VINVAL

EU 5th Framework INCO2 funded research project, contract no.: ICA4-CT-2001-10047

Review of tools for land use planning in West Africa in the framework of VINVAL project

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Research Report 2004-04

Impact of changing land cover on the production and ecological functions of vegetation in inland valleys in West Africa

Due to several reasons, food shortage problems are a major issue in sub-Saharan Africa. In attempts to solve the shortages considerable effort has been devoted to strategies for increasing agricultural production. This is being achieved by an expansion of cultivated area, as well as by higher productivity per unit. The need for new agricultural land has been a strong argument for the extensive clearing of natural vegetation. This has resulted in widespread environmental degradation. As this is now resulting in serious constraints to sustainable development, there is clearly a need to develop an integrated approach towards land use planning involving and balancing both agricultural production objectives and environmental concerns.

Overall Objective:

The overall objective of the project is to develop a tool for integrated land use planning at watershed scale that contributes to improve sustainable agricultural production systems in inland valleys in West Africa. Inland valleys are the upstream areas of drainage systems. This tool will take into account the balance between production and protection objectives and will assist in making informed decisions on allocating land use activities of small holder farmers across the watershed on both agricultural and natural land. Natural land is here defined as all land that is covered by natural and fallow vegetation. Such decisions are based on knowledge of the productive value of these land use activities and their impact on ecological functions.

Specific Objectives:

- Quantify the production, regulation (water, sediment and nutrient flows) and bio-diversity functions of natural and agricultural ecosystems at farm and watershed scale in three inland valleys in Ghana and Burkina Faso with distinct different land use intensities.
- Assess the economic importance of the tradeoffs and complementarities between natural and agricultural ecosystems and the different functions they provide.
- Develop a GIS-based tool for integrated, multifunctional watershed-level land use planning for use by extension services and planners. This tool will support the analysis of the impact of different land use development scenarios on the ecological and

production functions. The tool can be used in the decision-making process of land development.

Duration

This project will run from 2001 until 2005.

Location

The project will work in selected inland valleys of West Africa, where land cover ranges from almost natural to intensive agricultural production. The selected inland valleys are located in Ghana (Ashanti Region) and Burkina Faso (Kompienga).

The Participants

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The project outputs are organized in the following report series:

- **WP = Working Paper**

In these reports the most important results of the project activities are presented. These reports have the status of working papers of which some will be published in scientific journals.

- **MR = Mission reports**

These reports present the activities undertaken during missions of the European project partners to China and Vietnam.

- **PM = Project Management reports**

These reports contain information about two important issues, the progress of the VINVAL project and accounts of the official project workshops.

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Acknowledgements

This RDA report is part of the project Valuation of Inland Valleys (VinVal) financed by the European Union (PL ICA4-2000-10338).

The RDA team would like to thank the communities of Attakrom, Dwinyankwanta and Nyamebekyere for their hospitality and enthusiasm in participating in the project, as well as the extension officers who accompanied the RDA team. A video was made of the RDA in the three villages and will be shown to the communities.

Contents

1 Introduction

The VINVAL project aims at the development of an integrated land use planning tool at the water-shed scale. The size of the watersheds studied in the project, is between 500 and 1000 hectares. This tool should contribute to an improvement of sustainability of land use systems in inland valleys in West Africa. Inland valleys are the upstream parts of drainage systems. This tool will take into account the different production and ecological functions of land units under natural and fallow vegetations and under agricultural use. The tool may assist in making 'informed decisions' on allocating land use activities of small-holder farmers across the watershed, and on both agricultural and natural land areas. 'Informed decisions' require knowledge of the productive value of the main land use activities and their impact on ecological functions.

More specific, the objectives of the VINVAL project are (Van Diepen, 2001):

1. to quantify the production, regulation (water, sediment and nutrient flows) and biodiversity functions of natural and agricultural ecosystems at the watershed scale in three inland valleys in Ghana and Burkina Faso with distinctly different land use intensities;
2. to assess the economic importance of natural and agricultural ecosystems, the trade-offs and complementarities between these systems, and the socio-economic characteristics at the household level; and
3. to develop a GIS-based tool for integrated, multifunctional watershed-scale land use planning.

With respect to objectives 1 and 2, information is, for example, collected on the impact of land clearing on the natural resource base, the economic value of gathered products from natural land compared to agricultural production, and on the options for optimization of the present agricultural production systems. For present and promising future production systems, attainable yield levels will be estimated and input-output relationships will be established. These relationships indicate the effects of changes in e.g. land use, agricultural technology, input level and management on the agricultural productivity and ecological functions.

The results from these studies (1 and 2) are to be used for objective 3, to develop a tool for integrated land use planning at the water-shed scale. Through the GIS-interface of this tool, the spatial effects of various land use scenarios on production and on the natural resource base can be estimated and visualized. This tool may be used for estimating the optimal area under natural and/or fallow vegetation and the spatial land use distribution, required to avoid serious degradation of the natural resource base. The land use distribution is, of course, also considerably affected by the farmers' objectives of optimizing their agricultural production, based on the input-output relationships mentioned above. Summarizing, the tool is meant to analyse the impacts of alternative future land use development scenarios on the ecological functions and the agricultural production, and to support the decision making process in land use planning.

Available approaches for integrated land-use planning are given in this review. It gives first for different methods for land-use planning a short description (shortly in Section 2 and in more detail in Appendix A), and next an overview of literature on the wide range of available planning methods, on biophysical conditions in West-Africa, and on previous land use planning projects in the Sahelian zone (shortly in Section 3 and in more detail in Appendix B). To help with developing ideas about a new land use planning tool for West-Africa, a number of aspects (e.g. possible approaches, available data, time horizon, objectives) of such a tool are discussed (Section 4). Based on a discussion on the requirements of stakeholders and the intended end users of the tool and its implementation for land use planning purposes, an alternative approach for land use planning has been added and is discussed (Section 5). This leads to concluding questions and discussions (Section 6) on desired characteristics and features of the tool for land use planning (at the water-shed scale) within the VINVAL project.

2 Methods and tools for land use planning

A number of different approaches and methods for land use planning and for planning in related areas (e.g. nature conservation, watershed restoration, domestic areas) are described shortly in the following and in more detail in Appendix A.

2.1 Land use optimization and scenario studies (based on multiple goal linear programming)

In the project, parallel with the surveys on natural resources (land, water, etc.) and socio-economic conditions in the studied watershed or region (see Section 1), the goals of the local population, the regional government and possibly of other stakeholders are inventoried. These goals are, for example, sufficient income and food production, sufficient land cover, biodiversity, and water quality, and a maximum for nutrient leaching.

Since the early 1980s, a range of complementary analytical frameworks and operational tools have been developed (Stoorvogel & Antle, 2001). On the basis of their objectives we can distinguish explorative and predictive tools. ***Explorative*** tools analyse the potential (im)possibilities of strategic natural resource use configurations, often at regional or farm scale. To this purpose, a frequently used procedure is interactive multiple goal linear programming (IMGLP) (De Wit et al., 1988). IMGLP models generate optimal land use options under different sets of objectives and constraints. Regional IMGLP models as operationalized in the SysNet project (Roetter et al., 2004) form one of the major building blocks of the approach to multi-scale analysis. ***Predictive*** tools are required to analyse the likely land use changes in the short term as a result of introducing alternative agricultural policies and technologies (Bouman et al., 2000).

Exploration of land use options: A tool for scenario analysis in support of land use planning (LUP) is used to compute the extent, to which various goals can be met, given the available resources and the technically feasible options, and also to calculate the trade-off between different goals. These technically feasible options are based on Input-Output (I/O) tables. These I/O tables describe for current and alternative land use activities the relationships between biophysical inputs (e.g. fertiliser nutrients, labour) and resulting outputs in terms of produce, environmental pollution (e.g. nutrient leaching), etc. (see Appendix A.1.1).

Alternative land use development scenarios at the watershed scale are to be defined. For each scenario, the LUP tool identifies an optimum solution with respect to e.g. achievable production, environmental pollution, land and nature conservation. The LUP tool also indicates conflicts and trade-offs between goals, by quantifying how much of a given goal should be sacrificed to achieve another goal. These results for alternative land use development scenarios give a basis for selecting desirable and realisable combinations of land use and production technologies, to achieve various environmental and socio-economic goals.

Land use planning can be done with a Interactive Multiple Goal Linear Programming (IMGLP) modeling framework. An example is the Land Use Planning and Analysis System LUPAS (Hoanh et al., 2000; Roetter et al., 2000a, 2000b, 2004) which consists of quantified relationships between a set of objectives (e.g. food production, income), available resources (e.g. land area, water), and a range of production activities.

The main modelling components of LUPAS (Figure 1) are:
1) Resource balance and land evaluation;
2) Input/output estimation;
3) Multiple goal linear programming.

For more information on LUPAS and on these modelling components, see Appendix A.1.2.

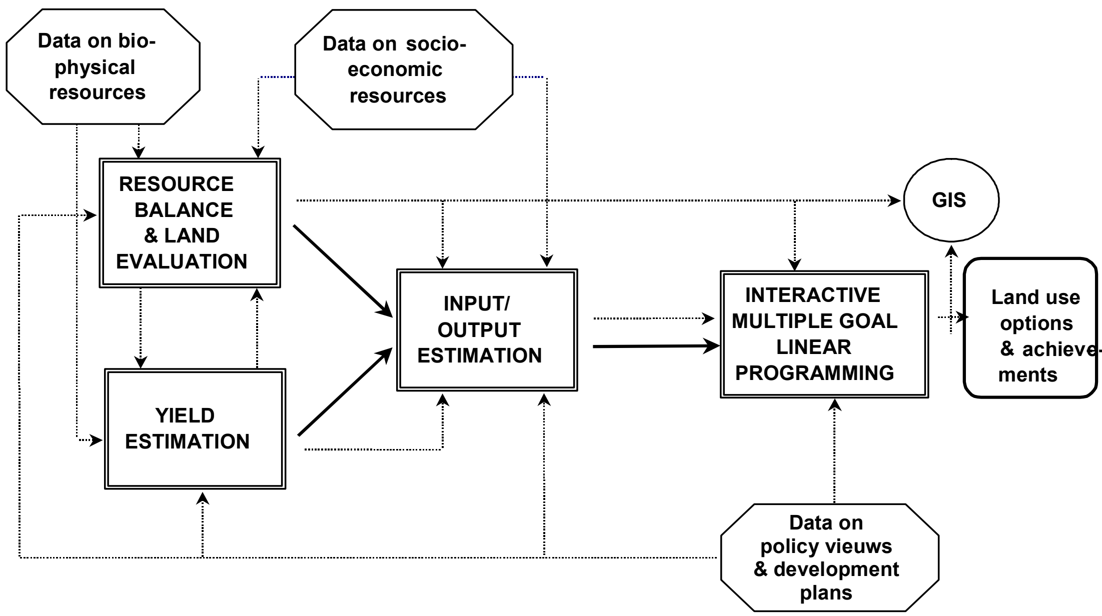

Figure 1. Structure of the LUPAS modelling framework.

2.2 Bottom-up and top-down planning approaches

Land use explorations based on Interactive Multiple goal linear programming in most cases start as a policy initiative which demands for feedback from target groups and/or local representatives, and which may be changed to some extent to get their support for policy implementation. This method is thus often initiated as a top-down approach which is generally applied at the regional and national scales. In the process of developing scenarios and evaluating results, however, gradually more and more different interest groups are being involved (Ittersum et al., 2004). A good example of a tool supporting such a mixed approach 'first top-down, then bottom-up' is the LUPAS system (see Section 2.1 and Appendix A.1.2 for more detail).

Bottom-up (village-level) planning in a truly participatory mode is based on a dialogue between policy makers and target groups to come to jointly developed and supported policy measures. The degree of participation may considerably vary during the whole process of policy initiation upto implementation. This method also has both top-down and bottom-up aspects. Normally it is applied at the smaller scales (e.g. villages and small watersheds). Participatory Rural Appraisal (PRA) as described in Appendix A.3, is an example of this method. For more information from the literature on planning approaches, see Appendix B.1. Within the VINVAL project, PRA's have been carried out for three communities in the Ashanti region of Ghana (Meijerink, 2003) and for four villages in the eastern region of Burkano Faso (Berg, 2003), situated in inland valley bottoms and representing land use of three increasing levels of intensity in both countries. The purpose of these PRA's is to collect a basic data set on inland valleys in West Africa , to exchange information between these communities and the researchers, and to supply data for other work packages within the VINVAL project, such as the development of a tool for watershed-scale land use planning. The collected information consists of socio-economic information at the household level and of information on agricultural production systems and natural resources.

2.3 Use of VINVAL results

The Land Use Planning analyses within VINVAL are to be done for watersheds in two different agro-ecological zones in West Africa (i.e. southern Sudan Savanna zone and Equatorial Forest zone) and for watersheds with a distinctly different level of land use intensity (see end of Appendix A.3). By covering such contrasting ecological and farming conditions, up scaling of these results at the watershed scale to much larger areas in West Africa is probably possible. This means that the risk of producing site-specific information and knowledge is avoided. Hence, derived understanding of how agricultural productivity and ecological functions can be maintained in an integrated way, can be applied to other watersheds.

2.4 Other modelling frameworks, tools and techniques

The other models and tools are described in Appendix A. A short description is given in the following.

Scenario analysis involves constructing stories about different plausible futures. Its basic principles for planning purposes are first, to understand as best as possible likely future trends and second, to make strategic decisions based on an analysis of the consequences of the most likely future scenarios (Appendix A.4).

Stakeholder analysis aims at a better understanding of environmental and development problems and their interactions through comparative analysis of the different perspectives and sets of interests of stakeholders at various levels (Appendix A.5).

NUTMON is a tool-box to accurately assess the main nutrient flows, losses and balances at the farm level, and also some financial indicators (Appendix A.2).

Land evaluation is a mainly qualitative approach for translating spatially organised (i.e. GIS) information on soil characteristics, landscape and relief, hydrology etc. into ratings per land unit of the potential, limitations and risks for production of a number of main crop species, of grasslands, etc. and risks for environmental pollution and soil degradation (Appendix A.6).

A Multiple-objective decision-making method for watershed planning with an integrative geographical information system-based decision making tool called RESTORE, has been developed for the USA. This tool is used to prioritize and evaluate restoration activities at the watershed levels. Its applications suggested that RESTORE can provide a valuable tool for analyzing complex watershed management issues (Appendix A.7).
To analyse **future land use and the adoption of new technologies** by farmers, linear programming techniques (optimization models) should be applied. Different optimization models with their strong and weak points are discussed in Appendix A.8.

3 Overview of literature

3.1 Literature on planning methods

Literature covering the following topics is collected:

a) overview of methods for participatory rural appraisal and planning;
b) examples of participatory rural planning;
c) application of land evaluation with GIS;
d) model for studying land use change and its effects.

Short descriptions of the papers and books on planning methods are given in Appendix B.1

3.2 Literature on biophysical conditions in West-Africa

Literature covering the following topics is collected:

a) Tools for analysing options for sustainable agricultural production systems in Sudan-Savanna zone;
b) Resource limitations in Sudan-Savanna zone;
c) Soil fertility and fertiliser use in Sudan-Savanna zone.

Short descriptions of the papers and books on biophysical conditions in West-Africa are given in Appendix B.2.

3.3 Information from previous Sahelian land use projects

Literature is collected from the following projects (see Appendix B.3):

a) Project on Sudano-Sahelian agricultural production;
b) Project ' Competing for limiting resources: the case of the fifth region of Mali'

4 Aspects of Land use planning tool for West Africa

A GIS-based tool for integrated land use planning at the watershed scale is to be developed for the VINVAL project. A number of aspects of such tool are discussed in the following, such as availability of data, possible type of approaches, main problems and potential developments in the agricultural production situation in watersheds in West Africa, etc. These aspects are to be used as a basis for choosing the most appropriate approach for a land use planning tool for watersheds in West Africa.

4.1 Available data

For each watershed information is collected on their biophysical and socio-economic characteristics. Biophysical monitoring at field and watershed level is done within workpackages 2 and 3 of the VINVAL project and the socio-economic monitoring within workpage 4 (Diepen, 2001; end of Appendix A.3). In addition, a large amount of information on the biophysical and socio-economic conditions in West-Africa can be derived from reports from the project on Sudano-Sahelian agricultural production (i.e. PSS) and from the project 'Competing for limiting resources: the case of the fifth region of Mali' (Appendix B.3).

4.2 Quantitative versus qualitative approach

Information on soil and land qualities and on their limitations may be indicated by ratings (Appendix A.6). These qualities and limitations may be based on the standard soil characteristics, using so-called pedo-transfer functions. In this way, digitized soil and land maps in a GIS may easily be converted into maps with potentials and limitations for specific types of land use. This may indicate the areas with high soil fertility and high crop production, poor areas with strong risk for erosion and land degradation, risk for salinity and/or flooding, etc. Advantage of this approach is the easy conversion of GIS-data into maps with all sort of land qualities and limitations. Disadvantage of this approach is that such ratings for different aspects (e.g. erosivity, soil fertility) cannot really be combined. Besides, the socio-economic aspects and the regional potential for agricultural production are not considered.

For more quantitative approaches to analyse possible land use and crop production in a region and to integrate biophysical and socio-economic information, optimization models for a region may be applied. See for example Appendix A1.2 for the approach and see Appendix B.2, Bakker et al., 1998 for its application to the Sahelian zone. This approach can be combined with a GIS, to delineate land units (Apppendix A1.2) and the final results of the optimization approach can partly be shown on maps (e.g. main types of land use). Disadvantage of this approach is that it is rather complicated, that the optimization is done for a whole region, considered as a super-farm, that the farmers are assumed to mainly maximize their production and income, and that spatial results on future land use are strongly based on this profit maximization (i.e. based on which crop gives highest profit). However, farmers may take into account the production risk (e.g. food security and/or risk of a crop with high price- or yield-risk and possibly a high profit) and have also social, religious and cultural objectives and obligations. For more information on the limitations of the optimization approach, see Appendix A.8. However, the agent-based models which distinguish between different farm groups and show more market interactions, are even more complicated (Appendix A.8) and hence, are not applicable within VINVAL.

For a rapid and effective way of obtaining behavioral, socio-economic and biophysical information on the factors that determine land use in a watershed, PRA may be used (Appendix A.3). PRA is however, based on the local perception of the present situation and gives limited information on future options for changes in land use and agricultural production. In addition, PRA is not a suitable method for collecting precise and statistically significant information.

4.3 Main options and limitations for land use and agricultural production in West-African watersheds

In the applied tool for land use planning of watersheds in West Africa, main options and limitations should be taken into account. Main *options* are for example: a) more use of inputs such as in particular inorganic fertilisers; b) shorter fallow periods; c) more or less land areas for nature reserves; d) more sustainable land use with less erosion, less soil nutrient depletion, and less soil degradation; e) partial mechanization, in particular for labour peak periods during land preparation and at harvest; f) improved crop varieties; g) improved land quality by terracing and/or by improved irrigation and drainage; h) more or less land area for grazing and options for animal production.

Main *limitations* for land use and in particular for agricultural production are: a) low soil fertility; b) too low fertiliser use; c) limited manure availability; d) low nutrient use efficiency by crops (related to poor soils and poor management); e) lack of high yielding crop varieties; f) practice of low planting densities; g) limited access to farm inputs; h) lack of marketing strategy; i) lack of adequate extension service to farmers (list of these limitations mainly from Pandey et al, 2001); j) lack of grazing land and fodder for animal production; k) land tenure.

Increase in agricultural production requires a more rapid acceptance of improved production technologies (see *options* above). This depends on institutional modifications that enhance technology transfer, on development of input delivery systems, improved policies of land tenure, improved availability of fertilisers and other inputs, and on improved policies that affect the input and output pricing structure (Pandey et al., 2001).

A number of other aspects (i.e. partly limitations and partly farmer’s objectives) that determine land use and agricultural production and should be considered, are: a) food security; b) economic optimization depending on e.g. profits from cash crops; c) soil limitations (e.g. limited rootability or acidity); d) required rotation (with leguminous crop or fallow) to restore soil fertility or reduce diseases; e) cultivated crops in dependence of available seed and knowledge; f) fodder demand from animal sector.

For land reclamation and improvement, the main options are: terracing, improved drainage, flood prevention, improved irrigation, rock bunds to reduce surface runoff, 'water pockets' with manure on the higher fields to improve soil fertility and crop production (Maatman et al., 1998). For land reclamation, availability of labour and machinery, investment potential and profit returns on input are often problematic.

4.4 Other factors that determine land use and agricultural production

In addition to the more land- and soil-related factors that determine land use and agricultural production, other factors are for example:
a) water availability and conflicts in water use. This is related to the risk for flooding and damage to crop production, availability of irrigation water and extent of irrigated area, availability of safe drinking water, etc.
b) labour demand and labour availability (in particular, the peak demand during land preparation and harvest periods in agriculture versus other job options, e.g. opportunities in urban areas).

4.5 Available land areas

Areas with a type of landscape and soils that are sensitive to respectively soil erosion, salinization and water logging, strong acidification, soil nutrient depletion, depletion of soil organic matter and desertification, etc. should not be used for arable crop production in the model analysis and in practice. In such areas, production is only allowed if land reclamation can be applied and more sustainable forms of agricultural production are possible (e.g. with considerable organic and inorganic fertiliser applications and/or improved drainage). Hence, for the different soil and landscape types, the limitations on land use should be defined: allowed for respectively arable cropping, grazing land, forest, etc.

4.6 Planning approaches

The LUPAS approach (Appendix A.1.2) starts with exploring a window of opportunities for agricultural development. The options for agricultural development become gradually smaller if more constraints (i.e. available land, labour or water) are taken into account. Such results are communicated to stakeholders who can comments on required objectives (e.g. minimum level of production for food security, maximum level of environmental pollution). These objectives can be taken into account in a next round of LUPAS calculations. This indicates that the scientists are producing results with LUPAS, discuss the results with stakeholders, and do new runs in correspondence with the ideas of the stakeholders. The main part of this approach is the development of a model and of scenarios (Appendix A.4) and the scientific analysis. The basis of this analysis is largely formed by the biophysical characteristics and limitations of the studied regions. This planning approach with some communication with the stakeholders, is clearly different from the Participatory planning approaches (see Appendix A.5 and A.3). These participatory approaches show much more interactions between the stakeholders and concentrate mainly on the planning and negotiating processes. In these approaches, however, the knowledge on options for land use and agricultural development is not clearly analysed or is taken for granted.

4.7 Time horizon of planning approaches

Approaches as PRA (Appendix A.3) collect information on the present agricultural, environmental and socio-economic possibilities and problems and hence, indicate the options for the near future. These results are strongly related to present land tenure, cropping systems, social structure, market and transport possibilities. Optimization models such as LUPAS (Appendix A.1.2), do not simulate the actual situation or near future developments. LUPAS results are mainly to define priorities for agricultural development, occurring over longer periods. The reason is that the large gap between actual agriculture and the presented sustainable agricultural system cannot be bridged overnight, as implementation of sustainable land use activities requires a large number of accompanying measures (Bakker et al., 1998).

4.8 Objectives of planning tool and its end-users

A planning tool can be used to show and analyse future options of land use, options for agricultural and economic development and production, consequences of different scenarios of land use for nature conservation, environmental pollution, employment, use of fertilisers and pesticides, etc. In addition to such analysis and communication of scenario results, there are other possible objectives of planning tools, such as education, training, interaction on planning options, showing land use conflicts, tool for mediation, etc. For these last objectives, the users of the tool outcome are not scientists and planners but may become other stakeholders such as farmers, extension service officials, village inhabitants, water board or irrigation system officials, etc.

5 Other thoughts about tools for land use planning within VINVAL project

(Gerdien Meijerink)

Before thinking about which tool VINVAL is going to design and use, we should ask ourselves what we try to achieve within VINVAL. What kind of (real) impact do we want to have? In general, I think we want to help stakeholders to make wise decisions about land use. Better decision-making is achieved through a better understanding of the situation and the effects that certain land use changes will have. This is why the tool should in the first place enhance *learning*. Learning is about increasing the understanding of the stakeholders involved (including ourselves!).

Learning is not achieved by presenting a series of model simulation outcomes (stored in either a computer or presented in a report). This amounts to simply giving information or advice, which is a rather top-down, linear way process. And it remains to be seen whether anyone will actually use the model or read the report. Learning is about increasing understanding about cause-effect relationships, about the effects of their decisions. This can only be done by letting those who learn, discover things for themselves: "if I or we do this, then this happens". Those who learn should be able to explore options themselves. This means that a set of causes and effects that have been set by researchers will not contribute much to learning.

Besides increasing understanding through learning processes, do we want to actually achieve *change*? Implementing change takes the process one step further. It means that decisions are taken and implemented. Decisions should be taken on the basis of some understanding of a situation and understanding of what effects the decision will have. Understanding cannot only be achieved by a prior learning process. Learning is always a prerequisite - change cannot be implemented without learning!

These two aims bring us immediately to the next question: for whom is VINVAL designing a tool? Or: who should learn, who should implement change? "Farmers", "policymakers", "decision-makers" are all terms that are too vague. We need to know very specifically whom we mean, within each region in Ghana and Burkina Faso.

Example of property/user rights

We can use an institutional framework to identify who should be included in the general term "stakeholder" (see Challen, 2000; Ostrom, 1990). This institutional framework considers property/user rights, whether they are formal or informal. Because VINVAL considers land use, property/user rights should be the focal point when determining the stakeholders (i.e. the holders of those property or user rights). In general, four different property right regimes can be distinguished:

- State property: state agencies determine use/access rules

- Private property: individual owners have a right to undertake socially acceptable uses and have a duty to refrain from socially unacceptable uses[1]. Others have a duty to allow these socially acceptable uses and have a right that only such socially acceptable uses will occur.
- Common property: a management group of owners has a right to exclude non-members and non-members have a duty to abide by exclusion. Individual members of the management group have both rights and duties related to use and maintenance.
- Open access: here no property rights are defined and therefore there is no defined group of users or owners. The benefit stream from use of the object is available to all.

An important distinction to make is between owner (or user) rights and use rights. A resource may be owned by one entity (state, private person or a group) but the rights to decide on the allocation or the use of that resource may be conferred to another entity (private person or group). In the case of Ghana, for instance, the Asantehene owns in principle all the land, but does not directly decide on its use. He has given the *Amakomhene* of Kumasi the right to own all land of Attakrom. A village head (*Odikro*) administers the land on his behalf. But it is the farmers who decide on the use of the land (under a set of rules and regulations) (Meijerink, 2003).

This example indicates the complexity of defining property right regimes and the inappropriateness of simple categories. Therefore Ostrom (1990) introduced a conceptual model which defines property rights as a hierarchy or a system of nested institutions. For most resources there are multiple levels of property rights, starting with broad powers of state or national governments to control use of resources, and ending with the ability of individual resource users to make use of these resources. There may be several different decision-making levels and each entity within a hierarchy may have their own particular goals. The sum of decisions will lead to a certain resource use pattern.

For Ghana and Burkina Faso this "system of nested institutions" should be sketched out in order to know who decides on what, and who the target stakeholders are of the VINVAL tool.

Tools

As D'Aquino et al. (2003) state: "to truly integrate people and principals in the decision-making process of land use management and planning, information technology should not only support a mere access to information but also help people to participate fully in its design, process and usage. That means allow people to use the modeling support not to provide solutions, but to help people to steer their course within an incremental, iterative, and shared decision-making process".

This means that any (computerized) model should be combined with participative processes. D'Aquino et al (2003) also state that with respect to land use planning tools, a supportive framework for *dialogue* about possible outcomes should be developed, rather than imposing a specific resolution for complex problems. It is not up to the model to provide solutions to

[1] The clause "socially acceptable" us included to make a distinction between a private property right and a *privilege*, in which case there are no duties expected

problems, but rather to encourage discussion of the different alternatives available, and to improve the effectiveness of a collective decision-making process.

An example of such an approach is given by D'Aquino et al. (2003) and Lynam et al. (2002), in which participatory approaches such as Role-Playing Games (RPGs) are combined with computerized information technologies such as Multi-Agent Systems (MAS) and Geographical Information Systems (GIS). More information on this approach is given in Appendix C.

6 Discussion on tool for land use planning within VINVAL and final questions

A number of aspects of the land use planning tool for VINVAL should be taken into account. These are in particular: a) model should not be too complicated to handle; b) required information is limited or can be derived from previous related studies; c) model developed for watershed scale; d) main options and limitations for changes in land use and agricultural production are considered.

A main point is who (e.g. farmer, researcher, planner) is going to use the tool and with which main purpose (e.g. qualitative analysis of main constraints for agricultural and economic development at present, options for agricultural and economic development in the long term, analysis of farm activities with highest benefits). For example, if the tool is mainly focussed on land use options and limitations, the spatial aspects are important, the model should be simple and the socio-economic aspects are not important, a land evaluation and land use planning system (Appendix A.6) is a good choice.

If the focus is more on optimizing future land use based on e.g. highest profit and/or lowest environmental pollution and socio-economic aspects should also be taken into account, an optimization model for land use planning (Appendix A.1.2: LUPAS) is to be preferred. However, this approach is quite complicated and requires large-scale and well-organized data-production for model-input and data-handling. Fortunately, comparable studies have been done for the same area. Hence, a large part of the input-data may be derived from the reports from the project on Sudano-Sahelian agricultural production (i.e. PSS) and from the project 'Competing for limiting resources: the case of the fifth region of Mali' (Appendix B.3). In that case, a standard version of the optimization model for the different watersheds in West Africa, based on the models, data and reports from the two Sudano-Sahelian zone projects mentioned above, can be developed. Next, based on the biophysical and socio-economic data that within VINVAL are specifically collected for each of the studied watersheds (see end of Appendix A.3), each watershed-specific model should be further developed and calibrated.

If the profitability of a number of main agricultural production activities is to be determined, a simple approach is to apply a TCG (Appendix A.1.1) for the main crops on the main land use types in the area.

If the tool should not provide solutions to problems but rather should encourage discussion of the different alternatives available and should help people in participating in the process of land use management and planning, the approach presented in Section 5 can be chosen.

For the choice of the land use planning tool, a number of main points should be discussed and answered:
a) what is the current practice in land use planning in each case study area?
b) which models and tools are applied at present for land use planning?
c) which options and limitations for agricultural production and land use (Section 4.3) should be taken into account;

d) which other aspects are required: e.g. GIS (i.e. spatial explicit), socio-economic aspects, short term (5 years) or long-term (30years), scale (village, watershed or region), optimal use of available natural resources, input-output relationships of main agricultural production activities and their costs/benefits, trade-offs between activities;
e) type of approach (see Section 2.2);
f) who should use the tool (e.g. researchers or policy makers or local stakeholders)? Can tool probably be used by the user and which level of tool complexity is acceptable?
g) who should use the information generated by the tool (e.g. policy makers, local stakeholders)? Can output probably be understood by these stakeholders?
h) which topics and problems should be taken into account in tool (e.g. soil fertility, availability of production inputs, knowledge, marketing, infrastructure, property rights, user rights) ?
g) which degree of preciseness of the tool output is required (e.g. qualitative versus quantitative approach, see Section 4.2) ?
h) what is the function of the tool (e.g. to provide solutions to problems or to encourage discussion of the different alternatives available and to improve the effectiveness of the decision-making process) ?
i) should the tool help in increasing the understanding (on present land use and options for future land use change) of the stakeholders and which stakeholders?

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Appendix A Methods and tools for land use planning

A number of different approaches and methods for land use planning and for planning in related areas (e.g. nature conservation, watershed restoration, domestic areas) are described in the following.

A.1 Land use planning (based on maximum goal achievement)

In the project, parallel with the surveys on natural resources (land, water, etc.) and socio-economic conditions in the studied watershed or region (see Section 1), the goals of the local population, the regional government and possibly of other stakeholders are inventoried. These goals are, for example, sufficient income and food production, sufficient land cover, biodiversity, and water quality, and a maximum for nutrient leaching. The land use planning (LUP) tool is used to compute the extent, to which various goals can be met, given the available resources and the technically feasible options, and also to calculate the trade-off between different goals. These technically feasible options are based on Input-Output tables (see Appendix A.1.1).

Alternative land use development scenarios at the watershed scale are to be defined. For each scenario, the LUP tool identifies an optimum solution with respect to e.g. achievable production, environmental pollution, land and nature conservation. The LUP tool also indicates conflicts and trade-offs between goals, by quantifying how much of a given goal should be sacrificed to achieve another goal. These results for alternative land use development scenarios give a basis for selecting desirable and realizable combinations of land use and production technologies, to achieve various environmental and socio-economic goals.

A.1.1 Technical Coefficient Generator

A Technical Coefficient Generator (TCG) is a tool to generate in a systematic way the effects of alternative agricultural production technologies in the form of Input-Output (I/O) tables, based on existing knowledge. These I/O tables describe for current and alternative land use activities the relationships between biophysical inputs (e.g. fertilizers nutrients, labour) and resulting outputs in terms of produce, environmental pollution (e.g. nutrient leaching), etc. The I/O tables specify the full range of technically feasible options that are entered into the LUP tool (Appendix A.1). A second, more direct application of TCG's is to generate output for cost-benefit and performance analyses of various land use systems (e.g. efficiencies of water use, nutrient use and labour use). An example of a TCG is TechnoGIN which has been developed particularly for cropping systems in East and Southeast Asia (Ponsioen et al., 2004).

A.2.1 Land use planning approach in more detail: LUPAS

A Interactive Multiple Goal Linear Programming (IMGLP) modeling framework such as the Land Use Planning and Analysis System LUPAS (Hoanh et al., 2000), consists of quantified relationships between a set of objectives (e.g. food production, income), available resources (e.g. land area, water), and a range of production activities.

The main modelling components of LUPAS (Figure 1) are:
1) resource balance and land evaluation;
2) input/output estimation;
3) Multiple goal linear programming.

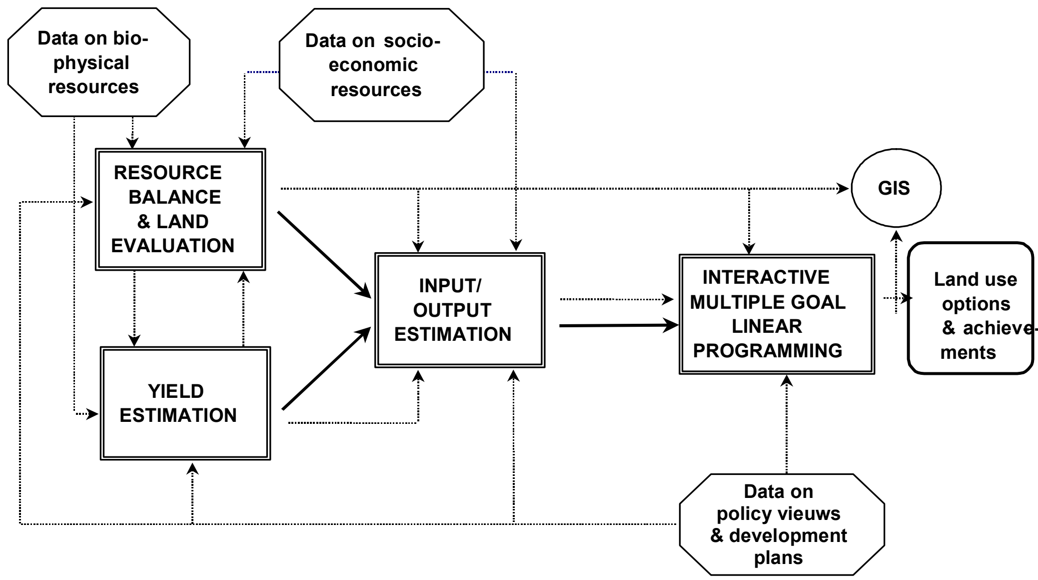

Figure 1. Structure of the LUPAS modelling framework.

The interactive scenario analysis with LUPAS model starts with exploring the 'window of opportunities' for agricultural development in a given region. This is done by first exploring the optimum for each development goal (e.g. maximum food production, maximum employment, maximum income, minimum pollution, minimum water use) with only the available land as resource constraint. Next, one development goal is given priority and optimized, whereas minimum target levels (i.e. constraints) are set to the other goals. Note that scenarios means here: projection of possible future situations which differ with respect to their weighing of the importance of income, environmental pollution, nature conservation, employment, etc. This meaning of scenario clearly differs from the time-related meaning applied in Appendix A.4 (i.e. path from present to future).

Resource balance and land evaluation: this component consists of a) delineating land units; b) assessing suitability of all land units for agricultural and other activities; c) assessing available land, water, labour and other (e.g. capital and natural vegetations such as forests) resources (i.e. constraints which are the maximum amounts of land, water, capital, etc. available for all land use activities); d) estimating demand for agricultural products; e) formulating development goals.

A land unit is defined as an area of land with specific characteristics and qualities. Such characteristics refer to agro-climate, topography, soil type, hydrology, etc. *Delineation of land units* is done by overlaying maps with these characteristics in a GIS. For *assessing the suitability of a land unit* for certain agricultural activities, this can be based on its characteristics in combination with expert knowledge. For example, heavy soil texture or stoniness prevents cultivation of root crops, steep slopes do not allow the cultivation of annual crops, long distance to townships prevents cultivation of vegetables, and an agro-climate with a severe drought period limits the length of the growth period and the cultivation of drought-sensitive crops. The *available land, water and labour resources* set a limit to, for example, the cultivated areas, the irrigated areas and the labour available during peak periods (e.g. harvest). Such data should be derived from land unit information (see above, delineation of land units), statistics, etc. For scenario analyses, future resource availability should be be estimated, based on trend projections. *Demand* and targets *for agricultural products* are to be estimated in each case study. *Formulating* development goals or *objectives* are already mentioned above (see begin of Appendix A.1.2) in the general description of the LUPAS approach.

Input/output estimation: for each of the production activities, such as rice production or milk production by cows, the inputs and the outputs (also called technical coefficients) have to be defined. The outputs are, for example, the yield level and the environmental pollution for rice production on a certain land unit and with a given technology level (degree of mechanization, crop management, fertiliser and biocide applications). For the soil-climate conditions of a land unit, the yield level is often calculated with a crop growth model for these conditions. Yield levels can also be based on crop experiments under similar conditions and crop management. The inputs are, for example, the required amounts of labour, water, fertiliser, and feed (for animal production) and can be derived from experiments, statistics, expert knowledge and/or models. With *Technical Coefficient Generators* (see Appendix A.1.1), an input-output matrix can be created more efficiently for a large number of combinations of land units, crop/livestock activities and technology levels. For each combination, a target production level can be specified or estimated, for which the TCG calculates the required inputs.

Interactive Multiple Goal Linear Programming (IMGLP): at the core of LUPAS is an optimization model, called IMGLP model. It is the integrating tool that is used to generate land use options by optimizing an objective (e.g. maximize income) for the specified I/O tables, given certain constraints (e.g. available water and land resources). For more information about this approach, see above (begin of Appendix A.1.2 and of Appendix A.1).

The basic approach and the main components of LUPAS, and its application for analyzing possible future agricultural production systems in Ilocos Norte province in the Philippines, are presented in detail by Roetter et al. (2004). More information on the LUPAS approach and on a number of its applications for analysing different land use systems in Haryana state, India, Kedah-Perlis region, Malaysia, Can Tho province, Vietnam, and Ilocos Norte province, Philippines is provided by Roetter et al. (2000).

A.2 NUTMON

This is a tool to accurately assess the main nutrient flows, losses and balances at the farm level. Such assessments are done for the main crop and livestock production activities of representative farms for the case study area. This approach gives insight in the present farm management and in particular soil fertility management, and may show in a next step how nutrient losses to the environment can be reduced through improved production techniques. Main nutrient losses in Africa are due to soil erosion and nutrient leaching, the last loss factor in particular for nitrogen. Nutrient depletion of soils often occurs, and is the result of these losses and of removal of nutrients in crop products. This nutrient removal is in Africa generally (due to the low fertiliser applications) higher than the nutrient input into the system through fertiliser and manure applications and through the natural nutrient supply (Stoorvogel et al., 1993; Bosch et al., 1998b).

NUTMON consists of a questionaire (to gather information on management at the farm level) and several software modules that have been designed to enter the collected information and to facilitate monitoring and analysis of farming systems in general and nutrient management and financial performance of the farm in particular. Main outputs are: (i) nutrient flows and balances (N, P, and K) for the farm as a whole and separately per pool (crops, livestock, etc.) within the farm; (ii) financial indicators (gross margins and cash flows); (iii) overviews of flows (material, nutrients, money) between pools. For more information about the NUTMON approach and a number of its applications, see www.nutmon.org and Jager et al. (1998), Bosch et al. (1998a) and Bosch et al. (1998 b).

A.3 Participatory Rural Appraisal

Sustainable Regional Development Kit (see Appendix B.1, Dore et al. (2000)) states that Participatory Rural Appraisal (PRA) is an approach to analyse local problems and to formulate tentative solutions with local stakeholders. It makes use of a wide range of visualisation methods for group-based analysis to deal with spatial and temporal aspects of social and environmental problems. It mainly deals with a community-level scale of analysis but is increasingly being used to help deal with higher level, systemic problems.

PRA grew out of a range of methodologies including agro-ecosystems analysis and rapid rural appraisal in the 1970s and 80s, in which the emphasis was placed on finding ways to express the diversity of local knowledge through facilitation by outsiders. It evolved from two distinct traditions: planners seeking to overcome the limitations of externally-dominated blueprint planning; and empowerment-oriented activists seeking to make their social transformation ideals more pragmatic. The term is somewhat misleading because the combination of techniques are equally applicable in urban settings and are not limited to appraisal — they are linked to planning processes and are being adapted for monitoring and evaluation purposes.

PRA is a rapid and effective way of obtaining behavioural, economic, sociological and biophysical information about a particular topic or situation. It is able to deal with complex systems and can provide insight into situations from multiple perspectives. It is interactive and can provide powerful learning experiences. On the other hand, PRA is open to being superficial and producing error in the data. It is not a suitable method for collecting precise and statistically significant information. PRA generates a large amount of data which needs comprehensive and thorough analysis and synthesis (Carman & Keith, 1994).

PRA is, for example, applied in the VEGSYS project, to analyse the farmer's perceptions of constraints and opportunities in vegetable-based farming systems in the Red River Delta of Vietnam (Hoi et al, 2002). Within the VINVAL project, PRA's have been carried out for three communities in the Ashanti region of Ghana (Meijerink, 2003) and for four villages in the eastern region of Burkano Faso (Berg, 2003), situated in inland valley bottoms and representing land use of three increasing levels of intensity in both countries. The lowest and highest land-use intensity areas consist of respectively about 20% and 50 to 80% agricultural land, with the remainder being natural areas (mainly forest). The purpose of these PRA's is to collect a basic data set on inland valleys in West Africa , to exchange information between these communities and the researchers, and to supply data for other work packages within the VINVAL project, such as the development of a tool for watershed-scale land use planning. The collected information consists of socio-economic information at the household level and of information on agricultural production systems and natural resources.

A.4 Scenario analysis

Sustainable Regional Development Kit (see Appendix B.1, Dore et al. (2000)) states that scenario analysis involves constructing stories about different plausible futures. The basic principles of scenario analysis for planning purposes are first, to understand as best as possible likely future trends and second, to make strategic decisions based on an analysis of the consequences of the most likely future scenarios. Scenario analysis can be a useful tool in helping people to think laterally, and to question assumptions and possibly unfounded beliefs about the future. Essentially, scenario analysis involves asking 'What if?'. Some forms of scenario analysis are: what are the different options for your region; what would be the impact of different external events on your region; what would be the alternatives; What would be the scenario for a 'do nothing' response to environmental issues? Scenarios present an internally consistent story about the path from the present to the future.

A.5 Stakeholder Analysis

SA is a tool for policy analysis and formulation, and has considerable potential in natural resource policy and project development. SA aims at a better understanding of environmental and development problems and their interactions through comparative analysis of the different perspectives and sets of interests of stakeholders at various levels. Any policy or intervention is likely to have consequences that bear differentially on different groups and individuals, and on society as a whole. SA is more relevant in complex situations where there are compatibility problems between objectives and stakeholders (Grimble & Wellard, 1997). Such situations are, for example, characterized by: (a) multiple users of a resource and their uses may not be compatible; (b) natural resources such as watersheds which cut across social, economic, administrative and political units with different stakeholders and different interests; (c) market imperfections where decision makers are not bearing the full costs of their actions; (d) multiple objectives and concerns of different groups of stakeholders.

There are two main branches in SA used for natural resource management in developing countries:

- The first branch has a farming systems and development background. This is an analytical tool for better understanding complex situations and predicting future situations and scenarios, and addresses both conflicts of interest between stake-holders and trade-offs between objectives.
- The second branch focuses on the social aspects of SA and its use as a management and mediating tool in project design, particularly for the avoidance and management of conflicts (Grimble & Wellard, 1997).

A.6 Land evaluation and land use planning

Information on soil characteristics, landscape and relief, hydrology etc. per land unit (in a spatially organized data base, i.e. GIS) may be translated into ratings per land unit of the potential, limitations and risks for production of a number of main crop species, of grasslands, etc. and for other uses than agricultural ones. Simultaneously, a rating of the risk for environmental pollution, soil degradation etc. per land unit may be produced. This mainly qualitative approach is described by Hoobler et al. (2003) (see Appendix B.1), and also by Diepen et al. (2002).

A.7 Multiple-objective decision-making method for watershed planning

A multiple-objective decision-making methodology and an integrative geographical information system-based decision making tool, RESTORE, has been developed to prioritize and evaluate restoration activities at the watershed levels (Lamy et al., 2002). For example, for a watershed the objectives (i.e. stakeholders' goals for restoration of watershed) and restoration options (e.g. reduced use of biocides on agricultural land) are first established. Next, attributes are identified (e.g. land use, hydrology). Attributes are site-based variables which chararacterize a land unit with respect to its potential to support various restoration options. In the next step, rules are established. The rules provide conclusions, describing a positive or negative impact of a specific restoration option at addressing an objective. Finally, the Simple Additive Weighted method is used to rank for each land unit the utility of restoration options by combining single objective scores weighted by the objective preferences of the decision maker. This results in a spatially explicit preferred landscape. This preferred landscape is the decision maker's preferred watershed restoration plan, integrating a mix of restoration options that are optimal or near optimal at addressing the various objectives of the decision maker. However, the selection of a preferred watershed restoration plan is an iterative process. RESTORE has been applied in two watersheds in Oregon. The results suggest that these methods can provide a valuable tool for analyzing complex watershed management issues.

A.8 Approaches to analyse land use change and technology adoption *(from paper by M.M. van den Berg, 2003)*

For analysing land use change, the approaches can be classified in two broad categories: 1) empirical-statistical models; 2) optimization models. The first category of models makes optimal use of existing data and is used to describe past changes. The results are, however, only valid within the domain of data. The second category of models is used to predict the effects of possible land use changes in the future. For the VINVAL project, the latter type of models is relevant, as we want to be able to predict the effects of biophysical, technological and policy changes, which are necessarily outside of the domain of the data.

The optimization models can be divided into two main types:

- First, models following the simultaneous equilibrium approach, generally assume a perfect coordination mechanism and maximize utilities. Optimization is carried out for the whole region, considering it as one super-farm.
- Second, agent-based models start from individual behaviour and interactions between individuals. This second approach is to be preferred, if markets are imperfect, farmers do not purely maximize profits and adjustment processes are of importance. For this last approach, farmers are classified into various relatively homogeneous groups. For each farm group, an optimization model is made. To account for market interactions, these models are linked through market equilibria in the most important markets. These representative farm models have some disadvantages when it comes to technology adoption. First, optimization models tends to specialize: the farmer switches completely

to the optimal activity. This can partially be controlled by subsistence and rotation requirements. Second, only a limited part of market interactions can be included if the aggregate model is to be solved.

- As an alternative to these farm models, a multi-agent systems (MAS) model may be used. MAS models origin from artificial intelligence, do not assume optimization and market exchange, but behave according to decision rules. These rules which are not necessarily based on theory, determine for example, the spread of information and the copying of behavior. This results in a gradual adoption of new technologies.

A.9 Conclusion

A.9.1 Bottom-up and top-down planning approaches

Interactive planning is a policy initiative which demands for feedback from target groups and/or local representatives, and which may be changed to some extent to get their support for policy implementation (ETC Leusden, see Section 3.1). This method is a mixed approach ('first top-down, then bottom-up', see Section 2.2) which is generally applied at the regional and national scales. A good example is the LUPAS system (see Appendix A.1.2).

Bottom-up planning in a truly participatory mode is based a dialogue between policy makers and target groups to come to a jointly developed and supported policy measures. The degree of participation may considerably vary during the whole process of policy initiation upto implementation. This method also has both top-down and bottom-up aspects and is mainly applied at the smaller scales (e.g. villages and small watersheds). PRA as described in Appendix A.3, is an example of this method.

A.9.2 Upscaling of VINVAL results

The Land Use Planning analyses within VINVAL are to be done for watersheds in two different agro-ecological zones in West Africa (i.e. southern Sudan Savanna zone and Equatorial Forest zone) and for watersheds with a distinctly different level of land use intensity (see end of Appendix A.3). By covering such contrasting ecological and farming conditions, upscaling of these results at the watershed scale to much larger areas in West Africa is probably possible. This means that the risk of producing site-specific information and knowledge is avoided. Hence, derived understanding of how agricultural productivity and ecological functions can be maintained in an integrated way, can be applied to other watersheds.

Appendix B Overview of literature

B.1 Literature on planning methods

Carman & Keith, 1994. Community consultation techniques. Purposes, Processes and pitfalls

This guide for planners and facilitators gives for a large number of consultation techniques a description, the type of application, the process of its use, and the advantages and disadvantages of its use. The consultation techniques belong to a number of main groups with respect to their use: (1) information dissemination, (2) information collection, (3) community-based planning techniques, (4) reactive planning technique, (5) decision making, (6) evaluation, and (7) participation process support.

Dore et al., 2000. Sustainable Regional Development (SRD) Kit (on CD-ROM)

This report is a stock take of the current status of SRD in Australia. It provides an analysis and set of general recommendations of what will be required to build on current efforts and to optimise the impact of SRD into the future. The report is an output from a project undertaken by Greening Australia in collaboration with the Australian Local Government Association. The material and analyses presented in this report have been gathered from multiple sources and studies. The material includes seven regional case studies, many discussions with regional, State and national players, a national conference (which brought together individuals from government and community, experienced in regional initiatives), and an extensive literature review.

This SRD development project and the resulting report has the following objectives:

- to improve the understanding of how to better integrate economic development and management of the natural environment in the pursuit of sustainable development;
- to enable the experiences and concerns of people working at the regional scale around Australia to be shared between regions and with policy makers. Complementary aims have been:
- to identify the issues and concerns of key groups in relation to SRD;
- to examine the current and potential roles and responsibilities of various regional organisations in relation to SRD;
- to establish the extent to which regional organisations believe they have adequate knowledge and resources to progress the quest for SRD;
- to assess and contribute to improving the communication networks of regional organisations both within and between regions;
- to produce an SRD Kit, to make information available that will assist regional organisations to improve environmental and economic integration and share their learning.

ETC Leusden, Overview of methods for participatory rural appraisal and planning (in Dutch)

This report gives for a large number of methods information on (1) the target group (e.g. farmers, policy makers), situation and scale; (2) results of its application (e.g. improved planning, improved situation and incomes); (3) phase of project (e.g. planning or execution phase) and its techniques (e.g. monitoring or workshops or interviews); (4) required time and human participation (e.g. farmers or policy makers and/or experts); and (5) examples of its application. The main part of the described methods belongs to Participatory Rural Appraisal (Appendix A.3), planning in industrialised societies and improving the social dialogue and participation.

Hoefsloot & Van den Berg, 1998: Successful examples of participatory regional planning at the meso-level

This report is the result of an investigation into the main factors for success in interactive regional planning processes in both industrialized and so-called Third World countries. A number of most interesting cases were investigated thoroughly to identify the main factors for success. The six cases were Gelderse Valley, the Netherlands (conflict between severe environmental problems from agriculture and natural and recreational areas), Chobe enclave, Botswana (conflict between hunting activities of local people and nature conservation), Murray-Darling basin, Australia (huge water catchment area where soil degradation is threatening the ecology and the economic base of agriculture), Comanche municipality, Bolivia (environmental degradation is threatening the socio-economic base of the living systems of rural population), Ouesse subprefecture, Benin (traditional shifting cultivation threatens the livelihood of the population), and Meket Woreda, Ethiopia (finding compromise between centralised development approach of government and participatory bottom-up approach).

For each case an overview of the problem perception (e.g. decreasing agricultural production, poor infrastructure, poverty, environment deterioration, uncertainty about land tenure) by the different stake-holders was compiled and combined in a matrix. This matrix is used to understand the starting point of each stakeholder in the negotiations, as well as the relationships between the different stakeholders. Secondly, the planning and negotiating process itself was analysed. Important points were: (a) who were the initiators of the new approach; (b) how did the negotiation and planning process evolve; (c) what were the important characteristics of the process; (d) was mediation an important element in the negotiation processes.

The third topic which received special attention, consisted of the 'knowledge systems', on which the different stakeholders base their perception and analysis of the problems in their regions. In order to get a better understanding of the positions taken up in the negotiations, it is necessary to understand the way of thinking and the knowledge base of each stakeholder. The way to investigate these, was mainly by identifying the different sources of information (e.g. scientific information from research or indigenous information based on traditional values) used by the stakeholders in the negotiations. Finally, the main factors for success were analysed. These were for example, recognition of mutual dependency of stakeholders, government policies and actions, funds available for process, voluntary nature of process, and good mediation.

Hoobler et al., 2003. Application of land evaluation and site assessment (LESA) and a geographic information system (GIS)

Objectives of this study were to integrate LESA methods and GIS to assess their use for land use planning in Wyoming. Factors used for calculating land evaluation scores, include land capability classification (i.e. limitations for crop production and risk in growing crops), prime farmland determination and irrigated sugarbeet yield (i.e. major crop as indicator). This was combined with site assessment factors which consisted of distance from city limits, from major roads and sewers. Maps were developed that displayed lands most suitable for agriculture within the study area. This appeared to be a rapid and versatile approach to assist in land management decisions.

Veldkamp & Fresco, 1996. CLUE: a conceptual model to study the conversion of land use and its effects

CLUE is a dynamic model to simulate the conversion of land use and its effects. Within CLUE, land use changes only occur if biophysical and human demands cannot be met by existing land use. Important biophysical drivers are biophysical suitability (i.e. climate, soil, relief) and their fluctuations (e.g. precipitation and temperature), land use history (e.g. land degradation), spatial distribution of infrastructure (e.g. terraces, drains) and land use, and the occurrence of pests, weeds and diseases. Important human land use drivers are population size and density (i.e. demand for food, labour force), regional and international technology level (determines attainable yield level), level of affluence (determines composition of food demand), economic conditions (e.g. markets, minimum quality requirements for products and price fluctuations), attitudes and values (determines production objectives such as more cattle), and the applied land use strategy.

Woodhill & Robbins, 1998. Participatory evaluation for land care and catchment groups

Dealing with environmental degradation is a complex task, so it is should not be surprising that the process of monitoring and evaluating landcare and catchment projects is complex too. This report is written to help landcare and catchment groups (in Australia) to improve the monitoring and evaluation of their projects. The report contains information on participatory monitoring and evaluation of projects in practice, making an evaluation of a community activity, and on structuring a project evaluation, and contains an overview of participatory techniques for evaluation.

B.2 Literature on biophysical conditions in West-Africa

Adiku, Stone, 1995. Using the Southern Oscillation Index (SOI) for improving rainfall prediction and agricultural water management in Ghana

The use of SOI for rainfall prediction and subsequent management of water for rainfed crop production in Ghana was explored. In southern Ghana, rainfall in the month with peak water demand for crop growth (i.e. June) was significantly related to the SOI in March/April. Hence, appropriate water management strategies (e.g. supplementary irrigation or drainage) could be planned ahead of time depending on the SOI in March/April. The SOI-phase system showed high promise of rainfall prediction and water management in southern Ghana.

Bakker, 1994. Multiple-goal planning as a tool to analyse sustainable agricultural production options in Mali

The paper describes a multiple-goal linear programming model for analysing options for sustainable land use in Mali.

Bakker et al., 1998. Sustainable land use in the Sudano-Sahelian zone of Mali: exploring etc.

This paper presents results of an exploration of possibilities for sustainable agriculture in Mali. Sustainable agriculture refers to a situation in which soil nutrient and organic matter stocks do not decrease and erosion is limited. The tool used for the exploration is a multiple-goal linear programming model, allowing to integrate quantitative agronomic and economic information, and to analyse conflicts that may exist between various development objectives. For three different climatic zones in Mali, an agro-ecologically sustainable land use system that maximizes income of the agricultural sector and satisfies self sufficiency targets, is identified for the year 2010. Land use is in all regions dominated by rangeland, but arable cropping systems become more important as rainfall and population density increase. It is shown that chemical fertilisers are an important element of sustainable and economically viable land use, especially in higher rainfall regions. It is argued that results should not be used to simulate the actual situation or future developments, but to define priorities for agricultural development. The large gap between actual agriculture and the presented sustainable agricultural system will not be bridged overnight. Implementation of sustainable land use activities requires a large number of accompanying measures to stimulate farmers to adopt them. Examples are regulations with respect to property rights, without which the grazing systems selected in the model cannot be applied, and modifications in the market and institutional environment that allow farmers to sell surpluses, buy fertilisers and borrow money.

Becker, Johnson, 2001. Cropping intensity effects on upland rice yield and sustainability in West Africa

Increased demand for land is forcing farmers to intensify their upland rice-based systems with a gradual shift from fallow rotation to sedentary agricultural production. Trials were conducted at farmer's fields in Cote d'Ivoire. Yield gaps were attributed to weeds and nitrogen supply. Increased cropping intensity and reduced fallow duration were associated with yield reduction. This intensification-induced yield loss appeared to be mainly related to increased weed infestation.

Breman et al., 2001. Resource limitations in Sahelian agriculture

Africa has poor soils and unfavourable climates for agriculture, and in particular in the Sahelian zone of West-Africa. The cost-benefit ratio of required inputs (in particular, inorganic fertilisers) does not favour their use. This situation is worsened by inadequate governmental policies. These are the main reasons that the 'Green revolution' has not taken off in sub-Saharan Africa. Few farmers can afford to use external inputs like fertilisers to correct the overexploitation of their soils, and soil depletion is threatening their future. As soil fertility improvement can trigger agricultural intensification and rural development, the interest for the community as a whole justifies support by governments and donors. The need is for an integrated use of locally available resources such as organic matter and phosphate rock, and inorganic fertilisers to improve the efficiency of the latter. In this way, the economic feasibility of fertiliser use improves. Simultaneously, governments should create an enabling environment for farmers to do such investments in their soils.

Breman, Kessler, 1997. The potential benefits of agroforestry in the Sahel and other semi-arid regions

Field studies support the conclusion that processes leading to an added value of woody plants in agroforestry systems are mainly related to reduced losses of water and nutrients. Such added values are therefore lowest where they are most needed, in resource-poor environments. Specific farmer's goals, agro-ecological and socio-economic conditions have to be taken into account to make optimal use of the potentials of agroforestry. The potential benefits of agro-forestry systems are mainly in terms of the improved efficiency of nutrient inputs than as an alternative for fertilisers. This has major implications for design and management of agro-forestry systems.

Duivenbooden et al., 1996. The integrated transect method (ITM) as a tool for land use characterisation

Technique to obtain data on physical characteristics and actual land use of valley systems by means of transect surveys and farmer interviews. ITM is illustrated using bio-physical results from inland valley agro-ecosystems in two agro-ecological zones in Cote d'Ivoire. Information on land use ratio, actual production ratio and fallow index is given for each land unit.

Hengsdijk, Keulen, 2002. The effect of temporal variation on inputs and outputs of future-oriented land use systems in West Africa

The (semi) arid area of West Africa is characterized by erratic rainfall that causes highly variable performances of cropping systems. For weather data sets for 31 years from two sites in Mali and for two soil types, the inputs and outputs of a millet system have been analysed. These in- and outputs were in particular the economic yield, N-losses and labour requirements. Fine-tuning of the sowing date resulted in a considerable increase in average millet grain yield, whereas the CV of yield clearly decreased.

Keulen, Veeneklaas, 1993. Options for agricultural development: a case study for Mali's fifth region

Multiple-goal linear programming technique has been applied in the framework of land use planning for the fifth Region of Mali. The results of the analysis are discussed, showing, for example, that animal husbandry is financially the most attractive sector.

Mwangi, 1997. Low use of fertilizers and low productivity in sub-Saharan Africa (SSA)

The gap between the increasing food demand due to population growth in SSA and the increase in food production in this area should be closed. A more rapid increase in food production requires intensive agriculture based on modern technologies, including fertilisers. Land scarcity results in shortened fallow periods, in decreased soil fertility and hence, in lower yield levels. Restoration of the soil fertility and increased output per hectare requires increased use of inorganic fertilizers. In 1990, farmers in SSA used on average 8.4 kg per hectare of plant nutrients, which is far short of what is needed to compensate for the mean nutrient removal in harvested crops. A stable policy environment conducive to change is absolutely critical to promote increasing use of inorganic fertilizers. Such increase in fertiliser use is essential to increase agricultural production and to ensure food security in SSA.

Ogungbile et al., 1998. Analysis of constraints to agricultural production in the Sudan Savanna zone of Nigeria using multi-scale characterization

A multi-scale characterization approach was used to identify the major constraints to agricultural production and to describe the major production systems in Sudan Savanna Zone of northern Nigeria. Relative emphasis was placed on the household-level characterization to have better understanding of the land use system, farmers' constraints and opportunities, so as to better target agricultural technologies and interventions in the Sudan Savanna Zone. Large variations exist in agricultural management practices among villages and households in terms of access to resources, such as labour, fertilisers, livestock, farm equipment and land.

Powell et al., 1996. Nutrient cycling in Integrated rangeland/cropland systems of the Sahel

This paper examines the sustainability of integrated rangeland/cropland systems in the Sahel. Nutrient balances for croplands and rangelands are compiled and the impact of livestock on these balances through grazing and manuring is given.

B.3 Information from previous Sahelian land use projects

Project on Sudano-Sahelian agricultural production (i.e. PSS):

a) Bade, J., Hengsdijk, H, Kruseman, G., Ruben, R., Roebeling, P., 1997. Farm household modelling in a regional setting: the case of Cercle de Koutiala, Mali. DLV-report no. 6, AB-DLO, Wageningen.
b) Bakker, E.J., Hengsdijk, H., Ketelaars, J.J.M.H., 1996. Description quantitative des systemes de production animale en zone Soudano-Sahelienne . PSS-report 27.
c) Breman, H,. Sissoko, K. (Eds.), 1998. Intensification Agricole au Sahel. Karthala, Paris, 996 p. Several articles by Bakker et al., Sissoko et al and Quak et al.
d) Hengsdijk, H., Quak, W., Bakker, E.J., Ketelaars, J.J.M.H., 1996. A technical coefficient generator for land use activities in the Koutiala region of south Mali. DLV-report no. 5, AB-DLO, Wageningen.
e) Quak, W., Hengsdijk, H., Bakker, E.J., Sissoko, K., Toure, M.S.M., 1996. Description agronomique quantitative des systemes vegetales en zone soudano-sahelienne. PSS-report 28.

Project ' Competing for limiting resources: the case of the fifth region of Mali':

a) Cissé, S., Gosseye, P.A. (Eds.), 1990. Report 1: Natural resources and populations. ESPR (Etude sur les Systèmes de Production Rurales), Mopti, Mali and CABO-DLO, Wageningen.
b) Duivenboden, N. van, 1990. Report 2: Production vegetales, animales et halieutiques. CABO-DLO, Wageningen.
c) Duivenboden, N. van, 1992. Sustainability in terms of nutrient elements with special reference to West Africa. Report 160, CABO-DLO, Wageningen.
d) Veeneklaas, F.R., 1990. Report 3: Formal description of the optimisation model. CABO-DLO, Wageningen.
e) Veeneklaas, F.R., Cisse, S., Gosseye, P.A., Van Duivenboden, N., Van Keulen, H., 1991. Report 4: Development scenarios.CABO-DLO, Wageningen.

Appendix C Using Self-Designed Role-Playing Games and a Multi-Agent System to Empower a Local Decision-Making Process for Land Use Management: The Self Cormas Experiment in Senegal

(Journal of Artificial Societies and Social Simulation vol. 6, no. 3 http://jasss.soc.surrey.ac.uk/6/3/5.html)

This project dealt with land use, with the goal to develop simulation tools to help the Rural Councils to explore new land-use rules. For example, it was intended to explore what parts of space would be reserved for specific activities; what the rules of access might be; which users might be encouraged and which might be controlled; etc. The Rural Councils were seen as the client group; they were sets of elected farmers in charge of managing resources of the Rural Community (20-300 villages). The goal was to find solutions that allowed multiple uses of a common space.

Workshops were organized in three villages. The theme of each of these workshops was the relationships between agriculture and livestock. About 25 farmers and herders of the villages participated in each workshop, with each workshop taking three days. The following was the general structure of the workshops.
Day one: Identification of the needs of the different actors (soil quality, water salinity, distance to water, distance between plots, etc.).
Day two: Design a map representing the village area and the indicators defined in the previous step. A GIS was available for this purpose.
Day three: Role-play game to represent the dynamics of the system. Month-by-month, each player decided which activity he was engaged in and where, by moving a post-it on the map.

The experiment links GIS, Multi-Agent Systems and Role-Playing Games within a self-design and use process. The main objective was to test direct modeling design of these tools by stakeholders, with as little prior design work by the modeler as possible. This "self-design" experiment was organized in the form of participatory workshops, which has led on discussions, appraisals, and decisions about planning land use management, already applied two years after the first workshops. During the role game, all agents look for a good place to make crops or to harvest pasture. They do this for each time step (monthly). The agents represent the actors, who may be farmers or herders. At time step 1 (July, in reality), they look for a good place for the wet season crop, and time step 6, they look for a good place for the dry season crop. At the end of the year, there is a regeneration of the resource.

Example

In Ngnith village, situated on the west side of Lake de Guiers, the main problem, as defined by local people, was a conflict between herders and farmers. The farmers cultivated crops along the riverside and the cattle had to cross the fields in order to have access to the river for drinking. Damage and conflicts often occurred.

The first day, the needs of each group were identified. Each player was alternatively farmer and herder, depending on the season. For the cattle, the distance to water was recorded, as was soil quality. The farmers cultivated two crops a year. For the crop cultivated at the beginning of the wet season, the soil indicator was the unique constraint. The second crop was for market garden produce, when the plots had to be near permanent water. The agents simply looked for places that satisfied their constraints. Consequently, problems emerged for the cattle, which had no access to water.

Once the role games were completed, the rules and spatial relationships that were presented in these role-play games were used to develop and parameterize the simulation model. This model was presented to the participants and was validated by them on the third day. The model was then used to explore different scenarios that could be used to resolve the conflict situations that had emerged.

Despite the fact that most workshop participants had never seen a computer monitor, they could easily follow the computer simulations and understood the representations and outputs. Once a simulation reproduced the known situation, the aim was to simulate various scenarios. Discussion began on the water issue. Two alternative scenarios were tested. In the first, a number of water points were sunk in the west. In the second scenario, channels were defined from the lake to extend the reach of the lake into the grazing areas.

The first scenario resulted in overexploitation of pasture around the water points. Then discussion about the channels occurred. Without access rules these channels were not useful. Farmers located their crops all along the channel and herders found that there was no access to the water. Proposals were then suggested to prohibit agriculture on the last kilometer of channel to allow cattle to have access to the water. These proposals were simulated and resulted in a broadly acceptable solution to the conflict problem, which has since become the focus of a set of implementation meetings involving the stakeholders and the Rural Council.

RPG

Role-Playing Games (RPGs) have already been used to support land use management. The games, which depend upon the prior diagnosis of the situation by experts, help players to share in this analysis and to draw upon some improvements based on it. But in our own experiment, we use a decidedly different form of RPG: a Self-Designed RPG. There are no prior rules and the setting of the game is drawn from previous diagnosis. The RPG is designed solely from a self-analysis of the players' situation and is produced in a single step.

This type of RPG inevitably relies upon very simplified rules and a crude game setting. But the goal is not to conceive a game that is technologically advanced and satisfying from our own expert point of view. The purpose is to create a novel design that includes "mediating supports", which could facilitate the emergence of worthwhile debates by taking into account all the different perspectives and building upon some truly common technical devices. The method seeks to help people to progressively formalize the elements-as they move forward through their debates-which appear useful to all for the improvement of their decision-making abilities. In fact, the usual technical complexity that designers often put into an RPG designed to support negotiation is due to the designers' need to reproduce any possible impact, especially an environmental impact, of the interactions among any players. This type of designer's RPG must take into account all the potential dynamics and effects between the environmental and socio-economic elements in order to help decision-makers find the best solution. This sort of designer instinctively contrives the whole process in the form of a perfect decision being located in a given time frame (the game's time), as opposed to the realistically complex situation that he should attempt to reflect in his RPG. His tacit hypothesis is that all the essential elements for the decision can be selected prior to the game and then deposited in the RPG. The possible weaknesses of this model lie in the ambiguous nature of the designing expert, who often positions himself as the master of the decision process. Many information systems fall into these traps.

From the outset, it was believed the decision-making process is primarily a continuous, iterative and incremental process. So the purpose of an effective tool of this type cannot be to produce right decisions but to help people to steer the process towards less imperfect decisions. Hence, the degree of complexity of the decision-making tools should mirror the progressive, continuous and iterative nature of the decision-making process, and this is the first challenge in the creation of support tools.

MAS

Among the range of modeling tools available, Multi-Agent Systems (MAS) seem to be particularly suitable. For several years, Multi-Agent Systems have been used in the field of natural and renewable resource management. A multi-agent system is a conglomeration of agents, which when acting together exhibit a greater system level behavior. The designer programs this behavior in some cases and in other cases this can be an emergent behavior. The system level behavior benefits from the individual actions of the agents. The project team designed a special MAS platform, CORMAS (COmmon-pool Resources and Multi-Agent Systems) that greatly simplified the task of modeling and simulation, and was used for knowledge integration in the collective learning processes that focus on integrated natural resource management issues.

The objective was to test a self-designed MAS requiring modelers to concentrate on producing an upstream modeling environment, rather than a real model, involving as little prior design work by the modeler as possible and enabling stakeholders to express themselves right from the initial stages in the design of their own model. In fact, in the previous self-designed RPG modelers, who attended the RPG as mere spectators of the discussions, had transcribed the crude rules of the RPG into a MAS model. They had also amended the platform so that the model could test the kinds of changes and regulatory scenarios imagined by participants. Thus, the multi-agent model corresponding to the RPG was programmed from the self-designed RPG. In other words, people construct and then test a model through an RPG before they were provided with a computer-modeling platform.

Since this flexibility in CORMAS allows modeling the previous RPG features exactly, participants have no problem understanding the MAS model and they immediately launch into simulation. By progressing gradually over a short time, the stakeholders learn to follow the different scenarios on the screen, discuss them and propose new ones. After playing out the scenario identified in the previous RPG, new situations emerge, are simulated and then discussed. This provides an opportunity for testing the sensitivity of a given set of collective rules and their consequences with respect to the shared set of assumptions already involved in the behavior of the individual stakeholders. Hot debates may often emerge and demonstrate the worth of these tools for the improvement of the collective processes.

GIS

GIS was used to visualize the actions and the various effects of the RPG.

Developing RPG in conjunction with GIS and MAS is an effective and valuable way of transferring a large measure of the hands-on power to the users. It would have been physically impossible without computer simulation to play out the different scenarios selected by the stakeholders and to observe their multiple impacts over sufficiently long time intervals. A modeling platform that is flexible enough offers many more possibilities for modifying the rules on demand than do cumbersome game or workshop sessions. The participants were themselves the initial designers of the models, and they were entirely aware of the gap between themselves and reality. Focusing on dynamics instead of results (MAS), and focusing on wide-ranging analysis instead of quantitative data (GIS), are the primary ways in which modeling results should be used. Having largely designed the model, participants were well aware that it was not a "magic" black box capable of seeing into the future.