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LAND EVALUATION AND FARMING SYSTEMS ANALYSIS FOR LAND USE PLANNING

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EXECUTIVE SUMMARY

In the present document on land evaluation and farming systems analysis for land use planning, it is argued that integration of land evaluation and farming systems analysis can substantially improve current practices in land use planning as an aid for sustainable land use and rural development.

The current state-of-the-art in both land evaluation and farming systems analysis is critically reviewed and their relative strengths and weaknesses are discussed, with respect to the basic philosophy as well as their applications in practice. A comparison of both methodologies is hampered because the approaches originate from very different backgrounds, and have evolved in the mainstream of different scientific disciplines. While land evaluation is rooted in soil science, and in actual practice puts heavy emphasis on an agro-technical analysis, where economics is often involved only as an afterthought, farming systems analysis is concerned more with socio-economic constraints. The levels of analysis also differ to some extent, with land evaluation emphasizing the regional aspects and farming systems analysis concerning itself more with the farm level. However, these differences also provide a useful starting point for exploiting the complementarity between the two approaches. The scope for integration of land evaluation and farming systems analysis for land use planning is in three areas. First, through linking the respective units of analysis, land use types, and cropping and livestock systems, all being components of farms; second, through linking the levels of analysis (national, regional, farm and components of farms) to provide full cover of the entire hierarchy of systems; and third, through linking data via geo-referencing.

The development and application of an integrated land evaluation and farming systems analysis sequence, LEFSA, can improve land use planning by combining the strong points of both methods. This volume suggests procedures for such an approach, including the use of new computer-based techniques.

Although a case study is discussed in some detail, it must be emphasized that the LEFSA sequence is largely a theoretical one at this stage, and that it is essential as a following step to formulate a research programme in which the suggested methodology can be further developed and tested in the actual practice of land use planning.

FOREWORD

The present volume finds its origin in a request by the Farm Management and Production Economics Service, Agricultural Services Division, FAO to produce a manual on 'farming systems analysis and its linkage with land evaluation and planning'. For that purpose a team was established, consisting of scientists working at the Wageningen Agricultural University and at the International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, both in the Netherlands. As the work proceeded, the importance of the subject became increasingly clear to us and in particular the need to discuss ways of integrating Farming Systems Analysis (FSA) and Land Evaluation (LE). However, the approach proposed and discussed here is new. As a consequence, we decided to produce a working document, rather than a manual (or guidelines for that matter), on 'Land Evaluation and Farming Systems Analysis for Land Use Planning'.

We hope to have argued convincingly that the current practice of land use planning has much to gain from closer linkages between LE and FSA. Integration of LE and FSA may appear to be obvious, but it has never been tried in practice. In the present volume, procedures for integrating LE and FSA for land use planning, the LEFSA sequence, are suggested. While the components of the LEFSA sequence have been tested in extenso as separate activities, the proof of the pudding for the LEFSA sequence as a whole must be in the eating.

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The reader is invited to comment upon the present volume and to contribute to a better integration and complementarity between land evaluation and farming systems analysis in the context of land use planning. Reactions can be directed to: Dr H.A. Luning, Department of Land Resource Surveys and Rural Development, ITC, P.O. Box 6, 7500 AA Enschede, the Netherlands.

Part I. THE STATE OF THE ART OF LAND EVALUATION AND FARMING SYSTEMS
ANALYSIS IN THE CONTEXT OF LAND USE PLANNING

1. INTRODUCTION

1.1. Background: new approaches to meet future human food needs

Over the past decades, land use in developing countries has been subject to an unprecedented pace of change, mainly as a result of the growing demand for crop and livestock products. In many areas, rapid urbanization, mining and deforestation have also greatly affected patterns of land use.

Projections for the year 2000 and beyond suggest that, due to population increase and income growth, demand for food and other agricultural products will continue to rise by over 3 % annually (Alexandratos, 1988: 70). In most countries the diet is expected to diversify in favour of higher value commodities such as livestock and horticultural products. This will have important implications for future land use.

Since the 1960s, growing food demands have been met through substantial increases in food supply, resulting from both area and per hectare yield increases. The degree to which it will be possible to meet future needs will depend on the ability to increase land productivity even more, since the potential for further expansion of arable land is very limited. Moreover, even where agricultural land use could still be extended, such as in tropical forest areas, this would pose a serious threat to fragile ecosystems.

Efforts to increase agricultural productivity through improved technology, however, have focussed so far nearly exclusively on relatively well-endowed areas, in terms of physical resources and infrastructure, and on a narrow range of staple cereals. While this so-called Green Revolution approach has been very successful in terms of output growth, the effects on equity have been more diffuse, depending on the nature of poverty in a given area. Other factors, e.g. institutional inadequacy, population growth and labour displacing mechanization, also have influenced equity issues. One firm conclusion seems to be that farmers in less-endowed areas not suitable for the main crops covered by the international agricultural research centres (especially wheat, maize and rice), most of Sub-Sahara Africa, did not

benefit from the advances in agricultural technology. For an extensive treatment of the consequences of modern crop varieties, see Lipton & Longhurst (1985 & 1989). The awareness of the consequences of the modern varieties has led to the search for new approaches in technology development and land use planning that would include disadvantaged groups and regions and other commodities.

In 1975, 1,078 million persons, or 54 % of the population, in developing countries, excluding China, lived in agro-ecological zones that could not support this population at low levels of inputs (Higgins *et al.*, 1982: 47)¹. In 2000, 1,072 million persons, or 30 % of the population, will still be living in such 'critical' areas. Although the absolute number of people is about the same, the percentage has decreased due to the expansion of irrigated lands, especially in India (Higgins *et al.*, 1982: 48-49). However, there is a limit to the expansion of irrigation. As population continues to increase and land/person ratios decline, intensification of land use becomes essential in the agricultural systems presently using few external inputs. Some regions may be developed rather easily into well-endowed areas, whereas in others such investments in infrastructure, drainage or irrigation facilities and supply systems will be not be economically justifiable. In any case, the most important contribution to production increases will have to be achieved through yield increases per unit area in well-endowed as well as in relatively marginal regions.

In recent years, sustainability has become a key concept to describe the successful management of resources for agriculture to satisfy changing human needs while maintaining or improving the quality of the environment and conserving natural resources (TAC, 1988). Although methods to assess sustainability are still being developed, there is little doubt that intensification of land use at low external input levels is hardly ever sustainable.

Today, one is witnessing a situation of changing demands on land use, of increased needs to deploy efforts in marginal areas and of growing concerns about environmental issues. Under these conditions, designing sustainable

¹ Of course, not all agriculture in those areas is characterized by low input use, for example the agricultural systems on Java. However, in large parts of those areas, the use of external inputs is indeed very low, especially in Africa.

land use systems capable of meeting qualitatively and quantitatively expanding needs of the population in developing countries, presents an enormous challenge to all those concerned - policy makers, planners, scientists and, last but not least, the population itself. What is needed is a clear assessment of the potential of the land and of the existing farming systems, as well as an identification of ways to attain these potentials, in order to develop adequate and sustainable land use plans.

1.2. Scope and objectives of these guidelines

Various methods have evolved to assess production potentials of land and farms. Among these, land evaluation and farming systems approaches are the most elaborate and, in many ways, seem the most promising. Land evaluation was developed as a physical land assessment method by soil survey specialists and has broadened as a concept by the inclusion of socio-economic aspects during the last twenty years (van Diepen et al., 1990). Almost concurrently, but entirely separately, the concepts of farming systems analysis and farming systems research evolved, in which agronomists and agro-socio-economists in particular, have played an important role. Farming systems analysis comprises various sets of diagnostic methods, that focus on the interactions of variables at farm level, covering both agro-ecological and socio-economic aspects, while farming systems research concentrates on experimental methods to test adapted technology at the farm level.

Both, land evaluation (LE) and farming systems analysis (FSA) are practised in the broad framework of land use planning, i.e. in the design of interventions to influence the way in which land resources are used. This volume reviews the state of the art of LE and FSA with a particular view to their contribution to designing sustainable land use systems. Some of the tensions between theory and practice in both approaches are discussed, as well as adjustments and new developments that have emerged in recent years. It also shows how land use planners can take better advantage of the complementarity between LE and FSA. This volume's main contribution, however, lies in an attempt to explore the interface between LE and FSA. It proposes a combined approach that intends to remedy some of the shortcomings of LE and FSA and to strengthen the complementarity between

the two. The LEFSA sequence, the integrated land evaluation and farming systems analysis sequential procedure, is intended as a methodological approach to assist in planning land use systems that best fit the needs of future generations of humankind.

The users of this volume may be farming systems experts, land evaluators, and others involved in land use planning activities. In some ways, this volume is complementary to FAO's Guidelines for Land Use Planning (FAO, 1989) and more specifically to the section on The Land Use Planner's Tool Kit, although the present volume is oriented more towards a specialist audience.

This volume is organized as follows: the present knowledge and experience about land use planning, land evaluation and farming systems analysis are briefly presented and discussed in Part I (chapters 2 and 3), and concluded by a critical review and comparison of the present state of LE and FSA (section 3.3), thus addressing the question how complementarity can best be attained (section 3.4). An answer to this question is worked out in Part II, which focusses on strengthening of the complementarity and integration of LE and FSA for land use planning. In chapter 4, the LEFSA sequence is presented, incorporating both LE and FSA. This sequence is described in a theoretical and prescriptive way. In chapter 5, an elaborated example is provided, in which the various steps of the LEFSA sequence are substantiated on the basis of field data. The issues of what information is needed and how it is to be collected are treated in chapter 6. New approaches and techniques are discussed in chapter 7, followed by conclusions and recommendations in chapter 8.

2. LAND USE PLANNING

2.1. Scope and objectives

2.1.1. Importance and objectives.

Land is an example of a natural resource which, when properly managed, can be used again ('renewable'²), but of which the total quantity is limited in relation to the demand for it (scarce). Land is not uniform. It consists of unique units each with specific characteristics and qualities resulting from genesis, location and use. It is possible to grade land units according to their qualities.

Land can be used for different purposes, of which food production is just one example. As land can be used in different ways, it is important to select that way which is most suited for a particular piece of land and which best serves the interests of those concerned and involved, or at least to avoid unsuitable uses. Different land uses are often in competition with each other. Furthermore the population of an area consists of different groups and individuals, each with their own interests. Consequently, there are bound to be conflicts over the use of land.

To feed the world population adequately, as well as to generate growing incomes and increasing employment opportunities, it is necessary to increase the productivity of land, however, not at the expense of land as a resource. Land should be conserved for future generations; land use should be sustainable. In determining the best modes of sustainable land use, land use planning has an important role to play.

² Renewable - being able to maintain or restore the 'original' state - must be considered in relation to certain qualities of land, like rainfall, location, and perhaps structure, if properly treated; other qualities, like fertility, are exhaustible and should be replenished either by nature or by man.

2.1.2. Definition and setting.

Land use planning is considered here a form of (regional) agricultural planning³. It is directed at the 'best' use of land, in view of accepted objectives, and of environmental and societal opportunities and constraints. It is meant to indicate what is possible in the future with regard to land and its use (potentials) and what should be done to go from the present situation to the future one, in other words, how to improve land and its use. In a similar sense Dent (1988: 183) defines land use planning as 'a means of helping decision-makers to decide how to use land: by systematically evaluating land and alternative patterns of land use, choosing that use which meets specified goals, and the drawing up of policies and programmes for the use of land'.

At one time land use planning took place for areas that were 'empty'. Nowadays these 'empty' areas, for which (re)settlement projects may be designed, are disappearing rapidly. Reclaimed areas are another category for which settlement plans can be made. However, in the majority of cases, land use planning is practiced for areas which are already used in one way or another. Change from the present land use to a projected, presumably improved, land use can only be achieved gradually with the participation of the users of the land. As the users of land are in most cases farm households with specified rights to (the use of) the land, it is difficult and (perhaps) undesirable to enforce changes. It is better to stimulate changes, by creating the proper infrastructure and incentives⁴. Land use planning, therefore, does not end at the stage of indicating the best use

³ Land use (planning) as such involves, of course, also other uses than agricultural ones, for example roads, or tourist, industrial and urban sites. However, given the agricultural background and context of the development of land evaluation and of farming systems analysis, it is practical to restrict land use planning in this volume to agricultural (and forestry) uses. Furthermore, it is impossible to plan the use of land in isolation. Land use means at the same time the use of labour and capital. Therefore, regional agricultural planning would be an even more correct term than land use planning. However, in view of the acceptance of the term land use planning, it will be used here.

⁴ Of course there are examples in which land use changes are enforced: the establishment of plantations in colonial times, the collectivization of Soviet agriculture, the establishment of communes in China, and the movements of farmers into planned villages in Tanzania and Ethiopia.

of land, but should include formulation of all types of measures to be taken by those involved in the use of land to achieve the desired use of land. These measures could include investment in land, for example irrigation. Land use planning aims at the identification of projects, programmes and policies to reach the desired changes.

In each particular situation, specific objectives are required. In general, they include efficiency of the use of scarce natural resources, equity between groups in the society with regard to the distribution of the benefits and costs of the use of those resources, and conservation of those resources for future use. Between those objectives there are often conflicts and tradeoffs. It is also likely that there will be conflicts between different groups of land users about the distribution of the benefits and costs of the use of land (Blaikie, 1985; FAO, 1989; Riddell, 1985). Examples of such groups, each with their own goals, are land owners and tenant farmers, big and small farmers, and commercial plantation owners and adjacent subsistence farmers. The goals of the different groups may also be different from 'national' objectives as formulated by the government. As a result, governments often disagree with farmers over the best use of land. Another source of disagreement could originate from differences between analyses based on private economic and financial considerations and analyses from national economic and/or social points of view, see, for example, Helmers (1977), Gittinger (1982) and Kuyvenhoven & Memmes (1985).

Regional agricultural planning, and, consequently, land use planning, are specific forms of intermediate level planning of sectors and regions within the national economy. Intermediate level planning may be defined as planning of sectors and regions with a view to bridging the gap between general macro-planning and specific project planning. Macro-planning sets, among other things, guidelines for sectoral growth, but usually does not deal with investment projects and their spatial distribution. Project planning goes into great detail of costs, benefits, organization and financing, but takes as given the broader socio-economic framework in which the project operates. In practice, project planning is often not related to the national framework and tends to lose sight of this broader socio-economic perspective. Proper identification and priority ranking of projects require a middle ground which is specific enough to generate project proposals and broad enough to play a role in the national context.

Regional agricultural planning considers the agricultural sector within one region. The justification for such a type of planning is that in most developing countries agricultural activities are very important, especially at the regional level, because often the largest part of the employment and of the income is generated within the agricultural sector, certainly if agro-processing is included. Furthermore, the regional approach in agricultural planning provides the possibility to take into account specific environmental conditions and therefore to arrive at realistic identification of projects.

However, it should be avoided to analyze the agricultural sector of a region too much in isolation from other sectors and regions of a country. If done so, it might overlook important linkages with, and constraints and opportunities for development in, other economic sectors, as well as comparative advantages elsewhere in the economy. Also, development possibilities in the agricultural sector of a region are dependent on developments in the other sectors and regions.

Regional agricultural planning is concerned with the following types of questions: Which crops are most suitable (in view of the objectives, opportunities and constraints) in a given region? What are the advantages of a region in comparison to other regions? What interactions with other regions are important? What are the implications of alternative land uses for income, income distribution and employment? What farm types would be required and are possible? What are the relations between different crops and animals? Would a land reform be advantageous and for whom? What amount of inputs are necessary? How is the marketing to be organized? Is it possible to set-up an agro-processing industry? What physical and institutional infrastructure is required? Which specific projects and programmes are required? What are the necessary policy changes?

Most forms of regional agricultural planning start with a diagnosis of the present situation and then try to identify possible future developments, taking into account the available resources, for example natural resources, like soils, climate and location; population resources, for example types of labour; capital resources, for example existing processing plants and other capital goods, national or local government budgets, and

international loans or grants; and the organization and management capacity of private or government institutions.

In regional agricultural planning the objectives can be derived in part from national objectives, but should be made region - and period - specific. In this context the goals of the farm households in the region play a key role. In general the interest of different groups in society should be taken into account. This is far from simple and constitutes one of the limitations of planning.

Planning, in general, has been criticized during the last two decades for not delivering what it promised. One point of criticism is that it takes too much time and person power. This can be countered by using types of planning appropriate for the purposes of planning in each particular situation and by being very target-oriented and selective in defining the required information and the methods of obtaining the data (chapter 6). Other points of criticisms are more conceptual, and can be summarized under four points (appendix 1):

1. administration bias,
2. lack of knowledge,
3. uncertain future, and
4. harmony versus conflict.

The criticism on planning in general is also relevant for regional agricultural planning and land use planning. The plans developed within that context should be formulated in such a way that they take into account the contradictions in society and are realistic with regard to what can be done, here and now, given the limited resources (financial, person power and implementation capacity) of a government and the limited power of a government to influence autonomous forces in society (Toye, 1989). And although planners have to realize their limitations, planning is useful and necessary to accelerate development. Obvious themes for planning are the physical and institutional infrastructure, and the creation of the right 'conditions' for agricultural development, compare Baum & Tolbert (1985: 27). Furthermore, a government which does not intervene in markets and does not implement programmes and projects, as a consequence of a lack of planning, creates a situation of 'laissez faire'. Such a situation is untenable, especially with regard to the agricultural sector as wide experience shows (Timmer, 1988: 301 & 323-328), and is not in the interest

of agricultural development, nor in that of the majority of the population. For an introduction to economic theories of markets and prices in less developed countries, see Colman & Young (1989).

2.2. Analytical concepts

Phases in planning.

Planning, or in the terminology of van Dusseldorp (1980: 6) planned development, is considered to consist of three main phases: plan preparation, implementation and evaluation. Plan preparation can be further subdivided into goal formulation, diagnosis of the present situation, plan formulation and acceptance of the plan. These phases are not clearly separated in time, but overlap. Furthermore, planning is an iterative process: conclusions in later phases may throw a new light on conclusions arrived at in earlier ones. For example, goals can be set preliminary at certain values, but later analysis might lead to the conclusion that those values are unrealistic, consequently they will have to be reformulated. In the 'Guidelines for Land Use Planning', that distinguishes ten steps in the process of land use planning, which are refinements of the above three main phases, this is called: 'two steps forward, one step back' (FAO, 1989: 15).

Project and programme identification.

Land use planning should result in the identification of projects and/or programmes, with which the proposed changes in the use of land should be accomplished. Detailed formulation and execution of these projects and programmes, however, are not part of land use planning.

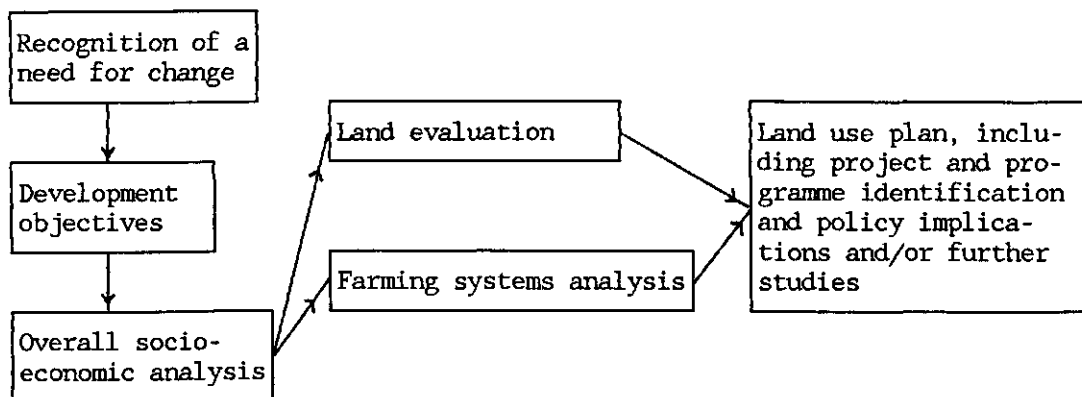
Policy implications.

It is important in land use planning to suggest changes in policies that do effect the use of land, if it is considered that such policy changes will be useful in bringing about a desired change in land use. However, the actual formulation of, and decisions with regard to policies require a higher level of planning.

2.3. Linking land evaluation and farming systems analysis to land use planning

Land evaluation as well as farming systems analysis can be regarded as tools for land use planning. As 'building blocks' they form part of the procedure for land use planning. This is visualized in figure 1. Other building blocks are a 'recognition of a need for change', the 'development objectives', and an 'overall socio-economic analysis'. Together these building blocks can be integrated into a land use plan. This is the essence of the 'LEFSA' sequence for the integration of land evaluation and farming systems analysis for land use planning presented in chapter 4.

Figure 1. A generalized procedure for land use planning.



The main contributions of land evaluation to land use planning are related to three aspects.

- I) Land evaluation looks at potentials for the use of land, for example potentials for the production of certain crops. It looks at future possibilities for the use of land, which is an important starting point for land use planning.
- II) These potentials are based on an evaluation of physical and biological resources, especially land and water, and their possible uses, coupled to an evaluation of economic and social opportunities and constraints. It therefore intends to link biophysical disciplines to socio-economic ones. This gives land use planning a more thorough base.

III) Land evaluation has a strong geographical orientation. At a requested scale, it maps present land use, and the land units, their properties and their potentials for certain land use types. This provides land use planning with an overview of the whole region it is supposed to tackle.

The contributions of farming systems analysis to land use planning are twofold.

- I) Farming systems analysis diagnoses the present situation with regard to farming and land use, by categorizing, describing and analyzing farms and their components, like the household system, and the cropping and livestock systems; and by indicating and analyzing the linkages of farm systems with aspects of higher-level systems that impose constraints on farm level performance, e.g. input supply, credit, extension, and prices and marketing. When farming systems analysis and land evaluation are combined, land use types can be placed properly into farm systems.
- II) Farming systems analysis gives insights in possible and necessary improvements in existing ways of farming. This can lead to recommendations with regard to the physical and institutional infrastructure, like a better input supply, but also to specific agricultural research programmes. These could be backed-up by a farming systems research programme, including on-farm experiments. As such a research programme can only be a long term exercise, it can not play a major role in land use planning in the short run; only in the long run, once results of farming systems research become available, these can be used in future cycles of land use planning.

In the following chapter, the state-of-the-art of land evaluation and farming systems analysis is discussed, both with regard to their theoretical frameworks, as well as with regard to how these approaches are applied in practice. In section 3.4, where the scope for complementarity and integration of land evaluation and farming systems analysis is discussed, reference will be made again to land use planning. From chapter 4 onwards, ways in which land evaluation and farming systems analysis can be used for land use planning are elaborated through proposals for an integrated land evaluation and farming systems analysis (LEFSA) sequence.

3. LAND EVALUATION AND FARMING SYSTEMS ANALYSIS: A COMPARISON OF CONCEPTS AND METHODS

3.1. Land evaluation

Land evaluation (LE) is the process of assessing the suitability of land for alternative uses. This process includes:

- i. identification, selection and description of land use types relevant to the area under consideration;
- ii. mapping and description of the different types of land that occur in the area; and
- iii. the assessment of the suitability of the different types of land for the selected land use types.

The concepts, methods and procedures are described in detail in 'A Framework for Land Evaluation' (FAO, 1976) and in subsequent FAO publications about LE procedures for specific land uses (rainfed agriculture, forestry, irrigated agriculture and extensive grazing, FAO, 1983; FAO, 1984a; FAO, 1985; and FAO, 1987, respectively).

3.1.1. Objectives.

The main objective of LE is to assess the suitability of different types of land, usually shown on maps as land (mapping) units, for selected and specified land use types. The selected land use types may include forestry, recreation and conservation land use types in addition to agricultural land use types, particularly when areas are involved where agricultural uses may not be productive, sustainable or socio-economically relevant.

In the land evaluation process, each land unit is assessed with regard to its suitability for the selected land use types. The biophysical characteristics of the land units involved may be the current ones or may be the ones after investment in 'land improvements'. Land improvements are reasonably permanent changes in the conditions of the land, e.g. by measures as irrigation, drainage or terracing. Such improvements should, of course, be relevant within the regional socio-economic context. It is

useful to distinguish between minor land improvements, which can be implemented by individual farmers, and major land improvements, which cannot normally be financed and executed by individual farmers (FAO, 1983: 229).

A land use type is specified in terms of socio-economic and technical attributes, and of requirements. Main, or key, attributes, mentioned are: type of product, labour intensity, capital intensity, level of technical knowledge, farm size, and land tenure relationships. A distinction can be made between those attributes belonging to the 'setting' of a land use type, e.g. farm size and land tenure relationships, and those more intrinsically related to the land use type, e.g. the (quantitatively specified) inputs and outputs. For more details, see appendix 5, part III.

Land use requirements are biophysical conditions that affect yield and yield stability of the land use type (ecological requirements), management of the land use type (management requirements), and yield sustainability of the land use type (conservation requirements). These requirements are expressed in terms of land qualities. The nature of these land qualities is extensively treated in FAO (1983, 1985 & 1987); for a listing, see appendix 5, part III, table 2.

In context of land evaluation, land includes all biophysical components of the environment that influence land use, i.e. (agro-)climate, landform, soil, surface hydrology, flora and fauna including the more permanent effects of current or past human activities on these components. Land is described according to its current qualities, or when land improvements are considered, according to the (predicted) qualities after the implementation of the improvements. Land qualities are determined by land characteristics, observable or measurable, biophysical properties of land (e.g. rainfall regime, slope, soil depth, soil drainage, pH, the occurrence of toxic plant species, etc.).

A requirement (e.g. nutrient availability in the root zone) is a condition necessary or desirable for the successful and sustained practice of a land use type. On the other hand, as was explained above, land units have certain qualities (e.g. nutrient supply by the root zone). By comparing the requirements with the qualities -matching- the suitability of the land use types for the land units is assessed. This assessment involves estimations

of the quantity and quality of the produce that can be obtained from each land unit based on the inputs and management as defined in the description of the Land use types. Matching is an iterative process. On the basis of the comparisons made, it may be decided (i) to adapt the inputs and management of the selected land use types; or (ii) to consider land improvements that alleviate adverse land qualities and thereby improve the suitability of land for certain land use types.

Fundamental principles in the suitability assessment in LE (FAO, 1976) are:

- the selected land use types must be relevant to national/regional development objectives as well as to the physical, economic and social context of the area concerned;
- the land use types are specified in terms of socio-economic and technical attributes, and of requirements;
- the evaluation involves the comparison of two or more land use types;
- land suitability refers to use on a sustained basis;
- the suitability assessment includes a comparison of yield (benefits) and inputs (costs); and
- LE requires a multi-disciplinary approach.

LE supports land use planning by supplying alternatives for land resource use and by providing for each alternative, information on yield and input levels (and/or benefits and costs), management, needs for infrastructural improvements and effects of the land use on the environment (on-site or off-site). Decisions on desirable land uses or land use changes and the planning of interventions in the form of policies, programmes and projects to implement such land uses or land use changes, are part of the (land use) planning process. LE specialists should be involved in the integration of LE results into this process.

3.1.2. Levels of analysis.

Levels of analysis and survey intensity depend on the objectives of the LE. These objectives determine the map scale of the land resource inventory, the degree of detail with which mapping units and land use types are described, and the terms in which land suitability is assessed. The level of analysis of a land evaluation determines to a large extent the manpower and cost requirements.

The way in which results of the land suitability classification are expressed is generally related to the degree of integration of biophysical and socioeconomic information. Two types of classifications are distinguished (FAO, 1983):

- qualitative land suitability classification; and
- quantitative land suitability classification.

Qualitative classifications do not include specific estimates of outputs (crop yields), inputs, or costs and returns. They result from biophysical evaluations of larger areas at reconnaissance scales. Quantitative classification may be in physical or economic terms. Quantitative physical classifications provide estimates of yields and management in kg/ha, number of treatments/season, labour days/ha, etc.). In economic classifications, the results are expressed, at least in part, in monetary terms (gross margin per ha or labour day, net income per ha). It is not advisable to present the results of a LE solely in monetary terms: such results may become outdated quickly because of price changes. The results of an economic classification should thus be presented as a supplement to the quantitative physical classification on which it is based.

Table 2 shows relations between LE context and objectives, map scales, description of mapping units and land use types, and terms in which land suitability is expressed.

3.1.3. Procedures.

LE involves the analysis of biophysical and socio-economic data. The LE methodology thus consists of integrating a number of concurrent and sequential activities which include the collection, analysis and integration of different data sets.

The aims of land resource surveys for LE are:

1. to divide the study area into land units that are as homogeneous as possible for the purposes considered; and
2. to describe the (relevant) land characteristics of these land units.

Two types of land resource surveys can be recognised:

1. General purpose surveys: information provided by these surveys can be used for the evaluation of land for many uses, now or in the future.

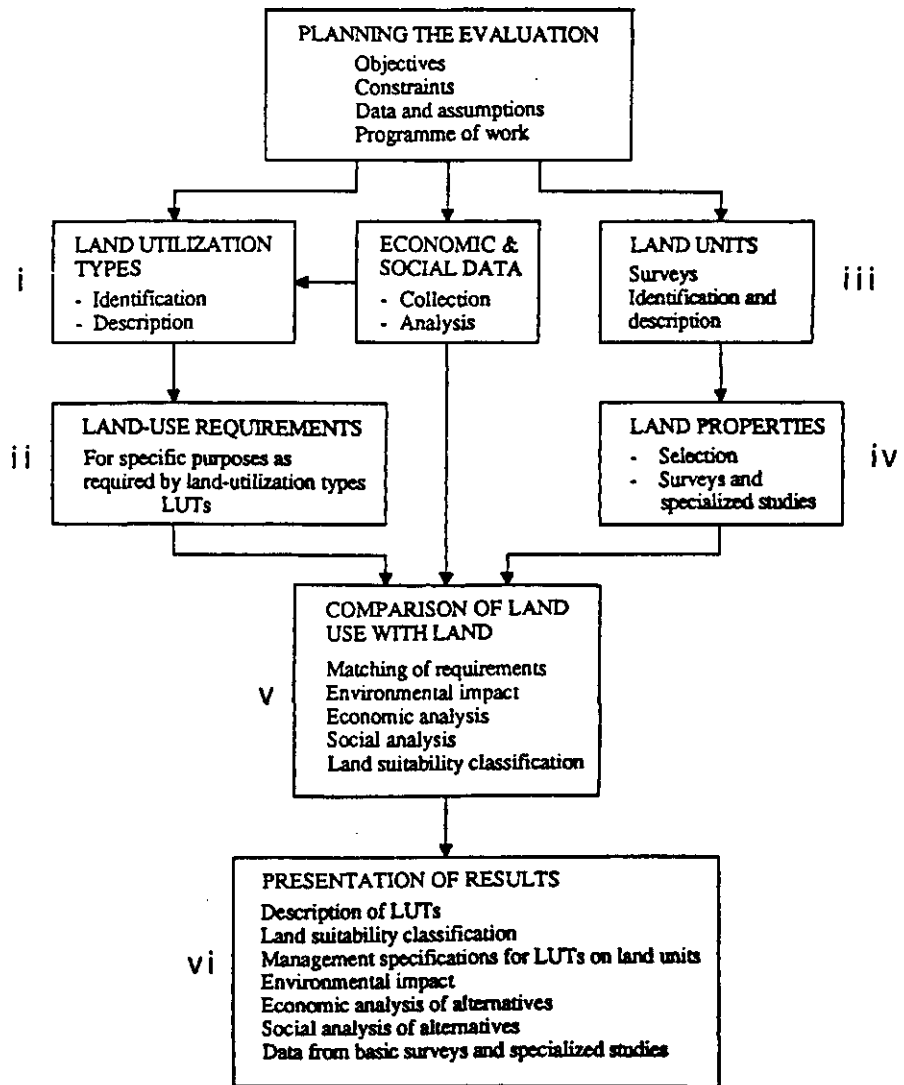
Table 2. Levels of analysis in relation to objectives and context of land evaluation.

Objective/context of LE	Nature of LE; scale of maps	Type of mapping units	Description of LUMs	Terms in which assessments are made
Broad biophysical potentials and constraints within countries	Agro-ecological zones; 1:500,000 to 1:2,000,000	Highly generalized, based on agro-climate, main relief types and major soil groupings	Major LUMs (e.g. rainfed annual crops, forestry); or crops with broadly defined management levels	Performance ² in qualitative terms (i.e. good, moderate, poor)
Selection of biophysically promising areas and land use options for development in (larger) regions within a country; choice of project location	Reconnaissance; 1:500,000 to 1:100,000	Compound with description of components and indication of % of mapping unit occupied by the components	Ditto	Qualitative; sometimes inputs and outputs in quantitative physical terms (kg, man-days, etc. in ranges per ha)
(Pre-)feasibility studies for districts projects, programmes; project identification	Semi-detailed ¹ ; 1:100,000 to 1:25,000	Ditto; sometimes (generalized) description of major components only	LUMs with specified technology and management levels (incl. cropping patterns, levels of input, practices, tinning, etc.)	Performance ² in quantitative physical terms and/or financial terms
Village planning; project implementation	Detailed ¹ ; > 1:25,000	Mainly simple mapping units with one major component and some inclusions	Ditto	Ditto

1) The cost-effectiveness of more detailed surveys and evaluations is greater when they are preceded by cheaper, less intensive surveys.

2) Performance is assessed in terms of production/productivity and sustainability per unit of land.

Figure 3. Land evaluation procedures.



Source: FAO, 1984.

General purpose surveys are mostly carried out as systematic surveys by national soil survey or land resource survey agencies. They are mostly time-consuming and costly.

2. Specific purpose surveys: based on land use types selected at the beginning of the survey (i.e. information collection is directed towards land qualities that affect the suitability of land for these land use types). Specific purpose surveys are cheaper, but new surveys may be needed when new land use types are considered in the future.

Figure 3 shows the overall land evaluation procedure. After planning the evaluation itself, it includes the following steps:

- i. Selection and description of land use types, which are relevant to policy objectives, the development objectives as formulated by planners and to the overall socio-economic, land use and agro-ecological conditions in the area (derived from the analysis of the 'economic & social data').
- ii. Determination of the land use requirements of each of the selected land use types.
- iii. Delineation of land (mapping) units based on the results of land resource surveys (climate, landforms, soils, land use, vegetation, surface and groundwater). Each of these land units has a number of characteristics such as slope, rainfall, soil depth, drainage, vegetation cover, etc., in which it differs from neighbouring land units.
- iv. Translation of the characteristics of each land unit into land qualities such as the availability of water and nutrients, the resistance to erosion, etc., which have a direct impact on the performance of the selected land use types.
- v. A 'matching' process in which the requirements of the land use types are compared with the qualities of each of the land units. This leads to suitability classifications of the land units in physical terms, separately for each of the land use types considered. Suitability classes express the relative fitness of a certain land mapping unit for a selected land use type. Suitability classes may refer to current land conditions, or, when land improvements are considered in the evaluation, to suitabilities after the implementation of these improvements.
- vi. An analysis of possible environmental impacts of land use changes that might be implemented on the basis of the results of the LE; and,

depending on the objectives of the LE, the expression of land suitability classes in financial terms.

The main types of information on land resources required for land evaluations for agricultural purposes concern agro-climate, surface and/or groundwater resources, landforms, soils, and present land cover and land use. In land evaluations for forestry, extensive grazing and nature conservation, a forest inventory and vegetation survey may be needed in addition.

Land evaluation is thus essentially based on a comparison of land resource data with land uses and the ecological, management and conservation requirements of these land uses. It is ideally carried out by a team which includes one or more land resource scientists, agronomists, (socio-)economists, rangeland specialists, forestry specialists, etc. The team composition is determined by the objectives of the evaluation and by the land uses considered to be relevant for the area.

3.1.4. Presentation of results.

The main results of LE include:

- i. Map(s) showing land (mapping) units, the suitability ratings for the land use types considered for each land unit, and the physical constraints of the land units for the land use types; and
- ii. Descriptions of the land use types in table format.

In more detailed LE, results of the economic analysis for highly, moderately and marginally suited land unit / land use type combinations are often added.

The map(s) show the degree of suitability of the land units for the land use types, and locations and areas (hectares) involved. The classification of land as 'suitable' indicates that the land is physically suited for the land use type and that sustained land use is physically possible and economically viable. 'Suitable' classifications for different land use types, however, do not mean that gross margins, employment characteristics, etc., are the same. The descriptions of the land use types, therefore, provide essential additional information, because they make it possible to determine the consequences of the implementation of a land use type in terms of income generation, labour requirements, infrastructure

requirements, etc. These are basic criteria used in the preparation of land use plans.

Appendix 3 shows a land evaluation case study (adapted from Sadhardjo, 1986) for a small, highland watershed in East Java, Indonesia. Table 1, 3 and 4 of this appendix show the main results of the land evaluation in a simplified form.

3.1.5. Land evaluation in practice.

Proper application of the LE methodology requires close cooperation between natural resource scientists, agronomists, agro-socio-economists, foresters, etc. In practice, land evaluations based on the framework carried out in the last decade range from pure biophysical evaluations to integrated, multi-disciplinary evaluations.

Pure biophysical evaluations are often carried out by soil survey organizations. Socio-economic aspects are not considered; land use types or crops may be selected on the basis of biophysical arguments only. Such evaluations cannot be considered as 'true' LE according to the FAO Framework. Despite the rather monodisciplinary character of such evaluations, however, they can be very useful, particularly in reconnaissance surveys of larger areas that aim at the selection of land use priorities and promising areas for development (project location).

More fully integrated land evaluations by teams of natural resource scientists, agronomists, agro-economists and other specialists are less common. Examples of such evaluations are, for instance, presented in FAO/UNDP (1977 and 1979), Beek et al. (1980) and de Meester & Legger (1988). Several FAO projects (e.g. projects in Liberia, Malawi, North-Yemen and Oman) are or have been applying a more integrated LE approach.

Current shortcomings of many land evaluations are related to problems in integrating agronomic and socio-economic information. In addition logistic and/or administrative constraints play a role, for instance:

- i. institutions applying LE are often natural resource agencies which do not always have qualified personnel in the fields of agronomy and socio- economics; and

- ii. a multi-disciplinary approach involving the cooperation of various institutions is mostly difficult to organize effectively.

A constraint of the LE methodology itself is the lack of clear procedures for the selection of land use types. Land evaluations in practice, therefore, seldom indicate the criteria used for the land use type selection. Farming systems information, which is essential for the selection, is often not available or inadequately used in the selection procedure. Another limitation in LE is the insufficient current quantifiable knowledge on ecology and agriculture, particularly in tropical areas. This makes the matching procedure less reliable. What are critical values of the land use requirements/land qualities with respect to a certain productivity/sustainability level of a land use system? A proper assessment must be based on knowledge of 'yield-management-land quality' relations. This knowledge is dependent on results of experiments/trials, farmers' knowledge and experience, and field observations by experienced surveyors.

Modelling of crop growth and land degradation may reduce the amount of information that is needed for the matching of land use requirements and land qualities. Models, however, require reliable, specific data sets for each study area for their calibration and validation. In addition, basic data are required to extrapolate the results of crop growth modelling to larger areas. The same applies to the use of 'transfer functions' (Bouma & van Lanen, 1987) which assess land qualities on the basis of simple, observable and measurable, land characteristics such as soil depth, clay content, rainfall, etc.

A constraint which applies to some (not all) land evaluations is the rather generalized description of the land units. Essential information on important components of land units is sometimes not included. The same may apply to the description of the variability of the land characteristics of mapping units or their components. This description is sometimes based on 'typical' situations or 'model soils' only.

3.2. Farming systems analysis

3.2.1. Background and objectives.

This section discusses mainly the body of knowledge that is concerned with diagnosis and analysis of farm level variables, which is defined as farming systems analysis (FSA) here. The experimental side of the farming systems approach, farming systems research (FSR), also referred to in the literature as on-farm trials, or on-farm or adaptive research, will receive only cursory attention because of its more limited relevance to land use planning.

FSA has emerged in response to the concern over the increasing gap between the yields obtained on experimental fields and actual farmer yields⁵. This gap can be attributed to the fact that agricultural research in the past has focussed much more on increasing, and understanding, the potential of crops and livestock, rather than on adapting agricultural technology to farmers' ecological and socio-economic production constraints. Farming 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. In other words, farmers use agricultural production to satisfy many, diverse needs. Thus they have multiple goals, and it is this acknowledgment that has provided an important starting point for FSA. Initially, many farming systems studies focussed on the question why many farmers have not been able to benefit from the new technology developed by agricultural scientists and why the impact of technology differs so widely between farmers and regions. The generalized conclusion was that 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. This has in turn led to efforts to adjust the agricultural research agenda to the needs and constraints of farm households in the tropics and subtropics.

⁵ An other important reason for the emergence of FSA was a need to know more about farming systems in general, especially for the analysis of agricultural policy questions (e.g. prices, credit and input supply).

Although many debates on the state of the art are still conducted, there appears to be a general agreement on the overall objectives of farming systems analysis and research. Both FSA and FSR were, and still are, nearly exclusively focussed with developing agricultural technology for small farmers⁶, i.e. farmers who undertake a variety of cropping and/or livestock activities, often on fields of limited size, use family labour and relatively few externally purchased inputs. Mostly, the focus is not on increasing yields of one crop, but on increasing the long-term stability of yields and reduce risks, for example through diversification of crops or crop varieties. Emphasis has therefore been put on crop and livestock species that hitherto have been rather neglected by the mainstream of agricultural research, such as cassava, sweet potato, yam, millet, beans, goats and buffalo. Within this context, farming systems analysis studies constraints and potentials in existing farming systems, in particular those that result from specific farm practices such as multiple cropping and the use of micro-variations in the environment.

Because farming systems analysis has most of its roots in agricultural research, its objectives and methods are primarily aimed at complementing and directing ongoing applied research in agriculture. A distinguishing feature of farming systems analysis in comparison to most classical research in agriculture is its interdisciplinarity and its attempts to integrate the results of various disciplines, in order to understand the linkages between the agro-ecological and socio-economic aspects of a farm. Many of the insights gained in this context, particularly the diagnostic procedures, however, can also be applied in other development-oriented programmes, such as land use planning.

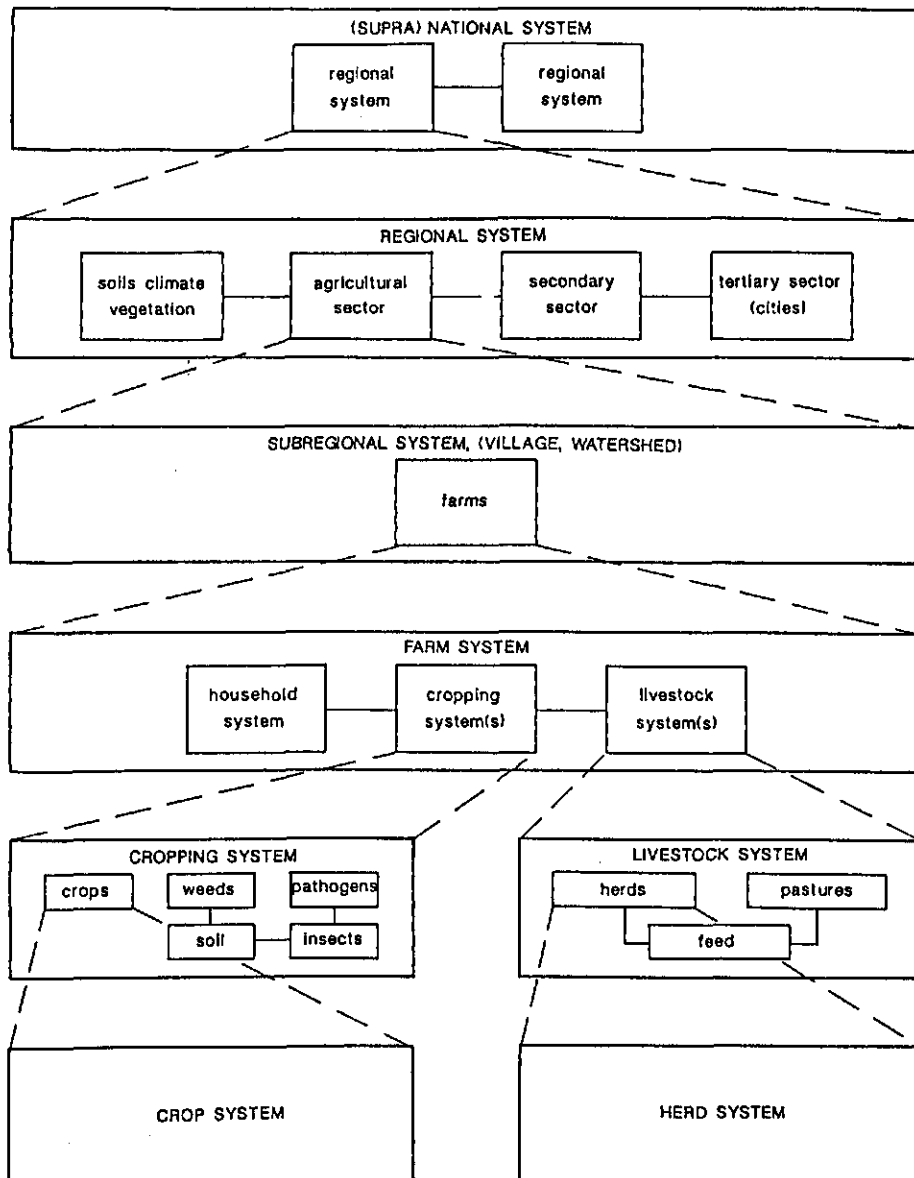
Farming systems analysis derives its theoretical framework largely from systems analysis (see appendix 4). It distinguishes between systems at various hierarchical levels, ranging from the plant system through the crop system, the cropping system, the farm system⁷ (which includes the farm

⁶ However, not exclusively, see note 5.

⁷ In contrast to the majority of authors, who do not make this distinction, the term farm system refers to a specific system level in the hierarchy at which the individual farm is studied as a system, whereas 'farming system' is referred for a class of similarly structured systems. FSA studies farm systems in order to group them into farming systems.

household⁸), to the higher level land use systems (village or watershed and regional or national systems), as illustrated in figure 4.

Figure 4. Agriculture as a hierarchy of systems.



Source: Fresco, 1986.

⁸ The farm system as defined here, is equivalent with the farm-household system as defined in FAO (1990: 15-16). Both includes the farm household, the farm (with cropping and livestock systems) and an off-farm component.

3.2.2. Procedures.

FSA and FSR procedures are often combined but they can be separated into two clearly distinct phases, each divided into a number of steps (Collinson, 1987): diagnosis and experimentation. Together, these procedures form a sequence that is repeated whenever necessary, even if this sequence is not rigorously defined.

FSA starts with an area approach rather than a thematic one: it concentrates on a given area and analyses the problems faced by farmers in that area (e.g. Conway, 1985a). It identifies homogenous target groups composed of farm households operating in approximately the same environment. This implies that these farm households are part of similar systems at different levels of the hierarchy: similar conditions at regional, village, farm and cropping system levels. The degree of similarity is always difficult to assess, even qualitatively, but in general farmers belong to the same target group if they experience the same problems and opportunities. The outcome of the diagnosis consists of possible solutions and opportunities to alleviate constraints in that environment. More specifically, then, the diagnostic phase has the following, interrelated objectives:

- to describe 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 require interventions; and
- to indicate potential improvements.

Ideally, diagnosis is an iterative process which becomes increasingly focussed on particular types of farm 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. The diagnostic work has, by definition, a strong multidisciplinary and interdisciplinary focus, and close collaboration with the farmers and

representatives of the rural community is prescribed, even if not always adhered to. Typically a diagnosis consists of the following steps.

1. Characterization of the study area. Through a study of secondary sources such as existing statistics and maps an initial impression of the problems and potentials 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 up to one month. During this period short visits to the area are combined with the training of field assistants. It results in the selection of representative pilot area(s) for further study. Pilot areas must reflect typical conditions in the region, with respect to climate, soils, relief, 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 rural appraisals (RRA), also known under other names, for example, exploratory/informal surveys (Collinson, 1982), sondeos (Hildebrand, 1981), exploratory diagnosis (FAO, 1990), 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 the objective of formulating hypotheses about possible interventions. Since interviewing procedures are highly dependent on the social context, the selection of the interviewees requires special care. Interviews are best combined with field observations (Ashby *et al.*, 1987). When the interviews for a particular pilot area or village are completed, a few days are spent to evaluate the results, draw conclusions and formulate tentative hypotheses.

The rapid appraisal may take several weeks, and may be repeated several times throughout the agricultural seasons. Its outcome consists of an ecological and socio-economic description of the pilot area (land use/village system) and identification of issues that need further study. Leading questions usually include: Why do farmers do what they do? Are there unidentified opportunities in the farm system? What constraints do farmers face? Are there great differences between farmers? If so, to what can they be attributed? Rapid appraisals constitute an essential step in the process of FSA, enabling development officers, planners and researchers

to communicate among themselves and with farmers. It goes without saying that quantitative data, especially of longer time series can only be obtained through formal surveys. Rapid surveys allow the latter to be more cost-effective and better focussed through the definition of farming systems zones (FAO, 1990) and recommendation domains (Byerlee et al., 1982).

3. Definition of farming systems zones and recommendation domains. Farmers within a broad target group, may still 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. Target groups may be divided into farming systems zones and recommendation domains. The latter are more narrowly defined: a more or less homogeneous group of farmers with similar circumstances for whom similar recommendations can be made (Byerlee et al., 1982)⁹. These classifications may change over time as the adoption of new techniques proceeds or as external circumstances change, so that new differences between farmers emerge. Initially, the categorization helps to identify similar groups, and later, when agricultural technology is being tested and extended, it helps to identify sites for on-farm tests and to tailor recommendations to the specific circumstances of different farmer groups. In the strict sense, recommendation domains in FSA relate to the farm 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 could be argued that each farm system constitutes a unique constellation of components and could be considered a farming system zone or recommendation domain by itself. This would of course be very impractical, and overlooks the fact that within the context of agricultural

⁹ Recommendation domains differ from farming systems in the sense that the former may refer to improvements in one component of the farm system only, e.g. virus-resistant maize varieties which are relevant to farmers with different farming systems. In other words, for a specific technology farmers of different farming systems may belong to the same recommendation domain. In contrast, farming systems zones are more or less homogeneous geographical areas of one or more farming systems. They represent areas for possible interventions (FAO, 1990: 79).

development what matters are relevant differences between groups and similarities within groups. During the definition of relevant differences, 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 farming systems zones or recommendation domains follows from the formal survey, so that quantitative correlations between different farm household and farm characteristics can be established.

4. Formal surveys. Formal surveys are a way to obtain quantitative data on the farming systems, cropping system and livestock systems in the pilot areas with the intention of verifying the hypotheses formulated during the rapid appraisal. Because they are without exception very demanding in terms of time and costs, these surveys must be as focussed as possible, and complement other forms of diagnosis. This means that it is only useful to conduct a formal survey if one knows exactly what information is required, and that such quantitative information will make a significant contribution to the understanding of the situation. Formal surveys require the use of sampling procedures, pre-tested and standardized questionnaires and other methods that allow statistical treatment of data. They demand well-trained personnel both for conducting the survey and for 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 visited more often, for example weekly, or are asked to keep records, so that more detailed data are acquired. Formal surveys may take several months including preparation, pretesting, data analysis and report writing (or more if multi-annual data are required). In any case, the time required for formal surveys should not be under-estimated.

5. Analyzing and presenting the results of the diagnostic phase. In the past, data processing constituted sometimes a bottleneck in many FSA programs. If processing and analysis take too long, the data may already be outdated by the time field experimentation starts. Preferably, processing should already take place in the course of the preceding phases.

The results of a diagnosis can be presented in several ways, and there is some emphasis in the literature to include ways that can also be grasped by farmers, and discussed with them so that they can give their feedback (Mutsaers et al., 1986). Diagrams, charts and other visual presentations

can be useful for that purpose because they give a summary of verbal data. Good results are obtained with transects that give a spatial representation of the farm system (figure 5).

The final report of the diagnostic phase should contain a description of the regional system, of the pilot area (villages or land-use units), of the farming systems, and of the recommendation domains within each of these.

Ideally, the outcome of the diagnostic phase is the analysis of constraints and potentials of distinct categories of farmers, including the interactions between different types of constraints as well as an identification of priority problems at each level of the hierarchy of systems.

In the classical sense, most FSA takes place in the context of agricultural research. In this case development options are translated into agricultural experiments. However, this is not the only way in which diagnostic results are used; the integration of FSA in regional and project planning can broaden the way in which farmer constraints can be solved.

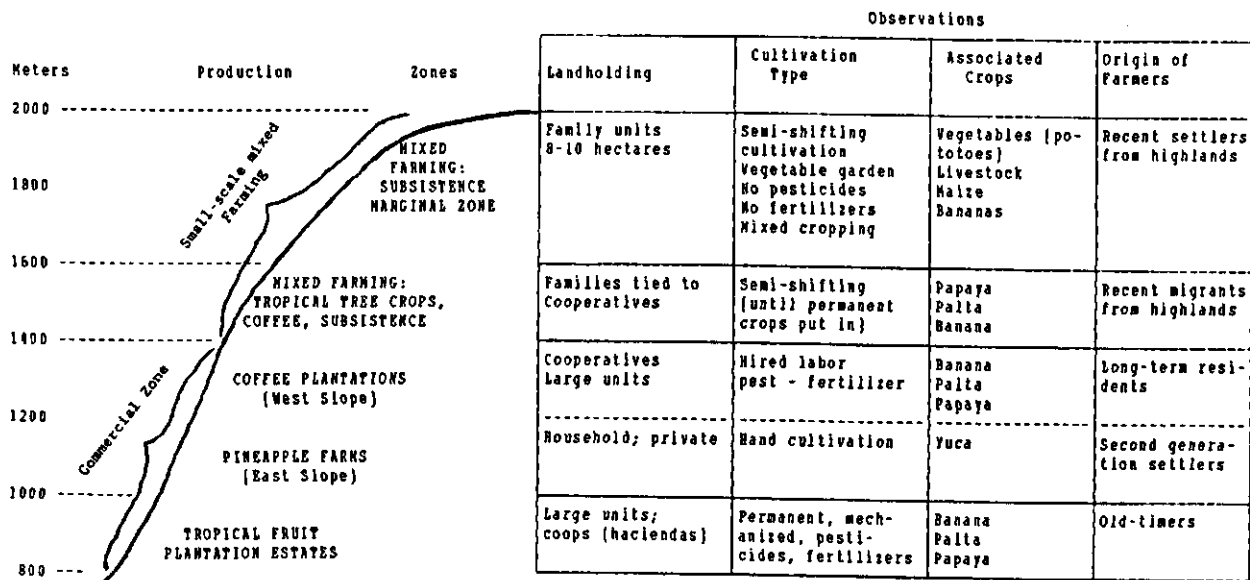
Some constraints may be addressed through on-farm experimentation, while others will need interventions by regional or national development agencies, such as marketing boards or credit unions, or even changes in national policies.

3.2.3. Strengths and weaknesses.

Over the past decade FSA has drawn much attention. By now, many development workers, planners and researchers in developing countries have become acquainted with some of the basics of FSA. The main benefits thus far are the development of a greater awareness of the constraints and potentials of small farmers, the emergence of a detailed set of survey methods and a formal approach to setting agricultural research and development agendas. Some methodological problems still remain, in particular questions relating to the limitation of data collection during diagnosis and the optimal design and phasing of on-farm interventions and experimentation. Most pressing, however, are institutional and organizational issues in FSA.

Figure 5. Agro-ecological transect, Chanchama, Peru.

Diagram 1: Agro-Ecological Transect. Chanchamayo, Peru.



Source: Rhoades, 1982.

The impact of FSA will remain limited unless it is part of a larger long term rural development effort, so that non-agricultural, non-experimental variables (that cannot be easily included in real time experiments, such as prices, marketing, input supply, etc.) can also be tackled effectively. The scope of FSA suggests that it can be an autonomous activity (and so it has been in several foreign aid projects), however, one must be aware for the risk of overestimating its role and equating FSA with rural development.

In the best instances of FSA, it has successfully shown the importance of a detailed analysis of farmer's constraints and the usefulness of an ongoing dialogue with farmers. However, the cost effectiveness of FSA has hardly been the subject of systematic evaluation. Clearly, if FSA depends on expensive expatriate personnel, its future role is limited. On the other hand, national development officers, planners and researchers require both

the training and the incentives as well as the logistics to conduct farm level surveys and donor supported programmes may help to get started.

There are many issues that have hardly been tackled by FSA, because of their organizational complexity. In particular, the design of sustainable land use systems, rather than minor improvements in existing farming patterns, has been neglected (Simmonds, 1986). Other aspects, such as the closer integration of crops and livestock and perennial species, or, on the other hand, the position of women farmers and agricultural labourers, require an extended and coordinated commitment by many government or private agencies. For farming systems analysts, as for other scientists, the ultimate challenge lies in slowing down the rate of natural resource degradation and the design of ecologically, economic and socially sustainable farming systems.

3.3. A critical comparison of land evaluation and farming systems analysis

A comparison of LE and FSA meets with the difficulty that the two approaches stem from very diverse backgrounds. LE has evolved from soil survey work and has always been closely associated with regional and project planning, whereas FSA is basically a diagnostic procedure and has mainly been carried out within the framework of agricultural research and development. Increasingly, however, quantified LE is used as an input into potential agricultural production research, although linkages between LE and FSR hardly occur.

Furthermore, one should also distinguish between theory and practice. Certain subjects or methods may be considered desirable, but are hardly ever dealt with in the normal practice of either LE or FSA, even if certain individuals may apply them. The FAO guidelines for land evaluation, for example, state clearly that selected land use types should be 'physically and socio-economically relevant to the local area concerned'. However, in practice this requirement is not sufficiently met, or should be researched more thoroughly before the actual evaluation takes place, especially with regard to the socio-economic aspects. Nevertheless, the two approaches have more in common and are more compatible than would seem at first sight. This section examines the relative differences between LE and FSA as they are

generally practiced and suggests areas of methodological as well as substantive complementarity that are further explored in part II.

3.3.1. Objectives and scope.

The scope of FSA is both narrower and wider than that of LE. FSA intends to analyze farm level constraints with the aim of developing adapted technology and interventions for specified categories of farmers, while LE is directed towards determining the suitability of certain types of land use. In diagnostic terms this implies that FSA focusses on determining present uses of land, in contrast to LE's emphasis on future and potential uses. To some extent, however, this difference reflects the past of both approaches rather than methodological necessity. FSA methods could also be applied in a regional planning context, even if this rarely happens, and, vice versa, LE methods could be integrated into the process of agricultural technology development. An important difference, at least on paper, is that FSA focusses not just on maximizing productivity per unit of land, but takes into account labour productivity as well as equity issues. Both approaches share the desire for sustainability of land use, although this concern is more easily stated than achieved. Although the setting of research agendas is an explicit outcome of FSA, LE may also result in clear recommendations for agricultural research to alleviate land-related constraints.

3.3.2. Disciplinarity.

While in LE the basic disciplines are soil science, economics, and to a lesser extent agronomy, the former hardly figures in FSA. FSA teams usually involve an agronomist, an economist and/or an anthropologist. The collaboration between the disciplines is a point of contention in FSA. In LE this does not seem to be the case, most probably because of the existence of a more clearly defined framework that structures the contribution of each discipline. However, in practice the inputs of the social sciences are very limited, as often there is no budget for an economist or sociologist, or such an input is outside the scope of the institution responsible for soil surveys and land evaluations. In contrast to FSA, LE does not aim at interdisciplinary, but only at multi-disciplinarity, i.e. a cumulation rather than a true integration of disciplines. Another difference lies in the fact that FSA attempts to

promote, with varying degrees of success, the involvement of farmers as active participants in an ongoing dialogue.

3.3.3. Units of analysis.

Both LE and FSA tend to start with an area or regional approach rather than a thematic approach limited to certain soil types or crops. The ultimate unit of analysis in LE is the land use type which can be characterized according to key attributes and has certain requirements with respect to land. FSA analyses farm systems that are composed of specific subsystems (e.g. cropping or livestock systems). Since land use types are nearly always, with the exception of newly reclaimed land, a component of farms, it is logical to assume a close correlation between cropping (or livestock) systems on the one hand and land use types on the other. See for an example of such an approach, appendix 2. Such an equation is only possible, however, if land use types are defined in a narrow sense rather than a broad sense, i.e. irrigated rice rather than irrigated crops in general. It would be even more desirable if more detail were provided in the definition of the land use types, since FSA tends to describe its cropping (or livestock) systems within a given region with great specificity, e.g. IR-36 at specified management and input levels rather than just irrigated rice, but mostly LE does not include that degree of detail. As will be discussed in section 4.2, the degree of detail is to a large extent a function of the objectives and the phase, and therefore the level of analysis. In the sequence of LE and FSA the degree of detail increases as one moves through time and approaches in the analysis the levels below the farming system. In other words, there will be a better chance of a good fit between land use type and cropping/livestock system, and hence more similarity, as time proceeds.

There are of course differences between the concepts that will remain of importance, especially in those cases where FSA and LE are not undertaken jointly. The term cropping or livestock system includes the land on which the crop(s) are grown, whereas in LE land is clearly separated from its use in order to carry out the matching between requirements and qualities. The soil is part of a land unit, and not of a land use type. Furthermore, the descriptors for the two concepts, land use type and cropping or livestock system, are not identical. In principle, both are based on an input-output analysis, although this is more often made explicit in FSA.

At present, FSA only provides generalized, aggregated regional information on natural resources, and hardly provides ecological detail at the cropping/livestock systems level, while LE often treats socio-economic data, including labour inputs, with a great deal of generality and particularly neglects or ignores the intrahousehold allocation of resources. Another important distinction is that LE ignores any relations between land use types within the context of the farm, in the sense that the allocation of resources to some land use types may withdraw resources from others and that farmers will optimize production at the farm level given their own specific objectives, instead of maximizing the productivity of each land use type. This type of farmer's 'compromise' between productivity and risk is a central issue in FSA: since, nearly without exception, farming systems consist of more than one subsystem, subsystem interactions are crucial to understanding the performance of the system as a whole. Consequently, there is a major difference with respect to the choice of the ultimate scarce factor: land or labour. LE focusses almost exclusively on land, whereas FSA concentrates on labour, and only to a lesser extent on land. In practice, LE may suffer therefore from a 'major crop bias' and generally disregards non-agricultural or off-farm activities by household members. FSA has drawn attention to the multiple factors that govern the functioning of farm households and the way in which these factors are translated into cropping (or livestock) patterns so as to enable farmers to make the most of their resources. Studies of scarce factor management by farm households and the determinants of risk avoidance strategies have put this issue into focus (e.g. Huijsman, 1985; Ellis, 1988).

3.3.4. Scale.

The discussion on the differences in units of analysis is closely linked to a discussion about the scale at which both approaches operate. It is often assumed that FSA deals with micro-level variations, whereas LE has a macro-level orientation, and is therefore, technically speaking, more small scale. This, however, is an unwarranted simplification. Scale in LE or FSA depends on objectives, and is not a fixed characteristic of the methodology. If time and funds permit, LE may well focus on detailed, large scale units. In the same way, FSA may concentrate on higher levels of the

hierarchy than the livestock or cropping systems, and study similarities between farming or village systems operating in different environments.

Issues of scale are closely related to variability within units. Small scale analysis implies large units that can never be entirely homogeneous. The degree of heterogeneity accepted depends on the objectives, but also on the way in which the analytical framework permits an understanding of factors causing heterogeneity. FSA is only interested in spatial patterns within the area insofar as they relate to socio-economic target groups, such as farmers on slopes and valley bottoms. Spatial variation (within and between land units), of course, is a key issue in LE. In general, the attention in LE centres on variation between land units rather than on variation within land units. Usually, for practical purposes, land units are treated as spatially homogeneous with respect to a certain land quality (with the exception of inclusions). However, sometimes a percentage composition of sub-units is provided, although these sub-units are not mapped. In that case, each sub-unit is evaluated separately. Notwithstanding, only on very large scale maps most land units are indeed spatially homogeneous with respect to certain land qualities (again with the exception of inclusions).

3.3.5. Methodological sequence.

In theory, LE as well as FSA follow an iterative sequence: as land use changes over time, there is a continual need for its assessment and for the introduction of new agricultural technology. Both LE and FSA start with a diagnostic phase (although the term is specific to FSA), implying the identification of existing land use types c.q. farm or cropping or livestock systems. Both also follow a comparative approach, although this is much more explicit in LE where alternative land use types are compared. FSA compares existing production patterns (farmer technology) with available technology. This has no equivalent in LE, which only uses assumptions about the suitability of certain types of land use (i.e. certain levels of technology) in a given situation.

The matching of land use types requirements with land unit qualities results in a suitability classification of land. However subjective this classification may sometimes seem, it differs radically from FSA whereby constraints in farm production as experienced by farmers, and not

necessarily objective constraints, are listed. FSA takes into account that farmers may use land in ways that are objectively unsuitable (the land use types requirements are not met), and that farmers strike compromises between resources and farm household goals. In other words, the best possible use of land as defined through LE is not always found, and this provides a starting point for considering (i) measures to improve land qualities through investment; or (ii) the development of new agricultural technology. To put it simply, LE aims to adapt land use to land, whereas FSA aims to match improvements to farmer constraints which include land qualities. However, if investments in land are economically feasible, LE couples improved land to improved land use.

3.3.6. Types of data.

LE as well as FSA are criticized for their time-consuming data collection procedures resulting in a great degree of detail that is not reflected in the final conclusions. There is a clear difference with respect to the type of data collected and accepted in the analysis. While the awareness of the need for quantitative data is growing among both groups of professionals, LE has been more successful in developing quantitative methods and linking up with quantified systems analysis. Notwithstanding this fact, LE as well as FSA remain surprisingly qualitative when it comes to the ultimate judgement of suitabilities. FSA has emphasized a number of data sources that have remained largely unutilized in LE, such as historical and seasonal production series, case studies, on-farm trials and observations of farm household activities. FSA has been oblivious particularly of the need to present data in graphical form, and mapping of spatial characteristics, apart from transects, is hardly ever considered. LE emphasizes mapping, and has recently integrated some of the geographic information systems methodology.

3.4. Land evaluation and farming systems analysis for land use planning: scope for complementarity and integration

It may be concluded from the above comparison that LE and FSA differ in the degree and type of detail that they can handle and therefore the degree and type of heterogeneity that can be taken into account. LE indicates the best

uses of land in so far as these are recognized and are estimated to be technically feasible, economically viable and socially acceptable. FSA has drawn attention to the fact that these conditions are often not met, especially under rapidly changing environmental and economic circumstances. In contrast to LE, FSA has emerged out of an explicit concern over less well-endowed regions and subsistence-oriented farmers using low quantities of external inputs, and its approach focusses on these problems. While there are marked differences in the relative strengths and weaknesses of LE and FSA, there seems to be considerable scope for complementarity between the two approaches. A few authors have attempted to combine elements of LE and FSA (Conway, 1985a; Young, 1985), but there has been no systematic effort to explore the entire scope of complementarity and possible integration. Two sets of scenarios can be envisaged: complementarity which assumes that LE and FSA remain separate procedures but can benefit from each other methodologically and conceptually, or integration of elements from both LE and FSA into a new set of procedures which meets some of the criticisms advanced against either approach and combines the strengths of each.

The most obvious form of complementarity is the sharing of information between practitioners of FSA and LE. During the diagnostic phase FSA could benefit immensely from the soil and climate data collected during a reconnaissance land evaluation, while in the constraints analysis at farm level, results from detailed land evaluations describing the suitability of land units for land use types would be very useful. Similarly, regional information on marketing, rural services, etc, farm level information on household priorities, labour and input constraints as well as detailed information on variations in cropping and livestock systems would be of help in different types of LE so that more realistic selections of land use types can be made. Rather than limiting its assessment of technology levels to three or more broad categories 'low', 'medium' and 'high', as is often the case, LE could base itself on the detailed descriptions of technology levels and the results of on-farm experiments in order to formulate land uses that take into account on-farm relations between land use types, i.e. interactions between cropping systems and between cropping and livestock systems.

There is also a temporal dimension in the methodological complementarity of LE and FSA. In this case the possible relation between FSA and FSR comes to

the fore. Once improved land use patterns have been identified through LE and FSA, adaptive research on most suitable cropping and livestock systems for specific target groups belongs to the domain of FSR. On the other hand, once adapted technology exists for clearly identified target groups, the land units where it may also be relevant (outside the initial target area) can be evaluated, in order to determine the area of extrapolation of the improved technology. The results of LE could also be fed more directly into the setting of research agendas for specific regions and countries, which is now almost exclusively based on cost-benefit ratios for specific crops. In practice, these kinds of information sharing occur haphazardly, if at all, because LE and FSA are undertaken by different institutions and involve scientists from different disciplines each using their own language. Such exchanges of information would not require any changes in the methodology of either approach, but would need an awareness of the similarity between the ultimate (most detailed) units of analysis of LE and FSA, land use types and cropping/livestock systems (as components of farm systems).

Integration of LE and FSA, however, is more far-reaching and has important methodological, conceptual and organizational implications. Seen in the context of land use planning, the goals of LE and FSA are more or less similar: to provide detailed recommendations and, where appropriate, pathways for their implementations, on improvements in land use as they are determined by ecological and socio-economic constraints, including current land use, and opportunities. The types of data collected for this purpose are complementary in nature as well as in time. Furthermore, the methods they use, even if these are shaped by their divergent disciplinary backgrounds, follow the same pathway, moving from the aggregated regional level through increasing degrees of detail and disaggregation in order to arrive at the ultimate unit of analysis, the land use type or the cropping/livestock system.

An integrated Land Evaluation and Farming Systems Analysis or 'LEFSA' sequence can therefore be formulated that draws upon the relative strengths of both approaches. This sequence moves from the regional level to the farm level and below, while specific activities are carried out at each level. Reconnaissance LE and rapid appraisal find their place at the regional level, while (semi-)detailed LE and the diagnosis of farmer constraints take place at the lowest level. While such a sequence is clearly defined in

time, with the regional level analysis coming before the detailed farm level work, the integrated LEFSA approach does not follow a sequential process, but is iterative within and between levels of analysis ('two steps forward and one step back') so that at each level data can be cross-checked and referred to higher levels when inconsistencies occur. Furthermore, conclusions reached at lower levels should be incorporated in analyses at higher levels.

There is no doubt that an effective integration of LE and FSA into a LEFSA sequence will present great difficulties. A full integration may not even be desirable. However, aiming at a closer integration of LE and FSA may eventually be more promising in dealing with the problems of poor farmers in difficult environments. Part II explores the potential and the constraints of integrating LE and FSA in the LEFSA sequence in a detailed way.

Part II. STRENGTHENING THE COMPLEMENTARITY BETWEEN LAND EVALUATION AND
FARMING SYSTEMS ANALYSIS

4. AN INTEGRATED LAND EVALUATION AND FARMING SYSTEMS ANALYSIS
SEQUENCE

4.1. Conceptual framework: hierarchical systems

Conceptually, any attempt to integrate LE and FSA starts with the recognition that both approaches work at various hierarchical levels. There are some differences of emphasis: LE focusses on the regional level in its reconnaissance work, and at the cropping systems level in its (semi-) detailed analysis, whereas FSA concentrates on the farm level. The first step is therefore to define hierarchical levels that are acceptable in both methodologies.

The levels proposed here are derived from the application of general systems theory to agriculture (Odum, 1983; Hart, 1985; Fresco, 1986). In analogy to ecology, agriculture is described as a hierarchy of systems. A system involves an arrangement of components (or subsystems), which processes inputs into outputs. Systems display special properties that emerge from the interaction of components. 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. For more details, see appendix 4.

Within the agricultural hierarchy, one finds the cell and the plant organs, followed by the plant itself at the lowest levels. Plants combine into crops and crops into fields that may carry crop populations of various species and varieties, weeds and pathogens. The farm is situated at the next higher level. Groups of farms combine into subregions. These in turn combine into regions, covering a part of a country. It appears immediately

that the higher levels in the agricultural hierarchy are less easily defined than the lower levels. At the lower levels, the analogy with ecology poses no problems. The plant corresponds to the level of the individual, 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/tree 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 units, e.g. villages, 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. One of the complicating factors at the (sub)regional and higher levels is the existence of the non-agricultural sectors, which are linked to the agricultural sector through the exchange of inputs and outputs. Figure 4, in section 3.2.1, presents a qualitative model of the agricultural hierarchy. It identifies levels of analysis, systems, system components, well as units of observation.

When the hierarchical structure of ecology is applied to agriculture, the result is a hierarchical series of nested systems of increasing complexity. As complexity increases, so does the difficulty of describing the systems in an unequivocal way. (Sub)regional systems, in particular, may be defined from a biophysical as well as a socio-economic point of view. What view prevails, depends to a large extent on the purpose one has in mind. While any attempt to represent reality by simplistic levels in a hierarchy is hazardous and may be philosophically objectionable, there is considerable merit in practice to attempt to create some order in the bewildering chaos of imaginable data. It provides a basis for concentrating on the most important relationships and to select data in that light. Accepting this, then two questions emerge: how are the levels of analysis and the corresponding systems described exactly, and how can LE and FSA be integrated at each level?

Figure 6 provides an overview of the hierarchy of the agricultural sector of a region, involving a description of levels or units of observation, corresponding systems and units of analysis as well as the major subsystems of each system. At each level, the unit of analysis refers to the subsystems of the system corresponding to that particular level, e.g. at

the farm level, not the farm itself but the interactions between the subsystems - cropping, livestock and household systems - are studied and analyzed.

In figure 6, at the (sub)regional and farm levels only one system is shown, while within the farm three types of subsystems are shown, household systems, cropping systems and livestock systems. These systems are considered to be at the same level, identified as the 'activity' level, see also figure 18 in section 6.1. It should be obvious that more types of subsystems are possible, for example agro-forestry systems.

Figure 6. Units of analysis within a hierarchy of systems in the agricultural sector of a region.

LEVEL/UNIT OF OBSERVATION	SYSTEM	UNITS OF ANALYSIS
REGION ¹⁰	regional	subregions reconnaissance land units economic sectors
SUBREGION	subregional	farm systems land units
FARM	farm system	household system cropping system livestock system parcels of land
HOUSEHOLD	household system	consumption/child care water and firewood agricultural processing off-farm work
PARCEL/FIELD	cropping system	crop systems weeds/insects/pathogens soil
HERDS/PASTURES	livestock system	animal systems pathogens forage

In figure 7, a connection is made between the hierarchy of systems as in figure 6 and land evaluation and farming systems analysis. Figure 7 is also

¹⁰ A region is defined as a part of a country and not, as in the usual FAO terminology, as a (part of a) continent; see also pages 11 and 47.

based on figures 2 and 4. At each level, the type of analysis which either land evaluation (box 2) or farming systems analysis (box 1) can or should do, is indicated.

Box 2, in figure 7, shows that biophysical factors determine land units, which are used by land use types. Together they form land use systems at the (sub)regional level. Land evaluation at this level is carried out at a reconnaissance scale, see also section 4.2 on the sequence of data collection. On the other hand, within the farm, at a larger scale, the production factor land, as parcels (being land units within a farm), is used in subsystems of the farm for, for example, the production of a crop.

Figure 7. Land evaluation and farming systems analysis in relation to the hierarchy of systems in the agricultural sector.

Box 1 Level of farming systems analysis		Box 2 Level/scale of land evaluation
general analysis of land use and types of farming (sub)regional improved land use/ 'optimization'	(Sub)regional system:	reconnaissance land evaluation: -land units with qualities -matching -land use types with requirements
analysis of farm systems and of interaction of subsystems improved farm systems / within-farm 'optimization'	Farm systems:	
analysis of sub-systems	Subsystems: household systems (including off-farm work) cropping systems livestock systems	(semi-)detailed land evaluation: -parcels with qualities -matching -land use types with requirements

At this 'activity/subsystem' level, a more detailed (semi-detailed and/or detailed, see section 4.2) land evaluation can and should be done. The

results of this land evaluation should be incorporated in an analysis at the farm level (box 1) to determine the best mix of, for example, cropping systems within the farm, in this way improving the farm system. If time and data permit, an optimization of activities at the farm level can be attempted, using, for example, linear programming (or non-linear optimization) models¹¹. Subsequently, the results of the (semi-)detailed land evaluation, as well as the improved farm systems should be incorporated in an analysis at the (sub)regional level to determine the best cropping pattern within the (sub)region, improving land use at this level. Again, if time and data permit, an optimization of activities and/or farm types at the (sub)regional level can be pursued, using (multiple goal) linear programming, see sections 6.5 and 7.3.3. Although the concept in figure 7 is not a solution to the 'larger scale - smaller scale' problem, it indicates some of the relations between land evaluation and farming systems analysis.

4.2. The 'LEFSA' sequence

The integration of LE and FSA procedures in a 'LEFSA' sequence is illustrated in figures 8a, 8b and 8c. This sequence relates to objectives, data used and activities for five levels of analysis: national, regional, subregional, farm and activity/subsystem. It shows the main tasks for LE and FSA in relation to land use planning and to each other. The 'ideal' sequence of tasks runs from the national level, via the regional and subregional levels, to the farm and activity levels and then back to the regional and national levels. The sequence is iterative and in practice should contain several loops. The sequence applies to a detailed land use planning process; for a more global analysis, it is possible to stop at the regional or subregional level and then to go back to the national level. On the next pages the LEFSA sequence will be outlined, then in chapter 5 an example of an -imaginary- application of the sequence will be provided. However, first some general remarks are made.

¹¹ Linear programming and other optimization models are 'luxury' techniques, involving well-trained and experienced specialists and requiring considerable time. Furthermore, these techniques are rather data demanding.

At the national and regional levels, LE and FSA tasks can be conducted more or less independently. Exchange of information is essential, however, particularly at the regional level. In the selection of priorities for further studies, close cooperation between LE and FSA specialists is desirable.

The tasks at the regional level aim at the selection of priority subjects and/or priority areas for further, more detailed analysis. This selection takes into account broad potentials and constraints assessed earlier at the national level. The choice of priorities and the rejection of less promising options for development are based on both socio-economic and biophysical criteria. Important in this connection are development objectives. For example, socio-economically backward areas with possibilities for improved land use and farming systems, or areas with current land degradation problems, may be considered priority areas if it is an objective to redress regional income disparities. On the other hand, if increased efficiency is the main objective, areas with a currently flourishing agriculture and further potentials may be considered priority areas, while areas with steep, stony or rocky land, may be excluded from further studies.

The complementarity of LE and FSA is most pronounced at the sub-regional level. The main objective at this level is the identification of projects, programmes and policies that improve land use and farm systems. Solutions to farmers' constraints are identified by FSA, while the suitability of land for (improved) uses is assessed by LE. When improved technologies are not available or not yet sufficiently tested, adaptive on-farm or on-station research will be needed. This calls for a 'research loop', see Young (1985). Information from FSA is used by LE for the selection of land use types that are relevant to current farming systems and the socio-economic context of the area concerned. FSA information is needed, in addition to describing the selected land use types, in technical and socio-economic terms. FSA, on the other hand, will benefit from information on land resource constraints identified during LE.

A more complete integration of LE and FSA is required for the preparation of plans that aim at the improvement of farming systems and land use at the subregional level. This is complicated, because spatially defined, more quantitative information from LE has to be combined with, in general, non-

spatial and more qualitative information from FSA. Some new methods that may facilitate this integration will be discussed in chapter 7.

The description of the LEFSA sequence follows below. The figures 8a, 8b and 8c, summarizing the different steps, can be found at the back of this section. Figure 8a is also enclosed as appendix 7 (loose), enabling the reader to refer to it while going through the description on the next pages. Figure 8a is a flow diagram, providing an overview of the whole LEFSA sequence for land use planning at all levels of the agricultural hierarchy. Figure 8b shows the LEFSA procedures at the national, regional and subregional levels. The subregional level in figure 8b overlaps with that level in figure 8c, as this figure shows the procedures for the more detailed analysis at the sub-regional, farm and activity/subsystem levels, based on the results of the global analysis at the national, regional and subregional levels according to the procedures in figure 8b.

The different steps of the LEFSA sequence are briefly described here. The numbers used refer to the numbers of the steps in figures 8a, 8b and 8c.

1. Objectives (national level).

Development objectives are determined by political and administrative processes. See, however, section 2.1.2 and appendix 1 for the difficulties with this determination. The national objectives should be considered as 'given' for land use planning at the regional level. National objectives give a strong guidance to the determination of objectives at the regional level, in conjunction with the specific circumstances of a region and the goals of the different types of land users. The objectives are important for the selection of land use types (6).

2. Socio-economic factors.

Socio-economic factors at the national and regional levels (e.g. population, income and income distribution) are important for the determination of the objectives (1), the first diagnosis of constraints in land use and farming (5) and the preliminary land use assessment (8). Other important elements in this respect are national and regional policies, infrastructure and markets.

3. Agro-ecological zonation.

Land evaluation at the regional/subregional level (7) is preceded by an inventory and analysis of resources related to the use of land at the national level. This involves a broad description of the land resources, the agro-climatic or agro-ecological zones, or sub-divisions thereof, and an assessment of the potentials and constraints. The agro-ecological zonation also influences the broad selection and definition of land use types at the regional level (6) and has a bearing on the first diagnosis of constraints in land use and farming (5).

4. Farming systems research.

There are important interactions between the analysis of farm systems (9) and the analyses of land use types/activities/subsystems (10) and farming systems research. In those analyses, problems and possible solutions are identified which often need further, more detailed, research. Farming systems research with the components on-station research, location trials and on-farm experiments, is one of the means to find new or improved methods to solve the problems that have been identified. Results of farming systems research, and more in general of agricultural research, also influence the first diagnosis of constraints in land use and farming (5). Furthermore there is an important 'research loop' (compare with such a loop in the diagnosis and design approach for agro-forestry research in Young, 1985) from farming (sub-)system analysis (9, 10), via farming/cropping systems research to the refined and detailed selection and description of land use types (11) for the (semi-)detailed LE (12).

5. First diagnosis of constraints in land use and farming.

At the regional and subregional level, a first diagnosis is made of the present situation, as well as its development in the recent past, with regard to the use of land and the ways and types of farming, emphasizing possible constraints. This is important for the selection of land use types (6), for a preliminary land use assessment (8) and as a first step in the analysis of farm systems (9), and their components (10).

6. Broad selection of land use types (regional level).

For the land evaluation at the regional/subregional level (7), a selection of relevant land use types has to be made. This is derived from the objectives (1), the agro-ecological zonation (3) and the first diagnosis of constraints in land use and farming (5).

7. Reconnaissance land evaluation.

At the regional and/or subregional level, a reconnaissance LE is executed. This consists of a land resources inventory, including climate and bio-physical resources, a description of the selected land use types (6), combined with a determination of the relevant requirements of each land use type (in such a way that the land use types are described in qualitative 'performance' terms, or with inputs and/or outputs in quantitative physical terms), a description and mapping of the land units, combined with the determination of the land qualities of each land unit (in such a way that the land units are 'compound with a description of components and an indication of the percentage of the mapping unit occupied by the components) and finally the matching of the requirements with the qualities to arrive at the suitabilities of the different land use types for the different land units. The reconnaissance LE is fed by the agro-ecological zonation (3) and by the selection of the land use types (6). The results of the reconnaissance LE are used for an analysis of farm systems, the subsystems within the farm systems and their interrelation (9, 10), for the preliminary land use assessment (8) and for a possible (semi-)detailed LE at the farm/activity level (12).

8. Preliminary land use assessment.

The preliminary land use assessment at the regional and subregional level, consists of a description of agricultural systems, of broad land use indications and of a selection of themes and areas for further study. It is based on the analysis of socio-economic factors (2), on the first diagnosis of constraints in land use and farming (5), and on the reconnaissance LE (6).

If no further analysis at the farm and/or activity level is carried out, the preliminary land use assessment is an end-product. It is useful for policy-makers, administrators and land-users as a source for improvements in their respective areas of work and influence (14). It is not, however, based on a thorough analysis of farm systems and their components and on a (semi-)detailed LE. It can therefore only serve as a basis for the formulation of more general policies, programmes and projects (15). In figure 8a this 'shortcut' is shown by arrows from (8) to (15) via (14), while in figure 8b the same is expressed by including a task 'planning improved land use'.

If further analysis is possible, results of the preliminary land use assessment are used for the analysis of farm systems.

9. Analysis of farm systems and interactions of land use types/activities/subsystems.

In this task a whole farm analysis is carried out. A description and diagnosis is made of constraints at the farm level and of the interactions and the competition for scarce common resources between land use types/activities/subsystems. Possible solutions are indicated. For a successful farm system analysis, it is necessary to group farms into more or less homogenous categories. Such a category is called a farming system. Several individual farms of such a category are studied. Each farm is considered a system. The analysis of farm systems often leads to recommendations for more in-depth farming systems research (4). The analysis of the farm systems is followed by analyses of the main components of the farm system (10). Results of these analyses are again integrated at the farm level. The analysis of farm systems is one of the inputs for the improvement of current farm systems and/or the with-in farm 'optimization' (13).

10. Analysis of land use types/activities/subsystems.

The whole farm analysis (9) is followed by analyses of the main land use types/activities/subsystems of the farm system. Individual cropping, livestock and household systems are analyzed to determine their constraints and possibilities. There is a strong interaction with the whole farm analysis. Also the subsystems analyses result in recommendations for farming systems research (4), with a 'research loop' to the refined selection and detailed definition of land use types (11). The analyses of land use types/activities/subsystems are used for the refined selection and detailed definition of land use types (11). Finally the results of these analyses are important inputs for improvements of current farm systems and/or the with-in farm 'optimization' (13). The latter requires, of course, a complete quantification of the relevant inputs and outputs.

11. Refined and detailed definition of land use types (activity/subsystem level).

For the (semi-)detailed LE (12), the selected land use types at the regional level (6) have to be reviewed and refined. This can be based on

the results of farming systems research (4), the preliminary land use assessment (8) and the activity level analyses of land use types/activities/subsystems (10). The latter analyses provide detailed descriptions of the relevant land use types, including accurate definition of the technology of the land use types.

12. (Semi-)detailed land evaluation.

The (semi-)detailed LE at the activity/subsystem level is based on the previous reconnaissance LE (7) and the activity/subsystem level selection of land use types (11). It describes, analyses and maps land units and their qualities in such a way that most land units are 'single with one major component and some inclusions' and that the land units are part of existing farm systems (being identical to parcels or fields of specific farms identifiable on the land unit map) and that land use types are specific with a detailed description of technology and management levels, including cropping patterns and rotations. The specified land use types and land units are matched to obtain suitabilities for each land use type for each land unit. The results of the (semi-)detailed LE are used for improvements of current farm systems and/or the within farm 'optimization' (13).

13. Improving current farm systems/within farm 'optimization'.

Based on the analysis of farm systems (9), the analyses of land use types/activities/subsystems and their interactions (10) and the matching of land units and land use types in the (semi-)detailed LE (12), current farm systems can be improved, or when given time and data available, within farm 'optimization' can be attempted. The improved or 'optimized' farm systems are an input for the improvement of land use at the (sub)regional level (14).

14. Improving land use at the (sub)regional level/(sub)regional 'optimization'.

Improved farm systems (13) are important for the improvement of land use at the (sub)regional level; it should lead to a better cropping pattern, given objectives and constraints, at this level. If time and data permit, an 'optimization' of activities and/or farm types at the (sub)regional level can be attempted. The task of improving land use at the (sub)regional level is the final step to a land use plan (15), which identifies appropriate

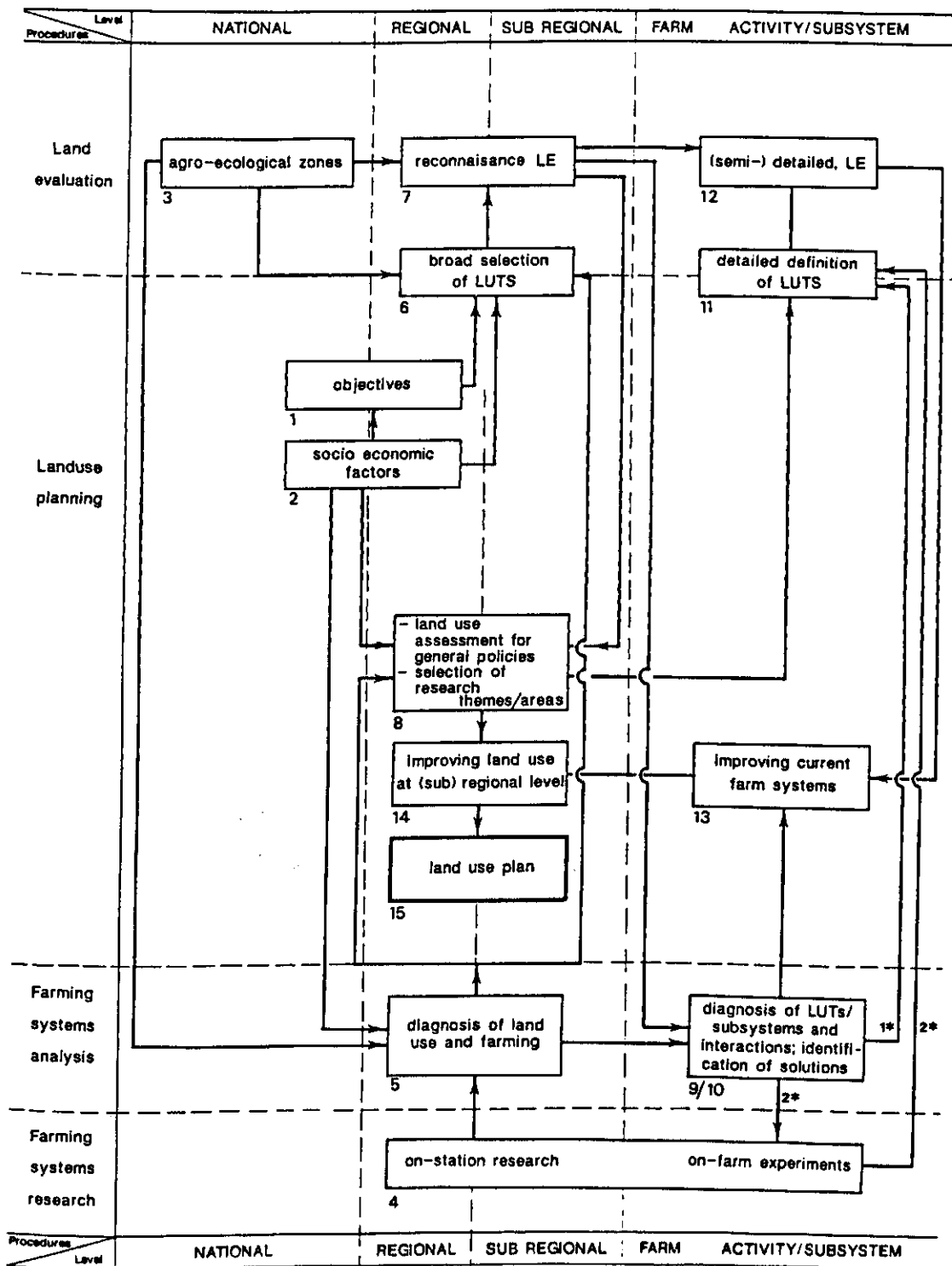
projects, programmes and policies to achieve the proposed future improved land use.

15. Land use plan.

The land use plan is based on the results of the step improving land use at the (sub)regional level (15). It consists of a diagnosis of the present situation with regard to the use of land, a description and analysis of the future improved situation and the projects, programmes and policies necessary to go from the present to the future situation. It prepares for the necessary decisions with regard to projects, programmes and policies.

The above description of the LEFSA sequence is rather theoretical. There is a need for an elaborated example in which the different steps are substantiated on the basis of field data. In chapter 5 such an example is outlined. This is based on a reinterpretation of a case study in regional planning for agricultural development in Sri Lanka (Polman, Samad & Thio, 1982). First, however, in section 4.3 an appraisal of the advantages and disadvantages of the LEFSA sequence is presented.

Figure 8a. LEFSA sequence for land use planning.



1* If current, tested technology is available for the definition of relevant LUTs.

2* If further research is needed for the definition of LUTs ('research loop'; Young, 1985).

Figure 8b. LEFSA procedures at the regional and subregional levels.

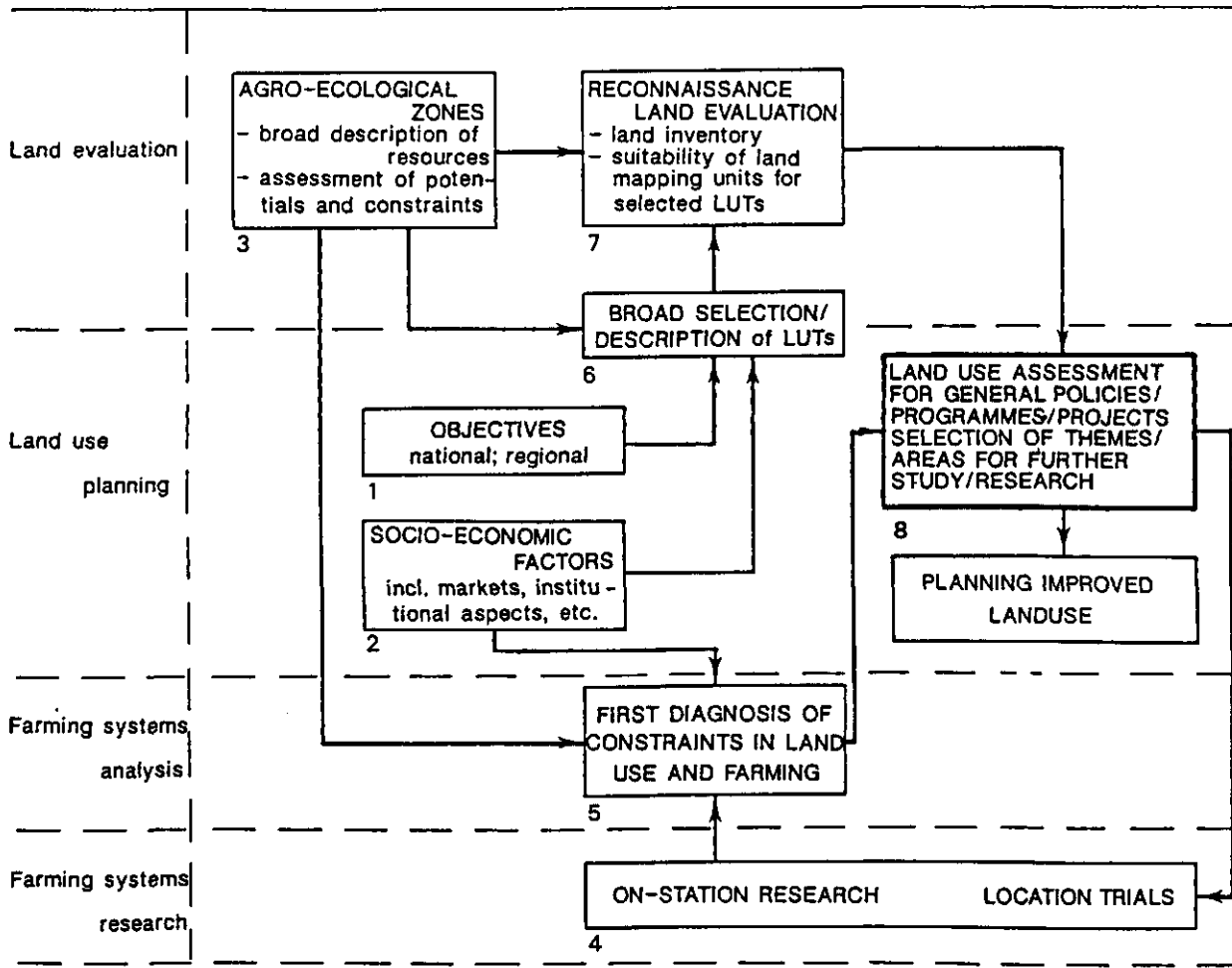
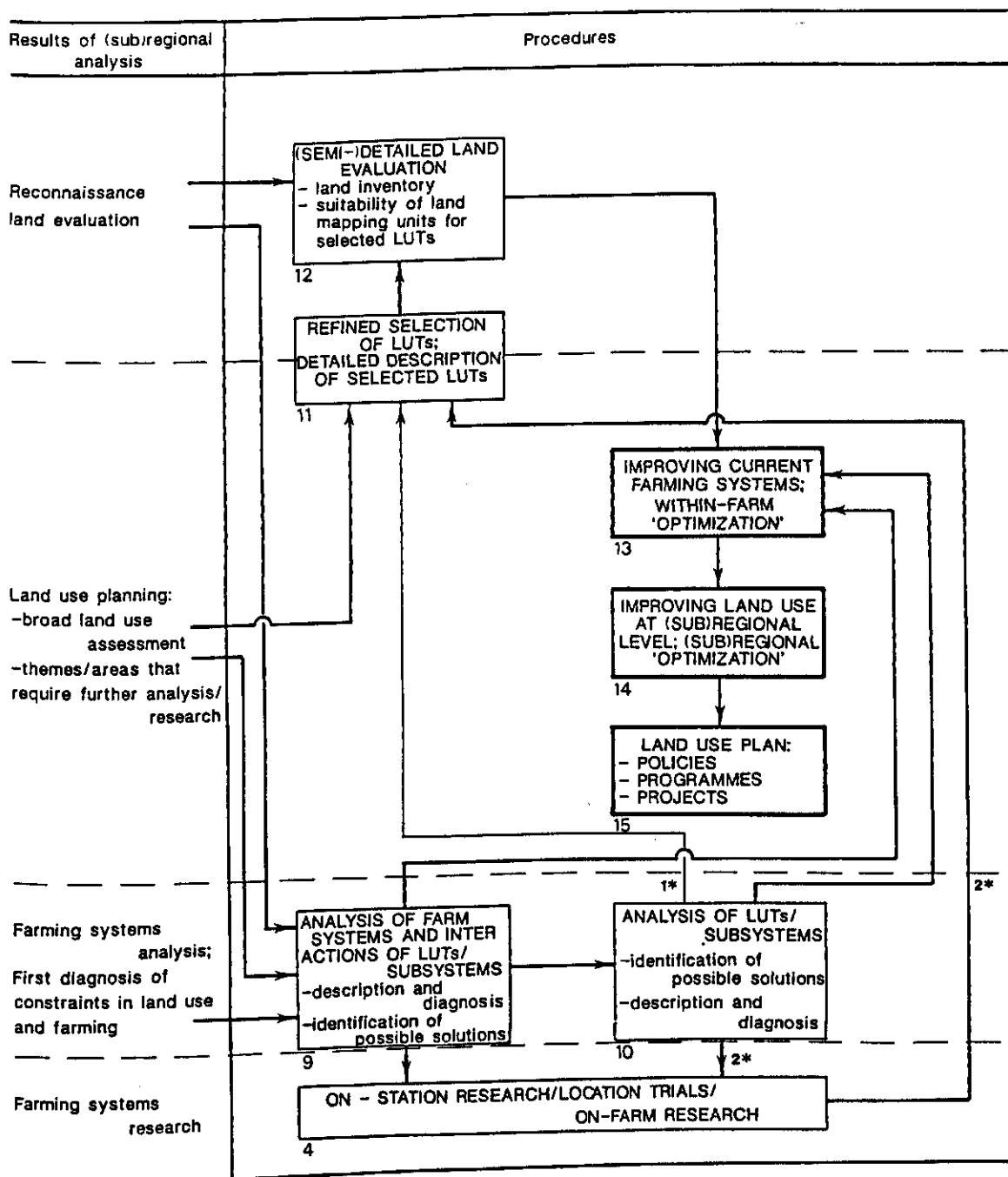


Figure 8c. LEFSA procedures at the farm and activity/subsystems levels, based on results of the regional and subregional levels.



1* If current, tested technology is available for the definition of relevant LUTs.
 2* If further research is needed for the definition of LUTs ('research loop'; Young, 1985).

4.3. The LEFSA sequence: major advantages and possible application problems

The complementarity of LE and FSA and the possible advantages for land use planning of combining both procedures in an integrated LEFSA sequence, have been discussed at length in section 3.4. A brief summary of the main advantages of the LEFSA sequence is presented below, treating separately the positive effects (i) on each of the component procedures (LE, FSA) and (ii) on the expected relevance and quality of the information obtained for land use planning. In addition, some comments are made on possible problems that may occur when the LEFSA sequence is applied in practice.

Major advantages of LEFSA for LE:

- LEFSA eliminates the problem that formal procedures for the selection of land use types are lacking in all LE documents (see paragraph 3.1.5.). The diagnosis of farming, land use types and interactions between land use types, which is part of FSA (see figures 8a, 8b and 8c, boxes 5, 9 and 10), provides necessary information for the selection of land use types that are acceptable to farmers, including labour considerations that are normally neglected in LE.
- The diagnosis of farming, land use types and interactions, which is part of FSA, provides, in addition, essential data that are needed for the description of selected land use types.
- LEFSA includes procedures that promote links between LE and agronomic research and directs attention towards socio-economic conditions affecting the selection and description of land use types.

Major advantages of LEFSA for FSA:

- Agro-ecological zones maps and land evaluation maps show 'units' that are biophysically relatively homogeneous; these units can provide (part of the) strata for farm surveys based on stratified random sampling procedures.
- The use of reconnaissance and/or (semi-)detailed LE information in FSA helps to define target groups with similar biophysical production opportunities as well as to select technologies that are adapted to local (favourable or adverse) biophysical resources.
- LE provides information (estimations) with regard to the physical sustainability of land use types.

- The use of LE maps in FSA adds a spatial element commonly lacking in FSA. This makes it possible to examine more directly the possibility of transfer of selected technologies to areas with comparable biophysical resources as assessed through LE procedures, but not yet covered by FSA.
- The use of a geo-referenced data base, including data on land units and their characteristics, as well as data on farm households and the parcels used by these households, will allow a better use of land resource data in FSA; this will require a proper recording of both farmstead and parcel locations in surveys for FSA, however.

Major advantages of LEFSA for land use planning:

- LEFSA provides common goals to FSA and LE, i.e. improvement of farm systems and land use (steps 13 and 14 of the LEFSA sequence); this will guide data collection procedures and analysis in both LE and FSA, thereby increasing the relevance of the information for land use planning.
- The use of LE information in FSA procedures, and of FSA information in LE procedures, as suggested in the LEFSA sequence, will improve the quality of both procedures and thereby the quality of the information provided by these procedures for land use planning.

The following problems might be expected when applying LEFSA in practice.

- Integrating the spatial information produced by LE and the generally non-spatial information which is provided by FSA may be difficult. Further research is needed for this. Promising methods that may reduce this problem are indicated in chapter 7.
- Implementing a LEFSA sequence on the basis of contributions of different agencies will require detailed agreements on activities to be carried out, their level of detail, timing, etc., in order to arrive at the desired integration. Such agreements may be difficult to reach, for instance when different budgets are involved.
- Although time and cost effectiveness can be increased by applying the LEFSA sequence, compared to conventional procedures in which LE and FSA are conducted more or less independently, information needs for effectively improving farm systems and land use (steps 13 and 14 of the LEFSA sequence) will remain high and demanding in terms of personpower and time.

- Theoretical and practical problems of combining analyses at a 'macro' level with those at a 'micro' level. This applies to problems of an ecological nature as well as to socio-economic problems.
- However grandiose the LEFSA sequence might appear, it still is a 'partial' approach. It analyzes the agricultural sector of a region at different levels, but in the way it does this, it isolates this sector from other economic sectors (e.g. industry and services) and regions in a country. Therefore, it might overlook problems and opportunities in the non-agricultural sectors, as well as comparative (dis)advantages of other regions.

In the next chapter, the example of the application of the LEFSA sequence is provided. As stated before, this example is based on a reinterpretation of a case study in regional planning for agricultural development in Sri Lanka.

5. A LEFSA SEQUENCE CASE STUDY: MATARA DISTRICT IN SRI LANKA.

In section 4.2, the complementarity and integration of land evaluation and farming systems analysis for land use planning via a sequence of interrelated steps - the LEFSA sequence - was presented. This was done in a theoretical and prescriptive way. There is a need for an elaborated example in which the different steps are substantiated on the basis of field data. Such an example is outlined in section 5.3 of this chapter. It is a rather lengthy example, but is considered essential for demonstrating an interpretation of the different steps in a particular case, and for making clearer the meaning of the individual steps and the sequence as a whole. In that way it is also possible to expose the strong and the weak points of the proposed approach. To that end, this chapter ends with section 5.4, in which the example is briefly evaluated. However, before embarking upon the application of the LEFSA sequence to the case, some background of the case is provided. In section 5.2, the Matara district in Sri Lanka is introduced, while in section 5.1, the origin of the case is presented.

5.1. Regional agricultural planning in Matara district

From 1979 to 1982 a team from the Agrarian Research and Training Institute, Colombo, and the Department of Development Economics of the Wageningen Agricultural University studied methods of agricultural planning at a regional level. The team participated in the preparation of plans for two districts in Sri Lanka: Matara and Ratnapura; as well as in the monitoring of the implementation of a plan in a third district: Kurunegala.

Matara was the first district to be studied. Field work was mostly done in 1980. Evidently the team did not follow the LEFSA sequence. It is therefore useful to outline briefly the methodology used at the time of the plan preparation. This also provides a comparison with the LEFSA sequence.

Following is a near quotation from Polman, Samad & Thio (1982: 5-6):

"The study basically followed a pragmatic approach to the optimal utilization of resources. The mathematics used do not go beyond the four basic arithmetic operations and the use of interest tables. The procedure of plan formulation is based on the gradual exclusion of

possibilities for development, starting from the least removable constraints and going on to constraints which are easier to relax or those of which the relaxation is in the hand of the government. In this order the following factors were scrutinized:

- a. availability of land, water and human resources;
- b. technical possibilities for crop production;
- c. market constraints on crop production;
- d. economic feasibility of crop production (profitability and role of crops in the farming system); and
- e. social feasibility of crop production (attitudes to adoption of new techniques of production and to change in cropping patterns).

The examination of these potentials and constraints leaves one with a range of feasible future situations from which an optimal one has to be chosen which contributes most to the stated objectives of development. The differences between the future and the present situation and the bottlenecks which have to be eliminated indicate the scope and nature of the projects and programmes to be implemented and the policies to be pursued. Once the projects and programmes have been identified two other constraints have to be examined:

- f. financial means; and
- g. implementation capacity.

These two constraints are not independent as implementation capacity can be overcome to a certain extent if adequate capital resources are available".

5.2. Matara district: an introduction

To introduce the Matara district to the reader a number of further near quotations from Polman, Samad and Thio (1982: 2-4) are given:

"The salient features of Matara are common to most of the wet zone districts in Sri Lanka. High population densities and man-land ratios, a virtually stagnant non-agricultural sector and a labour force dominated by educated youths, who cannot find suitable employment within the region, are among the outstanding features.

Located in the southernmost part of the wet zone the district is served by railway and a network of roads which make most of the district easily accessible from the capital city and other principal towns in the country.

Agriculture dominates the economy of the region, as is the case in several other wet zone districts, the agricultural sector of Matara exhibits a typically dualistic structure with a relatively well developed state-owned plantation sector alongside a non-plantation sector, in which a large number of private cultivators operates small and medium sized holdings.

Agriculture centres on perennial tree-crops. Traditional export crops such as tea, rubber, coconut and cinnamon are cultivated both on small holding and on plantations. Paddy occupies the first place among annual crops.

In a perspective, both regional and national, tea and cinnamon are the crops which make the largest contribution to the economy. Matara produces what has been classified as 'low country tea'. Teas of this quality fetch favourable prices and have good future prospect on the international markets. According to the 'Tea Master Plan' the total area under tea in the district ranks fifth largest in the island. In terms of the volume of production Matara is sixth. However, with regard to the production of specifically 'low country' teas, Matara is, together with the neighbouring district of Galle, one of the two principal producers.

Cinnamon is the other major crop of national importance cultivated in Matara. The district accounts for 40% of the total cinnamon acreage of Sri Lanka, but only about 25% of the national production comes from Matara. Sri Lanka supplies about 70% of the cinnamon traded in the World Market."

"Paddy is the only annual crop which occupies a significant land area in the district. In spite of a good rainfall pattern, adverse soil conditions¹² make Matara a poor rice growing district. The average yields are among the lowest in the island. The high local demand and low levels of productivity make Matara a paddy deficit district. Consequently, rice has to be imported from other districts in order to meet local requirements."

"An area in which Matara district plays a role vital to the national economy is its export of skilled labour. Literacy levels in the district are very high. Many professionals or those holding important positions in government and the administration are natives of the district. Politically too the district occupies a place of considerable importance.

Matara is not a poor district when compared to most others in the country. Although no reliable information is available on districts' incomes, evidence suggest that the inhabitants of Matara are possibly on average better off than those of most other districts in the island."

"The availability of adequate supplies of water and fertile soils conditions in most parts of Matara permits the cultivation of a large variety of tropical crops.

Elevation (as it determines the temperature regime) is a main determinant of land use. In the low coastal zone in the South coconut and paddy are the dominant crops. In the higher elevations one finds cinnamon, rubber, tea and also coconut and paddy. In the Northern part of the district, which is located at higher altitudes tea is the main crop. A wide range of tropical vegetables, fruit trees and spice crops are grown in homesteads throughout the district. Livestock farming is

¹² A large part of the land used for paddy cultivation are bog and half bog soils, (very) poorly drained, consisting of black to brownish black muck, mucky peat or peat, with a (very) high organic matter content (Dimantha & Jinadasa, 1981: 8). Another problem is the restricted number of hours of sunshine.

insignificant in the district except for dairy farming which is being practiced on a limited scale.

The district is densely populated with a long standing tradition in crop cultivation. Population pressure on land is high. There is hardly any possibility for the cultivation of new lands except for recultivation of some abandoned scrub lands. Clearing of forest for cultivation purposes would highly increase the risk of erosion.

Matara district experiences much rainfall. The distribution of rain is rather even throughout the year. Agriculture therefore is mainly rainfed. Irrigation is not easy also because of generally rolling topography. Paddy is the only crop which is irrigated. However, a major problem confronting paddy cultivation in the district is not irrigation but drainage (in relation to recurrent flooding). Poor drainage is a constraint particularly in low lying paddy lands. Improvement of drainage is very costly and the possible increases in paddy yields are not substantial."

5.3. The LEFSA sequences applied to the Matara case

As an illustration of the LEFSA sequence, its steps will be followed to present relevant information about Matara and the plan for the development of its agriculture between 1980 and 2000. The numbers of the following sections refer to the numbers of the steps as outlined in section 4.2. The reader is also referred to figure 8a in section 4.2 or appendix 7 (loose) to follow the steps on a flowchart. As it is an illustration, only major points are mentioned. Most of the information is real in the sense that the information is/was known (and in part used for the plan), however, some is constructed as obviously the LEFSA sequence was not followed at the time of the preparation of the plan. The latter especially applies for the (semi-) detailed LE at the farm and activity level (12), the construction of farming systems, which are more statistical 'averages' than real existing systems, and the detailed subsystem analysis within farm systems (10).

5.3.1. Objectives.

An official document stating the national agricultural development objectives does not exist. However, from different reports and statements made by leading politicians and government administrations the following national objectives can be derived:

1. self-sufficiency in food so as to eliminate food imports as far as possible;
2. export expansion in agricultural produce, not only from the traditional export oriented tree crop sectors (tea, rubber, and coconut), but also from minor-export crops such as cinnamon, coffee, cloves and pepper; and
3. expansion of employment opportunities in agriculture, particularly for the economically disadvantaged groups.

Applying these objectives to the agricultural sector of Matara, it is clear that the district has only a minor role in the achievement of self-sufficiency in food. However, the district can make a considerable contribution to the expansion of agricultural exports. Also there is much scope for creating additional employment in these export crops which are generally rather labour intensive. By creating more employment for groups that are at present under- or unemployed one provides benefits for economically disadvantaged groups. At the district level an important objective for agricultural development is, of course, the income obtained by the different producers. A further consideration is the prevention of erosion, especially by unwarranted deforestation and by the (improper) use of some of the land at the higher elevations, causing a deterioration of the natural land resources and more severe inundation problems at the lower elevations in the district.

The above leads to the following objectives for agricultural development at the district level:

1. expansion of production of export crops to contribute to the balance of payments; in order to select the best crops, the value added at economic - border - prices is used as a criterium;
2. improvement of incomes through the expansion of agricultural production in general, but in particular for small producers; the criterium used for the selection of crops is the value added at financial - farm-gate - prices;
3. employment generation; for the selection of crops, the criterium used is the average labour demand; and
4. reforestation of severely degraded land.

The objectives are to a large degree not conflictive, as the most important crops tea, cinnamon, rubber and coconut do generate value added per ha and

employment per ha in about the same order. However, the best cropping patterns differ when different prices are used, e.g. economic or financial prices. So trade-offs do exist between the first three objectives. The degraded land objective is treated as a constraint for all development options.

5.3.2. Socio-economic factors.

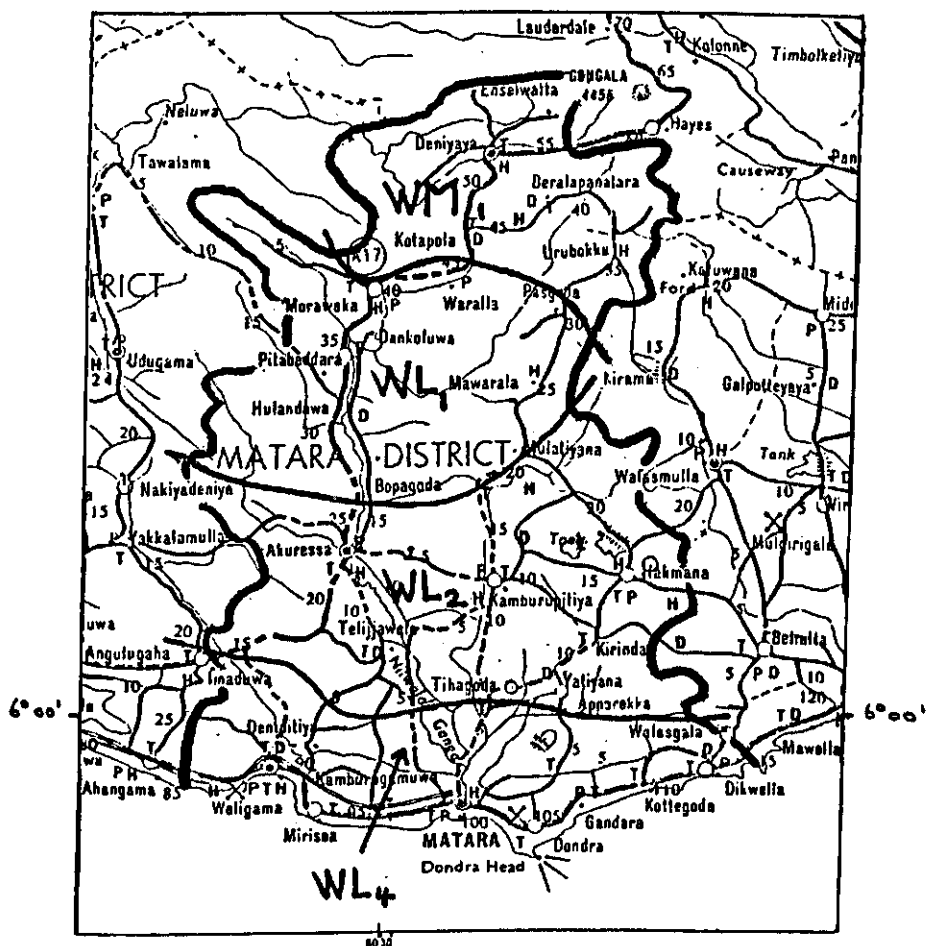
In 1981 Matara has a population of 643,494. With an area of 1288 km², the population density is 500 persons per km². Population growth is only 0.2% per year, due to the interaction of slowly diminishing birth and death rates, and age- and sex-specific rates of out-migration. Hence, in the year 2001 the population is expected to be 673,000, with a population density of 523 persons per km². Based on an agro-ecological zonation (3), the district is sub-divided into three sub-regions, North, Centre and South, see map 9. For statistical purposes the limits of these sub-regions were approximated with the boundaries of Grama Sevaka divisions, i.e. the smallest administrative unit in Sri Lanka. The South is most densely populated with 1217 persons per km², then the Centre with 432, while the North is least populated with 273 persons per km². The South is very densely populated, especially the three miles wide coastal zone, where also Matara town is situated. This coastal zone hardly has a rural character and is excluded from agricultural planning.

Matara is characterized by high unemployment rates. In the slack agricultural periods of 1981, unemployment is estimated to be as high as 45% of the labour force, while in the peak periods this is reduced to 25%. (Un)employment is not evenly spread over the sub-areas. For example in the North the slack unemployment is 44%, while in the peak periods there is a labour shortage of 9%. This is mainly caused by the peak demand of the dominating tea cultivation. Of the total labour force of 212,100 persons in 1981, 71,000 (33%) were employed in the non-agricultural sectors, mostly in the South, while 46,700 (22%) found permanent employment in the agricultural sector. Permanently unemployed were 51,900 persons (25%), while 45,500 (20%) could find employment in agriculture during the peak periods.

The physical infrastructure in the district is well developed. There is a relatively dense network of rural roads and public and private buses

connect the major rural towns and villages. Input supplies are not a bottleneck. On fertilizer there is on average a 50% subsidy. There are few major marketing problems with regard to agricultural products, except in the case of tea and cinnamon. Due to the restricted tea world market (low income-demand elasticity), the demand for tea is only slowly growing. As Sri Lanka has a large share of the world market (about 20%), it should not increase the tea supply too much. Based on the room on the world market and the share of Matara in the national tea production, it was estimated that the tea production in 2000 should not exceed 27 million kg of made tea. A same type of reasoning applies to cinnamon where Sri Lanka has an even larger share of 70% in the world market, the resulting market restriction

Map 9. A map of the Matara district, Sri Lanka.



Subregion:	Agro-ecological zone:
North	WM ₁ & WL ₁
Center	WL ₂
South	WL ₄

Scale: 8 miles to one inch (1:506,880)
0 ————— 10 miles
0 ————— 10 km

was 2.4 million kg of quills in the year 2000. Other marketing problems arise around the export taxes and levies charged by the government. These vary per product between 30 and 50% of the F.O.B. export price. Together with processing, transport and handling charges, this causes a considerable divergence between economic border prices and financial farm-gate prices.

5.3.3. Agro-ecological zonation.

In order to specify the agricultural potentials and to localize the projects to be implemented, the district is sub-divided into agro-ecological zones in accordance to the generally accepted classification of the Land and Water Use Division of the Department of Agriculture. This classification is made at the national level at a scale of 1:1,000,000, and is mainly based on differences in rainfall and altitude. For Matara four relevant agro-ecological zones are distinguished, which are specified by their main characteristics as follows:

zone	75% expectancy of annual rainfall (inch)	altitude (feet)	75% expectancy of dryness in a particular month	terrain
WM ₁	>125	1000-3000	jan, feb	steeply dissected, hilly and rolling
WL ₁	>100	<1000	jan, feb	rolling and undulating
WL ₂	> 75	<1000	jan, feb	rolling and undulating
WL ₄	> 60	<1000	jan, feb, mar, aug	undulating and flat

WM = wet zone, mid country; WL = wet zone, low country.

Other information provided on the agro-ecological map are the major soil groups and the 75% expectancy of rainfall in each month.

As the WM₁ and WL₁ zones appeared very similar with regard to biophysical characteristics, land use and farm types, it was decided to distinguish for planning purposes only three sub-regions, as described in section 5.3.2.

5.3.4. Farming systems research.

Farming systems research was not done in Matara district. Of course contacts were established with the relevant agricultural research stations and universities to find out possible technological improvements in the

cultivation of the different crops. Also the functioning of extension services was studied.

5.3.5. First diagnosis of constraints in land use and farming.

Farming systems in the small farm sector in Sri Lanka are closely related to the traditional three-way pattern of land use. The first element of this land use pattern is the cultivation of valley bottoms usually referred to as 'lowland'. Paddy is customarily cultivated in these lands under water-logged conditions and is ecologically the most suited crop for such land. The second element is the cultivation of the slopes and the ridges referred to as 'highland'. The highland is further subdivided physically into the highlands proper and the 'homestead' which forms the third element of the three fold system of land use. The homestead contains the dwelling and a small area under 'mixed crops', characteristically referred to as 'homegarden' crops.

Traditionally, a farm consisted of all types of land use, or components. However due to an increasing pressure on the land, farms are becoming smaller as well as 'loose' components. In 1973 the following farm types were observed as a percentage of the number of small holders:

- single component farms	52%
of which: homegarden	86%
highland	7%
lowland	9%
- two component farms	31%
- three component farms	17%

Evidently single component farms are predominant. These farms are in general very small with an average size of 0.3 ha. The most important activity is homegardening. Most of these farms are in the South, due to the high population density. The small farms cannot produce enough for self-sufficiency and the family members have to look for other sources of income.

Matara district comprises about 100,000 small holders farming units. Five major farm size classes have been distinguished: homesteads, micro-holdings, small holdings, medium sized holdings and small estates. The distribution of the number of farms and area over the different classes for the three sub-regions is presented in table 10. For simplicity the homestead class is combined with the micro holdings as this class (20,000

holdings with an average size of 0.07 ha) only occurs in the South. In addition to the private holdings there are state plantations, in the North totalling 2,600 ha and in the Centre totalling 3,050 ha.

Table 10. Number and area of farms per farm size class in each sub-region.

Sub-region	Farm size class									
	Micro holding 0-0.5 ha		Small holding 0.5-2 ha		Medium holding 2-4 ha		Small estates 4-20 ha		Total	
	no.	ha	no.	ha	no.	ha	no.	ha	no.	ha
North	1750	380	13000	14520	2000	5400	380	5300	17130	25600
%	10	1	76	57	12	21	2	21	100	100
Centre	19000	2850	22000	22425	2000	6000	550	9775	43550	41050
%	44	7	51	55	5	15	1	24	100	100
South	29000	3270	9000	8940	800	2140	200	2760	39000	17110
%	74	19	23	52	2	13	1	16	100	100
District	49750	6500	44000	45885	4800	13540	1130	17835	99680	83760
%	50	8	44	55	5	16	1	21	100	100

Source: Polman, Samad & Thio (1982).

In table 11 the average farm size and cropping pattern of each farm type (farm size class) is presented.

The yields of the different crops vary according to sub-region and farm type. The present yields depend on cultivation conditions and methods, and variety. There is ample room for improvements of the yields. The future average possible yields are based on observed yields at present under good management, and vary according to the suitability of the land units for the different land use types. Below, the range of both present and future yields is given:

	present ¹	future ²
- paddy (kg/ha):	1000 - 2500	1800 - 4000
- tea, VP (kg/ha, made tea):	1200 - 1800	1350 - 2700
- tea, seedling (kg/ha, made tea):	250 - 1000	675 - 1600
- rubber (kg/ha, sheets):	600 - 850	700 - 1400
- cinnamon (kg/ha, quills)	100 - 350	300 - 600
- coconut (nuts/ha):	3600 - 5400	6000 - 12000

¹ Source: Polman, Samad & Thio (1982).

² Source: Dimantha & Jinadasa (1981); and Moll & Schipper (1990).

Table 11. Average farm size and cropping pattern per farm type in ha.

Sub-region	Farm size class				All farm types
	Micro holding 0-0.5 ha	Small holding 0.5-2 ha	Medium holding 2-4 ha	Small estates 4-20 ha	

North					
size:	0.22	1.12	2.70	13.95	1.49
pattern:					
-paddy	0.06	0.22	0.30	-	
-tea	-	0.40	1.70	10.79	
-rubber	-	0.07	0.20	1.58	
-homest.	0.16	0.43	0.50	1.58	

Centre					
size:	0.15	1.01	3.00	17.77	0.94
pattern:					
-paddy	0.08	0.31	0.70	2.00	
-tea	-	0.03	-	2.91	
-rubber	-	0.12	0.70	4.00	
-cinnamon	-	-	0.50	4.09	
-coconut	-	-	0.50	3.27	
-homest.	0.07	0.55	0.60	1.50	

South					
size:	0.11	0.99	2.68	13.80	0.44
pattern:					
-paddy	0.01	0.30	0.30	2.50	
-rubber	-	-	0.38	1.00	
-cinnamon	-	-	0.20	3.20	
-coconut	-	0.29	1.70	7.00	
-homest.	0.10	0.40	0.10	0.10	

District					
size:					0.84

Source: Klijn, Moll & Schipper (1990).

Based on the present cropping patterns, yields, use of material inputs and hired power (buffalo or tractor) and labour inputs, one can estimate per farm type in each sub-region the average land and labour productivities, and the average gross farm incomes, in total and per family labour day. These are presented in table 12.

Table 12. Average productivities and gross farm incomes per subregion and farm type.

	productivity: value added		gross farm income	
	per ha land Rs. ¹	per labour day Rs.	total Rs.	per labour day Rs.

North				
Micro holding	2409	21	494	20
Small holding	7704	28	8444	28
Medium holding	11470	29	24494	38
Small estate	10686	24	66336	102

Centre				
Micro holding	2520	16	331	14
Small holding	2996	22	2772	20
Medium holding	4595	27	10332	32
Small estate	5857	28	51278	156

South				
Micro holding	1629	23	174	26
Small holding	2595	28	2344	25
Medium holding	4261	40	10342	45
Small estates	5279	40	47293	194

¹ Rs.: Sri Lankan Rupees.

Source: Klijn, Moll & Schipper (1990).

As families could make use of the 'food stamp scheme' if their income was lower than Rs. 3600 per year, this is considered here the poverty line. It is evident that on micro holdings and small holdings one cannot make a minimum living, except on small holdings in the North. As the wage level in 1981 was Rs. 15 per day, family labour earns more per day for the time worked on their own farms than wage labour, except on the micro holdings in the Centre.

The most important constraints to agricultural development are:

- limited amount of presently non-used land;
- for paddy cultivation: bog soils, inundations/drainage, hours of sunshine;
- present land use with low productive tree crops with a lot of 'sunk' capital;
- very small farm sizes;
- land tenure system on paddy lands;
- market constraints for tea and cinnamon;
- new investments in tree crops require considerable financial means and signify foregone income losses during unproductive years; and
- structure and functioning of the government administration and institutions.

5.3.6. Broad selection of land use types (regional level).

The 18 selected land use types mostly include crops presently grown in the district, except for sedges and citronella (Dimantha & Jinadasa, 1981). However, citronella had been grown two decades before, but was at current prices not attractive. Obviously, the land use types contribute in different degrees to the objectives. Also obviously, the selection was based on the present land use and the agro-ecological zoning. However, the socio-economic aspects were not studied in extenso before the land use types were selected, neither were they described and analyzed in great detail. The description with regard to key attributes was in rather gross qualitative categories. The following land use types (LUTs) were evaluated:

LUT	capital investment	recurrent	farm power	farm size	technical know how
1. tea	high	high	manual/ high	medium/ large	high
2. tea	medium	low	manual/ low	small/ large	low
3. rubber	high	high	manual	small/ large	high
4. rubber	medium	low	manual	small/ medium	low
5. coconut	high	medium	manual	small/ large	high
6. coconut	medium	low	manual	small/ large	medium
7. paddy, irrigated	medium	high	tractor	small/ medium	high
8. paddy, rainfed	medium	low	manual/ animal	small/ medium	medium
9. pasture	high	high	manual	medium	high
10. pasture	low	low	manual	small/ medium	low
11. minor export crops (cinnamon, nutmeg)	high	medium	manual	medium/ large	medium
12. minor export crops (cinnamon, nutmeg)	low	low	manual	small/ medium	low
13. annual crops (e.g. maize)	medium	high	manual	small	high
14. annual crops (e.g. maize)	medium	low	manual	small	low
15. forestry	low/high	low	manual	large	high
16. citronella	high	high	manual	small/ large	high
17. sedges	medium	low	manual	small	medium
18. annual crops in paddy fields	medium	low	manual	small	medium

Apart from the qualitative information about the key attributes, the technology commonly used was briefly described by referring to existing known situations, like, for example, for LUT 6 - coconut: 'existing plantations, low fertilizer applications'.

5.3.7. Reconnaissance land evaluation.

A qualitative, physically oriented land evaluation was executed at a scale of 1:63,360 (one inch to a mile, which is the normal scale in Sri Lanka for topographical maps), see Dimantha & Jinadasa (1981) for the full report. According to table 2, a map at such a scale is classified as semi-detailed. However, because of the very small farm sizes, it can be considered as a reconnaissance map. The district was subdivided into four agro-ecological zones, in which 39 land units were mapped, based on present land use and vegetation, rock class and soil group. The land units were further subdivided according to slope class, resulting in 129 units for evaluation. Following the FAO Framework (1976), the land use types were matched with the land units to obtain a suitability classification.

The land suitability evaluation is only a physical one and no economic or social criteria were considered. Qualitative economic criteria were only used for the brief description of the land use types. The following land qualities were taken into consideration:

1. moisture availability;
2. nutrient availability;
3. oxygen availability;
4. resistance to erosion;
5. absence of salinization hazard;
6. absence of toxicity hazard;
7. availability of sufficient radiation;
8. availability of a good harvesting period for rubber;
9. availability of a good ripening and harvesting period for paddy;
10. bearing capacity for mechanization of paddy fields (trafficability);
11. absence of flooding hazard;
12. availability of sufficient land space to achieve optimum planting density (rockiness); and
13. availability of a suitable temperature regime.

Unlike the definitions of suitability classes in the Framework (FAO,1976), four suitability classes were distinguished on the basis of physical criteria only:

- class I. suitable land where the combination of land qualities is fairly optimal and no significant limitations are expected in most years;

- class II. moderately suitable land that has few limitations for the considered land use;
- class III. marginally suitable land where the land qualities grade so low that there are fairly severe limitations for the considered land use; and
- class IV. unsuitable land for a considered land use type.

The results of the land evaluation were summarized in tables per agro-ecological zone, indicating the relative suitability of each land use type for each land unit. For an example of such a table, see table 4 in appendix 3.

5.3.8. Preliminary land use assessment.

Concurrently with the land evaluation, a present land use map, also at the scale of 1:63,360, was prepared, in which 20 categories of land use were distinguished (Dimantha & Jinadasa, 1981). This present land use map was based on 1973-1978 aerial photographs (scale 1:25,000), adjusted and updated by information provided by the Basic Village Statistics, recent sub-sector studies as the Tea Master Plan and the Rubber Master Plan, and, of course, field checking. The present land use is summarized per agro-ecological zone in table 13.

Table 13. Matara: land use per agro-ecological zone in ha.

Land use	Agro-ecological zone				District
	WL ₄	WL ₂	WL ₁	WM ₁	
Total area	20,500	61,400	23,100	23,800	128,800
Forests	800	9,900	6,000	6,000	22,700
Scrub lands	900	6,300	2,500	2,200	11,900
Towns, villages	800	100	-	100	1,000
Other non cultivated	800	700	-	-	1,500
Total non-cultivated	3,300	17,000	8,500	8,300	37,100
Paddy	3,710	11,200	1,900	1,700	18,510
Tea	-	3,700	7,100	7,800	18,600
Rubber	500	7,300	1,700	500	10,000
Cinnamon	1,100	4,600	600	600	6,900
Coconut	9,700	6,800	700	400	17,600
Others	2,200	10,800	2,600	4,500	20,100
Total cultivated	17,210	44,400	14,600	15,500	91,710
Of which in homesteads	6,500	12,600	3,100	3,600	25,800

The next step is to discuss the major crops. This involves per crop a presentation of the major ways of cultivation, technology applied, the inputs and outputs, the possibilities and constraints for improvements, and other problems. This is not elaborated here.

At this stage there are two possibilities. The LEFSA sequence is either followed to the detailed farming systems analysis and the (semi-)detailed LE at the farm and activity levels (steps 9, 10, 11, 12, and 13), or directly to step 14 and 15. In the latter case one opts for a more general or global analysis indicated by steps 14A and 15A. This path is followed here first. Of course, that does not exclude a more detailed analysis in a later stage.

5.3.14A. Improving land use at the (sub)regional level/ (sub)regional 'optimization'.

On the basis of a comparison of the present land use in each land unit and the more suitable uses as resulting from the suitability classification, possible land use changes are indicated. A summary of such changes, aggregated for simplicity, is presented in table 14. If a land use change appeared economically attractive and socially feasible, a project was identified. However, it can also be decided that the present land use is the best one. Even in that case the tree crops age and will have to be replanted some time in the future. This is precisely one of the constraints of the present situation: especially in rubber and coconut, too large a proportion of the stands consists of trees that are, or soon will be, too old. Another possibility is a change in the cultivation methods, e.g. the introduction of fertilizer and, in the case of coconut, a less dense stand of trees. These possibilities have been appraised economically on a per crop (land use type) basis, in combination with the identification of beneficiaries, e.g. small holder tea and rubber producers, and cinnamon producers.

Other important constraints that have been taken into account were the market constraints for tea and cinnamon, see under (2). The maximum amount of marketable tea at present price levels, can be produced on the present tea area of 18,600 ha - minus 1,000 ha of land that has to be reforested - with yields of 1,350 to 1,600 kg of made tea, or on a smaller area of 10,000 with a yield of 2,700 kg. In the latter case, the remaining

Table 14. Matara district, alternative land use types and their extends (ha) based on land suitability evaluation.

	Coastal zone (WLA)		Central zone (WL2)		Northern zone (WLI + WLI)	
	present land use	alternative	present land use	alternative	present land use	alternative
Total area	20500		61400		46900	
Towns, non-cultivated	1600		800		100	
Forest	800		9900		12000	
Scrub lands	900	rubber (900) or coconut (900)	6300	rubber (6300) or coconut (6300)	4700	coconut (700) and rubber (700)
Total, non-cultivated	3300		17000		16800	
Pastures, patna grass	-		300		1900	
Paddy	3710		11200		3600	
Tree crops, pure stands:						
- tea	-		3700	rubber, coconut, cinnamon, pastures (3700 each) or citronella (1600)	14900	forest (1000), rubber (600), coconut (7600), cinnamon (13900), pastures (13900), citronella (3000)
- rubber	500	coconut (500)	7300	coconut (7300) or tea (4000)	2200	coconut (1700)
- cinnamon	800		3400			
- coconut	5400	rubber (5000) or coconut + curd (5400)	3000	coconut + curd (3000) or tea (1000)		
subtotal	6700		17190		17100	
Homegardens, mixed:						
- coconut	4300		3800		1100	
- cinnamon	300		1200	forest (700)	1200	forest (1800)
- others	2100		10500		5200	
subtotal	6700		15500		7500	
Market gardens	100		-		-	
Total cultivated	17210		44400		30100	

area can be planted to cinnamon, rubber and/or coconut. In that case the value added at economic prices is higher than for the first alternative, but employment is lower. Hence, a trade-off exists between value added growth and employment growth. The second alternative produces tea at a lower cost price than the first one. However, from a private economic point of view, producing tea at lower than possible yields is more attractive than growing alternative crops. As it also appears almost impossible for social or political reasons to force or induce tea small holders, private estates, or state plantations, to uproot tea in favour of other crops, the alternative of continuing tea production on the present tea area was proposed.

The following results with regard to the value added and the employment in 1980 and in 2000 were obtained:

subregion:	1980		2000		% yearly growth	
	value added Rs.* 10 ⁶	employment days * 10 ⁶	value added Rs.* 10 ⁶	employment days* 10 ⁶	value added	employ- ment
North	490.2	9.9	811.8	11.4	2.6	0.7
Centre	311.3	7.7	491.5	8.0	2.3	0.2
South	76.0	1.7	149.0	2.4	3.4	1.7
total	877.5	19.3	1,452.2	21.7	2.6	0.6

On the basis of these analyses, and further research with regard to more detailed benefits and costs, eight projects and a programme for agricultural development of the district were identified (step 15A). However, if the analysis would have been pursued in a more detailed fashion (steps 9 to 13), the sub-region North would have been selected for further analysis and planning, being the sub-region which can contribute most to the growth of incomes and employment in an absolute way.

The above assessment of alternatives is based on comparisons of the results with regard to the objectives, using simple arithmetics and interest tables. However, the decision problem can also be approached with optimization techniques like (multiple goal) linear programming. This is illustrated with a very simple model, representing the main options and constraints of the above problem. An example of a more elaborated model is presented in Erenstein & Schipper (1991).

First a list of the variables and constraints of the linear programming model is given, the two goal functions are defined and a summary of the

results of the solutions is presented. The matrices and the results in detail are presented in table 15.

- a) List of variables and constraints of the linear programming models to determine in principle the choice between alternative crops on the present tea areas.

Variables (areas in ha):

TEVPHN	Tea, VP, high yielding (2700 kg/ha) in North
TEVPHC	Tea, VP, high yielding (2700 kg/ha) in Centre
TEVPLN	Tea, VP, low yield (2025 kg/ha) in North
TEVPLC	Tea, VP, low yield (2025 kg/ha) in Centre
TESEN	Tea, seedling (1600 kg/ha) in North
TESEC	Tea, seedling (1350 kg/ha) in Centre
CINN	Cinnamon in North (600 kg/ha)
CINC	Cinnamon in Centre (600 kg/ha)
RUBN	Rubber in North (1400 kg/ha)
RUBC	Rubber in Centre (1400 kg/ha)
COCN	Coconut in North (12000 nuts/ha)
COCC	Coconut in Centre (12000 nuts/ha)

Constraints:

AREAN	Present tea area (ha) in North, disregarding 1,000 ha degraded land
AREAC	Present tea area (ha) in Centre
TEAMAR	Tea market restriction (tons made tea)
CIMMAR	Cinnamon market restriction (tons of quills), taking into account cinnamon production on other cinnamon areas
RUBAREAN	Maximum rubber area (ha) on present tea area in North
COCAREAN	Maximum coconut area (ha) on present tea area in North
RETVA	Return of value added in case of employment alternative
RETVAS	Labour costs in case of income alternative.

- b) Goal functions:

The coefficients in the goal functions, either the value added in the income alternative or the labour costs in the employment alternative, are in Rs. * 1,000 per hectare. It is justified to use labour costs in the labour alternative, as the wage is constant (Rs. 15 per day) over all activities. The coefficients in the goal functions are annuities of the net present values at a 10% discount rate of the benefits and costs over the life cycle of the crops, to make the activities - the crops - comparable.

- c) Summary of results:

Alternative goal:	Cropping pattern (ha)				Value goal functions (Rs. * 1,000)	
	North		Centre		North + Centre	
	Income	Employment	Income	Employment	Income	Employment
Crops:						
Tea VP high	10,000	-	-	-		
Tea VP low	-	13,753	-	-		
Tea seedling	-	-	-	3,700		
Cinnamon	1,167	147	-	-		
Rubber	600	-	3,700	-		
Coconut	2,133	-	-	-		
Total	13,900	13,900	3,700	3,700		
Value added (annuities, Rs. * 1,000)					493,777	478,089
Labour costs (annuities, Rs. * 1,000)					131,583	164,589

Table 15. Linear programming: matrices and solutions of two alternative objectives in the Matara case.

Income alternative: maximize value added.									
TEAV44		OBJECTIVE: MAX		VARIABLES: 12		DATE 07-05-1990		TIME 13:54:18	
BASIS: NONE		CONSTRAINTS: 7		SLACKS: 7					
RETURN	43.440	43.440	31.170	28.520	22.840	9.1380	RETURN	13900.00	SLACK
AREAN	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAN	13900.00	USAGE
AREAC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAC	3700.0000	0.00000000
TEAMAR	2.7000	2.7000	2.0250	1.6000	1.3500	.60000	TEAMAR	27000.0000	0.00000000
CINMAR							CINMAR	700.000000	611.875000
RUBAREAN							RUBAREAN	600.000000	0.00000000
COCAREAN							COCAREAN	7600.0000	0.00000000
RETVA5							RETVA5	478089.27	-478089.27
RETURN	11.290	11.290	10.090	9.5310	8.8800	4.4430	RETURN	13900.000	0.0000000
AREAN	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAN	13900.000	0.0000000
AREAC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAC	3700.0000	0.0000000
TEAMAR	2.7000	2.7000	2.0250	1.6000	1.3500	.60000	TEAMAR	27000.0000	0.0000000
CINMAR							CINMAR	700.000000	611.875000
RUBAREAN							RUBAREAN	600.000000	0.0000000
COCAREAN							COCAREAN	7600.0000	0.0000000
RETVA5							RETVA5	478089.27	-478089.27
RETURN	43.440	43.440	31.170	28.520	22.840	9.1380	RETURN	13900.000	0.0000000
AREAN	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAN	13900.000	0.0000000
AREAC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAC	3700.0000	0.0000000
TEAMAR	2.7000	2.7000	2.0250	1.6000	1.3500	.60000	TEAMAR	27000.0000	0.0000000
CINMAR							CINMAR	700.000000	611.875000
RUBAREAN							RUBAREAN	600.000000	0.0000000
COCAREAN							COCAREAN	7600.0000	0.0000000
RETVA5							RETVA5	478089.27	-478089.27
RETURN	43.440	43.440	31.170	28.520	22.840	9.1380	RETURN	13900.000	0.0000000
AREAN	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAN	13900.000	0.0000000
AREAC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAC	3700.0000	0.0000000
TEAMAR	2.7000	2.7000	2.0250	1.6000	1.3500	.60000	TEAMAR	27000.0000	0.0000000
CINMAR							CINMAR	700.000000	611.875000
RUBAREAN							RUBAREAN	600.000000	0.0000000
COCAREAN							COCAREAN	7600.0000	0.0000000
RETVA5							RETVA5	478089.27	-478089.27
RETURN	43.440	43.440	31.170	28.520	22.840	9.1380	RETURN	13900.000	0.0000000
AREAN	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAN	13900.000	0.0000000
AREAC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAC	3700.0000	0.0000000
TEAMAR	2.7000	2.7000	2.0250	1.6000	1.3500	.60000	TEAMAR	27000.0000	0.0000000
CINMAR							CINMAR	700.000000	611.875000
RUBAREAN							RUBAREAN	600.000000	0.0000000
COCAREAN							COCAREAN	7600.0000	0.0000000
RETVA5							RETVA5	478089.27	-478089.27

Employment alternative: maximize value added less surplus.									
TEAV54		OBJECTIVE: MAX		VARIABLES: 12		DATE 07-05-1990		TIME 13:55:13	
BASIS: NONE		CONSTRAINTS: 7		SLACKS: 7					
RETURN	43.440	43.440	31.170	28.520	22.840	9.1380	RETURN	13900.000	SLACK
AREAN	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAN	13900.000	0.0000000
AREAC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAC	3700.0000	0.0000000
TEAMAR	2.7000	2.7000	2.0250	1.6000	1.3500	.60000	TEAMAR	27000.0000	0.0000000
CINMAR							CINMAR	700.000000	611.875000
RUBAREAN							RUBAREAN	600.000000	0.0000000
COCAREAN							COCAREAN	7600.0000	0.0000000
RETVA							RETVA	478089.27	-478089.27
RETURN	43.440	43.440	31.170	28.520	22.840	9.1380	RETURN	13900.000	0.0000000
AREAN	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAN	13900.000	0.0000000
AREAC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAC	3700.0000	0.0000000
TEAMAR	2.7000	2.7000	2.0250	1.6000	1.3500	.60000	TEAMAR	27000.0000	0.0000000
CINMAR							CINMAR	700.000000	611.875000
RUBAREAN							RUBAREAN	600.000000	0.0000000
COCAREAN							COCAREAN	7600.0000	0.0000000
RETVA							RETVA	478089.27	-478089.27
RETURN	43.440	43.440	31.170	28.520	22.840	9.1380	RETURN	13900.000	0.0000000
AREAN	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAN	13900.000	0.0000000
AREAC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAC	3700.0000	0.0000000
TEAMAR	2.7000	2.7000	2.0250	1.6000	1.3500	.60000	TEAMAR	27000.0000	0.0000000
CINMAR							CINMAR	700.000000	611.875000
RUBAREAN							RUBAREAN	600.000000	0.0000000
COCAREAN							COCAREAN	7600.0000	0.0000000
RETVA							RETVA	478089.27	-478089.27
RETURN	43.440	43.440	31.170	28.520	22.840	9.1380	RETURN	13900.000	0.0000000
AREAN	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAN	13900.000	0.0000000
AREAC	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	AREAC	3700.0000	0.0000000
TEAMAR	2.7000	2.7000	2.0250	1.6000	1.3500	.60000	TEAMAR	27000.0000	0.0000000
CINMAR							CINMAR	700.000000	611.875000
RUBAREAN							RUBAREAN	600.000000	0.0000000
COCAREAN							COCAREAN	7600.0000	0.0000000
RETVA							RETVA	478089.27	-478089.27

TEAV54 SOLUTION IS MAXIMUM									
PRIMAL PROBLEM SOLUTION		RETURN 164589.6000		DATE 07-05-1990		TIME 13:55:28			
VARIABLE	STATUS	VALUE	RETURN/UNIT	VALUE/UNIT	NET RETURN				
TEVPHN	NONBASIS	.00000000	11.290000	13.170000	41.730000				
TEVPHC	NONBASIS	.00000000	11.290000	13.170000	41.730000				
TEVPLN	NONBASIS	.00000000	10.090000	11.082500	-7.915000				
TEVPLC	NONBASIS	.00000000	10.090000	11.082500	-7.915000				
TESEN	BASIS	13753.125	9.5310000	9.5310000	.00000000				
TESEC	BASIS	3700.0000	8.8800000	8.8800000	.00000000				
CINN	BASIS	146.87500	4.4430000	4.4430000	.00000000				
RUBN	NONBASIS	.00000000	4.4430000	4.4430000	-1.4400000				
RUBC	NONBASIS	.00000000	2.4350000	2.4350000	-2.0960000				
RUBCO	NONBASIS	.00000000	2.4350000	2.4350000	-2.0960000				
RUBS	NONBASIS	.00000000	1.4200000	1.4200000	-3.1670000				
S.1	NONBASIS	.00000000	.00000000	.00000000	-4.4430000				
S.2	NONBASIS	.00000000	.00000000	.00000000	-4.4430000				
S.3	NONBASIS	.00000000	.00000000	.00000000	-3.1800000				
S.4	BASIS	611.87500	.00000000	.00000000	.00000000				
S.5	BASIS	7600.00000	.00000000	.00000000	.00000000				
S.6	BASIS	7600.00000	.00000000	.00000000	.00000000				
S.7	BASIS	478089.27	.00000000	.00000000	.00000000				
TEAV54	SOLUTION IS MAXIMUM		RETURN	164589.6000	DATE	07-05-1990	TIME	13:55:28	

TEAV44 SOLUTION IS MAXIMUM									
PRIMAL PROBLEM SOLUTION		RETURN 493777.2667		DATE 07-05-1990		TIME 13:54:41			
VARIABLE	STATUS	VALUE	RETURN/UNIT	VALUE/UNIT	NET RETURN				
TEVPHN	BASIS	10000.000	43.440000	43.440000	.00000000				
TEVPHC	NONBASIS	.00000000	43.440000	43.523000	-0.08300000				
TEVPLN	NONBASIS	.00000000	31.170000	34.459250	-3.28925000				
TEVPLC	NONBASIS	.00000000	31.170000	34.452250	-3.27225000				
TESEN	NONBASIS	.00000000	28.520000	28.804704	-.28470370				
TESEC	NONBASIS	.00000000	22.840000	25.561500	-2.72150000				
CINN	BASIS	1166.6667	9.1380000	9.1380000	.00000000				
RUBN	NONBASIS	.00000000	9.1380000	9.2210000	-.08300000				
RUBC	BASIS	600.00000	7.6000000	7.6000000	.00000000				
RUBCO	BASIS	2133.3333	7.5170000	7.5170000	.00000000				
RUBS	NONBASIS	.00000000	7.5170000	7.5170000	-.08300000				
S.1	NONBASIS	.00000000	.00000000	.00000000	-7.5170000				
S.2	NONBASIS	.00000000	.00000000	.00000000	-7.5170000				
S.3	NONBASIS	.00000000	.00000000	.00000000	-13.304815				
S.4	NONBASIS	.00000000	.00000000	.00000000	-2.7016667				
S.5	NONBASIS	.00000000	.00000000	.00000000	-.08300000				
S.6	BASIS	5466.6667	.00000000	.00000000	.00000000				
S.7	BASIS	131583.33	.00000000	.00000000	.00000000				
TEAV44	SOLUTION IS MAXIMUM		RETURN	493777.2667	DATE	07-05-1990	TIME	13:54:42	

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Basically the results of the linear programming models indicate the similar types of solutions as the manual calculations. This applies both to the resulting cropping patterns and to the trade-off between the income and employment alternatives.

It has to be emphasized that the improved (optimized) cropping patterns are based on land use types as activities at the sub-regional level. These land use types are not treated as sub-systems of farms. In fact, this is an unwarranted abstraction or aggregation. At farm level, decisions about the cropping pattern - the crops to be planted within the farm - are made on the basis of an assessment of the available resources, e.g. parcels of land with different qualities, labour and capital, in conjunction with the objectives of the farm household, like a maximum money income. In that case the financial farm gate prices are important and not the economic prices, and the market constraints do not play a role, except that in the longer run the prices could decrease because of an over-production at the (sub-) regional and national levels. Other objectives at the farm level as self-sufficiency in food or minimization of risks might be important as well. A more correct procedure would be to first improve (optimize) the cropping pattern at the farm level and subsequently improve (optimize) the aggregated land use at the sub-regional level, given the cropping patterns at the farm level. As it is in practice not feasible to do these improvements or optimizations simultaneously, it is advised to start with improved cropping patterns at the farm level, then to work at improving land use at the sub-regional level and then to return to the farm level and start a new round. After a number of iterations land use can be improved at both levels.

It is our contention that the improvement (optimization) of cropping patterns at the farm level can only be attempted if the LEFSA sequence is followed to the detailed farming systems analysis and the (semi-)detailed LE at the farm and activity levels, in other words by following steps 9 to 13. This course is pursued shortly. However, it is assumed that a more global analysis, as described - going directly from step 9 to step 14 - is also carried out, and that those results can be used as background for the more detailed research, but also for formulating a global land use plan as a basis for preliminary decisions with regard to projects, programmes and policies. This will be elaborated first.

5.3.15A. Land use plan.

In the agricultural development plan of the Matara district in Sri Lanka, eight projects and a programme were identified, affecting 75,000 families, mostly small holders, which corresponds to 60% of the rural population. Also more employment for estate labourers, mostly females, is created through the rehabilitation of tea and rubber estates. All projects, except a cinnamon training programme, are directly related to land and they cover 36,000 ha, or 39% of the cultivated area. The projects are localized on a project map at a scale of 1:63,360, the same scale as the land use and land evaluation maps. The projects involve either a rehabilitation and improvement of existing land use, or a change in land use. The first one is the most important, as present land use is in general in accordance with its suitability, as assessed by the land evaluation, and because most crops are perennials, for which uprooting and new planting involve high investments. Total investment is more than Rs. 900 million. The projects have a duration of 3 - 21 years. Assuming a scarcity value of capital of 10%, most projects are economically feasible. However, the ranking of the projects differ, depending on whether financial or economic prices are used. Most implementing agencies are existing organizations, although reorganization is recommended in some cases. The following projects are recommended:

project	families benefi- ciaries	ha	investment Rs.* 10 ⁶	IRR (%) financial	IRR (%) economic prices
1. cinnamon rehabilitation	1,000	4,000	13	23	-
2. minor & medium irrigation rehabilitation	9,300	2,700	5	21	-
3. estate rubber development	-	1,300	41	14	20
4. estate tea development	-	2,200	122	10	15
5. rubber new planting	7,900	7,900	199	10	19
6. livestock development	10,000	4,000	4	17	-
7. cinnamon peelers training programme	1,000	-	-	-	-
8. tea small holders	14,000	5,300	329	9	12
9. rubber rehabilitation	30,000	8,700	255	10	10.

5.3.9. Analysis of farm systems and interactions of land use types/activities/subsystems.

Based on step 5 - a first diagnosis of constraints in land use and farming - four farm types have been distinguished in each of the three sub-regions. These were based on average farm sizes and cropping patterns

obtained from village surveys and aggregated per sub-region. It has to be examined whether these farm types are 'real' existing farm systems. For the sake of the argument that is assumed to be the case, although it is known that in reality farms are more specialized than the average farm types indicate. For each farm type - farming system - a number of representative cases will have to be studied. Below, an example of a typical case of the medium holdings in the North of Matara will be discussed. The information on this farm system will be provided in accordance with the checklist in appendix 5 as far as practical and relevant.

1) Farm/household level.

The farm family, headed by a Mr. Wickremasinghe, consists of seven persons, man, wife, grand mother, two girls of 7 and 12 years, and two boys of 9 and 16 years. The needs of the family consist of food, a house, firewood and sufficient money to cover expenses for food, clothes, household items, consumer durables (e.g. radio, bicycles), travel, and, above all, school uniforms and other school requisites. The production goals of the farm are therefore to produce paddy as a basic food, and cash through the sale of crops like tea, rubber and, possibly, cinnamon. An additional income is earned through off-farm employment.

The farm consists of four parcels of land, that can be cultivated during two seasons, the Yala from April to September and the Maha from October to March. The first parcel of 0.3 ha, rainfed bunded paddy land in land unit 4 (according to the (semi-)detailed land evaluation) is planted to paddy in both seasons. Vegetables would be a good alternative to paddy in the Maha season. The second parcel of 1.70 ha, highland in land unit 2, is planted with tea. Alternative crops could be rubber and cinnamon. The third parcel of 0.20 ha, also highland but in land unit 6, is planted with rubber. An alternative crop could be coconut. The fourth parcel is a homegarden of 0.50 in land unit 7. It contains the house and is planted with various homegarden crops, like coconut, vegetables, fruit trees, spices and condiments; no alternatives are envisaged. The farmer and the eldest son are available for farm work. The eldest son represents 0.5 male labour equivalent as he also attends a secondary school. The wife and the grandmother represent 1.5 female labour equivalent. Household tasks, cooking, washing, child care, etc, require 1.0 female labour equivalent.

The farmer takes the decisions with regard to the farming activities, except for the homegarden, while his wife is responsible for the homegarden and the household activities. The farmer and his wife both completed the primary school. The younger children are attending primary school, while the eldest son is attending an agricultural college in Matara town. The extension service of the Agricultural Department follows the 'Training and Visit' approach and organizes bi-weekly meetings in the village, which the farmer attends regularly. An extension officer of the Tea Small Holders Development Authority visits the farm occasionally.

2) Activity/subsystem level.

The individual land use types/activities/subsystems - here referred to as **activities** to emphasize the economic aspects of these land use types or subsystems - will be treated under step 10, on a per hectare base for sake of comparison. In step 9 the emphasis is on the results of the activities with regard to the objectives of the household, e.g. food production, cash income generation or reducing of risks; the use by each activity of the resources of the farm, e.g. land and labour; and the interrelations in a biophysical and socio-economic sense between the activities, e.g. the use of rice straw by cattle and the use of dung by crops. In this analysis, the real 'size' of an activity is taken into account, e.g. 0.3 ha paddy, 1.70 ha tea, 0.2 ha rubber and 0.4 ha homegarden. Furthermore, the constraints and problems encountered at the farm level are examined. An obvious example is the limited availability of family labour, implying among other things that the time spent on paddy cultivation cannot be used for tea cultivation. Furthermore, the farm has to hire labour; as an example, in the peak month October 143 mandays are required, while only 42 days are available as family labour.

The contributions of each activity to the objectives of the household, as well as the use of the main resources are given below. There are no biophysical links between the different activities, i.e. that no output of one activity is used as an input by another activity.

1. household activities.

See under 1) farm/household level.

2. off-farm activities.

The farmer regularly works as a casual labourer for a shopkeeper and trader in another village. If employment is available, he can work about eight days per month at a wage of Rs. 20 per day, which amounts to Rs. 1920 per year.

3. on-farm activities.

The present cropping pattern was outlined under 1) farm/household level. First some details about each activity will be presented, then a summary of the contributions of each activity to the household goals and the use of the resources will be given.

Agro-economic aspects per activity.

Paddy.

On the 0.3 ha, and assuming 1.75 harvests annually, the volume of paddy is 1,313 kg, equivalent to 850 kg of rice. As the family has 5.5 consumer equivalents, who each consume about 180 kg of rice per year, the requirements for rice are 990 kg. So, production is not sufficient for the household consumption. A further complication is presented by the land tenure system, see below.

On an annual basis, the value added of the paddy activity is Rs. 1,462, the return to land, labour and capital Rs. 1,215 and total labour requirements are 45 days, unevenly spread over the year. The gross margin of the

activity depends on the amount of hired labour, which can vary from season to season and from year to year. Additional costs to determine gross farm income are the costs for renting the land. Mr. Wickremasinghe is owner of his land, but he shares this ownership with a sister and a brother in such a way that each can use the land in turn for one year. This type of customary ownership is called Thattumaru. As his sister and brother are both married and live in Colombo, they do not cultivate the paddy land in the years that they have the right to do so, but give the land in share cropping to the brother who resides on the farm. The farmer has to give 25% of the yield in kg to his brother or sister. It is often hypothesized with regard to Thattumaru, that such a type of ownership prevents each owner from making more permanent improvements, as he has to share the benefits with the other owners. However according to the farmer, there is no such evidence on the present farm according, except that the brother and sister insist on receiving rice, which excludes the cultivation of, for example, vegetables in the Maha season.

Tea.

Total production on 1.70 ha is 2550 kg of made tea, which gives a return to land, labour and capital of Rs. 38,845 in cash per year. The total labour requirements are 1173 days varying over the year more or less according to the rainfall pattern. In the wet months 126 days are necessary per ha and in the dry months 56 days. The gross margin of this activity depends on the amount of hired labour. This can vary from year to year. Additional costs to determine gross farm income are the costs for renting the land. However, Mr. Wickremasinghe is owner of his land, and in this case he does not have to share the ownership with his brother and sister.

Rubber.

Annual production of 0.2 ha is 170 kg of rubber sheets, which provides a return to land, labour and capital of Rs. 1,903. Total labour requirements are 53 days per ha. There is no fluctuation during the year. The gross margin of this activity depends on the amount of hired labour. This can vary from year to year. Additional costs to determine the gross farm income are the costs for renting the land. However, Mr. Wickremasinghe is owner of his land and also in this case he does not have to share the ownership with his sister and brother.

Homegardening.

The most important crops in the homegarden are coconut (10%) and cinnamon (14%). The remainder is occupied by other crops as vegetables, fruit trees, spices and condiments. Most of the homestead production is for family consumption, although occasionally some is sold. No inputs are applied. As 0.1 ha of the homegarden is occupied by the house and used for play- and living ground, only 0.4 ha is used as homegarden, providing a return to land, labour and capital of Rs. 600 per year, mostly in kind, except for the cinnamon quills, which are sold for a total value of Rs. 162.

Contribution to the household goals and resource use.

Returning to the farm level, one can summarize the contribution of each activity to the household goals, as well as the use of the resources:

	contribution to goals		use of resources	
	food kg of rice	cash Rs.	land ha	labour days
off-farm:				
casual labour	-	1920	-	96
on-farm:				
paddy	709	-	0.3	45
tea	-	38845	1.7	1173
rubber	-	1902	0.2	53
homegarden	-	162	0.4	26
total	709	42829	2.6	1393

The production of rice is not sufficient for the household needs, but as cash income is by local standards quite high, this can be supplemented by buying rice. However, as family labour availability is not sufficient to cover the labour requirements, labour must be hired at Rs. 15 per day. In total the family has 2 * 250 labour days available for farm work, so at least 893 days of labour have to be hired at a cost of Rs. 13,395. However, due to the fluctuation of the labour requirements during the year, more hired labour could be necessary. This is not the case here, as labour has to be hired in all months.

Problems and possibilities.

No special problems are present at this level except those applying in general to the agricultural sector in Matara, mentioned under step 5, and those related the production of paddy, tea and rubber, mentioned under step 10.

5.3.10. Analyses of land use types/activities/subsystems.

In the LEFSA sequence, as explained earlier, subsystems of farm systems are considered identical to land use types of LE at the (semi-)detailed scale and can also be considered as on-farm economic activities of the farm household. The same example as under step 9 will be pursued.

In the farm system of Mr. Wickremasinghe, four subsystems can be distinguished.

1. Paddy.

Agronomic aspects.

Soil preparation of the rainfed bunded paddy land (15 labour days) consists of ploughing with buffaloes. The farmer does not own the buffaloes, but rents them at Rs. 450 per ha. The paddy is broadcast (2 days) in the mud. The variety used is the 'New Improved Variety'. Fertilizer (5 days) is applied at a rather high dose of 550 kg of NPK, Urea and TPM. Weed control (5 days) is by chemicals, while also pesticides are used (2 days). Harvesting and processing takes 56 days. Harvesting is by sickle, threshing takes place by treading buffaloes. Winnowing is done by wind or hand

fanning. About fifty small rice mills in the district transform paddy into husked rice, with a transformation coefficient of 60-65%.

Agro-economic aspects.

Below, a simple input-output relation of paddy production in one season on one hectare is given. Each year it is tried to cultivate paddy in the two seasons. Because of climatic variability, this is not a success every year. On average, 1.75 harvests per year are possible.

Input-output relation for paddy per season per hectare:

	quantity kg	price Rs./kg	value Rs.
output			
paddy	2500	1.92	4800
inputs			
fertilizer	550	1.00	550
other			1485
total			2035
value added			2765
rent of buffaloes			450
return to land, labour and capital			2315

Total labour requirements are 85 days.

Problems and possibilities.

According to agronomists, only slight yield improvements can be expected under the climatic conditions in sub-region North, especially because of bog soils, inundation/drainage problems and restricted hours of sunshine.

2. Tea.

Agronomic aspects.

- variety.

The tea is of the VP (Vegetatively Propagated) type, and was planted by the father of Mr. Wickremasinghe about 30 years ago.

- plucking.

Ideally the tea leaves harvested should consist of two leaves and a bud, but three leaves and a bud are also accepted. However, because small holders are not paid according to quality but to quantity only, farmers often try to pluck even more coarse leaves and stalk. This results in an overall low quality of the tea processed by the five tea factories of the Tea Small Holders Development Authority.

- weeding.

Because of the high leaf cover the VP tea suppresses weed growth and weeding is hardly necessary.

- fertilizer.

According to the Tea Research Institute (TRI) a linear relationship exists between average annual nitrogen application and yield per hectare, at least up to yield levels of about 2000 kg of made tea: about 100 kg of nitrogen per 1000 kg of made tea. However, this relationship changes to about four kg of made tea per kg of nitrogen at yield levels above 2000 kg on the best land. In addition, about 15 kg of P₂O₅ and 35 kg of K₂O per 1000 kg of made tea is required.

Mr. Wickremasinghe applies 200 kg NPK and 200 kg Urea and obtains a yield of 1,500 kg of made tea per ha.

- pests and diseases.

Pests and diseases are controlled by the use of pesticides developed by the TRI against diseases as blister plight, poria, shot-hole borer and livewood termite.

- pruning.

Pruning to maintain tea as a bush, to cut away infested branches and to keep the bushes at the required height for plucking, takes place every three years.

- plant density.

On one hectare of VP tea 12,300 bushes are planted, regularly 'infilling' is required to avoid 'vacancies'.

- replanting.

VP tea should be replanted after 40 years.

- manufacturing.

Manufacturing is done in 48 rather old factories, of which five were built especially for small holders.

- labour requirements.

Plucking requires most labour in tea cultivation. On this farm 460 days per ha are spent in this operation. All the other operations, weeding, pruning, fertilizer and pesticide application, in short sundry, require 230 labour days per ha.

Agro-economic aspects.

Below, a simple input-output relation for a year that the tea is in full production is given. For decisions about establishing new tea plantations, one has to take into account the investments, the years without production and, consequently, the foregone income, and the aspects of credit.

Input-output relation for tea per season per hectare:

	quantity kg	price Rs./kg	value Rs.
output			
made tea	1500	16.50	24750
inputs			
fertilizer	400	1.00	400
other			1500
total			1900
value added			22850
other costs			-
return to land, labour and capital			22850

Total labour requirements are 690 days per ha.

Problems and possibilities.

There are no problems with the tea on the farm of Mr. Wickremasinghe. However, VP tea has a higher yield potential (up to 2025 kg of made tea per ha on the type of land where his tea is presently grown, see under step 12) than is realized at present. The plantation will have to be rehabilitated, more inputs applied and management improved. This would involve a substantial investment, some years with a reduced income, and probably the farmer will have to give up his off-farm work. Alternatively, one waits 10 years till the moment that the tea has to be uprooted anyway.

3. Rubber.

Agronomic aspects.

- planting material.
The rubber trees were planted 25 years ago and are soon due for replanting with rubber or for replacement with coconut. The present rubber is seedling rubber, but nowadays bud crafts are more usual, especially the clone PB 86.
- density ground cover and soil conservation.
The father of the present farmer planted 70 trees on 0.2 ha, as recommended. Ground cover is adequate and soil conservation measures as drains and stone walls were built by him and well maintained.
- fertilizer and use of agro-chemicals.
The use of fertilizer is about 100 kg per ha. As there is no evidence of damage by the panel or root diseases no chemicals are used.
- tapping practices.
The farmer applies the S/2 D/1 (half spiral, every day) tapping system like most small holders, in contrast with the estates which tap according to the S/2 D/2 system, that ensures a longer life. As the trees are becoming older and less productive, the farmer considers changing the tapping system to 'slaughter' tapping (2S/2 D/1), also because presently prices are favourable.
- intercropping.
The rubber is not intercropped, although there are substantial possibilities for intercropping during the immature stages.
- processing and marketing.
The farmer processes his own rubber into 'Ribbed Smoked Sheets' (RSS), which includes three important stages:
 - a. coagulation with acid;
 - b. milling through rollers into ribbed sheets; and
 - c. curing in a smoke house to dry and to prevent mould development.
 The processing plant is very small with obviously a very low daily production; in general sheets of a rather low quality are produced that, consequently, have to be sold for a low price. The sheets are sold to dealers in the village.

Agro-economic aspects.

Below, a simple input-output relation, referring to a year that the rubber is in full production, is given. For decisions about establishing new rubber plantations, one has to take into account the investments, the years without production and, consequently, the foregone income, and the aspects of credit.

Input-output relation per season per hectare:

	quantity kg	price Rs./kg	value Rs.
output			
sheets of rubber	850	8.25	7013
inputs			
fertilizer	100	1.00	100
other			400
total			500
value added		-	6513
other costs			
return to land, labour and capital			6513

Total labour requirements are 265 days per ha.

Problems and possibilities.

A problem is the low quality and, consequently, the low price of the rubber sheets. To improve this is very difficult or costly, given the processing technology at farm level. Prices vary in accordance with world market prices which is at times rather brusque. Like most of the rubber trees in the district, they are rather aged. Yields are declining already for some years and this will continue. Mr. Wickremasinghe decided that he will 'slaughter' tap the rubber in view of the current good prices and because he wants either to replant this area with budded rubber or start a small coconut plantation. This would require an investment for which he can obtain a subsidy.

4. Homegardening.

As said before, the most important crops in the homegarden are coconut (10%) and cinnamon (14%). The remainder is occupied by other crops as vegetables, fruit trees, spices and condiments. Most of the homestead production is for home consumption, although occasionally some is sold. It is estimated that one hectare of homestead provides a value added of about Rs. 1500 per year for which the family has to work 66 days. No inputs are applied. No special problems seem to exist. In general the impression is that there is little scope for improving the homegardens.

5.3.11. Refined selection and detailed definition of land use types (activity/subsystem level).

On the basis of the more global analysis, described before (i.e. going directly from step 9 to step 14 and 15 (14A and 15A)), it is decided to select the sub-region North for a (semi-)detailed land evaluation. In the North, the potential for further growth of incomes and employment is the highest of the three sub-regions.

Of the 18 land use types (LUTs) distinguished in the reconnaissance LE, a number are not relevant anymore as they were classified as unsuitable on most land units, or are unattractive at current prices from an economic point of view. The latter holds true for LUTs 4, 6, 9, 10, 13, 15, 16, and 17. However, from a soil protection point of view, LUTs 9 and 10 (pasture), and 15 (forestry) will be evaluated. Not relevant is LUT 7, irrigated paddy, as there is no scope for irrigation. Not suitable were the LUTs 2, 12, and 14. Hence, the LUTs 1 ('high' input tea), 3 ('high' input rubber), 5 ('high' input coconut), 8 (rainfed paddy), 9 ('low' input pasture), 10 ('high' input pasture), 11 ('high' input minor export crops),

15 (forestry), and 18 (annual crops in paddy fields) are relevant for a refined selection and detailed description.

The land use types should be described in detail. This is not done in the present example. However, most of this detail is provided in step 10 - Analysis of land use types/activities/subsystems - except for land use types presently not practiced in the sub-region. An example is the VP tea. Present yields are on average about 1,500 kg of made tea per ha, but can easily be increased to 2,700 kg per ha - if on the best (S1) land - mostly through applying more fertilizer (1250 kg in stead of 400 kg) after a three-yearly pruning. Such a jump in fertilizer use, implies a change of technique and, hence, another land use type. Obviously, such a new land use type has to be described in detail.

5.3.12. (Semi-)detailed land evaluation.

An appropriate scale for aerial photo's is 1:10,000, which would permit a map of the same scale, if a sketchmaster is used. At that scale areas of about 0.25 ha can be drawn accurately on a map and are readable for a user. If more refined digital image processing is used, the areas in the terrain can be as small as 0.10 ha. For readability, the map should be enlarged.

At this scale all farms in the sub-region can be mapped, except may be for the very small micro-holdings consisting of only a home garden. In the North, about 10% of the holdings, occupying 1% of the cultivated area, fall into this category (table 10). In general, it would not be economic to produce a map with the detailed parcels of all farms in a (sub)region. As farm systems can be grouped into farming systems, detailed land evaluation (which would permit a delimitation and classification of the parcels of individual farms) could be restricted to those farms that fall into the sample of each farming system.

The suitability classification is again based on biophysical criteria. Land use types are defined with a maximum normative¹³ yield, given a fixed

¹³ The maximum normative yield differs from the potential yield (see pages 121 & 132) and from the maximum station yield (page 121).

input¹⁴ and management level, under the best biophysical conditions in view of the sub-regional circumstances. Following the usual grading of suitabilities (e.g. FAO, 1976 & 1983), four levels are used, based on the range of the yield in relation to the normative yield. For computational convenience a point estimate of the yields is also provided.

Suitability level	range of yield relative to normative yield at a fixed input level	point estimate of yield relative to normative yield at a fixed input level
'good' S1	76% - 100%	$0.9 * 100\% = 90.0\%$
'fair' S2	51% - 75%	$0.9 * 75\% = 67.5\%$
'poor' S3	26% - 50%	$0.9 * 50\% = 45.0\%$
'not' N	< 26%	- .

On the basis of these biophysical classifications, economic calculations are made. Using point estimates is just for ease of calculation. It would be possible to work with ranges. Another possibility would be to use probability estimates, e.g. expected yield at each suitability level and variability. The percentages used in the above scheme are not a must, other ranges are also used, e.g. S1: 80-100%, S2: 40-80%, S3: 20-40%, and N: 0-20% (FAO, 1983: 61).

Another possibility - in stead of point estimates of the yield of a land use type for each suitability level, without specifying the land unit - is to estimate the expected yield for each land use type / land unit (parcel) combination. This would be preferable, but requires more and better information than often at present available.

It must be emphasized that much care should be taken in the estimation of normative yields, as this will be decisive for further calculations. Although much can be said about these estimations (van Diepen et al., 1991), for the time being and because it is outside the scope of the present volume, it will be assumed that this will be taken care of by the biophysical disciplines involved in a land evaluation. However, it is

¹⁴ Except for inputs which are directly proportional to the quantity harvested, e.g. harvesting labour, transport costs. This is a sub category of the 'activity variable costs' (FAO, 1986: Volume I, 3 Data structure, 8-9), namely costs not only variable in relation to the size of the activity measured in hectares (or animals), but also variable in relation to the output per hectare (per animal).

extremely important to compare the yields according to the above scheme with yields - and historical trends in these yields - as observed in the field (surveys, and other sources of information), in order to be realistic.

Continuing with the example of the farm of Mr. Wickremasinghe, the four parcels of his farm, and the relevant alternative land use types, are classified as in table 16.

Table 16. Suitability classification of the parcels in relation to relevant uses of a particular farm system (simplified).

Parcel:	Land unit	Present LUT	Season	Alternative LUTs				
				VP tea	Cinnamon	Rubber	Coconut	Paddy
paddy land	4	paddy	<u>Yala</u>	N	N	N	N	S2
-do-	4	paddy	<u>Maha</u>	N	N	N	N	S2/S3*
highland	2	tea	both	S2	S1	N	N	N
highland	6	rubber	both	N	N	S1	S2	N
homegarden	7	homegarden	both	N	N	N	N	N

* depending on rainfall, one Maha season out of four is a failure.

The suitability classification should be done for all farms per farming system and for all relevant farming systems. This would give the biophysical basis for improving the farm systems in the next step.

5.3.13. Improving current farm systems / within farm 'optimization'.

For each suitability level of each land use types for each parcel within a farm system, which is better than 'not', agro-economic indicators have to be calculated. Again the farm of Mr. Wickremasinghe will be the example.

The agro-economic indicators of the different land use types within the example farm are calculated in table 17. In the case of paddy, the indicators are per season. In the case of perennial crops, the economic indicators are annuities of the net present value of the differences

between the benefits and the costs¹⁵. In that way the investment and the years without production are accounted for. The interest rate used is 10%. Other interest rates give different results and might influence the relative attractiveness of the alternative land use types. However, it is assumed here that an interest rate of 10% is a reasonable estimate of the marginal return to capital in the Sri Lanka economy.

Table 17. Agro-economic indicators, related to the suitability levels in table 16.

	LUT						
	VP	Tea	Cinnamon	Rubber	Coconut**	Paddy	Paddy
normative yield (kg/ha)	3000		670	1560	13300	4000	4000
suitability level	S2		S1	S1	S2	S2	S3
estimated yield (kg/ha)	2025		600	1400	9000	2700	1800
labour use (manday/ha)	756/696*		359	200	93	83	65
economic indicators							
at economic prices: (Rs.)							
value added/ha	31172		9138	7600	5192	6032	2935
surplus/ha	21085		4695	5165	3921	4787	1960
value added/manday	41		25	38	56	73	45
economic indicators							
at financial prices: (Rs.)							
value added/ha	16543		8537	2673	3771	2549	821
surplus/ha	6456		4094	238	2500	1304	- 154
value added/manday	24		24	13	41	31	16

* including manufacturing for analysis at economic prices, excluding manufacturing at financial prices as the tea processing is not done on the farm.

** yield of coconut in nuts per ha.

In the longer term, there are two relevant decisions for the farmer. At the highland presently with tea, it can either be replanted with tea or planted with cinnamon. In the example in table 17, from the point of view of the farmer - at financial prices - tea is more attractive than cinnamon with regard to the value added per ha and the surplus per ha. Surplus is defined here as the value added minus the labour use, costed at the market wage of Rs. 15 per day. In terms of the value added per labour day, there is no difference. It is clearly advisable to continue with tea. In this case there is no significant discrepancy between an analysis using economic

15 - Net Present Value (NPV):

$$NPV = \sum_{t=1}^n \frac{(B_t - C_t)}{(1 + i/100)^t}$$

where: B_t =benefits in year t, C_t =costs in years t, and i =interest.

- Annuity (A) of NPV:

$$A = - NPV * \frac{i/100}{(1 + i/100)^{-n} - 1}$$

prices and one using financial prices. Also from the point of view of the country as a whole, Mr. Wickremasinghe should continue to cultivate tea.

The other choice concerns the highland presently with rubber, which is due to be uprooted within two years. At financial prices, coconut is more attractive to the farmer with regard to all indicators in table 17. It is advised therefore to replace the rubber trees with coconut, also because the farm has a shortage of family labour and coconut uses less labour than rubber. In this example, one can appreciate from table 17 that from a national point of view, rubber is more attractive than coconut, at least if value added or surplus per ha are the criteria. However, if the value added per labour day - a measure for labour productivity - is more important, then coconut would be preferred.

Following the longer term investment decisions, the farmer can design a strategy for reaching that situation. In view of distributing the investments over the years, as well as getting a plantation in which the ages of the trees are more evenly distributed, the following could be a possible approach. Starting from the 1980 situation, the farmer could slaughter tap the rubber in 1981, replace rubber trees on 0.1 ha by coconut in 1982, while continuing tapping the other half of the rubber trees. Then in 1983, he could replace the remaining rubber trees by coconut. From 1984 onwards, the farmer could uproot each year 0.1 ha tea and replant it with new VP tea. Obviously, such an investment scheme would require good management with an exact registration, but it is expected that Mr. Wickremasinghe, and soon his eldest son, are capable of doing that. It is decided to continue paddy cultivation and the home garden unchanged.

The above assessment for improvements should be done for all sample farm systems and generalized for the relevant farming systems, if possible. As an alternative to the above approach to improving farm systems, farm optimization models could be designed, if substantial benefits over a more conventional approach would be expected, and if data and time permit it.

It would be important to consider in the analysis aspects of risk and factor substitution and dynamic elements. Risk is an important aspect of agricultural production. This especially applies to yields and prices, but also the availability of factors of production and inputs is uncertain. The omission of risk is likely to overstate supply responses of farm households as well as the returns to investment (Hazell & Scandizzo, 1983). Another aspect of agricultural production is the use of different technologies for the production of the same commodity (different production methods or production techniques). This applies both to the use of inputs and factors of production, as well as to cultivation and husbandry methods. For each relevant - different production method, a separate land use type can be defined, each with different input-output coefficients. Lastly, it would be important to incorporate dynamic elements. In dynamic models the results of

one year (e.g. stocks, savings) are an input in the model of next year. This is, for example, the case with perennial crops or agro-forestry.

Here, it is not attempted to present a model of the example farm, as that would become too complicated for an illustration, and outside the scope of the present volume. The reader is referred to Hazell & Norton (1986) for an up to date text.

5.3.14B. Improving land use at the (sub)regional level/ (sub)regional 'optimization'.

Having assessed the improvements for all sample farm systems and generalized for the farming systems, they should be aggregated to the (sub)regional level. If, for example, the farm of Mr. Wickremasinghe can be considered representative for the farming system of medium holdings in the Northern sub-region in Matara (however, see the remarks at the beginning of step 9, and table 11), the results of his farm could be multiplied with the number of farms in this category (2000, see table 10), to obtain the sub-regional totals for this farming system. Doing this for all farming systems, one obtains the aggregated land use, productions, incomes and employment. If the sample farms are representative, this way of aggregation is justified for (sub)regions that are not too 'large' in the national context. Large in the sense of its contribution to the national production of agricultural commodities. In that case, the aggregated totals are not likely to influence, for example, price levels. If a region is large, its production, in relation to the production from other regions, influence price levels. In that case, prices are no longer fixed, which is one of the basic assumptions in planning at the farm level. Other problems are constraints that do not operate at the farm level, but are operative at the regional level, for example labour availability, or markets. Often one farm can hire labour without limits, or sell tomatoes in unlimited quantities, but if all farms want to hire so much labour, it may simply not be available and wages will increase, or if all farms start to produce tomatoes, prices will drop or the tomatoes will be left unsold. If that is the case, the farm plans will have to be adjusted. Such an adjustment is an iterative process, switching between the regional - meso - level, or even the national - macro - level, and the farm - micro - level. Because regions are involved, it becomes even more complicated than just the differences between macro- and micro-economics, as factors such as comparative

advantage among regions have to be taken into account. The land units in one region might be suitable for a certain crop, ecologically sustainable and economically viable, but in other regions the production of this crop might be even more attractive, either in absolute terms or in comparison with other production possibilities in the regions. Yet another complicating factor is that at the regional level the agricultural sector is not isolated from the rest of the economy of that region and of the country as a whole.

In economics, the relations between analyses at the micro and at the macro level are theoretically among the most difficult problems, even more so when different regions are involved, and as yet unsolved in a satisfactory way, certainly for practical situations. The present document cannot even attempt to provide any guidelines in this area, except via adjustments in a process of trial and error.

Theoretically there are possibilities for an approach through models at different levels. One could develop different models for the farming systems of a region, and incorporate the results of these models, with regard to the objectives and the use of regional resources and constraints, as activities in a model at the regional level. Up to now, this approach has met with little success, see Norton & Hazell (1986). Much further research is necessary in this area. It should be realized that such an approach would be very data commanding and require much time and qualified manpower, each time the LEFSA sequence is applied, especially if reality is so diverse that too many farming systems have to be distinguished. It is doubtful whether such efforts are justifiable from the point of view of creating a better land use, more sustainable and with farm systems providing a better livelihood for the farm households.

5.3.15B. Land use plan.

In step 15A, a global land use plan is created, on the basis of a reconnaissance LE (step 7) and a first diagnosis of land use and farming (step 5), and by taking into account economic and social constraints, and financial and institutional constraints. It contains specific projects and a programme. As no detailed farm and activity level research was executed for that plan, the following questions arise. Is a reconnaissance LE detailed enough in its recommendations with regard to the suitability of

crops? Is enough known of the farming systems to make sure that, if the projects are implemented,

- a. the participation of the farmers and their family members is probable, as they did not participate in the design of the projects;
- b. the crops to be stimulated fit into the farming systems;
- c. the farms are not more specialized than is assumed;
- d. a better description and analysis of the land use types/subsystems is not necessary to be sure of really good proposals to the farmers; and
- e. the farm household points of view, and objectives and constraints sufficiently are taken into account?

By following the complete LEFSA sequence (steps 8, 9, 10, 11, 12, 13, 14B and 15B), these questions can be better answered. Projects can be identified with target groups whose situation is better known and who participated in the design. However, it is a question whether the complete sequence should be done for all possible sub-regions and for all projects identified during the more global analysis, or only for those that, presumably, contribute most to the objectives. The last course seems to be the most plausible.

Still the question remains whether the more detailed analysis is really necessary for formulating and implementing a successful land use plan. In other words, is such a detailed analysis not too time consuming and too costly, in terms of personpower and financial resources, considering the possible benefits in terms of incrementally (compared to projects identified through the more global analysis only) better projects. This apart from the question whether such an exercise is not too complicated. A detailed analysis might be warranted if, on the basis of a more global analysis, it is clear that the prospects for successful projects are favourable, but that, in order to ensure success, more detailed information is essential.

It has not been possible to elaborate in the present volume an example of a possible detailed land use plan for a part of the Matara district, as this would require much more research. One of the recommendations of this document is to start a research project to see how the LEFSA sequence, especially steps 9 to 14 and 15, can be applied in practice. It is of course a pity that it could not be fully shown in the present volume how the LEFSA sequence could work from the national level down to the farm and subsystem/activity levels, and upwards again to a fully fledged

implementable - practical and acceptable for most farmers - land use plan. Still, the elaboration of the sequence in a case study has been most useful. In the next section some evaluative remarks about the application of the Matara case will be made.

5.4. Lessons from the Matara case

The application of the LEFSA sequence to the Matara case has elucidated the main principles of the possible complementarity and integration of LE and FSA for land use planning. It is useful to bring to the fore some preliminary conclusions about the reinterpretation of the available information about (the planning of the development of the agricultural sector of) Matara into an application of the LEFSA sequence. The reader is first referred to an overview of some comments with respect to each step in the LEFSA sequence on the next page.

Generally, there was no difficulty in following the sequence up to the regional and subregional levels, except for the none-existence of farming systems research. Of course, there will always be different interpretations as to 'where' to put 'what' information. It became more difficult and cumbersome at the more detailed farm and activity/subsystem levels. Above, in sections 5.3.14B and 5.3.15B, comments have already been made about:

1. the complexity of the 'detailed' steps;
2. the heavy information needs;
3. the person-power and time required;
4. theoretical economic problems;
- and 5. model building.

These will not be repeated here. However, the following problems need special emphasis: how to group farming systems ('enough, but not too many'), how to aggregate sample farm systems into farming systems and how to aggregate improved farming systems into an improved land use at the subregional and regional level. New modelling techniques might certainly be of help (see chapter 7), but the application of these models should be feasible within the usual time and person power constraints. In continued research around the complementarity and integration of LE and FSA for land use planning, these issues - possibilities and problems of grouping and aggregation as well as the feasibility of models - should be among the main topics of a research programme.

An assessment of the application of the LEFSA sequence to Matara district.

Step	Possible/positive	Problematic/negative
1. objectives	-possible on basis of existing documents	-conflicting objectives -farm level versus national objectives
2. socio-economic factors	-reasonable description	-is it sufficient?
3. agro-ecological factors	-good linkages with socio-economic data	-homogeneous enough? -relations with administrative boundaries
4. farming systems research		-absence of FSR
5. diagnosis of farming	-good insight in main farming systems -economic parameters	-farming systems as statistical averages -hardly any agronomy -basis for constraints?
6. broad selection of LUTs	-adequate	-no defined selection criteria
7. reconnaissance LE	-adequate	
8. land use assessment	-good present land use overview	-no assessment by crop -lack of agronomic data
14A. improving land use ('global')	-adequate -comparison 'manual' and 'programming model'	-relation farm level to regional/national level
15A. land use plan ('global')	-at this 'global' level adequate	-what about financial and implementation constraints?
9. diagnosis of farming systems	-good	-how to go from farm systems to farming system?
10. diagnosis of activities/subsystems	-good	-need for crop models? -agronomic data: practices, timeliness
11. detailed definition of LUTs	-necessary as an illustration; description of LUTs in step 10	-need for criteria -why only high level technology LUTs?
12. semi-detailed LE	-good basis for selecting 'best' LUTs for farm parcel	
13. improving current farming systems	-possibilities for improvements	-from farm system(s) to farming systems? -use of 'models'?
14B. improving regional land use 'in detail'	-indicates aggregation problems	-how from farm level to regional level?
15B. land use plan ('detailed')	-indicates problems and dilemmas	-does not present a land use plan

6. INFORMATION COLLECTION AND INTERPRETATION

This chapter presents those aspects of information collection and interpretation that are directly relevant to the LEFSA procedure. In section 6.1 the issue of what data are needed will be addressed. Underlying principles and processes in data collection are discussed in section 6.2. Issues in survey method selection which are relevant in the LEFSA sequence are treated in 6.3. The actual data collection in the LEFSA procedure is examined in section 6.4. Finally, in section 6.5 the interpretation and presentation of results are dealt with.

The following general literature is suggested for further reference: Bryant, 1976; Casley & Lury, 1981; Poate & Casley, 1985; Casley & Kumar, 1988; and more specifically for FSA in: CIMMYT, 1980; IRRI, 1984; Mutsaers *et al.*, 1986. Various approaches and methods exist with regard to the collection and interpretation of data on climate, landforms, soils and land use for LE purposes and these are well documented in literature. Reviews and/or examples can be found, for instance, in Vink (1975), Zonneveld (1979) and Dent & Young (1981). However, there is a conspicuous lack of similar documentation or literature on socio-economic aspects involved in land evaluation.

6.1. Information requirements for the characterization of systems

Information requirements must direct data collection¹⁶. These information requirements can only be properly defined in relation to the purpose and objectives of each case¹⁷. In addition, the selection of the analytical method is important. If one has not decided how to use the data one cannot decide what data are needed, in what detail, etc. Though it sounds trivial,

¹⁶ Often 'data' and 'information' are alternately used. However, in this context 'information' indicates knowledge in the context of a decision process or a communication need. Data refers to recorded symbols either representing information or providing information after processing.

¹⁷ The objectives of a 'study' should not just be presented in general terms, but also in expected output, defined with their scale in time and space.

logistic constraints play a critical role as well. The question is often more 'what results can I usefully achieve given available resources' than 'what resources do I need to achieve a given result' (Casley & Lury, 1981).

In this volume a central issue is: what data are needed to understand systems (see also appendix 4). This begs the question what minimal indicators or proxies are required. Apart from the questions of relevance, detail and quality of data required, one should take note of the degree of expected obsolescence of data, which is usually greater for socio-economic than for biophysical data. The effect of agricultural prices on changes in cropping patterns is a case in point.

The indicators (topics) relevant for the description and analysis of systems for land use planning are summarized in figure 18, which is in essence figure 7 with more detail. Figure 18 provides a starting point for formulating the information requirements of land use planning. These requirements can be distinguished by relevant system level. Leaving aside information requirements from the national and/or international levels, data are needed from the regional and/or subregional systems, and from the farm system(s) and subsystems. The regional and subregional levels can be subdivided into a societal or socio-economic part and an environmental or biophysical part. The information requirements of these parts are presented in more detail in part I and part II of appendix 5. Information requirements of the farm level, i.e. the farm system(s) and their components or subsystems, are presented in part III of the same appendix.

With reference to figure 18, the level in the hierarchy and the mapping scale determine to a large extent the degree of detail. For example, a description of a land use type at the regional level in a reconnaissance survey will be more general than the description of a land use type or cropping system at the farm level. Therefore, the information needs discussed in appendix 5, can only be indicative. The user will have to decide for each particular application the relevance of each item.

Figure 18. Information topics at different hierarchical levels of the LEFSA sequence.

(A) REGIONAL AND/OR SUBREGIONAL SYSTEMS (REGIONAL AND SUBREGIONAL LEVEL):

Socio-economic part:	Biophysical part/land use systems:
1. norms/beliefs	1. climate
2. community structure/politics	2. soils/topography
3. policies/programmes/projects	3. water/irrigation
4. institutions: health/education	4. location/access
research/extension	5. vegetation
input supply	6. land use:
credit	crops/fodder/fishponds/trees
land tenure	7. land use: animals
cooperatives	8. pests/diseases
marketing boards	
5. markets/prices: labour	
land	
capital goods	
current inputs	
farm products	
6. agro-industries	
7. farmer organizations	
8. set of farm systems	

(B) FARM SYSTEMS (FARM LEVEL):

* household	* farm
- needs/preferences	- goals
- composition, age/sex division	- land: availability per unit
- money availability	- capital items
- consumption	- labour: availability (age/sex)
- management: how, when and where decisions; who decides what	- management: how, when and where decisions; who decides what

(C) HOUSEHOLD, CROPPING, AND LIVESTOCK (SUB)SYSTEMS (ACTIVITY* LEVEL):

1. household production	2. off-farm	3. on-farm (land use types)
-child care	-off-farm work	-crop activities
-collecting water and firewood	-renting out of land and capital	-livestock activities
-cooking		-forestry activities
-artisanal activities		-others (fishponds, etc.)

* Activities are used in this figure and in the text as equivalents to '(semi-)detailed' land use types and to 'farm level' subsystems, and used in an economic sense: within activities, inputs (land + labour + money + capital items + current inputs) are combined together with a technology to produce outputs.

- inputs are coming from the farm system, or from other activities, or from outside the farm system, i.e. the regional and/or subregional systems.
- outputs are going to the household system (household consumption), or exchanged with regional systems (product markets); or 'feedbacks' are being felt at the (sub)regional system(s), both in the socio-economic part, as well as in the physical-biological part.

Finally, the base line from which one starts data collection can be very uncertain. Available information, pertaining to the same region and time period, is often conflicting. Table 19 illustrates this for various categories of land use in West Java (Sudarna, 1989). As the table shows, even an allegedly well-defined category like irrigated paddy shows up to a 60% difference in area commanded between various sources.

Table 19. Land uses in West Java according to different sources.

No.	Land use	DOA ¹		Irr. proj. ²		CBS ³		4th FYP ⁴	
		ha [#]	%	ha	%	ha	%	ha	%
1	Irrigated paddy	769	17	1132	26	897	21	1230	28
2	Rainfed paddy	439	10	272	6	309	7	-	-
3	Dry fields	407	9	1018	23	986	23	670	15
4	Mixed cropping	853	19	-	-	-	-	572	13
5	Estate crops	313	7	329	8	367	8	447	10
6	Forest	802	18	889	20	219	5	968	22
7	Grass land	-	-	63	1	63	1	-	-
8	Lakes and swamps	68	2	84	1	48	1	*	-
9	Settlements	372	9	359	8	407	9	265	6
10	Unproductive land	163	4	82	2	76	2	-	-
11	Others	219	5	190	4	-	-	265	6
Total		4405	100	4418	100	3372	100	4417	100

Sources: 1) DOA, Directorate of Agrarian Affairs, West Java (1984)
 2) West Java Irrigation Project (1986)
 3) CBS, Central Bureau of Statistics (1985)
 3) 4th FYP, Fourth Five Year Plan of West Java (1984).

Notes: #) hectares * 1000
 *) included in 11.

6.2. Some principles in information collection

The following principles structure the process of information collection:

- i. The 'funnel' principle. There is a hierarchy of surveys, parallel to the hierarchy of systems (national, regional, etc.). Most of the survey methods considered here, are located along a simple continuum: at the one end the relatively unstructured approaches to data collection, where the investigator has not yet arrived at the identification of problems and issues; at the other end the far more focussed types of approaches where the field of enquiry has been clearly delineated. The objective is typically either to measure

certain phenomena or to determine whether certain anticipated relationships are actually valid or not.

The subsequent investigations follow the funnel principle inasmuch as they start broadly (at national level) and end with a narrow focus (at local level) in a step-wise procedure. The whole of figures 7 and 8 can be treated as a funnel, but at each level separately the funnel principle is applied as well.

- ii. The LEFSA sequence entails that data collected at one level (outputs) are entered as inputs for the next level, leading to iterations and loops (even if not indicated in the figures by double arrows). The integrated LEFSA approach does not strictly follow a sequential approach, but is typically iterative within and between levels of analysis. This approach implies great flexibility in survey design and its actual conduct.
- iii. The principle of multi- and interdisciplinarity. The integration of bio-physical and socio-economic information is always difficult, as many factors constrain effective interaction. These constraints mainly lie in the nature of disciplines and the nature of knowledge (natural versus social sciences) on the one hand, and on the other in the nature of the problems encountered in the development process (Luning, 1985).

Multi-disciplinarity often does not go beyond a summation of the contributions, made by each discipline, which is not really integration. In contrast, inter-disciplinary work requires that the participants make use of their disciplinary perspectives, but their view of reality should not be constrained by that discipline. In inter-disciplinary work the specialist must 'unlearn' the prejudices, originating from his own discipline and reposition himself, starting from the real world situation, i.e. the 'problem', formulated on the basis of a shared conceptual framework.

The only way to break the barriers between specialists belonging to groups with different paradigms, scientific cultures and research styles in data collection and data processing is to reach agreement on the expected accuracy of the basic data and results. An important step

to achieve integration is to concentrate on the nature of the data matrix, which serves as a framework for the whole LEFSA sequence. This implies common units of research and agreement on variables used.

- iv. Geo-referenced quantitative information must be combined with qualitative information. As has been pointed out, much of the information collected in FSA is qualitative in nature, derived from descriptions, historical documents, case studies, group interviews and even participant observation. This kind of information must be carefully linked with geo-referenced LE data.
- v. Cost-effectiveness should be adhered to. A common constraint is the level of available survey resources (manpower, skills, budget, time, transport, etc.). Clearly, there are options and trade offs between, for instance, coverage and depth of surveys, which may greatly effect the quality of data. Given a fixed level of research funds and other resources, the question should be posed, for example, whether data on crop labour requirements and yield data can meaningfully be obtained from a single visit survey of informants. The opportunity cost of time spent on different types of surveys should be assessed seriously before embarking on any particular study. Cost effectiveness is also underlying Chamber's (1983) celebrated two 'principles of optimal ignorance':
- to know what is not worth knowing; and
 - proportionate accuracy: recognizing the degree of accuracy required.

The latter is important in case a system (or part of it) is studied, like in the LEFSA procedure. What is the use of measuring a particular variable to the third decimal if the variable to which it has to be related can only be produced in rounded figures of thousands?

Stratification in sampling is a 'cost-reducing' tool. Effective stratification can reduce the sample size required for a given level of accuracy. Moreover, stratification is an important multi- and interdisciplinary activity. It applies both to bio-physical parameters (for instance the delineation into agro-ecological zones, see for example Jaetzold & Schmidt, 1983) and socio-economic factors (landlord-tenancy, gender, farm size, etc.), separately and in combination.

6.3. Issues in survey method selection

Often the issue is not only what alternatives to choose from, but also how to conduct a structured set (a hierarchy) of surveys, as briefly described under the funnel principle in section 6.2. There are also very specific survey methods and techniques, as in farming system analysis and research (on-station research, location trials, on-farm experiments, see step 4, figures 8a, 8b and 8c).

In LEFSA the choice of survey method is intimately linked with the sequence. In what follows the reference numbers are those of figure 8a, 8b and 8c.

6.3.1. Formal versus informal methods.

In the last decade significant progress has been made in the development of informal survey methods, they are known under the name Rapid Rural Appraisal. Rapid Rural Appraisal is defined as an investigation used as a starting point for understanding a local situation; carried out by a multi-disciplinary team, lasting from approximately one to four weeks, based on information collected in advance (secondary data), direct observations and interviews where it is assumed that all relevant questions cannot be identified in advance. The latter point needs to be emphasized: the key to Rapid Rural Appraisal is to move to the main problems, opportunities and actions. As pointed out in a seminar in 1987 at the Khon Kaen University, Thailand, three aspects of Rapid Rural Appraisal are particularly important: it is explorative in character (flexible, open-ended), it is practiced by a multi-disciplinary team and it is preoccupied with rapidity in learning¹⁸. Rapid Rural Appraisal has been practiced under various names: exploratory survey, preliminary, informal survey, sondeo; see among others, Hildebrand, 1981; Collinson, 1982; Khon Kaen University, 1987).

¹⁸ Rapid learning requires iteration: progressive, repetitive or cyclical learning methods.

6.3.2. Hierarchy of surveys.

Linked to the various steps in the sequence (from national to local systems) there are particular types of surveys. A logical sequence is as follows:

1. Secondary data collection, etc.

This includes checking the quality of these often statistical data (see Zarkovich, 1966). This activity is carried out in steps 2, 3 and 5 of the LEFSA sequence. Sources of conflict are usually related to definitions, differences in the adopted systems of work, possible biases. To handle inadequate, conflicting data, one should combine different methods and sources, such as (internal) cross-checking, sensitivity analysis, indicating explicit margins of error, carrying out consistency checks and operating on orders of magnitude.

2. Rapid Rural Appraisal/informal/exploratory/reconnaissance survey.

This is carried out in steps 5, 6 and 7 of the LEFSA sequence. It should be borne in mind that the Rapid Rural Appraisal type of survey in LEFSA is not necessarily restricted to socio-economic data gathering, but includes rapid natural resource surveys as well. For instance, inspecting an area by (ultra-)light aircraft (preferably with a mounted video camera) or using Landsat imagery may be the obvious Rapid Rural Appraisal for a particular situation. Rapid Rural Appraisal studies show how proxy variables and small sample methods can be employed to appraise aspects of the physical environment, which are normally assessed by longer, more expensive methods. Case studies known pertain to soils, plant indicators, erosion.

An interesting case has been worked out by Conway (1985b) in the analysis of agro-ecosystems in N. and N.E. Thailand. An important phase of the procedure is pattern analysis, i.e. space, time, flow and decision patterns were studied. It 'leads into a discussion of system properties and a common agreement on what constitutes the most important contributing relationships and variables'.

One may stop data collection at this juncture, as the expected benefits of a lengthy extended or formal survey may be small. In comparing formal and informal survey techniques for FSA, Franzel &

Crawford (1987) found in a particular case study from Kenya that the contribution of the formal survey was marginal relative to its costs.

3. Lengthy extended survey.

This survey, which is 'further down' the funnel, centers on those elements which have been identified and singled out for further study during Rapid Rural Appraisal. These could be studies of constraints (see for instance field guidelines on cropping systems, etc. by IIRRI, CIMMYT, IITA). These typically FSA (and FSR) oriented analyses have a parallel in the LE studies where crucial land requirements and land qualities (both constraints and opportunities) need to be assessed in detail. The steps 9, 10, 11 and 12 are usually all of the lengthy extended survey type and are mostly of a partial nature, studying components/elements of a (sub-)system. We will return to this in more detail in section 6.3.3.

6.3.3. Survey methods and information gathering techniques.

Clearly, techniques are related to methods and these depend on the type of survey and the use to which information is to be put. A major decision in socio-economic surveys lies between single and multiple visits. The former is cheapest, but may lead to superficial output of poor quality. Accuracy can be improved by returning to respondents, but with limited survey resources (budget, personnel, equipment, time) there is evidently a trade-off between coverage (many single-shot visits) and depth (limited number of informants, more frequently visited). One may decide to employ case studies of a few respondents (often in combination with a lengthy extended survey based on stratified random sampling), where detailed understanding of complex relationships is considered more important than ensuring the representativeness of the data collected. One may opt for repeated, regular visits for particular periods/seasons, where an accurate record is needed of, for example, female labour use in farm and household, draught power use, yield measurements. For many purposes we would prefer time series data, but have to contend with cross sectional data. One needs to be particularly conscious of this in agriculture. How did agricultural conditions in the survey year compare with other years? (Mettrick, 1983). One should consider whether to select the individual informant, a family or a group of respondents. The latter is useful to detect differences of

opinion and it may stimulate debates. In Rapid Rural Appraisal the key informant plays a central role.

In land inventories for LE, the tools used, determine to a large extent the cost-effectiveness. The use of remote sensing data (aerial photographs, satellite imagery), for instance, can substantially improve the cost-effectiveness of the inventories. The interpretation of remote sensing data makes it possible to delineate relatively homogeneous areas with respect to landform, drainage and land cover properties. These areas serve as 'strata' for field data collection programmes in which 'stratified random' or 'purposive' sampling procedures are applied.

The fieldwork that follows includes:

- i. checking the validity of the interpretations made; and
- ii. collection of additional data, which can commonly not be interpreted from remote sensing images, by means of sampling.

Sampling generally includes:

- i. visual observations on micro-relief, soil, plant types/communities, sheet and rill erosion features, etc. and/or the variability of such features within the interpretation units or strata; and
- ii. interviews with local land users/farmers on management practices and type and amount of products extracted.

The cost-effectiveness of the use of remote sensing data depends, to a large extent on scale. In small scale (e.g. reconnaissance) inventories, the saving of time and costs by the use of such data will commonly be very high. In very detailed surveys, the use of such data may contribute only little to the efficiency of the data collection. The use of satellite imagery has proven its utility, particularly in small-scale inventories. In more detailed inventories, such imagery can also be useful when it is used in conjunction with aerial photographs because it often contains data of other seasons and/or years that cannot be interpreted from airphotos of the same area.

In surveys for LE, the combination of i) observations on biophysical properties of land with ii) farmers' interviews on the same sites, has proven to be extremely useful; it provides a data set for the analysis of relations between land qualities, crop and soil management and estimated crop yields. The results of such an analysis provide valuable local

experience and knowledge which can greatly contribute to the realistic assessment of the suitability of land for various uses in the area concerned.

Data-related criteria must also be mentioned. Lipton & Moore (1972) distinguish: registered versus non-registered, and single point versus continuous data. Registered data is concerned with, for example, the number of bags of a certain type of fertilizer bought for rice cultivation. An example of non-registered data is the amount of farm manure used last year. Single point data refer, for example, to a particular action at a fixed point in time (hired contract labour to do the first weeding of maize) versus continuous data: events that continue over time like the application of family labour on the farm, are unlikely to be recalled. In designing questionnaires (see below) this distinction is often ignored and survey questionnaires (which are used in lengthy extended survey) show in many instances that one greatly underestimates and ignores the difficulty (and often the sheer impossibility!) of obtaining non-registered and continuous data. If one really requires them, the only solution is by farm-record keeping and/or direct observation.

6.3.4. Bias and error in surveys.

Whereas the unit under investigation is flexible in Rapid Rural Appraisal (usually there are various types of resource persons), the more detailed and structured surveys are directed to randomly or purposively selected observational units. The choice of the observational unit is important. Broadly speaking one could take as point of entry the (farm) household or the parcel. The latter is useful in LEFSA: geo-referencing and the use of 'sample areas' leads to better insight in the relations between household resources and land resources. However, difficulties often arise in locating the owner/tiller of farm parcels. Other observational units could be the irrigation block (tubewell), a coffee cooperative, a land unit, etc. Objectives and purpose direct this choice. The choice of the sampling frame (in lengthy extended survey) is a crucial one and a clear definition of the target population or target area is required. The essential and most important feature of a sampling frame is its completeness, since it represents the 'universe' from which individual sample units must be selected. It may contain both bias and error.

Bias. Bias occurs in survey design, in sampling, in the response to surveys and in the subsequent steps of recording, analysis and reporting. In Rapid Rural Appraisal, open-ended checklists of issues are used and built-in cross-checks by interviewing different types of resource persons can greatly reduce bias. In lengthy extended surveys it is usual to work with a list of households, which often comprise a considerable amount of bias, e.g. if derived from extension workers' list. As Casley & Lury (1981) observed: the construction of a (new) frame is so expensive and time consuming that it is usually necessary to use what is available, at least as a starting point. As regards bias in the response, memory bias has been mentioned in relation to non-registered and continuous (flow) data, often caused by seasonal phenomena. There are many other sources of bias as well, such as road-side bias in interviewing (see Chambers, 1983, for a more exhaustive treatment). Another, often ignored bias is caused by the differences in conceptualization (Best, quoted in Mettrick, 1983) due to substantial cultural and educational differences between respondent and interviewer.

Errors. Two major sources occur: sampling errors and observation errors. In designing the survey one should aim at minimizing these two sources of error. Random sampling (see appendix 6) should reduce sampling errors, but it must be realized that observation errors may be by far the most important source of error.

A practical issue is how much variability one accepts within land units. Objectives determine the degree of permissible aggregation, and thus acceptable error.

Much depends on the degree of complexity of the household economy. A smallholder enterprise in the medium-potential area in Kenya with a uni-modal rainfall (with just a two acre field around the compound of a nuclear family) is much easier to analyze than an enterprise of an extended family (sometimes comprising more than fifty members) in Southern Mali or Senegal. Here, the division of labour between sexes and within the extended family, and the fragmented mixed cropping system, makes a single visit type of survey a farce if one wishes to understand the actual operation of such an enterprise. The judicious timing of multiple visits may also greatly improve the quality of data, thus reducing error. Farm systems are strongly governed by biological processes with their particular cycles and rhythms.

Substantial error reduction can often be attained by a good organization of immediately checking the data as they come from the field, so that recalls are still possible. A major source of errors in Rapid Rural Appraisal lies in the inexperience of interviewers. This is in fact Rapid Rural Appraisal's greatest drawback: it cannot be executed by mere assistants. See also sub-section 3.2.2 on the procedures of FSA.

The observational method selected has direct relevance for the error level. Interviews are much faster than direct observation (land measurement, crop cutting, livestock count, etc.) but bias and error can be very substantial. Basically, cost considerations (including time availability) determine the choice. Ideally an a priori assessment should be made setting additional costs against expected incremental benefits of better information.

6.4. Data collection in the LEFSA procedure

As has been observed in section 3.3.6, both LE and FSA have been criticized for time consuming, often costly, data collection procedures. The LEFSA sequence is offering scope for complementarity in which sharing of information must be considered in the light of cost-effectivity. In addition, this complementarity should lead to improvements in land use planning, taking into account ecological and socio-economic possibilities and constraints. Below, we link data requirements and collection aspects (reviewed in the previous sections of this chapter) with the relevant steps of the LEFSA procedure, presented in figures 8a, 8b and 8c. As pointed out, the method of data collection is directly related to objectives and scale.

Step 1. Objectives. Although the formulation of objectives usually does not require specific information, objectives do not come out of the blue. There must be a perception, a recognition that changes in land use are needed. This perception is based on available information, how unstructured that may be. It is particularly socio-economic and environmental background information that helps initially in the formulation of objectives often involving several parties. In the course of the LEFSA sequence, as more information becomes available one may even turn back to step 1 and query the original objectives, thus setting in motion partially or wholly a new LEFSA sequence.

Step 2. Socio-economic factors. These factors, collected for (inter)national and regional levels are not only important for a preliminary land use assessment, but are relevant for the steps (at national/regional levels) in LE and FSA as well. Socio-economic factors pertain inter alia to population, employment, economics of resource use, income and income distribution, demand/supply patterns and projections for staple foods, export and other cash commodities (crops, livestock, etc.). It also includes institutional aspects, such as markets and policies.

In step 2, secondary data sources are consulted. Agricultural sector plans should be perused for possibilities (for instance an unattained world market quatum for particular commodities) and constraints. Wherever these agricultural sector plans are not available, recent World Bank country studies can be an important source of information. Efforts should be made to present a historical perspective of critical parameters (e.g. population growth, patterns of land use). These time series often disclose interesting trends. Secondary data analysis helps the process of data reduction as well.

Step 3. Agro-ecological zoning. In this step, secondary data collection and analysis also play a central role (it is also highly relevant for diagnosis of farming, step 5). At steps 2 and 3 one operates at the national level. Agro-ecological zoning is always a first stratification according to bio-physical criteria. At the national level LE and FSA are carried out rather independently (section 4.2). In fact, FSA is only expressed in broad aggregates, directly linked with agro-ecological and agro-climatological zoning (see for example Jaetzold & Schmidt, 1983; Oldeman, 1975). At the national stage, LE provides the building stones (agro-ecological zoning, major kinds of land use and farming, population density) as shown for example in table 1 of appendix 2. Good quality information on agro-ecological zoning greatly helps the data reduction process later on in the LEFSA sequence: it can save a lot of superfluous questions in the lengthy extended survey questionnaire!

Step 5. Diagnosis of farming, followed by broad selection of land use types (step 6) and reconnaissance LE (step 7). As a basis serves the analysis of the agro-ecological zoning and the data collected and analyzed in step 2. Moreover, on-station research results are fed into step 5. Steps 5, 6 and 7 typically refer to the (sub)regional level. The principal method of data

collection for these steps is Rapid Rural Appraisal. Socio-economic data collection takes place through resource persons, individually or in groups. The issue of sub-stratification is a major one. A typical product of a Rapid Rural Appraisal in FSA is the construction of an agricultural calendar as a first step to look at possible family labour constraints in smallholders' farming. These 'first steps' can lead to considerable data reduction. For example, the agricultural calendar for a particular region may show that labour peaks occur during the period of late planting and first weeding (three weeks in June/July) and during harvesting of the first crop, land preparation for the second crop (four weeks in October/November). In subsequent steps (9-12) one can reduce further data collection (if required) to these two periods.

To facilitate a smooth linkage with step 6 (broad selection of land use types) and step 7 (reconnaissance LE), FSA should include data on major land units, as distinguished and expressed by local farmers, thus tapping indigenous knowledge of local soils and their properties. The advantage of the LEFSA sequence is that spatially defined, more quantitative information from LE can now be combined with - in general - non-spatial and more qualitative information from FSA. In addition, FSA data should be geo-referenced as much as possible. A great improvement in the quality of LE information is now possible with the additional FSA data. As has been observed in practice, the choice/first selection of relevant, promising land use types in a particular local setting so far has been a weak and little worked-out procedure. Assumptions can now be made more explicitly. The LEFSA sequence thus leads to a better land use assessment in this stage and later on at the subregional/farm level.

Land evaluation as such can greatly benefit from Rapid Rural Appraisal type of surveys. LE's socio-economic analysis of a land use type usually does not go beyond a general description of key attributes (produce, capital and labour intensity, power, income levels). The impact of land tenure and the relationship between farm size and cropping/farming systems, aspects that are the object of study of FSA, need also be considered in LE. LE has in the past often been carried out through a top-down approach, as appears to be implicitly suggested in the Framework for Land Evaluation (FAO, 1976). Working with farmers in LE in a structured way has more recently been introduced (Fox, 1987). This requires the application of tools such as Rapid Rural Appraisal. A reconnaissance LE should start with a Rapid Rural

Appraisal type of investigation. For instance, land use type selection and description, including the land use type key attributes, are based on information derived from Rapid Rural Appraisal. Whereas the Rapid Rural Appraisal team for FSA usually consists of at least an agronomist and an agricultural economist, the composition for LE (socio-economic context) is commonly an agricultural economist with a soil scientist. In the LEFSA sequence, the Rapid Rural Appraisal should preferably be carried out by one team consisting of an economist, an agronomist and a land resource specialist. Problems of timing of Rapid Rural Appraisals and organization of exchange of information, which occur when two separate appraisals are carried out, will be avoided in this way.

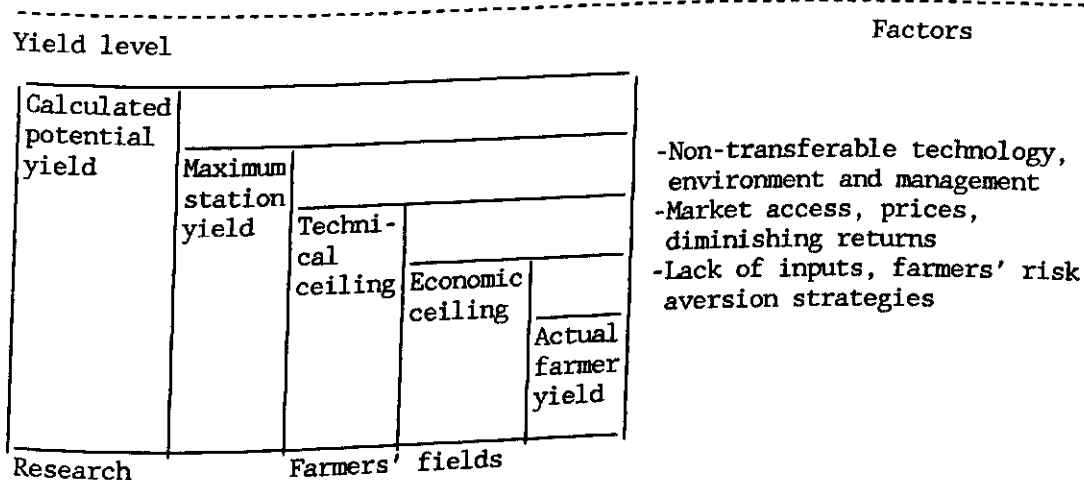
Steps 9, 10 and 11-12. After step 7, the land use assessment - for general land use policies - is made. It can also lead to the selection of research themes and areas. In steps 9, 10 and subsequently in 11 and 12 the lengthy extended survey takes a central position. As discussed in the previous section, alternatives within lengthy extended survey are possible and depend very much on objectives. There may also be a further step-wise procedure with, for example, two-stage, stratified random sampling combined with selective case studies (restricted to certain time period and location) for a sub-sample, concentrating on a particular theme. The LE is carried out at a (semi-)detailed scale, with land suitability for the new selected options considered further. Whereas at the national and regional levels LE was mainly supplying data to FSA, now the reverse data flow from FSA to LE is more substantive. Although subregional and farm levels are presented separately in figures 8a, 8b and 8c, here they are discussed in combination. This is convenient, as many of the surveys conducted at the subregional level are directly or indirectly associated with the farm level. Even where surveys are focussed on the socio-economic context of a subregion (for example agricultural institutions serving the farmers) it is necessary to crosscheck some of this information with the intended beneficiaries. For instance, to gain insight in the functioning of the local agricultural extension system, one should discuss independently the same topic with both the extension agent and (female, male) members of the farm household.

It is particularly the farmers' constraints and problems, diagnosed in the formal FSA that provides the (semi-)detailed LE with a base for land use type selection. This is, once more, done iteratively. At the regional

level, a first set of relevant land use types are identified, which, with new, more detailed, FSA information becoming available, can be scrutinized and revised. It is particularly at this stage that feedback loops are introduced and used. The appropriate approach is usually the yield gap analysis, conducted by the FSA team, but with additional questions concerning soils, their constraints and related topics, provided by the LE group. As figure 20 shows, both biophysical and socio-economic factors are taken into account. The calculated potential yield shown in this figure is based on genetic characteristics of the crop considered and on temperature and radiation conditions at the site where the crop is grown; all other factors influencing yield are considered to be at their optimum in the calculation of this yield. Maximum station yields are generally lower than calculated potential yields because of local climate and soil constraints and/or soil and water management practices which are not 'optimal'. The size of the gap between maximum station yields and actual farmer yields depends on the transferability of technologies developed at research stations, on the management of the farm household, on the socio-economic conditions, and on the biophysical conditions of the farmers' fields which are often less favourable than those of the research station.

Hence, land resources must be evaluated in terms of their biophysical capability, the socio-economic context constraining their development and the means (labour, capital, other inputs) available for possible alternative land use practices.

Figure 20. An example of possible yield gap analysis.



Source: Adapted from Fresco, 1984, after World Bank (1982) and Zandstra et al. (1981).

The 'funnel' principle also applies at the subregional level. There may be sound reasons for starting with a mixed qualitative/quantitative survey, that could be topic-focussed and semi-structured, somewhat half-way the earlier mentioned continuum. At the sub-regional level, surveys tend to be more costly in time, manpower, etc., than in the earlier stages. Moreover, contingencies have to be planned to address research resource-consuming iterations and loops. This makes the role of a well-conceived and well-conducted pilot survey of crucial importance at this stage, where substantial errors, omissions and duplications come to the fore. Additional cost-effective measures have to be taken, e.g. a thorough planning of the survey(s), including considerations regarding design, definition of target groups, formulation of a questionnaire, selection of the sample, securing data processing and analysis requirements and the preparation of the reporting format.

In selecting the appropriate survey technique one has a number of options. First, the precise data (both qualitative and quantitative) expected from the survey have to be identified. The earlier stages have led to the necessary reduction in data requirements. A number of specific questions has to be addressed: will single point (stock) data suffice, or is it necessary to collect continuous (flow) data, as in input-output relations? What is the likely trade-off between coverage and depth of surveys? What quality (accuracy, precision) of data is required, what detail is necessary?

Farm and activity/subsystem level (steps 9-12). It is at this level that a more complete integration of LE and FSA is required for the preparation of plans that aim at the improvement of farming systems in the context of land use planning. On the one hand, FSA is carrying out a rigorous analysis of the farm systems and the interactions between the land use types/activities/subsystems, and of the main land use types/activities/subsystems themselves; on the other hand, a (semi-)detailed LE is effectuated.

An attempt should be made to link FSA and LE from the onset by geo-referencing. This is further explored in section 7.2. Land units of LE are geo-referenced automatically as they are mapped. If the parcels/fields of farms can be linked to the land unit, all the farming and cropping systems information, hence FSA information, becomes also geo-referenced. At this level the interactions between sub-systems receive major emphasis.

Referring to figure 18 one must strike a balance between surveys and investigations dealing with the farm(system) proper (B in Figure 18) and the regional and/or sub-regional systems (A) on the one hand, and the household, cropping and livestock (sub)systems (C) on the other hand. There is a limit to resources available for surveys, which has further consequences for analyzing, processing and reporting.

The farm and activity/sub-system levels, with the household, off-farm and on-farm activities, should not appear at the end of the hierarchy of surveys, as an afterthought. In the Rapid Rural Appraisal at the preceding levels, i.e. regional and subregional level, they should be included from the beginning in assessing resource availability and use, constraints and potentials. It is particularly through FSA that the role of, for example, livestock and off-farm activities and their impact on the other activities can be assessed. The results of the analysis at this micro level should be channelled back into the (sub)regional, perhaps even into the national levels, to inject reality in earlier stages of analysis at macro and meso levels. Concurrently with the diagnosis of activities' constraints, also the national/regional context has to be considered the analysis: whatever may appear feasible at the farm enterprise level may be constrained by market quota, purchasing power, etc.

6.5. Interpretation and presentation of results

The results of the LEFSA sequence (figures 8a, 8b and 8c) are intermediate outputs to be used as inputs in the procedures leading to land use plans, as laid down in proposals for projects, programmes and policies. The central issue is the improvement of current farm systems, linked to the selected land use types/activities/subsystems (current, as well as improved). Such improvements will often entail interventions and new technologies, putting a bigger claim on, for example, family labour. These interventions, etc., can be analyzed through constraint analysis, comparative analysis, using the gross margin approach, input-output analysis, to mention a number of descriptive methods of socio-economic analysis. Alternatives to this category are the prescriptive methods, for

instance whole-farm and partial planning, budgeting, and programme planning (Upton, 1973).

An advantage of the LEFSA procedure is that it introduces new methods and techniques of data collection and analysis into either LE, FSA or its combination as a cross-fertilization. For example, LE ignores possible relations between land use types within the context of the farm (see section 3.3.3). Farmers will optimize production (or any other goal) taking the perspective of the farm/household level, instead of maximizing the productivity of each land use type. In this situation the equal marginal returns principle (see glossary) used in FSA & FSR (see Mutsears *et al.*, 1986: 168 ff.) is appropriate.

Whatever advanced analysis is intended, the preliminary analysis will be descriptive and in many LEFSA sequence studies, simple tabulations and comparisons of the data will be sufficient (Dillon & Hardaker, 1980). Exploratory analysis should start right at the beginning as the results of exploratory and formal surveys are coming from the field. Quality control of data, directly after the interviews have taken place, is required, so that recalls and rechecks are possible. Tabular analysis starts with the construction of a system of classification of the data. General purpose tables present an overview of a great amount of primary data. In a more advanced stage of analysis special purpose tables are constructed. In addition to purpose, the dimensions (number of variables) should be defined. A one dimensional table presents data classified according to one variable, in a two-dimensional table, two variables are used for classification, etc. In actual practice, 'a four dimensional table is about as complicated as one can expect most readers to grasp' (Dillon & Hardaker, 1980).

Instead of a tabular analysis a pictorial presentation can be made. Most commonly used are graphs, scatter diagrams, pie charts and frequency distributions. Whereas some tables may be self-explanatory it is often necessary to give further explanation in the text of the report. Whenever the results of a survey are based on a probability sample, apparent differences in averages between classes in the data, etc., should be tested for statistical significance (e.g. T- and F-tests, and Chi-square test).

The conclusions reached in the descriptive phase should not only apply to the level one is investigating. For example, on-farm labour shortage, associated with a new technology, must thus be evaluated against the patterns of labour supply and demand at the next higher level of aggregation (district, region) and its likely consequences must be assessed.

In the prescriptive phase an important method is optimization, taking a farm household as a decision-making unit. The type of analysis and its likely interpretation determine what data to collect and how. In optimization, data will be provided on the objective function, activities of the household and constraints, with particular attention to resource conservation, labour, income and income distribution. When the number of activities and constraints is limited and the household's objectives can be expressed in simple decision rules, the method of programme planning (Upton, 1973) can be used. In more complex situations, linear programming (see, for example, Upton, 1987, and Hazell & Norton, 1986) is appropriate. Sensitivity analysis, simulations and risk analysis are complementary approaches. A particular form of linear programming, interactive multiple goal linear programming can be very relevant in the context of land use planning (see section 7.3.3). The ultimate choice depends on objectives, resources and manpower.

In this context, optimization should be considered as a way of structured thinking about possible alternatives, i.e. various scenarios in land use planning. Its actual output may not always be the first priority. If the outcome of the optimization exercise deviates substantially from the actual situation, it may be attributed to two factors: firstly, the qualitative and quantitative assumptions concerning objective function, activities and constraints were not realistic; or secondly, the farm households have not yet arrived at the situation depicted in the (normative) linear programming construction. In practice it may be a mixture of the two. Finally, the present availability of microcomputers and statistical software packages enable all sorts of sophisticated analyses and presentations. However, one should be aware that the analyst must always have the knowledge of the underlying assumptions concerning the structure of the data. This must hold true if the analysis is to be valid.

7. NEW TOOLS FOR THE INTEGRATION OF LAND EVALUATION AND FARMING SYSTEMS ANALYSIS FOR BETTER LAND USE PLANNING

7.1. Introduction

A close integration of LE and FSA, as discussed in the previous chapters, builds on the methods developed within each of the methodologies. The rapid advances in information sciences allow the use of digital techniques for information storage, processing and retrieval. These possibilities can greatly strengthen the LEFSA sequence. Without claiming, or even attempting to be exhaustive, some of the most promising developments in this area are discussed below. They have in general in common that information does not need to be aggregated and classified a priori, which leads to appreciable loss of information (de Wit & van Keulen, 1987), but can be stored as 'basic data', so that no detail is lost in the analysis, but can at any level be retrieved whenever required. This is especially important because of the iterative character of the LEFSA sequence.

In the past large numbers of different data could not be easily handled, requiring aggregation at an early stage in the analysis. In LE that led to loss of information on spatial variability. In FSA, geo-referencing and both spatial and temporal variability were lost. In a digital data base all information can be stored to be used whenever deemed necessary, that is it can be classified and aggregated in the planning exercise. This makes more efficient use of the data possible, a positive development in view of the costs and efforts involved in collecting them.

This was one of the reasons for FAO (1986) to develop the 'Farm Analysis Package' (FARMAP), a software package for the processing and analysis of farm survey data, suitable for micro-computers. Such packages, or more general, (relational) data base programmes can be of great help in land use planning.

7.2. The use of relational data bases and geographic information systems

A geographical information system (GIS) is a computerized data base management system capable of handling entities of which the location is known (x, y, z coordinates). In a GIS data can be collected from maps and be stored, manipulated and represented as maps. Geo-information systems use software for computer graphics in most cases combined with software for alphanumeric data handling. In a GIS the relationships between the entities in the data base can be established by map manipulation, alphanumeric (table) operations or combinations of these two. Most GISs have therefore the characteristics of Relational Database Management Systems (RDMS). The structure of such a geo-data base can be designed with normal (alphanumeric) data base design procedures, as will be done below. A land-related data set can be useful to support planning and decision making procedures. To identify which interventions are necessary and feasible, and to judge the consequences of such interventions, data on natural resources (land, climate, etc.) and data on farm systems (farm household data, crop rotations, agricultural practices, etc.) are required.

While LE aims at a 'suitability' classification of land units, presented on a map, information in FSA is presented as textual and numerical information, generally without much geo-referencing. As a consequence, information on land units cannot be combined (or 'linked') with information at the farm level, as it is unknown which (and how many) farms are on what land units.

These disadvantages can largely be overcome by the development and application of geographic information systems (Burrough, 1989a), containing all the data required to solve resource management problems, in the context of this volume especially with respect to land use planning. Each user ('problem solver') must have access to all the data needed for a specific problem-solving procedure. It is therefore of prime importance that in the GIS environment the data are well-structured through a disciplined data base design.

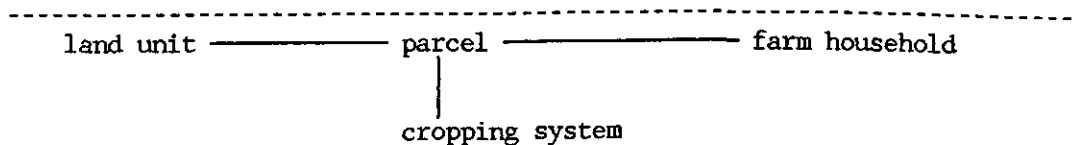
7.2.1. Data base design for land evaluation, farming systems analysis and land use planning.

For the purpose of land use planning many different types of data are necessary, of which the minimum set contains at least:

1. the land resources (including climate, etc.)
2. land utilization, i.e. the human activities on these land resources (cropping and livestock activities, including alternative activities that seem promising)
3. a series of additional data (for example, on macro-economic policies, prices, etc.)

It depends on the purpose and the level of detail of the planning exercise and the type of problems to be solved which data are needed and to what degree of detail.

If LE and FSA would store field data in a relational data base (without aggregating the assembled data first), such a data base could contain the following entities in its conceptual scheme:



In which:

land unit contains information on the physical characteristics of the different mapped units (soil type, slope, etc.);
parcel contains information on the parcel which a farmer uses (size, legal status, access to water, etc.);
cropping system contains information on the crops or livestock patterns applied on these fields by a specific farmer, the land use types;
farm household contains information on the farming unit (name, labour availability, equipment, etc.).

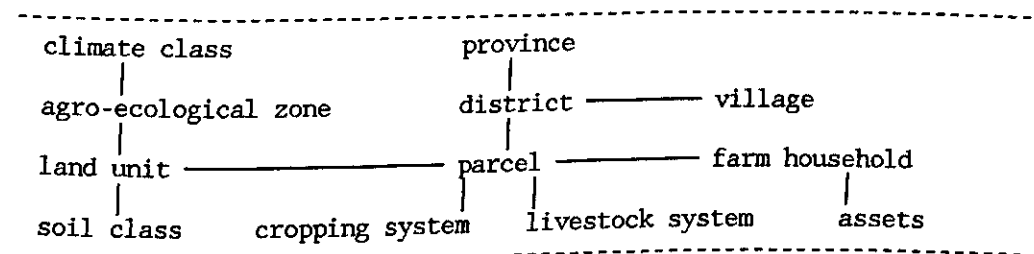
The land evaluation procedure provides the data for the entities land unit and to some extent for cropping system, FSA provides data for the entities parcel, farm household and cropping system. Land unit data are collected with geo-referencing and represented on a map. If the location of the parcels is stored in the GIS it will be possible to relate the parcel to the land unit by giving the land unit number as an attribute to the parcel. All the other entities can then also be related to the land unit. To which land unit a surveyed parcel belongs can be assessed through an overlay of

the land unit map and the (topographic) map used in the farm survey. Hence, a cropping system is linked to a parcel originating from the farm survey.

Even if the LEFSA sequence is not fully applied, land use planning could benefit substantially from a data base structure as indicated above, as all the relevant queries can now be answered on the basis of original detailed data.

7.2.2. Expansion of the data base.

The data base schematically presented before, can provide answers to most of the LE and FSA queries, but it may not be sufficient for land use planning, as information relevant to that purpose is still lacking, such as prices, population, administrative boundaries, etc. The data base can, however, easily be expanded to provide space for storage of such additional information. In that case the conceptual scheme of the data base could have the following structure:



The left hand side of the scheme can contain the information on the natural resources. In the entities province, district, and village information on administrative matters and socio-economic information can be stored. This information often relates to administrative units and can be collected from statistical publications. In the entities parcel, farm household, cropping and livestock system the data from the farm surveys can be stored, including prices of inputs and farm products. The dotted lines indicate that more entities can be added, according to the type of information collected.

It should be emphasized, that this scheme does not represent a fully 'normalized' data base. Before implementation in a RDMS, normalizations will have to be performed, which will in most cases lead to the

identification of additional entities (for example persons, if information about each member of the household is known).

Some of the entities defined can easily be mapped (climate, agro-ecological zones, land units, districts and villages). Other entities cannot be mapped, as they are descriptive or concepts and not geo-referenced (cropping system, livestock system, farm household, assets). However, all entities can be related to each other by using a common attribute as a key. The location (x,y,z coordinates) can also function as a key between two mapped entities. In that case the line between two entities can also represent a cartographic overlay procedure.

The entities farm household and parcel do not necessarily have to contain information on all the farm households and parcels in the area. A farm survey will generally only cover a sample of the total population. This does not have to cause problems, if data on the total number of farms in an area (village or district) can be extracted from other sources (for example statistics). The total can then be compared to the sample size in that area. If the sample is not too small, extrapolations can be made to the total number of households. If farm and parcel data appear not to be available on certain land units, that provides an indication for gaps in the farm survey, which from the 'conventional' aggregated FSA information would not have been detected.

7.2.3. Data bases for higher levels of land use planning.

The data base design illustrated above, would be very suitable for detailed regional land use planning. For planning at a higher level of aggregation, generally less detailed information at the farm and parcel level is available. As in LE, only some global land use type descriptions may be available. Farm information from statistical sources or limited field work can then, however, still be related to the land unit map through a land use or vegetation map. Such maps may be based on information from remote sensing. Land units with a more or less homogeneous cover/land use are delineated. In composing these maps, care should be taken that the different land use types and cropping and livestock systems can be identified within the land use/cover mapping units. This might require changes in the way land use/cover classes are presently defined by the land use/cover surveyors. For this purpose the level of homogeneity in land use

yield potential of the main agricultural crops under a wide range of environmental conditions are possible (van Diepen *et al.*, 1989; de Wit & van Keulen, 1987; van Keulen *et al.*, 1987; Jones & O'Toole, 1987; van Keulen & Wolf, 1986). In first instance, comprehensive models have been developed, that were mainly aimed at increasing understanding of the interactions between the main growth factors (de Wit *et al.*, 1978). These models mainly served as a research tool. On the basis of their results, more simplified versions, so-called 'summary models' (Penning de Vries, 1982), were developed and application increased, among others for quantified land evaluation (SOW, 1985).

An example is the WOFOST crop growth model (van Diepen *et al.*, 1988), that simulates growth of an annual crop during one growing season in daily intervals, using a state variable approach. This assumes that the state of each system can be quantified at any moment, and that changes in the state can be described by mathematical equations, that contain only the state of the system at that moment and driving variables. Major physical and physiological processes such as CO₂ assimilation, respiration and phenological development are quantitatively described, and the exchange processes with the environment as CO₂ uptake, transpiration, water and nutrient uptake are incorporated. The rates of all these processes are determined by the state of the crop at any moment and the controlling environmental conditions.

The effects of the main yield-determining factors are evaluated using a hierarchical approach, in which at the highest hierarchical level the number of factors that are considered is reduced, by assuming that technical constraints that can feasibly be removed, have indeed been eliminated. At subsequently lower hierarchical levels increasingly more factors are taken into account. Hence, first potential yield is determined, reflecting the genetic potential of the crop under those weather conditions, that determine the duration of the growth period and the length of the various phenological phases (temperature) and the rate of growth during that period (solar radiation). These yields that assume optimum growing conditions throughout the growth periods are achieved in agricultural practice for instance in Western Europe and in South American plantation crops. In most developing countries these yields are not aimed for, but they may serve as a yardstick against which possible future developments can be measured.

At the next level water-limited yield is calculated, taking into account periods with water shortage and/or excess water. To quantify the soil water balance, in addition to rainfall, the soil physical properties with respect to transport and storage of water are considered. This analysis not only quantifies the possible yield-reduction resulting from the effects of water, but also the requirements for irrigation and/or drainage.

At the next hierarchical level the effects of the major plant nutrients are quantified, to arrive at nutrient-limited yield. Nutrient availability from natural sources is estimated in this approach using the QUEFTS (Quantitative Evaluation of the Fertility of Tropical Soils) system (Janssen *et al.*, 1989), and translated into crop yield by assuming maximum dilution of the elements in the tissue (van Keulen & van Heemst, 1982), taking into account the interactions between the elements. These calculations also quantify the amounts of fertilizer required to arrive at either water-limited or potential yield.

It is not the intention to exhaustively inventorize in this volume the deterministic crop simulation models that are available at the moment. However, in addition to the models developed and applied in the 'Wageningen school' (cf. Rabbinge *et al.*, 1989; Penning de Vries *et al.*, 1989; van Keulen & Wolf, 1986), models were developed in the framework of the International Benchmark Sites Network for Agro-technology Transfer (IBSNAT). These so-called CERES (Crop-Environment Resource Synthesis) models for different crops have contributed substantially to the development of the methodology and are widely applied (cf. Jones & O'Toole, 1987; Jones & Kiniry, 1986; Martin *et al.*, 1985; Ritchie & Otter-Nacke, 1985). Basically these models are very similar in approach to the WOFOST model, described here in some more detail, with the exception that photosynthesis is treated in less detail, but that a development-dependent light use efficiency is used, in combination with a radiation interception model. Leaf area dynamics are treated in much more detail, however.

Many objections have been raised to the use of deterministic crop growth models, ranging from disenchantment with the methodology altogether (Monteith, 1981; Passioura, 1973), through the problems associated with their data requirements, the 'parameter crisis' (Burrough, 1989a), and the stochastic nature of the input data used (Burrough, 1989b), the fact that

the results of deterministic crop growth models necessarily pertain to 'single events' and are therefore difficult to apply in a spatially and temporally variable environment, to the complaint that the models cannot reproduce the actual situation.

However, application of such models provides the opportunity (or creates the necessity) to formulate consistent quantitative opinions on the behaviour of the systems under consideration, their potentials and the biophysical constraints that are operative. The consequences of alternative opinions can therefore easily be made explicit and as such the models form a tangible basis for discussion.

In the framework of the LEFSA sequence, deterministic crop growth models will find their major application in the formulation of alternative land use types, i.e. quantification of production activities that are not (yet) practiced in the area, but have potential applicability (Subsection 7.3.3).

7.3.2. Computerized land evaluation techniques.

With the increasing availability of high speed computers and software geared to the easy handling of large numbers of data, automated land evaluation systems have been developed in recent years. Most of these are of a purely physical nature, as the crop growth and animal production models (Subsection 7.3.1). A few systems have been developed, that permit a further analysis by incorporating results of farming systems analysis to arrive at overall agro-economic suitability assessments.

7.3.2.1. Land Evaluation Computer System (LECS).

This comprehensive system, developed by a team of FAO in Indonesia (Wood & Dent, 1983), is based on the principles of the Framework for Land Evaluation (FAO, 1976) and aims at land evaluation on a regional scale on the basis of small scale soil surveys (1:100,000 and smaller), carried out according to the land system approach. Results from other soil surveys, based on the physiographic approach can however, also be used. The results of the survey form the basis for the data tables required by the system: soil/terrain data evaluated by the soil/terrain module and climatic data evaluated by the climate module. The modules have the capability to generate data via transfer functions in case of missing data (for instance

permeability from texture, or temperature from altitude). These modules are assumed to have general applicability and can therefore be used under various conditions. In addition, agro-economic tables and soil conservation practice tables are required that are much more site-specific and have to be based on results of local farming systems analysis.

The procedure consists of four consecutive steps, producing (i) an agro-ecological crop suitability classification, (ii) a soil degradation hazard assessment, (iii) an agro-economic crop suitability classification and (iv) a soil conservation requirement assessment.

(i) The agro-ecological suitability classification is based on FAO's Framework, hence crop requirements and land qualities are matched, to arrive at the suitability, expressed as a fraction of what is considered the locally feasible non-constrained yield (which is the same as the 'normative' yield in section 5.3.12 of the Matara case). The result is thus a semi-quantitative assessment, that is comparative rather than absolute.

(ii) Soil erosion losses are estimated on the basis of the Universal Soil Loss Equation of Wischmeyer. On the basis of a user-specified required 'resource-life span', indicating the duration of the period that present production capacity must be maintained, permitted soil erosion is estimated. Present and permitted soil erosion are transferred to the Soil Conservation Module.

(iii) In the agro-economic crop suitability classification, the results of the agro-ecological suitability classification are combined with user-specified information on the requirements for labour, capital and technical know-how at different crop management levels. In combination with the local socio-economic environment and the available resources, the technical and economic feasibility of improved crop production systems can be explored, leading to an agro-economic suitability classification.

(iv) The soil conservation measures necessary to arrive at the permitted soil erosion levels are quantified here for the technically and economically feasible production systems.

7.3.2.2. Integral Land Evaluation.

Another approach to the use of computers for the purpose of land evaluation was developed by the Land Evaluation Group at the University of Guelph under the name 'Integral Land Evaluation' (Smit *et al.*, 1984; Land Evaluation Group, 1983). The method deals with the choice of land for

specific uses, to meet basic needs of society, such as economically acceptable agricultural production levels, and the needs for goods, services and amenities. The mathematical model generates quantitative information on the flexibility of land use (i.e. the number of land use alternatives), and the technical feasibility of land use options in view of the available land resources and socio-economic objectives.

As an illustration of the approach, a prototype land evaluation model for Ontario was developed. This prototype was run for three scenarios characterized by increasing targets on food production. The results indicate that with increasing demands, the flexibility in land use decreases and available agricultural land becomes critically limiting. If different information is available and with adapted analytical tools, the methodology can be applied at other geographical scales to address 'what if' questions, as demonstrated with a study on the effects of alternative scenarios for erosion control on maize yields at the county level in Canada (Land Evaluation Group, 1983).

7.3.2.3. Land Use Planning (LUPLAN).

The software of LUPLAN, a computerized aid for land use planning, was developed at CSIRO in Australia (Ive *et al.*, 1985). The main components are a geographic data base, a land evaluation module and a land use allocation module. The land evaluation module calculates suitability ratings according to a predefined methodology (for example the USDA land capability system, the Storie Index, or any user-supplied criterion). LUPLAN calculates a suitability index ('attractiveness score') for each relevant land use on each mapping unit. In the further analysis, the land use with the highest score is initially selected as the most preferred land use. The resulting total land use plan is then reviewed to determine to what extent the socio-economic objectives (policy guidelines) have been attained. If the plan as a whole is not acceptable the relative importance of the policy guidelines can be adjusted and an alternative land allocation plan generated.

7.3.2.4. Comprehensive Resource Inventory and Evaluation System (CRIES).

The CRIES system (Schultink, 1987), developed mainly for use in developing countries, focusses on evaluation of alternative land use options and policy scenarios in terms of the private and public benefits achieved. The major components of the system are a geographic information system, based on grid cells, and an agronomic information system. It includes separate modules for calculation of the water balance, for yield predictions, calculation of erosion hazards, statistical analysis and linear programming for optimization. The evaluation procedure can be applied to farming systems, or to regional or national levels. The assessment of the physical resource potential is carried out on a single grid area or a larger aggregate, and results in identification of that (unrealized) potential. In combination with the other modules, the system provides a possibility to determine the comparative advantages of sites or zones for land use alternatives.

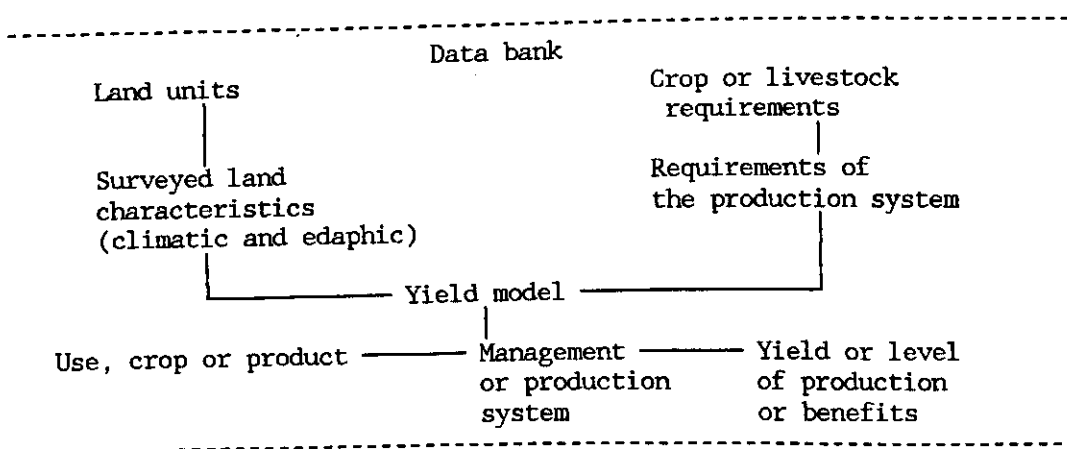
7.3.2.5. A World Soil and Terrain digital data base (SOTER).

This data base is being developed at the International Soil Reference and Information Centre (ISRIC) after initial endorsement by the International Society of Soil Sciences (ISSS). SOTER has the following characteristics: 1) average scale 1:1 M; 2) compatible with databases of other environmental resources; 3) amenable to updating and purging of obsolete and/or irrelevant data; 4) accessible to a broad array of international, regional and national users responsible for the development, management and conservation of environmental resources; 5) transferable to developing countries for national database development in greater detail (ISSS, 1986). Sims (1988) discussed the use of the SOTER database as a basis for land use planning, and the Land and Water Development Division of FAO is rendering active support to the propagation of the SOTER approach.

Following the SOTER data base, a twin project was designed for the 'Global Assessment of Soil Degradation (GLASOD)' (UNDP, 1987). The immediate objectives of GLASOD are 'to strengthen the awareness of decision makers and policy makers on the dangers resulting from inappropriate land and soil management to the global well being and to improve the capability in regional and national institutions to deliver accurate information on

qualitative and quantitative soil degradation for national and regional agricultural planning purposes' (Sombroek & Oldeman, 1989: 2).

The information on soils and climate that is stored in this data base is basically intended to be used to classify land units in relation to their suitability for various uses, especially taking into account erosion and degradation risks, to arrive at recommendations for land use that results in maximum sustained production. The logic and structure of this computerized systems approach are derived from the basic notion that in decision making two steps are involved: (i) What are the possible alternatives? (ii) Which of the alternatives is the best from the point of view of the needs or objectives of the decision maker? In order to judge what crops and land uses are possible on a given land unit, basically the framework procedure is followed. To be of practical use to planners, extension workers and/or farmers, the results must be presented in quantitative terms, be reasonably accurate, and must allow comparisons between alternative land uses. Hence, the system must be further developed:



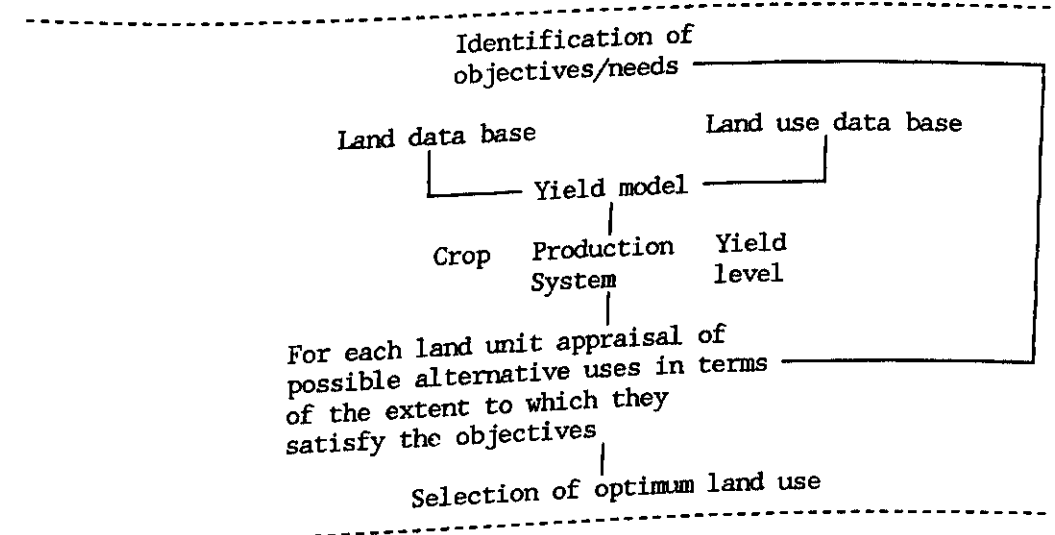
Different production activities require different combinations of land characteristics, which have to be expressed in quantitative terms. In addition to the requirements of the specific crop or animals species, the production systems as such (cropping/livestock systems or land use types in the LEFSA terminology) may have certain requirements in terms of soils and climate: steep slopes are not suitable for intensive mechanized arable farming, and glasshouse production is not suitable for regions with frequent hailstorms.

The yield model may be any method of estimating yield or output from a defined land unit with known characteristics, and results in a list of possible uses or products, an identified production system and a level of output.

In selecting the 'best' or 'optimum' use of the land, it should be realized that these notions are relative terms, that depend on the objectives to be pursued, which may be different for different users. For example, for the individual farmer the major objectives may be meeting the basic food requirements of the farm household, followed by maximum cash income and reduced labour input. At the national level food self-sufficiency for the country, higher rural incomes and environmental protection may be important goals. Hence,

- i usually there are more objectives
- ii objectives must be identified, before 'best' or 'optimum' can be defined in terms of land use
- iii objectives may, to a greater or lesser extent, be incompatible
- iv objectives can be ranked in order of immediate priority
- v objectives and their relative importance can change over time; that reduces the value of printed suitability maps and increases the usefulness of computerized data bases, that allow rapid access, manipulation, retrieval and combination for re-classification (section 7.2).

The total sequence can now be represented by:



Assessment of alternative land uses may involve economic appraisal, market surveys, calculation of labour requirements, environmental impact assessment, and the use of trade-off or optimization techniques (Subsection 7.3.3). The system provides the possibility to identify, describe, and analyze alternative land use patterns in terms of their products, the components of their production systems, and their economic and social aspects. It is possible to carry out the optimization analysis at any selected level of aggregation, i.e. national, district, village, or farm. However, at each level the purpose, the map scale and level of detail will be different.

7.3.2.6. Agro-ecological zones (AEZ) study.

The agro-ecological zones study was initiated some 15 years ago (FAO, 1978-1981), to address the need for an overview of the extent of potentially cultivable land in the developing world and its production potentials. Originally, the requirements of eleven, mainly tropical, crops with respect to climate and soil-based land qualities were translated into simple variables that could be estimated from available long-term climate means and soil information. The soil information was classified in agro-ecological map units, which consisted of soil map units, further subdivided by length of the growing period, and by their estimated composition in terms of individual soil units, slope classes, surface texture classes, and phases. The length of the growing period was estimated from annual precipitation and potential evapotranspiration, taking into account, in a rather simplified manner, soil moisture storage capacity. The growing season was considered to start when rainfall exceeds half the potential evapotranspiration for a ten-day period, and to extend into the dry season until accumulated rainfall deficit (difference between potential evapotranspiration and rainfall) has reached a value of 100 mm, assumed to be available from stored soil moisture.

Recently, a computerized land resources appraisal of Bangladesh was carried out, based on the AEZ principles (Brammer *et al.*, 1986-1988). In this case much more detailed information was required and available than in the original region-wide application. In this appraisal each individual basic land unit passes through a series of 'suitability sieves', separately for each crop and for different input (management) levels. These suitability sieves refer to agro-climatic, agro-inundation, agro-edaphic and agro-

landform conditions. The main growing period (Kharif), when rainfed wetland rice can be grown on suitable land, was assumed to start in the first ten-day period for which rainfall exceeds 0.5 times potential evapotranspiration and for which the preceding ten-day period had at least 50 mm rainfall, sufficient to start inundation. This period ends in the first ten-day period when the accumulated rainfall deficit exceeds 100 mm. This climate-determined length of growing season, may then be modified according to soil-type specific inundation regime. For the secondary growing period (Rabi), that follows the wet season, and in which upland crops are grown, the start is the first ten-day period in which potential evapotranspiration exceeds rainfall and it ends when accumulated rainfall deficit exceeds 250 mm, a value for soil moisture storage capacity that seems to apply to the loamy to silty clay loam soils of the holocene deposits in Bangladesh. The result of the analysis is an agro-ecological land suitability assessment for the various combinations of crops and soil types.

Similar efforts of applying the AEZ methodology at the national level as in Bangladesh have been made in several other countries. Examples are in Ethiopia (e.g. FAO, 1984b) and Kenya (e.g. Jeatzold & Schmidt, 1983). In the latter, the variability of the rainfall was also taken into account, as was the case in a later stage in Ethiopia (FAO, 1988a).

In recent years the awareness of the complexities and diversities in the natural and human environments has led to an increased demand for location specific information. Consequently, data collection efforts on natural resources, from ground truth as well as from aerial photography and remote sensing, have expanded substantially, resulting in more refined systems of classification and evaluation of physical and biological variables. Most of these, however, are small-scale efforts (over 1:50,000), and there have been few attempts to produce overlays with socio-economic data such as population and infrastructure. Moreover, the approaches adopted by the international agricultural research centres vary greatly (Bunting, 1987). Exceptions with regard to the incorporation of socio-economic data can be found in, for example, Jeatzold & Schmidt (1983, see also appendix 2), and in Polman, Samad & Thio (1982) and Schipper (1983). However, in the latter two cases the agro-ecological zonation was not based on the length of growing period approach of the FAO system, but on a more simple classification, mainly according rainfall regime and altitude (Joshua,

1987). Another example of combining socio-economic data with agro-ecological zonation at the national level (FAO, 1988a), can be found in Ethiopia (FAO, 1988b). In this case the population supporting capacity was analyzed in the framework of a national 'master' land use plan.

The computerized systems for (aid in) land evaluation discussed in this subsection do certainly not present a complete picture of what is being used at the moment, and in view of the rapid developments, many more may be expected to show up in the near future. Although each specific purpose may require its own specific 'model', there seems to be an urgent need for standardization in the field, and the LEFSA sequence could possibly provide a useful framework for such coordination.

7.3.3. Interactive multiple goal linear programming.

For effective land use planning it is necessary to answer such questions as: what is the agricultural potential of a region? Which production techniques for crops and livestock are available? What are the inputs required to realize the production potential offered by the available natural resources and the available production techniques? Under what socio-economic conditions is it attractive to practice the different techniques? Is there scope for other, improved or alternative techniques that are not yet practiced in the region? Does introduction of such techniques require further research? What are the constraints associated with the introduction of these techniques?

The answer to such questions not only depends on the technical possibilities in a region, as determined by the available natural and human resources, but also on the goals of development. Emphasis on different goals, such as for example, self-sufficiency in food production, risk-avoidance, achievement of rural incomes on a par with urban incomes, may lead to different development pathways, with their associated differences in choice of production techniques. Any development plan for a region must be technically feasible and it must take into account all the possible goals imposed on the region and the constraints to satisfy the various goals.

The method described here (cf. de Wit *et al.*, 1988) can be used to evaluate the agricultural potentials of a region and to analyze to what extent the

available techniques can meet the demands under various constraints , under various policy options and under different socio-economic conditions. The input requirements and the investment needs also follow from the analysis.

7.3.3.1. The method.

The method, briefly described here, is based on a linear programming approach that optimizes a mix of production processes, subject to a set of constraints. The production processes are defined as 'activities' or 'production techniques', each yielding certain 'outputs' and requiring certain 'inputs'. The inputs draw on resources that are limited, and may therefore be constraining for application of the techniques or for the level of intensity at which they can be executed. An example of a linear programming model in the context of land evaluation in Sierra Leone can be found in Diltz (1980).

When only one goal has to be pursued (optimized) the approach is straightforward. However, when a number of possibly conflicting goals have to be pursued, the choice for a certain development path becomes dependent on the relative value attached to each of the goals, which is not necessarily the same for different decision makers or interest groups. The Interactive Multiple Goal Linear Programming technique allows attainment of a desired solution by stepwise optimization of the various objectives. In a first cycle the lower bounds of all the goals considered are set at their minimum values, to ascertain attainment of feasible solutions that satisfy all these minimum requirements at the same time. Then each of the goals is optimized on its own, with the lower bounds of the other goals defined as minimum goal restrictions. This first cycle yields thus for each of the goals the most favourable value that can be attained, and also the most unfavourable value that can be expected. The total solution space ('the feasible region') is defined in this way, but the ideal situation where all the goals reach their maximum value simultaneously does not exist. The most satisfactory solution from the point of view of a particular 'user' may now be obtained in subsequent iteration cycles by tightening one or more of the goal restrictions and repeating the optimization for one or more of the other goals. The choice of the goal restrictions and the degree to which they are tightened reflect the specific interests of the user. During the stepwise maximization of the goals, under increasingly tighter restrictions on the other goals, the solution space is gradually reduced until a

situation is reached where the user cannot improve on any of his goals without sacrificing on another one. In that way he becomes aware of the opportunities for exchange between the various goals in his desired solution space, i.e. he obtains the opportunity costs of one goal in terms of the other goals.

Interactive multiple goal linear programming is an example of multiple criteria analysis. Other types of linear programming based models with multiple goals are: 'goal', 'multiple objective' and 'compromise' programming (Romero & Rehman, 1989). In the context of land use planning, a case of compromise programming is provided in Erenstein & Schipper (1991).

Different users may of course have different objectives or attach different weights to the various goals, and may therefore end up in different corners of the solution space. In terms of the LEFSA sequence that means that in interactive contact with different interest groups (government, development agencies, local population) different desired land use plans could evolve. The method, however, also allows them to explore the possibilities for a compromise that is satisfactory to all interest groups, even though it is not ideal for any one in particular.

7.3.3.2. Regional analysis, farming systems analysis and planning.

When the method described above is applied to regional analysis and planning in the field of agriculture, the activity matrix contains 'all' existing and conceivable production techniques for a region, including those that may still be in a research and development phase. These may include cropping activities, animal husbandry activities, and any other activities related to the agricultural sector. The relevant production activities (land use types or cropping/livestock systems) can be derived from land evaluation. The technical coefficients in the matrix, which quantify the inputs and outputs for implementing and operating each activity, can be obtained from farming systems analysis for production activities currently practiced in a region. For activities not yet practiced in the region, these coefficients could be obtained from crop growth simulation models and animal production models or from available statistical information.

The resources of the region (or constraints) include the area and the 'quality' of the various land types available (land units), which have to be defined on the basis of land evaluation. Next to land, other resources, such as the population living in the region and its demographic composition, additional labour that may be hired from outside the region, endowment of capital goods, animal breeds and herd sizes present in the region, are included in the model. In addition to resource constraints, other restrictions, like crop rotation requirements, are taken into account. Most of these data will have to be derived from farming systems analysis and rural surveys, as well as from statistical sources.

In applying the method, a distinction is made between tradeables and non-tradeables. Prices are in general attached only to goods and services that can be traded across the border of the region, such as fertilizers, products from arable farming (e.g. grains, tubers, fibers) and from animal husbandry (e.g. meat and milk), or to those that have an alternative employment in other sectors of the economy, as is the case with farm labour for which off-farm employment opportunities exist¹⁹. Non-tradeables, for example labour of the local population for which there is no alternative source of employment, or land that can only be used for activities included in the model, or products that cannot be easily transported such as straw and organic manure, often do not have a directly observable price. In general, no prices are attached to those goods and services, however, they do have an opportunity cost, and therefore an implicit price.

7.3.3.3. The results.

The analysis results in (i) identification of consistent, technically feasible development pathways for what is regarded the most satisfactory combination of all goal variables; (ii) identification of the major constraints for such developments; (iii) evaluation of the costs of greater achievement of one goal in terms of sacrifices on the other goals and the constraints, which can lead to identification of technical bottlenecks and constraints; (iv) translation of the selected combinations of goal

¹⁹ One of the disadvantages of linear programming models is that it is difficult to include relationships between prices and quantities, because of linearity constraints. However, by imposing different prices (or price ratios), the sensitivity of the model results to different market conditions can be established. An other approach might be to linearize non-linear relationships, see, for example, Hazell & Norton (1986).

achievement into a combination of activities, i.e. the mix of production techniques (cropping systems and livestock systems) necessary to achieve the goals, the needs for investments, imports, exports and credit in the proper sequence, the labour requirements and their qualifications, etc.

The method of analysis is not an econometric one, containing many (often uncertain) behavioral relations. Social constraints, like unequal accessibility of the means of production, land titles, or economic behavioral patterns are also not taken into account. In general, one can say that this method is only a partial analysis. The analysis therefore does not 'predict' the future development of a region, but it defines technically feasible development pathways, that best attain a certain set of goals. This part of the analysis, including definition of the policy measures necessary to realize the required developments, must be subject to further investigation, that goes beyond the scope of the method described here.

7.3.3.4. An example.

The method of multiple goal linear programming was applied in the framework of a joint Dutch-Egyptian project on land use planning for the Mariut region in Egypt (van Keulen & van de Ven, 1988; Ayyad & van Keulen, 1987). The major agricultural activities in the region are animal husbandry, mainly sheep and goats, rainfed barley cultivation, and fruit tree cultivation, mainly olives and figs. For each of these activities several production techniques (land use types) were defined, based on the regional resources and varying in degree of intensification.

To define the soil resource, four main soil groups are distinguished, further subdivided into soil types according to soil depth and soil texture (FAO, 1970). For each soil type a representative set of soil physical and soil chemical characteristics was defined. The soil physical properties refer mainly to the water transport and storage characteristics, the soil chemical properties refer to the supply of plant nutrients from natural sources (soil fertility) and the recovery of applied fertilizer. These characteristics were used in the simulation model for crop growth.

Barley cultivation is not possible under the natural rainfall regime, as moisture availability is insufficient. Present land use is such, that

barley is cultivated in low lying areas, where run-off water collects. Three moisture regimes were defined, annual infiltration of 250, 300 and 450 mm, respectively. For the 300 and 450 mm moisture regimes run-off must be actively promoted through construction of dikes. Maintenance of these structures is defined as an input for these land use types. Barley production under these conditions was estimated using the crop growth simulation model WOFOST (Subsection 7.3.1), on the basis of local data on weather, soils and crops.

The agricultural operations necessary for cultivation can be carried out in hand labour, with animal traction or with mechanized equipment. Weeding is not considered worthwhile for the 250 mm water regime, as yield increase is insufficient. For the improved water management systems weeding is optional and can either be carried out by hand, or using herbicides. In the cultivation systems using mechanized equipment, harvesting can either be done by selfbinder or by combine. Not all combinations were considered relevant for the Egyptian situation, hence a total of seventeen barley cultivation systems were included in the analysis (table 21)

Table 21. Barley cultivation systems defined in land use planning for the Mariut region.

Available power source	Water regime	Weeding practice	Harvesting equipment	Number
animal traction	250 mm	no		(1)
		no		(2)
	300 mm	hand		(3)
		herbicide		(4)
		no		(5)
	450 mm	hand		(6)
		herbicide		(7)
no		selfbinder	(8)	
mechanical equipment	250 mm	no	combine	(9)
		no	selfbinder	(10)
	300 mm	no	combine	(11)
		herbicide	selfbinder	(12)
		herbicide	combine	(13)
	450 mm	no	selfbinder	(14)
		no	combine	(15)
		herbicide	selfbinder	(16)
		herbicide	combine	(17)

The barley systems produce grain, straw and grazing land, i.e. the aftermath that can be used in animal production systems. Grain can either

be sold or used as concentrate replacement in animal production systems; straw is used as supplementary feed.

Fruit tree production activities comprise production of olive oil, table olives and figs. For olive production six systems have been defined, three for production of fresh olives, three for olive oil production; for each of the products a 'traditional' system, an improved system with mechanization and an intensified system with irrigation. For fig production also three systems have been defined, two producing fresh figs, one traditional and one mechanized, and one producing dried figs. In all cases the orchards require fertilizer, preferable manure to meet the nutrient requirements of the trees and to improve soil structure.

For small ruminants five production systems have been defined: two are extensive systems, in which the feed requirements consist of natural vegetation and the grazing area between the barley fields. In one of these, representing the 'traditional' animal husbandry system in the region, supplementation consists of concentrates and barley straw. In the other system vegetable residues and berseem hay may replace part of the barley straw. Two systems, designated 'intermediate', represent the level of intensification prevalent at the moment in the region; the feed resources are identical to those for the traditional systems, but because of the higher production target, supplements must be of higher quality; they are again distinguished on the basis of use of barley straw. Finally an 'intensive' system has been defined, where the major part of the feed is ingested under feedlot conditions.

The natural vegetation serving as animal feed is partly produced on the natural rangeland and partly on that proportion of the arable land that is not cultivated, but serves as catchment area for run-off collection for the barley and fruit tree production systems. Hence, production of animal feed is directly related to the cropping pattern.

Annual costs for the animal husbandry systems comprise purchase of vitamin A, medical care, etc., increase with system intensity. Investments in hardware, like shearing equipment amount to only a few Egyptian pounds per year. In intensive systems the rangeland is fenced, which increases the investments, the life expectancy of the fences being set at ten years.

The outputs of the animal production systems consist of sheep and goat hoggets, meat and wool, in addition to animal traction and manure, that can be used in some of the crop systems. Hoggets can either be kept for rearing or they can be sold. In the present study a steady state situation is considered and the dynamics of development are not taken into account, hence all hoggets in excess of replacement requirements are sold. Marketing activities comprise purchase of inputs, like sowing seed, fertilizer, concentrates and other supplementary feeds and the sale of marketable products, i.e. surplus barley grain, fresh olives and olive oil and fresh and dried figs.

The potentials of the multiple goal linear programming technique are best utilized if the number of goal variables is high and the number of goals formulated as constraints accordingly low. In that way a high degree of flexibility is achieved, and the options for technically feasible development possibilities are kept as open as possible. In this study the following goals were defined: net income, i.e. income before taxes; employment; herd size; import of concentrates; conservation of traditional agricultural systems; government subsidies; mechanization; export of mutton and goat meat; area under fruit trees.

To illustrate the capabilities of the method, three policy views with their aspirations were defined for the region:

- The government's aims can be described as: increased settlement in the area with an income for the population at a reasonable level; a low export quota for meat; abolishment or restriction of subsidies on inputs; a limited area under fruit trees.
- The aspirations of the local population: high consumptive income; a free export market or at least an export quota as high as possible; a low level of unemployment; no additional settlers; an increase in the level of mechanization in the area; no limitations on the area under fruit trees.
- A 'conservationists' point of view: definition and quantification of the goals for this view proved difficult; in the model they have been defined as: an extensive area under traditional systems; limited use of imported concentrates; restriction on the herd size.

As explained, in the first round all the goals are optimized on their own, with only minimum restrictions on the other goal variables. The results of that round are presented in table 22.

The results presented in the table show, that it is possible to withdraw all government subsidies and still obtain a feasible solution. Maximum net income amounts to 37.6 million LE, which is achieved with an export of 22.5 million kg of meat, about ten times the present quota and only slightly lower than can maximally be produced. Employment in that case is 18700 person-years, about two-thirds of what can be attained (27600). These results thus present the solution space ('the feasible area') for the region.

Table 22. Results of the first iteration round for all goal variables.

	NINC	EMPL	EWEQ	CONC	EXTS	SUBS	MECH	EXP	TREE
	10 ⁶ LE	10 ³ p-yr	10 ³ EE	10 ⁶ kg	10 ³ ha	10 ³ LE	10 ³ h	10 ⁶ kg	10 ² ha
NINC	<u>37.6</u>	18.7	267	119	40	1060	95	22.5	29.2
EMPL	4.8	<u>27.6</u>	248	25	390	1010	173	0	40.4
EWEQ	66.6	4.9	<u>272</u>	121	4	1076	322	0	9.6
CONC	3.7	10.6	96	<u>0</u>	150	32	0	0	9.6
EXTS	1.7	26.3	254	26	<u>424</u>	1007	0	0	9.6
SUBS	2.3	9.6	96	9	0	<u>0</u>	0	0.1	9.6
MECH	7.7	16.1	146	9	230	612	<u>456</u>	0	40.4
EXP	23.7	5.1	272	112	5	1074	230	<u>22.9</u>	9.6
TREE	5.4	10.2	96	9	0	406	0	0	<u>40.4</u>

Notes:

- Goals:
 - net income (NINC), i.e. income before taxes;
 - employment (EMPL);
 - herd size (EWEQ);
 - import of concentrates (CONC);
 - conservation of traditional agricultural systems (EXTS);
 - government subsidies (SUBS);
 - mechanization (MECH);
 - export of mutton and goat meat (EXP);
 - area under fruit trees (TREE).
- LE is Egyptian pounds, EE is ewe equivalents, a 'standard' animal, reflecting the composition of the animal population, p-yr is person-year and h is hours.
- The maximum or minimum of a goal is the underlined number in a row, with the other goals being unconstrained in the same row; for example, the maximum herd size (EWEQ) as indicated in the third row is 272,000 ewe equivalents, at this value the employment (EMPL) is 4.9 thousands person-years.

Starting from this solution space, the possibilities for realization of the government policy goals are examined as an example. Its main aim is increased settlement in the region to alleviate the population pressure in other areas like the Nile valley. The present employment is 22000 person years, and in the next round an increase of 10 percent is aimed at. Hence minimum employment is set at 24200 person-years and the other goals considered are net income, subsidies, area under fruit trees and export crops (table 23).

Table 23. Results of optimization for the government as an interest group.

		NINC 10 ⁶ LE	EMPL 10 ³ p-yr	SUBS 10 ³ LE	EXP 10 ⁶ kg	TREE 10 ² ha
round 2	NINC	27.7	24.2	1006	5.9	31.4
	SUBS	6.2	24.2	0	0	32.4
	EXP	5.1	24.2	947	0	9.6
	TREE	5.4	24.2	950	0	9.6
round 3	SUBS	24.2	24.2	0	6.0	28.2
	EXP	24.2	24.2	1011	4.0	31.4
	TREE	24.2	24.2	1017	5.6	10.5
round 4	SUBS	24.2	24.2	947	4.0	31.4
	TREE	24.2	24.2	1011	4.0	30.9

Goals: - net income (NINC), i.e. income before taxes; - employment (EMPL); - government subsidies (SUBS); - mechanization (MECH); - export of mutton and goat meat (EXP); - area under fruit trees (TREE).

The results in table 23 (round 2) show that for all four goals feasible solutions are obtained. Maximum consumptive income is 27.7 million LE, which at full employment for 24200 persons, amounts to an annual income of 1145 LE/person, i.e. rather low compared to the present wage for hired labour of 1500 LE and not providing any incentive for settlement in the region.

To explore the possibilities further, however, minimum annual income is set at 1000 LE/person-year, hence 24.2 million LE aggregated. In round 3 (table 23) three goals then remain to be optimized. For the government, export should be minimized, as at present the Mariut region has a monopoly on export of meat, a position that is difficult to justify towards farmers

outside the region. The minimum amount that must be exported to achieve the minimum goal values for both employment and income is 4.0 million kg. Without subsidies, employment and income can still reach the required level, but then export has to increase to 6.0 million kg. The minimum area under fruit trees can be achieved, at an export of 5.6 million kg.

For the sake of argument the government is assumed to prefer the minimum export of 4.0 million kg, and the remaining two goals are optimized in round 4 (table 23). The results show, that because of the successive tightening of the goal variables not much scope is left now for manoeuvring: the required subsidies vary between 1 million and 950.000 LE and the area under fruit trees between 3090 and 3140 ha. Hence, more complete realization of any of the goals can only be achieved now at the cost of giving in on any of the others.

The required land use for this solution (land use plan) is illustrated in table 24.

Table 24. Selected agricultural production systems and regional balance for the 'final solution' of the government policy view.

crop activities		animal husbandry activities	
barley system 6	3 500 ha	rangeland	336 300 ha
dried figs	2 820 ha	system 1	54 000 EE
irrigated olives	260 ha	system 2	117 000 EE
fruit tree area	3 090 ha	system 3	74 000 EE
		total herd size	225 000 EE
concentrate import	29 600 ton		
subsidies	1 000 000 LE		
mechanization			
tractors	78		
sale activities		purchase activities	
grain	14 500 ton	N fertilizer	347 ton
fresh olives	1 170 ton	P fertilizer	140 ton
dried figs	7 063 ton	berseem hay	1 170 ton
meat, domestic market	1 400 ton	vegetable residues	7 120 ton
meat, export	4 000 ton		
wool	260 ton		
consumptive income	24.2 10 ⁶ LE		
employment	24 200 p-yr		

The interactive multiple goal linear programming technique can help to decide on feasible development possibilities in a region, within a wide

range of technical and socio-economic conditions, and as such forms a powerful tool in land use planning. The validity of the results obtained depends largely on the accuracy of the technical coefficients in the activity matrix, on the degree of realism of the scenario's that govern the interactions between the activities, and on proper definition of the goal variables. The results of analyses with this method can be used as a basis for discussion with various interest groups in a region, and can help in making the consequences of goals and aspirations explicit. It should be emphasized that the analysis does not provide a prediction of what will happen, but a consistent picture of the technical capabilities of a region within a well-defined (socio-)economic environment. Within the LEFSA sequence it could be applied to examine the possibilities for alternative land use plans under different conditions.

7.4. Expert systems

The distinction between 'computerized aids in land evaluation' and 'expert systems' is gradual. In each 'model' the opinion of the developer with respect to the real system is reflected and as such it forms the explicit formulation of that opinion. However, as the developments in expert systems may be expected to be substantial in the near future, at least treatment of one example in this volume seems warranted.

7.4.1. Automated Land Evaluation System (ALES).

This system has the format of an expert system (Rossiter, 1989) based again on the FAO Framework for land evaluation. It allows the user to build decision trees, containing ratings for land qualities and requirements for land utilization types. The four major components are : (i) a 'knowledge base' (the actual expert system), containing descriptions of different land uses in both physical and economic terms, (ii) a data base, containing information on the natural resources (mainly land), (iii) an inference algorithm, allowing matching of land and land uses, (iv) an 'explanation' facility, that permits analysis of the results.

(i) The knowledge base is specified by the user and contains the relations between land and land use requirements, in which land use can either be a

single crop or a crop rotation. Land use requirements are defined in the system in terms of levels of limitations. Similar levels of limitations may originate from different combinations of land characteristics, as derived from the decision trees.

(ii) The data base, to be developed by the user, contains information from natural resource surveys. Both discrete and continuous information can be handled by the system, which provides possibilities to generate missing information via decision trees.

(iii) In the inference algorithm matching of land qualities and land use requirements takes place according to user-supplied procedures, which results in an evaluation matrix, that allows easy selection of the best land use for a particular land and the best land for a particular land use. Suitability is expressed both qualitatively, according to the Framework principles, and quantitatively in relation to a non-constrained yield or 'normative' yield, for use in economic evaluation.

(iv) The explanation facility allows the user to analyze the results through a backward chain through the system. Interactive use of this facility is possible, to improve the evaluation procedure.

8. CONCLUSIONS AND RECOMMENDATIONS

The 1990s appear to become a time for widespread concern about the future of the world. Climatic changes, environmental pollution and continuing population pressure on land coupled with the inability of many countries to meet the growing demands for agricultural products, present 'mega-scale' issues. These problems are no longer limited to the third world, or portions of it, but affect all levels of the hierarchy of living systems, from the cell to the world economy. The need for some form of deliberate planning to make optimal use of the land resources at our disposal is evident. Solutions are unlikely to come from single disciplines or theoretical schools, but will require the contributions of many thinkers from as many backgrounds as possible.

The state of the art in land evaluation and farming systems analysis

This volume intends to contribute to the debate on global land resource management and land use planning by discussing the state of the art in land evaluation (LE) and farming systems analysis (FSA), two approaches that, from rather diverse backgrounds, attempt to improve land use and agricultural production. LE has evolved from soil survey work and has always been closely associated with regional and project planning, whereas FSA is basically a diagnostic and experimental procedure within the framework of agricultural research. FSA aims to analyze farm level constraints with a view to developing adapted technology for specified categories of farmers, while LE is directed towards determining the suitability of certain types of land use. Differences and similarities have been discussed at length in this volume, leading to the conclusion that many of the apparent differences between LE and FSA are primarily a reflection of the past of both approaches rather than conceptual or methodological necessities. For example, scale in LE as well as FSA depends on objectives and on the perceived variability between units, rather than on characteristics of the respective methodologies. If time and funds permit, LE may well focus on detailed, large scale units, while in the same way, FSA may concentrate on higher levels of the hierarchy than the livestock or cropping systems, and study similarities between farming or village systems operating in different environments.

One point of contention may be the choice of the ultimate scarce factor: land or labour. LE focusses exclusively on land, whereas FSA concentrates on labour, and only to a lesser extent on land. In practice (although not in theory), LE may suffer therefore from a 'major crop bias' and disregard for non-agricultural or off-farm activities by household members. FSA, on the other hand, has drawn attention to the multiple factors that govern farm management and the way in which these are translated into cropping (or livestock) patterns so as to enable farmers to make the most of their resources. Consequently, the comparative approach is much more explicit in LE where different land uses are compared, whereas FSA compares existing production patterns (farmer technology) with available technology. The matching of land use type requirements with land unit qualities results in a suitability classification of land. This presents a major difference from FSA whereby constraints in farm production as experienced by farmers, and not necessarily objective constraints, are listed. To put it simply, LE aims to adapt land use to land, whereas FSA aims to develop and adapt technology to farmer constraints which include land qualities. However, if investments in land are economically feasible, LE couples improved land to improved land use.

LE as well as FSA are criticized for their time-consuming data collection procedures. Although LE has been far more successful in developing quantitative methods and linking up with quantified systems analysis, both approaches remain surprisingly qualitative when it comes to the ultimate judgement of suitabilities. FSA has emphasized a number of data sources that remain hitherto unutilized in LE, such as historical and seasonal production series, case studies, on-farm trials and observations of farm household activities, but has been particularly oblivious of the need to represent data in graphical form, and mapping of spatial characteristics, apart from transects, is hardly ever considered, in contrast to the mapping work in LE.

The first section of this volume concludes that, notwithstanding these differences in approach, there is considerably merit in exploring fully the similarities between LE and FSA with a view to providing a sounder basis for land use planning. There are three areas where LE and FSA are complementary. Firstly and most importantly, in linking the respective units of analysis. LE focusses ultimately on land use types which can be characterized according to key attributes and have certain requirements

with respect to land. FSA analyzes farming systems that are composed of specific subsystems (cropping or livestock systems). Since land use types are nearly always, with the exception of newly reclaimed land, a component of farms, inevitably there is a close correlation between cropping (or livestock) systems on the one hand and land use types on the other. Secondly, linking the levels of analysis in order to provide a full coverage of the entire hierarchy of systems. Thirdly, in geo-referencing the farm level data collected through FSA procedures so that they can be linked to LE data. Any exchange of information between LE and FSA would be to the mutual benefit of each procedure.

An integration of LE and FSA

Even if LE and FSA remain separate procedures they can benefit from one another methodologically and conceptually. Part two of this volume, however, goes well beyond complementarity and discusses how elements from both LE and FSA can be integrated into a new set of procedures which meets some of the criticisms advanced against both approaches but combines the strengths of each. It presents such an integrated set of LE and FSA procedures, the LEFSA sequence, which couples the relative emphasis on soils and natural resources and the more quantified, formal matching procedures of LE with the socio-economic focus, the diagnostic and on-farm testing approach of FSA. The sequence moves from the regional level to the farm level and below, while specific activities are carried out at each level. Reconnaissance LE and rapid appraisal find their place at the regional level, while (semi-)detailed LE and the diagnosis of farmer constraints take place at the lowest level. While such a sequence is clearly defined in time, with the regional level analysis coming before the detailed farm level work, the integrated LEFSA approach does not follow a sequential process, but is iterative within and between levels of analysis ('two steps forward and one step back') so that at each level data can be cross-checked and referred to higher levels when inconsistencies occur.

Procedures for data collection in LEFSA, and particularly ways to reduce the data load, are also considered. The kind of data and how these should be collected and managed are carefully described for each step of the LEFSA sequence. Problems and potentials in the application of entire sequence are illustrated with a detailed case study. Furthermore, the use of modelling and geographic information systems in LEFSA are discussed and proposals for integrated data base management are formulated.

- Sustainability implies an effective understanding of ecological and socio-economic interactions in land use. The coupling of ecological and socio-economic variables remains one of the difficult challenges for any truly interdisciplinary approach. While LE and FSA guidelines make explicit mention of the need to do so, they do not yet provide concrete procedures to do this. Since LE and FSA present different 'gaps' in this respect, a combination of both is likely to improve their effectiveness.
- Sustainability is, by definition, a dynamic concept that requires an assessment of the changes in land use systems. LE and even FSA have a tendency to limit themselves to rather static pictures, although the concept of system in FSA suggests otherwise. Although the LEFSA sequence strengthens the systems thinking in FSA and LE, the approach may remain weak, because cumbersome, in capturing the varying scales of changes at different levels. Climate and soils, for example, change at a much slower pace than crops, livestock or households. Further work may be required on providing adequate indicators of change of each of the land use system elements.

Recommendations for the application and implementation of LEFSA

The incorporation of LEFSA into existing land use planning and technology development procedures will be a lengthy and difficult process. In some cases, it may be more useful to select the appropriate elements rather than the entire sequence. Nevertheless, the message of this volume remains that even when one is occupied with a single step within the LE or FSA methodology, it is essential to retain a sense of perspective of the integrated LEFSA. New computer based data retrieval and mapping technology that make it possible to refer to disaggregated data allows one just to do that. Nevertheless, it remains a point of concern that in developing countries many services dealing with agriculture and land in its broadest sense, are poorly equipped and understaffed. The LEFSA sequence cannot address this problem: although it does avoid duplications through the sharing of information, it does not necessarily reduce the work load of the individual services involved. It remains essential, therefore, that the practical applications of an integrated LE and FSA approach be adapted to the specific needs and possibilities of the countries concerned. A critical assessment of relevant elements of the LEFSA sequence will be required in order to shorten and simplify the procedure.

At present, the LEFSA sequence is a theoretical construct. It is based on a great deal of experience with most of its components, but the sequence has never been implemented in its entirety. The underlying assumption is that the separate strengths of LE and FSA can be integrated in such a way that the resulting whole is more than its parts. While there are strong reasons to believe that a combination of the approaches yields valuable additional information, this assumption needs empirical verification. It is recommended therefore that an applied research programme be formulated to further elaborate and test the LEFSA sequence. Such a programme must consist of three interrelated parts or phases. Firstly, a conceptual phase in order to refine the various steps LEFSA sequence as proposed in this volume. Secondly, a phase to reinterpret existing case materials or projects (e.g. FAO studies on LE and land use planning, FSA studies) in order to establish how an integration of the results according to the LEFSA sequence would yield better results for land use planning. And, thirdly, a field testing phase where the entire LEFSA sequence is carried out in one or preferably more than one set of conditions where an integrated contribution to land use planning is needed.

There is always a risk that a new approach becomes a goal in its own right rather than a means to a further purpose. In order to avoid the top-down imposition of LEFSA (or LE or FSA for that matter), it will be essential to devote sufficient time with future users in developing countries and develop appropriate training mechanisms. Last but not least, LE, FSA and LEFSA are but tools to help people to decide on and implement forms of land use that are better able to meet their needs. The ultimate significance of any formal procedure depends on the degree to which it addresses societal problems and helps society to solve these.

GLOSSARY

Activity - A process using a technology that combines inputs to generate particular outputs for sale, barter or household consumption. An activity can be independently analyzed from an economic viewpoint (after FAO, 1986). An activity is considered a subsystem of a farm system. There exist a similarity between the concept **activity** and the concepts **cropping system**, **livestock system** and **land use type**.

Agro-ecological zone - A relatively extensive area, defined in terms of climatic conditions, major landform, hydrological regime, major soil groupings and/or (semi-)natural vegetation, which is suited for a certain range of crops and cultivars.

Cropping system - A system, comprising soil, crop, weeds, pathogen and insect subsystems, that transforms solar energy, water, nutrients, labour and other inputs into food, feed, fuel or fiber. The cropping system is a subsystem of a farm system. There exists a similarity between the concept **cropping system** and the concepts **activity** and **land use type**.

Data base - A structured (non-redundant) set of data whereby the data can be shared for different uses (questions).

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

Equal marginal returns - The constant value added by the last unit of resource in each of its alternative uses, if the returns from a limited resource are maximized, i.e. when the input is allocated to its most profitable use.

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.

Farming system - A class of similarly structured farm systems.

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

Farming Systems Analysis (FSA) - A set of procedures to describe and analyze variables and parameters at the farming systems level with the aim

of defining solutions to constraints. FSA covers both agro-ecological and socio-economic aspects.

Farming Systems Research (FSR) - A research methodology to translate farm level constraints into testable technology and the testing of this technology under experimental station as well as farmer conditions (on-farm trials). FSR is usually preceded by FSA.

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).

Geographic Information System - A computerized data set containing entities with known coordinates.

Geo-referencing - Establishing the location of an entity (object) by registering its x, y (and z) coordinates in a specific coordinate system.

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 to the region/nation at the highest levels.

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

Interactive Multiple Goal Linear Programming - An optimization technique that allows formulation of various objectives, evaluation of the degree to which these can be attained and the opportunities for exchange between the different objectives.

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 cultivation of two or more crops on the same field with only partially overlapping growth periods. The crops grown in intercropping are called crop associations.

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

Land - An area of the earth's surface, the characteristics of which embrace all reasonably stable, or predictably cyclic, attributes of the biosphere including those of the atmosphere, the soil and underlying rock, the hydrology, the plant and animal populations and the results of the past and present human activity, to the extent that these attributes exert a significant influence on present and future uses of the land by man.

Land characteristic - A property of land, used to distinguish land units

from each other. It should preferably be a property that can be measured or estimated.

Land evaluation - The process of assessment of the performance of land when used for specified purposes, involving the execution and interpretation of surveys and studies of landforms, soils, land use, vegetation, climate and other aspects of land in order to identify and make a comparison of promising land use types in terms applicable to the objectives of the evaluation.

Land quality - A usually complex attribute of land which acts in a manner distinct from the actions of other land qualities in its influence on the suitability of land for a specified land use type.

Land suitability - The fitness of a given type of land for a specified type of land use.

Land suitability classification - Classification of specific types of land in terms of their absolute or relative suitability for a specified type of use.

Land unit - An area of land demarcated on a map and possessing specified land characteristics and/or qualities (identical to Land mapping unit, FAO, 1976).

Land use planning - Land use planning is considered a form of (regional) agricultural planning. It is directed at the 'best' use of land, in view of accepted objectives, and of environmental and societal opportunities and constraints. It is meant to indicate what is possible in the future with regard to land use ('potentials') and what should be done to go from the present situation to the future one, in other words, how to change land use. In a similar sense Dent (1988) defines land use planning as 'a means of helping decision-makers to decide how to use land: by systematically evaluating land and alternative patterns of land use, choosing that use which meets specified goals, and the drawing up of policies and programmes for the use of land'.

Land use requirement - The conditions of land necessary or desirable for the successful and sustained practice of a given land use type (e.g. crop requirements, management requirements, conservation requirements).

Land use system - A specified land use type practiced on a given land unit, and associated with inputs, outputs and possibly land improvements such as terracing, irrigation, drainage, etc.

Land use type (LUT) - A specific kind of land use under stipulated biophysical and socio-economic conditions (current or future), seen as a subsystem of a farm. A land use type can be described according to its

setting, technical specifications and requirements (see appendix 5, part II). There exists a similarity between the concept **land use type** and the concepts **activity**, **cropping system** and **livestock system**.

LEFSA sequence - A procedure for land use planning based on an integration and combination of Land Evaluation and Farming Systems Analysis.

Limitations - Endogenous factors at the subsystem level, adversely affecting system performance.

Livestock system - A system comprising pastures and herds and auxiliary feed sources transforming plant biomass into animal products. The livestock system is a subsystem of a farm system. There exists a similarity between the concept **livestock system** and the concepts **activity** and **land use type**.

Matching -

- i. The process of mutual adaptation and adjustment of the descriptions of land use types and land qualities, which has as the main aim to find the best combinations of (improved) land use and (improved) land qualities.
- ii. The (specific) process of comparing land use requirements with land qualities of land units.

Model - A simplified representation of a limited part of reality with related elements.

Modelling - The process of developing a model and studying its behaviour.

Multilocational experiments (or trials) - Experiments conducted outside the physical location of a research station so as to include 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 - Experiments that aim at evaluating the biological and technical feasibility of improved technology in farmers' fields, while design and supervision are the researchers' responsibility.

On-farm trials - Experiments that aim at evaluating the economic viability and social acceptability of improved technology that has previously been evaluated in on-farm experiments.

Parcel - A land unit as part of a farm. A certain land tenure relationship exists between the parcel and the farm household; furthermore the parcel is managed by the farm household.

Qualitative land suitability classification - A land suitability classification in which the results are expressed in qualitative terms

only, without quantitative estimates of outputs (crop yields), inputs, or costs and returns.

Quantitative economic land suitability classification - A quantitative land suitability classification in which the results are expressed, at least in part, in economic terms.

Quantitative physical land suitability classification - A land suitability classification in which the results are expressed in physical numerical terms (e.g. grain yields, amounts of fertilizer inputs).

Rapid Rural Appraisal - A study used as a starting point for understanding a local situation; carried out by a multi-disciplinary team, based on information collected in advance, direct observation and interviews. Often associated with a 'sondeo', or informal, preliminary, or exploratory surveys.

Recommendation domain - A group of farmers, more or less homogeneous with respect to a specific technology or innovation, and operating under similar conditions, for whom comparable recommendations can be made.

Reconnaissance survey - A general purpose survey providing generalized information on larger areas and their main features (e.g. natural resources and their spatial distribution, usually at map scales of 1:100.000 to 1:500.000; a reconnaissance survey is mostly preliminary to more detailed surveys which cover, for instance, selected areas with promising potentials for development.

Regional agricultural planning - The process of analyzing and planning the development of the agricultural sector of a region. It is a specific form of intermediate level planning of sectors and regions within the national economy.

Regional system - A complex large scale unit, utilizing land, 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.

Relational data base - A non-redundant structured set of data whereby each entity can be related to other entities (data stored in two-dimensional tables).

Remote sensing - Sensing the earth's surface using electromagnetic radiation which is reflected or radiated by the surface. It includes air photos and electronic scanning devices carried by aircrafts or satellites. Remote sensing data and images contribute, among others, to the monitoring, updating and mapping of land resources, land cover and land use.

Representative sample - A number of individuals from a population, that is selected 'at random' and is large enough in relation to the 'permissible relative error', to allow statistical treatment and conclusions about the population as a whole (see appendix 6).

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 of production systems and/or availability of food to all sectors of the population).

Special purpose land evaluation - A land evaluation in which the potential types of land use are limited in number and are clearly defined in the objectives of the evaluation.

Sustainable land use - Land use guaranteeing continuing productivity of land without severe or permanent deterioration in the resources of the land.

System - An arrangement of components (or subsystems) that process inputs into outputs. Each system consists of boundaries, components, interactions between components, inputs and outputs (see elements).

REFERENCES

- Alexandratos, N. (Ed.)(1988). World agriculture toward 2000. An FAO study. Belhaven Press, London.
- Ashby, J.A., C.A. Quiros & Y.M. Rivera (1987). Farmer participation in on-farm varietal trials. CIAT, Cali, Colombia. (Discussion Paper).
- Ayyad, M.A. & H. van Keulen (Eds.)(1987). The 'Mariut' project. Final report submitted to Directorate General for International Cooperation (DGIS), Part 1, Part 2, Part 3. CABO, Wageningen.
- Baum, W.C., & S.M. Tolbert (1985). Investing in development. Lessons of World Bank experience. Oxford University Press, Oxford.
- Beek, K.J. (1978). Land evaluation for agricultural development. Some explorations of land use systems analysis with particular reference to Latin America. International Institute for Land Reclamation and Improvement/ILRI, Wageningen.
- Beek, K.J., L. Reis & R. Thiadens (1980). Data analysis in land evaluation: Some experiences in a land reclamation project in Portugal. In: FAO (1979).
- Beek, K.J., P.A. Burrough & D.E. McCormack (Eds.)(1987). Quantified Land Evaluation. ITC, Enschede, The Netherlands. (ITC Publication No. 6).
- Best, J. (no date). Some aspects of farm survey methodology. Reading University (mimeo). Quoted in: Mettrick (1983).
- Blaikie, P. (1985). The political economy of soil erosion in developing countries. Longman, London.
- Bouma, J. & H.A.J. van Lanen (1987). Transfer functions and threshold values: from soil characteristics to land qualities. In: Beek, Burrough & McCormack (1987).
- Bouma, J. & A.K. Bregt (Eds.)(1989). Land qualities in space and time, Proc. ISSS Symp., Wageningen. Pudoc, Wageningen.
- Brammer, H.J., J. Antoine, A.H. Kassam & H.T. van Velthuis (1986-1988). Land resource appraisal of Bangladesh for agricultural development. FAO, Rome. (BGD/81/035, Technical reports, 10 Volumes).
- Broussard, J.M. (Ed.)(1988). Agriculture. Socio-economic factors in land evaluation. Office for Official Publications, Commission of the European Community, European Community, Luxembourg. (Report EUR 11269 EN).
- Bryant, K. (Ed.)(1976). Field data collection in the social sciences.

Experiences in Africa and the Middle East. Agricultural Development Council, Singapore.

- Burrough, P.A. (1989a). Modelling land qualities in space and time: the role of geographical information systems. In: Bouma & Bregt (1989: 45-60).
- Burrough, P.A. (1989b). Matching spatial data bases and quantitative models in land resource assessment. *Soil Use and Management*, 5: 3-8.
- Byerlee, D., L Harrington & D. Winkelmann (1984). Farming Systems Research: issues in research strategy and technology design. Proceedings of the First Thailand National Farming Systems Workshop: 233-243. Bangkok, Thailand.
- Byerlee, D. & R. Tripp (1988). Strengthening linkages in agricultural research through a farming systems perspective: the role of social scientists. *Experimental Agriculture*, 24: 137-151.
- Bunting, A.H. (Ed.)(1987). *Agricultural Environments*. CAB International, Wallingford.
- Casley, D.J. & D.A. Lury (1981). *Data collection in developing countries*. Oxford University Press, London.
- Casley, D.J. & K. Kumar (1988). *The collection, analysis and use of monitoring and evaluation data*. John Hopkins University Press, Baltimore and London.
- CGIAR (1987). *Agricultural Systems Research for Developing Countries*. Workshop proceedings. Hawkesbury, Australia.
- CGIAR/ICRISAT (1987). *Proceedings of the workshop on farming systems research*. ICRISAT, Hyderabad.
- Chambers, R. (1983). *Rural development: Putting the last first*. Harlow, Longman, London.
- Chenery H. & T.N. Srinivasan (1988). *Handbook of development economics*. Volume 1. North-Holland, Amsterdam.
- CIMMYT (1980). *Planning technologies appropriate to farmers. Concepts and procedures*. CIMMYT, Mexico.
- Collinson, M.P. (1982). *Farming systems research in Eastern Africa: the experience of CIMMYT and some national agricultural research services, 1976-1981*. Department of Agricultural Economics, Michigan State University, East Lansing.
- Colman, D. & T. Young (1989). *Principles of agricultural economics. Markets and prices in less developed countries*. Cambridge University Press, Cambridge.

- Conway, G.R. (1985a). Agricultural ecology and farming systems research. In: CGIAR (1987).
- Conway, G.J. (1985b). Rapid rural appraisal and agro-ecosystems analysis: a case study from northern Pakistan. Khon Kaen, Thailand.
- Cools, J.W.F. (1978). Accuracy and reliability in farm management surveys. Department of Development Economics, Agricultural University, Wageningen. (Unpublished M.Sc. Thesis).
- Dent, D. & A. Young (1981). Soil survey and land evaluation. Allen and Unwin, London.
- Dent, D. (1988). Guidelines for land use planning. Fifth draft. FAO, Rome.
- Diepen, C.A. van, C. Rappoldt, J. Wolf & H. van Keulen (1988). CWFS crop growth simulation model WOFOST. Documentation Version 4.1. Centre for World Food Studies/CWFS, Wageningen.
- Diepen, C.A. van, J. Wolf, H. van Keulen & C. Rappoldt (1989). WOFOST, a simulation model of crop production. Soil Use and Management, 5: 16-24.
- Diepen, C.A. van, H. van Keulen, J. Wolf & J.A.A. Berkhout (1991). Land evaluation: from intuition to quantification. Advances in Soil Science, 15: 139-204.
- Dillon, J.L. & J.B. Hardaker (1980). Farm management research for small farmer development. FAO, Rome. (Agricultural Services Bulletin No. 41).
- Diltz, D. (1980). Methodology for qualitative economic land suitability evaluation for agriculture. UNDP/FAO, Freetown, Sierra Leone. (AG: DP/SIL/73/002; Technical Report 9).
- Dimantha, S. & L.D. Jinadasa (1981). Land suitability evaluation and land use study of the Matara district. Agrarian Research and Training Institute, Colombo, Sri Lanka.
- Dusseldorp, D.B.W.M. van (1980). The place of regional planning in the process of planned development. In: van Dusseldorp & van Staveren (1980).
- Dusseldorp, D.B.W.M. van & J.M. van Staveren (Eds.)(1980). Framework for regional planning in developing countries. International Institute for Land Reclamation and Improvements, Wageningen.
- Ellis, F. (1988). Peasant economics. Farm households and agrarian development. Cambridge University Press, Cambridge.
- Erenstein, O. & R.A. Schipper (1991). Land use planning: an application of multilevel and multiobjective linear programming models. Department of Development Economics, Wageningen Agricultural University, Wageningen. (Draft paper).

- FAO (1970). Preinvestment survey of the North-western Coastal Region, United Arab Republic. ESE: SF/UAR 49. Techn. Report 2, Physical conditions and water resources. FAO, Rome.
- FAO (1976). A framework for land evaluation. FAO, Rome. (FAO Soils Bulletin, No. 32).
- FAO (1978-1981). Reports on the agro-ecological zones project. FAO, Rome. (World Soil Resources Report 48, Methodology and results for Africa; 48/2, Southwest Asia; 48/3, Central and South America; and 48/4, Southeast Asia.
- FAO (1979). Land Evaluation Guidelines for Rainfed Agriculture. Report of an expert consultation held in Rome in December 1979. FAO, Rome.
- FAO (1983). Guidelines: land evaluation for rainfed agriculture. FAO, Rome. (FAO Soils Bulletin, No. 52).
- FAO (1984a). Land evaluation for forestry. FAO, Rome. (FAO Forestry Paper, No. 48).
- FAO (1984b). Ethiopia. A land resource inventory for land use planning. FAO, Rome. (AG: DP/ETH/78/003, Technical report 1).
- FAO (1985). Guidelines: land evaluation for irrigated agriculture. FAO, Rome. (FAO Soils Bulletin, No. 55).
- FAO (1986). FARMAP user's manual. The FAO Farm Analysis Package. Volume I, II and III. FAO, Rome.
- FAO (1987). Guidelines: land evaluation for extensive grazing. Final draft. FAO, Rome.
- FAO (1988a). A summary of the agricultural ecology of Ethiopia. FAO, Rome. (AG/ETH/82/010, Technical report 5, in collaboration with NMSA and CSO: FAO/TCP/ETH/6658).
- FAO (1988b). Master land use plan. Ethiopia. Main report. FAO, Rome. (AG/ETH/82/010: Technical report 1).
- FAO (1989). Guidelines for land use planning. FAO, Rome.
- FAO (1990). Guidelines for the conduct of a training course in farming systems development. FAO, Rome.
- FAO/UNDP (1977). Samar Island: Reconnaissance land resource survey of priority strips for integrated rural development. Soil and land resources appraisal and training project, Manila, Philippines.
- FAO/UNDP (1979). Agusan river basin: Land resource evaluation for agriculture. Soil and land resources appraisal and training project, Manila, Philippines.
- Fox, J. (1987). Why land evaluations for agriculture go awry. In: Beek, Burrough & McCormack (1987).

- Franzel, S. & E.W. Crawford (1987). Comparing formal and informal survey techniques for farming systems research: a case study from Kenya. *Agricultural Administration & Extension*, 27.
- Fresco, L. (1984). Issues in farming systems research. *Netherlands Journal of Agricultural Science*, 32, 4: 253-261.
- Fresco, L. (1986). Cassava in shifting cultivation. A systems approach to agricultural technology development in Africa. Royal Tropical Institute, Amsterdam.
- Gittinger, J.P. (1982). *Economic analysis of agricultural projects*. John Hopkins University Press, Baltimore and London.
- Hart, R.D. (1984). Agro-ecosystem determinants. In: Lowrance, Skinner & House (1984).
- Hart, R.D. (1985). Conceptos básicos sobre agroecosistemas. Centro Agronómico de Investigación y Enseñanza, Turrialba, Costa Rica.
- Hazell, P.B.R. & R.D. Norton (1986). *Mathematical programming for economic analysis in agriculture*. Macmillan Publishing Company, New York.
- Hazell, P.B.R. & P Scandizzo (1983). Risk in market equilibrium models for agriculture. In: Norton & Solis (1983: 203-249).
- Helmers, F.L.C.H. (1977). *Project planning and income distribution. A study with particular reference to developing countries*. Veenman, Wageningen. (Communications Agricultural University Wageningen, The Netherlands, No. 77-5).
- Higgins, G.M., A.H. Kassam, L. Naiken, G. Fisher & M.M. Shah (1982). Potential population supporting capacities of lands in the developing world. FAO, Rome. (Technical report of INT/75/P13).
- Hildebrand, P.E. (1981). Combining disciplines in rapid appraisal: the sondeo approach. *Agricultural Administration*, 8: 423-432.
- Hoekstra, D.A. & S.H. Lok (1977). Sampling in farm surveys. *Farm management notes. (Asia and the Far East)*. FAO, Rome.
- Huijsman, A. (1986). Choice and uncertainty in a semi-subsistence economy. A study of decision making in a Philippine village. Royal Tropical Institute, Amsterdam.
- ISSS (1986). Project proposal 'World Soils and Terrain Digital Database at a scale of 1:1M (SOTER)'. M.F. Baumgardner (Ed.). International Society of Soil Science, Wageningen.
- ISSS (1989). Proceedings of the Second Regional Workshop on a Global Soils and Terrain Digital Database and Global Assessment of Soil Degradation. W.L. Peters (Ed.). International Society of Soil Science, Wageningen. (SOTER Report 4).

- IRRI (1984). Basic procedures for agro-economic research. IRRI, Los Baños.
- Ive, J.R., J.R.Davis & K.D. Cocks (1985). LUPLAN: a computer package to support inventory, evaluation and allocation of land resources. *Soil Survey and Land Evaluation*, 5: 77-87.
- Janssen, B.H., F.C.T. Guijking, D. van der Eijk, E.A.M. Smaling, J. Wolf & H. van Reuler (1990). A system for quantitative evaluation of the fertility of tropical soils (QUEFTS). *Geoderma*, 46: 299-318.
- Jaetzold, R. & H. Schmidt (1983). Farm management handbook of Kenya. Vol. II: Natural conditions and farm management information. Part C: East Kenya (Eastern and Coast Provinces). Ministry of Agriculture, Nairobi, Kenya.
- Joshua, W.D. (1987). Agro-ecological characterization in Sri Lanka. In: Bunting (1987: 289-297).
- Jones, C.A. & J.R. Kiniry (Eds.)(1986). CERES-Maize. Texas A & M University Press, College Station, Texas.
- Jones, C.A. & J.C. O'Toole (1987). Application of crop production models in agro-ecological characterization. In: Bunting (1987: 199-209).
- Keulen, H. van & G.W.J. van de Ven (1988). Application of interactive multiple goal linear programming techniques for analysis and planning of regional agricultural development: A case study for the Mariut region (Egypt). In: Broussard (1988: 36-56).
- Keulen, H. van & J. Wolf (1986). Modelling of Agricultural Production: Weather, Soils and Crops. Simulation Monographs. Pudoc, Wageningen.
- Keulen, H. van & H.D.J. van Heemst (1982). Crop response to the supply of macronutrients. Agric. Res. Rep. 916. Pudoc, Wageningen.
- Keulen, H. van, J.A.A. Berkhout, C.A. van Diepen, H.D.J. van Heemst, B.H. Janssen, C. Rappoldt & J. Wolf. (1987). Quantitative land evaluation for agro-ecological characterization. In: Bunting (1987: 185-197).
- Khon Kaen University (1987). Proceedings of the 1985 international conference on Rapid Rural Appraisal. Khon Kaen, Thailand.
- Klijn, T., H.A.J. Moll & R.A. Schipper (1990). Employment, incomes and land use options. Matara district. Department of Development Economics, Agricultural University, Wageningen. (Unpublished course material).
- KSU (1986). Selected proceedings of the symposium on farming systems research 1984. Kansas State University, Manhattan.
- Kuyvenhoven, A. & L.B.M. Mennes (1985). Guidelines for project appraisal. An introduction to the principles of financial, economic and social cost-

- benefit analysis for developing countries. Directorate-General for International Co-operation, Ministry of Foreign Affairs, The Hague.
- Land Evaluation Group (1983). Land evaluation group-report '83. School of Rural Planning and Development, University of Guelph, Guelph, Canada. (Publ. LEG-15, Univ.).
 - Lipton, M. & R. Longhurst (1985). Modern varieties, international agricultural research and the poor. The World Bank, Washington. (CGIAR study paper, Number 2).
 - Lipton, M. & R. Longhurst (1989). New seeds and poor people. Unwin Hyman, London.
 - Lipton, M. & M. Moore (1972). The methodology of village studies in less developed countries. IDS, Sussex. (IDS Discussion Paper, 10).
 - Lowrance, R., B. Skimmer & C. House (Eds.)(1984). Agricultural ecosystems. Unifying concepts. John Wiley & Sons, New York.
 - Luning H.A. (1985). Survey Integration comes of age? ITC Journal, 1985-4.
 - Lynam, K.J. & R.W. Herdt (1988). Sense and sustainability: sustainability as an objective in international agricultural research. Paper presented at the CIP/Rockefeller Conference on Farmers and Food Systems, September 26-30, 1988.
 - Martin, E.C., J.T. Ritchie & T.L. Loudon (1985). Use of the CERES-Maize model to evaluate irrigation strategies. In: Advances in evapotranspiration. Proceedings of the National Conference, December 16-17, 1985. ASAE, Michigan: 342-350.
 - Meester, T. de & D. Legger (Eds.)(1988). Soils of the Chuka-South Area, Kenya. Department of Soil Science and Geology, Agricultural University, Wageningen.
 - Mettrick, H. (1983). Notes on socio-economic surveys. ICRA course, 1983, Wageningen.
 - Moll, H.A.J. & R.A. Schipper (1990). Alternative land use types and input-output data crops. Matara district. Department of Development Economics, Agricultural University, Wageningen. (Unpublished course material).
 - Monteith, J.L. (1981). Epilogue: Themes and variations. Plant and Soil, 58: 305-309.
 - Mutsaers, H.J.W., N.M. Fisher, W.O. Vogel & M.C. Palada (1986). A field guide for on-farm research. Farming Systems Program, IITA, Ibadan, Nigeria.
 - Norton, R.D. & L. Solís (Eds.)(1983). The book of CHAC: programming

studies for Mexican agriculture. John Hopkins University Press, Baltimore.

- Odum, H.T. (1983). Systems ecology. John Wiley and Sons, New York.
- Oldeman, L.R. (1975). An agro-climatological map of Java. Contributions Central Research Institute for Agriculture, 17, Bogor, Indonesia.
- Passioura, J.B. (1973). Sense and nonsense in crop simulation. J. Austr. Inst. Agric. Sci., 39: 181-183.
- Penning de Vries, F.W.T. (1982). Phases of development of models. In: Penning de Vries & van Laar (1982: 20-25).
- Penning de Vries, F.W.T., & H.H. van Laar (Eds.)(1982). Simulation of plant growth and crop production. Simulation Monographs. Pudoc, Wageningen.
- Penning de Vries, F.T.W., D.M. Jansen, H.F.M. ten Berge & A. Bakema (1989). Simulation of ecophysiological processes of growth of several annual crops. Simulation Monograph 29. Pudoc, Wageningen.
- Pearse, A. (1980). Seeds of plenty, seeds of want. Oxford University Press, Oxford.
- Poate, C.D. & D.J. Casley (1985). Estimating crop production in development projects. World Bank, Washington.
- Polman, F.J., M. Samad & K.S. Thio (1982). A demonstration of resource based socio-economic planning in Matara district. Agrarian Research and Training Institute, Colombo. (Report No. 1 in: Regional Planning for Agricultural Development in Sri Lanka).
- Putte van de, R.A. (1989). Land Evaluation and project planning. ITC Journal, 1989-2.
- Rabbinge, R., S.A. Ward & H.H. van Laar (eds.)(1989). Simulation and systems management in crop protection. Simulation Monograph 32. Pudoc, Wageningen.
- RAWOO (1989). Sustainable land use in developing countries. Perspectives on an integrated approach. RAWOO, The Hague. (Working Paper 2).
- Rhoades, R.E. (1982). The art of the informal agricultural survey. CIP, Lima.
- Riddell, R. (1985). Regional development policy. The struggle for rural progress in low-income nations. Gower, Aldershot.
- Ritchie, J.T. & S. Otter-Nacke (1985). Description and performance of CERES-Wheat: a user-oriented wheat yield model. In: Willis (1985: 159-175)
- Rocheleau, D.E. (1984). Criteria for re-appraisal and re-design: Intra-

- household and between-household aspects of FSRE in three Kenyan agro-forestry projects. In: KSU (1986).
- Romero, C. & T. Rehman (1989). Multiple criteria analysis for agricultural decisions. Elsevier, Amsterdam.
 - Rossiter, D. (1989). ALES: a microcomputer program to assist in land evaluation. In: Bouma & Bregt (1989: 113-116).
 - Sadhardjo, Siswamartana (1986). Land evaluation and watershed management. Case study of Brantas watershed, Konto sub-watershed and Upper-Konto watershed. ITC, Enschede, The Netherlands. (Unpublished M.Sc. Thesis).
 - Schipper, R.A. (1983). Reduced planning efforts: the key-region approach in Ratnapura. Agrarian Research and Training Institute, Colombo. (Report No.5 in: Regional Planning for Agricultural Development in Sri Lanka).
 - Schipper, R.A. (1988). Farming and land use. In: Meester & Legger (1988: 141-179).
 - Schultink, G. (1987). The CRIES resource information system: computer-aided land resource evaluation for development planning and policy analysis. Soil Survey and Land Evaluation, 7: 47-62.
 - Simmonds, N.W. (1985). Farming systems research, a review. World Bank, Washington.
 - Simmonds, N.W. (1986). A short review of Farming Systems Research in the tropics. Experimental Agriculture, 22: 1-13.
 - Sims, D. (1988). Use of SOTER database. In: ISSS (1989: 77-82).
 - Smit, B., M. Brklacich, J. Dumanski, K.B. MacDonald & M.H. Miller (1984). Integral land evaluation and its application to policy. Can. J. Soil Sci., 64: 467-479.
 - Sombroek, W. & R. Oldemans (1989). Global Assessment of Soil Degradation 'GLASOD'. International Soil Reference and Information Centre, Wageningen.
 - SOW (1985). Potential food production increases from fertilizer aid: A case study of Burkina Faso, Ghana and Kenya. Vols. I and II. Centre for World Food Studies/CFWS, Wageningen.
 - Spencer, D.S.C. (1972). Micro-level farm management and production economics research among traditional African farmers: Lessons from Sierra Leone. Michigan State University, East Lansing. (African Employment Study Rural Employment Paper No. 3).
 - Sudarna, A. (1989). Towards an information system for integrated watershed management. A case study from West Java. ITC, Enschede, The Netherlands. (Unpublished M.Sc. Thesis).

- TAC (1988). Sustainable agricultural production: implications for international agricultural research. TAC, Rome.
- Timmer, C.P. (1988). The agricultural transformation. In: Chenery & Srinivasan (1988: 275-331).
- Toye, J. (1989). Development planning at the cross roads. Development 89, Vol. 4.
- UNEP (1987). Project document. Global Assessment of Soil Degradation. UNEP, Nairobi and ISRIC, Wageningen. (FP/9101-87-88(2694); FP/4101-87-88(2694); FP/6101-87-88(2694); FP/6201-87-88(2694)).
- Upton, M. (1973). Farm management in Africa. Oxford University Press, Oxford.
- Upton, M. (1987). African farm management. Cambridge University Press, Cambridge.
- Vink, A.P.A. (1975). Land use in advancing agriculture. Springer Verlag, Berlin.
- Willis, W.O. (Ed.)(1985). ARS wheat yield project. Agricultural Research Service, USDA, Washington. (USDA-ARS-38).
- Wit, C.T. de & H. van Keulen (1987). Modelling production of field crops and its requirements. Geoderma, 40: 253-265.
- Wit, C.T. de, H. van Keulen, N.G. Seligman & I. Spharim (1988). Application of interactive multiple goal programming techniques for analysis and planning of regional agricultural development. Agric. Syst., 26: 211-230.
- Wit, C.T. de, et al. (1978). Simulation of assimilation, respiration and transpiration of crops. Simulation Monographs. Pudoc, Wageningen.
- Wood, S.R. & F.J. Dent (1983). LECS, a land evaluation computer system methodology. AGOF/INS 78/006 Manual 5, Version 1. FAO, Rome.
- Young, A. (1985). Land evaluation and agro-forestry diagnosis and design: towards a reconciliation of procedures. Soil Survey and Land Evaluation, 5, 3.
- Zandstra, H.G., E.C. Price, J.A. Litsinger & R.A. Morris (1981). A methodology for on-farm cropping systems research. IIRI, Los Baños.
- Zarkovich, S.S. (1966). Quality of statistical data. FAO, Rome.
- Zonneveld, I.S. (1979). Land evaluation and land(scape) science. Textbook VII-4. ITC, Enschede, The Netherlands.

APPENDICES

It is good to be aware of the limitations of planning. Planning in general has been criticized during the last two decades for not delivering what it promised to deliver. This is also relevant for land use planning. One type of criticism is that it takes too much time and personpower. This can be countered by approaches to planning at the appropriate scales of intensity, and by being very purposeful and selective in defining the required information and the methods of obtaining the data. In this respect, see also chapter 4 and 6, and appendices 5 and 6. Other types of criticisms are more conceptual. These can be summarized under four points, (1) administration bias, (2) lack of knowledge, (3) uncertain future, and (4) harmony versus conflict.

1. Administration bias. Most planning in developing countries is directed by and at the government. Implicit often is the assumption that if the government wants something it also happens. This however is not reality because of a number of reasons. (a) The government only controls part of the economy. (b) The government does not have the instruments to force the non-controlled part of the economy to implement the planned. It can only influence and induce (via policies, programmes and projects). (c) In the part of the economy which the government does control, the planned is often poorly executed. Also, and possibly more important, some of the things planned are impossible to implement. In other words the plan itself is inadequate, or does not take into account the capacity to implement.

2. Lack of knowledge. Planning is often based on insufficient and imperfect knowledge of the reality. If it would be possible to gather more/sufficient data/information, this would require much time and resources (money and qualified personpower). The efforts to collect more data to improve the quality of planning often have resulted in a plan that was too late and lagged behind the facts. Planning is often out of date and out of touch.

3. Uncertain future. The future is uncertain and can not be predicted with any perfection. There are many unpredictable, surprising and disturbing happenings which may prevent the implementation of a plan as designed. This calls for a flexible type of planning. Especially comprehensive resource-based types of planning, such as land use planning, are not suited for this, but it is also in the nature of a government organization not to be flexible. Still, planning forms part of what is happening in society at large. It is therefore important to take into account autonomous developments, changes in external conditions and current events.

4. Harmony versus conflict. An implicit axiom in planning is often the existence of societal harmony, which is understood and worded by the government. The government would be able to formulate the 'common interest', and has the right and obligation to do this. However there are many conflicts in society, which means that interests are opposite. Big farmers against small ones, landowners against tenants, farmers against landless labourers, government against tax payers, importers against exporters, capital against labour, rural subsistence farmers against city dwellers, food producers against food consumers, etc. Planning tries to start from national goals like economic growth, full employment and self-sufficiency in food, and to give everybody a fair share (income distribution). In reality this can only be accomplished in a process of 'negotiation' between the important interest groups in society. To put it in other words, 'the' people does not exist, a people consists of many

groups with sometimes parallel, sometimes conflicting interests and goals. It is therefore a fiction that the government can formulate 'the' national goals, and if the government does, it implicitly chooses for a certain group or for a pre-determined compromise. In the latter case, it balances group interests.

The above boils down to the following. A government should only plan those areas where it is in control of resources, in particular via the allocation of its budget, but in more general terms through its apparatus (ministries, departments, services, authorities, local councils, etc.). Next to this a government can try to influence other groups in society via negotiation and/or policies, for example with regard to prices, markets, credit, subsidies, taxes, research, extension, land reform, etc. Also via its apparatus it can execute projects or delegate to other agencies. In this case one has to think especially of projects for infrastructure, irrigation, marketing facilities, extension, research, and programmes for the introduction of new crops, etc. Planning should be less comprehensive and concentrate on the important issues within the mandate of the government. There should be less attention for planning and more for implementation.

The above analysis of planning in general is also relevant for regional agricultural planning and land use planning. These plans should be formulated in such a way that they take into account the contradictions in society and that they are realistic with regard to what can be implemented given the limited resources and power of government to influence autonomous forces in society. It should make planners modest. Nevertheless planning is useful and necessary to accelerate development. Furthermore a government which does not intervene in markets and does not implement programmes and projects, as a consequence of non-planning, creates a situation of 'laissez faire, laissez passer', which is not necessarily in the interests of the majority of the population. However being aware of the limitations of planning can only improve planning.

Appendix 2. LAND USE TYPES AS COMPONENTS OF FARMING SYSTEMS: A SIMPLE EXAMPLE.

As part of a soil survey and land evaluation of the Chuka-South Area, Kenya (de Meester & Legger, 1988), land use types were described and analyzed as components of farming systems (Schipper, 1988). The area comprises two 1:50,000 topographical map-sheets of a part of the eastern slopes of the Mount Kenya, with a total size of 1540 km². The type of farming in this area depends on differences in climate and population density. The latter, however is not independent of the differences in climate.

With regard to climate, the most important variable is rainfall that varies strongly over relative short distances in relation to altitude. From east to west over a distance of about 60 km, altitude increases from about 450 m to about 2200 m, with a decrease in mean temperature from 24-29 °C to 14-16 °C, while at the same time average annual rainfall increases from about 600 mm to about 2400 mm. This makes the area ecologically very diversified. Jaetzold & Schmidt (1983) distinguish 10 different agro-ecological zones in the area. Field observations suggest that these zones could be aggregated into five groups, A through E, and that each group - except group A, being not-farmed montane tropical rain forest - can be associated with a distinct farming system (Schipper, 1988). The area is densely populated. On average the density is about 165 persons per km², however this ranges from 30 per km² in the dry lowlands in the eastern parts to 700 in the more favourable parts. The agro-ecological groups are summarized in table 1. It is important to note here that the classification of farming systems in this case is based on an agro-climatic zonation, although this is related to a socio-economic variable as population density.

Table 1. Agro-ecological groups and farming systems.

Agro-ecological group	Agro-ecological zones ¹	Population density ²	Farming system as characterized by its main activities
A	LH ₀	n.a.	n.a.
B	LH ₁ & UM ₁	300-600	Tea-coffee-dairy
C	UM ₂ & UM ₃ & UM ₄	400-700	Coffee-maize-beans
D	LM ₃ & LM ₄	100-400	Cotton-maize-pigeon pea
E	LM ₅ & IL ₅	30-100	Livestock-millet-cotton

1) Jaetzold & Schmidt (1983):
 LH₀ = Lower Highland, per humid
 UM₁ = Upper Midland, humid
 UM₃ = Upper Midland, semi-humid
 LM₃ = Lower Midland, semi-humid
 LM₅ = Lower Midland, semi-arid

LH₁ = Lower Highland, humid
 UM₂ = Upper Midland, sub-humid
 UM₄ = Upper Midland, transitional
 LM₄ = Lower Midland, transitional
 IL₅ = Inner Lowland, semi-arid

2) Population density in persons per km².

Source: Schipper (1988).

In Schipper (1988) each farming system is described in such a way as to show the importance of the main land use types in the farming systems, as well as their key attributes and technical specifications (see chapter four), within the farming system. An example is provided in table 2 and table 3.

Table 2. Summary description of the Cotton-maize-pigeon pea farming system.

The Cotton-maize-pigeon pea farming system is based on bush fallow with (mixed) annual food crops such as maize, millet, sorghum, pigeon pea and cow pea, and with cash crops (cotton, tobacco). Self-sufficiency through subsistence farming is the first goal of the producer. Animals (Zebu cattle, sheep and goats) are kept as a cash reserve and for meat, partly on the holding and partly herded. Holdings are only in part adjudicated; renting of land occurs only incidentally. The area used for this system totals some 440 km² and carries a population of about 80,000 people. The population density varies between 100 and 400 persons per km².

This farming system is confined to agro-ecological group D, zones LM₃ and LM₄. The altitude of the land ranges from 760 to 1280 meter a.s.l.; the average annual temperature is 22-25 °C. The various land use types in this farming system (and their basic economic data) are presented in table 3.

Table 3 suggests an average gross margin of Ksh 2,000 per year from the main cropping activities, or some Ksh. 1,800 per hectare-year. The margin per adult amounts to some Ksh 1,000 per person-year. The main resources of the cotton-maize-pigeon pea system are:

land: average holding: 4.7 hectares; range: 2.2-13.8 hectares
people: average household size: 8.1 persons
normative labour force: 1.1 female adult and 0.7 male adult
animals: average herd: 4 heads of cattle + 5 goats or sheep
animal traction is rare.

Part of the land in use for this type of farming is hilly and rocky, or has a low fertility status or a low water holding capacity (luvisols). Erosion is a major problem on some 40 percent of the fields and erosion control measures such as terraces (20 percent of the farms), trash lines (60%), trees (40%) and stonelines (30%) are common.

Source: Schipper (1988: 153 & 155).

Table 3. Land use types as components of the Cotton-maize-pigeon pea farming system and their basic economic data.

LUTs	% of farmed land	Average size (ha)	Yield per ha	Price per kg	Value of Production (Ksh.)	Variable costs per ha	Labour days per ha	Gross Margin per ha per labour day
Annual crops	typical all size farms	(kg)	(Ksh.)	(Ksh.)	(Ksh.)	(Ksh.)	(Ksh.)	(Ksh.)
1st rains								
Maize	16	0.3	1000	1.94	1900	200	110-150	1700
Sorghum	11	0.2	500	1.10	600	100	110-210	500
Millet	5	0.2	500	1.25	600	100	110-130	500
Pigeon peas	11	0.3	400	2.25	900	100	100-130	800
2nd rains								
as 1st rains plus								
Cotton ⁽¹⁾	5	0.5	0.1	400	5.00/2.45	1800	130-170	1300
Tobacco	1	0.1	0.02	700	12.50	100	200	8700
Pasture/forage		0.4			Bana grass, napier grass			
Agro-forestry		0.1-0.2			Woody biomass like trees around the house and in crop land, hedges, wood lots and bush. Bush becoming more important.			
Other crops	Occurrence : (% of farms)	76-100% : cow peas						
		51- 75% : beans, green gram						
		26- 50% : sunflower, coffee						
Intercropping	Occurrence : (% of instances)	pure cropping (30%)						
		two crop combinations (55%)						
		three or four crop combinations (15%)						
Animal husbandry								
- Types and numbers:	50-70% of farmers possess	cattle and/or goats/sheep						
	hard sizes:	cattle: mean 4, range 2-12; goats/sheep: mean 5, range 3-16						
- Feed		Some zero-grazing/'rope' grazing towards eastern part, otherwise herding						
- Purpose/								
Production		Mostly as cash reserve and security: some milk for home consumption; cattle is hardly eaten, goat/sheep more often						
- Integration with								
crop production		Little except for use of crop residues and use of manure (only partly) and as part of bush-fallow system. Very little ox-ploughing.						

(1) Manual land preparation, the cultivation extends into first rains.

1. Introduction

This case study deals with land evaluation for watershed management. The area is the upper part of a watershed and is considered to be a problem area. There is not enough land for agricultural production. The on-going soil erosion and (illegal) exploitation of forest land is causing damage to downstream areas (siltation of reservoirs and lack of water in dry periods). Quick actions are needed to improve this situation. The terms of reference for the land evaluation, therefore, ask for information of sufficient detail to make possible the implementation of a land use plan. The land evaluation is thus carried out at a detailed level and includes an economic analysis. The scale of the land unit map is 1:20,000.

The area consists of gentle to very steep volcanic slopes. The elevation ranges from 900 to 1,900 meter a.m.s.l. The soils of the area are fertile and very deep, partly due to recent deposits of volcanic ash from active volcanoes located not far from the area.

The main agricultural land uses are wetland rice, dryland crops (maize, beans) and vegetable growing. Rice and vegetables generally receive supplemental irrigation in the dry season. Dryland crops and vegetables are grown on both terraced and non-terraced land and also on steep slopes. Shrubland, plantation forest and natural forest occur mainly in the higher parts of the area. They are used by the local people for fodder, fuelwood and timber collection. The forestland is managed by Perum Perhutani. Dairy cattle is kept in stables in the desas and is for a large part dependent on fodder collected in the shrubland and forestland.

More than 85% of the population is directly involved in agricultural production. Land is scarce. The average farm size is about 0.5 ha. Labour resources are abundant, but seasonal labour availability is a problem. Capital resources are limited. Soil erosion is evident throughout the agricultural area. Erosion rates are highest on steep slopes (slumping of sawahs) and under dryland crop cultivation (lack of terraces or improperly made terraces). Erosion, however, is not felt as a problem by the farmers because the soils are deep and fertile. A sustained productivity appears possible despite the large amounts of soil that are lost annually.

Forestland is increasingly subject to fuelwood, fodder and timber collection by the villagers. This exploitation of the forest is leading to the expansion of areas covered by low-value shrubs where only few trees are left.

Soil erosion and forest degradation have severe downstream effects:

- Rapid siltation of reservoirs used for hydropower generation and irrigation reducing their lifetime and economic value.
- Reduced dry season flows (which are needed for irrigation) because a large proportion of the wet-season rainfall leaves the upper watershed as direct run-off.

2. Selection of land use types

Continuation of the present land use will lead to:

- Aggravation of downstream problems.

- Continuation of the collection of fuelwood and fodder from extensive areas of forestland; and an increase of the area under low-value shrubs at the cost of the forest.
- Increasing un(der)employment of the growing local population.

The land use types (LUTs) to be selected for the land evaluation of the area should help to reduce the above problems. They should therefore:

- Reduce soil erosion.
- Provide fodder, fuel and timber without leading to the degradation of the natural vegetation.
- Create more employment (i.e. labour-intensive land uses).
- Provide subsistence food (rice) and cash income to the local population.

Based on these considerations, the following LUTs were selected:

- LUT 1: Irrigated wetland rice-vegetables-vegetables
- LUT 2: Irrigated vegetables (continuous cropping)
- LUT 3: Coffee plantation
- LUT 4: Agro-forestry (pulp, fuel, fodder)
- LUT 5: Timber production
- LUT 6: Protection forest.

LUT 1 and 2 take care of the food (rice) and cash income situation in the area. LUT 3 and 4 are alternatives for the presently grown dryland crops that provide a better soil cover and will thereby reduce soil erosion. In addition, the LUTs will produce fodder and/or fuelwood needed by the local people. LUT 5 caters for the regional and national requirements for timber and provides employment for the villagers. LUT 6 is essential for areas that are too steep or vulnerable to allow more productive uses.

3. Description of land use types

A summary description of the LUTs is provided in table 1, some general remarks are made here.

Agricultural LUTs

Agricultural LUTs have as general characteristics:

- Capital and labour intensity: due to the abundance of labour and lack of capital resources at the farm level, crop production should be labour intensive and minimize the use of capital investment, e.g. labour saving machinery.
- Small farm size: less than 1 ha.
- Infrastructure and institutional needs:
 - Extension services: both for agricultural production and soil conservation
 - Credit facilities: for all production requirements. Are most important in vegetable production, since high recurrent inputs and capital investment with respect to soil conservation measures are needed
 - All-weather roads: for transporting the products
 - Marketing cooperations: (for vegetable crop) to avoid unproportionate benefits of middlemen, and for strengthening marketing resources. Marketing of food crops can be done through village cooperations
- Produce: Annual volume of production per ha is given separately for each LUT, as well as annual gross margin (estimated).

Table 1. Selected land use types and their key attributes.

Land use type (LUT)	Produce	Yield/ha/yr (SI land)	Labour requirements (man-days/ha/year)	Capital investments	Recurrent costs	Plot size	GM/ha/yr (x Rp000) (SI land)	NPV/ha/yr (x Rp000) (SI land)
LUT1: rice-vegetables (irrigated) ²	Rice Potato Cabbage	3.3 t 8.0 t 13.0 t	1,100	Moderate (improved drainage)	High	Small	1,380	-
LUT2: vegetables (irrigated) ²	Potato Cabbage	8.0 t 13-14 t	1,050	Ditto	High	Small	1,390	-
LUT3: coffee ³	Coffee Timber ⁶ Fuelwood	1.0-1.2 t 25 m ³ 4 m ³	190	Mod.-high (terracing, ditches plant material)	Low	Small	800 ¹	1,700
LUT4: agro-forestry ⁴	Pulpwood Fuelwood Fodder	8 m ³ 8 m ³ 30 t	220	Ditto	Medium	Medium	100 ¹	265
LUT5: timber ⁵	Timber Fuelwood Fodder	15 m ³ 3.5 m ³	80	Mod.-high (clearing, terracing, plant material)	Low	Large	-	40

GM = gross margin; NPV = net present value.

- 1) GM at full production.
- 2) Requires (re-)organization of operation and maintenance of irrigation systems, drainage improvements, credit facilities and marketing cooperation to maintain the indicated yield levels.
- 3) Requires terracing or terracing improvement, extension services and credit.
- 4) Requires village organization to arrange harvest schedule of fuelwood.
- 5) Requires road construction/improvement for increased accessibility.
- 6) Once in 30 years.

Sources: Sadhardjo, 1986.

Forestry LUTs

Forestry LUTs have as general characteristics:

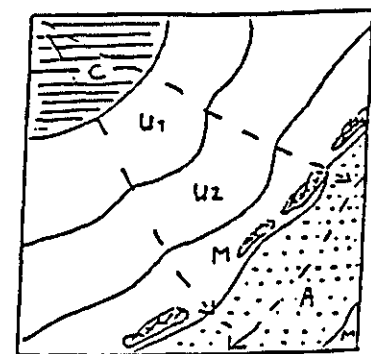
- Produce: Pulp wood, fuelwood or timber.
- Sizes of plots: large in the case of timber production, medium when for agro- forestry LUTs.
- Power sources: the abundance of labour requires labour intensive LUTs.
- Capital input: very high during establishment periods and low for recurrent inputs.

The current management of Perhutani is not considering fuelwood production. The proposed LUTs, however, aim at the production of fuelwood for the needs of the population. With this system, forest protection will be easier, because collecting fuelwood will be localized at certain places. Village fuelwood organizations are necessary and should be operated on the basis of cooperation between the forest service and the local authorities. Harvesting of fuelwood is, therefore, not considered as a benefit for Perum Perhutani. The benefit of the forest service is only in terms of pulp and timber. Labour absorption gives benefits in terms of jobs and income for the population. Economically, benefits are expressed in terms of net present value.

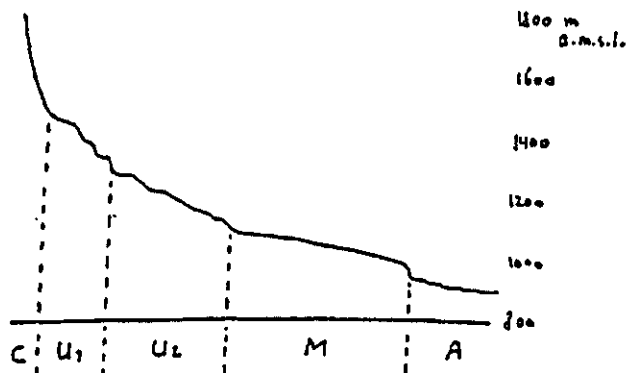
4. Land units and their characteristics

Figure 2 shows a simplified land unit map. Table 3 shows the land characteristics.

Figure 2. Land units: sketch map and cross-section.



a. LMUs



b. Cross-section (sketch)

Table 3. Land units and their characteristics.

Land characteristics	Land units (LU)					
	C	U1	U2	M	A	
Landform	Cone	Upper slope	Upper slope	Middle slope	Alluvial plain	
-degree of dissection	Severe	Mod-severe	Moderate	Moderate	Slight	
-lichology	Andesite	Volc.ash/tuff	Volc.ash/tuff	Volc.ash	Alluviason	
-slope (%)	>70	30-60	15-30	8-15	2-12	
Elevation (m a.m.s.l.)	>1,500	1,300-1,500	1,100-1,300	1,000-1,100	900	
Rainfall amount/reliability	Moderate	High	High	Mod.-high	Moderate	
Soil						
-effective depth (cm)	30-120	>120	>120	>120	>120	
-drainage (class)	Excessive	Well	Well	Mod.-well	Imperfect	
-texture	Sandy loam	Loam	Silt loam	Sandy clay loam	Sandy clay	
-av. watercapacity (mm)	60-150	>150	>150	>150	>150	
-organic matter (%)	n.d.	12	8	5	1.5	
-ph	6.5	6.0	6.0	6.0	6.5	
-base saturation (%)	n.d.	40	30	60	80	
-CEC (meq/100 g)	n.d.	30	35	25	30	
-structure stability (class)	n.d.	High	Mod.-high	Moderate	Low-mod.	
Erosion susceptibility (class)	High	Mod.-high	Moderate	Moderate	Low-mod.	
Surface water resources for irrigation	?	Low-mod.	Moderate	Good	Very good	
Land use/cover (% of LU)						
-pekarangan	-	-	-	15	-	
-sawah, partial irrigation	-	-	-	25	70	
-dryland crops, terraced	-	-	10	30	20	
-dryland crops, not terraced	-	10	20	20	-	
-shrubland	-	20	70	10	10	
-pinus plantation	-	40	-	-	-	
-natural forest	100	30	-	-	-	

n.d. = no data.

Source: Sadhardjo, 1986.

5. Land suitability

Table 4 shows the results of the land suitability classification. LUT 6 is not included in this table, but is the only use that can be recommended for land unit C.

The main aims of the land evaluation are watershed management and reduction of the siltation rate in downstream reservoirs. All LUT-land unit combinations that lead to unacceptable rates of erosion have been classified therefore as N (Not Suitable).

Table 4. Land suitability classification.

Land unit	1 Rice-vegetables	2 Vegetables	3	4 Coffee	5 Agro-Timber forestry
C	Ne,a	Ne,a	Ne,a	Ne,a	Ne,a
U1	Ne,t	Ne	Ne,t,c	S2c	S2a
U2	Ne,t	S2x	S2t	S1	S1
M	S2p,t	S1	S1	S1	S1
A	S1	S3w,t	Nw	Nw	Nw

S1 = Highly suitable

S2 = Moderately suitable

S3 = Marginally suitable

N = Not suitable

Limitations:

a = accessibility

c = clearing requirements

e = erosion/slumping hazard

p = ability to pond water on soil surface for wet rice growing

t = temperature requirement

x = small size of terraces limiting the use of draught animals

w = oxygen availability to roots

Source: Sadhardjo, 1986

FSA draws heavily upon ecological systems for its theoretical basis. In analogy to ecology, agriculture is described as a hierarchy of systems. A system involves an arrangement of components (or subsystems) which process inputs into outputs. Systems display special properties that emerge from the interaction of components. 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.

Within the agricultural hierarchy, one finds the cell and the plant organs, followed by the plant itself at the lowest levels. Plants combine into crops, and crops into fields that may carry crop populations of various species and varieties, weeds and pathogens. The farm is situated at the next higher level. Groups of farms combine into villages or subregions. 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, the analogy with ecology poses no problems. 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 4 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, at the main component. The crop system may involve plant populations of varying species and varieties. 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 the 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 farm system. The cropping system may involve complex spatial and time arrangements of various crops, 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 their management and land qualities are similar. 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 system. The farm 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 farm 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 analyzed at this level. The term farming system is reserved for a class of similarly structured farm systems.

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 farm systems must also involve money and information exchanges.

Farm systems are components of higher level systems that for simplicity sake are called subregions here, and may be a village, a small administrative region, 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 analyzed from an biophysical - ecological - or socio-economic perspective. Ecologically speaking, it consists of climate, soil 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 (services, marketing and urban) sector. The primary production (agricultural) sector comprises all the farms in the region.

In figure 4 (section 3.2.1.) 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 farm system. The same applies to the higher levels in the hierarchy. In one single region, there may be a few subregions (or village 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. Farm 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.

System output is limited by exogenous factors as well as by endogenous factors. Exogenous factors or constraints 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 system 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 (farm system level) or consumer preferences (regional system).

Endogenous factors or limitations 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 understanding system performance.

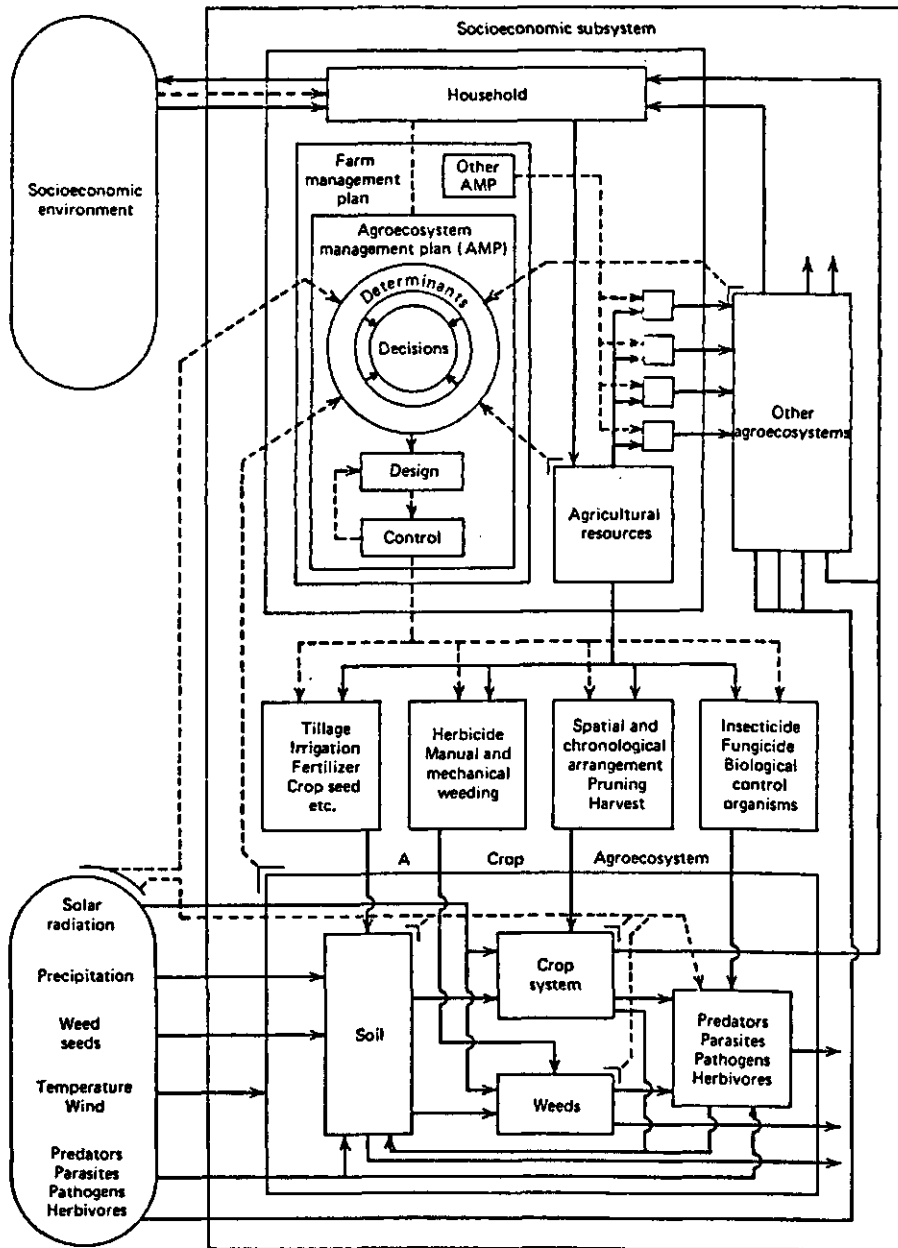
Nevertheless, it must be realized that constraints and limitations do not determine system outputs in a rigorous way. Variations between systems at the same level may be considerable. This applies in particular to the farm system where farmers' choices play a role. Combinations of exogenous and endogenous constraints, for example the physical and biological environment, obviously set limits to potential production, but do not fix the ways in which the farm system deals with the physical 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 systems exist side by side. Which farm system prevails in a given case depends on household resources, access to inputs, the division of labour and cultural factors.

Systems can be considered similar if they are similar in structure, i.e. the characteristics of their components and component interactions, and in function, i.e. the way inputs are transformed into outputs. Similarity and degrees of similarity between systems provides the basis for classification 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. Farm systems are usually distinguished with respect to the interaction of animal and crop production, but it may be important to consider access to resources and degree of market integration. The classification of farm 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.

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 farm system/cropping system/livestock system to analyze input/output flows. Two types of models are used. Structural models represent the components of the farm 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 figure 1 of this appendix).

Figure 1. The flow of energy and materials (solid lines) and information (dotted lines) in a farm system.



In figure 1, the management of an agro-ecosystem is conceptualized as a series of decisions based on different types of determinants.

Source: Hart, 1984.

The indicators (topics) relevant for the description and analysis of systems for land use planning were summarized in figure 18 (section 6.1), which is in essence figure 7 (section 4.1) with more detail. Figure 18 provides a starting point for formulating the information requirements of land use planning, presented in this appendix. These requirements can be distinguished by relevant system level. Leaving aside information requirements from the national and/or international levels, data are needed from the regional and/or subregional systems, and from the farm system and subsystems. The regional and subregional levels can be subdivided into a societal or socio-economic part and an environmental or biophysical part. The information requirements of these parts are presented in part I and part II of appendix 5, respectively. Information requirements of the farm level, i.e. the farm system(s) and their components or subsystems, are presented in part III of this appendix.

With reference to figure 18, the level in the hierarchy and the mapping scale determine to a large extent the degree of detail. For example, a description of a land use type at the regional level in a reconnaissance survey will be more general than the description of a land use type or cropping system at the farm level. Therefore, the information needs presented here, can only be indicative. The user will have to decide for each particular application the relevance of each item. In other words: it may not be necessary to collect information on all items in a particular case.

Part I. SOCIO-ECONOMIC PART OF REGIONAL SYSTEMS.

Information requirements for land use planning from the socio-economic part of the (sub)regional systems should be very modest, as land use planning forms only a part of the regional agricultural planning process. Data should only be gathered on aspects of the regional system which directly influence land use. Other information is to be collected in the framework of more general regional agricultural planning. In practice it will be difficult to draw a line as it is here in this text. Still an attempt will be made.

Relevant aspects of the regional system, socio-economic factors, are presented in the following checklist (see also figure 18, numbers refer to the numbers in this figure). In a particular case, decisions must be taken as to whether an item should be researched at all and to what depth.

SOCIO-ECONOMIC PART OF REGIONAL SYSTEMS: A TENTATIVE CHECKLIST.

1. norms/beliefs

- * classification of natural environment and resources
- * objectives and goals, differentiated per important group
- * time horizons

2. community structure/politics

- * important groups and (power) relations between groups

- * local politics
- * gender issues: relationships, decision making and labour distribution
- * labour relations

3. policies/programmes/projects

- * policies
 - a. prices
 - time series of all major agricultural products and inputs at farm, wholesale and consumer level; import and export prices
 - inflation rates
 - official price policy versus factual one
 - b. subsidies and taxes
 - price support subsidies; input supply subsidies
 - export subsidies and taxes
 - import subsidies and taxes
 - c. land tenure
 - land reform
 - tenancy
- * programmes/projects
 - on-going and/or proposed programmes and projects affecting land use: purpose, goals, actions, impact, etc.

4. institutions

- * research
 - relevant present agricultural research
 - main types of agricultural research needed as identified through, for example, land evaluation and farming systems analysis
- * extension
 - innovations/messages extended
 - adoption rates for different innovations
- * input supply
 - involvement of government or semi-government institution
 - if so, what is mandate and what is it actually doing
 - if directly involved in trade, market share
 - prices of inputs through institution
- * credit
 - role of banks (government and non-government) in credit to farms
 - terms of credit (collateral, administrative procedures, pay back period)
 - interest rates
- * land tenure
 - role of government institutions in field of land tenure
 - land tenure laws and their application in practice, e.g. tenancy
 - land reform institutions
- * cooperatives
 - role of cooperatives with regard to credit, input supply and marketing
- * marketing boards
 - mandate

- actual way of operating: market regulation, market information, buying and selling, price setting, costs and benefits

5. markets/prices

* labour

- employment opportunities inside and outside agriculture
- wages for different types of labour

* land

- availability of land for sale and for rent
- land prices

* capital goods

- availability, types, quality
- major trading houses
- imports
- prices

* current inputs: seed, fertilizer, pesticides etc.

- location of markets
- inputs availability, types of inputs, quality
- major trading houses
- imports
- prices

* farm/household products/outputs

- location of markets
- transport system
- marketing channels for major products
- marketing margins
- type and degree of competition
- major trading houses
- performance of marketing functions like grading, sorting, etc.
- quality standards, weighing procedures
- prices

6. agro-industries

- * types/products
- * market shares
- * contracts/prices
- * employment
- * value added
- * export/domestic market

7. farmer organizations

- * role of farmer organizations with regard to credit, input supply and marketing
- * role of farmer organizations with regard irrigation systems and soil conservation measures

8. set of farming systems

- * interactions between farming systems
- * dominance of certain farming systems

Part II. BIOPHYSICAL PART OF (SUB)REGIONAL SYSTEMS / LAND USE SYSTEMS.

The headings used for indicating the areas of information requirements follow figure 18. Information requirements of the physical-biological part of the (sub)regional systems for land use planning are extensive. These data come under the general headings of:

1. climate/weather
2. soils/relief
3. water/irrigation
4. location/access
5. vegetation
6. land use: crops/forage crops
7. land use: livestock/wildlife
8. diseases/pests.

More specific the information needs can be specified for land units and for land use types, being the constituting parts of a land use system, see Beek (1978). Land units have land qualities: properties that characterize a land unit. Examples are soil moisture variability, nutrient availability, resistance to erosion, distance to the market. Land units can 'supply' those qualities, while land use types 'demand' these qualities. In connection to land use types, land qualities are therefore called requirements. In chapter three more has been said about qualities and requirements, here they serve as topics about which information will have to be collected, if relevant, for both the land unit and the land use type.

The various published documents about land evaluation (FAO, 1976, 1983, 1984a, 1985, 1987) agree that land use types should be described according to 'key attributes' and 'requirements'. Main key attributes mentioned are: type of product, labour intensity, capital intensity, level of technical knowledge, farm size, and land tenure relationships. Here, the proposed information needs with regard to the key attributes are directed more to the relations of a land use type with the farm systems of which it is a part. This is called the setting. In addition, technical specifications are defined. These are of an agronomic and economic nature. **In a particular case, decisions must be taken as to whether an item should be researched at all and to what depth.**

Last but not least a list with the most common requirements is given. Which requirements are relevant in a particular land use planning exercise depends on the specific circumstances! Once it has been decided which requirements are relevant one knows which land qualities should be taken into account with the description of the land units.

LAND USE TYPES AS PART OF LAND USE SYSTEMS: A TENTATIVE CHECKLIST.

1) Setting

- * socio-economic
 - description of type of farming system
 - size of farms
 - importance of land use type in farming system
- * description of technology
- * agro-ecological zone
- * season

2) Technical specification

* agronomic

- description of cultural practices
- description of (labour) operations
- quantitative inputs and outputs

* economic

- market orientation (percentage sold)
- capital intensity (capital per hectare, and/or per unit of product)
- labour intensity (labour per hectare, and/or per unit of product)
- costs of inputs
- costs of production
- value of outputs
- gross margin(s) per hectare, and/or per labour day
- net benefits (annuity of

3) Requirements

In table 2 (next page) three sets of requirements are given, one for rainfed agriculture, one for irrigated agriculture and one for extensive grazing. For details the reader should consult FAO (1983), FAO (1985) and FAO (1987). Again it is important to stress that in a particular land use planning exercise the user should only include those requirements that are relevant, in this case those requirements that are critical for the classification of land use types with regard to their suitability.

With regard to extensive grazing land use requirements at the forage production level should be complemented by those at the livestock production level (FAO, 1987), see table 1.

Table 1. Land use requirements at the livestock production level.

-
- grazing capacity
 - drinking water
 - biological hazards
 - climatic hazard
 - accessibility to animals
 - fencing or hedging
 - location
 - conditions for hay and silage
-

The information needs of land use planning from land units as parts of land use systems follow from the lists of requirements of the land use types. As qualities are often the result of the interaction of certain land characteristics, a discussion of this subject would become besides the scope of the present document, the reader is referred to the above mentioned FAO publications, and soil and land evaluation handbooks.

The whole process of collecting data on land qualities and land use requirements form part of a land evaluation. As land evaluation is a part of land use planning the results of a land evaluation form a point of departure for the next step in land use planning. An example of such a result, is a two-way table indicating, either qualitatively or quantitatively, the suitability of each land use type for each land unit; complemented by a map indicating the land units. See table 4 of appendix 3 for an example.

Table 2. Requirements of land use types.

Rainfed agriculture:	Irrigated agriculture:	Extensive grazing, forage production level:
-radiation	-radiation	-radiation
-temperature	-temperature	-temperature
-moisture	-growing period	-moisture
-oxygen for roots	-water	-oxygen for roots
-nutrients	-aeration	-nutrients
-rooting	-nutrients	-rooting
-germination/ establishment	-rooting	
-air humidity		
-ripening		
-flooding tolerance		-flooding tolerance
-hazards tolerance	-flood, storm, frost, etc	
-salt tolerance	-salt tolerance	-salt tolerance
	-sodicity tolerance	
	-pH, micronutrients,	
	-toxicities	
-soil toxicities		-soil toxicities
-pests/deceases	-pests/deceases	-undesirable species
-workability of soil		
-mechanization	-mechanization	-mechanization
		-soil workability
-land preparation/ clearance	-land clearing	
	-water-application	
	-pre-harvest management	
	-harvest/post-harvest	
-storage/processing		
-timing of operations		
-access to parcel/field		
-size of farm		
-location	-location	
-erosion hazard	-long-term erosion	-erosion hazard
-soil degradation hazard	-environmental hazard	
	-flood protection	
	-drainage	
	-land grading	
	-physical, chemical/ organic aids	
	-leaching	
	-reclamation period	
	-irrigation engin. needs	
	-long term salinity/ sodicity hazard	
	-ground/surface water hazard	
	-farmers attitudes to irrigation	
		-surface sealing
		-genetic potential vegetation
		-fire susceptibility
		-hay/silage

Part III. FARMING SYSTEMS.

The headings used for indicating the areas of information needs follow figure 18. Here information needs are related to the farm level and to the activity or subsystem level. The information related to goals and needs, to the decision process, and to 'stock' information about means of production is part of the farm level. How the means of production are allocated to and used in the different activities, and the results (outputs and feedbacks) obtained - 'flow' information - belongs to the activity or subsystem level. In a particular case, decisions must be taken as to whether an item should be researched at all and to what depth.

FARMING SYSTEMS: A TENTATIVE CHECKLIST.

1) Farm/household level

- information about the needs/preferences of the households ('consumption side') and the goals of farms ('production side').
- special attention to intra-household decision making with regard to the allocation and use of scarce means ('household economics')
- composition of household, age/sex division
- availability of money
- consumption pattern
- stock of means of production and general allocation/use

* land

- availability of land according to type and quality (parcels, related to land units with land qualities)
- fragmentation
- tenancy arrangements
- accessibility
- use of land per activity: 'cropping pattern'

* capital items

- stock of capital goods like ploughs, tractors, harvest knives, etc.
- use of capital goods per activity
- livestock as a capital input to agricultural activities, e.g. type and number of animals for ploughing

* labour

- availability of household labour according to sex and age
- use of labour per activity per period specified according to sex and age and according to categories as household labour, hired labour and exchange labour
- use of labour per operation (like ploughing, seeding, harvesting, etc)

* management

- management is the type of labour input which makes decisions about what to produce (which activity), how much and how (which production methods/technology)
- knowledge, skills and attitudes of decision maker(s)

2) Activity/subsystem level

1. household activities

- * child care
 - time allocation by whom
- * collecting water and firewood
 - source
 - time allocation by whom
- * cooking
 - time allocation
- * artisanal activities
 - inputs and outputs
 - time allocation by whom

2. off-farm activities

- * off-farm/non-farm work
 - number of days per year and per periods of year
 - wage labour or exchange labour
 - wages
 - type of employer
 - sector of the economy
- * renting out of land
 - how much land
 - income derived
 - tenancy arrangements
- * renting out of capital goods
(e.g. working with oxen-span to plough land of neighbours)
 - frequency and time involved
 - payments received and costs incurred

3. on-farm activities

- * general
 - general overview: cropping pattern per season and year, rotations, animal husbandry pattern and activities, like for example agro-forestry (reminder: on-farm activities are related to land use types with land use requirements in land evaluation)
 - results of activities are of two types: outputs (= physical products) and feedbacks
 - outputs are mentioned under activities; important is to mention that apart from the outputs which are used directly by the farm household ('subsistence'), a part is sold at 'markets' which provide the farm household with cash to buy inputs and consumer products, and a part is used as capital e.g. young animals to be used for plowing
 - feedbacks can be distinguished in socio-economic feedbacks and ecological feedbacks. The results of farming systems do influence community structure, norms and beliefs, external institutions, policies and programmes and projects.

Also the way of farming has its influence on the natural surroundings for example through erosion and deforestation, or through land improvements like sawahs.

* crops

- per major crop: inputs, timing of operations, technology, outputs, value of inputs and outputs, gross margins and net returns; part of output for subsistence and for sale; cash/kind character of inputs.
- efficiency measures as gross margin per hectare and gross margin per labour day
- types and quantity of inputs and outputs, operations, and technology
- inputs from other activities (e.g. dung from cattle)
- outputs to other activities (e.g. straw to cattle)

* livestock

- per animal husbandry activity: type of animals, sex and ages, inputs, timing of operations, technology, outputs, value of inputs and outputs, gross margins and net returns; part of output for subsistence and for sale; cash/kind character of inputs
- efficiency measures as gross margin per animal and gross margin per labour day
- types of animals, sex and ages, type and quantity of inputs, operations, and technology
- inputs from other activities
- outputs to other activities

Whereas probability sampling is normally chosen for lengthy extended surveys, non-probability sampling (particularly accidental and purposive sampling) are used in Rapid Rural Appraisal. A good reference source, including an estimation of population parameters from samples, is found in Chapter 2 of FAO Agricultural Services Bulletin No. 41 (Dillon & Hardaker, 1980). In probability sampling, the selection of multi-stage stratified random sampling (drawing systematic samples from an unbiased sample frame) is to be recommended. Efficiency reasons may suggest cluster sampling. Where no sampling frame exists, grid or line sampling are a possible alternative. In farm management studies in West-Africa, the cost route method (Spencer, 1972) has been popular. Houses (or parcels) are selected at random (or systematically) along one or more routes (footpaths) leading away from the village.

Some basic considerations

As has been shown in the main text (section 6.3), one is regularly confronted with a range of possible survey design alternatives. One has to choose the one appropriate to the problem at hand and the total resources available for the survey. This requires a clear idea of the data needed and the acceptable precision constraints, given an overall resource constraint. When approaching the problem of sampling one should keep in mind the following basic considerations.

Firstly, the value of sample data lies in its input as an estimation of population parameters. The entire raison d'être of sampling is to make an informed guess about the likely size of the population mean and variance from the sample data. Its ability to achieve this depends on essential rules of probability theory, embodied in the Central Limit Theory and the normal distribution curve. The core of the sampling process lies in the statistical design.

Secondly, since the crucial factor governing cost is the size of the sample it is important to understand that for a given desired range of precision choosing too large a sample is as inefficient as too small. A common mistake is to think in terms of sampling fractions (take a 1% or 5% sample). Precision depends only on the size of the sample and not on the population size.

A decision on a sample size per homogeneous group (for instance a matrix block after stratification) is in fact deciding on a certain level of precision of a sample mean (\bar{x}).

If estimates of both the standard deviation (s) and the population mean (X) are known (and if it can be assumed that sample mean \bar{x} is approximately normally distributed about the population mean), it can be shown that with y as relative error of the sample mean and t as the Student variable, the sample size n should become as follows: $n > ((t * s)/(y * \bar{x}))^2$. Usually, however, both s and \bar{x} are unknown, as is the case in a farm survey. The only solution then is to choose a modest sample size, for instance 15 sampling units and calculate the relative error at, for example, 95% probability. If this error exceeds a previously determined permissible

error, then the standard deviation and the mean of this sample can be used in the above formula to obtain an estimate of the sample size required¹.

Assuming, for instance, that s and \bar{x} , based on 15 sampling units, are 9 and 17, respectively, and permissible relative error (y) is 20 percent, then the sample size would be: $((2 * 9)/(0.2 * 17))^2 = 28.028$, i.e. about 13 additional sampling units are required to obtain the level of precision demanded (at 95% probability). As both the sample mean and standard deviation may change with a larger sample, this calculation has to be repeated with newly found values for these parameters.

It is clear that the sampling procedure should take account of the possibility for an enlarged sample. This should be taken care of in the logistics of the fieldwork.

An additional complication is that in farm economic surveys, there are many variables included for each sampling unit, so called multi-variate sampling. These variables may differ in their distribution and each would require a different sample size. For planning purposes, point estimates will usually be sufficient, hence certain variables have to be surveyed through an increased sample without requiring a complete set of data for each sampling unit (Hoekstra & Lok, 1977).

The above remarks have an important bearing on the way surveys are to be conducted. In this connection we introduce the coefficient of variation (c_v), which expresses the variance in relative terms: $c_v = \sigma/\bar{x}$, or an estimate of $\hat{c}_v = s/\bar{x}$.

From field data it appears that the c_v becomes rather constant at a sample size of 20-25. Deviation from this observation may be an indication that the classification into homogeneous groups needs readjustments or point at irregularities (errors in reporting, non-response errors) in data collecting. A continuously high c_v may mean that the variability of a certain key variable is large and reflects the magnitude of uncertainty involved.

It is thus advisable to organize this type of survey in such a way that for each block in the initial matrix, a limited number of samples (say 20) from an infinite population is chosen with the possibility of an extension, once a brief, mid-way analysis of the most important variables point at the need for additional sampling, re-definition into homogeneous groups proper, etc.

The following example demonstrates that large samples per block (97-126) in the matrix are unnecessary and thus costly. Table 1 compares for a number of key variables a large sample and a sub-sample thereof (between 20 and 28). The values for these key variables in the sub-sample lie in the same order of magnitude and the c_v has an acceptable value (for this type of farm surveys).

¹ At 95% probability and for samples with more than 15 units, Student's t-values remains fairly constant at about 2. Wherever possible we would plead for uniformity in the application of t and y . Only s then remains as a variable factor.

As can be observed, the average gross production value decreases and the c_v increases with decreasing reliability of irrigation from class I to class III. The latter is no doubt related to the increasing magnitude of uncertainty in irrigated rice farming, which is almost identical to rainfed farming in class III.

Table 1. A comparison of the values of key variables obtained from a sample and a sub-sample thereof in a farm survey of irrigated farming, Panay, Philippines.

Quality of irrigation	Selected key variables	n	\bar{x} (in pesos)	s (in pesos)	\hat{c}_v (in %)	Remark
Irrigation class I (good)	gross production value/ha	22	4025	860	21	subsample
		126	3866	842	22	sample
	variable costs/ha	22	1698	421	25	subsample
		126	1720	390	23	sample
Irrigation class II (medium)	gross production value/ha	28	2937	729	25	subsample
		115	2871	784	27	sample
	variable costs/ha	28	1250	410	33	subsample
		115	1366	423	31	sample
Irrigation class III (practically rainfed)	gross production value/ha	20	1749	790	45	subsample
		97	1883	872	46	sample
	variable costs/ha	20	822	397	48	subsample
		97	985	412	42	sample

Source: Cools (1978).

In the choice of desired precision, the following factors need be taken into account.

The first one is the purpose of the data collection, which may need a high or low degree of precision.

The second one is whether measurement or non-sampling errors are themselves large. It is pointless to insist on a very high precision (very low sampling errors) if the latter is the case.

Thirdly, as emphasized earlier, a good sampling frame is essential.

Fourthly, for many survey designs a prior guess about various population estimates is required. It is also relevant where cost constraints are critical.

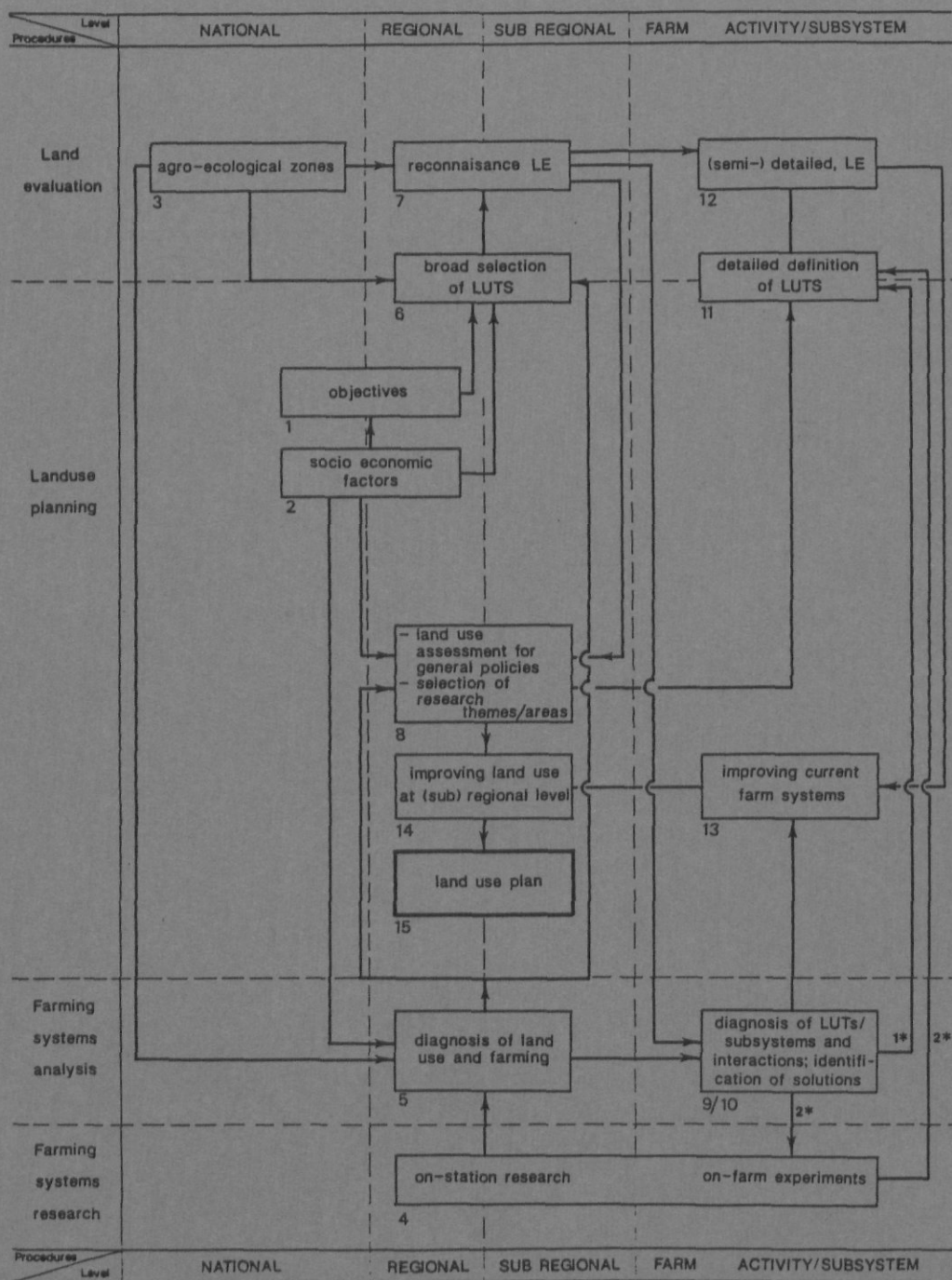
Fifthly, one should realize that there is no unique survey design for all situations. Simple random sampling may be perfectly valid in one situation, where in another one the choice would be stratified random or cluster sampling.

Last, but not least, the role of effective stratification (discussed more fully in the main text) should be mentioned once more.

Appendix 7.

LEFSA PROCEDURES FOR LAND USE PLANNING.
(Figure 8a, loose)

Figure 8a. LEFSA sequence for land use planning*.



1* If current, tested technology is available for the definition of relevant LUTs.

2* If further research is needed for the definition of LUTs ('research loop'; Young, 1985).

* Figure 8a of: Fresco, Louise O., Herman G.J. Huizing, Herman van Keulen, Henk A. Luning & Robert A. Schipper (1992). Land evaluation and farming systems analysis for land use planning. FAO working document. FAO, Rome; ITC, Enschede & Wageningen Agricultural University, Wageningen.