experimentation starts. The results of a diagnosis can be presented in many ways. It is important to think of ways that can

also be understood by farmers, and discussed with them so that they can give their feedback. Diagrams, charts and other visual representations can be useful for that purpose because they give a summary of verbal data (in contrast to graphs that summarize quantitative relations). Good results are obtained with transects that give a spatial representation of the farming system (fig. 3). Charts are handy for an overview of resource flows in the farming system (fig. 4) and may even link data at different levels of the hierarchy (fig. 5).

The final report of the diagnostic phase should contain a description of the regional system, of the pilot areas (villages or land-use units), and of the recommendation domains (homogeneous groups of farms) within each of these. This is not always easy, and many instances of diagnostic FSA work have been criticized for being either incomplete or too detailed, for ignoring social and political differences between farmers and for neglecting the position of women farmers and agricultural labourers. Often indeed, the focus has been on annual crops and crop-related activities to the detriment of off-farm employment, livestock and tree crops.

V THE DESIGN OF INTERVENTIONS IN A FARMING SYSTEMS CONTEXT

1. Translating farmers' constraints into agricultural research

By the end of the diagnostic phase, the problems of farmers in each recommendation domain should be ranked by order of importance, and the causes of each problem and the interaction between them should be clearly understood. Furthermore, diagnosis should result in an identification of priority problems at each level of analysis, and a prioritization of these problems by potential solution. The design phase then consists of identifying a series of alternative solutions to each priority problem for each recommendation domain. Design, in a way, is about translating farmers' constraints into agricultural research. Often the diagnosis reveals many more problems than an FSA program can hope to deal within a relatively short period of time, and many of these may lie outside the realm of improved agricultural technology. A selection is then necessary, so that both farmers' wishes can be taken into account as well as the specific mandate of the institute at which the FSA team is located. In some cases this may mean a compromise: not all farmers' wishes can be accomodated and not all recommendation domains can be addressed simultaneously.

For example, poor infrastructure and subsequently marketing bottle-

necks may be an important regional problem, but improving infrastructure is hardly a matter of agricultural research. Problems that cannot be solved by improved agricultural technology are referred to relevant other agencies. Researchers may then want to focus on improving storage facilities at farm or village level, and storage qualities of grains in particular, or work on crop varieties that allow flexible harvesting times so as to overcome supply bottlenecks.

Within a farming system context the design phase focusses on the way in which improved agricultural technology can help to alleviate the constraints faced by farmers. Design is therefore essentially a comparative process: by comparing the analysis of farmer constraints (resulting from the diagnosis) with existing scientific knowledge in the field of agriculture, recommendations for adapting that knowledge to specific circumstances are formulated. In theory, it is possible that the appropriate technology is already available, so that no adaptation is necessary, but this is unlikely to be the case in ecologically and economically diverse environments. Usually, this means that the design phase must be followed by a phase of on-farm experimentation.

In other cases, no "on the shelf" technology is available for adaptation, so that more research station work is required before bringing technology to the farmers and experimenting with it under their ecological and management constraints. If that is the case, FSA also has a role to play in directing agricultural research programs.

In any case, during the design phase, the FSA team must work closely with its colleagues at the research station. They are the specialists who bring forward technical solutions to specific farmer constraints that are then evaluated against farmers' priorities and possibilities. The agronomist or biological scientist's role is to formulate a range of technical options to solve a particular problem, whereas the sociologist or economist's role is to narrow down these options to those that seem compatible with the farming system. Together they pre-screen the solutions before discussing them with farmers and implementing them. Those options that conflict with the resources available in the farming system or at other levels (e.g. that require additional infrastructure or a different price structure) may still be considered, but are unlikely to present opportunities in the short term. Throughout this process, the active participation of farmers in the identification of solutions is highly desirable, because farmers themselves are experts when it comes to assessing the risks involved in a new technology.

2. Designing on-farm experiments

In a simplified form, design involves therefore a <u>problem statement</u> (e.g. "farmers in area X face food shortages due to low millet yields"), an analysis of the <u>cause(s)</u> ("low availability of nitrogen on millet fields"), <u>hypotheses</u> about possible technical solutions ("intercropping with cow pea improves nitrogen availability in millet", "early planting reduces nitrogen losses"), and, finally, if these technical solutions seem compatible with other resource constraints, <u>detailed proposals</u> for on-farm experimentation. These proposals must include the selection of treatments, the number of replications on each farm, the size of the plots and the total number of trials, as well as a choice of representative villages and farms. For example, this could include a trial of testing of three different millet-cow pea intercropping arrangements at two planting dates with and without nitrogen fertilizer, compared to farmer practices, on seven farms in each of three villages, with four replications in each trial. The most difficult step is usually the selection of the treatments, or in other words, the way in which the hypotheses are translated into trial design. On-farm work concerns <u>two types</u> of hypotheses, those concerning technical and biological relations that can be quantified ("a legume intercrop improves nitrogen availability by y%" and therefore increases yield by z%"), and those that deal with farmers' reactions to improved technology and that are more difficult to quantify ("if low cost legume seed is available and millet yields increase substantially, farmers will be interested in providing the additional labour to grow the legume intercrop"). Both types of hypotheses require on-farm verification.

Whether on-farm experiments should involve only one or two changes in technical input-output relations (e.g. plant density only or variety x plant density), or a series of interacting changes, remains to be seen. Clearly, farmers as well as researchers are interested in exploiting synergistic interactions as fully as possible (e.g. the combined effects on yield of a new variety, fertilizer use and early planting). But the acceptability of such a "package" approach depends on the demands made by the "package" on scarce resources and the current productivity of these resources. In the design of on-farm experiments, it is essential to understand the contribution of each proposed change in technology through separate experiments so that the package as a whole can be tailored to specific target groups.

In designing experiments, possible solutions to priority problems can be of two kinds, and sometimes both need to be tested. In the case of nitrogen deficiencies causing low millet yields, a direct solution may be to increase nitrogen availability through fertilizer or

through a leguminous intercrop. However, indirect solutions may in-
volve a review of the entire crop sequence to see whether millet can
benefit from the residual effects of nitrogen fertilizer on a prece-
ding cash crop such as cotton, or even improvements in other farm
activities so that surplus cash becomes available for the purchase of
fertilizer for millet.

VI ON-FARM EXPERIMENTATION

While on-farm experimentation is possibly the single most important
contribution of FSA to agricultural research methodology the idea of
conducting experiments on farmers' fields is not new. Plant breeders
have been involved in so-called multilocational trials for a long
time. However, these are intended to complement the physical and
biological conditions of the research station, and not as a testing
ground which includes farmers' management as a variable. FSA makes
use of both multi-locational trials (also called on-farm experiments)
and on-farm tests.
The first activity aims to test successful technology under control-
led conditions on farmers' fields, or to test the biological, quanti-
tative hypotheses that are formulated during the design phase. Re-
searchers bear the primary responsibility for these trials, although
the farmer may be involved in carrying out some of the work on
his/her land. The aim of the research at this stage is to assess the
technical feasibility of the new technology and in particular to
ascertain whether the technology stands up to expectations when used
outside the research station. In order to allow statistical analysis
these trials are conducted under prescribed research procedures and
require precise plot designs, replications etc. In many aspects, this
stage of farming systems research hardly differs from conventional
agricultural research.
However, upon completion of the experiments on-farm tests must fol-
low. In these tests, farmers are actively involved as joint managers
together with the researchers. The purpose of the tests is to refine
and adapt the technology and to determine its socio-economic viabili-
ty and acceptability under farmer conditions, or to test the qualita-
tive hypotheses about farmers' reactions to the new technology. On-
farm tests are usually conducted in two steps: firstly on a small-
scale in specific, representative sites, and thereafter on a larger
scale to validate the earlier findings for the recommendation domain
as a whole.
This description implies that on-farm experiments (trials or tests)
are never meant as demonstration plots, but must be seen as an inte-

gral part of the research process. In terms of objectives, lay-out, management, timing and location, on-farm plots have very different characteristics, even if their presence may evoque similar reactions from farmers as demonstration plots.

Normally, the FSA team initiates on-farm experimentation as the last major step in the sequence, i.e. following the design and preceding extension/diffusion of technology. There may be some merit in introducing on-farm work at an earlier stage, even during diagnosis, to screen possible solutions and to get a better understanding of farmers' constraints, or even to assist in formulating the hypotheses for further testing. For example, it may be helpful to know whether low cassava yields are a result of low planting densities or of poor soils or of both - a matter on which, among other things, a few explorative experiments on farmers' fields may throw some light. The results of these experiments could assist in an ex-ante evaluation of the most pressing factors to be tackled through improved technology. The advantage of working on farmers' fields as early as possible in the research process is particularly clear in the case of varietal improvement for situations where strong genotype - environment interactions are to be expected, but even these need to be explored in multilocational on-station trials as well as in on-farm experiments. The theory of on-farm experimentation is based on two disciplines: statistics to determine the various designs, testing and data analysis procedures, and social sciences to deal with farmer involvement and organizational matters. Due to the lack of controlled conditions and the great diversity among farmers, even within the same recommendation domain, statistical tests often show high variance and may be difficult to interpret. FSA researchers, while adhering to replicable scientific methods, should resist the temptation of involving a great number of replications per location or many levels of several test factors within the same environment. The most successful to date seem to be experiments and tests that deal with combinations of two levels of the major production factors, allowing an assessment of the effects of each factor as well as the interaction between the factors (e.g. fertilizer x variety). Tests involving slight changes in cultural practices (e.g. changes in planting dates) appear more difficult to conduct successfully. In general, on-farm experimentation does not aim at producing an entire response curve to a given treatment (as would be required in station research), but at socially and economically significant increases in response. A high number of replications per location (more than two) multiplies the number of data to be analysed and is often not justified in view of the variations between locations. While sacrificing some accuracy, more rele-

vant results are obtained by replicating experiments and trials over a number of farms than within each farm. On-farm tests are normally carried out without a control plot (because farmers do not usually have control plots on their farms) and with few if any replications. The role of the researcher is limited here to observations; he/she does not interfere with farmer practices but observes how farmers change the prescribed technology in order to fit their needs.

Sofar, the majority of this work deals with technology at the cropping systems level and annual crops in particular. Procedures to deal with livestock or perennial crops, or that involve experiments at the farming systems level have hardly been developed yet. On-farm experimentation requires <u>multiple</u> <u>assessments</u> of its results: of its technical feasibility, its economic viability and its social acceptability.

But even if the statistical design is adequate, there is no guarantee that the on-farm experiment or test will actually achieve its goal. The ultimate evaluation of a technology lies in the hands of the farmer or rather the farm household. On-farm experimentation methods have been criticized in the past for not paying sufficient attention to farmers' knowledge and priorities. Even if technology appears successful, the FSA team must monitor its application and especially its modification by farmers over time, as well as possible changes in non-treatment variables. Farmers are likely to do some "fine tuning" of technology to make it fit their requirements, a process which can greatly increase the researchers' understanding of the farming system. Likewise, unacceptable technology must be carefully examined to reveal any gaps in the diagnosis. If the on-farm experimental work fails to produce any tangible results, diagnosis and/or design are at fault, and researchers may have to go back to their data or even to conduct complementary studies to improve it.

VII THE IMPLEMENTATION OF FARMING SYSTEMS ANALYSIS

In many ways, FSA implies a departure from standard research procedures. Most national research agencies are organized on a disciplinary or commodity basis, and most of their work is carried out under well controlled experimental conditions. In contrast, FSA as an effective way to translate farmer problems into research, requires the collaboration of interdisciplinary teams, extensive field work and experiments outside the research station. Moreover, coordination is needed with other agencies, e.g. extension, marketing boards, seed supply companies, universities and so on. While diagnostic and on-farm experimental work could be (and in some projects are indeed)

carried out in relative isolation, the FSA sequence needs to be institutionalized in order to guarantee continuity. Thus far, FSA has been dominated by donor funded, short term projects, although a major effort is made in some countries (for example in Eastern and Southern Africa) to establish FSA teams on a regional basis who work within the national agricultural research services. In other cases, FSA is located at universities, or is fully integrated within the commodity and component research structure without being recognizable as a separate entity. Whatever structure is established, two aspects are paramount: long-term continuity and linkages with research on the one, and extension on the other hand.

In all cases, the establishment of FSA procedures has important managerial implications. FSA requires extremely careful planning of the contributions of a great many different parties throughout a lengthy and complex research sequence. Furthermore, its success may depend on factors that are outside its control, such as the stability of crop prices, seasonal variations in climate and so on. FSA procedures are lengthy, may be iterative and do not fit the conventional annual budget planning structures.

Furthermore, the training of research workers has to be adapted to allow them to work in FSA teams. Interdisciplinarity in FSA involves not only the combination of various disciplines (multidisciplinarity) but also the joint planning, implementation and analysis of research by scientists from different fields. The disciplines are highly complementary and a joint framework is needed to allow communication. Ideally, agronomists identify technical constraints and indicate what technical solutions may be tested, economists determine the current resource constraints and evaluate the economic feasibility of new technology, while sociologists look at intrahousehold as well as interhousehold relations and determine whether technically and econo- mically sound technology is in fact socially acceptable. However, this description does not mean that the input of the different disci- plines is sequential. On the contrary, all scientists must be invol- ved from the beginning and participate equally in all the stages of FSA. In some countries, interdisciplinary teams are located in the same institution which greatly facilitates communication. In other countries, scientists are posted to an FSA team for a limited amount of time only. Often the FSA team is formally located in a provincial or even national capital, allowing only temporary stays in the field. Whatever the case, stimulating leadership as well as the necessary facilities and incentives have to be present. Furthermore, a FSA team can only operate successfully if it is composed of experienced scien- tists who have had ample opportunity to learn "the tricks" of the research trade and are familiar with the range of research methods

available in their field.

VIII   FARMING SYSTEMS ANALYSIS: STRENGTHS AND WEAKNESSES

Over the past decade FSA has drawn a lot of attention, and therefore
also many critics. By now many researchers in developing countries
have become acquainted with some of the basics of FSA.   It would seem
that the main benefits are the development of a greater awareness of
the constraints and potential of small farmers, and the emergence of
a detailed set of research methods. Some methodological problems also
remain, in particular questions relating to the limitation of data
collection during diagnosis and the optimal design and phasing of on-
farm experimentation. Most pressing, however, are institutional and
organizational issues in FSA.
The dilemma associated with FSA is that its impact will remain lim-
ited unless it is part of a larger rural development effort, so that
non-agricultural, non-experimental variables (prices, marketing,
input supply etc.) can also be tackled effectively. At the same time,
however, the scope of FSA suggests that it can be an autonomous
activity (and so it has been in several foreign aid projects), at the
risk of overestimating its role and equating FSA with rural develop-
ment.
In the best instances of FSA, it has been successful in bridging the
gap between agricultural research and extension and has shown to both
the importance of a detailed analysis of farmer constraints and the
usefulness of an ongoing dialogue with farmers. FSA, however, is far
too costly an exercise to be undertaken just for the purpose of
reducing the distance between farmers and researchers. In fact, the
cost effectiveness of FSA has hardly been the subject of systematic
evaluation. Clearly, if FSA depends on expensive expatriate personnel,
its future is limited. On the other hand, national scientists require
both the training and the incentives as well as the logistics to work
on farmers' fields and donor supported programmers may help to get
started.
Finally, there are many technical issues that have hardly been
tackled by FSA because of their organizational complexity. Subjects
dealing with improving the long term sustainability in farming sys-
tems, in particular the closer integration of crops and livestock and
perennial species, require an extended and coordinated commitment by
many government or private agencies. It would seem that the ultimate
challenge for farming systems analysis lies in this field.

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Constraints - exogenous factors limiting system performance that are situated at suprasystem level.

Crop system - an arrangement of crop populations that transform solar energy, nutrients, water and other inputs into useful biomass. The crops in the crop system can be of different species and variety, but they only constitute one crop system if they are managed as a single unit. The crop system is a subsystem of the cropping system.

Cropping system - a land use unit comprising soils, crop, weed, pathogen and insect subsystems, that transforms solar energy, water, nutrients, labour and other inputs into food, feed, fuel and fiber. The cropping system is a subsystem of the farming system.

Elements (of a system) - the components, interactions between components, boundary, inputs and outputs.

Farming system - a decision-making unit comprising the farm household, cropping and livestock systems, that produces crop and animal products for consumption and sale. The farming system is a subsystem of a higher level land use system, such as village or watershed, that, in turn, forms a component of the agricultural sector of the regional system.

Farm household system - a group of usually related people who, individually or jointly, provide management, labour, capital, land and other inputs for the production of crops and livestock, and who consume at least part of the farm produce.

Formal survey - a systematic method to obtain quantitative information on characteristics of a large sample (of farms), nearly always through interviews and measurements (e.g. of fields).

Hierarchy of systems - a model of agriculture involving units (systems) arranged according to increasing scale and complexity, ranging from the plant cell at the lowest and the region/-nation at the highest levels.

Informal survey - field study in which farmer interviews, direct observations and existing information are used to develop an understanding of farming systems constraints and potential.

Intercropping - the cultivation of two or more crops simultaneously on the same field, with or without a row arrangement (row intercropping or mixed intercropping). Relay intercropping is the growing of two or more crops on the same field with the planting of the second crop after the first one has already flowered.

Key informant - well-informed person from the region or village who can provide accurate background information; not necessarily a person of authority.

Limitations - endogenous factors limiting system performance that are situated at subsystem level.

Livestock system - a land unit comprising pastures and herds and auxilliary feed sources transforming plant biomass into animal products.

Multilocational experiments (or trials) - experiments conducted outside the physical location of a research station with a view to including a larger range of edaphic and (micro)climatic conditions.

On-farm experimentation - generic term to indicate all kinds of scientific experimentation that are carried out to evaluate new agricultural technology within the context of existing cropping and livestock systems. Main types are on-farm experiments and on-farm trials.

On-farm experiments - aim to evaluate the biological and technical feasibility of improved technology on farmers' fields while design and supervision are the researchers' responsibility.

On-farm trials - aim to evaluate the economic viability and the social acceptability of technology that has previously been evaluated in on-farm experiments.

Recommendation domain - a more or less homogeneous group of farmers with similar circumstances for whom similar recommendations can be made.

Regional system - a complex large scale land utilization unit that produces and transforms primary products and involves a large service sector. Components of the regional system are natural resources, human resources, the agricultural sector, the secondary and tertiary sectors.

Representative or random sample - a selection of individuals from a population of whom specific characteristics are studied that is large enough to allow statistical treatment and conclusions about the population as a whole.

Research strategy - the allocation of research resources to specific activities in order to maximize the efficiency and effectiveness of research according to certain societal goals (such as improving the sustainability and availability of food to all sectors of the population).

System - an arrangement of components (or subsystems) which process inputs into outputs. Each system consists of boundaries, components, interactions between components, inputs and outputs (see elements).
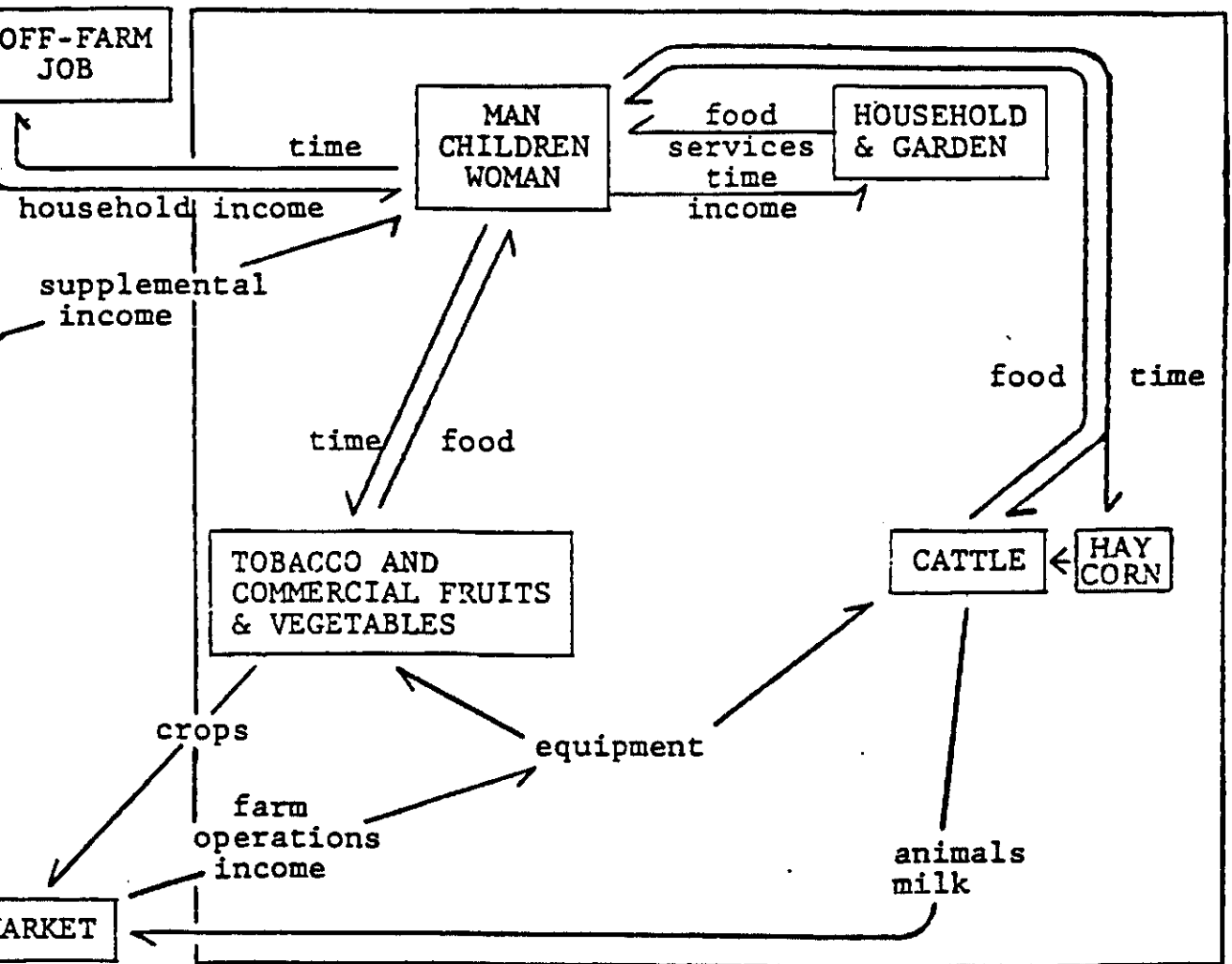
Fig. 1. Model of a mixed crop-livestock farming system in South West
Virginia (after Caldwell et al. (1983) and Teo (1982)).

In: Caldwell, J.S., M.H. Rojas and A.M. Neilan: "The
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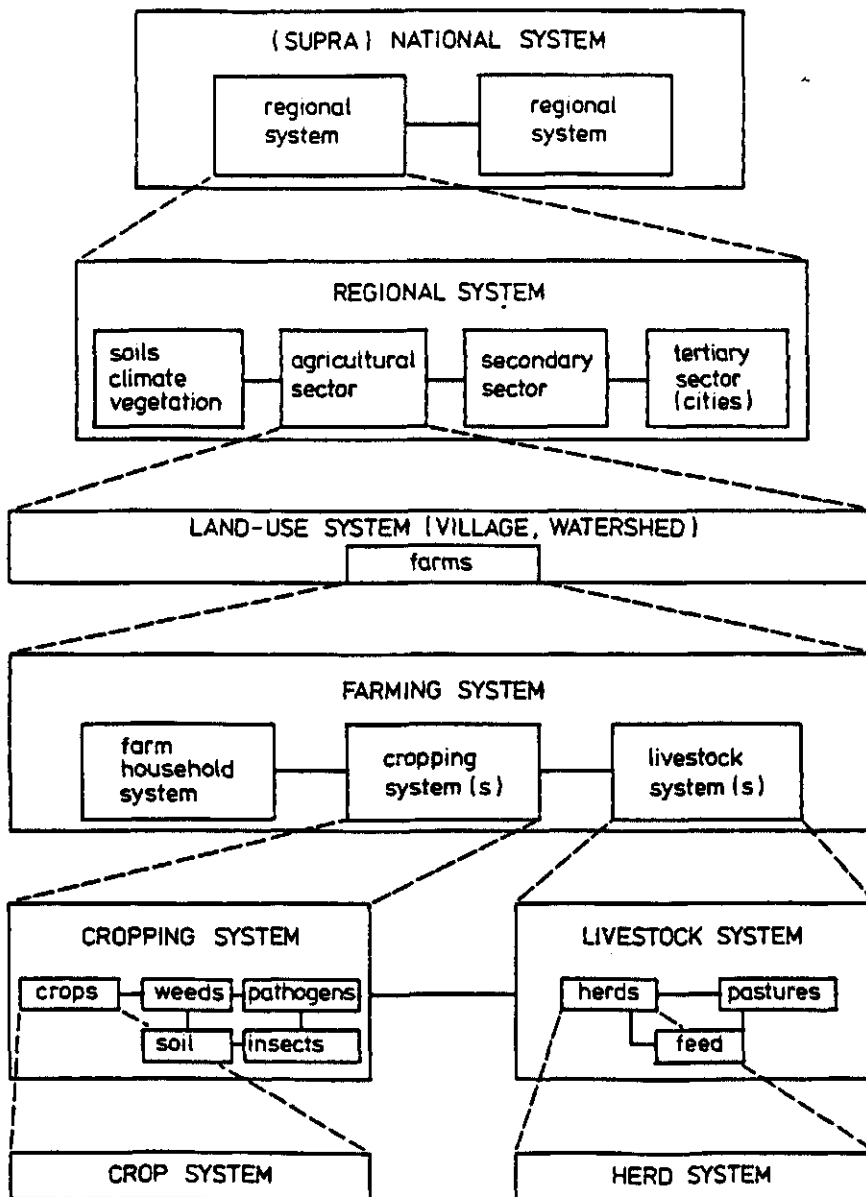Manhattan, 1986.

Fig. 2. Agriculture as a hierarchy of systems (adapted from Hart &
         Pinchinat 1982, Odum 1983).

In: Fresco, L.O. Cassava in shifting cultivation - a systems
approach to agricultural technology development in Africa.
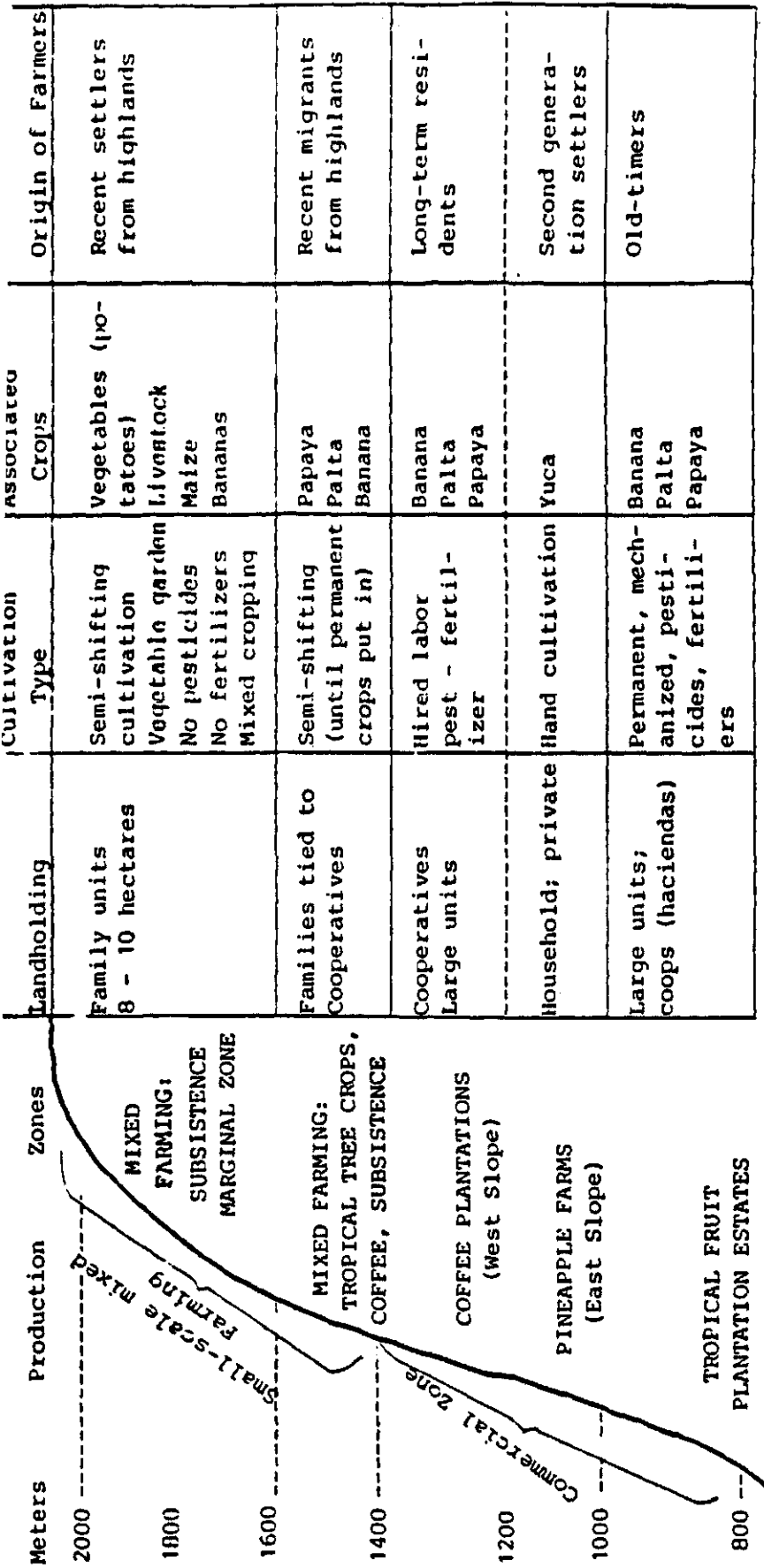KIT, Amsterdam, 1986.

Fig. 3. Diagram I: Agro-Ecological Transect. Chanchamayo, Peru

Meters	Production Zones	Landholding	Cultivation Type	Associated Crops	Origin of Farmers
2000 – 1800 – 1600 –	MIXED FARMING: SUBSISTENCE MARGINAL ZONE	Family units 8 – 10 hectares	Semi-shifting cultivation Vegetable garden No pesticides No fertilizers Mixed cropping	Vegetables (potatoes) Livestock Maize Bananas	Recent settlers from highlands
1400 –	MIXED FARMING: TROPICAL TREE CROPS, COFFEE, SUBSISTENCE	Families tied to Cooperatives	Semi-shifting (until permanent crops put in)	Papaya Palta Banana	Recent migrants from highlands
1200 –	COFFEE PLANTATIONS (West Slope)	Cooperatives Large units	Hired labor pest – fertilizer	Banana Palta Papaya	Long-term residents
1000 –	PINEAPPLE FARMS (East Slope)	Household; private	Hand cultivation	Yuca	Second generation settlers
800 –	TROPICAL FRUIT PLANTATION ESTATES	Large units; coops (haciendas)	Permanent, mechanized, pesticides, fertilizers	Banana Palta Papaya	Old-timers

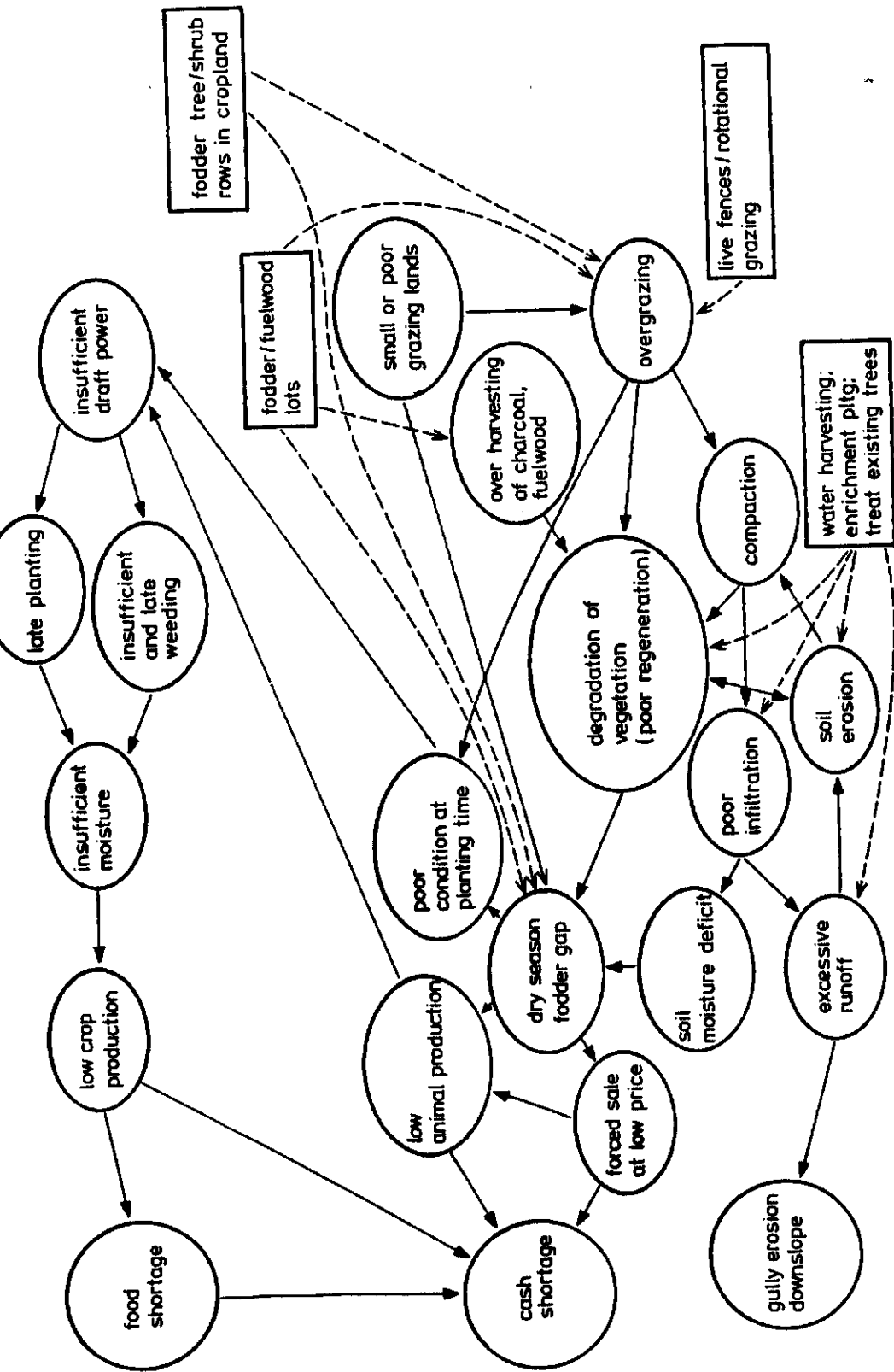Small-scale mixed farming

Commercial zone

Fig. 4. Resource flows in a mixed farming system
Adapted/Updated from Vonk, 1983.

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Intra-Household and Between-Household aspects of FSRE in
three Kenyan Agroforestry Projects.
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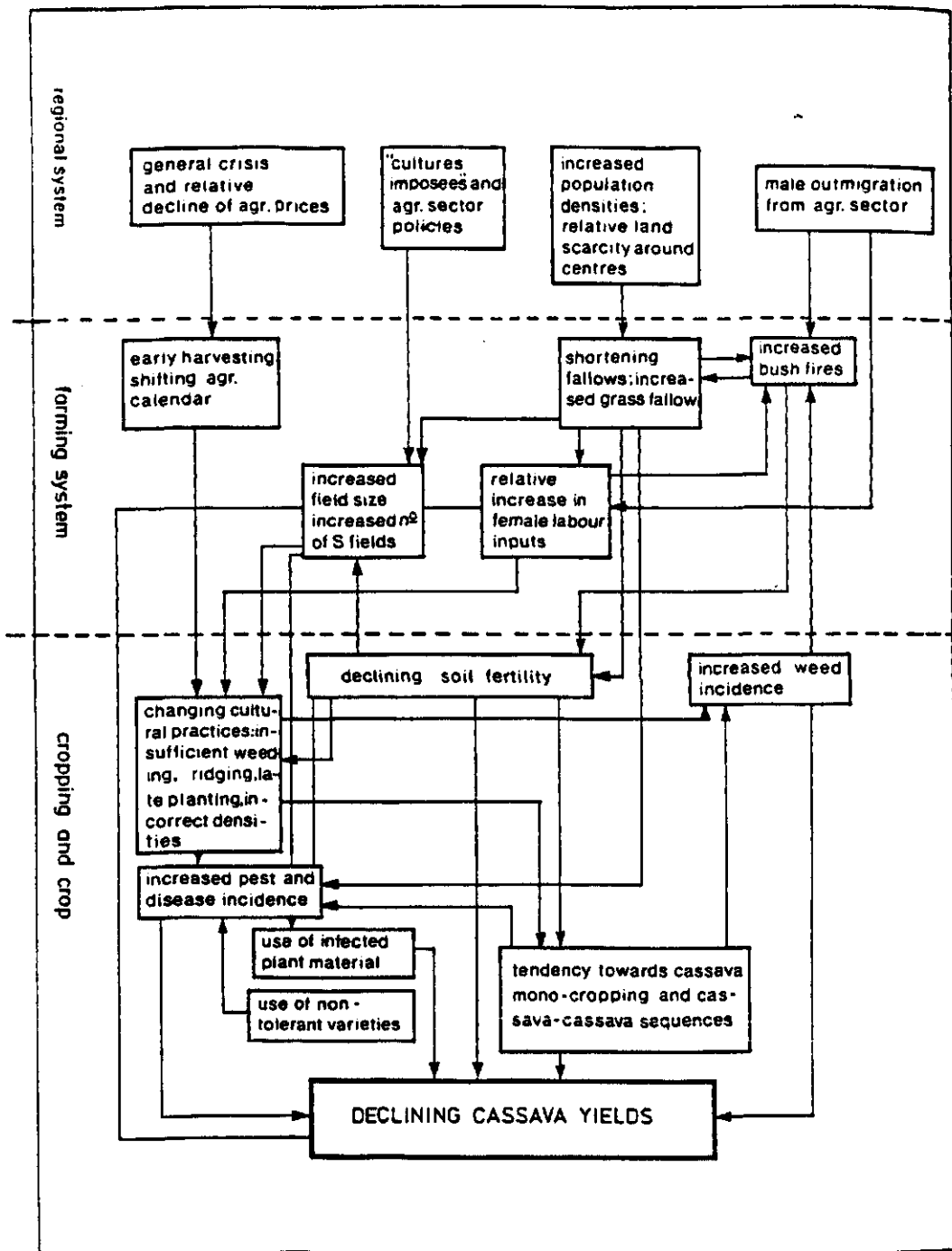hattan, 1986.

Fig. 5. Factors associated with low cassava yields at different levels of the hierarchy.

In: Fresco, L.O. Cassava in shifting cultivation - a systems approach to agricultural technology development in Africa, KIT Amsterdam, 1986.

Table 1. <u>Steps</u> <u>and</u> <u>Levels</u> <u>of</u> <u>Analysis</u> <u>in</u> <u>Farming</u> <u>Systems</u> <u>Analysis</u>

System level	activity/step	output	time period (months)
DIAGNOSIS			
regional	characterization of research area	secondary data analysis brief field visits	1 - 3
land use system/ village	rapid appraisal of pilot area	exploratory survey data (primary)	1 - 3
farming system	definition of recommendation domains	categorization of homogeneous farmer groups	1
farming/cropping & livestock systems	formal surveys	primary quantitative data	6 - 18
DESIGN			
cropping/live-stock & crop systems	priorization hypotheses trial design	detailed design procedures	3 - 6
EXPERIMENTATION			
cropping/live-stock & crop systems	on-farm experiments	biological and technical feasibility of technology	at least one season
cropping/live-stock & crop systems	on-farm trials social acceptability	economical viability	at least two seasons
cropping/live-stock & crop systems	analysis of OFE	redesign of OFE further diagnostic studies	3 - 6 m
DISSEMINATION			
regional system	dissemination of successful technology	extension messages for fine tuning	ongoing