Tradeoff Analysis

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as an operational and accepted tool for policy analysis

Final report

Wageningen, 2005

Ecoregional Fund

This report is the final report of a project funded by **the Ecoregional Methodology Fund**:

Since the early 1990s, the Consultative Group for International Agricultural Research (CGIAR) has supported the establishment of a series of ecoregional programs. These are typically consortia, involving national agricultural research systems (NARS), international agricultural research centers (IARCs), advanced research institutes, nongovernmental organizations (NGOs), and local and national government agencies that aim at resolving major development problems related to the sustainable use of natural resources within an ecoregion. There are other multi-institutional programs outside the CGIAR, as well, that have a similar perspective. Progress in these ecoregional programs requires that socioeconomic and political concerns be well integrated in the development of improved approaches for managing natural resources. Such approaches may include both new ways of using the land and supportive policies. Several methodological tools exist that can help to achieve this. For example, the ecoregional studies approach of the Agricultural University of Wageningen and methodologies used by the International Consortium for Agricultural Systems Applications (ICASA). But not all of these tools are available to ecoregional programs and there remain important methodological gaps. A workshop reviewing the progress of the Fund discussed some of these gaps (ISNAR 1998).

The goal of the Fund is:
to stimulate ecoregional initiatives within or outside the CGIAR that aim at the development and implementation of sustainable, productive agriculture, rural development, and natural resource management.

The purpose of the Fund is:
to support the development of methodologies (1) for research that is ecoregional in scope and (2) for enhancing the implementation of new approaches to natural resource management and rural development in ecoregions.

Tradeoff Analysis as an operational and accepted tool for policy analysis

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1. Introduction

In the last decade international agricultural research went through numerous changes. An important new field of research has been the integrated analysis at regional scale levels[1]. Numerous publications have been focusing on this field (*e.g.*, Heerink *et* al., 2000). Although definitions vary, this can be seen as an increasing call for ecoregional research where research is focusing on an integrated analysis of a region including the various stakeholders and including all the different elements (rather than individual producers and a single aspect like *e.g.* erosion. The Ecoregional Methodology Fund has been contributing to this development. In its first phase the ecoregional methodology fund supported 10 different programs that dealt with one or several of the key steps of ecoregional research identified to be:

1. Problem definition and delineation of the ecoregion (or resource management domain)
2. Characterization of current conditions, trends and history (agroecological and socio-economic) in relation to the identified problem.
3. Development of models of ecoregional processes that permit evaluation of alternative land use options and management schemes.
4. Presentation, discussion, and amendment of options.
5. Implementation of improved land use options, policies or management schemes.

One of the projects dealt the development of the Tradeoff Analysis (TOA) Model in a project entitled "Regional scaling of field-level economic-biophysical models: DME-NOR". The basic concepts originated in a project funded by the Rockefeller Foundation. The Ecoregional Fund and the Soil Management Collaborative Research Program (SM-CRSP) of US-AID provided subsequent funding. This joint funding led to the development of the Tradeoffs Analysis framework. This framework encompasses a process to assess these tradeoffs that follows similar steps as the ones presented above for ecoregional research. The tool had been applied in the mountainous regions in the Andes. Results of the work were presented on a range of national and international conferences and workshops and had been published in the international scientific literature. In that sense the development of the TOA model has been successful. A list of publications can be found on the TOA project web site (www.tradeoffs.montana.edu).

TRADEOFF ANALYSIS *provides insight into the complex nature of agricultural systems and deals with a broad range of sustainability issues related to policy intervention, technological innovations and changes in environmental conditions (e.g. climate change). Tradeoff Analysis is a methodology for an integrated analysis of tradeoffs between economic and environmental indicators. The analysis to quantify these relationships is based on a multi-disciplinary approach and is implemented in the Tradeoff Analysis Model that incorporates both bio-physical as well as econometric-process simulation models. The communication between these very different models is based on explicit definitions of spatial and temporal scales and the model integration software. The methodology is based on spatially-explicit econometric simulation models linked to spatially-referenced bio-physical simulation models to simulate land use and input use decisions.*

[1] Regional scale levels are here defined as watershed (from a biophysical perspective) or district (from a social organizational perspective) scale levels.

Although successful at the level of a limited number of case studies, one wondered whether the applicability of the TOA model is broader. A number of possible problems were envisaged:

- The TOA model was developed for the Andean highlands and had not been applied outside this region.
- Training material and manuals were still lacking.
- The software had to be adapted to make it more generic.
- The application of the Tradeoff Analysis Model was constrained by the data requirements of the model.

Many models developed in the scientific community remain research tools and do not make the step to actually being used. In this project we explored the possibilities and opportunities for the TOA model to make this step.

This document reports on the activities carried out in the joint ecoregional fund/SM-CRSP program in Eastern Africa (although examples are provided from other case studies). The document is set up in the structure provided by the ecoregional fund. Please note that we do not report on the actual TOA methodology as this has been done in a range of publications (see the reference list and/or the TOA websites: www.tradeoffs.nl and www.tradeoffs.montana.edu).

2. Original program goal and objectives

The TOA model was developed in the context of a research project. Its first application of the TOA model in Ecuador coincided with its proper development. Although the model was thoroughly tested for the case study in Ecuador, the TOA framework encompassing stakeholder involvement throughout the application was biased. In the discussion with stakeholders, even the researchers themselves were not clear about the final product (read methodology) during the discussions. A second application in the Peruvian Andes was a more legitimate test of the tool although the tool was applied under similar mountainous conditions and with comparable cropping systems. The research team that developed the Tradeoff Analysis Model is aware of these constraints and applied for an extension of the Tradeoff Analysis Project in the second phase of the SM-CRSP. The proposal entitled "The Tradeoff Analysis Project Phase 2: Scaling Up and Technology Transfer to Address Poverty, Food Security and Sustainability of the Agro-Environment" (2001) was approved by US-AID and tackles a number of the issues listed in the introduction. The new SM-CRSP proposal funds applications of the Tradeoff Model in different environments and focuses on a number of methods and issues related to scaling up the analysis to larger region that may have a higher policy interest. Finally, the project will deal with the development of protocols and materials to transfer the TOA method and the TOA Model software to existing and future users groups. To supplement the work of the SM-CRSP program, this project was applied to the eco-regional methodology fund. The eco-regional methodology fund proposal Phase II includes 5 different programs that are required for a proper consolidation and application:

1. Consolidation of the Tradeoff Analysis Model
2. Testing and application of ecoregional methods in regional case studies
3. Development of user-oriented, generic software for TOA Model
4. Strategies for institutionalizing the TOA Model
5. Communication of research results.

In the first phase of the TOA Program a jointly managed project was created with the SM-CRSP and the Ecoregional Methodology Fund to develop the TOA methodology. A cooperation rated as successful by external reviewers in the DME-nor project (External Evaluation Panel, 1999). For the second phase of the Ecoregional Methodology Fund we proposed to set up a similar joint project that aims to consolidate and apply the TOA model. It is clear that this could not be done with a single contribution from the Ecoregional fund. We therefore proposed closely linked projects in which US-AID funding is used to compliment the funding from the Ecoregional Methodology Fund. Only in such a way, it is possible to consolidate and apply the Tradeoff Analysis Model in a proper manner.

The project aimed to take the TOA model to a different ecoregion and to develop a strategy to lift the tool from a research tool by the TOA team to a tool that is being used by different institutions in this ecoregion. The new project activities focused on East Africa, although in the context of the SM-CRSP activities were also initiated in Senegal and Panama. The project aimed to learn from these experiences and develop a strategy to do so in more general terms: how to institutionalize complex ecoregional

research tools. By doing so, the project deals with the five major programs as they have been identified in the eco-regional fund proposal Phase II.

In various applications of the TOA model, the TOA team encountered serious problems due to the data requirements of such a large modeling exercise. The model requires insight in agricultural management by a population of farmers through a dynamic survey under the population of farms. At the same time the model claims to be site-specific requiring insight in the spatial variation of environmental conditions. The model deals with sustainability issues that each require field trials to be able to quantify them in an appropriate manner. Finally, we would like to evaluate alternative land use scenarios (*e.g.*, the introduction of alternative scenarios or policies). For the evaluation of scenarios, research is needed to estimate potential effects on labor requirements or the relations of potential changes in management with production. Although the studies are data intensive we increasingly see that data sets become available through different projects. Note that often these studies are not being used and that new datasets are being collected. In this project we would like to study the potential of using existing datasets. In East Africa, soil fertility decline is seen as one of the major threats to agricultural productions. The NUTMON program (www.nutmon.org) has been active in studying soil nutrient budgets and has its roots in eastern Africa. On paper the data requirements of the NUTMON approaches are rather similar to those of the TOA methodology. As a result various potential data sets are available in Eastern Africa. In this project we will explore the possibility to run the TOA model on the basis of the NUTMON datasets. In addition alternative procedures to reduce the data requirements will be evaluated (*e.g.* digital soil mapping and simplified econometric models).

THE NUTMON TOOLBOX *has been developed by Wageningen University and Research Centre for the diagnosis of soil nutrient dynamics at the farm level. The toolbox is the result of a range of research projects that are principally located in East Africa. The toolbox includes participatory tools to map nutrient flows on the farm (including the economical aspects), software for storage and screening of survey data and software to analyse the farming systems in terms of nutrients and economics.*

3. Project strategies

3.1. General workplan

To meet its objectives, *i.e.* an accepted and operational tool that is ready for application, the project elaborated a strategy for the actual implementation of the overall objectives. While developing the strategy it considered two important boundary conditions. Firstly, the project started significantly later than originally envisaged and effectively only had 1½ year to meet its objectives. Secondly, it is managed jointly with the SM-CRSP project but finishes several years before the SM-CRSP project.

The project team thought in general terms about the key elements that were required to transform the tool into an accepted tool. Firstly, we had to be convinced that the tool is appropriate for the questions that are being asked. It is undesirable to get into a situation of technology push. To avoid this, we developed an implementation strategy that is described in Section 3.2. Secondly, we had to create a tool that could actually answer the questions with a realistic investment in resources. We knew from earlier experiences that the TOA model required a significant input in data. Research in the larger TOA program has led to numerous developments that allowed for a reduction in input data or effective procedures to collect the input data (e.g. digital soil mapping techniques and climate interpolators). In the particular case of east Africa we decided to explore the possibility to link up with the Nutmon program. The strategies developed to link TOA and Nutmon are described in Section 3.3. Key for the institutionalization of the TOA model was the development of new partnerships. Those are described in Section 3.4.

3.2 The implementation strategy

To make a tool for ecoregional research available to research groups within a specific ecoregion, we need to know whether there is an actual interest in the type of analysis that we are proposing. The research program therefore initiated with visits to various research groups in Kenya. The visits included brief presentations of the TOA framework and a discussion on the potential applications. However, at that point in time these were no examples from Kenya or East Africa. High priority was given to select a site in Kenya where we could apply TOA. In this application we could also identify and solve potential problems with the TOA due to its application in a new environment. As soon as an initial application was operational and the necessary changes were made, we could organize a training workshop. For this training workshop, projects would be invited that were about to start with a data analysis or broader activity for which TOA seemed a good fit. The training workshop includes general introductory presentations and hands-on exercises. To allow for sufficient disciplinary depth the group was split in two parallel sessions dealing with the economic and bio-physical aspects respectively. Finally there was a planning session in which each project made specific plans for the implementation of the TOA. After the workshop each project included a team that was trained in the use of the TOA model. However, it is clear that it will be difficult for those teams to work

independently. They would be provided with backstopping by the TOA team. The backstopping could involve e-mail contacts but also more intensive field support and additional training. Although it will be difficult for the projects to finish the application within the framework of the ecoregional fund project, they can receive continued support through the US-AID project. Plans for continued support can be made during the final TOA workshop in June 2005. Although this implementation strategy has been developed and implemented within the program it will evaluated and may be functional in future application of TOA.

3.3 The TOA-Nutmon linkage

In the past, dynamic surveys of farm household activities and farm management have often been used as an important technique to adequately model agricultural decision-making. The applicability of the TOA Model would be significantly increased if we could show that the model can be run using this type of previously collected data. Wageningen UR has extensive experience in nutrient monitoring in its NUTMON program (www.nutmon.org). NUTMON is an integrated, multi-disciplinary methodology that targets different actors in the process of managing natural resources in general and plant nutrient in particular. Using the NUTMON method farmers and researchers jointly analyze the environmental and economic sustainability of tropical farming systems. Participatory research techniques such as resource flow mapping, matrix ranking and trend analysis are used to obtain the farmers' perspective. Among with the participatory analysis, NUTMON guides a quantitative analysis to generate important economic and soil management indicators such as nutrient flows, nutrient balances, cash flows, gross margins and farm income. Both the qualitative and quantitative analyses are then used to improve or design new technologies which tackle soil fertility decline can help to increase the economic performance of the farm.
However, despite the fact that many applications of NUTMON showed the mining of soil fertility to be a major threat in East African cropping systems, the projects were unable to guide changes in policy to reduce this threat. In contrast, the aim of the Tradeoff Analysis method is to answer the questions: What will be the effect of technology changes or policy interventions on the decline of soil fertility?

3.4 New partnerships

New research activities require new partners. The current research group includes a range of CGIAR institutes (CIP, CIAT and ILRI), universities (Montana State University, Wageningen University) and national agricultural research centers in South and Central America. This diversity makes the modeling group an increasingly interesting partner in global and regional initiatives that are currently underway.
A regionally-based process is underway to promote greater integration of the activities of the CG system and its partners in Eastern and Southern Africa (ESA). The process of integration is to respond to global and regional challenge programs. Challenge programs are proposed as new methods of financing research in the CG and their aim is to promote integration. The sub-Saharan Africa group has proposed an Africa regional challenge program on integrated natural resource management and policies. The objectives of these regional challenge programs are clearly consistent with the

objectives of proposed joint Ecoregional Fund and SM-CRSP projects for applications of the TOA Model. This consistency is illustrated with the following output developed by the sub-Saharan Africa group for a proposed regional challenge program on Policies.

> *[There is a need for…] instruments to address trade–offs between private and social costs and benefits, including policy instruments to guide food security decision making on appropriate agricultural inputs, those to guide fair trade decision making for the removal of trade barriers at national, regional and international levels, and appropriate policy options, norms and standards for sustainable land use. (Final report ESA working group 2001)*

The above example together with, for example, the African Highlands Initiative illustrates that there is a basis in East Africa to further institutionalize the TOA method. Active lobbying and participation in these activities is needed for an effective implementation of the analysis in these initiatives.

This project should results in an application of the TOA model for Machakos and in a number of projects in the region with which partnerships have been developed.

4. Program activities

In this Section an overview will be given of all the activities that have taken place within the ecoregional fund project

Soil Data

- A dutch Msc student did a MSc thesis research on digital soil mapping and soil variability in a small section of Machakos district (Ellenkamp, 2005).
- Soil resources in Machakos were mapped and sampled.
- The results of the study are currently being written up and an abstract has been accepted for oral presentation at the Pedometrics conference this fall in Florida (Annex 2).

Crop growth simulation models

- Crop growth simulation models from the DSSAT (Decision Support System for AgroTechnology Transfer) have been set up to simulate the inherent productivity for maize and beans. The experimental data from the Fertilizer Use Recommendation Program were used to calibrate the models.

Nutmon

- Existing NUTMON databases for Machakos were analyzed and converted into a format suitable for the estimation of the econometric simulation models.
- The process of data extraction has been documented for future applications.
- A literature review yielded a database with almost 100 publications related to Soil fertility and the Machakos study area.
- A module has been developed that allows for the linkage between Nutmon and the Tradeoff Analysis model. A draft journal article has been written that describes the linkage between TOA and Nutmon.

TOA

- The economic simulation models that describe the decision making process by farmers needed to be adapted to deal with the livestock component in the Machakos study area.
- A variety of scenarios dealing with technological innovations and policy interventions have been analyzed for the Machakos area. A draft journal article describing the analysis has been prepared. After discussions at the final workshop this article will be finalized.
- Quick advances in model development were only possible through intensive contacts of the project team in Kenya, Wageningen and Bozeman MT. Alejandara Mora Vallejo and Jetse Stoorvogel traveled to Kenya on separate occasions in March, 2004. Between April 9 and 16, Alejandra Mora Vallejo and Jetse Stoorvogel visited John Antle at Montana State University in Bozeman, MT. The first week of June, John Antle visited Wageningen to continue working on the model. The second week of June, the core project team (John Antle, Charles

Crissman, Andre de Jager, Jetse Stoorvogel, and Alejandra Mora Vallejo) met in Nairobi for a field visit to resolve a number of methodological questions, to obtain better insight in the systems and to discuss indicators and scenarios. Finally, they met with a number of institutions that are perceived as potential clients for the methodology.

Case studies

- TOA presentations were given at:
  - Kenya Agricultural Research Institute
  - ICRAF
  - ILRI
  - Nairobi University
  - Egerton University
- Projects at Egerton University, KARI-ICRAF (funded by the Global Environmental Facility) and at Makerere University (Uganda) were selected for further collaboration.
- A training workshop was organized to train the people from the three projects and to develop work plans for the TOA component in the projects.
- Contacts were maintained with the different projects
- Imelda Nalukenge from Makerere University made a one week visit to Wageningen University and Research Centre to jointly extract the Nutmon data for the Palissa study area. Subsequently, she traveled to Montana State University with Gerdien Meijerink (LEI-DLO) to work on the economic modeling.
- Different investigators from the TOA team visited the different projects to collaborate on the different case studies.
- A final workshop will be organized in June, 2005 in which people will report back and further collaboration will be discussed.
- Wachira Kaguongo maintained intensive contacts with the KARI/ICRAF project.

Training and communication

- A new Tradeoff website has been developed with the key features of the tool and training materials.
- A suitable framework for a 1-week introductory training course was developed and tested in the Senegal workshop (in the context of the SM-CRSP program).
- A draft book on the tradeoff analysis has been written and will be presented at the final workshop.
- Information leaflets have been developed for most TOA applications to illustrate the potential use of the model.

5. Program outputs

5.1. The Machakos application

The research team planned to develop an application of the tradeoff analysis model for the Machakos study area. A number of different data sets developed with the Nutmon toolbox for soil fertility monitoring were available for this district. One of the main hypotheses of the project was that these data sets are suitable for a TOA application. During the project the data sets were analyzed using Nutmon and transformed into the structure of the TOA model. A few problems with the Nutmon software were encountered. These problems were resolved with the support of Joost Vlaming (one of the developers of the Nutmon software and currently private consultant).

The Machakos study area

Soil data from the Kenyan Fertilizer Use Recommendation Program (FURP) were reviewed and a soil database in the TOA format was developed. In a second phase additional soil data were collected and a more detailed soil database has been established. Although the original intention was to make use of a proper digital soil mapping techniques using relationships between soil properties and the various soil forming factors, an intermediate step was included using a detailed geomorphologic map for the study area. Field observations indicated that this map explained very well the soil variation in the study area. The Machakos model that was presented at the end of the project included this soil map. Digital soil mapping exercises are still carried out and will be presented at the Pedometrics conference in September 2005 (See annex 2).

The relevant DSSAT crop growth simulation models were set up and calibrated using the FURP experimental data. Agriculture in Machakos is highly complex with small fields and a large variety of crops. For many of these crops no crop growth simulation models are available. We therefore decided to work with the inherent productivities[2] of two crops: beans (a mostly water limited crop) and maize (both water and nutrient limited)

The econometric simulation models have been set up by John Antle. This required a number of adaptations from the earlier models that were developed for TOA applications in Ecuador, Peru and Senegal. For example, the earlier applications did not include the farm level. Management decisions were simulated at the field level only. Besides a new structure for the econometric models, adaptations were made to

[2] The inherent productivity of an agricultural field is defined as the expected productivity with a typical management. The production is a function of the inherent environmental characteristics of that field. Within the Tradeoff Analysis Model, the inherent productivity is one of the important driving factors behind management decisions.

the TOA shell (aggregation module) to be able to deal with farm and field level. In the farming systems in Machakos, the zero-grazing unit plays an important role through the production of manure and for income generation (milk production). In addition to the existing interfaces for soil erosion, pesticide leaching, and carbon sequestration a new interface was developed for the calculation of the soil nutrient balance using the budgeting system as used in Nutmon.

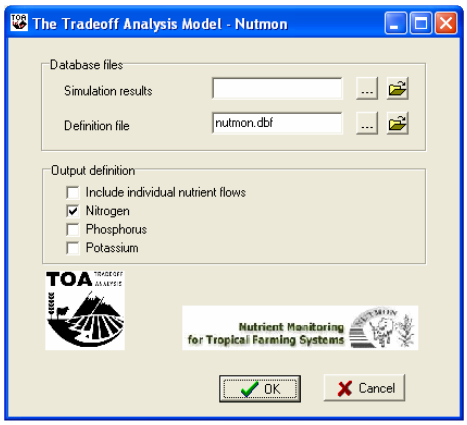

Figure 1: The new interface for soil nutrient balances.

Now that the econometric simulation model incorporates both the farm level and the field level, the aggregation procedure had to be extended with a module for merging the results at these two levels. This resulted in a new module that writes and executes a specific SAS program for aggregation and merging of the data as shown in Figure 2.

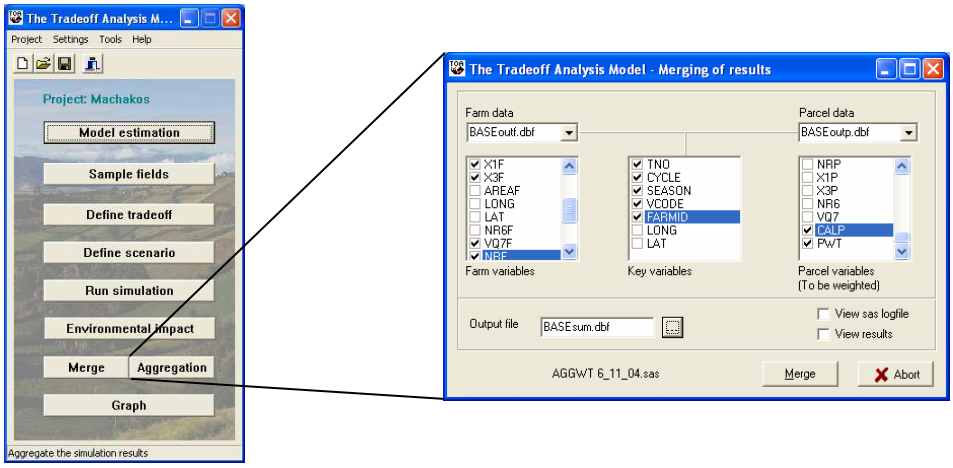

Figure 2: The new TOA module to merge farm and parcel level data.

Although, a very satisfactory TOA application was established for Machakos, questions came up while working with the data. A few hiates in the Nutmon databases were identified. Nutmon does not register the sequence of cropping activities nor does it register the use of family labor to specific activities. In a field trip to Machakos, the project team looked for answers to these questions. In discussions about indicators

and scenarios within the project team and with possible clients of the methodology, new indicators were identified to deal with food security and poverty. These indicators were included in the models.

Figure 3 and 4 show some initial results with respect to the main indicators soil nutrient depletion and poverty. More results will be generated in an interactive session in the final workshop. Thos results will be included in the final version of this report. It should be noted that stakeholder involvement was minimal in the Machakos study. First of all, the model was mainly developed for illustrative purposes during the TOA training workshop. Secondly, the application was based on earlier Nutmon programs that had intensive stakeholder involvement. Key for this ecoregional program is the application of TOA in a number of research projects carried out by trained TOA teams and with backstopping through the project. Those projects will have respective stakeholder involvement.

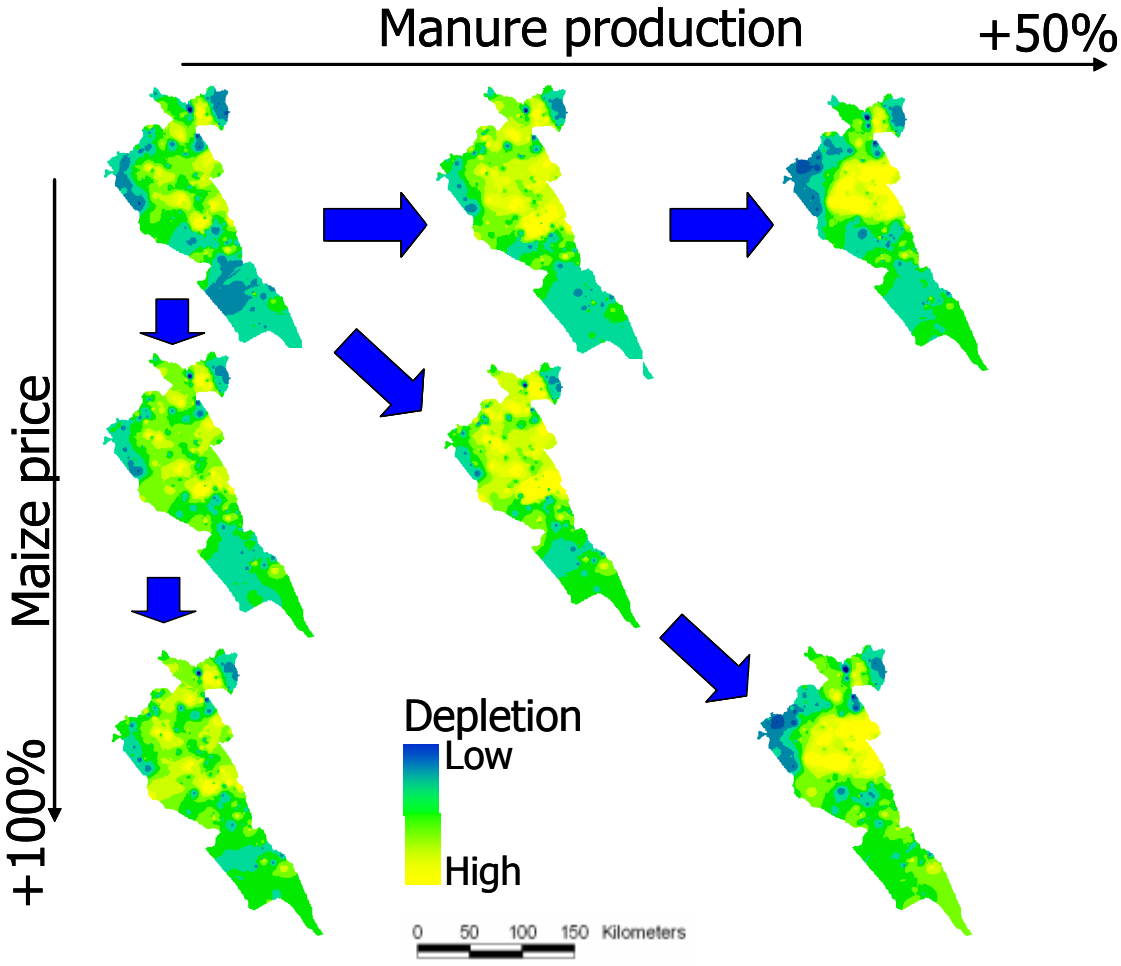

Figure 3Pathways for soil nutrient depletion under different scenarios

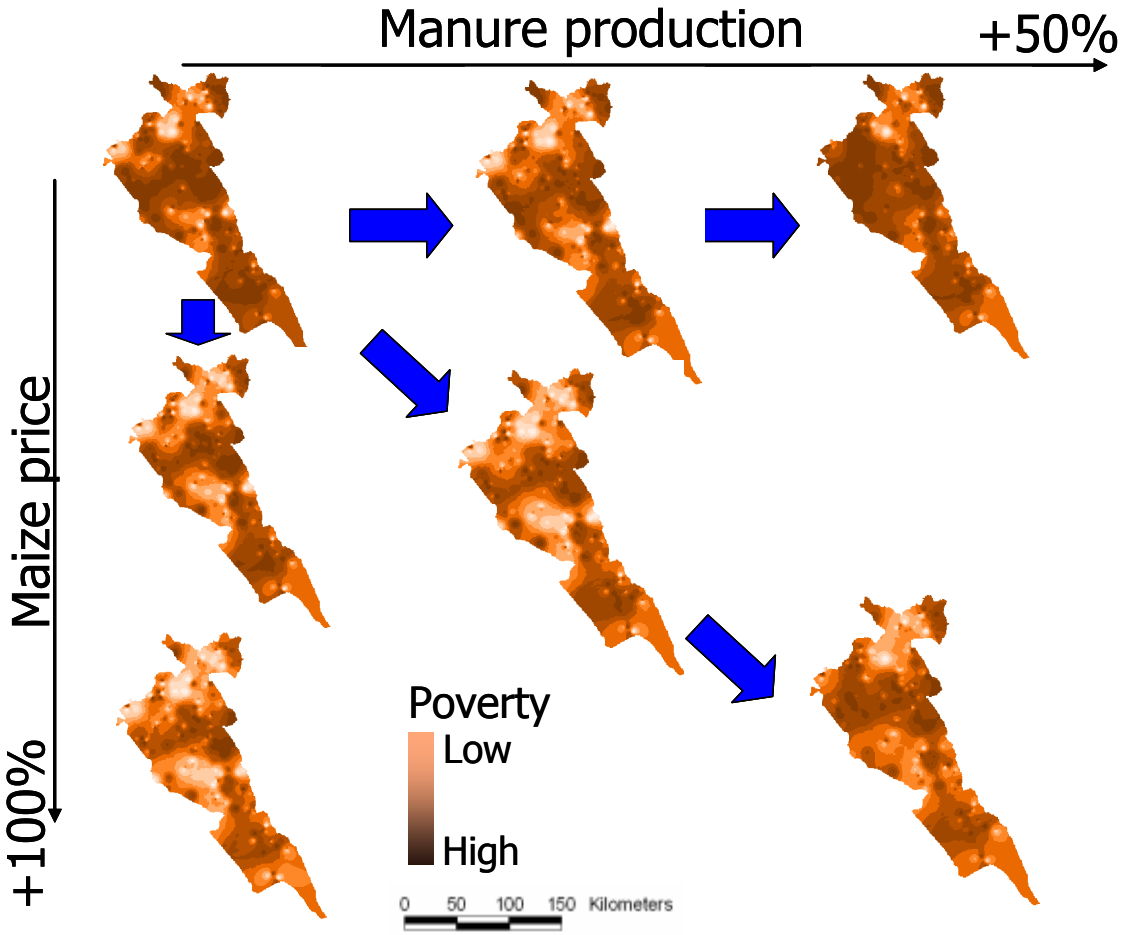

Figure 4 Pathways for poverty under different scenarios

The Machakos model has been finalized. The application in Machakos was crucial for a number of objectives. From a methodological point of view the TOA model had to be tested under smallholder mixed farming systems. These systems are much more complicated than the conditions where the TOA model has been applied earlier. For example, to tackle the issues of zero grazing on the farms, the farm level had to be introduced in the TOA model. Also from a methodological point of view the linkage with the NUTMON system has been established. Because a large number of NUTMON studies have been carried out in the past (and are currently being carried out), the linkage with NUTMON provides a possibility to lift the NUTMON tool from the level of a diagnosis of soil fertility problems towards a tool with which interventions can be evaluated. A standardized procedure to take NUTMON data and use them within the TOA framework was developed and documented. The activity was slightly delayed to the release of the new version 3.0 of NUTMON. Joost Vlaming of Envista Consultancy and programmer of NUTMON provided excellent and efficient support to make the transition into the new NUTMON version as smooth as possible. Probably the most important role of the Machakos model is to illustrate potential users of TOA its value in an East African setting.

The results of all the activities in Machakos will be published in a book that will be available at the end of the project. The book includes a number of journal articles that have been published or submitted to international journals.

5.2. Training materials

A large number of research projects have made use or are using the Nutmon toolbox for monitoring tropical farming systems. Although Nutmon provides detailed insight in these systems, it does not allow for a more regional intervention focused analysis. At the moment, we observe a general trend that Nutmon studies are followed up by on-farm participatory research (e.g. through farmer field schools). The Nutmon-tradeoff interface allows for a new way of analyzing the Nutmon data at the regional level. This has been illustrated for Machakos. Training materials for the Nutmon toolbox do exist and Envista and the Agricultural Economics Research Institute (LEI-DLO). In the context of this project training materials for the TOA model have been developed. The training materials include a 1-week course and are provided at the TOA website (The program of the workshop is presented in Annex 3). The materials are based on the materials and experiences from the Senegal workshop. They formed the basis for the successful training workshop in Nairobi in October, 2004. Teams from different projects were present at the workshop that provided training in the concepts of the Tradeoff Analysis Methodology and hands-on training in the use of the TOA software. To provide sufficient in-depth training the group was split in the workshop in two sessions dealing with the economic simulation model and the biophysical simulation models. All training materials from the Senegal and Kenya workshops are posted on the TOA website (www.tradeoffs.nl). The TOA website is also constantly updated with new information on the methodology, applications and courses. It also includes on-line training to get acquainted with the models.

Data requirements and model complexity are the two major constraints of regional land use modeling and thus the TOA model. We are constantly searching for new methodologies for effective data collection. Examples are the use of existing datasets (NUTMON), new data acquisition methodologies (digital soil mapping), and tools for data mining (climate interpolation methods). The Machakos case study is a good case study where these techniques are being applied. This has to receive ample attention in training materials and will be transferred with the TOA methodology. In addition we are striving for the simplification of the models. A minimum data set approach has been developed for the economic simulation models by John Antle and Roberto Valdivia. This approach does not need the farm survey data and provides similar tradeoff curves. However, the analysis does not allow for the site specific analysis currently available for Machakos. The minimum data set approach has been tested in the CIP led ecoregional fund project in Panama.

5.3 Applications

Three different projects have been identified that are interested in the application of the TOA methodology:

- A proposal of KARI and ICRAF to the Global Environmental Facility was approved for a large scale project in the lake Victoria basin to study land degradation and carbon sequestration.
- Egerton University will be the basis for an inter-CRSP program including the pond dynamics, livestock and soil management CRSP. The TOA methodology is proposed as a tool for an integrative assessment in the study area that should focus and integrate the various disciplinary studies.
- A large Nutmon-based project is being performed by various institutions (LEI-DLO among others) in Uganda. The focus is currently on farmer field schools but significant interest does exist to carry out a more policy oriented analysis.

During the various trips of the project team to Kenya, researchers from these projects have been contacted and discussions have been held in terms of the organization of the collaborations. For the TOA team the process of institutionalization includes the following steps:

- Informing project staff
- Training of project through training workshop
- Formalization of the process to incorporate TOA
- Execution of TOA by project staff with backstopping of TOA-team.
- Second workshop to bring the different projects together and jointly share experiences and solve problems

Training materials have been developed using the Machakos case study. We will briefly report on the three projects:

KARI/ICRAF GEF proposal

After a presentation at ICRAF, the project showed interest in using the TOA methodology. The project include detailed measurements on land degradation and carbon sequestration. Although its objectives included integrated assessment of these issues less attention was made in the research methodology. The TOA model seemed to be an excellent fit. The large surveys would provide the required data for an application and KARI and ICRAF staff was highly trained making both data requirements and model complexity less of an issue. The project was due to start in the summer of 2004. However, due to a variety of reasons the project was postponed. The currently the project is due to start in the summer of 2005. Nevertheless, Wachira Kaguongo started to collect the data for an initial TOA application using data from an earlier NUTMON project in Western Kenya and the Ecoregional Fund PROSAM project. This would give the project a head start as soon as the GEF funding finally comes through.

Egerton CRSP program

Egerton University has relationships with two different CRSP programs: the global livestock CRSP and the Pond CRSP. After initial discussions all projects agreed that it would be highly desirable to join the projects and start an inter-CRSP activity. The TOA framework would be a suitable tool to link the pond and livestock oriented activities at Egerton in a more integrated analysis. The TOA program would provide training and backstopping. Egerton has been trained and started data collection. Data collection took longer than expected and Egerton staff participating in the project was

replaced. Project leadership informed the TOA project that they are planning to start the TOA analysis this summer.

Makerere University
Probably the most intensive contacts have taken place with Makerere University. The study builds on a NUTMON application and probably is a closer fit than the other two programs. On the other hand, the agricultural systems in the Palissa region are very different than the systems in the Machakos study area. This required a significant change in the economic simulation model. Nevertheless, after intensive backstopping and interaction a first setup of the TOA model for Palissa has been established. Staff from Makerere has been extremely active and invested significant resources to develop the TOA application. In addition they are interested to include the TOA framework in the curriculum of the university.

A final application of the TOA model that has not been envisaged in the original TOA proposal was the application of the TOA model in the Ecoregional Program in Panama coordinated by CIP. Details of this application are given in the final report of that project. A different approach has been followed in the Panama project. In other applications an initial TOA application serves for illustrative purposes. Only then we can develop a training workshop and get the interest from various projects. In the Panama case, very little time was available. In addition the questions had a very general character. We therefore decided to apply a simple version of the economic simulation model (originally developed for a US application) that runs on the basis of census data. This resulted to be a successful strategy. Roberto Valdivia organized a training workshop in Panama and they were able to set up and understand the model relatively quickly.

5.4 A summary of outputs

The Tradeoff Analysis Model
- A new NUTMON-TOA linkage has been developed.
- The economic simulation model has been updated to deal with farms as units of analysis (in contrast to the field level in earlier applications).
- To accommodate the farm level a new module has been added to the TOA software that merges parcel and farm level results.

Training materials
Training materials have been developed and applied. All materials have been published on the TOA website.

Publications
- Antle J., J. Stoorvogel, W. Bowen, C. Crissman, and D. Yanggen. 2003. The Tradeoff Analysis Approach: Lessons from Ecuador and Peru. Quarterly Journal of International Agriculture 42(2):189–206.

- Ellenkamp, G.R., 2004. Soil variability and landscape in the Machakos district, Kenya. A detailed soil survey as part of the study on the influence of soil variability on tradeoffs between agricultural productivity and soil fertility. MSc Thesis, Wageningen University
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In addition drafts of papers have been Developer that describe the TOA-Nutmon linkage, methodological advances made in the Machakos case study, and the scenario analysis of Machakos. These publications will be compiled in a publication on the Machakos case study.

Trained project staff

Staff from various projects in Kenya, Uganda and Panama has been trained in the use of the Tradeoff Analysis Model.

6. Dissemination, use of outputs, and impacts

As mentioned in the previous Chapters, the TOA model has been disseminated to various projects in Kenya, Uganda, and Panama. The various projects apply or aim to apply the TOA framework to carry out an integrated assessment. In that sense the project has been successful. However, it is very difficult to evaluate at this point in time whether or not the model will be applied and that the various projects will actually have impact. The effective project duration of a year and three months has been to short. However, due to joint management with the SM-CRSP activities can continue into the future. Increasingly the project team realizes that sustainable dissemination is not just the dissemination to research projects but also to institutions. A good example is the continuing collaboration with the International Potato Center (CIP). CIP is interested in developing a TOA team. The intention has is part of a memorandum of understanding between CIP and the TOA program. CIP's TOA team has two tasks. Firstly it should develop research proposals to strengthen CIP's Natural Resource Management Division. Secondly, CIP has to deal with a number of questions to structure its own research program. In the case of Makerere University the original transfer took place towards a specific project but now a broader embedment within the university.
Another development has been the introduction of the Nutmon team into the potential of the TOA model. This may result into the incorporation of TOA in future Nutmon programs.

7. Budget discussion

When this draft final report was written, the final financial statement was not made. Therefore we will only give an overview of the different budget costs:

Personnel Costs	**Budget**
Programming	5000
Postdoc	30000
PhD student	25000
KSS	5000
LEI-DLO	30000
Envista Consultancy	5000
Sub-total	100000
Project operational costs	
International travel	40000
Domestic travel	15000
Soil analysis	7500
Aerial photos	750
Field supplies	7500
Equipment	12500
Training workshop (50%)	7000
Final workshop	15000
Data collection	5000
Publications	11000
Sub-total	121250
Total	**221250**
Sub-total direct costs	221250
Other costs	
Indirect costs (@10%)	22125
Total all costs	243375

8. Related R&D grants and activities

Most important related grant is the Soil Management CRSP TOA project as explained in the introduction. This has been the most important source of funding for the TOA program. Within the context of this particular Ecoregional TOA program, the Nutmon program is almost as important. Just like the TOA program, the Nutmon program has been funded through a range of research projects. Part of the participation of the Agricultural Economics Research Institute has been funded through these Nutmon programs. Another related grant was the Ecoregional fund project in Panama in which the TOA model has been applied.
In the TOA project three different case studies were identified in Kenya and Uganda. The projects in the case studies have their own sources of funding including for example the Global Environmental Facility, the European Union, and the Pond and Livestock CRSPs

9. Lessons learned

In this Chapter we discuss the lessons that were learned during the project according to the 5 main programs as they were defined in the overall project proposal "Consolidation and Application of Ecoregional Methods".

9.1. Consolidation

Program 1. *Consolidation of frameworks and methods for ecoregional research and development:*

- *A general framework for ecoregional research and development*
- *A tool box with a set of applicable tools for operationalizing the framework*

The project did not focus on a range of frameworks and methods but rather on a single methodology. The unique character of the TOA framework is that it allows for the integration of different tools. As such the advances that were made during the development of the framework are more related to the integration rather than the development of tools. In previous applications we have shown that the TOA model was able to work with models simulating agricultural decision making and a range of models ranging from crop growth simulation models, pesticide leaching models, soil erosion (both tillage and water) models to human health models (related to pesticide use). The strategy that has been followed to develop the linkages with all these models focused on the development of a standard for the communication of input and output datasets. An interface has been developed for each of the models that transfers the model specific data structures into the standard structures and vice versa. However, this type of linkage is only possible if the models do not interact dynamically. In the case study for Ecuador we explored the possibility for a more dynamic interaction between the economic models, the crop growth simulation models, and the tillage erosion models (Antle and Stoorvogel, 2005). This coupling of the simulation models with feed back loops will also be relevant in the Machakos case study where soil nutrient depletion affects the expected productivities in the future and as a result future management. A important step towards the toolbox was set by linking the Nutmon and TOA frameworks. The Nutmon framework so far principally dealt with monitoring farms in a standardized way and analyzing soil nutrient flows and the economic performance of the survey farms. Through the linkage with the TOA framework we are now capable to make the step from diagnosis towards intervention. On the other hand the survey instruments that were used in the TOA applications were developed on a case-by-case basis. The linkage with Nutmon now allows us to use a standardized but flexible framework for farm monitoring.

9.2. Testing and application of ecoregional methods in regional case studies

Program 2. *Testing and application of ecoregional methods in regional case studies:*

- *An account of the ways in which the NRM problems were identified, characterized and evaluated in each of the three cases*
- *Feedback to Programs 1 and 4 for improvement of the ecoregional frameworks and methods and the strategies for institutionalization*

Over the years, the TOA framework has been applied in a range of different case studies. Originally developed for Ecuador, we now have applications in the USA, Panama, Peru, Senegal, Kenya, and Uganda. Although the overall framework worked well in the different case studies, each case study required specific adaptations. In different case studies different sustainability indicators were given priority and, as a result, it was necessary to develop new model interfaces. In addition, the core economic simulation model had to be adapted for each application. A good example is the introduction of livestock in the Machakos case study that required the models to move from the field level up to the farm level. Only then we were able to deal with the zero-grazing unit. Finally, we observed that in some case studies more general results were required that were, for example, not site specific. An example comes from the other ecoregional fund project in Panama, where the TOA framework was applied without dynamic surveys but with more general census data.

The general framework (originally developed and published in Crissman *et al.* (1998)) that has been developed for the implementation of the TOA has been functional in most case studies. It includes steps that deal with stakeholder involvement, the identification of key indicators and disciplinary research. This will provide the necessary input to set up and parameterize the TOA model. The TOA model can be run interactively with stakeholders to analyze alternative scenarios for technological innovations and policy interventions. If necessary, this may require additional data collection or model development to run specific scenarios. Linking Nutmon and TOA was highly appropriate as the two frameworks were highly complimentary. E.g. in the Nutmon project in Machakos, stakeholder meetings were organized and set up in a way that was very similar to the ones in the TOA project. As a result we could directly start with the application of the TOA model.

9.3. Development of user-oriented, generic software for TOA Model

Program 3. *Development of user-oriented software for ecoregional analysis:*

- *An operational web-based software system that includes a complete range of methods and tools of varying complexity*

In an early phase of the TOA program user-oriented software has been developed (in many TOA publications referred to as the user shell). The software has been documented (Stoorvogel, 2001) and an interactive training module has been

developed on the TOA website. On the website, it is possible to walk through the different elements of the model and receive specific training. The user shell is computer software that allows for the linkage of an array of different models and tools. In principal the models that are applied in a case study are not predefined and users can select the most appropriate tools on the basis of selected indicators and on the level of detail that is required in the outputs. In the Ecuador case, pesticide leaching originally was simulated with a complex mechanistic simulation model. In a second phase we started to realize that only few model parameters were actually variable in the study area and as a result we started to apply a relatively simple model obtaining similar results and performing well in the study area (Stoorvogel *et al*, 2003). Similarly, a relatively simple version of the economic model has been applied in the recent ecoregional project in Panama. The model provided the first answers that were required and was much easier to transfer to local institutions.

9.4. Strategies for institutionalizing the TOA Model

Program 4. *Strategies for institutionalizing ecoregional analysis:*

- *Reports on the reviews of experiences with the institutional use of ecoregional methods and related types of decision-support tools*
- *A set of guidelines for those working in ecoregional methods, to ensure the use of the methods developed.*

It has not been easy to transfer the TOA methodology to local institutions in Peru and Ecuador. The combination of the complexity of the model and the level of training and experiences with quantitative modeling certainly constraint the transfer of the tools. In Kenya and Senegal, the modus operandus was very different compared to the earlier projects in Ecuador and Peru. In Ecuador, the model was actually developed during the application. In many instances it was even for the TOA team itself to envisage the final product. In addition, it is a long process to develop the tool and it is difficult to keep the local institutions interested. In many cases they have clear questions and they would like answers within a reasonable time frame. In Kenya and Senegal the strategy was very different as explained in Section 3.2. An initial application that could be developed with limited additional data collection, a training workshop, and finally backstopping of the different projects. Although the transfer went better than in the earlier cases we are still facing numerous constraints: in part dealing with the complexity of the tool but certainly also the complexity of dealing with research organizations that depend to a large extent on external funding. One can question whether one is transferring the methodology to a project rather than to an institution? If so, how sustainable is the process of institutionalization? Secondly, as we have seen in the case of the KARI-ICRAF project (and actually also in the approval of the second phase of the ecoregional fund), funds are expected to arrive, but due to numerous reasons the project starts later than originally expected.

In the case of Panama the process went very different. Due to serious time constraints but also to a very different kind of questions being asked the project, the project started to develop a much more simple application. The transfer took place in a single workshop after which the project team was able to continue working.

Of course the long term success of institutionalization can only be seen after several years. Universities, national agricultural research centers and CG-Centers are likely to be the first to adopt the TOA methodology. In the Uganda case Makerere University has expressed its desire to incorporate the methodology into the curriculum of the University. Also the University of California in Davis has shown interest and a joint course is scheduled to take place in the beginning of 2006 Again, with the hope to include the TOA methodology in the curriculum of the University. ISRA (Senegal), KARI (Kenya), and IDIAP (Panama) are good examples were staff members have been trained at national agricultural research centers and the TOA methodology may be picked up. Finally, a long standing cooperation with CIP and the starting collaborations with some other CG centers like ICRAF show us that these centers are interested in the usage of the TOA methodology. For their highly trained staff the complexity of the tool is less of a problem. The commitment to set up a TOA team under their in many cases overcommitted staff has proven to be problematic.

9.5. Communication of research results.

***Program 5**. Communication of results of activities supported by the Ecoregional Fund*

- *A set of printed publications on activities supported by the Fund*
- *Training materials*
- *A Web site*
- *Public awareness materials*

The TOA team increasingly became aware of the importance of the various ways of communication. The traditional forum for scientific research, *i.e.*, the peer-reviewed scientific journals has not proven to be a highly effective medium to communicate a tool like TOA. It nevertheless still is an import way of communication. The TOA team has published in the peer-reviewed journals but in addition has paid attention to other forms of communication.

In 2001, the TOA user manual was published to give a more extensive description of the TOA model (Stoorvogel *et al.*, 2001). In 2003, work in Ecuador dealing with the analysis of pesticides impacts was published in a form that was better accessible to the general public (Yanggen *et al.*, 2003). In 2005 (just after the final workshop of the ecoregional fund, the studies for the Machakos study area will be published (Stoorvogel *et al.*, 2005). This type of publication has proven to be extremely useful. Local institutions often do not have access to the international journals and in this way the materials can be distributed in an effective manner.

The two TOA websites dealing with the projects (www.tradeoffs.montana.edu) and the TOA model (www.tradeoffs.nl) have proven to be effective. It is relatively easy to make reference to a website and everybody has access to the data and materials. The websites also played an important role in collecting and storing all the information of the project.

10. Follow up

The Tradeoff Analysis program has been an on-going activity since the early 1990's. Different donors have funded particular elements of the research that has been carried out. With the contribution of the Ecoregional Fund, we made a major step forward to develop the tool into an operational tool. The three different case studies provided new insights in how to deal with the institutionalization and transfer of the TOA methodology. However, due to the late start of the current phase of the ecoregional fund time has been short to actually carry out a proper evaluation of the case studies. However, as mentioned in the original proposal the project was jointly managed with the SM-CRSP TOA project. This project still has two project years ahead and as such we are looking here at work in progress. New opportunities are ahead of us.

First of all, we would like to continue to support the various projects that have been mentioned in this report (Egerton – KARI/ICRAF – Makerere). We made a commitment to these projects to provide required backstopping.

Marthijn Sonneveld has been hired as a post-doc to evaluate the different projects and draw conclusions for future TOA applications. Can we identify data needs and minimum model complexity on the basis of key questions being asked in an application? What are the various models that are being linked to the TOA user shell and when should they be used? Let us draw lessons from the various applications.

Still there are a number of methodological questions to be resolved. For example, can we establish a closer coupling between the economic and bio-physical models to analyze the feedbacks of soil degradation on agricultural management (to be presented in a summer school in August 2005). We keep working on more efficient ways for data collection (*e.g.* digital soil mapping).

Intensive discussions with CIP resulted in detailed plans to build the required capacity within CIP to apply the tradeoff analysis. In a memorandum of understanding between CIP and the TOA program CIP indicated its interest in the methodology both for application in various projects (*e.g.* The Africa Challenge Program) but also to answer a number of its own questions: Where and when to promote a specific (sweet) potato related technology?

Increasing attention will be given to include the TOA methodology in the curriculum of various universities (Makerere University, UC Davis, and Wageningen University).

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Annex 1: People involved in the Ecoregional Fund Program

Agricultural Economics Research Institute
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Envista Consultancy
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Wageningen University
- Dr Lieven Claessens
- Dr Jetse Stoorvogel
- Alejandra Mora Vallejo MSc

World Agroforestry Center
- Dr Lou Verchot

Annex 2: Abstract Pedometrics conference

Abstract for the Biannual Meeting of Commission 1.5 Pedometrics, Division 1 of the International Union of Soil Science (IUSS), September 12-14, 2005; Naples, Florida, USA. The abstract has been accepted for an oral presentation. Full paper will be published in a special issue of Geoderma.

Digital Soil Mapping for a Tradeoff Analysis Application in Kenya

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Detailed information on land characteristics is an essential input for land use analysis and sustainable land use planning. Since traditional soil mapping is costly and time-consuming, large areas have soil information of poor quality and low resolution. This is especially true in developing countries where lack of infrastructure and expertise are common constraints. In this respect, the use of Digital Soil Mapping (DSM) techniques (McBratney et al., 2003) appears to be an interesting alternative to capture soil spatial variability in a rapid and cost-effective manner by combining observation data, auxiliary information and expert knowledge.

DSM was applied in the Machakos District (Kenya) as an input for the Tradeoff Analysis Model (TOA) (Stoorvogel et al., 2003). TOA is currently being applied for the integrated assessment of mixed farming systems and analysis of their impacts on the environment, particularly regarding soil fertility decline. Since TOA is a spatially explicit land use model, data on the spatial variation in land characteristics is required. However, the Machakos study area is 20,000 km2 in size and soil data available are limited. Initially, soil inputs for the TOA model were derived from the 1:1,000,000 Exploratory Soil Map of Kenya (Sombroek et al., 1980) in combination with the Fertilizer Use Recommendation Program (MoA, 1987). This soil map describes the whole area based on only seven representative soil profiles. Of course this is an extreme simplification of actual soil variation. Therefore, it was necessary to produce a more detailed and accurate soil map using a more quantitative approach.

Soil spatial prediction was based on the concepts of the soil forming factors equation (Jenny, 1941) and soil-landscape relationships, combined with geo-statistical methods. Jenny's equation states that soil formation is a function of climate, organisms, relief, parent material and time. Capturing the spatial variation of these factors can provide a better understanding of soil variability. Through various analyses we got insight in the variation in parent material, land cover, topography and climate. An earlier analysis on the basis of the SOTER methodology (Engelen and Wen, 1995) yielded a combined geology and landform map on the basis of topographic maps (scale 1:50,000 or 1:100,000). Land cover was derived from satellite imagery on the Africover map. It was used to mask non agricultural areas and to further subdivide the agricultural area into intensive agriculture in the hilly terraced areas near Machakos and extensive agriculture and pastoralism in the lower dry areas from Makueni to the south. In terms of relief, the 90 m resolution DEM was analyzed with the LAPSUS model (Schoorl, 2002) in order to disaggregate soil units according to soil dynamics (erosion, deposition, stability) by means of a mechanistic approach. Finally, only two weather stations are present in the area. Weather data (temperature, precipitation and solar radiation) were interpolated with a mechanistic model for climate interpolation (Baigorria Paz, 2005).

Field work yielded 170 additional soil observations for the DSM exercise. The sampling sites were fairly regularly spread out over the area, while ensuring that each main geologic unit was sampled at least once. Soil observations and chemical analyses were correlated with the factors of soil formation. These correlations were used in a regression-kriging framework (Hengl et al., 2004) to predict soil properties such as soil organic matter and texture. These properties are required as inputs by the crop simulation models incorporated in TOA. The prediction accuracy was evaluated by cross-validation. The results show that the digital soil map is more accurate than the map derived from the 1:1,000,000 soil map.

Finally, the performance of the TOA model was tested for both the coarse initial soil map and the map derived using DSM techniques. The Tradeoff Analysis methodology allows for the ex-ante evaluation of agricultural policies and alternative management strategies through an integrated analysis of tradeoffs between economic and environmental indicators (Stoorvogel et al., 2001; Stoorvogel et al., 2003). TOA combines spatially explicit econometric production models with spatially explicit mechanistic biophysical models, and provides quantitative insight into the complex nature of agricultural systems and is thus beneficial to decision making by farmers and agricultural managers (Stoorvogel et al., 2003). Results show that the quality of the soil map is clearly reflected in the quality of the TOA outcomes and that high resolution data can be obtained for this specific land use analysis.

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Annex 3: Program TOA training workshop

Tradeoff Analysis Program / Kenya Agricultural Research Institute

East Africa Tradeoff Analysis Workshop
ILRI, Nairobi, Kenya
September 6-10, 2004

PROGRAM

Day 1: Monday, September 6, 2004

Tradeoff overview

8:30-9:30	Opening session
9:30-10:00	Introduction of participants, workshop goals
10:00-10:30	Coffee
10:30-11:15	TOA conceptual framework
11:15-12:15	Illustrative results from other case studies
12:30-13:30	Lunch
13:30-15:00	Machakos tradeoffs - scenarios (breakout groups)
15:00-15:30	Coffee
15:30-16:00	Reports from breakout groups
16:00-17:00	Machakos scenarios and results

Details can be found in the on-line course Section 1

Day 2: Tuesday, September 7, 2004

The Tradeoff Analysis software

8:30-9:30	The conceptual framework of agricultural systems
9:30-10:00	Breakout groups
10:00-10:30	Coffee
10:30-11:15	Reports from breakout groups
11:15-12:15	Demonstration of the tradeoff analysis software
12:30-13:30	Lunch
13:30-17:00	On-line introductory course

Details can be found in the on-line course Section 2-8

Day 3: Wednesday, September 8, 2004

Disciplinary data and models

8:30-17:00 Two disciplinary groups are set up and hold separate sessions on items below:

Biophysical group

- GIS tools for data analysis
- DSSAT crop model
- Nutmon toolbox
- Analysis of spatial variance

Economics group

- Designing and Implementing econometric-process simulation models
- Using the econometric-process simulation models with the TOA software

Details can be found in the on-line course Section 9

Day 4: Thursday, September 9, 2004

Disciplinary data and models – Continued

8:30-12:30 Disciplinary group meetings continue

Applying the TOA approach and models for Machakos

14:00-14:15 Introduction to the scenarios
14:15-16:00 Running Machakos scenarios (individuals and/or groups)
16:00-17:00 General discussion

Details can be found in the on-line course Section 10

Day 5: Friday, September, 2004

Design Of Applications

8:30-12:30 Breakout groups for application development
12:30-13:30 Lunch
14:30-15:00 Group reports on applications
15:00-16:00 Workshop evaluation and closing ceremony

Details can be found in the on-line course Section 11-12

Executive summary

The Tradeoff Analysis Methodology is one of the ecoregional methodologies developed with support of the ecoregional methodology fund. It includes as part of its research process the Tradeoff Analysis Model©. The current project aims to consolidate this tool including:

- the demonstration of its applicability,
- the development of training material,
- strategies for the transfer of the methodology to research projects,
- the institutionalization of the tool, and
- a clear identification of the role of the Tradeoff Analysis Methodology in the broad field of land use analysis.

The research project is structured into three work packages dealing with i) the application of the tradeoff analysis model, ii) training material and technology transfer, and iii) communication of results.

The project is jointly executed with “the tradeoff analysis project phase 2: scaling up and technology transfer to address poverty, food security and sustainability of the agro-environment” funded by the Soil Management Collaborative Research Support Program of USAID.

WAGENINGEN UNIVERSITY

MONTANA STATE UNIVERSITY
Mountains and Minds