Farm household level optimal resource allocation

An explorative study in the limestone area of East Java

Teunis van Rheenen

Stellingen

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1 Kennis van opties voor lange-termijn ontwikkeling levert een bijdrage aan strategische beleidsvorming. (Dit proefschrift)

2 Het oude Nederlandse gezegde "de mest is gheen heiligheit, toch doet hij wond'ren woer't leit" is voor de regionale ontwikkeling van Oost-Java van toepassing. (Dit proefschrift)

3 Goed interdisciplinair werk is onmogelijk zonder gedegen disciplinaire kennis.

4 Veel studies die gebruik maken van interactieve meervoudige doelprogrammering zijn niet interactief.

5 Het gebruik van *expert knowledge* als een zogenaamde *quick and crude method* blijkt erg nuttig in de FLORA-procedure. (Dit proefschrift)

6 Verlagen of zelfs afschaffen van subsidies op landbouwinputs zoals kunstmest in het Kalksteengebied ten zuiden van Malang is milieukundig gewenst, teeltkundig mogelijk en bedrijfseconomisch acceptabel. (Dit proefschrift)

7 De rol die de landbouw kan spelen om het inkomen per capita te verhogen in het Kalksteen gebied ten zuiden van Malang is beperkt. (Dit proefschrift)

8 De waardering van mest door mensen en mestkevers vertoont duidelijke overeenkomsten.

9 Het gebruik om gemengde zaadmonsters van zelfbevruchters te verzamelen voor *ex situ* conservatie vergroot de kans op verlies aan verscheidenheid.

10 Om voedselvoorziening in de toekomst veilig te stellen moet Nederland zijn bijdrage aan de *Consultative Group for International Agricultural Research* verhogen en anderen bewegen hetzelfde te doen.

11 Dat de chromosomen van de mens en die van de Orang-oetan, de Gorilla en de Chimpansee voor een aanzienlijk deel identiek zijn, zou erop kunnen wijzen dat hun bouwplan van dezelfde ontwerper afkomstig is.

12 Een aanzienlijk percentage van de AIO's haalt het podium niet. In voorkomende gevallen zou de promotor het afbreken van het onderzoek in het openbaar moeten verdedigen.

Teunis van Rheenen
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Farm Household Level Optimal Resource Allocation

An explorative study in the limestone area of East Java

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Farm Household Level Optimal Resource Allocation

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Teunis van Rheenen

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Abstract

The role of agriculture changes markedly when an economy is transforming from developing to developed. The dramatic structural transformation in the development process has consequences for the policies to be implemented. Acknowledging differences between countries, generally speaking, four phases can be distinguished: (1) getting agriculture moving, (2) agriculture as a contributor to growth, (3) integrating agriculture into the macro-economy, and (4) agriculture in industrial economies. In many low income countries, the agricultural sector is still in the 'getting agriculture moving' phase. Due to policies that discriminate against agriculture in many low income countries the sector has not been able to play its potential role in economic development and hence hampering overall economic development. This awareness gives extra reason to evaluate the possibilities for agriculture. Agricultural research is one of the instruments that can be used to enhance the role of agriculture in development. Those that will eventually have to accomplish the goals that are set for agriculture are farm household members. To determine the research agenda at farm household level, agricultural research institutes have relied increasingly on farming systems analysis methods.

Farming systems analysis methods, however, have not been free from problems (Chapter 2). These problems are: farming systems analysis is vulnerable to subjectivity, has been too qualitative, is mainly farmer oriented, has been mainly crop oriented, has suffered from institutional problems, has been confronted with time conflicts, lacks gender differentiation, and has seen no unification of methods. To overcome some of these problems a new methodology for farming systems analysis was designed. Because this new methodology is more quantitative than most farming systems analysis methods it is named *quantitative farming systems analysis*. The new methodology encompasses the analysis of the bio-physical and socio-economic components of farming systems. The information that is generated through these analyses is used in a farm household level optimal resource allocation procedure.

The working method for the farm household level optimal resource allocation procedure includes three stages and seven steps (Chapter 3). Stage 1: model preparation including (1) goal variable definition and constraint determination, (2) system definition and time horizon determination, and (3) generation of data requirements. Stage 2: (4) construction of the FLORA model. Stage 3: model utilization including (5) computing the playing field, (6) conducting sensitivity analyses, and (7) scenario construction.

The study area is situated in the limestone area, South of Malang, East Java, Indonesia (Chapter 4). This area was selected because farm households in the study area are confronted with relatively low incomes, low crop productivity, and high levels of

soil loss. Both the local government and the Brawijaya University, where the project was located, share efforts to improve the welfare of farm households in the study area.

Results computed during Stage 3 of the farm household level optimal resource allocation procedure are presented in Chapter 5. The manner in which the procedure was developed deviated from the original design. The reasons for this are described (Chapter 6). Also the contribution of the FLORA procedure in overcoming the problems facing farming systems analysis methods is evaluated. Due to institutional conditions the procedure to establish goals for research interactively with stakeholders had to be postponed, but this dissertation enables goals for research to be presented to stakeholders and trade-offs between goal variables to be demonstrated. This dissertation concludes that future efforts to implement QFSA to establish goals for agricultural research should focus on: clear research objectives, selective data collection, better interdisciplinarity, phasing of research activities, and simple and quick modelling procedures.

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In 1990, I received a telephone call from my brother Willem, who asked whether I had seen the advertisement in the Wageningen Agricultural Newsletter for a PhD position. At that time he didn't realize how much his call would affect my life during the next five years. Hind-sight makes me feel most grateful to him, but I must admit at times during that period my feelings showed an alarming lack of gratitude.

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Voor Badja en Henk

CONTENTS

1 Introduction

1.1 Agriculture in development

The role of agriculture changes when an economy is transforming from developing to developed. Rapid agricultural growth accompanies or precedes general economic growth, as Lewis stated:

> Now if the capitalist sector produces no food, its expansion increases the demand for food, raises the price for food in terms of capitalist products and so reduces profits. This is one of the senses in which industrialization is dependent upon agricultural improvement; it is not profitable to produce a growing volume of manufactures unless agricultural production is growing simultaneously. This is also why industrial and agrarian revolutions *always* go together, and why economies in which agriculture is stagnant do not show industrial development [Lewis (1954, p. 433, emphasis added) quoted in Timmer (1988, p. 268)].

The relatively large traditional agricultural sector undergoes dramatic structural transformation in the development process with different consequences for policies to be implemented (Kuyvenhoven, 1989). This structural transformation has implications for the role that the agricultural sector can play in an economy. Johnston and Mellor (1961) list five roles for agriculture in economic development:
- to increase the supply of food for domestic consumption,
- to release labour for industrial employment,
- to enlarge the size for the market for industrial output,
- to increase the supply of domestic savings, and
- to earn foreign exchange.

The roles, however, will change during different phases of the agricultural transformation process. Acknowledging differences between countries, generally speaking four phases in the agricultural transformation process can be distinguished, as was done by Timmer (1988), who names each phase - with its own policy setting (Figure 1.1) - after their main authors:

The Mosher environment: Getting agriculture moving A set of conditions is required for the transformation from a traditional agriculture to one that can be characterized as one exhibiting sustainable growth. New or improved technologies, substantial investment in research and infrastructure, institutional changes and inducive price and market policies are required in combination to achieve this transformation.

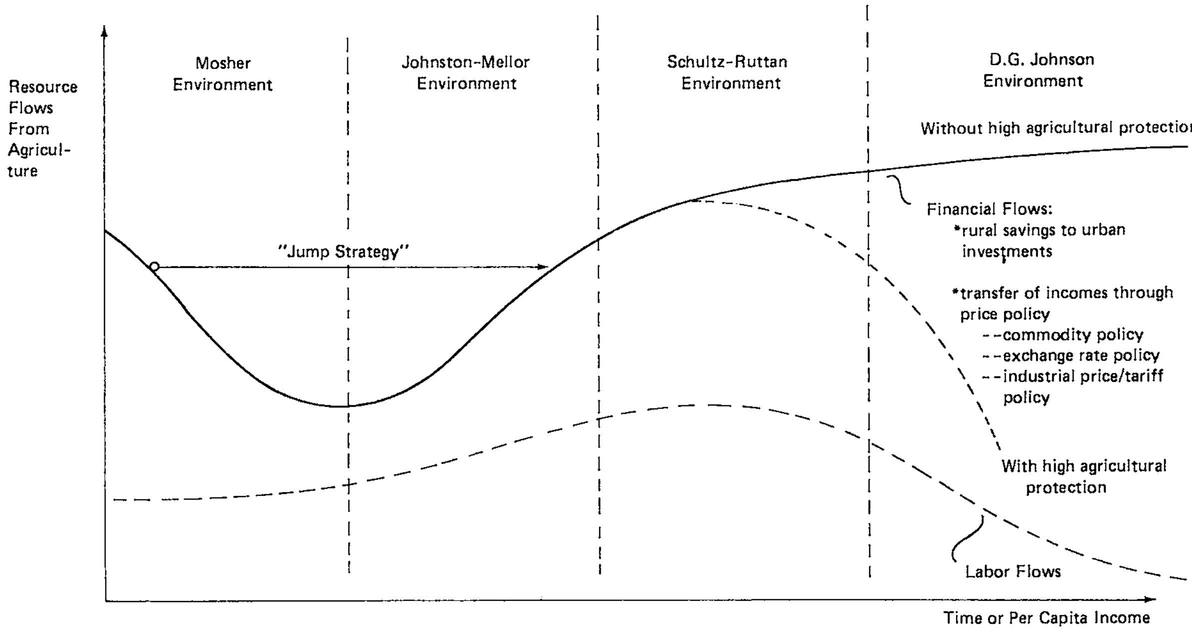
The Johnston-Mellor environment: Agriculture as a contributor to growth Earlier efforts are already visible in terms of higher productivities. The agricultural sector becomes a key contribuant to the overall growth process. There is a disequilibrium between the agricultural and industrial sectors - particularly in the field of labour productivity generally due to the still limited capacity of the industrial and services sector to absorb labour from agriculture.

The Schultz-Ruttan environment: Integrating agriculture into the macro-economy During this phase the agricultural sector is increasingly integrated into the rest of the economy while at the same time it has become an increasingly vulnerable and complex sector. Resources, labour and capital, are shifted out of the agricultural sector into other sectors (industry and services) where returns are higher. During this phase the agricultural sector has become more sensitive to macro-policies, instruments and influences, and the influence of traditional agriculturally focused instruments decreases.

The Johnson environment: Agriculture in industrial economies In this phase the agricultural sector has become completely integrated into the rest of the economy. The sector is often increasingly protected against market influences which are considered undesirable in the process of achieving sectoral goals.

As the World Bank (1986a) has pointed out, in many developing countries agriculture has not been able to play its potential role in national economic development:

> The general economic policies that developing countries have pursued have, however, limited the growth of agricultural production and hampered efforts to reduce rural poverty. In many cases, sector specific pricing and tax policies have also resulted in substantial discrimination against agriculture. In addition, government interventions at all stages of production consumption and marketing of agricultural products and inputs, though undertaken to improve the efficiency of the market, have frequently resulted in greater inefficiencies and lower outputs and incomes. As a consequence farm incomes in many developing countries are stagnating and little progress is made in overcoming the problems of poverty (World Bank, 1986a; p. 61).



Policy Settings:

"Getting Agriculture Moving"—institutional change; new technology; structure of markets and incentives; significant investments in rural infrastructure

"Agriculture as a Contributor to Growth"—establish market links with industry; technology and incentives to create a healthy agricultural sector; improve factor markets to mobilize rural resources

"Integrating Agriculture into the Macro Economy"—declining share of food in urban budgets; push to make agriculture efficient; shift resources out, but substantial income distribution problems from lagging rural labor productivity

"Agriculture in Industrial Economies"—small share of food commodities in consumer budgets; income distribution a political issue; unemployment in industrial sector creates pressures to keep labor in agriculture; environmental concerns and "way of life" issues

Figure 1.1: Changing environments for agriculture's contribution to economic growth, Source: Timmer (1988, p. 282).

Policy changes are required to allow agriculture to play its potential role in economic development. Pinstrup-Andersen and Pandya-Lorch (1995) point out that policies with the triple goal of poverty alleviation, increased productivity in food production and sustainability are required. In their view these would include policies to improve water management, expand agricultural research, and deal effectively with externalities resulting in land degradation and deforestation. They conclude by mentioning the following dual challenge:

> Today, the challenge is both to grow more food and to assure that the food is accessible by all people at all times. The 1960s and 1970s were dominated by concerns to grow more food, while the 1980s were characterized by concerns of poor distribution. The time has come to stabilize the pendulum and to focus on both more food and better access. Even though today there is enough food to feed the world, that does not help the many people who cannot get access to it. We have to focus on both better distribution of food and increased production of food to meet the needs of the ever growing population and to generate the incomes needed by the poor to convert their food needs into effective demand, recognizing that available food will not be evenly distributed (Pinstrup-Andersen and Pandya-Lorch, 1995; p. 108).

If agriculture is to fulfil the different roles mentioned by Johnston and Mellor (1961) in economic development, it should be given that chance to do so. In many low-income countries the agricultural sector is still in the early stages of the 'Mosher environment' as far as its contribution to economic growth is concerned. This implies - according to Timmer (1988) - that the policy setting should include institutional change, introduction of new technology, improvement of the structure of markets and provision of incentives for farm households and significant investments in rural infrastructure.

Agricultural research is one of the instruments that can be used to enhance the role of agriculture in economic development. Agricultural research institutes have increasingly become aware that if their research is to be effective, it will have to be compatible not only with the policy environment but also with the farm household system. When all is said and done, those who have to accomplish or achieve goals that are set for agriculture are the actors in the field, i.e. farm household members. To determine their research agenda research institutes have increasingly relied on farming systems analysis (FSA) techniques. Yet, the techniques used to formulate the research agenda are confronted with problems. This thesis describes the *design of a new method for farming systems analysis* and proceeds *to develop a procedure with which long term goals for agricultural research at farm household level* can be established, considering three points of view. The points of view are consistent with the triple goals introduced by Pinstrup-Andersen and Pandya-Lorch (1995). Each will be elaborated below.

1.2 Three points of view

1.2.1 Agro-technical

Although parts of the agricultural sector of a country may not have a comparative advantage, a major policy aim of most policy makers is to be self-sufficient as far as *food production* is concerned. The steady supply of agricultural products from the rural areas is often considered a prerequisite for political stability. The purchasing power of part of the population may, however, be so low, that although food supply is sufficient, people do not have the means to buy food. Under these circumstances, there are several options open to policy makers, for example, making food cheaper with the aid of producer or consumer subsidies, importing food, or stimulating programmes that will make agricultural production more efficient and hence its products cheaper. Due to acute shortages of funds, governments in most developing countries are not in a position to finance expensive subsidy programmes and are at the same time often discouraged to do so by major international financial organizations like the World Bank or the International Monetary Fund. Obtaining higher levels of efficiency at farm household level is the preferred option. Another reason why improving efficiency levels of agricultural production at farm household level is required is that in many developing countries the population growth rates have been high and are expected to remain so in the near future. This inevitably will lead to an increase in the demand for food. Especially for those countries, where present production levels have not been able to keep up with demand, agricultural production will have to increase. This increase will particularly have to come from higher yields per hectare, rather than through an expansion of the production area as the latter is often no longer possible.

1.2.2 Household socio-economic

Improving the welfare of the rural population is often a major issue for policy makers. This inevitably also means that attention will have to be given to *farm households*, because the majority of the households that live in the rural areas can be described as farm households, as they are primarily dependent on farming activities for their income generation, although a substantial part of their income is often derived from non-agricultural activities. The five roles that agriculture can play in economic development, as mentioned by Johnston and Mellor (1961), will be enhanced by improving efficiency levels at the farm household. For example, if a large proportion of the households in the rural areas are farm households, then they also represent a significant proportion of the domestic market for industrial products. If these households do not have the purchasing power to buy these products, then the home market will stagnate. Also, farm households can be an important source of private or public savings and of revenue for the government, in the form of for example taxes, albeit, only if they are in a position to generate sufficient income. Incomes that can be generated from farming activities have increasingly come under pressure. Numerous factors have contributed to this situation, for example, poor information services, political unrest and domestic policies that discriminate against the agricultural sector. An additional reason is the effect of the agricultural policies of most developed countries, particularly the European Union and the United States of America. Agricultural policies in many developed countries have over-stimulated agricultural production to such an extent that production has outgrown demand and the excess is sold on the world market where prices have become depressed. Such policies have often affected domestic prices of agricultural products in developing countries as well as their possibilities to obtain access to markets in developed countries (Kuyvenhoven and Koekoek, 1991).

1.2.3 Environmental

From an *environmental* point of view, the awareness has grown that farm households play a major role in determining the environmental future of a region. Farmers are society's caretakers of some major non-renewable resources, such as the soil base and, partly, the water cycle (Stroosnijder *et al.*, 1994).

'No doubt, the agricultural resource base has deteriorated in many parts of the world, and, if unchecked, the deterioration will increase the cost of agricultural production in these areas. Deforestation and soil erosion already are catastrophic in many regions. In the Sahel, for example, an estimated 1 % of the natural forest cover is lost each year' (World Bank, 1986b, p 16). With land resources of most countries becoming scarcer, increasingly society as a whole has a stake in what farm households do with their resources and claim that the activities should be sustainable as well as productive. In this thesis, the following environmental effects associated with agriculture are taken into consideration: soil erosion, loss of nutrients and accumulation of biocides. These negative side effects of farming can increasingly be quantified and it is possible to screen activities on these aspects.

1.3 Objectives of the study

Demands and expectations regarding the role that agriculture should or could play in an economy have changed over the years. Increasingly, when agricultural research institutes determine their research agenda they have to give consideration to different and often conflicting points of view. No longer can they merely concentrate on achieving higher production levels for crops or only pay attention to the preferences of farm household members. They also have to give attention to - for example - preferences of policy makers or the environmental effects of agriculture. Most agricultural research institutes, when determining their research agenda at farm household level, have relied on FSA techniques. FSA is the understanding of the structures and functioning of farming systems, the analysis of constraints on agricultural production at the farm level, and ways to translate this understanding into adaptive research programmes (Fresco, 1988).

FSA approaches have, however, been confronted with problems. These can be summarized as follows: FSA is vulnerable to subjectivity, has been too qualitative, is mainly farmer oriented, has been mainly crop oriented, has suffered from institutional problems, has been confronted with time conflicts, lacks gender differentiation, and has seen no unification of methods. These problems complicated the setting of the research agenda and gave reason for the development of a new approach to farming systems analysis to overcome some of the above mentioned problems. As this new approach is more quantitative than most FSA techniques, it is named *Quantitative Farming Systems Analysis* (QFSA). Figure 1.2 shows the various components which are included in QFSA. Making use of information that is generated by the analyses of the bio-physical and socio-economic components of farming systems, a *Farm Level Optimal Resource Allocation* (FLORA) procedure is developed. With this procedure long-term or ultimate goals for crop and livestock research can be established. Trade-offs between goals can be demonstrated. This study mainly concentrates on the development of the FLORA procedure and aims to realize the following objectives:

- to develop a methodology with which long term goals for crop and livestock activities can be established,

- to contribute to overcoming some of the problems that have confronted farming systems analysis techniques, and
- by establishing and analyzing long term goals for research considering the three points of view, enhance the role of agriculture in economic development.

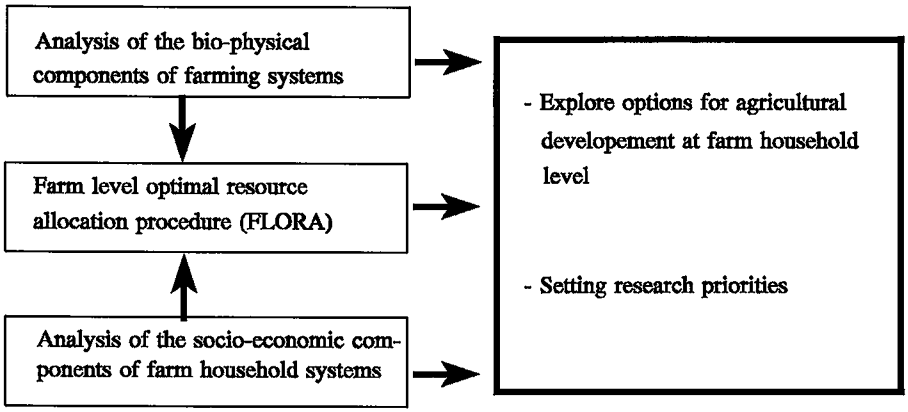


Figure 1.2: Quantitative farming systems analysis.

1.4 Organization of the research

The research for this study is organized as follows. Problems facing FSA are first discussed in Chapter 2. The new methodology that was designed to overcome these shortcomings - the QFSA methodology - is described. The methodology includes the analysis of the bio-physical and socio-economic components of farm household systems. The types of analyses included in the design of QFSA are discussed as well as the quantitative and qualitative information that the analyses will generate. Next, the manner in which the information can be used for the FLORA procedure is explained. The FLORA procedure can be used interactively with stakeholders in rural development at farm household level and a description is given of how this can be done.

Chapter 3 describes and discusses the working method that is followed when developing the FLORA procedure. The working method encompasses three stages and seven steps. The stages are: model preparation, construction and utilization and the steps include:

- Making explicit the goal variables and determining the constraints that face agricultural development at farm household level. Goal variables reflecting three points of view - agro-technical, socio-economic and environmental - are included in the procedure. Three types of constraints were distinguished, namely demands that are placed on the goal variables, normative and technical constraints.
- Defining the system on which QFSA and hence also the FLORA procedure focuses and determining the time horizon. Three types of typical farms are defined and the manner in which this is done is described. Activities[1] are included in the procedure that at present are not practised in the research area where QFSA is developed. It therefore is necessary to set a time horizon, indicating when such activities could become a reality. The basis on which the time horizon is established is explained.
- Meeting the data requirements of the FLORA procedure. The procedure requires both quantitative and qualitative information. Not all information requirements for the procedure were met according to the original design. The various data collection efforts that took place to operationalize the FLORA procedure are discussed.
- Construction of the FLORA model. Part of the FLORA procedure includes the development of the FLORA model. The technique of analysis that is used for the FLORA model is multiple goal linear programming. A number of different techniques of analysis are presented and the reason for selecting multiple goal linear programming is given.
- Computing the playing field[2]. The technique of analysis selected encompasses several optimization cycles. During the first iteration cycle each goal variable is successively optimized while the demands that are placed on the other goal variables are set at their lowest values. The playing field encompasses the ideal[3] and anti-ideal values and the manner in which this field is computed is described.
- Conducting sensitivity analysis. Various types of sensitivity analyses are mentioned and conducted.
- Constructing scenarios. Three scenarios are constructed and the manner in which this is done is explained.

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[1] The term activity here refers to well defined sets of inputs and outputs for crops and livestock.

[2] The playing field is also referred to as the "potency matrix", see Spronk (1981).

[3] Ideal considering the goal variable being optimized.

The FLORA procedure was developed with information from farm households, south of Malang, East Java, Indonesia. Chapter 4 describes the physical characteristics of the research area, farm household resources and the major income generating activities of these farm households. Results of the FLORA procedure are presented in Chapter 5. This is done by a presentation of the playing field, the various sensitivity analyses and the scenarios. Chapter 6 is a reflection on the development of the FLORA procedure within the context of QFSA. The procedure was developed in an interdisciplinary project in Indonesia with the aim of contributing to the objectives of QFSA. The actual development of the procedure deviated from the original design and the extent to which this was the case is explained. Finally, the contribution that the FLORA procedure can play in overcoming some of the problems confronting FSA is discussed.

2 Making farming systems analysis a more objective and quantitative research tool[4]

2.1 Introduction

Farming systems research has gained wide popularity and acceptance in the scientific world during the last decades. This can be concluded from the enormous amount of literature that appeared since the mid 1970s. A systems approach implies 'studying the system as an entity made up of all its components and their interrelationships, together with relationships between the system and its environment. Such a study may be undertaken by perturbing the real system itself (e.g. via farmer managed trials or by pre- versus post adoption studies of new technology). More generally it is carried out via models (e.g. experiments, researcher and/or farmer managed on-farm trials, unit farms, linear programming and other mathematical simulations) which to varying degrees simulate the real system' (TAC, 1978).

Over the years various methods concerning a systems approach in agricultural research have been published. A specific group of approaches characterized as 'farmer's orientated' or 'bottom-up' is commonly referred to as farming systems research and development (FSR&D). Shaner *et al.* (1982) define FSR&D as:

> An approach to agricultural research and development that (1) views the whole farm as a system, and (2) focuses on the interdependencies among components under the control of members of the farm household and how these components interact with the physical, biological, and socio-economic factors not under the households' control. The approach involves (1) the diagnostic phase: selecting target areas and farmers, identifying problems and opportunities; (2) the development phase: designing and executing on-farm research; and (3) the implementation phase: evaluating and implementing the results. In the process, opportunities for improving public policies and support systems affecting the target farmers are also considered.

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[4] Adapted version of: Stroosnijder, L. and Rheenen, T. van (1993).

The ultimate aim of FSR&D is to enhance the welfare of farm household members. Expectations were high in the 1970s, but in retrospect it becomes clear that FSR&D has not always been able to live up to these expectations.

Farming systems analysis (FSA) is the initial and crucial stage of FSR&D and comprises the above described step (1) and partly (2). FSA is the understanding of the structures and functions of farming systems, the analysis of constraints on agricultural production at farm level, and ways to translate this understanding into adaptive research programmes (Fresco, 1988). In other words, FSA is a tool that may be used to describe and analyse farming systems and to set a research agenda. The basic steps in FSA are:

- diagnosis: the analysis of farming systems and the identification of constraints; and
- design: the step from diagnosis to research, both on- and off-station.

Some of the problems that have faced FSA will be discussed in Section 2.2.

Section 2.3 describes how an attempt was made to improve methodologies used for FSA with the aid of new and old developments in research techniques. As this new approach places more emphasis on the quantification of the various components of farming systems than the more classical FSA techniques, it was referred to as *Quantitative Farming Systems Analysis* (QFSA). With the aid of quantitative and qualitative knowledge generated as part of QFSA, ultimate goals for agricultural research were explored at farm level. Trade-offs between goals are demonstrated. The feasibility of these options will then be examined. The analysis will take into account the constraints that exist at farm level. It is envisaged that QFSA - developed by an INterdisciplinary RESearch training project (INRES)[5] - will overcome some of the problems confronting FSA. When it appears successful, FSA will become more than a tool for cropping and livestock systems optimization to which it has evolved at present, despite its definition. This study concentrates on the development of a procedure to establish long-term goals for research at farm household level. In Section 2.4, the QFSA approach is discussed. The QFSA methodology described in this chapter is a result of pursuing initial objectives of the INRES research project.

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[5] An Interdisciplinary Research Training project (INRES) is developing QFSA in the limestone area south of Malang on the eastern part of the island of Java, Indonesia. The research team comprised seven staff members of the Malang University representing five disciplines and two Dutch scientists with support of interdisciplinary task groups of the Brawijaya University in Malang, Wageningen Agricultural University and the State University of Leiden.

2.2 Problems with farming systems analysis

QFSA is designed to overcome some of the short-comings of existing FSA methodologies. Methodologies used in FSA are documented in Byerlee and Collinson (1980), Conway (1985) and Collinson (1987). The diagnostic phase usually includes a study of background information, an informal survey (rapid rural appraisal/sondeo), and a formal verification survey. Collinson (1987) mentions that the output of a good diagnosis will include:

- the identification of problems for which experiments may be done with a priority ranking;
- assessment of the extent to which certain technological innovations are suitable for the system and a system - wide cost/benefit analysis for each innovation;
- a description of the characteristics of target group farmers and farms as a basis for the choice of representative locations where on-farm experiments may be executed;
- a description of current husbandry practises for setting the levels of non-experimental variables for experiments to be done by scientists and for evaluating farmer management;
- considering the farmers' circumstances the identification of realistic treatments for the experiments; and
- an assessment of farmers' judgements of the results gained from the experiments.

Some of the problems that have faced FSA are:

(1) FSA is vulnerable to subjectivity. In FSA, strong emphasis is laid on the participation of the farmer in determining the main constraints to be solved, i.e. a bottom-up approach. In practise, however, FSA can be vulnerable to subjectivity and may become top-down biased. This can be the case when the scientist perceives the problems of the farmer in isolation, and decides the priority for problem solving, often not considering the interaction between the various activities being practised by the farmer.

(2) FSA is mainly farmer orientated. It should be, but it should not *only* be farmer orientated. The farming systems lie in a region and the region will be administered by policy makers. These policy makers have certain development objectives for the region. The instruments they may choose to use such as subsidies, taxes and infrastructure will influence the 'operational space' of the farming systems. In a region, for example, where the main crop cultivated is cassava, it is conceivable that policy makers want to stimulate the cultivation of cash crops (e.g. coffee). Temporary subsidies may be given to farmers to grow the cash crop, while at the same time measures may be taken to discourage farmers from growing cassava. In this case research resources may be better spent on analysing the transition possibilities from cassava to coffee. While it is the farmer who

eventually decides which crop will be grown, he is influenced by his environment and by policy measures. In Section 2.3, a technique is presented that enables FSA to include policy makers.

(3) FSA has mainly been *crop* oriented. Norman (1978) mentions that FSA is somewhat a misnomer. He notes that to date research has been mainly confined to crop production processes and that the approach rarely has been applied to livestock processes. He adds that other areas generally omitted from consideration to date are more explicit consideration of off-farm enterprises and a more holistic systems approach, which goes beyond the farm gate and attempts to endogenize, for example, the marketing process.

(4) FSA has suffered from institutional problems (Collinson, 1982; Moscardi *et al.* 1983; Gilbert *et al.*, 1980). It is argued that recommendations may be rejected because they are inappropriate to the institutional setting for which they were designed. Programmes would become more realistic, appropriate and acceptable if they took account of the capabilities, resources and past activities of the host institutions. Heinemann and Briggs (1985) further stress that only with the active and constructive support of the local staff and farmers can there be a self-sustaining problem-solving research system. At the INRES project, the Indonesian staff from a local university with a strong commitment to provide a scientific basis for rural development played a dominant role in the execution of the programme.

(5) FSA is confronted with time conflicts. As discussed in Norman (1978), FSA is confronted with time conflicts in two ways. First, in the FSR&D approach a conflict exists between short-run private gains and long-run social costs. If only the farmer is allowed to indicate the constraints in his system, these will tend to be biased towards the former, which could exacerbate the latter. The linear programming technology described in Section 2.3 enables the user to take into account the long-run social costs. Secondly, there is inevitably a time lag in the recognition of a problem, the finding of a relevant solution and its adoption by farmers (Norman, 1978). The use of multi-period linear programming can be of aid in simulating the time gap and making the options for development more realistic.

(6) FSA has been too qualitative. This has made it a difficult tool for policy makers and scientists to accurately assess problems in a region. Hence, determining the order in which problems would have to be addressed becomes obscure.

(7) FSA has concentrated insufficiently on gender differentiation (Feldstein and Poats, 1990; Safiliou-Rothschild, 1988; Rocheleau, 1991). Numerous studies have pointed out that many household activities are gender specific. This may have consequences for the adoption of proposed changes in activities. Certain solutions proposed on the basis of FSA may therefore not be feasible as they are not conform the realities of on-farm circumstances.

(8) There has been no unification of FSA methods. In the literature one comes across many different descriptions of how FSA should be conducted. Standardization of methods would reduce costs for future FSA studies.

2.3 QFSA methodology

The QFSA methodology was designed to investigate the characteristics at farm household level and to use that knowledge to explore options for development and to establish the research agenda. This section describes the techniques used for the development of the QFSA methodology. The analysis of crop and livestock subsystems is described in subsection 2.3.1 where also attention will be given to the interactions of those components in mixed systems. Subsection 2.3.2 will focus on the analysis of the socio-economic components in a farming system and subsection 2.3.3 will present a technique used to combine technical and socio-economic information.

2.3.1 Analysis of the bio-physical components of farming systems

At the start of the project it was decided to assess the bio-physical constraints and possibilities at farm household level the following information is required from bio-technical disciplines:

- Potential and attainable production levels for various product groups on well-defined land units in the considered region; product groups are represented by: (a) single cropping, e.g. cassava, maize, and (b) intercropping, e.g. cassava/maize.
- Technologies related to attainable and potential yields; variation in agronomic methods, such as fertilizer use, soil and water conservation, pest and disease control, etc..
- Analysis of the reasons for yield gaps between potential and attainable and between attainable and actual yields for the various product groups.
- Worked-out concepts of the ways to sustain production potential: control of soil erosion and degradation and maintaining structure and depth of soils.
- Per livestock type, actual and potential technologies with related inputs and outputs.

To provide the above information, the bio-physical disciplines combine disciplinary knowledge into an extended Quantified Land Evaluation[6]. In the quantified land evaluation approach, a farming system is defined as a combination of different land use

[6] For more details on quantified land evaluation, see Driessen (1986, 1988), Diepen *et al.* (1989) and Lanen (1991).

systems, practised by one household on the basis of decisions made in response to physical factors, own priorities and external incentives.

A land use system is a combination of a land utilization type and a land unit. A land unit is an area that can be considered homogenous with regard to the defined land utilization type. A land utilization type is a collection of 'key attributes', i.e. biological and technical aspects of the production environment that are relevant to the production capacity of the land. Examples are: crop(s) grown, animals kept, utilization of inputs like implements, labour and fertilizer.

A land unit can be characterized from a 'supply' and a 'demand' point of view. From the supply side a land unit is described by a number of relevant characteristics which form together the land quality. The demand point of view is determined by the land utilization type (i.e. the crops that one wants to grow and the cropping techniques one wants to use). Fresco *et al.* (1990) define a land utilization type as a specific kind of land use under stipulated biophysical and socio-economic conditions (current or future), seen as a subsystem of a farm.

Quantified land evaluation matches land qualities with requirements. Not, as was and still is common practice in most land evaluation methods, through a simple rating system, but by using dynamic crop modelling. Only then an optimal matching between the varying requirements both in space and time and the varying qualities can be achieved. In this analysis the socio-economic attributes are tentatively considered exogenous and invariate.

Crop growth models are used to estimate yield potentials, in three steps: (1) unconstrained (potential) production without water and nutrient stress in a pest and disease free environment, (2) water-limited production and (3) water and nutrient-limited production. Modelling needs input data which are obtained from intensive surveys on representative farms with regard to land utilization and land utilization types with corresponding land qualities and land utilization requirements.

With the above quantified land evaluation analysis the following output is generated:

- a data base on land units with their land qualities;
- a data base on land utilization types (key attributes) with corresponding land utilization requirements;
- estimates of crop production on selected land utilization systems with specified (set) activities and inputs for the three hierarchical input levels;
- estimates of animal production on selected farms with specified (set) activities and inputs.

Multiple land utilization systems (more than one crop on a land unit at one time) will be handled by combining single - land utilization system analysis taking into account effects exerted on the crops by each other. To handle mixed farming systems an interfacing module, which describes the feedback mechanisms between on-farm primary and secondary production, will be used to link models for plant production with those for animal production. Use will be made of crop growth simulation models (e.g. Spitters *et al.* 1989) and livestock simulation models (Kingwell and Pannell 1987; Udo and Brouwer 1992). The cropping and livestock components of a farming system affect each other, both on the input as well as the output side and the interaction will be established by linking the crop growth and livestock simulation models.

Finally, the bio-physical disciplines will provide the data needed in the integration phase of the new methodology being developed, i.e. input data for a comprehensive farming system model. The comprehensive farming systems model is used to explore the bio-physical limits at farm household level as will be discussed in sub-section 2.3.3.

2.3.2 Analysis of the socio-economic components of farming systems

As Byerlee *et al.* (1982) point out, it is farmers, not fields, that make decisions, and therefore socio-economic criteria are just as important as land qualities and key attributes in determining farmers' activities. This implies that special attention will have to be given to both the socio-economic environment as well as to the decision making processes taking place within a household. The socio-economic environment can be split into three levels, the micro or household level, the meso or sectoral and regional level and the macro or national and international level. Variables that are exogenous at the micro level (prices) may be endogenous at higher levels (Hazell and Norton, 1986). For the methodologies to be developed knowledge at all three levels is required.

At the start of the project it was decided that to assess the socio-economic constraints and possibilities at farm household level, the following information is required from the socio-economic disciplines:

- A detailed input - output analysis of the farm activities being practised at present in the region and the constraints.
- A summary of the most important changes that have taken place in the past five years.
- The reasons why farmers introduced technological innovations.
- The way farmers received information about possible innovations (extension services, farmer meetings, radio).
- Objectives of the farmers and their priorities (profit maximization, risk minimization).
- The ways in which the farmers social and cultural environment (norms and values) influences their activities.
- Activities that are gender-specific.

- Information on the educational level of the farm household.
- Organisations of which the farmers are members.
- The gap between potential, attainable and actual production levels for the activities of the farmer and her/his household; and the socio-economic and technical explanation for these gaps.
- An indication of the stakeholders in agricultural development.
- Indications of demographic trends.

To gain a better understanding of the socio-economic structures of the micro level, the researchers developing QFSA decided - at the start of the project - to conduct an Intensive Farm Household Survey (IFHS), in which input/output data were collected for 36 selected farms, for both on-farm and off-farm activities. Surveys to gain information concerning rural households have been conducted very often, however, detailed surveys such as organised for the development of QFSA are rare. For the development of the new methodology, an IFHS as conducted by INRES was considered essential (for more details on the IFHS, see Chapter 3).

Decision-making processes within the household were also studied. These studies use results of in-depth interviews of farm households, mainly those of the last five years by considering important decisions that were made within the household before and during the IFHS. Special attention was given to decisions that involved technological innovations and for this purpose use was made of several existing theories on decision making (Barlett, 1980; Huijsman, 1986). An attempt was made to determine the reasons for the household to reach certain decisions, to identify information sources, to establish which decisions farmers are likely to take considering their objectives, and to determine which cultural factors govern these decisions. Information gained from the IFHS and the decision making analysis together with estimates on demographic developments are to be used to select, judge, and adapt the scenarios proposed by the technical disciplines (see subsection 2.3.1). This is a challenging task since socio-economic disciplines hitherto often limit their analysis to socio-economic changes in the rural society based on a comparison of the present situation with that of the past.

2.3.3 Linking the bio-physical and socio-economic components of farming systems

The information obtained from the analysis of the bio-physical and socio-economic components of farm household systems is used as input in a Farm household Level Optimal Resource Allocation (FLORA) procedure. The FLORA procedure encompasses the development of an Interactive Multiple Goal Linear Programming (IMGLP) model, named the FLORA model. This mathematical programming technique is considered more suitable than econometric modelling techniques to explore ultimate goals for research, taking into account technological innovations. With IMGLP various goals can be taken into account, and their trade-offs can be illustrated[7].

IMGLP involves a number of iteration cycles. During the first cycle the lower bounds of all the defined goal variables are set at their minimum requirements. Considering the constraints, the user will obtain a feasible solution that satisfies these minimum requirements. Each goal variable is then maximized on its own, with the lower bounds of the other goal variables defined as minimum restrictions. After the first cycle a situation may be reached where for each of the goal variables no better value may be obtained than the one calculated, and a value less favourable than the minimum goal variable restriction generated will be unacceptable. In continuing cycles, one or more goals may be tightened and the iteration cycles will be repeated for the other goal variables. The choice of the goal variables and the degree in which they are tightened will depend on the user and on his specific interest. In the course of tightening goal restrictions the solution space will be narrowed until it will not be possible to improve on any of the goals without sacrificing on any of the others. The opportunity cost of one goal variable can then be expressed in terms of the other goal variables. This provides the various stakeholders with a clear insight in the trade-offs between the different (and often conflicting) goal variables in a fixed economic environment.

The IMGLP technique facilitates interaction between researchers and representatives of stakeholder groups in agricultural development at farm household level. Examples of stakeholder groups are farmers and policy makers. Within these two main groups subgroups may exist, for example, small farmers and large farmers, policy makers responsible for the agricultural sector or for the financial situation of the region's administrative institutions. Representatives of these groups will be identified and with them the developer of the FLORA model will interact. The following 10 points describe how at various levels decision makers can be included in IMGLP:

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[7] The value of IMGLP for agricultural research is described by van Keulen (1992). For illustrations of its application on a regional basis one is referred to de Wit *et al.* (1988), Veeneklaas (1990), van Keulen and Veeneklaas (1992) and Rabbinge *et al.* (1994). However, IMGLP has so far not been used at the farm household level, within the context of farming systems analysis.

1 A vector of minimum goal values is presented to decision makers (farmers, policy makers), together with a set of potential improvements within the set of feasible solutions of these minimum goal values.
2 Decision makers are asked to indicate whether or not they find the solutions that meet minimum requirements satisfactory.
3 If not, the decision makers are asked to give an indication which minimum goal values will have to be increased.
4 On the basis of a new vector of minimum goal values, a new set of potential improvements of these values is calculated and presented to the decision makers.
5 As a result of the new vector of minimum goal values, there will be a shift in the indicated minimum goal values. The question will arise for the decision maker: is this shift outweighed by the shift in the potential values of the other goal variables?
6 If the shift is unacceptable, the decision maker gets the opportunity to revise earlier wishes with respect to the changed minimum goal value.
7 If the shift is acceptable the decision maker can continue to raise any of the other or even the same minimum goal value.
8 A reduction will take place in the set of feasible solutions, and the decision maker will have to decide whether or not to continue.
9 When the decision maker decides to stop, he can select a suitable solution from the set of solutions satisfying the minimum conditions. Each time a set of Pareto optimal solutions has been produced. One refers to a 'Pareto optimal solution' when it is impossible to improve welfare of one individual or group of individuals without reducing the welfare of another individual or group of individuals.
10 If the decision maker wishes, a set of feasible solutions satisfying the minimum conditions on the goal variables can be subjected to a second analysis.

The FLORA procedure shows how farm household systems could look like in a number of years seen against the background of the goals set for research of the various stakeholders in rural development. When going from the farm household level to the regional level, aggregation biases will occur, because not all farm households are alike. Hazell and Norton (1986, p. 143) state that ideally a model should be constructed for every individual farm, and all individual models linked together to form the sector model. Let the vector X_i^* denote the optimal solution to the i th farm model, then the optimal solution with exact aggregation to the sector model would be a simple aggregation of X_i^*. This is most times not feasible and it will be necessary to work on the basis of representative farm households.

2.4 Discussion

This chapter has discussed some of the shortcomings of FSA. The design of a new FSA methodology, namely QFSA, is described. QFSA makes use of research techniques that have previously not been combined within the context of FSA. These are quantified land evaluation, crop and livestock growth simulation models, farm household data collection, decision making analysis and linear programming techniques. The QFSA methodology is developed in the limestone area, south of Malang, East Java, Indonesia, making use of information collected at farm household level. The reason for designing QFSA is to overcome some of the problems of FSA.

QFSA is no panacea to rural development without taking into consideration influences from the regional level. QFSA primarily focuses on the farm household level, where variables that are affected by decisions at the regional or macro level (e.g. prices, subsidies, and taxes) are exogenous. It is, therefore, incorrect to aggregate, for example, farm level optimizations to the regional level without taking into consideration the behaviour of variables that are endogenous at higher levels. An aggregation from the farm to the regional level should take into account such an aggregation bias. However, if some of the problems mentioned in section 2.2 are solved, then FSA will have become a more objective and quantitative research tool.

This dissertation mainly concerns itself with the FLORA procedure. There are two reasons for describing the QFSA methodology in this chapter. First, QFSA forms the broader context within which the FLORA procedure was to be developed. Results that are generated by the FLORA procedure can be used in combination with the results that are generated by the other components of QFSA to determine goals for research, demonstrate trade-offs between goal variables and finally determine the research agenda itself. The procedure makes use of information that is generated during the analysis of the bio-physical and socio-economic components of farm household systems. Inevitably this places the procedure in a vulnerable and dependent position. Deviations from the design or problems that confront the development of QFSA effects the FLORA procedure. Secondly, the FLORA procedure is to contribute towards the objectives of QFSA to overcome some of the problems that confront FSA. In chapter 6 the development of the FLORA procedure is evaluated considering the design of QFSA and the role that the procedure played in overcoming some of the problems that face FSA.

3 The FLORA procedure: working method

3.1 Introduction

The design of the Quantitative Farming Systems Analysis methodology was described in the previous chapter. QFSA is a methodology that helps to explore options for development and to prioritize the research agenda through identification of the relative importance of various processes for the behaviour and results of a system. Particularly, when funds for agricultural research are scarce, the research agenda for the short and the medium term should - as much as possible - support the realization of long term research goals. Part of the QFSA methodology is the Farm household Optimal Resource Allocation (FLORA) procedure, with which long term goals for agricultural research can be established and trade-offs illustrated. This chapter describes the working method used to develop the FLORA procedure, which includes seven main steps (see Figure 3.1).
In Section 3.2 goal variables are identified representing three points of view, agro-technical, household socio-economic and environmental. Also three types of restrictions are distinguished, namely goals, normative and technical constraints. The system - defined in Section 3.3 - that the procedure focuses on is the farm household, albeit allowance is made for limited external links. The time horizon is determined in such a way that all crop and livestock activities that have been included in the activity matrix could - technically speaking - be realized by the end of the time horizon. To obtain the data requirements for the FLORA procedure, use is made of information derived from farm household surveys, a data base containing information concerning the climate in the research area, crop and livestock growth models, expert knowledge and literature (Section 3.4). The FLORA model is a multiple goal linear programming model and is used to derive feasible options for development (Section 3.5). The playing field is computed by iteratively optimizing each goal variable while the demands that are placed on the other goal variables are set at their lowest value. Ideal and anti-ideal values are obtained for the various goal variables by computing the playing field. The boundaries indicate to stakeholders at the farm household level the 'best' and the 'still acceptable' values that can be realized. This process is described in Section 3.6. Section 3.7 describes the different types of sensitivity analysis that are conducted with the FLORA procedure, and Section 3.8 does this for the scenarios. The working method of the FLORA procedure is summarized in Section 3.9.

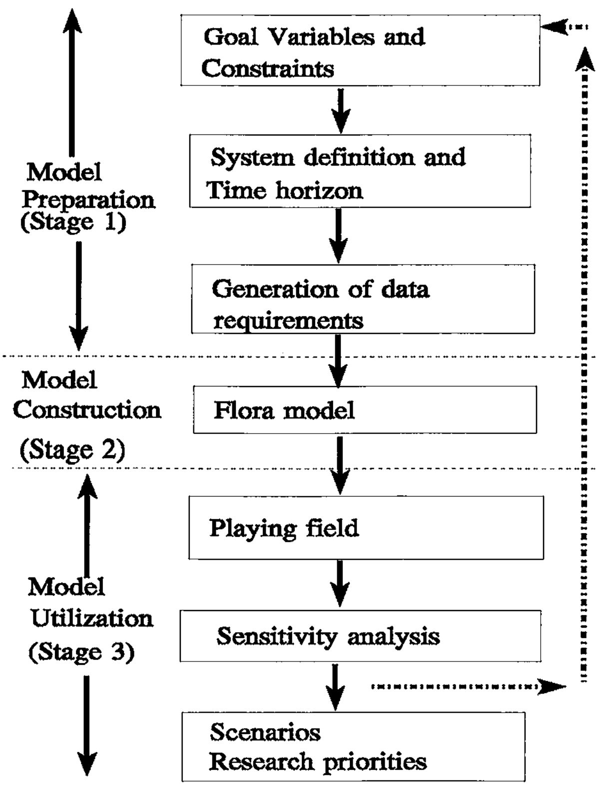

Figure 3.1: The FLORA procedure.

3.2 Goal variables, goals and constraints

Three categories of goal variables were included in the FLORA procedure (Table 3.1). Each goal variable is expressed in appropriate units. Each of these goal variables is briefly discussed.

Agro-technical goal variables The extent to which farm households in the research area will be able to produce food was explored with the agro-technical goal variables. This was done by optimizing per typical farm household (defined in Section 3.3) the production of: staples, pulses, fruit, and meat. Because different types of cropping activities were included in the study, it was necessary to work with a common denominator. For this purpose use was made of the energy per kg product.

Table 3.1: Goal variables included in the FLORA procedure.

Category	Goal variables	
Agro-technical	GV11	Staples
	GV12	Pulses
	GV13	Fruit
	GV14	Meat
Household socio-economic	GV21	Working capital
	GV22	Employment
	GV23	Income (un-specified)
	GV24	Income (specified)
Environmental	GV31	Nitrogen loss
	GV32	Biocide accumulations
	GV33	Soil loss

Household socio-economic goal variables For this category four ideal and anti-ideal values were calculated: minimization of working capital for the purchase of external inputs, including hired labour; minimization of labour utilization; maximization of gross margins, irrespective of the type of activity; and maximization of gross margins, while partly specifying the activity category from which the gross margins are to be generated. If access to credit facilities to finance working capital requirements is problematic or the available working capital is preferably invested in non-agricultural activities, certain minimum levels of production are to be realized with a minimum amount of working capital required for the purchase of external inputs. The extent to which working capital can be reduced was explored. Such minimum requirements will depend on pre-determined levels of staples, pulses and fruit production and gross margin generation from crop and livestock activities. Farm household self-sufficiency for staple, pulse and fruit requirements were included in this study as a strategic goal. Off-farm activities are expected to become more important in the future, limiting the time that will be available to meet household self-sufficiency requirements. The minimum amount of time required for self-sufficiency requirements was explored.

Gross margins from crop and livestock activities were maximized. The generation of gross margins from only one category of activities may involve a high risk. For example, if all land would be cultivated with cassava and the crop would be affected by a disease, or the price of cassava products would unexpectedly drop, this would drastically affect farm household income. It would, therefore, be wise to maximize the generation of gross margins from different categories of activities. The effect that such a diversification strategy has on the generation of the farm household gross margin was explored, by specifying that at least one third of the maximum production levels for staples, pulses and fruit had to be realized. The difference between the results obtained when gross margins are maximized compared to the situation where the activity category is specified is also an expression of the financial costs that have to be incurred in order to enjoy a less risky life.

Environmental goal variables Java is one of the most populated islands in the world. Especially in a situation where land is scarce and the demand for food production is still increasing, the negative effects of agriculture should be limited as much as possible. This is particularly the case for upland agricultural areas. Three side-effects of cropping activities were taken into consideration. Nitrogen loss (emission) per typical farm was minimized. Equally, biocide input (immission) per typical farm was minimized. Soil loss has generally been recognized as one of the major environmental problems caused by agriculture in the uplands of Java. Especially in the limestone area south-east of Malang, where land has already been eroded to such an extent that limestone outcrops can be observed, special attention for cropping practices which limit erosion as much as possible is essential. Therefore, soil loss per typical farm was minimized.

Goals These are demands that are imposed on the goal variables. They included demands placed on food production, gross margins and soil loss. Farm household self-sufficiency in staples, pulses and fruit was considered a strategic goal. Each household was assumed to consist of four people and three and a half times the per capita 1990 level of annual supply for consumption for staples, pulses and fruit was considered the absolute minimum level that would be required to meet household consumption. Data were derived from the 1989/1990 Food Balance Sheet for Indonesia. Gross margins generated from crop and livestock activities had to at least equal average farm household gross margins that were generated from crop and livestock activities in 1990/91. Soil loss may not exceed 10 $t.ha^{-1}.year^{-1}$ (Stroosnijder, 1994, personal communication). With the goals, sensitivity analysis was conducted.

Normative constraints (NCs) These constraints are ultimate limits to the ideal values of the various goal variables that were been included in the study. An example of such a constraint is the land area that is managed by members of the farm household. NCs were derived from policy objectives, expert knowledge or data collected during farm household surveys. Normative constraints that were taken into consideration are: (1) farm size, (2) farm household labour, (3) hired labour. With these constraints sensitivity analysis was conducted.

Technical constraints (TCs) These are constraints that technically limit the extent to which goal variables can be optimized. Technical constraints are determined by water availability, radiation and evapotranspiration. Such constraints determine the yield levels that can be obtained for cropping activities that have been included in the study. These constraints were not subjected to sensitivity analysis. Table 3.2 shows the constraints that were included in the study and the assumptions they were based on.

Table 3.2: Constraints that are taken into consideration.

Constraint	Assumption	Based on	Type[1]
Gross margin	Gross margin from crop and livestock activities should at least equal 1990/91 levels. 1990/91 farm gate prices were used.	Expanded Farm Household Survey and expert knowledge	G
Food production	Farm household annual minimum requirements for staples, pulses and fruit have to be met.	1989/1990 Food balance sheets for Indonesia	G
Farm size	Equal to average farm size per geographical unit. Proportional relation between land units is similar to the relationship that was found in each geographical unit.	Expanded Farm Household Survey	NC
Farm household labour	Three adults and one child	Objectives of the Indonesian government family planning policy	NC
Hired labour	Up to half the farm household labour	Exceeding this level might give management problems	NC
Soil loss	May not exceed 10 $ton.ha^{-1}$	Expert knowledge	G
Rainfall	Average rainfall data	van Loon and van Rheenen (1995)	TC
Radiation	Average radiation data	van Loon and van Rheenen (1995)	TC
Evapotranspiration	Average evapotranspiration data	van Loon and van Rheenen (1995)	TC

[1]G = goal; NC = normative constraint; TC = technical constraint.

3.3 System definition and time horizon

System definition The FLORA procedure focuses on the farm household system. Three sub-systems were included in the analysis, namely perennial, annual and livestock activities. Crop and livestock activities were linked via nutrient flows. For each geographical unit typical farm households were defined. A typical farm household was defined as having average land endowments and potential farm household labour availability. The proportional relation between land qualities was similar to that found among farm households in the research area which served as a case study for the development of the FLORA procedure.

External links Four types of external links were distinguished: (1) crop nutrient requirements, (2) hired labour, (3) livestock feed derived from outside the farm household system, and (4) hired draft power. Nutrients required for crop activities were either derived from manure or were purchased against 1990/91 prices. Labour requirements could be met either from the farm household or hired against 1990/91 wage rates. Livestock feed requirements could be met by on-farm feed production or off-farm feed resources. Draft power requirements for cropping activities could be met either by cattle present on-farm or hired against 1990/91 prices.

Time horizon Crop and livestock activities were included in the FLORA procedure that are at present not practised in the research area. It was necessary to determine at which time such activities could be adapted in the study area, i.e. a time horizon. The time horizon was set at 25 years, so that by 2020 all activities, technically speaking, could be adopted in the research area.

3.4 Data requirements

Data requirements for the FLORA model comprise three major components, (1) bio-physical aspects, (2) possible future crop and livestock activities and (3) characterisation of farm households in the research area. For a description of the bio-physical aspects attention was primarily focused on climate and land quality. Crop and livestock activities were identified making use of general knowledge of crop and livestock growth models and expert knowledge. For a characterization of farm households in the research area use was made of data collected during farm household surveys in the research area. These three components are not mutually exclusive, for example the bio-physical aspects also determine future crop activities and to a large extent livestock activities. Table 3.3 presents an overview of the various data collection efforts; their contribution towards the FLORA model is indicated.

Section 3.4 gives an indication of the type of data collected. The description is brief and only the type of data and source are given. Subsection 3.4.1 discusses the data collection conducted to describe the bio-physical aspects of the research area. Subsection 3.4.2 describes which possible crop and livestock activities were identified and their interaction in the FLORA model. Data collection used for the characterization of farm households in the research area is discussed in Subsection 3.4.3.

Table 3.3: Data collection and the contribution towards the FLORA procedure.

Subject	Data collection[1]	Contribution to FLORA
Climate	Primary and secondary	- Input for crop modelling
Land resources (qualitative)	Primary	- Input for crop modelling
Possible crop activities	Primary and secondary	- Input for the activity matrix
Possible livestock activities	Primary and secondary	- Input for the activity matrix
Farm households	Primary	- Access to resources land and labour per farm household - Deduction of farm household objectives - Description of the present situation - Deduction of normative assumptions

[1]Primary data: data collected by the project; secondary data: data from published sources.

3.4.1 Bio-physical aspects

Climate and weather Primary and secondary data were used to construct a climate profile for the research area. In the area two weather stations were established where radiation, air temperature, soil temperature, wind speed, relative humidity and rainfall were recorded. Climatic data were used as input for crop growth simulation models. A detailed description of the methodology is given by Widianto (1991).

Land Land being managed by farm households was classified into land unit (LU) classes. Driessen and Konijn (1992) define a land unit as internally uniform areas of land. It is irrelevant whether a tract of land is uniform in all aspects[8]. The question is whether variation that occurs affects the functioning of the land under the intended use. Attention was particularly focused on intended land use options, and for a definition of the LUs only bio-physical aspects were considered. Five land characteristics were used to determine the LU class: (1) soil depth, (2) soil texture, (3) slope, (4) terracing, and (5) site (Table 3.4).

Table 3.4: Land units and their associated characteristics.

Land unit	Land Characteristics
LU1	Very deep (>75 cm) clay soils on terraced, flat (3 % slope) valley bottoms
LU2	Very deep (>75 cm) clay soils on lower slopes (3 - 50 %), terraced in places
LU3	Deep (50 - 75 cm) slightly gravelly or stony heavy clay soils on upper slopes (15 - 20 %) slope, poorly terraced or not terraced
LU4	Shallow (< 25 cm), very gravelly or stony soils on steep slopes (>50 %), many rock outcrops, not terraced

Land managed by households that participated in the expanded farm household survey was investigated and land quality assessments were done.

3.4.2 Data sources used to identify possible crop and livestock activities.

Possible activities[9] were identified for crops, crop combinations and livestock. This section describes the procedures that were followed to define possible activities for crops and crop combinations, and the type and source of data for livestock activities. In the FLORA model crop and livestock activities are linked through feed and nutrient flows and draft power.

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8 For example: soil, vegetation, physiography, hydrology, climate/weather, infrastructure, etc.

9 An activity is defined as a set of inputs that are required to realize a certain level of outputs.

3.4.2.1 Crop activities

A selection was made of crops and crop combinations that were considered both suitable for the research area from an agronomic point of view and desirable considering farm household preferences. The steps that were followed are:
- production situations (PSs) were defined;
- production orientations (POs) were established;
- with the aid of literature data, crop expert consultations and crop growth models, outputs and inputs required to realize those outputs were calculated, and thus a target oriented approach was followed; and
- through an iterative procedure with crop experts the quality of the Input-Output (I-O) coefficients was improved. Each of these steps will be discussed below.

Production situations and orientations A production situation is determined by soil, rainfall, radiation and evapotranspiration. Crop growth is assumed to be affected only by the production situation. Four production situations were defined: potential (PS1), where crop growth will depend only on the prevailing radiation in the area; water-limited (PS2); water-and nutrient-limited (PS3); and water-limited and production is reduced by pest and diseases (PS4).

Production orientations determine the production aims which will depend on the goal variables that are included in the FLORA model. Two production orientations were defined:
- yield-oriented agriculture (YOA), where the production aim is to achieve the highest possible levels of output. YOA will take place in PS1 and PS2.
- low-input oriented agriculture (LIOA), where the aim is to achieve the highest levels of output, with restricted amounts of either nutrients and/or biocides per hectare. LIOA will take place in PS3 and PS4.

For LIOA two production aims were distinguished:
- to realize a production level that is equivalent to 60% of YOA under PS2 (PS3)[10]; and
- to realize crop production without the utilization of biocides (PS4). Nutrients required for crop production can be derived from either chemical fertilizers or manure.

Two sets of cropping activities were defined:
- mineral nutrient requirement is derived only from chemical fertilizers, and

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[10] This level of output was chosen because at this level a clear reduction in the efficiency of nitrogen utilization can be observed (Geus, 1967).

- mineral nutrient requirements are derived from manure as the main fertilizer and chemical fertilizers as additions. The required amounts of manure and chemical fertilizers are calculated by matching the nutrient demand of a cropping system with the concentration of nutrients in manure. The nutrient requirement that can be met with the smallest amount of manure determines the amount of manure that is supplied, while the remaining nutrients are supplied in the form of chemical fertilizers. The reason for choosing this level of manure gift was because supplying more manure meant wasting nutrients.

The following production technologies were distinguished:

- YOA with optimal moisture supply;
- YOA with natural moisture supply;
- LIOA with natural moisture supply and limited utilization of nutrients;
- LIOA with natural moisture supply and limited utilization of biocides.

The data collection exercise for crop activity I-O coefficients was yield target oriented. Labour requirements were based on task times. Both YOA and LIOA were assumed to be practised by applying *best technical means*, i.e. tradition, level of knowledge, layout of parcel and agro-business structure present no limitations. Consideration, however, was given to available farm equipment and size of parcel. The concept of best technical means implies that each input is applied optimally at a given production level (de Koning *et al.* 1995).

Formulation of guestimates I-O coefficients were derived through an iterative procedure. Initially an extensive review of literature took place for relevant crops and for specific questions crop experts were consulted. With the aid of crop growth models production levels were computed, nutrients and other requirements necessary to realize these output levels were calculated. This resulted in the formulation of I-O coefficients for 22 crop and crop combinations. Annex 3.1 presents the crops, supporting literature and crop growth models that were used.

Evaluation of I-O coefficients by a panel of experts Scientists with a proven record of expertise for a certain crop were asked to participate in a panel of crop experts (Annex 3.2). They were furnished with the theoretical background concerning the manner in which the I-O coefficients had been generated and requested to give an expert judgement. Their comments and suggestions were used to improve the coefficients which were then returned to the expert for screening. The process continued till the coefficients were considered as accurate as possible. Table 3.5 presents the two sets of I-O coefficients for maize on LU1 for the four production situations that were screened by the maize crop expert. Finally, an expert seminar took place to which all participating crop and erosion experts were invited. The way the FLORA model could be used was presented to the experts and remaining questions were addressed. Comments and suggestions made during this seminar were then utilized for a final revision of the I-O coefficients. Table 3.6 presents the I-O coefficients for maize on LU1 for the four production situations, with and without manure, as they were used in the FLORA model. The crop I-O coefficient quantification exercise resulted in the quantification of inputs and outputs for 572 crop activities. The type of inputs and outputs that were identified are reported in Annex 3.3. Van Loon and van Rheenen (1995) present a complete review of the crop activity I-O coefficients, as well as a summary of the main comments and suggestions that were given by the experts.

Table 3.5: The first and second sets of I-O coefficients for maize on land unit 1.

	First set				Second set			
Productions Situations:	1	2	3	4	1	2	3	4
Outputs: (dry matter)								
Storage organs (kg.ha^{-1})	9860	6500	3900	3250	9730	6400	3840	3200
Green parts (kg.ha^{-1})	8900	5400	3240	2700	2880	1500	900	750
Woody parts (kg.ha^{-1})	1820	1000	600	500	6140	4970	2982	2485
Roots (kg.ha^{-1})	270	240	144	120	1710	1860	1116	930
Environmental effects:								
Nitrogen loss (kg.ha^{-1})	32	31	27	28	31	32	29	30
Biocides accumulation (kg.ha^{-1})	5.3	4.5	4.5	0.0	2.1	1.3	1.3	0.0
Soil loss (t.ha^{-1})[(1)]	2.05	6.16	6.16	6.16	2.05	6.16	6.16	6.16
Inputs:								
Urea (kg.ha^{-1})	517	398	299	284	508	423	317	302
TSP (kg.ha^{-1})	144	115	69	0	133	112	67	0
BS (kg.ha^{-1})	0	0	0	345	0	0	0	341
KCl (kg.ha^{-1})	296	211	126	105	238	188	113	94
Fungicides (kg.ha^{-1})	12	10	10	0	4	2	2	0
Insecticides (kg.ha^{-1})	5	5	5	0	5	5	5	0
Seed (kg.ha^{-1})	15	15	13	12	15	15	13	12
Irrigation (cm)	12	0	0	0	12	0	0	0
Labour (md.ha^{-1})[(2)]	79	76	73	67	79	75	73	75
Draft power (cd.ha^{-1})[(2)]	18	18	18	18	18	18	18	18

[1]Data concerning erosion were screened by the erosion expert
[2]Labour and draft power are specified according to operation and month

Table 3.6: The I-O coefficients for maize on land unit 1 as they were used in the FLORA model.

	Without manure				With manure			
Production Situations:	1	2	3	4	1	2	3	4
Outputs: (dry matter)								
Storage organs (kg.ha^{-1})	9730	6400	3840	3072	9730	6400	3840	3072
Green parts (kg.ha^{-1})	2880	1500	900	720	2880	1500	900	720
Woody parts (kg.ha^{-1})	6140	4970	2982	2368	6140	4920	2982	2386
Roots (kg.ha^{-1})	1710	1860	1116	893	1710	1860	1116	893
Environmental effects:								
Nitrogen loss (kg.ha^{-1})	30	19	20	7	0	15	20	7
Biocides accumulation (kg.ha^{-1})	3	2	2	0	3	2	2	0
Soil loss (t.ha^{-1})$^{(1)}$	2.05	6.16	6.16	6.16	2.05	6.16	6.16	6.16
Inputs:								
Manure (kg.ha^{-1})	0	0	0	0	2507	1725	1338	828
Urea (kg.ha^{-1})	326	204	143	80	217	124	85	44
TSP (kg.ha^{-1})	76	52	41	0	0	0	0	0
KCl (kg.ha^{-1})	124	86	70	35	33	24	21	5
Fungicides (kg.ha^{-1})	4	2	2	0	4	2	2	0
Herbicides (kg.ha^{-1})	5	5	5	0	5	5	5	0
Seed (kg.ha^{-1})	15	15	13	12	15	15	13	12
Irrigation (cm)	12	0	0	0	12	0	0	0
Labour (md.ha^{-1})$^{(2)}$	55	48	42	40	60	52	46	43
Draft power (cd.ha^{-1})$^{(2)}$	18	18	18	18	18	18	18	18

[1]Data concerning erosion were screened by the erosion expert
[2]Labour and draft power are specified according to operation and month

3.4.2.2 Livestock activities

I-O coefficients were computed for cattle, sheep and goat activities. Existing livestock growth models, which have been adapted for the research area were used (Efdé, 1996). Three livestock production levels (LPLs) were defined: potential (LPL1), attainable (LPL2), and actual (LPL3). LPL1 is not determined by the type of feeds in the research area, or temporal feed availability, but rather by the maximum growth curve of the livestock species that are present in the research area. Feed inputs also included maize bran and soya bean cake. LPL2 was determined by two types of rations, which were determined by feeds that are available in the research area. However, the temporal availability - for the determination of the I-O coefficients - was not taken into consideration. For LPL3 the output was determined by two feed rations that were similar to those that were fed to livestock in the research area in 1991/92. These livestock production levels are computed for five livestock units (Table 3.7). A detailed description of the procedures that are followed to arrive at the I-O coefficients is reported by Efdé (1996). For each ration - excluding maize bran and soya bean cake - two source options were given: all feed was produced on-farm (FS1), and feed was partly produced on-farm and the required remainder originated off-farm (FS2). Labour requirements for FS1 are less than for FS2. Labour requirements for livestock activities are reported in Van Loon and van Rheenen (1995). As the livestock growth models were adapted for the research area, additional screening by livestock experts was unnecessary. Fifty two livestock activities are included in the FLORA model and the type of I-O coefficients that are quantified are summarized in Annex 3.3.

Table 3.7: Definitions of livestock units.

Cattle Unit 1 (CU1)	An adult cow, giving birth to a calf. The feed requirements for both the cow and the calf are computed.
Cattle Unit 2 (CU2)	An adult cow, producing draft power in the agricultural season and giving birth to a calf. The feed requirements for the growth of both the cow and the calf are computed.
Cattle Unit 3 (CU3)	An adult, non reproducing and non lactating cow, kept for meet production and producing draft power in the agricultural season.
Goat Unit (GU)	An adult goat, giving birth to a kid. The feed requirements of the growth of both the goat and the kid are computed.
Sheep Unit (SU)	An adult ewe, giving birth to a lamb. The feed requirements for the growth of both the ewe and the lamb are included.

Source: Efdé (1996).

3.4.2.3 Linkage between crop and livestock activities

Crop and livestock activities are linked via nutrient flows in two ways: (1) feed from crops consumed by livestock, and (2) nutrients excreted by livestock and utilized by crops.

Feed from crops, consumed by livestock For each cropping activity the output of the production per hectare of green parts that can be used as feed for livestock was computed (van Loon and van Rheenen, 1995). The temporal availability of green parts was also determined. Table 3.8 presents the temporal availability of fodder from the various crops that were included in the FLORA procedure.

Nutrients excreted by livestock, utilized by cropping activities For each livestock activity the production of manure was computed (Efdé, 1996). The nutrient requirements of cropping activities can be met from either the on-farm livestock produced nutrients or from chemical fertilizers purchased off-farm.

Traction power Traction power is one of the outputs produced by CU2 and CU3 and is required by a number of crops and crop combinations for land preparation. The required traction power may either be derived from on-farm or off-farm sources. In the latter case monetary inputs (taking 1990/91 prices) will be required.

Table 3.8: Fodder availability: 0 = not available, 1 = available, 3 = is never consumed by livestock.

	Month											
Crop	1	2	3	4	5	6	7	8	9	10	11	12
Maize	1	1	1	1	1	1	0	0	0	0	1	1
Cassava	1	1	1	1	1	1	1	0	1	1	1	1
Sugarcane	1	1	1	1	1	1	1	0	1	1	1	1
Upland rice	1	1	1	1	1	1	1	1	1	1	1	1
Paddy rice	1	1	1	1	1	1	1	1	1	1	1	1
Groundnut	1	1	1	1	1	1	0	0	0	0	1	1
Elephant grass	1	1	1	1	1	1	1	1	1	1	1	1
Native grass	1	1	1	1	1	1	1	1	1	1	1	1
Coconut	3	3	3	3	3	3	3	3	3	3	3	3
Melinjo	1	1	1	1	1	1	1	1	1	1	1	1
Kapok	1	1	1	1	1	1	1	1	1	1	1	1
Teak	3	3	3	3	3	3	3	3	3	3	3	3
Gliricidea	1	1	1	1	1	1	1	1	1	1	1	1
Fragrance	3	3	3	3	3	3	3	3	3	3	3	3
Banana	3	3	3	3	3	3	3	3	3	3	3	3
Common bean	1	1	0	0	0	0	0	0	0	0	1	1

3.4.3 Farm households

As part of a reconnaissance phase, a baseline survey or *sondeo* was carried out among 184 respondents spread out over four villages situated in different agro-ecological sub-regions in the southern uplands of the Malang district. On the basis of findings of this survey and general knowledge among the participating researchers, it was decided to concentrate further research efforts on farm households with medium sized farms that were involved in animal husbandry and were growing mainly the subsistence crops maize and cassava. This delimitation of farm households was in line with the FSR&D philosophy to concentrate on the so-called recommendation domains, homogenous groups of farmer households.

The farm households from the baseline survey served as a sample frame for the selection of 36 farm households living in two out of the original four villages. To obtain data on resource utilization, these farm households were monitored from October 1990 to February 1992 by means of an Intensive Farm Household Survey (IFHS). Apart from adding to a general understanding to resource allocation, on the basis on which a typology of farm households could be worked out, the collected data provided indications for the FLORA model concerning task times and prices. In the survey, each household was visited every six days by enumerators who recorded for each household member: activities performed, and for each activity: the operation that it involved, plots (if applicable), inputs and outputs, and expenditures. Frequent visits were considered necessary for accurate data recording. A coding system was designed on the basis of a structure developed by the FAO for the FARMAP farm management analysis system thus that all activities are entered in a simple and uniform manner (Moll, 1990). Fluctuations in household size and composition and the tenure status of livestock were recorded in resource files[11]. Data entry was carried out by graduate students and data checking by the research staff. The numerous visits although rarely exceeding one hour each time, allowed enumerators and also project staff to foster friendly relations with household members and to gain their confidence, thereby increasing the willingness of the latter to provide information. There were no refusals all along the survey. On the contrary, many farmers, some of whom were related to the enumerators, considered the visits social events. However, some farmers tended to preselect information, mentioning only some activities or plots, assuming that their other activities would not interest the researchers.

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11 For the computerized data storage and processing use was made of dBASEIV software package to remain in line with all other research activities in the project which also made use of this package.

Other farmers were quite aware of the fact that each additional plot or activity would entail a disproportionate increase in questions. Towards the end of the survey, there were signs of increasing boredom and confusion among respondents, also because it was not clear how long the exercise would continue. Several attempts were made to keep up morale, by organising an excursion, by handing out small presents, sugar and coffee as compensation for the drinks offered to project staff. Several goats were also donated to the two village communities as a whole on the occasion of the annual offering festival.

However, with time the lack of representativeness of the IFHS sample was considered more and more unacceptable. To make up for this deficiency a second so-called Expanded Farm Household Survey (EFHS) was conducted involving 149 households selected on the basis of clustered sampling in the same two villages. The EFHS consisted of two interview rounds on farm household activities[12] for 1990/91 and 1991/92 respectively, and one round of field measurements and land quality assessments. Most of the information required for the FLORA procedure was derived from the EFHS.

3.5 The FLORA model: selecting technique of analysis

Except for those studies that have only a descriptive aim, almost all studies that are conducted at farm household level have in common that they aim to contribute - one way or another - towards the well-being of farm household members. They also have in common that they are confronted with a multi-objective decision making environment. The approach and technique of analysis that is selected will depend on the purpose of a study. This Section discusses several approaches to multi-objective decision making which are summarized in Table 3.9.

Predictive planning The development of models at farm household level with a predictive aim, to date, has mainly been the domain of economists[13] It is especially in this discipline that a great deal of work has been done to develop theories with which households can be analysed in a theoretically consistent fashion. Chayanov was one of the first

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[12] Labour inputs were excluded.

[13] E.g. Lau *et al.* (1978); Barnum and Squire (1979); Kuroda and Yotopolous (1980); Rosenzweig (1980); Ahan *et al.* (1981); Adulavidhaya *et al.* (1984); Strauss (1986a&b); Singh and Janakiram (1986); Pitt and Rosenzweig (1986).

economists to present an analysis of farm households in the 1920s. Conclusions derived from his analysis were very much determined by demographic factors. Since then others

Table 3.9: Approaches to multi-objective decision making

	Requirement	Possible technique of analysis
Predictive planning	Predictable future (without intervention) and knowledge of the impact of intervention	Traditional econometrics; trend analysis
Conventional planning	Availability of a set of feasible plans; targets and specified loss if target are not met	Minimize expected loss; Minimize maximum loss
Optimization planning	Objectives instead of targets. Relative weights attached to objectives	Optimize objective function (e.g. by linear programming)
Compromise planning	Set of objectives but no a-priori dominance weighting scheme necessary. Interaction between decision maker and technician	Screening on Pareto (only efficient solutions are taken into consideration), selection among these efficient solutions, in pairs or otherwise. Satisficing (formulating acceptable values for each objective)

Source: Veeneklaas (1990)

have been inspired by his work, although there has been shift towards models that are based on the main features of the so-called New Home Economics. These are summarized by Ellis (1988, p. 123-124) as follows:

- The household, not the individual (unless the two coincide) is the relevant unit for analyzing utility maximization.

- Utility is not only, or even generally, derived directly from market commodities, it is obtained from the objects of final consumption (we shall call them 'use values') produced within the household.

- These use values are referred to in the theory as *Z*-goods to distinguish them from purchased commodities (*X*-goods), and hence the utility function takes the form:

$$U = f(Z_1, Z_2, Z_3, \ldots\ldots, Z_n) \tag{3.1}$$

- The production of Z-goods within the household requires inputs of household time as well as purchased goods and services, hence a major emphasis of the theory is on the time allocation of the household between Z-goods production and wage work.

- The household produces Z-goods from market inputs (x_i) and time spent on them (T_i), hence the home production function takes the form:

$$Z = f(x_i, T_i) \tag{3.2}$$

- The household maximises utility, not subject to a simple budget constraint, but subject to its production function, a total time constraint, and a money income constraint.

- The total time constraint (T) is given by the work time outside the household (T_w) and the sum of the times allocated to Z-good production (ΣT_i):

$$T = T_w + \sum T_i \tag{3.3}$$

- The money income constraint (Y) is determined by the market wage rate multiplied by the time allocated to wage work (wT_w). In equilibrium this money income must equal the value of x-goods (market commodities) used as inputs into the Z-good production ($\Sigma p_i x_i$), where p_i are the prices of the x-goods:

$$Y = wT_w = \sum p_i x_i \tag{3.4}$$

- By valuing all units of the household's time, T, at the market wage rate the time constraint and money income constraint can be collapsed into a single constraint, defined as the household 'full income' (F):

$$F = wT = w\sum T_i + \sum p_i x_i \tag{3.5}$$

- It can be shown, and is intuitively in keeping with micro-economic theory, that the equilibrium of the household occurs where the ratio of marginal utilities of any pair of Z-goods (the marginal rate of substitution between them) equals the ratio of their full marginal cost of production (MC_i/MC_j). Here the full marginal cost of any Z-good, say Z_i, is the sum of, *first*, the wage rate multiplied by the marginal product of the household time allocated to its production, and, *second*, the market prices multiplied by the marginal products of the market commodities used in its production.

Why this great interest in farm household modelling with predictive aims and in which way did the developers of these models envisage that they could contribute towards the welfare of farm households? Singh *et al.* (1988, p. 4-6) state that agricultural household models would enable the analyst to examine the consequences of policy in three dimensions:

- the effects of alternative policies on the wellbeing of representative households (eg. income or nutritional status);
- an understanding of the behaviour of the agricultural households would shed light on the spill-over effects of government policies on other segments of the rural population; and
- governments are interested in the performance of the agricultural sector from a more macro-economic perspective.

Clearly these models are all very much policy-oriented. Without doubt, the well-being of agricultural households is to a large extent determined by policy makers. Understanding a household's economic behaviour is not only a matter of intellectual challenge, but also a prerequisite for the evaluation of policy reforms (Kooreman, 1986). However, the potential role that new technologies can play in the well-being of households will not always become apparent with the aid of these models.

In predictive, multi-objective decision making studies at farm household level, the functioning of the system at present and in the past is analyzed, and on that basis observed trends are extrapolated into the future. There are three major reasons why techniques of analysis supporting predictive planning were considered inappropriate for the FLORA procedure:

- While predictions that one makes for the near future may seem reasonably trustworthy, those that are made for longer periods become increasingly unreliable. It is generally recognized that there is only limited knowledge in the working of factors that determine the dynamics of the economic process. Taking this into consideration, great care is warranted when using models in which behaviour of economic actors are specified in great detail (Van Eijk *et al.*, 1986).
- It is possible that certain present behavioral patterns need change in the future. Thus it is doubtful whether predictive farm household models are the most appropriate tools to analyse the potential role of new options. For example, the introduction of high yielding rice varieties in an area where so-far farmers have preferred to rear cattle.
- Knowledge of the impact of certain interventions - agro-technical or socio-economic - is often lacking and consequently difficult to predict with any degree of certainty.

Conventional planning A necessary condition for conventional planning is the existence of a set of feasible plans. When these are available it is possible to compute certain targets as well as the losses when these targets are not met. Such a planning procedure is possibly appropriate when a system is confronted with a limited number of feasible solutions. However, when there are many feasible solutions and several stakeholders this type of planning becomes time-consuming and inflexible. It also will be difficult to show the trade-off effects between different objectives that are being optimized. The search for a solution in an iterative and interactive (modeller with stakeholders) manner, which can be considered a suitable approach to identify a compromise is difficult with conventional planning.

Optimization planning Objectives rather than targets are the focus of this planning approach. *A priori* knowledge is assumed of the weighting that should be attached to objectives. When farm household systems are being considered from different points of view (agro-technical, environmental and household socio-economic), optimization planning is not really suitable because the weighting that should accompany the objectives is not necessarily known in advance. The weighting that is given to different objectives may depend on knowledge of the optimized values of the individual objectives. In other words, certain stakeholder threshold values may vary, depending on the values in which certain goals are achieved. These threshold values are not always known in advance.

Compromise planning With this type of planning a set of objectives is taken into consideration. However, no *a priori* dominance weighting scheme is necessary. This provides flexibility which can be utilized for interaction between the modeller and stakeholder(s). Because of conflicting objectives at farm household level, and likely compromises in goals for development, the compromise type of planning was considered most appropriate for the FLORA procedure. A suitable and frequently used technique of analysis for such planning is Interactive Multiple Goal Linear Programming (IMGLP)[14]. Due to institutional problems, however, the FLORA model was not used in an interactive manner with stakeholders in rural development. As required for the IMGLP technique a playing field (or potency matrix) was computed. A number of sensitivity analyses were conducted to illustrate how the model can be used to analyze trade-offs between goal variables and for three scenarios efficient solutions were computed. A condensed version of the FLORA model is presented in Annex 3.4.

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[14] Examples of such studies, albeit not at farm level, are Veeneklaas (1990); De Wit *et al.* (1988); WRR (1987); Rabbinge *et al.* (1994).

3.6 The playing field

In Section 3.2, goal variables were identified considering agro-technical, household socio-economic and environmental points of view. The technique of analysis selected for the FLORA procedure - as described in Section 3.5 - was multiple goal linear programming (MGLP). An iteration cycle with MGLP encompasses the iterative optimization of each goal variable. During the first iteration cycle, each goal variable was optimized and the goals on the other goal variables were set at their lowest values. After the first iteration cycle, for each goal variable the ideal and anti-ideal values were computed. The combination of the ideal and anti-ideal values for each goal variable were defined as the playing field. Table 3.10 summarizes the optimizations when computing the playing field.

Table 3.10: Optimizations and demands[1] placed on goal variables (GV) when computing the playing field.

Goal variable	GV11	GV12	GV13	GV14	GV21	GV22	GV23	GV24	GV31	GV32	GV33
Staples (GV11)	MAX	G	G	G	G	G	G	G	G	G	G
Pulses (GV12)	G	MAX	G	G	G	G	G	G	G	G	G
Fruit (GV13)	G	G	MAX	G	G	G	G	G	G	G	G
Meat (GV14)	U	U	U	MAX	U	U	U	U	U	U	U
Monetary input (GV21)	U	U	U	U	MIN	U	U	U	U	U	U
Employment (GV22)	U	U	U	U	U	MIN	U	U	U	U	U
Gross margin (GV23/24)	G	G	G	G	G	G	MAX	MAX	G	G	G
Nitrogen loss (GV31)	U	U	U	U	U	U	U	U	MIN	U	U
Biocides accumulation (GV32)	U	U	U	U	U	U	U	U	U	MIN	U
Soil loss (GV33)	L	L	L	L	L	L	L	L	L	L	MIN

[1]G = Greater than or equal to a predetermined value
L = Less than or equal to a pre-determined value
U = Unconstrained
Max = Maximize
Min = Minimize

Once the playing field has been computed, it can be presented to stakeholders in rural development at farm household level. The playing field indicates the ultimate goals for research considering different points of view in a situation where there has been no compromise yet. This information can serve as a starting point for negotiations. Each stakeholder representative is now aware of the 'best' (ideal value) and the 'least acceptable' (anti-ideal value) result that he can realize for each goal variable.

3.7 Sensitivity analysis

When determining the playing field a number of arbitrary choices and assumptions were made concerning goals and constraints. This section describes how the sensitivity of these choices and assumptions was tested. These tests included the relation between the gross margin generating capacity and the factors of production working capital, land and labour, as well as the relation between the area of land and the consumption requirements for staples, pulses and fruit products.

Gross margins and working capital The financing of smallholder production has attracted the attention of policy makers for a variety of reasons (Von Pischke, 1981). In Indonesia, this attention resulted initially in massive government interventions in rural financial markets through programmes such as BIMAS[15], KIK[16], and KMKP[17]. Later the limited effectiveness of these programmes became apparent and contributed to a change in policy towards financial liberalization (Schmidt, 1991). Although the debate on market failure versus government failure regarding rural financial markets is outside the scope of this study, the importance of external finance for smallholders' production was analysed with the FLORA model. In the sensitivity analysis the effect of access to external finance on the composition of activities and income was assessed in two situations:

- Situation A: The farmer has no access to external finance for the purchase of inputs and is thus totally dependent on own financing; and
- Situation B: the farmer has unlimited access to external finance for the purchase of inputs, but external financing results in additional costs.

Gross margins and land area One of the basic factors of production for every farming system is land. When computing the playing field average land resource endowments are assumed for typical farm household systems. In the sensitivity analysis that is presented in Chapter 5 land resource endowments were increased in steps of 0.25 ha from 0 ha to 2.25 ha. The proportional relation between the four land units was maintained when land size was increased.

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[15] BIMAS stands for *Bimbingan Masal* or mass guidance.

[16] KIK stands for *Kredit Investasi Kecil* or small investment credit.

[17] KMKP stands for *Kredit Modal Kerja Permanen or working capital credit.*

Gross margins and soil loss For each typical farm household the effect of a change in the soil loss restriction on farm household gross margins was made explicit. This was done by changing the permitted level of soil loss per typical farm from 0 ton to 20 tons in steps of 2 tons. This implied that for each additional step a typical farm in Putukrejo could lose an extra 2.78 $t.ha^{-1}$, in Kedunglor 2.30 $t.ha^{-1}$ and in Kedungkidul 1.72 $t.ha^{-1}$.

Gross margins and potential labour availability Potential labour availability per typical farm household was assumed not to exceed three labour units. In the sensitivity analysis the effect of varying the potential labour availability on the gross margin generated from crop and livestock activities was analysed. This was done by varying the potential labour availability from 0 to 6 labour units in 12 equal steps.

Partial[18] *diet requirements and land area* The activity matrix of the FLORA model contains crop and livestock activities. As described above for the crop activities two production orientations were taken into consideration, namely YOA and LIOA. The relation was established between land area and supportable number of persons for whom 1990/91 consumption levels of staples, pulses and fruit can be met. The following steps were taken:

- the annual consumption levels of staples, pulses and fruit per person were determined,
- for YOA, and
- for LIOA the area of land that would be required to meet 1990/91 consumption levels of staples, pulses and fruit was computed per typical farm in steps of 5 adults.

3.8 Scenarios

A scenario was defined as an 'end-vision' considering the goal variable that is being optimized as part of an underlying point of view. Three scenarios were constructed considering three points of view: agro-technical, household socio-economic and environmental. Table 3.11 describes briefly the scenarios.

[18] Partial because only consideration is given to staples, pulses and fruit.

Table 3.11: Scenarios constructed in this study

Scenario	Point of view	Description
A: Food production	Agro-technical	Each typical farm household should produce the 1990 level of per capita daily supply of energy from staples, pulses and fruit for at least 4 households.
B: Income generation	Household socio-economic	Each typical farm household strives to maximize income from crop and livestock activities.
C: Soil conservation	Environmental	Each typical farm household strives to maximize income from crop and livestock activities, under environmental restrictions.

A-Scenario: Food production It is assumed here that in 2020 in Indonesia only 25 % of the population will take part in agricultural production, which would be a considerable decrease from the estimated 48 % in 1990 (ILO, 1994). This conforms with the trend commonly observed when economies develop, i.e. the percentage of the population active in crop and livestock production decreases. Assuming national self-sufficiency in food, each farm household will have to produce enough staples, pulses and fruit for four households. To quantify the levels of production that each farm household should produce, the 1990 per capita supply for consumption of staples, pulses and fruit were used. Assuming that each household consists of four people, then each farm household of the 25 % of the population engaged in agriculture would have to produce for 16 people, including the farm household. There are several ways in which this goal can be realized. In the A-scenario, three variants were constructed, each for YOA and LIOA:

- achieving the goal without the utilization of manure and with as little land as possible,
- achieving the goal with manure and mineral fertilizers, and as little working capital as possible, and
- achieving the goal with manure and mineral fertilizers, and as little labour as possible. These variants are summarized in Table 3.12.

Table 3.12: Variants computed for the food production scenario.

Variant	Characteristics
All variants	- Farm households produce 16 times the 1990 level of per capita supply of staples, pulses and fruit - All other goals and constraints taken into consideration when computing the playing field are valid, except the gross margin goal
YOA-A1	- *Objective:* utilization of as little land as possible - No manure is utilized - YOA is assumed
YOA-A2	- *Objective:* utilization of as little working capital as possible - Both manure and mineral fertilizers are utilized - YOA is assumed
YOA-A3	- *Objective:* utilization of as little labour as possible - Both manure and mineral fertilizers are utilized - YOA is assumed
LIOA-A1	- *Objective:* utilization of as little land as possible - No manure is utilized - LIOA is assumed
LIOA-A2	- *Objective:* utilization of as little working capital as possible - Both manure and mineral fertilizers are utilized - LIOA is assumed
LIOA-A3	- *Objective:* utilization of as little labour as possible - Both manure and mineral fertilizers are utilized - LIOA is assumed

If one is interested only in the goal variable which is optimized, then it is sufficient to execute only one optimization. If one is also interested in the efficient values of other goal variables and one of them is not in a Pareto Optimal situation, then it will not be sufficient to conduct only one optimization. For example, if in the YOA-A2 variant, manure requirements could be met by one cow or four goats, or a combination, each would require different levels of labour. By only minimizing the working capital goal variable the computed level of labour need not be the minimum level. For this reason a stepwise Optimization According to Priority (OAP) procedure was followed. This procedure is similar to Lexicographic Goal Programming (Romero and Rehman, 1989). With the OAP the optimized values of the previous optimization cycle was included in the

Table 3.13: Priorities accorded to goal variables under different variants.

	Scenario variants		
Goal variable	YOA-A1 LIOA-A1	YOA-A2 LIOA-A2	YOA-A3 LIOA-A3
Working capital	2	1	2
Labour	3	2	1
Land area	1	3	3
Gross margins	4	4	4
N-loss	4	4	4
Biocide accumulation	4	4	4
Erosion	4	4	4

next optimization cycle as a constraint that had to be met. Hence, the goal variable that is last to be optimized is given the lowest priority. The order of priority that was accorded to the goal variables is presented in Table 3.13. Once the gross margin goal variable is optimized, no further optimizations are required, because then a Pareto Optimal solution is obtained.

B-Scenario: Income generation scenario It is assumed here that the objective of farm households is to maximize the gross margin they can generate from crop and livestock activities. A further assumption is that the available farm household labour for crop and livestock activities will not exceed 65 % of the potential labour availability. The other 35 % is assumed to be available for off-farm labour opportunities. The number of cattle, goat and sheep that a farm household can rear is restricted, because it is not known how much off-farm fodder will be available. When computing the playing field livestock production is constrained by the potentially available farm household and hired labour. The extent to which farm households will be able to generate gross margins from crop and livestock activities is explored for both YOA and LIOA. As the gross margin goal variable is accorded the highest priority, it is not necessary to use the OAP procedure. Table 3.14 reports the characteristics of the variants that were computed for the B-Scenario.

C-Scenario: Soil conservation scenario It is assumed here that in the long-run it will be advisable to stop cropping activities on land units 3 and 4. Due to their slopes these land units are the most vulnerable for soil loss. A further assumption is that farm households will attempt to maximize income generation from crop and livestock activities. As was the case in B-Scenario the assumption is that farm households will use only 65 % of the potentially available farm household labour and the number of cattle, goat and sheep that may be reared is restricted. The extent to which farm households are able to generate income from crop and livestock activities is explored for both YOA and LIOA. Table 3.15 summarises the variants that were computed for the C-Scenario.

Table 3.14: Variants computed for the income generation scenario.

Variant	Characteristics
All variants	- Assumption: 65 % of the potentially available farm household labour is available for crop and livestock activities - Assumption: households may rear no more than 2 cattle, 3 goats and 3 sheep - All other goals and constraints taken into consideration when computing the playing field are valid, except the gross margin goal
YOA-B	- *Objective:* maximize gross margins from crop and livestock activities YOA is assumed
LIOA-B	- *Objective:* maximize gross margins from crop and livestock activities LIOA is assumed

Table 3.15: Variants computed for the soil conservation scenario.

Variant	Characteristics
All variants	- Assumption: 65 % of the potentially available farm household labour is available for crop and livestock activities - Assumption: households may rear no more than 2 cattle, 3 goats and 3 sheep - Assumption: no crops are cultivated on land units 3 and 4 - All other goals and constraints taken into consideration when computing the playing field are valid, except the gross margin goal
YOA-C	- *Objective:* maximize gross margins from crop and livestock activities YOA is assumed
LIOA-C	- *Objective:* maximize gross margins from crop and livestock activities LIOA is assumed

3.9 Summary

This chapter described the working method followed to develop the FLORA procedure. The seven steps that were included can be divided into three stages: model preparation, construction, and utilization. The steps that belong to the model preparation stage are: (1) goal variable definition and constraint determination, (2) system definition and time horizon determination, and (3) generation of data requirements. Information collected during this stage is used in the second stage, the construction of the FLORA model. During this stage use is made of the MGLP technique of analysis. MGLP is selected because the FLORA procedure is developed to explore long term goals for research within the context of QFSA. The technique of analysis that was selected can be used to explore the potential role that new technologies can play in the future, and at the same time MGLP facilitates the interaction between researcher and stakeholders in rural development. The third stage of the FLORA procedure is the utilization of the FLORA model and includes the following steps: (1) computing the playing field, (2) conducting sensitivity analysis, and (3) constructing scenarios. The playing field includes for each goal variable the ideal and anti-ideal values. These values when presented to stakeholders in rural development make them aware of the 'best' and 'worst' values that can be realized for the goal variables included in the procedure. During the first stage of the FLORA procedure several assumptions were made. To test the sensitivity of the model outcome for these assumptions sensitivity analyses were executed. Three scenarios were constructed, focusing on: (1) food production, (2) income generation and (3) a soil conservation.

The procedure described in this chapter has no predictive pretention, it does have predictive significance. Considering agro-technical, household socio-economic and environmental points of view, long term goals for research are made explicit and trade-offs between goal variables analysed. In that sense the procedure can be seen as a first stage of a planning procedure. Once a goal for research has been decided upon, the next step will be to determine the development path that will lead to the realization of the selected goal.

In Chapter 2 the design of QFSA was explained. The working method for the FLORA procedure - as described in this chapter - deviates from the original design. This is particularly the case for the manner that data requirements were met for the FLORA model and the interaction with stakeholders in rural development. Chapter 6 evaluates those deviations.

4 Farm household systems in the study area

4.1 Introduction

The FLORA procedure - described in Chapter 3 - explores options for farm household systems. Many of the required data are therefore site and area specific. The study area that was selected for the development of quantitative farming systems analysis is situated in the limestone area south of Malang, East Java, Indonesia (Figure 4.1). This area was selected because farm households in the study area are confronted with relatively low incomes, low crop productivity and high levels of soil erosion. Both the government and the University of Brawijaya share efforts to improve the welfare of farm households in the area. Options for development were explored concerning possibilities within a time span of 25 years. This chapter characterizes the situation as it was in 1990/91, describing the study area in general and particularly focusing on farm household resources and activities.

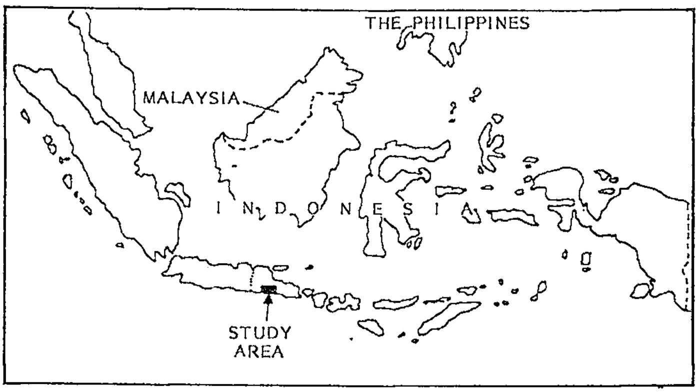

Figure 4.1: Location of the study area.

4.2 The setting

For the development of QFSA, farm households were selected in two villages, Putukrejo and Kedungsalam, both situated south-east of Malang (Figure 4.2). Selection criteria

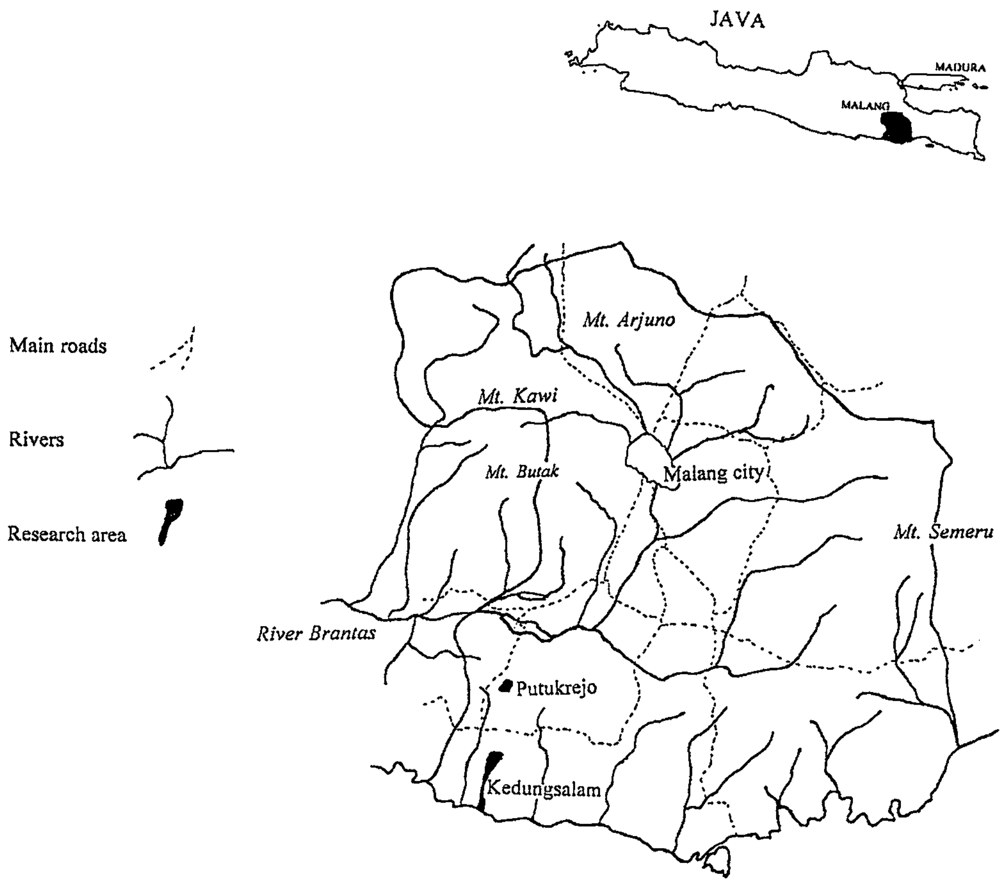

Figure 4.2: Map of the Malang area, East Java.

were discussed in Chapter 3. Mainly on the basis of land quality the two villages were divided into three geographical units: Putukrejo, Kedunglor (= north Kedungsalam), and Kedungkidul (south Kedungsalam). The village of Putukrejo is situated on the most elevated part of the limestone range at an altitude of 500 m above see level with relatively deep soils. For Kedungsalam the altitude ranges from 0 metres to 400 metres and soil depths are shallow to medium deep. The population of Kedungsalam (10,091) is almost three times that of Putukrejo (3,922). However, as Kedungsalam is more endowed with land than Putukrejo (33.6 km^2 against 7.5 km^2), population density per km^2 is considerably lower (300 against 523 people/km^2) (Sensus Penduduk, 1990).

Upland farming - which is defined by Nibbering (1991, p. 16) as: 'dry farming with predominantly annual crop systems' - is common in the study area. In Java, this type of farming mainly takes place in the hilly or mountainous regions and is different from the type of farming that is commonly practised in the lowlands (<500 m), where the cultivation of wet rice predominates. The three most common farming systems that can be distinguished in upland farming are: *tegalan* farming, or permanent dry farming; *kebonan* farming, or agro-forestry farming; and highland horticulture. Tegalan and kebonan farming takes place in the uplands of moderate elevation up to 1000 - 1200 m. Palte (1989, p. 215 and 216) conducted an extensive study concerning the development of upland farming in Central and East Java and part of his epilogue is quoted here because it is also applicable to the study area:

> 'Upland cultivation and settlement started in central and east Java when people from the overcrowded lowland areas sought to avoid the pressure caused by the growing population and by the feudal and colonial levies. The latter reason was probably more important in the early 19th century, whereas later on it was particularly the population pressure that motivated the lowlanders to move to the empty hills and the mountain ranges. The migration to the uplands resulted in the clearing and settlement of the extensive wastelands. As long as land was plentiful, the upland farmers practised a three to four year fallow system. For the peasants who originated from the lowland villages, this extensive type of farming constituted a radical change from the intensive sawah cultivation.
>
> When the possibilities to clear new land had come to an end, and population growth in the upland caused pressure on the local agricultural resource base as well, a number of adaptive processes took place. These included: the change to permanent dry field cultivation, the application of farm-yard manure (whereby livestock is kept in the yard), the adoption of soil conservation measures (e.g. terracing, interculture), the substitution of staple crops with higher energy values, the recourse to commercial cultivation, and - more recently - the use of mineral fertilizers. Some of these actions were widespread, whereas other responses were adopted only locally; not all changes happened everywhere at the same time or to the same degree, nor have they come to an end. As a result of the

variations in development trajectories, three major upland farming systems evolved. These are: (1) the permanent cultivation of arable crops (especially of staple food on dry fields, usually at low stagnant production level); (2) the various types of agro-forestry, in particular mixed gardening; and (3) in some favourable highlands, the horticulture of vegetablés of the temperate climates.'

In the study area five land use systems were distinguished:
- *tegalan* (type 1), mainly non irrigated land, where trees are distributed very sparsely or are not present at all;
- *tegalan* (type 2), where trees can be found along the field edges, terrace rims or randomly distributed;
- *kebonan*, multistorey land use systems;
- woodlands; and
- *bongkor*, where land is not used for agricultural purposes, and is either not suitable for agriculture (e.g. because soils are too shallow) or is left fallow to regain fertility.

Table 4.1 presents the differences that were observed in the study area. In Putukrejo and Kedunglor *tegalan* (type 2) is the most common land use system and in Kedungkidul almost half of the land is not used for agriculture, which is almost as much as the percentage of land that was classified as LU4. In Putukrejo no land is utilized for wood production and in Kedungkidul this is 7 %. This indicates that as farms are less well endowed with land of good quality, they will be more inclined to cultivate crops for wood production.

Table 4.1: Land use systems in the study area, 1992, expressed as percentage of farm area.

Land use system	Putukrejo	Kedunglor	Kedungkidul	Study area
Tegalan (type 1)	41	12	6	17
Tegalan (type 2)	50	52	29	43
Multi-story systems	9	12	9	10
Woodlands	0	3	7	4
Bongkor	0	21	48	26
Total	100	100	100	100

Source: INRES EFHS Data Base (File: Ardes).

4.3 Climate

The Malang study area is located between 8°15 to 8°25 S and 112°25 and 112°30 E. The climatic pattern is mainly determined by the tropical monsoon circulation, which divides a year into two main seasons - dry and wet - with short transitional periods between them. The dry season lasts from June to September and the wet season from November to April. Data that was used to construct the rainfall profile for the study area was mainly derived from measurements as they were taken in Pagak from 1960 to 1990. Measurements concerning rainfall that were taken in Kedungsalam for a period of 10 months indicated that the study area, as far as rainfall is concerned, is similar to Pagak. Annual rainfall varies from 1130 mm to 2700 mm, with an average of 62 to 147 rainy days. Both rainfall (Figure 4.3) and the number of rainy days show a great deal of variation (cv for the former = 0.23; cv for the latter = 0.25). For more details on climate in the study area see Annex 4.1.

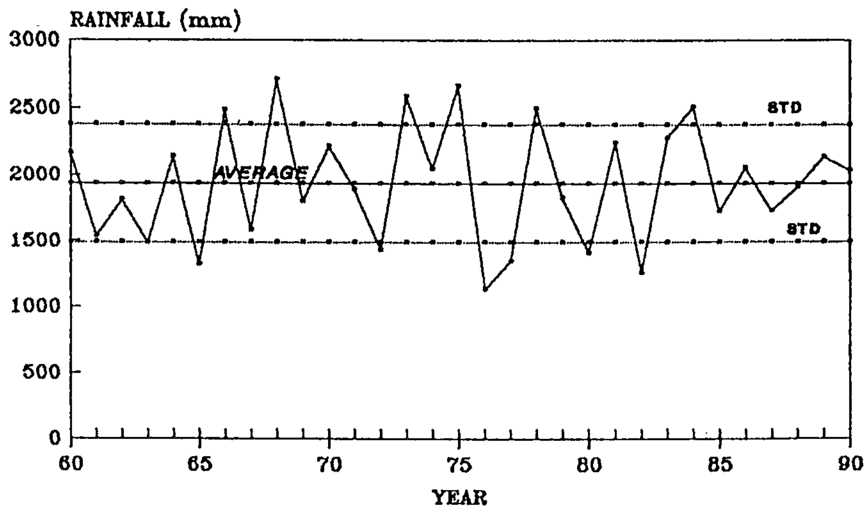

Figure 4.3: Average annual rainfall in Pagak, 1960 - 1990. Source: Widianto (1991).

4.4 Farm household resources

4.4.1 Land

The Malang study area is hilly to mountainous and consists of volcanic deposits of the early miocene age over limestone bedrock. Slopes vary from relatively flat to very steep and soil loss has occurred - partly as a result of human exploitation - for a long time at various degrees of severity, resulting in soil erosion due to water run-off. Soil materials were deposited in the valley bottoms resulting in deep soils (> 75 cm), with a structure that can be described as heavy clay. The fertility status of the soil is homogeneous, and is

Table 4.2: Distribution of the landholding size for the geographical units in the Malang study area, October 1990 to October 1991.

Farm size (ha)	Putukrejo	Kedunglor	Kedungkidul	Study area
No land	5	1	0	6
0.01 - 0.25	5	7	3	15
0.26 - 0.50	14	11	7	32
0.51 - 0.75	9	10	5	24
0.76 - 1.00	6	9	7	22
1.01 - 1.25	2	10	4	16
1.26 - 1.50	0	3	5	8
1.51 - 1.75	1	1	3	5
1.76 - 2.00	2	2	2	6
> 2.00	5	3	7	15
Total	49	57	43	149
Average (ha)	0.72	0.87	1.16	0.90

Source: INRES EFHS Data Base (File: Ardes).
Note: Plots for which there were no measurements, estimates were made.

characterized by a low organic matter content in the top soil (1 - 2 %), low nitrogen and phosphorous content, but medium to high cation content (K, Ca and Mg), high cation exchange and a neutral pH.

The average farm size in the study area is 0.90 ha (Table 4.2). In Kedungkidul the average farm size is largest (=1.16 ha), while in Putukrejo it is smallest = 0.72 ha). The majority of farm households is smaller than 1.25 ha.: For Kedungkidul 51 % and Putukrejo 80%. For the study area as a whole 67 % of the households has a farm still smaller than 1.25 ha.

LU1 (see Table 3.4) is most suitable for arable farming, while LU4 is least suitable. Table 4.3 shows that when going from north to south (i.e. from Putukrejo to Kedungkidul) farmers are less well endowed with land of good quality. In Putukrejo 95 % of the land belongs to LU1 and LU2, while in Kedungkidul this is only 25 %.

Table 4.3: Distribution of land according to land quality for the geographical units in the Malang study area, October 1990 to October 1991.

	Land Units				Total	
Geographical units	LU1	LU2	LU3	LU4	%	ha
Putukrejo	12	83	4	1	100	35.46
Kedunglor	25	35	26	14	100	49.47
Kedungkidul	10	15	26	49	100	49.76
Study area	16	40	20	24	100	134.69

Source: INRES EFHS Data Base (File: Ardes).

4.4.2 Labour

Farm households often include the core family, grandparents and grandchildren. More than a quarter of the households in Kedungkidul included grandparents and up to 40 % of the households included grandchildren. In Kedunglor and Kedungkidul, more households were headed by young couples than in Putukrejo, possibly because in the former two geographical units it is relatively easier for young couples to start their own household than it is in Putukrejo. In Putukrejo, the land is of better quality and the demand for land is higher. The average household size for the study area as a whole is 4.3 (Table 4.4). Average labour units[19] (LAU) per household (HH) were highest for Kedunglor (3.6) and

[19] Labour Unit is equivalent to one adult worker and is defined as persons between the age of 16 and 59 years old. Children from 10 to 15 years old and persons above the age of 59 are assigned a value of 0.5 LAU. Children below the age of 10 are not considered as part of the workforce.

lowest for Putukrejo (2.9). The dependency ratio[20], which gives an indication of the demand that is placed on the labour force in a household to provide for non-productive members, didn't vary much between the two villages.

Table 4.4: Average household size, labour units and dependency ratio for households in the three geographical units of the Malang study area, October 1990 to October 1991.

	Geographical units			
Household characteristics	Putukrejo	Kedunglor	Kedungkidul	Average
Household size	3.9	4.6	4.4	4.3
Labour Units	2.9	3.6	3.0	3.0
Dependency ratio	1.3	1.3	1.5	1.4

Source: INRES EFHS Data Base (File: EHHCOMP 1).

4.4.3 Labour to land ratio

The ratio household size/farm size for the study area as a whole was 4.8 persons per ha. and is highest for Putukrejo (5.4) and lowest for Kedungkidul (3.8) (Table 4.5)

Table 4.5: Labour to land relation in the study area, October 1990 to October 1991.

	Geographical Units			
Labour to land relation	Putukrejo	Kedunglor	Kedungkidul	Average
Household size/ Farm area	5.4	5.3	3.8	4.8
Labour Units/ Farm area	4.0	4.3	2.6	3.3

Source: INRES EFHS Data Base (Files: EHHCOMP1 and ARDES).

Ratios presented in Table 4.5 indicate the extent to which farm households can provide labour to operate the land they manage. However, these ratios are to be interpreted cautiously. When the labour unit/land ratio is high, it does not necessarily mean that all labour is used for on-farm soil-related income-generating activities as this depends on alternative employment opportunities.

[20] Dependency ratio is defined as the household size divided by the number of labour units present in the household.

4.5 Major on-farm income generating activities

4.5.1 Crops

Wet rice is grown in all three geographical units, but the relative importance per farm household was highest in Kedunglor (Table 4.6 and Figure 4.4). Farm households in Putukrejo are better endowed with land units 1 and 2 than those in Kedungsalam. Although rice is considered a high prestige food in Indonesia, wet rice was of greater importance per average farm household in Kedunglor than in Putukrejo; this can be explained by the commercialisation of agriculture in Putukrejo. The percentage of farm land cultivated with sugar cane, a crop that is only grown by farmers for sale, gives evidence of this development. Van der Molen and Schultink (1994) mention the following reasons that the cultivation of sugar cane per household was much greater in Putukrejo than in the other two geographical units:

- better land quality and suitability for sugarcane cultivation,
- larger parcels and land holding per farmer,
- shorter distance to the sugar factory,
- better infrastructure and better developed market structure.

Most of the sugarcane grown in the study area was intercropped with maize. During the survey it was observed that some large farmers also grew sugarcane as monocrop.

Table 4.6: Area per farm household of major crops and crop combinations grown in the study area, 1992.

	Geographical units					
	Putukrejo		Kedunglor		Kedungkidul	
Crop/crop combination	ha	%	ha	%	ha	%
Wetland rice	0.06	8	0.12	14	0.05	4
Sugarcane/maize	0.32	44	0.01	1	0.00	0
Maize/cassava	0.25	35	0.37	42	0.23	20
Homegarden	0.07	10	0.10	12	0.10	9
Bongkor	0.00	0	0.18	21	0.57	49
Other	0.02	3	0.09	10	0.21	18
Total	0.72	100	0.87	100	1.16	100

Source: INRES EFHS Data Base (File: Ardes).

In each geographical unit both maize and cassava were important crops and almost always intercropped. Reasons given for intercropping were: risk aversion, a more stable supply of food, and reduction of production losses due to pests and diseases. Maize is usually planted at the beginning of the rainy season and where it is grown as a mono crop a second maize crop is planted in the second half of the rainy season. With the improved Arjuno variety, released in 1980, yields at experimental stations were as high as five tons dry grain per hectare (Soetarjo *et al.*, 1986). Yields obtained by farmers in the study area were low ($\pm$ 2.2 tons). Cassava is usually planted at the beginning of the rainy season and harvested after seven months, although harvesting may commence

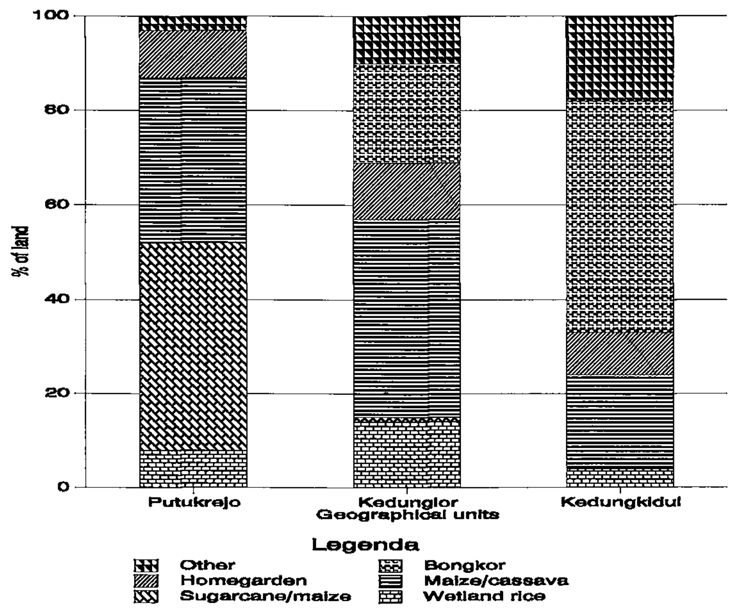

Figure 4.4: Crops grown by farm households in the research area, expressed as a percentage of the land being managed, 1992.

earlier if household food supplies have been depleted. Soetarjo *et al.*, (1986) report that fresh tuber yields of improved varieties can reach 25 $t.ha^{-1}$. In the study area fresh tuber yields varied from 5 to 17.5 tons and the average was 9 tons. Although cassava is not a favourite crop for human consumption purposes, it is one of the most common crops in the uplands of Java. Reasons are: cassava is a very suitable crop for mixed cropping systems, because the timing for planting and harvesting can be flexible; low labour requirements per unit product; compared to most other crops grown for staple consumption cassava is more drought tolerant; and cassava can still perform well on soils where nutrients have been depleted (Efdé, 1996). When soil fertility is reduced rice will often be the first crop to be taken out of production, followed by maize and finally cassava, after which the land will be left fallow for a number of years to regain its fertility. This sequence of growing staple crops reflects farm household preferences. Both cassava, maize and rice are utilized for human and livestock consumption purposes.

Each farm household in the study area possessed a homegarden, i.e. a tract of land that directly surrounds the house. On this piece of land numerous different annual and perennial crops are grown together of which the most common are cassava, maize, banana, coconut, melinjo and coffee.

While in Putukrejo no land is used for wood production, in Kedunglor this is 3 % and in Kedungkidul 7 %. The most common type of wood produced is teak. The same increasing trend can be observed for *bongkor*, i.e. land that is left fallow. This land is only utilized to collect fodder for livestock and firewood for cooking or lime burning.

4.5.2 Livestock

Most households in the study area possess at least one type of livestock, of which cattle is most preferred. Due to the high population density and consequent lack of grazing area, livestock is stall-fed, placing great demands on farm household labour, particularly in the dry season, when fodder has to be collected from outside the farm (e.g. from grass grown along the road sides). On-farm fodder is mainly derived from maize leaves and rice straw. Table 4.7 shows the kinds of livestock kept by farm households in the study area.

Table 4.7: Kinds of livestock kept by farm households in the Malang study area, 1990 - 1991.

	Households with						Average size of the herd per farm household		
	Goat		Sheep		Cattle				
	hh[1]	%	hh	%	hh	%	Goat	Sheep	Cattle
Putukrejo	4	8	3	6	22	45	0.1	0.2	1.0
Kedunglor	9	16	22	39	37	65	0.4	1.0	1.1
Kedungkidul	4	9	9	21	26	60	0.3	0.6	1.3
Study area	17	11	34	23	85	57	0.3	0.6	1.1

Source: INRES EFHS Data Base (File: Eanil).
[1]hh = households

4.6 Gross margins and farm household expenditures

For a discussion of income generation six activity categories were distinguished: (1) annual crops, (2) perennial crops, (3) livestock, (4) on-farm, non agricultural, (5) off-farm activities and (6) remittances. Because remittances received from friends and relatives also contribute towards the income that farm households can consume, they have been included as a separate category. Farm household income is expressed as gross margins, which is computed as product times price minus the costs that are incurred for the purchase of external inputs.

4.6.1 Gross margins

Table 4.8 presents the various activity categories from which income was derived by households that participated in the expanded farm household survey (see Chapter 3) and the differences between the geographical units. An average farm household in Putukrejo generated an income that was more than one and a half times higher than farm households in the two other geographical units. This difference was to a large extent caused by the annual crop activity category. In Putukrejo the gross margins generated by annual crops were almost seven times higher than for an average household in Kedungkidul and almost six times higher than an average household in Kedunglor.

Table 4.8: Farm household income generation per activity category, in the Malang study area, October 1990 to October 1991.

	Geographical units							
	Putukrejo		Kedunglor		Kedungkidul		Study area	
Activity category	Rp	%	Rp	%	Rp	%	Rp	%
Annual crops	1434	69	252	19	207	18	623	41
Perennial crops	103	5	195	14	206	17	169	11
Livestock	54	3	56	4	138	12	87	6
On-farm, non agricultural	7	0	51	4	168	14	81	5
Off-farm	399	19	770	57	441	37	522	34
Receiving remittances	83	4	30	2	19	2	43	3
Total	2080	100	1354	100	1179	100	1526	100

Source: INRES EFHS Data Base (File: EIO1).

The most important crops that contributed towards the generation of gross margins were sugarcane, maize, wet rice, and cassava. In the following discussion only those crops that contributed more than 5 % to the generation of gross margins will specifically be mentioned. The other crops are grouped together in the category *other*.

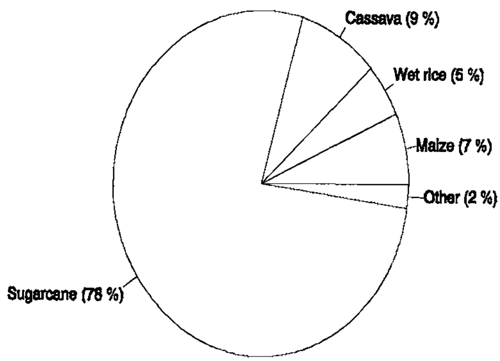

Figure 4.5: Crops that contribute to the generation of gross margins in Putukrejo, 1990/1991.

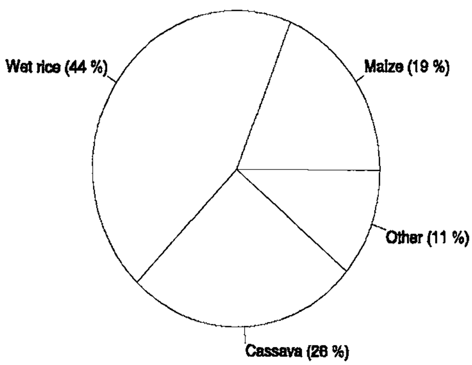

Figure 4.6: Crops that contribute to the generation of gross margins in Kedunglor, 1990/1991.

In Putukrejo, sugarcane was by far the most important crop for the generation of income. Up to 78 % of the total income from annual crops was from sugarcane (Figure 4.5). Thirty nine percent of the farmers grew sugarcane. Cassava contributed 9 % of the income from annual crops. Eighty two percent of the farmers produced cassava and on average a farm household in Putukrejo produced 3.1 t fresh tuber. Maize and wet rice followed with 7 and 5 % of the income from annual crops. Eighty six percent of the farmers produced maize, 22 % wet rice. While most of the sugarcane was sold and transported to Malang for processing, it was common practise to sell cassava, maize and rice only when the farm household consumption needs had been met. The income contribution of the category *other* was only 2 %.

In contrast to Putukrejo, sugarcane was hardly cultivated in Kedunglor (Figure 4.6). In fact in this geographical unit only members of one farm household reported that they had cultivated sugarcane. Especially wet rice contributed towards the generation of income from

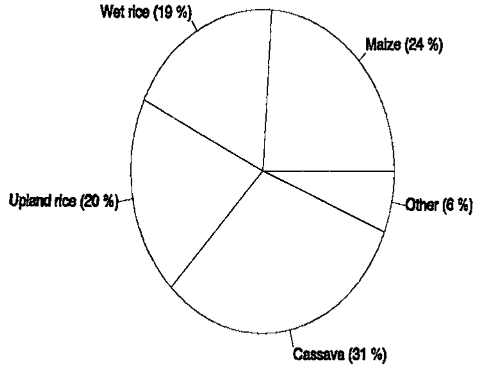

Figure 4.7: Crops that contribute to the generation of gross margins in Kedungkidul, 1990/1991.

annual crops (44 %). Forty two percent of the farmers produced wet rice, with an average production per farm household of 406 kg dried grain. Cassava and maize were cultivated here by 93 % of the farmers, with an average production per farm household of 1,350 kg fresh tuber and 270 kg dried grain respectively. The contribution towards the generation of income from the category *other* in this geographical unit was 11 %.

In Kedungkidul, where the income from annual crops was lowest compared to the two other geographical units, cassava was the most important crop (31 %) (Figure 4.7). Almost all households produced cassava, with an average production per household of 1,480 kg fresh tuber. Maize, the second most important crop, was grown by 98 % of the farm households. The income contributions of wet rice and upland rice were about the same (19 %), with 14 % of the households having wet rice and 21 % upland rice. Average production per farm household was 125 kg dry grain for both wet rice upland rice.

Average households in Kedunglor and Kedungkidul generated almost two times more income from perennial crops than those in Putukrejo. For Kedunglor perennial crops contributed 14 % of the total farm household income, for Kedungkidul this was 17 %, while for Putukrejo this was only 5 %.

The data presented in Table 4.8 for gross margins generated from livestock activities only show the value of the meat that is sold. Generally, livestock in the study area is kept for security purposes, to be sold in case of unforseen circumstances when suddenly cash is required to meet expenses (e.g. medical expenses or costs of a burial).

The income generated per average farm household from on-farm non-agricultural activities was greatest in Kedungkidul and smallest in Putukrejo. The type of activities included in this category are home industry (i.e. the manufacture of handicrafts), lime burning, collection of limestone, bamboo weaving, carpentry, the manufacture of mattresses, charcoal production and sewing. For both Putukrejo and Kedungkidul limestone burning was the only on-farm non-agricultural activity that was really important, while in

Kedunglor also home industry, bamboo weaving and sewing contributed towards the generation of income.

The contribution of off-farm activities ranged from 19 % in Putukrejo to 57 % in Kedunglor and was 34 % for an average farm household in the study area as a whole. In this category activities are included such as trading, working as a wage labourer, driver or factory worker. For farm households in Kedunglor and Kedungkidul this category was the most important source of income. Farmers were urged to seek employment outside their own farm enterprise, due to poor quality of farm land.

4.6.2 Expenditures

Figure 4.8 shows the expenses that were incurred by households in the three geographical units from October 1990 to October 1991. They are monetary flows. Going from north to

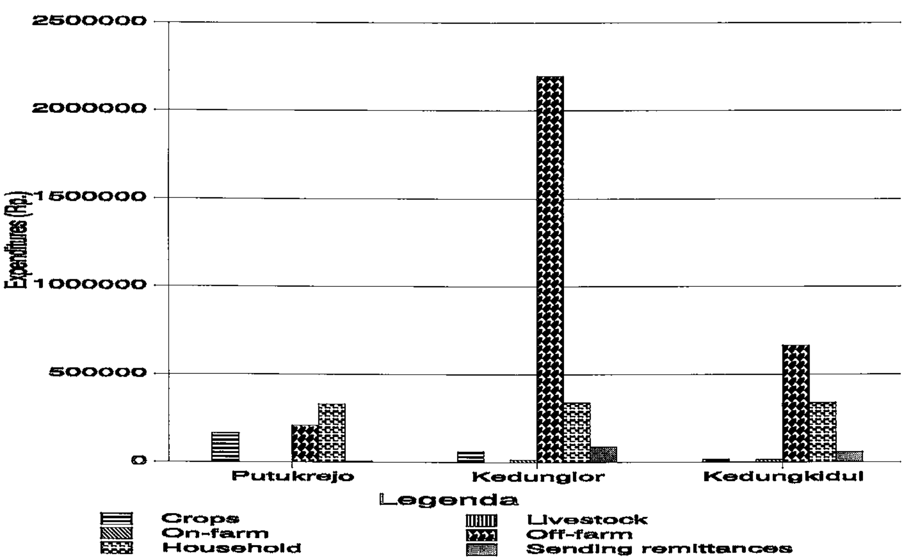

Figure 4.8: Farm household expenditures in the INRES study area, by activity, from October 1990 to October 1991.

south the money spent on cropping activities decreased from Rp. 162,823 to Rp. 17,672 per average farm household. The money spent on livestock production was negligible. This was probably due to the fact that 1990/91 was an exceptionally dry year, resulting in fodder shortages. Farmers preferred to sell cattle rather than to buy. The money used for on-farm non-agricultural activities was low and for none of the geographical units did it exceed Rp. 20,000 For all three geographical units most monetary expenses went to the off-farm activity category. Especially trading required a large proportion of money to finance stocks. Little difference was observed between the geographical units in money spent on household activities, being approximately Rp. 336,000. The household activities included both the regular and incidental costs, including donations.

4.7 Discussion

Agriculture has been practised in the study area for approximately a century and has shown a great deal of dynamics. Older farmers in the study area still recall the time when all the land was under forest (Solichin, personal communication). Agriculture has evolved plantations owned by foreign colonial companies to small holder agriculture. The agricultural sector still continues to change, for example farmers are contracted by fruit merchants in Malang and other cities to grow citrus. Although one may distinguish between *tegalan* and *kebonan* types of farming, this does not mean that there is no dynamics between the two systems. *Tegalan* may well turn into *kebonan* and vice versa. Especially in a region where so much dynamics is being observed, the exploration of options for development is highly relevant. The more so as change may occur due to shifts in the economy of the region.

Knowledge of the bio-physical aspects is essential, as it may help to understand the boundaries of possible cropping activities. Information derived from farm household surveys makes it possible to deduce farm household objectives, quantify system constraints, compare future possibilities with present situations and set normative assumptions that will be included as constraints in the FLORA model.

5 The FLORA procedure: presentation of results

5.1 Introduction

Chapter 3 discussed the working method followed for the FLORA procedure. The seven steps that were identified can be divided into three stages: model preparation, construction and utilization[21]. This chapter will concentrate on the model utilization stage and is organized as presented in Figure 5.1.

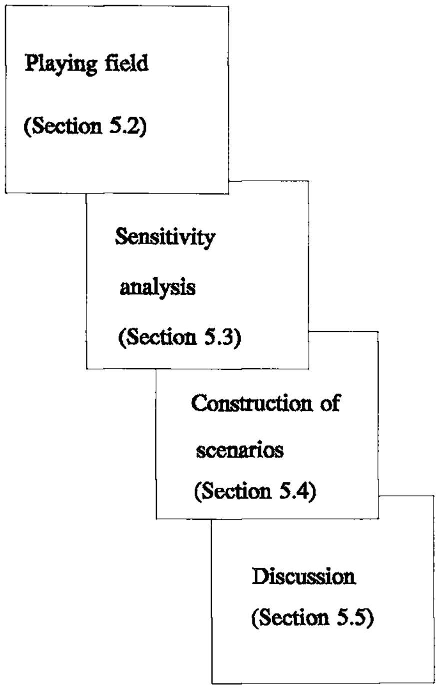

Figure 5.1: Organization of this chapter.

All results are presented per typical farm household (defined in Section 3.2). Each of the goal variables included in the FLORA procedure is expressed in its own units. Because of

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[21] Stage 1: (1) goal variable definition and constraint determination, (2) system definition and time horizon determination, (3) generation of data requirements. Stage 2: (4) construction of the FLORA model. Stage 3: (5) computing the playing field, (6) conducting sensitivity analysis, and (7) scenario construction.

the different crops and livestock types, it was necessary to use a common denominator for the agro-technical goal variables. For this purpose use was made of the energy value of crop and livestock products. Working capital and gross margins are expressed in Indonesian Rupiahs. For outputs use was made of 1990/91 farm gate prices and for inputs the purchasing prices that farmers had to pay that year. The labour goal variable is expressed in mandays and is assumed to be equal to an 8 hour working day. Nitrogen loss is expressed in kg N that is lost, due to either emissions or leaching. Biocide accumulation is expressed in kg accumulation of active materials. Soil loss is expressed in tons of soil that is lost because of cropping activities. With the exception of results presented in Annex 5.7 for cropping activities it is assumed that a rainfed situation prevailed.

5.2 The playing field

The constraints that were taken into consideration when computing the playing field are presented in Annexes 5.1, 5.2 and 5.3. Annexes 5.4, 5.5 and 5.6 show the results after the first iteration cycle for the typical farm households in each geographical unit. For all cropping activities natural moisture supply is assumed, however, to illustrate the effect of optimal moisture supply, in Annex 5.7 for the Putukrejo typical farm household ideal values for the goal variables under natural moisture supply are compared to optimal moisture supply. For a description of the present situation of farm households in the study area see Chapter 4. Table 5.1 presents the ideal (IV) and anti-ideal (AV) values for each goal variable. The 'ideal value' represents the solution where the goal variable achieves its optimum value. The 'anti-ideal value' or 'nadir value' is the solution where the goal variable achieves its worst value. When goal variables conflict, as is the case for several goal variables included in the study, the simultaneous realization of the ideal values is infeasible. The difference between the ideal and the anti-ideal values for each goal variable, provides stakeholders with knowledge concerning the range over which the goal variable value can vary.

5.2.1 Agro-technical goal variables

To obtain an indication of the number of people for whom the consumption requirements can be met for staples, pulses, fruit and livestock products, use was made of the 1989/90 Food Balance Sheets for Indonesia and the preliminary data presented in those sheets. The annual per capita supply of energy of staples for consumption was $2.97*10^6$ KJ. Assum-

Table 5.1: The playing field: Ideal (IV) and anti-ideal (AV) values.

	Putukrejo		Kedunglor		Kedungkidul	
Goal variable	IV	AV	IV	AV	IV	AV
Staple crops (10^6 KJ)	163.95	10.41	165.27	10.41	178.00	10.41
Pulses (10^6 KJ)	40.18	1.45	40.15	1.45	31.35	1.45
Fruit (10^6 KJ)	18.45	1.00	26.20	1.89	25.31	1.99
Livestock (10^6 KJ)	8.44	-1.00	8.44	-0.19	8.43	-0.17
Working capital (10^3 Rp)	4.76	3744.40	2.61	3651.91	2.70	3747.57
Labour (Md)	25.75	1167.76	20.27	1132.42	43.66	1116.10
Gross margin (10^3 Rp) (Unspecified)	7,744.76	1,591.00	7,853.17	561.40	7,223.14	681.10
Gross margin (10^3 Rp) (Specified)	7,309.25	1,591.07	7,616.69	561.40	7,215.45	681.10
N-loss (kg)	0.18	26.26	0.29	33.44	0.43	51.67
Biocides accumulation (kg)	0.00	4.06	0.00	4.30	0.00	3.03
Soil loss (t)	1.44	7.20	0.60	8.70	0.62	11.60

Note: All data are presented per typical farm household ing that this level remains unchanged in the future, then a typical farm in Kedungkidul is - technically speaking - able to meet the staple consumption requirements of 60 people; in Putukrejo this would be 55 people. However, per hectare enough staples could be produced for 52 people in Kedungkidul and for 77 in Putukrejo. This difference is caused because a typical farm in Putukrejo is better endowed with land of good quality than a farm in Kedungkidul. Better quality land is more suitable for the cultivation of staple crops. The per capita annual supply of energy for consumption from pulses in Indonesia was $0.42*10^6$ KJ. Results presented in Table 5.1 indicate that a typical farm in Putukrejo and Kedunglor could - technically speaking - produce enough pulses for 96 people, and for a typical farm in Kedungkidul this is 75. For fruit the per capita annual supply for consumption in Indonesia in 1990 was estimated at $0.06*10^6$ KJ, implying that a typical farm in Kedunglor or Kedungkidul could meet the fruit consumption requirements for 437 or 422 people. The extent that livestock production is possible at typical farm household level is the same for the three geographical units, because livestock production is mainly constrained by the potential labour availability per typical farm household. The per capita annual supply of energy from meat in 1990 was $0.04*10^6$ KJ. Results presented in Table 5.1 indicate that a typical farm would be able to meet the consumption requirements for 211 people as far as meat is concerned.

5.2.2 Household socio-economic goal variables

The difference between the ideal and anti-ideal values concerning working capital is large per typical farm household. The anti-ideal values were determined by demands placed on the agro-technical goal variables and the household socio-economic goal variables concerning gross margins. For each farm household the highest level of working capital was computed when optimizing livestock production. Livestock activities were then selected that require inputs such as maize bran and soya bean cake, which are relatively expensive. However, those activities are still selected because they require less labour than livestock activities that do not make use of externally purchased inputs, and yield a higher level of production. Minimum labour requirements range from 20 mandays in Kedunglor to 44 mandays in Kedungkidul. This implies that for each typical farm household more than 95% of the potentially available farm household labour is available for off-farm employment. This high percentage is caused by the high production efficiency levels for crop and livestock activities. A typical farm household in Kedunglor is able to generate the highest level of gross margins from crop and livestock activities, compared to a typical farm household in Putukrejo and Kedungkidul. The effect of specifying the activity category from which gross margins should be generated has little effect on typical farm household gross margins (comparison with the ideal value for GV23), ranging from a decrease of 6 % in Putukrejo to a negligible decrease in Kedungkidul.

5.2.3 Environmental goal variables

The difference between the ideal and anti-ideal values computed for N-loss per typical farm household is large and most so in Kedungkidul (51.25 kg). The ideal values were obtained when the goals were just met. The anti-ideal values for N-loss for each typical farm were computed when staple crop production was optimized and was highest for a typical farm in Kedungkidul and lowest for a typical farm in Putukrejo. It is possible to meet the goal variable demands while reducing the accumulation level of biocides to 0. For biocides the anti-ideal values were computed when optimizing the production of pulses. Ideal values for soil loss ranged from 0.60 ton per typical farm household to 1.44 per typical farm household in Putukrejo. For each typical farm household the anti-ideal values were equal to the maximum level of permitted soil loss. For Putukrejo this anti-ideal value was obtained only during one optimization (Annex 5.4), whereas in Kedunglor and Kedungkidul this was the case for 8 and 7 optimizations, respectively (Annexes 5.5 and 5.6).

5.3 Sensitivity analyses

In section 5.2 the playing field per typical farm household was made explicit. The field was determined by the goal variables, goals, activities and constraints that were included in the FLORA model. Several sensitivity analyses were conducted. They were mainly conducted with the aid of the constraint method. The basic idea of this method is to optimize one of the goal variables while the others are specified as constraints. The efficient set is then generated by parameterizing the right hand side of the goal variables treated as constraints. This is similar to the technique that was first proposed by Marglin (1967, p. 24-25).

5.3.1 Gross margins and working capital

Situation A: Situation A is characterized by the inclusion of a working capital constraint in the model, while maximizing the generation of gross margins from crop and livestock activities. Initially the production is not constrained by working capital: the farmer is able to finance all purchased inputs from own resources. This is equivalent to the level of working capital that is required when gross margins are optimized, when computing the playing field. Thereafter the amount of working capital utilized in the unconstrained situation is reduced in steps of 10 % to represent an increasingly binding working capital constraint. Figure 5.2 shows the effect of a reduction of the working capital from 0 % to 90 % of the working capital required to realize the ideal gross margin value in the playing field. The maximum reduction in farm household gross margins is 19 % at 90 % working capital reduction for a typical farm household in Kedungkidul.

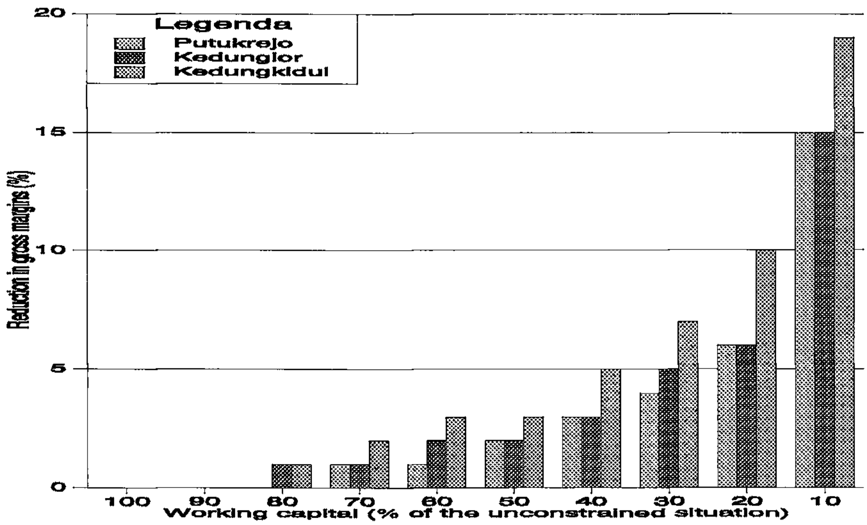


Figure 5.2: Working capital and gross margins from crop and livestock products

At first the effect is not noticeable but by constraining working capital to more than 20 % it clearly becomes a bottle-neck when optimizing gross margins. However, the decrease in gross margins is still small considering the fact that the available working capital is ultimately restricted to 10 % of the working capital required to achieve the ideal gross margin value in the playing field. Table 5.2 shows for Putukrejo the activities selected in the unconstrained case and in the situation where only 10 % of the working capital is utilized. The small decrease in gross margins can be explained by the low value of the ratio between the required working capital and gross returns. For all activities that are reported in Table 5.2 the ratio is smaller than 0.039. In both situations all land being managed by the farm household is being utilized. A decrease can be observed in the quantity of livestock activities. This decrease is caused by: (1) the unavailability of farm household labour, and (2) the unavailability of working capital to hire labour.

Table 5.2: Crop activities that were selected in the unconstrained[1] and constrained[2] working capital situations.

Activity	Season[3]	Production situation[4]	Land unit	Fertilization type[5]	Gross margins (10^3 Rp)	WCGR ratio[6] (%)	Unconstrained (ha)	Constrained (ha)
Groundnut	1	2	2	2	6,128	0.002	0.418	0.191
Groundnut	2	2	2	2	5,887	0.002	0.168	0.091
Groundnut	2	2	1	2	9,105	0.009	0.007	0.086
Groundnut	2	4	2	2	4,497	0.011	0.000	0.240
Groundnut	2	4	3	2	2,365	0.011	0.019	0.029
Maize/cassava	3	2	2	2	4,185	0.025	0.029	0.000
Maize/cassava	3	2	3	2	2,855	0.038	0.007	0.000
Maize/cassava	3	2	4	2	1,887	0.038	0.000	0.000
Paddy rice	3	2	2	2	3,903	0.013	0.000	0.049
Melinjo	3	2	2	2	2,748	0.013	0.000	0.034
Melinjo	3	2	4	2	1,349	0.026	0.000	0.007
Banana	3	2	1	2	6,355	0.034	0.079	0.000

[1]Unconstrained situation: No restriction set on working capital.
[2]Constrained situation: 10 % of the monetary input that was required in the unconstrained situation.
[3]1 = Crop(s) on land first half of the rainy season; 2 = Crop(s) on land second half of the rainy season; 3 = Crop(s) on land first, second half of rainy season and perhaps longer.
[4]1 = Potential; 2 = Water limited; 3 = Water and nutrient limited; (4) Water and nutrient limited and no use of biocides.
[5]1 = No use of manure; 2 = Use of mineral fertilizers and manure.
[6]WCGR ratio: ratio between working capital and gross return

Situation B: The additional costs in the model are expressed through price increases on all purchased inputs ranging from 0 % (the unconstrained situation) to 50 % in five steps. This range reflects current interest costs for formal rural credit in Indonesia (Yaron, 1992; Moll and Palallo 1994) and the likelihood that farmers require finance only for part of the external inputs required. An increase in the price of all externally purchased inputs with 50 % decreases the gross margins with a mere 4 %. This is because the WCGR ratio is so low for most activities and a number of livestock activities are assumed not to require any working capital at all.

5.3.2 Gross margins and land area

The effect of land size increase on the generation of farm household gross margins from crop and livestock activities is shown in Figures 5.3, 5.4 and 5.5.

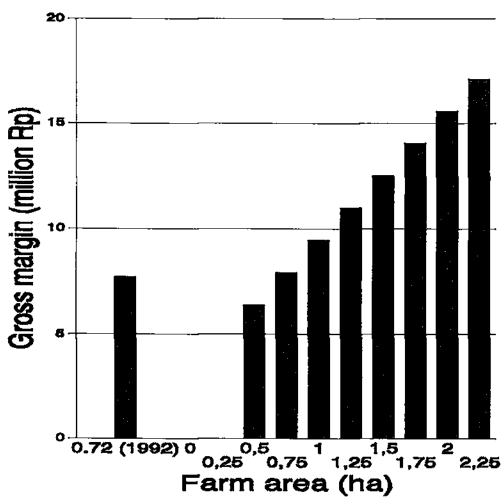


Figure 5.3: Putukrejo: farm size and gross margins from crop and livestock activities

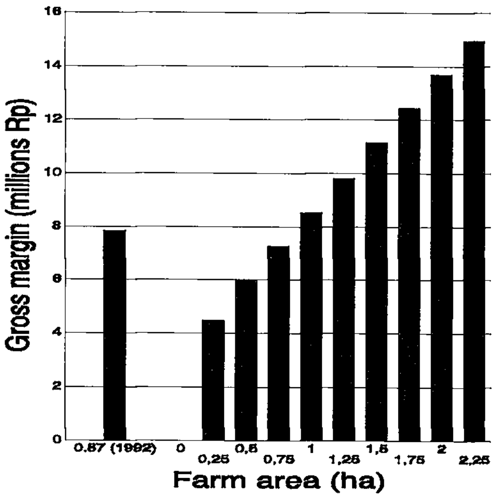


Figure 5.4: Kedunglor: farm size and gross margins from crop and livestock activities

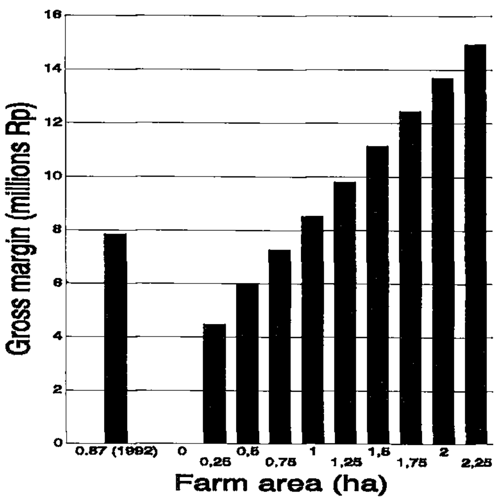


Figure 5.5: Kedungkidul: farm size and gross margins from crop and livestock activities

Table 5.3 shows the percentage change in gross margins compared to the ideal value of the playing field where geographical unit farm size averages were assumed. For each geographical unit a farm size of 0 ha was excluded as households were to be self-sufficient in food. A typical farm household in Putukrejo managing 0.25 ha will not be able to meet the restriction that gross margins from crop and livestock activities will at least have to be equal to the 1990/91 value. In this geographical unit the increase in gross margins generated from crop and livestock activities is largest (= 121%) when farm size increases from the 1992 average of 0.72 ha to 2.25 ha. In Kedungkidul the increase is 46 %. The differences between the geographical units is due to differences in land quality and size.

Table 5.3: Farm size and percentage change in gross margins compared to the ideal gross margin value.

	% Change in gross margins compared to the ideal gross margins value belonging to the 1992 average farm size		
Farm size (ha)	Putukrejo[1]	Kedunglor[2]	Kedungkidul[3]
0.25	-100	-43	-44
0.50	-17	-24	-29
0.75	2	-7	-17
1.00	22	9	-7
1.25	42	25	5
1.50	62	42	15
1.75	81	58	25
2.00	101	74	35
2.25	121	90	46

[1]Putukrejo: 1992 average farm size = 0.72 ha.
[2]Kedunglor: 1992 average farm size = 0.87 ha.
[3]Kedungkidul: 1992 average farm size = 1.16 ha.

5.3.3 Gross margins and potential labour availability

Figure 5.6 shows the effect of a change in potential labour availability on the generation of farm household gross margins. On the vertical axis the change in gross margins is expressed as a percentage of the ideal value that was computed in the playing field. When computing the ideal and anti-ideal values in the playing field, the labour availability constraint was set at 4.5 labour units[22] per month. As potential labour availability per typical farm household increases, the proportion of gross returns generated by annual cropping activities decreases, both in relative and absolute terms (Table 5.4), while the

[22] Household labour = 3 labour units; hired labour = 1.5 labour units.

proportion of both perennial and livestock activities increases. For both Putukrejo and Kedunglor the proportional contribution to gross returns of annual crops decreases from more than 90 % (LAU = 0.5) to less than 40 % (LAU = 6).

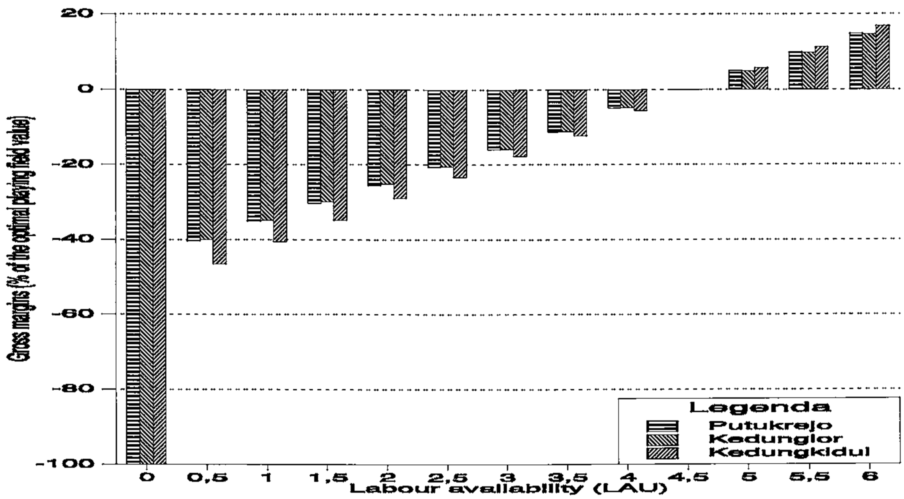


Figure 5.6: Farm household potential labour availability and gross margins from crop and livestock activities

Figure 5.6 does not show diminishing returns. This is because livestock activities are only constrained by labour availability. Each additional unit of labour will therefore also result in additional livestock activities.

5.3.4 Gross margins and soil loss

Figure 5.7 shows how a change in the feasible level of soil loss affects the capacity of a typical farm household in Putukrejo to generate gross margins from crop and livestock activities. Once the soil loss restriction is loosened up to 8 tons per typical farm, no further increase in gross margins is possible. When computing the ideal gross margin value in the playing field for the Putukrejo typical farm household, soil loss was not binding (see Annex 5.4) and therefore did not effect the level of gross margins that could be generated from crop and livestock activities. To achieve the highest level of gross margins, a typical farm in this geographical unit would have to accept 6.21 tons of soil loss per year.

Table 5.4: Contribution to total gross returns of annual, perennial and livestock activities, expressed as a % of total gross returns.

	Putukrejo			Kedunglor			Kedunglor		
	Crops			Crops			Crops		
Household labour availability	Annual	Perennial	Livestock	Annual	Perennial	Livestock	Annual	Perennial	Livestock
0.0	0	0	0	0	0	0	0	0	0
0.5	93	3	5	91	5	4	75	20	6
1.0	84	3	13	83	5	11	71	16	13
1.5	78	3	19	77	5	17	72	9	19
2.0	72	4	24	71	6	23	70	6	24
2.5	66	4	29	66	6	28	63	7	30
3.0	61	5	34	61	7	33	58	7	35
3.5	55	6	39	55	7	38	53	8	39
4.0	49	7	45	50	7	42	48	7	44
4.5	45	7	48	47	8	46	44	8	48
5.0	42	7	51	44	8	49	41	8	51
5.5	39	8	54	41	8	51	37	8	54
6.0	36	8	56	38	8	54	35	9	57

Soil loss was binding when optimizing gross margins for a typical farm in Kedunglor (see Annex 5.5), and therefore constrained the level of gross margins that can be generated from crop and livestock activities. Figure 5.8 shows that once the soil loss restriction is loosened to 14 tons there are no further improvements on gross margins. The increase in gross margins compared to the ideal gross margin value is only 3 %. Also for a typical farm household in Kedungkidul, when computing the playing field, the soil loss restriction was binding when computing the ideal gross margins value in the playing field value (see Annex 5.6). Figure 5.9 shows that by loosening the constraint to 20 tons a typical farm in Kedungkidul will generate 7.633 million Rp with an annual soil loss of 18.58 tons per typical farm. The increase in gross margins is 6 % compared to the ideal value of the playing field.

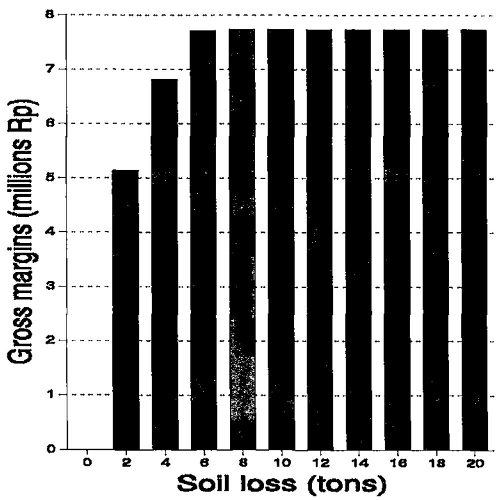


Figure 5.7: Putukrejo: soil loss and gross margins from crop and livestock activities.

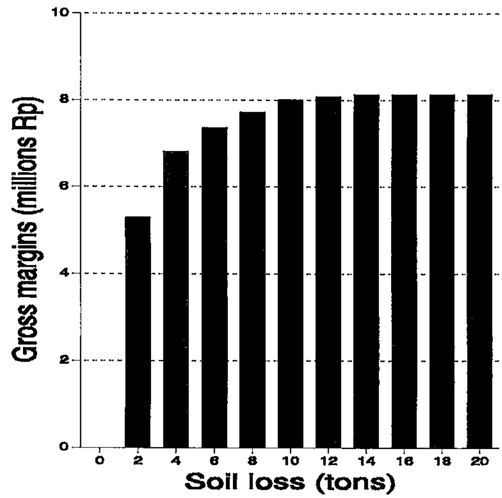


Figure 5.8: Kedunglor: Soil loss and gross margins from crop and livestock activities.

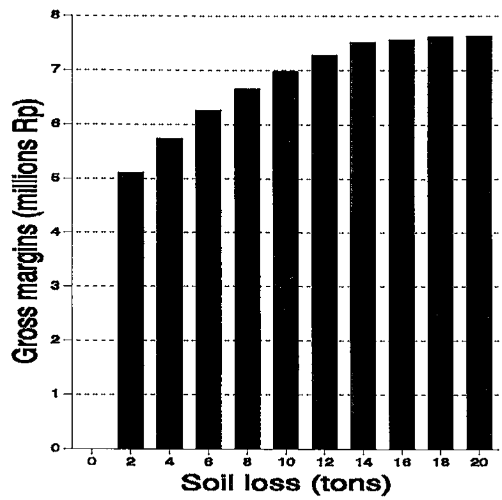


Figure 5.9: Kedungkidul: Soil loss and gross margins from crop and livestock activities.

Figures 5.7, 5.8 and 5.9 show that gross margins are not very sensitive for soil loss. This is because farm size was kept constant and also gross margins can be generated from livestock activities. The sensitivity analysis presented in this Section makes explicit the trade-off between soil loss and gross margins from crop and livestock activities. For example, if the decision were made that a soil loss of more than 2 tons per typical farm would not be acceptable, a household in Putukrejo would be able to generate slightly more than five million Rp. Generating a higher level of gross margins will be accompanied by a higher level of soil loss (Figure 5.7).

5.3.5 Partial[23] diet requirements and land area

Table 5.5 shows the area that is required to meet consumption requirements for staples, pulses and fruit, assuming yield oriented agriculture and low input oriented agriculture. The extra area that is required when low input oriented agriculture is assumed is largest for a typical farm household in Kedungkidul. The typical farms in Kedunglor and Kedungkidul are able to produce enough staples, pulses and fruit for up to 45 persons, 10 more than a typical farm household in Putukrejo.

Table 5.5: The area that would be required per typical farm to meet 1990/91 consumption levels of staples, pulses and fruit.

	Putukrejo			Kedunglor			Kedungkidul		
Persons[1]	YOA[2] (ha)	LIOA[3] (ha)	Increase (%)	YOA (ha)	LIOA (ha)	Increase (%)	YOA (ha)	LIOA (ha)	Increase (%)
5	0.091	0.143	57	0.091	0.143	57	0.091	0.143	57
10	0.181	0.287	59	0.181	0.287	59	0.181	0.287	59
15	0.272	0.449	65	0.272	0.431	58	0.272	0.485	78
20	0.377	0.614	63	0.362	0.598	65	0.389	0.769	98
25	0.482	IP[4]	NA[5]	0.454	0.818	80	0.532	1.104	108
30	0.588	IP	NA	0.557	IP	NA	0.717	IP	NA
35	0.694	IP	NA	0.679	IP	NA	0.931	IP	NA
40	IP	IP	NA	0.847	IP	NA	1.145	IP	NA
45	IP	IP	NA	IP	IP	NA	IP	IP	NA

1 Persons: Number of adults for whom 1990/91 consumption levels of staples, pulses and fruit can be met
2 YOA: Yield oriented agriculture
3 LIOA: Low input agriculture
4 IP: Impossible
5 NA: Not applicable

23 Partial diet requirements: only consumption levels of staples, pulses and fruit are taken into consideration.

5.4 Scenarios

5.4.1 A-Scenario: Food production

This scenario is *goal oriented*, where the goal is a typical farm household production of the 1990 level of per capita supply of energy from staples, pulses and fruit for at least four households. There are several ways (variants) by which this goal can be achieved. An efficient solution is obtained by optimizing goal variables according to priority (see Section 3.8).

The optimization results are presented in Table 5.6. The range for the yield oriented agriculture variants - as far as working capital is concerned - was small. The range was wider for the low-input oriented agriculture variants, which was caused by the Kedungkidul typical farm household where working capital requirements were highest. For the LIOA-A2 variant, working capital requirements were lowest and ranged from 7.62 thousand Rp in Kedunglor to 14.21 thousand Rp in Kedungkidul. For labour the range for the yield oriented agriculture variants was smaller than for the low-input oriented agriculture variants. Also here the large range for the low-input oriented agriculture variants was mainly caused by the Kedungkidul typical farm due to the fact that in this geographical unit a typical farm is less endowed with land of good quality. Consequently, more labour is required to cultivate the land and meet manure requirements. With the exception of the YOA-A1 variant, land requirements for the Kedungkidul typical farm were consistently higher than for the other two typical farms. For none of the typical farms was the required farm area larger than the average farm size in the geographical unit. Gross margins varied from 1,1 million Rp in Kedungkidul to 2.3 million Rp in the same geographical unit. For the environmental goal variables, the environmental costs - N-loss, biocide accumulation and erosion - were often highest for a typical farm household in Kedungkidul.

Different ways (variants) in which the same goal can be achieved are shown. No indication can be given which variant should be given preference, as this will depend on the stakeholders' preference in rural development. If, for example, the objectives that the stakeholders have in common would be to use as little land as possible, then preference will be given to the YOA-A1 variant.

Table 5.6: Food production scenario: optimization results per typical farm.

Scenario variant	Putukrejo	Kedunglor	Kedungkidul	Range (%)[1]
Working capital (10^3 Rp)				
YOA-A1	82.71	78.29	79.48	1
LIOA-A1	95.54	83.79	107.79	29
YOA-A2	19.16	19.12	20.74	8
LIOA-A2	7.62	7.23	14.21	97
YOA-A3	780.17	746.35	775.35	5
LIOA-A3	795.19	714.42	1134.25	59
Labour (md)				
YOA-A1	21.27	21.16	21.00	1
LIOA-A1	29.00	29.50	26.00	13
YOA-A2	98.00	95.00	118.00	24
LIOA-A2	105.00	99.00	530.00	438
YOA-A3	86.25	82.37	86.26	5
LIOA-A3	96.06	86.82	140.78	62
Land (ha)				
YOA-A1	0.29	0.29	0.29	0
LIOA-A1	0.48	0.46	0.53	15
YOA-A2	0.33	0.32	0.36	13
LIOA-A2	0.54	0.51	0.66	29
YOA-A3	0.33	0.31	0.35	13
LIOA-A3	0.58	0.51	0.98	92
Gross margins (10^3 Rp)				
YOA-A1	1590.17	1599.90	1594.44	1
LIOA-A1	1577.07	1604.31	1537.07	4
YOA-A2	1829.87	1815.98	1850.99	2
LIOA-A2	1848.76	1840.31	2307.98	25
YOA-A3	1322.89	1337.91	1322.16	1
LIOA-A3	1318.93	1364.00	1117.12	22
N-loss (kg)				
YOA-A1	8.81	8.60	8.66	2
LIOA-A1	14.23	12.82	11.83	20
YOA-A2	6.75	6.87	7.81	16
LIOA-A2	6.58	6.37	17.76	179
YOA-A3	6.83	6.66	7.39	11
LIOA-A3	6.50	6.47	8.12	26
Biocide accumulation (kg)				
YOA-A1	0.74	0.78	0.71	10
LIOA-A1	0.43	0.57	0.33	73
YOA-A2	1.71	1.71	1.70	59
LIOA-A2	0.00	0.00	0.25	--
YOA-A3	1.69	1.56	1.84	18
LIOA-A3	0.00	0.01	0.00	--
Erosion (t)				
YOA-A1	1.75	1.66	1.65	6
LIOA-A1	2.58	2.56	3.85	39
YOA-A2	2.04	1.92	2.37	23
LIOA-A2	3.42	2.99	6.39	114
YOA-A3	1.98	1.87	2.91	56
LIOA-A3	3.84	3.02	11.86	293

[1]Range = the difference between the largest and the smallest value expressed as a percentage of the smallest value.

5.4.2 B-Scenario: Income generation scenario

This scenario is *goal-variable* oriented. The goal variable optimized is gross margins from crop and livestock activities under several constraints (See Section 3.8). The optimization results for the B-scenario are presented in Table 5.7.

Table 5.7: Household socio-economic scenario: Optimization results, per typical farm.

	Putukrejo	Kedunglor	Kedungkidul	Range (%)[1]
Working capital (10^3 Rp)				
YOA-B	182.44	214.72	280.47	54
LIOA-B	153.82	182.10	227.38	48
Labour (md)				
YOA-B	609.12	607.08	611.47	1
LIOA-B	631.00	640.00	632.00	1
Land (ha)				
YOA-B	0.72	0.87	1.16	61
LIOA-B	0.72	0.87	1.16	61
Gross margins (10^3 Rp)				
YOA-B	5,881.46	6,021.51	5,353.10	12
LIOA-B	4,592.69	4,702.66	4,054.11	16
N-loss (kg)				
YOA-B	10.30	21.80	42.74	315
LIOA-B	5.32	13.29	43.89	725
Biocide accumulation (kg)				
YOA-B	4.05	3.58	3.04	33
LIOA-B	0.12	0.36	0.84	600
Erosion (t)				
YOA-B	6.00	8.70	11.60	93
LIOA-B	5.87	8.70	11.60	98

[1]Range = the difference between the largest and the smallest value expressed as a percentage of the smallest value.

Differences between the typical farms were caused by dissimilarities concerning land size and quality. A typical farm household in Kedungkidul requires more working capital than a typical farm household in Putukrejo. Labour requirements did not differ much between typical farm households or between variants. For both variants the range for gross margins was almost the same. For each typical farm and each variant all available land resources were used. N-loss was highest for a typical farm in Kedungkidul, for the YOA variant was 4 times higher than for a typical farm in Putukrejo and for the LIOA variant it was more than 8 times higher. For the LIOA variant the N-loss per typical farm in Kedungkidul was slightly higher than for the YOA variant. This was so because activities that were selected when YOA was assumed lost their comparative advantage when the LIOA variant was assumed; activities that were then selected have a higher N-loss per hectare value. Biocide accumulation was considerably lower with the LIOA variant compared to the YOA variant. In the YOA variant the Putukrejo typical farm had the highest biocides accumulation value. For the LIOA variant it was the lowest. Except for the Putukrejo typical farm, the soil loss per typical farm was binding in both variants.

5.4.3 C-Scenario: Environmental scenario

As is the case in the previous scenario, the environmental scenario is 'goal-variable' oriented. Table 5.8 presents the optimization results for the environmental scenario.

Table 5.8: Environmental scenario: optimization results per typical farm.

	Putukrejo	Kedunglor	Kedungkidul	Range (%)[1]
Working capital (10^3 Rp)				
YOA-C	178.02	153.55	133.15	34
LIOA-C	146.64	134.99	125.70	17
Labour (md)				
YOA-C	611.00	618.00	627.00	3
LIOA-C	629.00	630.00	633.00	1
Land (ha)				
YOA-C	0.69	0.51	0.29	138
LIOA-C	0.69	0.51	0.29	138
Gross margins (10^3 Rp)				
YOA-C	5,741.73	5,088.92	3,416.57	68
LIOA-C	4,490.22	4.021.29	2,782.72	61
N-loss (kg)				
YOA-C	9.26	7.82	4.96	87
LIOA-C	3.36	3.28	3.28	2
Biocide accumulation (kg)				
YOA-C	3.89	2.82	1.48	163
LIOA-C	0.11	0.11	0.11	0
Erosion (t)				
YOA-C	5.42	4.10	2.22	144
LIOA-C	5.29	3.97	2.09	153

[1]Range = the difference between the largest and the smallest value expressed as a percentage of the smallest value.

For both variants a typical farm in Putukrejo requires the highest amount of working capital and a typical farm in Kedungkidul the lowest. Labour requirements between the typical farms didn't differ much and for the LIOA variant were slightly higher than for the YOA variant. The decrease in land size was greatest in Kedungkidul. Especially in this geographical unit a typical farm will be hardest hit by a policy measure implying that no crops can be cultivated on the poor soils. The reduction ranged from 1.16 ha to 0.29 ha, while for a typical farm in Putukrejo this range was only from 0.72 ha to 0.69 ha. Consequently, the reduction in gross margins that can be generated from crop and livestock activities is also greatest for a typical farm in Kedungkidul, as is the case for the environmental goal variables.

Across the variants, substantial differences can be observed for the various goal variables included in the scenarios. By comparing the variants the opportunity costs of goal variables are made explicit, i.e. the sacrifice or gain that is achieved on a goal variable when a variant is selected. The extreme values for the variants across scenarios are shown in Figure 5.10.

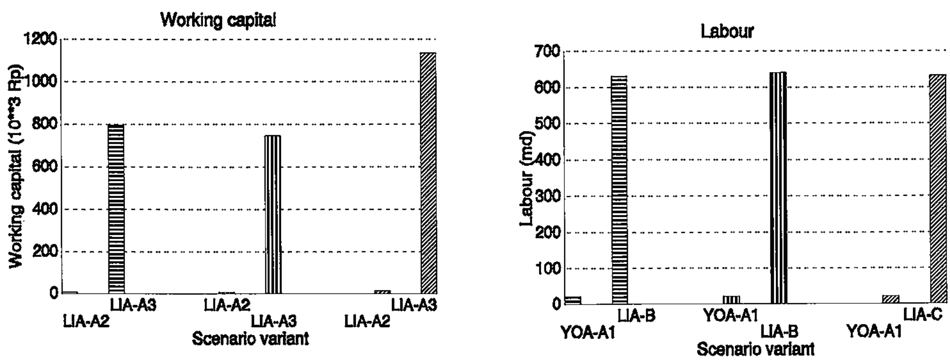
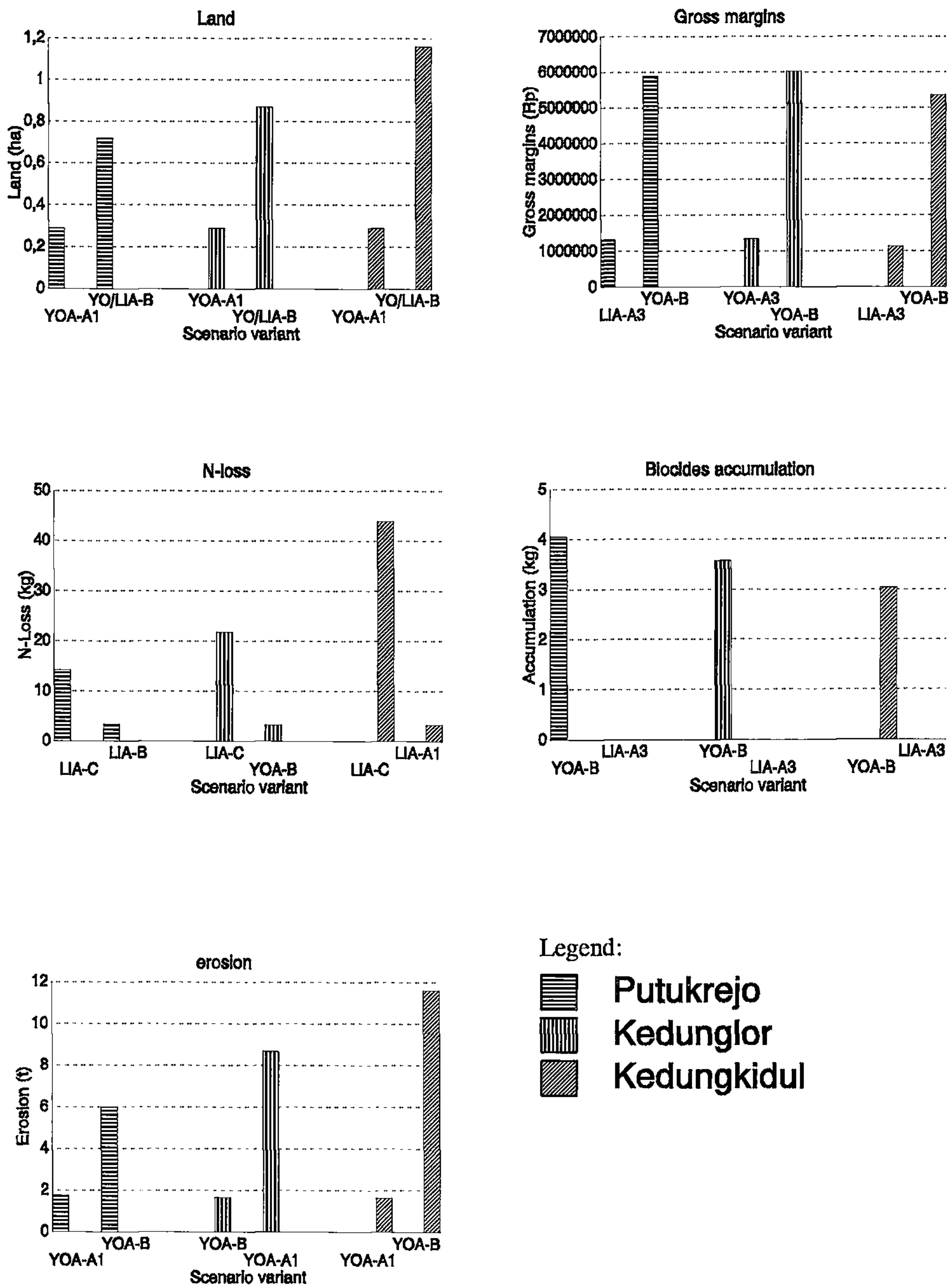


Figure 5.10: Goal variables: extreme values across scenarios



(Figure 5.10: continued)

5.5 Discussion

In this chapter the model utilization stage of the FLORA procedure was described. The playing field was computed, sensitivity analysis conducted and scenarios constructed.

In the model goal variables determine the possible directions for development, the goals and constraints determine the optimal values for the goal variables. The time horizon was established in such a way that all activities that were included in the activity matrix could - technically speaking - be realized by the end of the time horizon. Having a longer time horizon will therefore not influence the results from an agro-technical point of view. The playing field makes explicit to stakeholders in rural development the options open to them at farm household level, considering goal variables, constraints and the type of activities included in the study. When computing the playing field, constraints were initially set as loose as possible. The resulting ideal and anti-ideal values do not indicate likely scenarios but indicate extreme end-visions.

Sensitivity analyses were conducted with respect to the following goal variables: gross margins and working capital, gross margins and farm size, gross margins and potential labour availability, gross margins and soil loss, and partial diet requirements and farm size. Sensitivity analyses concerning working capital and gross margins from crop and livestock activities indicated that reducing working capital to 10 % of the amount used to realize the optimal playing field value, decreased gross margins by only 19 %. Further, increasing the price of all inputs by 50 % reduced gross margins by only 4 %. These results indicated that reducing subsidies on agricultural inputs will have minor effects on gross margins generated from crop and livestock activities. This is due to the low value of the ratio between required working capital and gross returns (WCGR ratio). By substituting one activity for another with a slightly lower WCGR ratios, the level of gross margins that can be generated from crop and livestock activities will not be effected very much.

Sensitivity analyses concerning the parameters farm size and gross margin suggested that increasing the farm size from the 1992 average to 2.25 ha, will increase the gross margins generated from crop and livestock activities by 121 % in Putukrejo and 46 % in Kedungkidul. These differences are caused by differences in land quality. Sensitivity analyses concerning gross margins and potential labour availability showed that higher labour inputs cause the relative contribution of perennials and particularly livestock activities to increase. The soil loss constraint appeared to have no effect on gross margins from crop and livestock activities for a typical farm household in Putukrejo, but increased the gross margins by 6 % compared to the ideal gross margins value in the playing field for a typical farm household in Kedungkidul. The last sensitivity analysis conducted concerned the relation between farm size required to meet the consumption requirements of staples, pulses and fruits. The analysis shows that farm size would have to be considerably lager when the low-input oriented agricultural orientation is assumed.

An illustration was given of how the FLORA procedure can be used to present scenarios. For this purpose three scenarios were constructed, namely a food production, household socio-economic and environmental scenario. For each scenario different variants were computed. For the food production scenario six variants were distinguished. Within each variant the same goal was to be achieved. Both between variants and between typical farm households the goal variables showed considerable differences. The World Development Report (1990) classifies middle-income countries as those with a per capita income between US$ 545 and US$ 6,000. The income per capita for Indonesia in 1990 was US$ 570. If we assume that irrigation facilities will not be introduced in the research area and that the other assumptions underlying the income generation scenario (B-Scenario) are realistic, then the role of crop and livestock activities in raising the per capita income of typical household members in the research area to the upper per capita income boundary for middle income countries will be limited. Even when yield-oriented agriculture is assumed, the income per capita for typical farm households ranges from US$ 727 to US$ 817[24]. As there is no reason to expect relative prices of agricultural products to increase substantially in the future, these amounts can be expected to decrease rather than increase. Comparing gross margin values of the household socio-economic scenario with those of the environmental scenario shows that a typical farm in Kedungkidul will be hardest hit if lands of lesser quality are taken out of production. The scenarios do not in any way indicate development paths, nor do they dictate research agendas. However, they do suggest ultimate goals for agricultural research at the typical farm household level.

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[24] The 1990 exchange rate of US$ 1 = 1,842 Rp was used.

6 QFSA and the FLORA procedure: development with hindsight

6.1 Introduction

In Chapter 2 the design of quantitative farming systems analysis was described. The main reason for developing QFSA was to overcome some of the problems that confronted the more classical FSA techniques. Summarised: FSA is vulnerable to subjectivity; is too qualitative; is mainly farmer orientated; is mainly crop oriented; suffers from institutional problems; is confronted with time conflicts; lacks gender differentiation; and has seen no unification of methods. Part of QFSA is the FLORA procedure, described in Chapter 3, with which it is possible to determine long-term goals for agricultural research and hence function as a decision support tool. Also the procedure can be used to illustrate trade-offs between goal variables. It was foreseen that the FLORA procedure would make use of quantitative and qualitative information generated by researchers developing QFSA. Results computed by the FLORA procedure can be combined with information obtained by the analysis of the bio-physical and socio-economic components of farm household systems. This accumulation of knowledge can be used to illustrate trade-offs between goal variables, set goals for development and determine the research agenda that will be required to realize the selected goals. By following this working method for QFSA, it was envisaged that some of the problems confronting FSA could be overcome.

This chapter addresses the following questions:

- In which ways and why did the actual development of the FLORA procedure deviate from its original design?
- Which role is the FLORA procedure to play in overcoming problems that confront classical FSA techniques?

At the initial stage of the development of QFSA, the FLORA procedure was placed in a dependent and vulnerable position. This problematic position is discussed in Section 6.2. Section 6.3 focuses on the contribution of the FLORA procedure to solving the problems of classical FSA techniques. How the FLORA procedure deviated from its original design is explained. In Section 6.4 conclusions are drawn regarding future use of the FLORA procedure.

6.2 The dependent position of the FLORA procedure

The FLORA procedure requires both technical and socio-economic information for proper functioning. To obtain such information data collection strategies had to be adjusted as explained below.

6.2.1 Agro-technical information requirements for the FLORA procedure

Table 6.1 summarises the main technical information requirements for the FLORA procedure.

Table 6.1: Bio-physical information requirements for the FLORA procedure.

Subject	Original planning	Actually realized
Land	Soil science group of the project would provide information concerning quality and quantity of land.	Estimates and measurements were obtained during the Expanded Farm Household Survey
I-O coefficients	Maize and cassava: crop growth models would be adapted for the research area. Perennials: not specified at beginning of project.	For 22 annual and perennial crops and crop combinations use was made of general knowledge of crop growth models, literature reviews and expert knowledge provided the required information
	Livestock: livestock production models to be adapted for the research area.	As planned.
Climate	Collected and provided by project.	As planned.

Information requirements concerning land, both quantitative and qualitative, were to be generated by the soil science group of the project. A detailed data base concerning land units and land qualities as planned to be one of the outputs of quantified land evaluation analysis, and could then be used in the FLORA model. This data base was actually developed and made available, however, was not used because it *only* concerned the 36 farm households that participated in the intensive farm household survey. As was mentioned in Chapter 4, it was decided to focus research on farm households with medium-size farms, that practised animal husbandry and that grew subsistence crops, notably maize and cassava. The representativeness of these households was questioned. Therefore, estimates were made on the fields managed by farm household members that participated in the expanded farm household survey concerning quality and measurements were done concerning farm size and slope.

For the generation of I-O coefficients for crop activities, existing crop growth models would be adapted and validated for the research area and particular emphasis be given to the single and multiple cropping systems of maize and cassava. Both for annuals and perennials it was difficult to generate I-O coefficients according to the original design. The gathering of field data caused a delay in the development and operationalizing of the crop models. The researchers had difficulties in determining which data could be taken from literature and which had to be derived from field experiments, in the light of how detailed one has to consider the project aims (Efdé, 1996). As the crop modelling efforts in the project were confronted with considerable delay, an alternative manner to generate I-O coefficients was developed. I-O coefficients were mainly based on expert knowledge, literature and general knowledge of crop growth models. Instead of the originally planned 2 crops a total of 22 crops or crop combinations were included in the FLORA procedure. Both livestock and climate data exchange took place according to the original plan.

6.2.2 Socio-economic information requirements for the FLORA procedure

Table 6.2 summarises the main socio-economic information requirements for the FLORA procedure, the manner in which these data requirements were to be met according to the original design, and how they were actually realized.

Information concerning farm household preferences were to be provided by the socio-economic group of the project by conducting a detailed decision making analysis at farm household level. Such a detailed analysis would include aspects such as

- a summary of the most important changes that had taken place over the past five years,
- analysis of the reason why farmers introduced technological innovations,
- the way farmers received information about possible innovations,
- priorities of farmers as far as their preferences are concerned,
- the ways in which the farmers' social and cultural environment influence their activities, and
- the organizations of which farmers are members.

The results of the decision making analysis were not available for the FLORA procedure when this was required. Instead, preferences of farm household members were directly derived from numerous conversations (i.e. expert knowledge) and from data collected in the farm household surveys.

According to the original design of QFSA, information concerning resource endowments of farm households would be derived from the intensive farm household survey. At a later stage it was decided that this type of information would actually be provided by the expanded farm household survey, because the sample was larger and conclusions drawn would be more representative for the geographical units as a whole. Prices were obtained according to the original plan, but also additional information from the expanded farm household survey and expert knowledge was used to improve the data set. Information concerning the scenarios to be constructed were to be obtained from the socio-economic group of the project and for this the decision making analysis would also play an important role. The scenarios were constructed making certain assumptions concerning long term directions for development. For example, for the food production scenario, the assumption was made concerning the percentage of the population that would still be active in agriculture in 25 years time. This assumption had implications for the demands that were to be placed on the agro-technical goal variables. The percentage of the population still active in agriculture would have to produce sufficient staples, pulses and fruit for the population not active in agriculture.

Table 6.2: Socio-economic information requirements for the FLORA procedure

Subject	Original planning	Actually realized
Farm household preferences	To be provided by the socio-economic group of the project by detailed decision analysis	Information obtained from conversations with farm household members and farm household surveys
Farm household resource endowments	To be provided by information collected during the intensive farm household survey	Information collected during the expanded farm household survey
Prices	To be provided by information collected during the IFHS	Information collected during the intensive and expanded farm household surveys and expert knowledge
Possible directions for development	Indications would be obtained using simple trend analysis	Simple assumptions were made for future development (e.g. labour availability)

6.3 The FLORA model and problems confronting FSA

It was envisaged that the FLORA procedure could contribute to overcoming some of the problems confronting the classical FSA techniques. This Section discusses the role that the procedure played - or could have played - in overcoming some of these problems.

Subjectivity can be reduced by following the FLORA procedure. How effectively this is done depends on the choice of goal variables and the manner in which they are derived. Ideally, a pre- and a post- FLORA model development meeting with stakeholders in rural development should take place. A pre-development meeting should have taken place during Stage 1 (see Figure 3.1) of the FLORA procedure and would facilitate the selection of goal variables (a reflection of stakeholders' preferences). A post-model development meeting - which should take place in Stage 3 of the FLORA procedure - could be used to illustrate the trade-offs between goal variables and to set goals for crop and livestock research that can be considered as an acceptable compromise for the various stakeholders. Neither of these meetings were organized by the project, however. A pre-development meeting was not organized because representative farm household stakeholders were still unknown. It was also feared that organizing such a meeting would raise the expectations of farm households which could probably not be met afterwards. Therefore, the selected goal variables are based on literature, expert knowledge and informal discussions with farm household members. However, the direct involvement of stakeholders in an early stage of the exercise is a pre-requisite to the successful application of the FLORA procedure.

A post-development research goal setting meeting did not take place because, as was argued, the aim of the project was to develop a tool for setting research goals, not to implement rural development. Neither of these two meetings took place, which had implications for the manner in which the FLORA model was eventually used. As was mentioned in Chapter 2, the FLORA procedure would utilize a technique of analysis known as interactive multiple goal linear programming (IMGLP). To operationalize this technique of analysis active participation of stakeholders is necessary. When this proved difficult the FLORA model was used in an alternative manner. As would be the case for the IMGLP technique a playing field (or potency matrix) was computed. Then sensitivity analysis were conducted to illustrate how the FLORA model can be used to analyze trade-offs between goal variables. Finally, for three scenarios efficient solutions were computed. So, instead of computing a solution as part of an interactive process with stakeholders, stakeholders are given information concerning trade-offs between goal variables and possible goals for research for typical farm households in the research area.

The FLORA procedure can also reduce subjectivity in analytical judgement because it demonstrates possible improvements and associated costs more explicitly than classical FSA techniques. Comparing goals for research is more difficult and sensitivity analysis is virtually impossible with these techniques. However, the excessive data collection effort made for the FLORA procedure was largely redundant and should be regarded as an error of judgement. The FLORA procedure made FSA less qualitative indeed, but it was done rather inefficiently.

A number of goal variables included in the FLORA procedure are not only a reflection of farm household preferences, viz. those objectives that were chosen from an agro-technical or environmental point of view. Broadening the scope of classical *farmer-oriented* FSA was therefore achieved. Similarly, the FLORA procedure is not exclusively *crop oriented* as classical FSA often is, since it incorporates both crop and livestock components of the farming system. Non-agricultural development options are not yet introduced because adequate information was lacking. Hard boundaries[25] constraining non-agricultural development options are less easy to identify than those of agricultural production processes.

The research team - developing QFSA - was confronted with both internal and external *institutional problems*[26]. This chapter only discusses the former. They resulted from a lack of communication, understanding and agreement among researchers with regard to the role of the various themes in the FLORA procedure. This situation resulted in answers being given to questions that were not asked, and questions being asked that were difficult if not impossible to answer. QFSA, and the FLORA procedure as part of it, is meant to stimulate participating researchers to ask one another clear and unambiguous questions, but the working method needs to have the wholehearted support of everyone, general agreement on purpose and timing, and the skills and means to deal with methodological implications. Failure to organize pre- or post-development meetings was also partly due to institutional problems. The research team was part of an academic organization (and not a development organization, for instance) and had only a mandate to develop QFSA. Interventions were therefore not expected.

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25 Hard boundaries of agricultural production processes are constraints such as the availability of sunlight, the temperature and crop characteristics.

26 Internal institutional problems are problems that could be influenced by members of the research team, whereas external institutional problems could not. The ending of the aid relation between the governments of the Netherlands and Indonesia is an example of the latter.

Time conflicts confront the more classical FSA techniques, viz. a time conflict between short-run private gains and long-run social costs, and a time lag between recognizing a problem and finding a solution and its adoption by farmers. The FLORA procedure can overcome the first time conflict in that it can make long-term development perspectives and their social costs explicit, albeit only at farm level. As for the second time conflict, the FLORA procedure, as it was developed, has not really been an improvement.

It is feasible to incorporate various forms of differentiation into the FLORA model by adding constraint specifications. *Gender differentiation* is one of them. In our case this would prove redundant as the activities examined in the analysis were not gender-specific. The high frequency of visits in the multi-visit farm household survey was meant to accommodate the inclusion of activities in a gender-specific manner. This, however, increased the size of the data base considerably. It would have saved much time and money if the researchers had first enquired whether the activities studied had any gender specific characteristics or other characteristics that justify frequent visits.

Lastly, the development of the FLORA procedure has contributed only in a modest way to the re-thinking of FSA techniques. There is no reason to believe that the FLORA procedure has contributed to a *unification of methods.*

6.4 Conclusions

In retrospect, despite some setbacks which occurred in the process of developing the FLORA procedure, the effort was fruitful. Some of the reported setbacks belong to the domain of inevitable trial and error. Others can be ascribed to the fact that the project placed a great deal of attention to on-the-job training and learning, although this is not an acceptable excuse for some of the mistakes that could have been avoided. In future attempts to prepare and to utilize the FLORA procedure as a tool for setting research goals, the experience gained while developing QFSA suggests to focus on:

- clear research objectives,
- selective data collection,
- better interdisciplinarity,
- phasing of research activities; and
- simple and quick modelling procedures.

Lack of unanimity on research objectives is detrimental to collaboration between researchers supposed to realize a common goal. It is not enough to make a general and abstract statement about objectives. Objectives have to be formulated as concrete as possible, and theoretical and operational implications should be looked into and agreed upon as much as possible.

Data collection will always be an important part of the FLORA procedure, but it should be clearly imbedded in research questions and therefore be selective. Uncertainty as to the usefulness of data at the start of a research effort does not warrant excessive collecting of all imaginable details; it should be reduced by means of pre-scanning studies that will point out the topics on which to concentrate. Likewise, more and better qualitative work will reduce the need for excessive quantitative work, and a number of small, but focused surveys are preferable to a comprehensive one trying to cover everything.

In the project, developing QFSA, it long remained uncertain to the participating researchers what exactly interdisciplinary research implied. It was sometimes interpreted as having to encroach onto another person's discipline. It was only after the team members had been working for several years that they realized that interdisciplinarity is achieved when the output of the work of one scientist, who concentrates on his own discipline, enhances the endeavours of another discipline. Therefore, the questions that disciplines pose to one another should be clear and commonly agreed upon.

In a situation where hierarchically linked models are developed, one may expect - to some degree - a phasing of activities. Work on the FLORA procedure should commence on a full-time basis after crop and livestock production models have been developed or a decision has been made on which existing models can be used. Then via an iterative process between the developer of the FLORA procedure and researchers from the bio-physical disciplines, an exchange of information should take place. In this manner, problems will become more explicit early on, and more attention can be paid to their solution.

It is advisable to keep the FLORA procedure as simple as possible and its gestation period as short as possible. Simplicity will make it easier for stakeholders to work with FLORA and to interpret its outputs. The sooner one has, with the aid of FLORA, established general development goals as well as the trade-offs between them and clarified these, to all parties concerned, the sooner one can proceed to the setting of research priorities. On the basis of the studies thus selected, development paths then need to be explored and designed, which tackle the various obstacles to development, while taking into account short term considerations that stakeholders may have. This may require additional field studies. For the FLORA procedure, however, this means that quick and inevitably dirty methods to find the necessary data input on farm household resources, farm household objectives, input-output coefficients, as well as the wider socio-economic context, will have to be used to speed up the entire research process.

In conclusion, it can be said that most of the objectives for which FLORA was developed were attained. The development of FLORA met many problems. However, most of these problems are not due to weaknesses of the FLORA procedure and its models *per se*, but they are inherent to the human factor involved, which is just as much present in classical FSA and in any other interdisciplinary research undertaking. The choice of methods, collaboration between disciplines, and the need for all to subscribe to the same goal, will always arise. By using FLORA, however, these problems are made to appear more acute, because FLORA makes greater demands on transparency, concreteness, explicitness and interdisciplinary collaboration. It is in this manner that the FLORA procedure can help improve judgements about research priorities.

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Summary

Background of this thesis

The role of agriculture changes markedly when an economy is transforming from developing to developed. This dramatic structural transformation in the development process has consequences for policies to be implemented. Acknowledging differences between countries, four phases can be distinguished: getting agriculture moving, agriculture as a contributor to growth, integrating agriculture into the economy, and agriculture in industrialized economies. In low-income countries, the agricultural sector is usually in the 'getting agriculture moving' phase. Due to policies that discriminate against agriculture in many low-income countries, the sector has not been able to play its potential role in economic development, hence hampering overall development. This awareness gives extra reason to identify the possibilities for agricultural change. Agricultural research is one of the instruments that can be used to enhance the role of agriculture in development. However, those that will eventually have to accomplish the goals that are set for agriculture are farm household members. This thesis focuses therefore on the development of a procedure with which the possibilities for agricultural change can be explored at farm household level.

Problems with farming systems analysis

To determine the research agenda at farm household level, agricultural research institutes, particularly in developing countries, have increasingly made use of farming systems analysis (FSA) methods (Chapter 2). FSA methods, however, have not been free from problems. These problems are: FSA is vulnerable to subjectivity, has been too qualitative, is mainly farmer-oriented, has been mainly crop oriented, has suffered from institutional problems, has been confronted with time conflicts, lacks gender differentiation, and has seen no unification in methods.

The research project

In 1989 an Interdisciplinary Research (INRES) project was started in Malang, East Java, Indonesia. The INRES project was a cooperative project between Brawijaya University in

Malang, Wageningen Agricultural University and the University of Leiden. The objective of the project was to develop a new method with which some of the problems confronting FSA can be met. Because this new method is more quantitative than most FSA methods, it is called *Quantified Farming Systems Analysis* (QFSA). For QFSA, research techniques are used that sofar have not been combined and used within the context of FSA. These research techniques include, amongst others, crop and livestock growth models, intensive farm household data collection, and an analysis of decision processes at farm household level.

The FLORA procedure

Information generated with the above research techniques in QFSA are used to determine the optimal resource allocation at farm household level. For this purpose a procedure was developed named FLORA: Farm household Level Optimal Resource Allocation (Chapter 3). The FLORA procedure is part of QFSA and this thesis concentrates on the development and application of the procedure. The FLORA procedure encompasses three stages and seven steps.

Stage 1: Model preparation

(1) goal variable definition and constraint determination,
(2) system definition and choice of time horizon,
(3) generation of data requirements.

Stage 2: Model construction

(4) construction of the FLORA model.

Stage 3: Model utilization

(5) computing the playing field,
(6) conducting sensitivity analysis,
(7) establishing scenarios.

Goal variables are included in the procedure considering different points of view, agro-technical, household socio-economic, and environmental. Both normative and technical constraints are specified. Attention is focused on farm household systems. The time horizon is chosen in such a way that all activities that are included in the procedure can be realized. Information required for the FLORA procedure - quantitative and qualitative - is collected at farm household level, generated with crop and livestock growth models, and made available through expert knowledge and literature.

The FLORA model, which is part of the procedure, is a linear programming model. This technique is considered the most suitable one to explore technological possibilities not yet present in the research area. The model is first used to compute the so-called playing field. This playing field encompasses for each goal variable the 'ideal' and 'anti-ideal' values. The ideal value for a goal variable is the optimal value, considering goals and constraints. The anti-ideal value is the value that deviates most from the optimal value considering the restrictions. For stakeholders in rural development the playing field gives the range of possible development options. When computing the playing field a number of assumptions are made. To test the sensitivity of the model results for these assumptions, sensitivity analysis is applied. Three end-visions (scenarios) are constructed: food production, income generation and soil conservation. For each of these end visions different variants are computed.

The study area

The study area of the INRES project is situated in the limestone range, south of Malang (Chapter 4). This area is selected because farm households are confronted with relatively low income, low crop productivity and high levels of soil erosion. Both the local government and the Brawijaya University share efforts to improve the welfare of farm households in this area. Mainly on the basis of land quality the research area is divided into three geographical units, named Putukrejo, Kedunglor and Kedungkidul. The first mentioned geographical unit lies in the north of the study area and the last in the south, bordering the Indian Ocean. Putukrejo is most and Kedungkidul least endowed with land of good quality. Per geographical unit so-called *typical farm households* were defined. This was done on the basis of available land and labour. Common activities in this area are maize and cassava cultivation, limestone burning and cattle rearing.

Results of the FLORA procedure

All results are calculated per typical farm household (Stage 3, Chapter 5). Results show that in the long-term a reduction of subsidies will hardly effect the possibilities for farm households to generate income from crop and livestock activities. Objectives concerning food production can - technically speaking - easily be realized. For each geographical unit the required farm land is still far below the present average. With the assumptions made, the future role of agriculture to bridge the gap between per capita income in the study area and the expected per capita income range for middle-income countries will however be limited. Policies that discourage agriculture on land of poor quality will particularly affect farm households in Kedungkidul, despite the fact that in this geographical unit the average farm size is larger than in the north.

The FLORA procedure and QFSA

In Chapter 6, two questions are answered: (1) in which way did the development of the FLORA procedure deviate from the original design, as described in Chapter 2 and (2) can the FLORA procedure contribute to solving the problems confronting FSA. Especially the manner in which information was provided to the procedure deviates from the original design. This is the case both for the quantitative and qualitative information requirements. In certain aspects this can be considered as a 'blessing in disguise'. For example, instead of the originally planned two annual crops maize and cassava, 22 crop and crop combinations were included in the procedure. Eventually more use was made of general knowledge of crop models and expert knowledge than had been anticipated.

In several ways the procedure can contribute towards solving problems confronting FSA. By including goal variables, considering different points of view, subjectivity of FSA can be reduced. Due to institutional problems it proved impossible to utilize the procedure in an interactive manner with stakeholders in rural development. With the FLORA procedure FSA does not only focus on crop and livestock activities; its scope has therefore been broadened. Time conflicts are only partly solved with the FLORA procedure. The procedure can be used to explore long-term options for development, as well as the costs that are associated with these options. The procedure does not reduce the time gap between recognizing a problem and finding a solution. The FLORA procedure can take into consideration gender issues. There is, however, no reason to assume that the procedure has contributed towards a unification in methods. In conclusion, this thesis recommends that future efforts to implement QFSA should focus on clearly defined research objectives. These are necessary to implement selective data collection exercises. Better interdisciplinarity can be achieved through thorough disciplinary research. To avoid unnecessary delays, more attention should be focused on a better phasing of research efforts. The use of simple and quick model procedures will improve the effectiveness of QFSA.

Samenvatting

Achtergrond van dit proefschrift

De rol van de landbouw verandert aanzienlijk wanneer een land zich economisch ontwikkelt. Deze ingrijpende structurele veranderingen tengevolge van het ontwikkelingsproces hebben invloed op het te implementeren beleid. Ook al zijn er verschillen tussen landen, toch kunnen in het algemeen enkele duidelijke fasen ten aanzien van de landbouw in het ontwikkelingsproces worden onderscheiden: het op gang brengen van landbouw ontwikkeling, het bijdragen van de landbouw aan de algehele groei, integratie van de landbouw in de economie, en de positie van de landbouw in industriële economiën. In veel lage-inkomenslanden bevindt de landbouw zich in de eerste fase. Doordat veel beleidsmaatregelen een negatief effect hebben gehad op de landbouw, wordt de sector veelal niet in staat gesteld zijn potentiële rol binnen de economie te vervullen, wat een belemmering is voor algehele economische ontwikkeling. In toenemende mate is men zich hiervan bewust geworden, en dit is één van de redenen om de potentiële mogelijkheden die de landbouw biedt te onderzoeken. Landbouwonderzoek is één van de middelen die ingezet kunnen worden om de rol van de landbouw in een economie beter te benutten. Daarbij zijn het de landbouwhuishoudens zelf die de uiteindelijke doelstellingen met betrekking tot de landbouw moeten verwezenlijken. Dit proefschrift houdt zich bezig met de ontwikkeling van een procedure die het mogelijk maakt om deze mogelijkheden van de landbouw op micro-niveau te verkennen.

Problemen met 'farming systems analysis'

Ter bepaling van de agenda voor onderzoek op het niveau van landbouwhuishoudens, wordt door agrarische onderzoeksinstituten, met namen in lage-inkomenslanden, in toenemende mate gebruik gemaakt van *farming systems analysis* (FSA) methoden (Hoofdstuk 2). Echter, bij het gebruik van FSA methoden doen zich verschillende problemen voor. FSA methoden: zijn gevoelig voor subjectiviteit, zijn te kwalitatief, zijn hoofdzakelijk georiënteerd op boeren, zijn voornamelijk gewas-georiënteerd, worden geconfronteerd met institutionele problemen, en met tijdsconflicten, hebben onvoldoende aandachtig voor geslachtsdifferentiatie, en zijn weinig uniform in methoden.

Het onderzoekproject

In 1989 is een project gestart in Malang, Oost Java, Indonesië, met het doel een nieuwe methoden te ontwikkelen om de genoemde problemen van *farming systems analysis* te overwinnen. Dit project, genaamd het INterdisciplinary RESearch (INRES) project was een samenwerking tussen de Brawijaya Universiteit te Malang, de Landbouwuniversiteit Wageningen en de Rijksuniversiteit Leiden. Omdat deze nieuwe methode meer kwantitatief is dan de meeste *farming systems analysis* methoden is hieraan de naam *quantitative farming systems analysis* (QFSA) gegeven. Voor QFSA worden onderzoektechnieken aangewend die tot op heden niet zijn gecombineerd binnen het kader van FSA. Deze onderzoektechnieken zijn, onder andere, gewas-en veeteelt-groei modellen, intensieve gegevensverzameling op landbouwhuishoudniveau, en een analyse van beslissingsprocessen binnen het huishouden.

De FLORA procedure

Informatie die gegenereerd wordt door de toepassing van genoemde technieken in QFSA wordt benut ter bepaling van de optimale allocatie van hulpbronnen op huishoudniveau (Hoofdstuk 3). Hiervoor is een procedure ontwikkeld genaamd FLORA: *Farm household Level Optimal Resource Allocation*. De FLORA procedure is onderdeel van QFSA en dit proefschrift concentreert zich met name op de ontwikkeling en toepassing van deze procedure. De FLORA procedure omvat drie fasen in zeven stappen.

Fase 1: modelvoorbereiding

(1) bepaling van doelvariabelen en beperkingen,
(2) systeemdefinitie en bepaling van de tijdshorizon,
(3) voortbrenging van de benodigde gegevens.

Fase 2: modelconstructie

(4) modelconstructie.

Fase 3: modelgebruik

(5) berekening van het speelveld,
(6) uitvoeren van gevoeligheidsanalyses,
(7) opstellen van eindvisies.

Doelvariabelen in de procedure zijn opgenomen vanuit verschillende invalshoeken, namelijk agro-technisch, sociaal-economisch op huishoud niveau en milieubeschermend. Zowel normatieve als technische beperkingen worden opgelegd. Het systeem waar de aandacht op wordt gevestigd is het landbouwhuishouden. De tijdshorizon is zodanig gekozen dat alle activiteiten die opgenomen zijn, gerealiseerd kunnen worden. Gegevens voor de FLORA procedure - zowel kwantitatief and kwalitatief - zijn verzameld op huishoudniveau, gegenereerd met behulp van gewas-en veeteelt-groeimodellen, en er is gebruik gemaakt van literatuur en kennis van experts.

Het FLORA model, dat onderdeel uitmaakt van de procedure, is een lineair programmeringsmodel. Na kennis te hebben genomen van alternatieve technieken werd een lineair programmeringsmodel het meest geschikt geacht om de mogelijkheden van alternatieve technologieën te verkennen die op dit moment nog niet aanwezig zijn in het studiegebied. In eerste instantie wordt het model aangewend om een zogenaamd 'speelveld' te berekenen. Het speelveld omvat voor elke doelvariabele de 'ideale' en 'anti-ideale' waarden. Een ideale waarde voor een doelvariabele is de optimale waarde die verkregen wordt rekening houdend wordt met doelen en restricties. Een anti-ideale waarde komt overeen met die waarde van een doelvariabele die het meest afwijkt van de optimale waarde binnen gestelde restricties. Voor belanghebbenden in rurale ontwikkeling geeft het speelveld de marge aan voor mogelijkheden van ontwikkeling. Bij het berekenen van het speelveld zijn een aantal veronderstellingen gemaakt. Om de gevoeligheid van de modeluitkomsten voor de veronderstellingen te toetsen wordt gevoeligheidsanalyse toegepast. Drie eindvisies (scenario's) worden uitgewerkt: voedselproduktie, inkomensgeneratie en bodemconservering. Voor ieder van deze eindvisies zijn verschillende varianten uitgewerkt.

Studiegebied

Het studiegebied van het INRES project ligt in het kalksteengebied ten zuiden van Malang (Hoofdstuk 4). Dit gebied is geselecteerd omdat landbouwhuishoudens hier geconfronteerd worden met relatief lage inkomens, lage gewasproduktiviteit en hoge erosie. Zowel de lokale overheid als de Brawijaya Universiteit zetten zich in om de welvaart van landbouwhuishoudens in dit gebied te verbeteren. Het studiegebied is geclassificeerd naar landkwaliteit en opgedeeld in drie geografische eenheden, genaamd Putukrejo, Kedunglor en Kedungkidul. De eerstgenoemde geografische eenheid ligt in het noorden en de laatste ligt in het zuiden en grenst aan de Indische Oceaan. De meest noordelijk gelegen geografische eenheid is het beste voorzien van land van goede kwaliteit, terwijl de meest zuidelijk gelegen geografische eenheid de armste bodems kent. Per geografische eenheid zijn zogenaamde *typical farm households* gedefinieerd. Dit is gedaan op basis van landkwaliteit en beschikbaarheid van arbeid. Veel voorkomende activiteiten in dit gebied zijn het verbouwen van maïs en cassava, het branden van kalksteen en het houden van vee.

Resultaten van de FLORA procedure

Alle resultaten zijn berekend per *typical farm households* (Fase 3, hoofdstuk 5). Resultaten laten zien dat op lange termijn de invloed van het verminderen van input subsidies voor de mogelijkheid van huishoudens om inkomen te verwerven uit gewas-en veeteelt-activiteiten gering is. Doelstellingen ten aanzien van voedselproduktie kunnen technisch gemakkelijk gerealiseerd worden door landbouwhuishoudens in het onderzoeksgebied. Opvallend is - bijvoorbeeld - dat voor elk van de geografische eenheden de minimum noodzakelijke bedrijfsgrootte voor voedsel-produktie nog ver beneden het huidige gemiddelde voor elk gebied ligt. Bij de gemaakte veronderstellingen geeft het model aan dat in de toekomst de bijdrage van de landbouw aan het verkleinen van het verschil tussen inkomen per hoofd uit landbouwactiviteiten en de bovengrens voor het hoofdelijk inkomen voor midden-inkomenslanden beperkt is. Bij beleidsmaatregelen die gericht zijn om landbouwactiviteiten op gronden van minder goede kwaliteit te ontmoedigen, zullen landbouwhuishoudens in het zuiden van het onderzoeksgebied het meest getroffen worden. Dit ondanks het feit dat in dat gebied de gemiddelde bedrijfsgrootte groter is dan in het noorden.

De FLORA procedure en QFSA

In Hoofdstuk 6 worden twee vragen beantwoord: (1) in welke opzichten wijkt de uiteindelijke ontwikkeling van de FLORA procedure af van de oorspronkelijke opzet, zoals beschreven in Hoofdstuk 2, en (2) kan de procedure een bijdrage kunnen leveren aan het oplossen van de problemen waarmee FSA geconfronteerd is. Met name in de wijze waarop is voorzien in de informatiebehoefte van de FLORA procedure wijkt af van de oorspronkelijke opzet. Dit geldt zowel voor de kwantitatieve als kwalitatieve informatie voorziening. In bepaalde opzichten kan dit beschouwd worden als een *blessing in disguise*. Bijvoorbeeld, in plaats van de oorspronkelijke twee eenjarige gewassen maïs en cassava zijn uiteindelijk in de procedure 22 gewas en gewascombinaties opgenomen.

Uiteindelijk is veel meer gebruik gemaakt van algemene kennis van gewasgroeimodellen en expert kennis dan oorspronkelijk was voorzien.

Op verschillende manieren kan de procedure een bijdrage leveren aan het oplossen van problemen waarmee FSA geconfronteerd is. Door het opnemen van doelvariabelen vanuit verschillende invalshoeken kan de subjectiviteit van FSA verminderd worden. Als gevolg van onder andere institutionele problemen bleek het niet mogelijk om de procedure op een interactieve wijze te benutten met belanghebbenden in rurale ontwikkeling. Door de FLORA procedure is FSA meer dan alleen een instrument dat zich uitsluitend richt op boeren en gewassen. Tijdsconflicten worden gedeeltelijk door de FLORA procedure opgelost. Zo kan de FLORA procedure lange-termijn opties voor ontwikkeling verkennen, alsmede de kosten die daarmee gepaard gaan. De procedure levert echter geen bijdrage aan het verkleinen van de tijd tussen het erkennen van een probleem en het vinden van een oplossing. De procedure is geschikt om rekening te houden met geslachtsdifferentiatie. Er is geen reden om op dit moment aan te nemen dat de procedure een bijdrage heeft geleverd aan een uniformering in methoden. Tot slot van dit proefschrift worden een aantal conclusies getrokken ten aanzien van toekomstige inspanningen om QFSA te implementeren. Heldere onderzoeksdoelen ten einde te komen tot een selectieve gegevens-verzameling zijn nodig. Betere interdisciplinariteit kan bereikt worden door grondig disciplinair werk. Meer aandacht zou gevestigd moeten worden op een fasering van onderzoeksactiviteiten. Het gebruik van eenvoudige en snelle modelprocedures zal de effectiviteit van QFSA ten goede komen.

Curriculum vitae

Teunis van Rheenen was born on the 8th of July, 1964, in Ogbomosho, Nigeria. His mother was responsible for his primary schooling with the aid of correspondence courses. At the age of 12 he moved to Kenya where he attended the Imani School at Thika and achieved his A levels in 1984. During the same year he started his study in agricultural economics at the Agricultural University Wageningen, The Netherlands, where he graduated in 1990. As part of his study he spent six months in 1983 at the Centro Internacional de Mejorimiento de Maize y Trigo in Mexico. In June 1990, he started research for his PhD. His research topic was 'Modelling for farm household optimal resource allocation'. As part of his PhD research he spent two years in Indonesia at the Interdisciplinary Research Project located at the Brawijaya University, Malang, East Java. In this project, he was a member of an interdisciplinary Indonesian and Dutch research team. The aim of this team was to develop new methods to conduct farming systems analysis. At the project he also was survey coordinator and in that capacity he organized and managed several farm household surveys. During his PhD research he actively participated in several international meetings in Indonesia, Sri Lanka, Peru and The Netherlands. In September 1995, he helped to organize a course in land use planning in Bogor, Indonesia. He has supervised a number of undergraduate students.

Annex 3.1: Supporting literature and computer models, used for the calculation of the inputs and outputs of the crop activities.

Crop names	Supporting literature[a]	Computer models
Arachis hypogaea L.	Brotonegoro et al. (1986); Giller & Wilson (1991); van Hoof (1987); van Hoof & van der Ham (1989); Sharma and Soekarno (1990); Shorter & Patanothai (1989)	PS123[b]
Ceiba pentandra (L.) Gaertn.	Andam (1985); Cannell (1971); Corley (1983); Corley et al. (1971); Toxopeus (1950)	Ceiba[c]
Cocos nucifera L.	Foale (1986); Ohler (1984); Ouvrier (1984); Visser (1986); Wiersum (1989)	Cocos[c]
Fagraea fragrans Roxb.	Fundter et al. (1989)	Timber[c]
Gnetum gmemon L.	Verheij (1989); Visser (1986)	Gnemon[c]
Gliricidia sepium (Jacq.) Kunth ex Walp.	Brewbaker et al. (1989); Giller & Wilson (1991); Otarola & Ugalde (1983); Wiersum (1989)	Gliricidia[c]
Manihot esculenta Crantz	Cock (1985); Effendi (1980); Gijzen (1985); Nishiyama et al. (1980); Veldkamp (1985)	PS123
Musa L.	de Bruin (1989); Espino et al. (1991); Stover & Simmonds (1987); Waaijenberg (1992)	Musa[c]
Pennisetum purpureum Schumach.	't Mannetje (1992)	PS123
Phaseolus vulgaris L.	Adams et al. (1985); Giller & Wilson (1991); Sinha et al. (1988); Smartt (1989); White & Castillo (1989)	PS123
Oryza sativa L.	De Datta (1981); Moorman & van Breemen (1978); Satomi et al. (1978); Tantera et al. (1973)	PS123
Oryza sativa L.	De Datta (1981); Moorman & van Breemen (1978); Tantera et al. (1973)	PS123
Saccharum officinarum L.	Irwan (1986); Jaipal & Dendsay (1990); Shinh et al. (1988); Sturgess (1980)	PS123
Tectona grandis L.f.	Wolterson (1980)	Timber
Zea mays	Effendi (1980); MARIF (1986); Ojo et al. (1986)	PS123
Native grass	Blair et al. (1985); Giller and Wilson (1991); de Wit & van den Bergh (1965)	Ngrass[c]
Intercrop Arachis hypogea & Zea mays	Groot (1993); van Hoof (1987); literature listed for crops in monoculture	PS123, Intercrop[c]
Intercrop Cocos nucifera & Manihot esculenta	Cannell (1971); lit. listed for crops in monoculture	Cocos, PS123, Intercrop
Intercrop Cocos nucifera & Zea mays	Cannell (1971); Hozyo et al. (1984); lit. listed for crops in monoculture	Cocos, PS123, Intercrop
Intercrop Gliricidia sepium & Manihot esculenta	Cannell (1971); lit. listed for crops in monoculture	Gliricidia, PS123, Intercrop
Intercrop Gliricidia sepium & Zea mays	Cannell (1971); lit. listed for crops in monoculture	Gliricidia, PS123, Intercrop
Intercrop Manihot esculenta & Zea mays	van Hoof (1987); lit.listed for crops in monoculture	PS123, Intercrop

[a] Literature used for all crop activities: *(fertilization)* Atanasiu & Westphal (1981); Nijhof (1987 a&b); Soerjani et al. (1987); *(diseases and biocide use)* Canter (1986); FAO (1987); Kalshoven (1981); Oudejans (1991) *(Erosion)* Hamer (1981); Wischmeier & Smith (1978); *(model parameters and general agronomic information)* Corley (1983); Driessen and Konijn (1992); Doornenbos and Kassam (1979); Doornenbos and Pruitt (1977); Purseglove (1968; 1972) [b] Described in Driessen & Konijn (1992) [c] Described in van Loon & van Rheenen (1995)

Annex 3.2: Names of various crops with experts who improved the input/output estimates.

Crop names + Crop code (=c)	English/Indonesian name (variety)	Names of experts	Occupation or Function and Institute (Residence)
Arachis hypogaea L. (c=5)	Groundnut/Kacang tahah (Spanish type)	dr ir W.C.H. van Hoof	Agronomist/ Expert rural development Cebemo (Oegstgeest)
Ceiba pentandra (L.) Gaertn (c=10)	Kapok	-	-
Cocos nucifera L. (c=8)	Coconut/Kelapa (Mapangit)	ir J.G. Ohler	Coconut expert, KIT (Amsterdam)
Fagraea fragrans Roxb. (c=13)	Tembusu	dr ir N.R. de Graaf	Senior lecturer, Dept. of Forestry (Wageningen)
Gnetum gmemon L. (c=9)	Melinjo	dr ir E.W.M. Verhey	Fruit expert/ Consultant (Bennekom)
Gliricidia sepium (Jacq.) Kunth ex Walp (c=12)	Quick stick/Gamal	prof. dr ir L.J.G. v.d. Maessen	Plant taxonomy, Dept. of Plant Taxonomy (Wageningen)
Manihot esculenta Crantz (c=2)	Cassava/Ubi kayu	dr ir G.H. de Bruijn prof. dr ir L.O. Fresco	Agronomist/ Consultant (Wageningen) prof. Tropical crop science, Dept. of Agronomy (Wageningen)
Musa L. (c=14)	Banana/Pisang (Dwarf Cavendish)	dr ir E.W.M. Verhey	(described above in this table)
Pennisetum purpureum Schumach. (c=6)	Elephant grass/Rumput gajah	prof. dr ir L.'t Mannetje	Grassland science Dept. of Agronomy (Wageningen)
Phaseolus vulgaris L. (c=16)	Common bean/Buncis	dr ir H.A. v. Rheenen	Principal scientist (plant breeding), ICRISAT (Hyderabad)
Oryza sativa L. (c=15)	Paddy rice/Paddy (IR36)	dr F.W.T. Penning-de Vries	Agronomist/ AB-DLO (Wageningen)
Oryza sativa L. (c=4)	Upland rice/Paddy gogo	dr F.W.T. Penning-de Vries	(described above in this table)
Saccharum officinarum L. (c=3)	Sugar cane/Tebu (Ps56)	ir E.V. v.d. Spek	Head agronomy, HVA international (Amsterdam)
Tectona grandis L.f. (c=11)	Teak/Jati	dr ir N.R. de Graaf	(described above in this table)
Zea mays L. (c=1)	Maize/Jagong (Arjuna)	prof. dr ir P.C. Struik	Temparate crop science, Dept. of Agronomy (Wageningen)
- (c=7)	Native grass/Rumput rumputan	prof. dr ir L.'t Mannetje	(described above in this table)
Intercrop Arachis hypogea & Zea mays (c=18)	-	dr ir W.C.H. van Hoof	(described above in this table)
Intercrop Cocos nucifera & Manihot esc. (c=22)	-	ir J.G. Ohler	(described above in this table)
Intercrop Cocos nucifera & Zea mays (c=20)	-	ir J.G. Ohler	(described above in this table)
Intercrop Gliricidia sep. & Manihot esc. (c=21)	-	prof. dr ir L.J.G. v.d. Maessen	(described above in this table)
Intercrop Gliricidia sepium & Zea mays (c=19)	-	prof. dr ir L.J.G. v.d. Maessen	(described above in this table)
Intercrop Manihot esculenta & Zea mays (c=17)	-	dr ir W.C.H. van Hoof prof. dr ir L.O. Fresco	(described above in this table)
Erosion: All crops	-	prof. dr ir L. Stroosnijder	Soil and Water Conservation (Wageningen)

Annex 3.3: Inputs and outputs that were quantified.

Inputs and outputs that were quantified for crop activities

Inputs	Units	Outputs	Units	External effects	Units
Urea	$kg.ha^{-1}$	Storage organs	$kg.ha^{-1}$	Nitrogen loss	$kg.ha^{-1}$
TSP	$kg.ha^{-1}$	Green parts	$kg.ha^{-1}$	Biocide accumulation	$kg.ha^{-1}$
KCl	$kg.ha^{-1}$	Woody parts	$kg.ha^{-1}$	Erosion	$t.ha^{-1}$
BS	$kg.ha^{-1}$	Roots	$kg.ha^{-1}$		
Manure	$kg.ha^{-1}$				
Fungicides	$kg.ha^{-1}$				
Herbicides	$kg.ha^{-1}$				
Seed	$kg.ha^{-1}$				
Irrigation water	$l.ha^{-1}$				
Draft power	$cd.ha^{-1}$				
Labour	$md.ha^{-1}$				

Inputs and outputs that were quantified for livestock activities

Inputs	Units	Outputs	Units
Leguminous tree leaves	$kg.liu^{-1}$	Meat	$kg.liu^{-1}$
Non-leguminous tree leaves	$kg.liu^{-1}$	Milk	$l.liu^{-1}$
Native grass	$kg.liu^{-1}$	Off-spring	Calve/kid/lamb
Elephant grass	$kg.liu^{-1}$	Traction	$ha.liu^{-1}$
Sugarcane leaves	$kg.liu^{-1}$		
Cassava leaves	$kg.liu^{-1}$		
Mais straw	$kg.liu^{-1}$		
Rice straw	$kg.liu^{-1}$		
Maize bran	$kg.liu^{-1}$		
Soyabean cake	$kg.liu^{-1}$		
Labour	$hrs.liu^{-1}$		

Annex 3.4: FLORA model, condensed version

Land use

- Total Land

$$CL_{m,l}+FL_{m,l}\leq TL_{m,l} \qquad \text{All m,l} \qquad \textbf{(1)}$$

- Crop land

$$CL_{m,l} = \sum_{o}\sum_{p}\sum_{ft} CL_{o,p,ft,l} \qquad \text{All m,l} \qquad \textbf{(2)}$$

Labour

$$CLA_m + LLA_m = LT_m \qquad \text{All m} \qquad \textbf{(3)}$$

$$LT_m \leq LHH_m+LHI_m \qquad \text{All m} \qquad \textbf{(4)}$$

$$LHI_m \leq 0.5*LHH_m \qquad \text{All m} \qquad \textbf{(5)}$$

Traction power

$$CTR_m \leq \sum_{t} LPTR_{t,m} + HTR_m \qquad \text{All m} \qquad \textbf{(6)}$$

Crop production

- Storage organs:

$$CPYS_j = \sum_{o}\sum_{p}\sum_{ft}\sum_{l} ys_{j,o,p,ft,l}*CL_{o,p,ft,l} \qquad \text{All j} \qquad \textbf{(7)}$$

- Green parts

$$CPYG_{m,j} = \sum_{o}\sum_{p}\sum_{ft}\sum_{l} yg_{j,m,o,p,ft,l}*CL_{o,p,ft,l} \qquad \text{All j,m} \qquad \textbf{(8)}$$

- Woody parts

$$CPYW_j = \sum_{o}\sum_{p}\sum_{ft}\sum_{l} yw_{j,o,p,ft,l}*CL_{o,p,ft,l} \qquad \text{All j} \qquad \textbf{(9)}$$

- Roots

$$CPYR_j = \sum_{o}\sum_{p}\sum_{ft}\sum_{l} yr_{j,o,p,ft,l}*CL_{o,p,ft,l} \qquad \text{All j} \qquad \textbf{(10)}$$

Crop inputs

- Labour

$$CLA_m = \sum_o \sum_p \sum_{ft} \sum_l l_{m,o,p,ft,l} * CL_{o,p,ft,l} \qquad \text{All m} \qquad \textbf{(11)}$$

- Traction requirements

$$CTR_m = \sum_o \sum_p \sum_{ft} \sum_l t_{m,o,p,ft,l} * CL_{o,p,ft,l} \qquad \text{All m} \qquad \textbf{(12)}$$

- Nutrients

$$CN_i = \sum_o \sum_p \sum_{ft} \sum_l n_{i,o,p,ft,l} * CL_{o,p,ft,l} \qquad \text{All i} \qquad \textbf{(13)}$$

$$\sum_o \sum_p \sum_{ft} \sum_l my_{i,o,p,ft,l} * CL_{o,p,ft,l} \leq LPMA \qquad \textbf{(14)}$$

- Planting material

$$CPM_j = \sum_o \sum_p \sum_{ft} \sum_l pm_{j,o,p,ft,l} * CL_{o,p,ft,l} \qquad \text{All j} \qquad \textbf{(15)}$$

- Biocides

$$CB_k = \sum_o \sum_p \sum_{ft} \sum_l b_{k,o,p,ft,l} * CL_{o,p,ft,l} \qquad \text{All k} \qquad \textbf{(16)}$$

- Irrigation water

$$CW = \sum_o \sum_p \sum_{ft} \sum_l w_{o,p,ft,l} * CL_{o,p,ft,l} \qquad \textbf{(17)}$$

- Working capital excluding labour

$$CWC = \sum_m pt * HTR_m + \sum_i pn_i * CN_i + \sum_j pp_j * CPM_j + \sum_k pb_k * CB_k \qquad \textbf{(18)}$$

Livestock outputs

- Meat

$$LPME_t = \sum_m \sum_{pl} \sum_d mg_{m,t,pl,d} * LIU_{t,pl,d} \qquad \text{All t} \qquad (19)$$

- Milk

$$LPMI_t = \sum_m \sum_{pl} \sum_d mi_{m,t,pl,d} * LIU_{t,pl,d} \qquad \text{All t} \qquad (20)$$

- Traction power

$$LPTR_{t,m} = \sum_{pl} \sum_d tr_{m,t,pl,d} * LIU_{t,pl,d} \qquad \text{All t,m} \qquad (21)$$

- Manure

$$LPMA = \sum_m \sum_t \sum_{pl} \sum_d ma_{m,t,pl,d} * LIU_{t,pl,d} \qquad (22)$$

Livestock inputs

- Labour

$$LLA_m = \sum_t \sum_{pl} \sum_d l_{m,t,pl,d} * LIU_{t,pl,d} \qquad \text{All m} \qquad (23)$$

- Feed
  - Green parts

$$LF_{m,j} = \sum_t \sum_{pl} \sum_d f_{j,m,t,pl,d} * LIU_{t,pl,d} \qquad \text{All m,j} \qquad (24)$$

$$LF_{m,j} = CPYG_{m,j} + CPOF_{m,j} \qquad \text{All m,j} \qquad (25)$$

  - Purchased feeds

$$LF_{pf} = \sum_m \sum_t \sum_{pl} \sum_d f_{pf,m,t,pl,d} * LIU_{pf,m,t,pl,d} \qquad \text{All pf} \qquad (26)$$

- Working capital excluding hired labour

$$LWC = \sum_{pf} pf_{pf} * LF_{pf} \qquad (27)$$

<u>General farm working capital</u>

$$TWC = CWC + LWC + \sum_{m} pl*LHI_{m} \tag{28}$$

<u>Goal variables</u>

Energy

- Staples

$$G(1) = Energy(staples) = \sum_{js} e_{js}*CPYS_{js} \tag{29}$$

- Pulses

$$G(2) = Energy(pulses) = \sum_{jp} e_{jp}*CPYS_{jp} \tag{30}$$

- Fruit

$$G(3) = Energy(fruit) = \sum_{jf} e_{jf}*CPYS_{jf} \tag{31}$$

- Meat

$$G(4) = Energy(meat) = \sum_{t} e_{t}*LPME_{t} \tag{32}$$

Working capital

$$G(5) = Working\ capital = CWC + LWC + \sum_{m} pl*LHI_{m} \tag{33}$$

Labour

$$G(6) = Labour = \sum_{m} CLA_{m} + \sum_{m} LLA_{m} \tag{34}$$

Gross margins

$$G(7) = Gross\ margins = \left(\sum_{j} p_{ys,j}*CPYS_{j} + \sum_{j} p_{yw,j}*CPYW_{j} - CWC \right)$$

$$+\left(\sum_{t} p_{me,t}*LPME_{me,t} + \sum_{t} p_{mi,t}*LPMI_{mi,t} + \sum_{t}\sum_{m} p_{tr,t}LPTR_{t,m} - LWC \right) \tag{35}$$

$$- \sum_{m} pl*LHI$$

N-loss

$$G(8) = N\text{-}loss = \sum_{o}\sum_{p}\sum_{ft}\sum_{l} nl_{o,p,ft,l} * CL_{o,p,ft,l} \qquad (36)$$

Biocides accumulation

$$G(9) = biocides\ accumulation = \sum_{o}\sum_{p}\sum_{ft}\sum_{l} ba_{o,p,ft,l} * CL_{o,p,ft,l} \qquad (37)$$

Soil loss

$$G(10) = soil\ loss = \sum_{o}\sum_{p}\sum_{ft}\sum_{l} sl_{o,p,ft,l} * CL_{o,p,ft,l} \qquad (38)$$

Variables included in the FLORA model

Variable	Description	Unit of measurement
CL	Crop land	ha
FL	Fallow land	ha
TL	Total land	ha
LT	Total available labour	md
LHH	Household labour	md
LHI	Hired labour	md
CPYS	Crop production: storage organs	kg
CPYG	Crop production: green parts from own farm	kg
CPOF	Crop production: green parts from outside farm	kg
CPYW	Crop production: woody parts	kg
CPYR	Crop production: roots	kg
CLA	Labour input for crops	md
CTR	Traction power for crops	cd
CN	Nutrient requirements for crops	kg
CPM	Crop planting material	kg
CB	Crop biocides	kg
CW	Irrigation water	l
CWC	Working capital required for crops, excluding hired labour	Rp
LPME	Livestock meat production	kg
LPMI	Livestock milk production	kg
LPTR	Livestock traction supply	cd
HTR	Hired traction	cd
LPMA	Livestock manure production	kg
LIU	Livestock unit	cattle, goat or sheep
LLA	Labour requirements for livestock	md
LF	Livestock feed requirements	kg
LWC	Working capital requirements for livestock, excluding hired labour	Rp
TWC	Total working capital, including hired labour	Rp
Goal variables		
G(1)	Energy derived from staples	J
G(2)	Energy derived from pulses	J
G(3)	Energy derived from fruit	J
G(4)	Energy derived from meat	J
G(5)	Working capital	Rp
G(6)	Labour	md
G(7)	Gross margins	Rp
G(8)	N-loss	kg
G(9)	Biocide accumulation	kg
G(10)	Soil loss	t

Coefficients included in the FLORA model

Coefficient	Description	Unit of measurement
ys	Storage organs	$kg.ha^{-1}$
yg	Green parts	$kg.ha^{-1}$
yw	Woody parts	$kg.ha^{-1}$
yr	Roots	$kg.ha^{-1}$
l	Labour	Crops: $md.ha^{-1}$
		Livestock: $md.liu^{-1}$
t	Traction	$cd.ha^{-1}$
n	Nutient utilization	$kg.ha^{-1}$
pm	Planting material	$kg.ha^{-1}$
b	Biocide utilization	$kg.ha^{-1}$
w	Water utilization	$l.ha^{-1}$
pl	Price of labour	$Rp.md^{-1}$
pt	Price of traction power	$Rp.cd^{-1}$
pn	Price of nutrients	$Rp.kg^{-1}$
pp	Price of planting material	$Rp.kg^{-1}$
pb	Price of biocides	$Rp.l^{-1}$
pf	Price of purchased feeds	$Rp.kg^{-1}$
mg	Meat gain	$kg.liu^{-1}.month^{-1}$
mi	Milk production	$lt.liu^{-1}.month^{-1}$
tr	Traction supply	$cd.liu^{-1}$
ma	Manure production	$kg.dm.yr^{-1}$
my	Manure use	$kg.dm.ha^{-1}$
f	Feed requirements	Green parts: $kg.liu^{-1}$
		Purchased feeds: $kg.liu^{-1}$
p	Price	Rp. per unit input or output
e	Energy content	$j.kg^{-1}$
nl	N-loss	$kg.ha^{-1}$
ba	Biocide accumulation	$kg.ha^{-1}$
sl	Soil loss	$t.ha^{-1}$

Notes:
liu = Livestock unit; cd = Cattle days; md = mandays

Indices included in the FLORA model

Indices	Description	Elements
m	Month	1 = January ... 12 = December
o	Crop combination	1 = Maize ... 24 = cassava / coconut
p	Production situation	1= Potential ... 4 = water limited and yield reduced by pest and diseases
ft	Fertilization type	1 = Mineral fertilizers only, 2 = manure and mineral fertilizers
l	Land unit	1 = LU1 ... 4 = LU4
j	Crop specification	1 = Maize ... 16 = common bean
i	Mineral fertilizer type	1 = Urea ... 6 = KSO
k	Biocide type	1 = Fungicides ... 3 = herbicides
pl	Production level	1 = Potential ... 3 = attainable
d	Ration and source	1 = Diet with maize bran, feed source 1 ..... 8 = 1990/91 diet observed in Kedungsalam, feed source 2
t	Livestock type	1 = Cattle unit 1 ... 5 = sheep
pf	Purchased feeds	1 = Maize bran; 2 = soya bean cake
js	Staple crops	1 = Maize ... 4 = paddy rice
jp	Pulse crops	1 = Groundnut ... 2 = common bean
jf	Fruit crops	1 = Coconut ... 3 = banana
yw	Wood	1 = Coconut ... 6 = fragrance
ys	Storage organs	1 = Maize ... 16 = common bean
tr	Traction power	1 = from livestock unit 1 ... 5 = from livestock unit 5
me	Meat	1 = from livestock unit 1 ... 5 = from livestock unit 5
mi	Milk	1 = from livestock unit 1 ... 5 = from livestock unit 5

Annex Chapter 4

Annex 4.1

Oldeman (1975) makes use of rainfall data to define agro-climatic zones. The consumptive use of water by crops is used to define a dry and a wet month. A month with enough rainfall to grow paddy rice ($\geq$ 200 mm) is defined as a wet month, while a dry month is defined as one during which the evapotranspiration limit for most upland crops is just not met ($\leq$ 100 mm). Taking these definitions into consideration the study area could be classified into the 'D2' agro-climatic zone type as they are defined by Oldeman (1975). For an area that falls into the 'D2' agro-climatic zone, there are 3 or 4 consecutive wet months and 2, 3 or 4 dry months. It is however important to recognize that due to the great variation in rainfall from year to year, the study area could almost be classified into the 'D3' agro-climatic zone type. In a 'D3' agro-climatic zone, there are 3 or 4 consecutive wet months and 5 or 6 dry months. For the period 1960 - 1990 for up to 45 % of the years this was the case.

Daylength, which depends on latitude and time of the year, varies in the study area from 11.6 hrs in December to 12.6 hrs in June. In the dry season the proportion of bright sunshine is usually higher (62 - 77 %) than in the rainy season (47 - 57 %). Air temperature is all year approximately 25 °C. For two places close to the study area, Karankates and Malang, the difference between the maximum and the minimum temperatures were 1.3 and 1.7 °C respectively. The mean annual relative humidity for the study area is rather high and varies from 70 to 90 %, the dry season having a lower relative humidity than the wet season. Measurement that were taken in the study area did not indicate the presence of extreme wind speeds. In general, for most locations in Indonesia mean wind speeds are low throughout the year. Measurements at Malang, Karenkates and Kepanjen - the latter also being close to the study area - showed annual mean wind speeds of 5.9, 1.8 and 3.7 $km.h^{-1}$, respectively. Potential evapotranspiration varies from approximately 2.0 mm in the wet season to approximately 5.0 mm in the dry season.

Annexes Chapter 5

Annex 5.1: Playing field: constraints and goals

		Typical farm household		
Constraint	Demand	Putukrejo	Kedunglor	Kedungkidul
Gross margins: (10^3 Rp.year^{-1})				
Annual crops	≥	1,434	252	207
Perennial crops	≥	103	195	206
Livestock	≥	54	56	138
Farm size (ha)	≥	0.72	0.87	1.16
Land quality: (ha)				
Land unit 1	≤	0.086	0.218	0.116
Land unit 2	≤	0.605	0.296	0.174
Land unit 3	≤	0.029	0.226	0.302
Land unit 4	≤	0.007	0.122	0.568
Labour availability: (md.month^{-1})				
Household	≤	72	72	72
Hired	≤	36	36	36
Energy: (10^6 J.year^{-1})				
Annual	≥	10.41	10.41	10.41
Pulses	≥	1.45	1.45	1.45
Perennial	≥	0.22	0.22	0.22

Annex 5.2: Input and output prices

Input	Unit	Price (Rp)	Output	Unit	Price (Rp)
Nutrients:			**Crop outputs:**		
Urea	kg	235	Maize grain	kg	200
NHSO	kg	180	Cassava tuber	kg	55
TSP	kg	285	Sugarcane stem	kg	266
BS	kg	20	Rice grain	kg	300
KCl	kg	300	Groundnut	kg	1750
KSO	kg	160	Coconut	nuts	140
			Coconut wood	kg	13
Fungicides	kg	1500	Melinjo fruit	kg	1300
Insecticides	lt	4200	Melinjo wood	kg	13
Herbicides	kg	5500	Kapok fruit	kg	75
			Kapok wood	kg	13
Planting material:			Teak wood	kg	50
Maize	kg	425	Gliricidea wood	kg	13
Sugarcane	kg	1180	Fragrance wood	kg	50
Upland rice	kg	500	Banana fruit	kg	300
Groundnut	kg	2300	Common bean	kg	885
Elephant grass	kg	50			
Native grass	kg	50	**Livestock:**		
Coconut	seedling	500	Cattle meat	kg	2500
Melinjo	seedling	2500	Cattle milk	lt	700
Kapok	seedling	2100	Traction power	cow days	2500
Teak	seedling	2800	Goat meat	kg	1350
Gliricidea	seedling	1400	Goat milk	lt	700
Fragrance	seedling	2800	Sheep meat	kg	1350
Banana	seedling	875	Sheep milk	lt	700
Paddy Rice	kg	500			
Common bean	kg	630			
Cattle feed:					
Maize bran	kg	275			
Soyabean cake	kg	900			
Traction	Cattle days	2500			
Labour	Mandays	1500			

Annex 5.3: Rainfall (Pagak), radiation (Malang) and potential evapotranspiration (Malang): 30 year average (1960 - 1990).

	Rainfal (mm.month^{-1})	Radiation (W.m^{-2})	Pot.evapotranspiration (mm.month^{-1})
January	208	203	89
February	188	217	115
March	157	193	128
April	116	193	133
May	71	210	123
June	33	216	118
July	11	229	136
August	26	220	146
September	64	213	151
October	138	212	149
November	215	202	112
December	228	198	80

Annex 5.4: Putukrejo: First iteration cycle: optimization results per typical farm.

Goal variable	GV11	GV12	GV13	GV14	GV21	GV22	GV23	GV24	GV31	GV32	GV33	Restriction
Agro-technical:												
GV11: Staple crops (10^6 KJ)	**163.95**	10.41	37.19	93.01	69.20	10.41	10.41	54.64	10.41	10.41	63.98	$\geq$ 10.41
GV12: Pulses (10^6 KJ)	1.45	**40.18**	5.93	1.45	1.45	11.94	33.03	22.16	1.45	12.22	3.31	$\geq$ 1.45
GV13: Fruit (10^6 KJ)	1.00	1.00	**18.45**	4.18	1.30	1.34	5.42	6.15	2.60	1.00	1.00	$\geq$ 0.22
GV14: Livestock (10^6 KJ)	0.08	-0.08	-0.75	**8.44**	-0.08	0.07	5.37	5.12	-0.20	0.39	-1.00	
Socio-economic:												
GV21: Working capital (10^3 Rp)	214.32	142.99	185.57	3,744.40	**4.76**	45.52	540.09	491.48	10.06	21.75	43.31	
GV22: Labour (md)	75.91	63.57	575.86	1,013.43	68.00	**25.75**	1,167.76	1,122.84	109.43	210.90	512.31	
GV23/4: Gross margins (10^3 Rp)	3,030.20	4,513.30	3,938.60	4,208.72	1,606.30	1,591.00	**7,744.76**	**7,309.25**	1,875.60	1,863.36	2,375.30	$\geq$ 1,591.00
Environmental:												
GV31: N-loss (kg)	26.26	10.21	16.22	17.44	9.40	3.96	6.57	15.46	**0.18**	0.31	10.69	
GV32: Biocides accumulation (kg)	1.13	4.06	2.23	0.74	0.00	1.30	3.36	2.96	0.00	**0.00**	0.47	
GV33: Soil loss (t)	3.39	6.05	7.20	5.93	3.17	2.15	6.21	5.60	4.68	4.10	**1.44**	$\leq$ 7.2

Annex 5.5: Kedunglor: First iteration cycle: optimization results per typical farm.

Goal variable	GV11	GV12	GV13	GV14	GV21	GV23	GV23	GV24	GV31	GV32	GV33	Restriction
Agro-technical:												
GV11: Staple crops (10^6 KJ)	**165.27**	10.41	10.41	90.02	10.41	10.41	37.30	55.03	10.41	10.41	10.41	≥ 10.41
GV12: Pulses (10^6 KJ)	1.45	**40.15**	1.45	1.45	1.45	1.45	30.59	23.33	1.45	1.45	1.45	≥ 1.45
GV12: Fruit (10^6 KJ)	1.89	1.97	**26.20**	5.86	2.46	2.51	5.88	8.73	2.42	2.43	1.89	≥ 0.22
GV14: Livestock (10^6 KJ)	0.08	-0.03	-0.08	**8.44**	-0.08	0.08	5.14	5.07	-0.19	-0.16	0.01	
Socio-economic:												
GV21: Working capital (10^3 Rp)	216.13	187.44	161.95	3,651.91	**2.61**	17.58	501.81	488.23	10.54	9.58	114.51	
GV22: Labour (md)	80.75	138.48	88.97	1,013.61	48.62	**20.27**	1,132.42	1,118.78	107.17	89.36	87.38	
GV23/24 Gross margins (10^3 Rp)	3,115.01	4,561.82	2,930.15	4,382.54	614.13	588.20	**7,853.17**	**7,616.69**	640.92	612.46	561.40	≥ 503.00
Environmental:												
GV31: N-loss (kg)	33.44	12.70	13.45	17.07	1.79	2.16	16.57	21.91	**0.29**	0.56	2.47	
GV32: Biocides accumulation (kg)	1.89	4.30	2.28	0.90	0.00	0.42	3.42	2.93	0.14	**0.00**	0.23	
GV33: Soil loss (t)	6.69	8.70	8.70	8.70	1.56	0.92	8.70	8.70	6.46	5.90	**0.60**	≤ 8.70

Annex 5.6: Kedungkidul: First iteration cycle: optimization results per typical farm.

Goal variable	GV11	GV12	GV13	GV14	GV21	GV22	GV23	GV24	GV31	GV32	GV33	Restriction
Agro-technical:												
GV11: Staple crops (10^6 KJ)	**178.00**	10.41	10.41	93.72	10.41	10.41	64.66	59.27	10.41	10.41	10.41	$\geq$ 10.41
GV12: Pulses (10^6 KJ)	1.45	**31.35**	1.45	1.45	1.45	1.45	21.62	20.82	1.45	1.45	1.45	$\geq$ 1.45
GV13: Fruit (10^6 KJ)	1.99	2.08	**25.31**	5.56	2.60	2.60	6.99	8.43	2.60	2.29	2.00	$\geq$ 0.22
GV14: Livestock (10^6 KJ)	0.19	0.09	-0.04	**8.43**	0.14	0.19	4.97	5.02	0.19	-0.17	-0.03	
Socio-economic:												
GV21: Working capital (10^3 Rp)	256.03	233.20	197.73	3,746.57	**2.70**	18.00	464.66	480.45	10.06	15.35	35.93	
GV22: Labour (md)	128.45	178.60	275.69	1,019.05	54.89	**43.66**	1,108.00	1,116.10	109.44	94.99	112.57	
GV23/24: Gross margins (10^3 Rp)	3,298.60	3,704.12	2,653.55	4,318.92	691.60	681.10	**7,223.14**	**7,215.45**	656.37	633.22	654.32	$\geq$ 551.00
Environmental:												
GV31: N-loss (kg)	51.67	14.68	20.12	25.09	1.85	2.20	30.39	28.99	**0.43**	0.94	2.50	
GV32: Biocides accumulation (kg)	1.68	4.42	1.98	1.09	0.00	0.43	2.90	3.03	0.17	**0.00**	0.23	
GV33: Soil loss (t)	10.12	11.60	11.60	11.60	1.75	0.95	11.60	11.60	6.02	5.98	**0.62**	$\leq$ 11.60

Annex 5.7: Ideal values under optimal and natural moisture supply for the Putukrejo typical farm household

	Ideal values		
	Natural moisture	Optimal moisture	Difference (%)
Staple crops (10^6 KJ)	163.95	296.41	81
Pulses (10^6 KJ)	40.18	121.24	202
Fruit (10^6 KJ)	18.45	54.62	196
Livestock (10^6 KJ)	8.44	9.77	16
Working capital[1] (10^3 Rp)	4.76	4.76	0
Labour (md)	25.75	24.30	6
Gross margins (10^3 Rp) (Unspecified)	7,744.76	16,002.91	107
N-loss (kg)	0.18	0.15	17
Biocide accumulation (kg)	0.00	0.00	-
Soil loss (t)	1.44	0.47	67

[1]Excluding the costs for irrigation.