A Client-Oriented Systems Tool Box
for
Technology Transfer Related to Soil Fertility Improvement
and
Sustainable Agriculture in West Africa

(COSTBOX)

September 1999 - December 2002

FINAL REPORT

May 2003

An International Center for Soil Fertility and Agricultural Development (IFDC) – Africa Division
BP 4483
Lomé
Togo

CONTENTS

LIST OF ACRONYMS

ABU/IAR	:	Ahmadu Bello University / Institute of Agricultural Research, Zaria, Nigeria
CARDER	:	Provincial authority for agricultural development in the Zou (Bénin)
CENAP	:	Soil science institute of Benin
CNDC	:	Combating Nutrient Depletion Consortium
CIAT	:	International center for Tropical Agriculture
CIRAD	:	Centre de Coopération Internationale en recherche Agronomique pour le Développement : an international center for agronomic research and development, Montpellier France.
CREMA	:	NGO in Southern Togo
DARS	:	Dispositif d'Appui à la Recherche-Système (a department within ITRA to link research and extension on farming systems)
DSSAT	:	Decision Support System for Agrotechnology Transfer: a set of crop growth simulation models
DST	:	Decision Support Tool
EPHTA	:	Ecoregional Program for the Humid and sub-Humid Tropics of sub-Saharan Africa.
ESA	:	Ecole Supérieure d'Agronomie (Agricultural College, Lomé, Togo)
FCFA	:	Monetary unit in most French speaking countries of West-Africa (1€ = 655 FCFA)
GIS	:	Geographic Information System
ICAT	:	Institut de Conseil et d'Appui Technique (the national extension organization of Togo)
ICRISAT	:	International Crops Research Institute for the Semi-Arid Tropics
IDSS	:	Information and Decision Support System (software that links DSSAT and GIS)
IFDC	:	An International Center for Soil Fertility and Agricultural Development
IFS	:	International Foundation for Science
IITA	:	International Institute for Tropical Agriculture
INRAB	:	Institut National de Recherche Agronomique du Bénin (national agricultural research institute of Benin)
INRM	:	Integrated Natural Resource Management
ITRA	:	Institut Togolais de Recherche Agronomique (national agricultural research institute of Togo)
IWMI	:	International Water Management Institute
NARES	:	National Agricultural Research and Extension Services
NCSU	:	North Carolina State University
NGO	:	Non-Governmental Organizations
QUEFTS	:	Quantitative Evaluation of Fertility of Tropical Soils
SG-2000	:	Sasakawa Global 2000
SM-CRSP	:	Soil Management Collaborative Research Support Program: a collaborative program between universities in USA
SWNM	:	Soil, Water and Nutrient Management Program
TSBF	:	The Tropical Soil Biology and Fertility Institute of CIAT
UGFA	:	University of Ghana, Faculty of Agriculture
UIFA	:	University of Ibadan, Faculty of Agriculture
WARDA	:	West Africa Rice Development Association

EXECUTIVE SUMMARY

Despite considerable efforts to introduce the use of decision support tools to improve soil fertility management and crop production in sub-Saharan Africa, such tools are still not widely used. In 1999, the COSTBOX project was started to develop methodologies for effective introduction of decision support tools to African NARES, NGOs, and universities.

The first major activity of the project was to conduct a survey on the causes of non-adoption of systems analysis as a tool in agricultural decision-making. Results pointed to causes such as lack of involvement of clients in projects that attempt to introduce systems analysis, the fact that in many modeling projects the problem is defined in such a way that it fits the model instead of the other way round, the complexity of some models, the lack of good quality data and a lack of basic knowledge of systems analysis.

To deal with these issues, the project entered into close collaboration with research institutes and universities in Togo, Benin, Nigeria and Ghana. Within the framework of these collaborations, workshops were organized for researchers to get acquainted with a variety of models, and basic courses on systems analysis and modeling were provided to students and staff at the universities. To limit the complexity of the models, only models were used that address the field level. Geo-referenced databases on soil and weather variability were developed to improve access to data.
In-depth training was provided to a limited number of scientists with the view to create small groups within the research institutes that could help their colleagues in the application of decision support tools (DSTs).

In close collaboration with partners, DSTs were used to address current research topics in a number of case studies, which showed the possibility to use these DSTs to arrive at practical site-specific recommendations regarding fertilizer application and choice of variety and sowing-dates. A guide has been produced to promote the use of DSTs. The guide contains nine case studies and an overview of available tools and where to obtain them.

The project showed that there is considerable interest in DSTs at research institutes and universities. Its use allows better targeting of scarce resources from farm to national level. However, more time is required to integrate its use in universities and research institutes, while also the quality of data needs to be improved to be able to obtain meaningful output of the decision support tools. It is recommended to establish a regional service for West Africa providing training to students in the field of systems analysis and modeling and training and support to researchers of agricultural institutes in the region. Such a service could be part of an international institute or a university based in the region.

1. INTRODUCTION

Agricultural productivity gains in many parts of West Africa fall short of the requirements to feed the burgeoning population despite a long history of agricultural research in the region (Crosson and Anderson, 1994[1]).

Factors that have contributed to stagnation in agricultural development are the unfavorable socio-economic and policy environments, like poor access to input and output markets, the overexploitation of natural resources and the limited transfer and adoption of agricultural technologies by smallholder farmers. The latter is partly related to the inappropriateness of the technologies disseminated by the extension services. For instance, in spite of important variations in soil fertility - not only between regions but also within villages - fertilizer recommendations often do not take these variations into account, even resulting in blanket recommendations for a country as a whole. Adapting agricultural technology to the specific conditions of the farmer requires a farmer participatory approach in research and extension. However, costs of developing appropriate technologies for every situation are prohibitive and more efficient ways should be used to achieve this. Moreover the traditional method of technology development is time-consuming and can sample only a fraction of the management alternatives available to farmers.

The use of modern decision support tools (DSTs) in research and extension offers possibilities to address a much larger variety of situations. Such decision support tools often include computer based devices that provide access to (geo-referenced) data bases or that allow a quick evaluation of a number of technological options (fertilizer, sowing time) with reference to a particular situation. However, earlier attempts to introduce the use of such tools were not very successful due to the limited knowledge of such tools at the level of agricultural research and development institutes in sub-Saharan Africa. The use of such tools or its results is even less at the level of policy makers (Breman, 1995[2]).

2. OBJECTIVES

The overall objective of the project is to develop methodologies for effective introduction of, and active participation in, a systems approach by African NARES, NGOs, and universities and to introduce decision-making based on the use of systems analysis in the area of soil fertility improvement and sustainable crop production.

Methodologies to stimulate the use of decision support tools will be developed in the framework of ongoing soil fertility improvement research conducted under the Combating Nutrient Depletion Consortium (CNDC) in the Eco-regional Program for the Humid and sub-Humid Tropics of sub-Saharan Africa (EPHTA). The project aims to directly influence decision-making at the management level in NARES and NGOs

---

[1] Crosson, P. and Anderson, J. K. 1994. Achieving a sustainable agricultural system in sub-Saharan Africa: 1990-2025, World Bank Technical Paper, The World Bank, Washington, D.C.

[2] Breman, H. 1995. Modélisation et simulation dans l'élaboration de systèmes de production animale durables. Pages 473-492 In Powell, J.M., Fernandez-Rivera, S., Williams, T.O., Renard C. (Eds.) Livestock and sustainable nutrient cycling in mixed farming systems of sub-Saharan Africa. Vol II. International Livestock Center for Africa, Addis Ababa, Ethiopia.

and indirectly at policy-level. The NARES and NGOs play the crucial role of enhancing the knowledge base and decision-making by farmers and planners.

The specific objectives needed in the development of the methodologies to secure active involvement of African scientists in systems application are:
1. To develop methodologies integrating the use of systems and participatory approaches and results in a client-oriented decision support tool box for technology transfer.
2. To create confidence in the research and extension agencies and NGOs in the use of systems tools and their results through on-station and on-farm validation.
3. To develop short-term training and hands-on applications to strengthen the capacity of NARES, universities, and NGOs in using the decision support tool box, including natural resource and socioeconomic databases and simulation models.
4. To demonstrate the values of decision support tools to policymakers, and thus provide an impetus for long-ranging changes in agricultural development.

Based on these objectives the African NARES, NGO's and universities are considered the envisaged users of the tools to be introduced and are therefore the primary clients and partners of the project.

3. PROGRAM STRATEGIES

The Africa Division of IFDC, based in Lomé (Togo) was the convener of the program. Initially eight institutes were to collaborate in the program:
- IFDC Africa Division
- Department of Soil Science Institute for Agricultural Research Ahmadu Bello University, Zaria, Nigeria
- Institut National des Recherches Agricoles du Benin (INRAB), Cotonou, Benin
- Cocoa Research Institute of Ghana
- Institut Togolais de Recherche Agronomique (ITRA), Lomé, Togo
- Faculty of Agriculture, University of Science and Technology, Kumasi, Ghana
- International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria
- African Studies Program, University of Wisconsin-Madison, USA

IITA was involved as the host of the Ecoregional program for the Humid and sub-Humid Tropics of sub-Saharan Africa (EPHTA) and it was agreed to start working in one of their sites in Togo. Unfortunately the funding of EPHTA was not continued from 2000 onwards.

The African Studies Program of the University of Wisconsin-Madison, USA was originally included in the project to investigate the causes of non-adoption of decision support tools in Africa and to play an active role in the project. It appeared, however, that they wanted to limit their involvement to hiring an external consultant for the survey. It was therefore decided to ask prof. dr. Röling of the Department of Communication and Innovation Studies of the Wageningen University to advise regarding the set-up of the inquiry and to execute the survey by the project staff.
Collaboration with the Cocoa Research Institute and with the University of Science and Technology in Ghana did not work out due to a lack of interest from their side.

On the other hand, other institutes showed an interest in the program and decided to participate in certain parts of the program:

- Department of Soil Science, University of Ghana, Legon (Accra)
- Institut de Conseil et d'Appui Technique (ICAT) (the national extension organisation of Togo)
- Ecole Supérieur d'Agronomie, Université de Lomé, Togo
- Faculté d'Agronomie, Université Nationale du Bénin, Cotonou, Benin
- Service National de la Météorologie, Lomé, Togo

The program had also a close interaction with the Combating Nutrient Depletion Consortium, which was funded through the Soil, Water and Nutrient Management (SWNM) program of the CGIAR.
In addition there were joint activities with the Soil Management CRSP (Universities of North Carolina, Hawaii and Texas A&M) and with the International Foundation of Science, Sweden.

First a survey was carried out into the causes of non-adoption of decision support tools in countries of West-, East and Southern Africa.
The results pointed to causes such as:

- A lack of involvement of the clients in projects that attempt to introduce systems analysis
- In many modeling projects the problem is defined in such a way that it fits the model instead of the other way round
- The complexity of some models
- The lack of good quality data
- A lack of basic knowledge of systems analysis, which calls for the inclusion of systems analysis in higher agricultural education

Based on these results it was hypothesized that a methodology to introduce the use of DSTs should include the following elements:

1. A participatory approach towards clients
2. Tools that permit addressing the issues that the clients are dealing with
3. Tools that are user-friendly and have limited data requirements
4. Training
5. Accessibility and quality of data

To test these hypotheses the project adopted the following strategy:

1. Using a participatory approach by closely involving partner organizations. Partner organizations are encouraged to identify topics in on-going research programs that may benefit from the use of decision support tools, and to subsequently apply these tools.
2. Including different tools in the program to be able to address a variety of issues. Mainly tools that address the field level are used in order to limit complexity and data requirement
3. Increasing the ability of the clients to use these tools,
   - Organizing workshops to acquaint scientists and decision-makers with a variety of decision support tools

- Establishing a core group per research institute that promotes the use of decision support tools and provides support to their colleagues in the use of DSTs. This group receives further training.
- Collaborative execution of the case studies
- Providing basic courses on systems analysis and modeling at universities to promote incorporation of these subjects into the regular curricula
- Developing a guide for decision support tools, that briefly discuss a number of DSTs, their associated data needs and what issues they can address, and illustrate their use by providing a number of case studies.

4. Facilitating access to good quality data
   - Developing geo-referenced databases on soil and weather
   - Encouraging agricultural labs to improve upon the quality of their work

4. PROGRAM ACTIVITIES AND OUTPUTS

4.1 Survey

A survey was conducted into the causes of non-adoption of the use of decision-support tools. Prof. dr. Röling of the Department of Communication and Innovation Studies of the Wageningen University was invited to advise on the set-up of the inquiry (Röling, 1999, see reports). Hypotheses regarding the causes of non-adoption of systems-tools were developed through:

- Literature study
- A preliminary survey among Nigerian soil scientists, conducted by Prof. Chude of ABU
- Use of the AGMODELS-discussion group on Internet.

Persons and organizations were identified that have been or were still involved in activities where the development and use of DSTs played a role. They were visited and interviewed in a participatory way, using the hypotheses as a guide for the interviewer. The interviews were conducted in Mali, Burkina Faso and Niger by Dr. Struif Bontkes, in Nigeria by prof. Chude (ABU-IAR, Zaria) and in Kenya, Mali and Zimbabwe by Dr. U. Singh (IFDC). A report was written on the survey and presented at the 2001-INRM-conference in Cali, Colombia (Struif Bontkes, Singh and Chude, 2001, see reports). The results of the survey have been used to guide the activities of the program.

4.2 Testing decision support tools with a particular attention to soil fertility issues in small-holder agriculture

The first project year was used to try out a number of existing decision support tools in close collaboration with the Institut Togolais de Recherche Agronomique (ITRA) and the Institut de Conseil et d'Appui Technique (ICAT) at the EPHTA pilot site for Togo in Tsagba. The purpose of this activity was to obtain insight in the possibilities and the limitations of different tools when dealing with small-holder farming systems. This activity was **not** meant to improve such tools.

The main activities were:

1. Testing a number of tools (DSSAT (Ceres-Maize), QUEFTS, COTONS) on different crops (maize, groundnut, cowpea and cotton) in farmers' fields
2. Training of partners in the use of decision support tools
3. Drawing conclusions with the partners (ITRA and ICAT) regarding the possibilities to use DSTs.

Ceres-Maize is one of the simulation models that is integrated in the Decision Support Systems for Agrotechnology Transfer (DSSAT) that includes a large number of crops (Jones et al., 1986[3]; Hoogenboom et al., 1994[4]). The model calculates the daily development of the crop using data on soil, weather and varietal characteristics, resulting in the prediction of a yield. It was basically developed for well controlled temperate conditions, but its use has gradually been expanded to other areas as well (Singh et al., 1993[5], Jagtap et al., 1999[6]; Wafula, 1995[7]). It addresses a number of factors that influence crop growth but does not take into account P and K, i.e. in the model it is assumed that these nutrients are not limiting crop growth.
COTONS is a similar model meant for cotton (Jallas, 1999[8]).

QUEFTS stands for **QU**antitative **E**valuation of the **F**ertility of **T**ropical **S**oils. On the basis of a limited number of soil data QUEFTS estimates the yield of an unfertilized crop (maize) that can be obtained when there are no serious growth limitations other than soil fertility. In calculating the yield interactions between N, P and K are taken into account. QUEFTS also estimates the yield that can be expected after application of fertilizer N, P and K, and the expected financial return of the fertilizer application. Finally, it estimates the optimal way to divide a given budget between application of N, P and K fertilizer (Janssen et al., 1990[9]).

It appeared that there were sometimes important differences between observed yields and the yields, calculated by the DSTs. This was related to several factors, such as the quality of the soil data, the variability within the fields (especially soil depth),

---

[3] Jones, C.A. and J.R. Kiniry (Eds). 1986. *CERES Maize: A simulation model of maize growth and development.* Texas A & M University Press: 165p.

[4] Hoogenboom, G., P.W. Wilkens, and G.Y. Tsuji (1994). *DSSAT v3.* University of Hawaii, Honolulu, The United States of America, p.1 – 94.

[5] Singh, U., P.K. Thornton, A.R. Saka and J.B. Dent. 1993. Maize modeling in Malawi: a tool for soil fertility research and development. Pages 253 – 273. In: F.P. de Vries et al. (Eds). *Systems Approach for Agriculture Development.* Proceedings of the International Symposium on Systems Approach for Agriculture Development, 2 – 6 December 1991, Bangkok, Thailand.

[6] Jagtap, S.S., F.J. Abamu, and J.G. Kling. 1999. Long-term assessment of nitrogen and variety technologies on attainable maize yields in Nigeria using CERES-Maize. *Agricultural Systems* 60: 77 – 86.

[7] Wafula, B. M. 1995. Application of crop simulation in agriculture extension in Kenya. *Agricultural Systems* 49, 399 –412.

[8] Jallas, E., M. Cretenet, R. Sequeira, S. Turner, E. Gerardeaux, P. Martin, J. Jean and P. Clouvel. 1999. *COTONS, une nouvelle génération de simulation des cultures.* Agriculture et Développement 22, p. 35-46.

[9] Janssen, B.H., F.C.T. Guiking, D. Van der Eijk, E.M.A. Smaling, J. Wolf and H. Van Reuler (1990): A system for quantitative evaluation of the fertility of tropical soils (QUEFTS). Geoderma 46, p. 299 -318

the presence of trees in the field, but also because the models used were not developed for these conditions. For instance, the standard parameter set for QUEFTS was developed for maize in Kenya and Surinam, and resulted in serious underestimation of available P for West-African soils. Similarly COTONS has been developed in the USA and could not deal with the effects of drought.

4.3 Workshops on the use of decision support tools

Prior to the COSTBOX project a first workshop was organized in February 1999 by IITA, Ibadan, Nigeria to harmonize use of DSTs in the region. In July 2000, a 4-days workshop on the use of DSSAT and QUEFTS was organized for staff of ITRA and ICAT in Lomé. The purpose of this workshop was to acquaint participants with both DSTs and to identify opportunities in on-going research programs where these DSTs could be used.

The results of these activities were presented and discussed in a meeting of the Steering Committee including the Directors General of ITRA and ICAT and representatives of the University of Lomé. It was decided to continue the work and to establish a structure within ITRA that will promote the use of DSTs and provide support to other researchers.

Apart from the 4-days workshop on the use of decision support tools for the Togolese partners, similar workshops were organized in various places (see reports). The following workshops were organized:

- November 2000 in Niaouli (Bénin) for staff of INRAB, Faculty of Agronomy of the UNB and of the national agricultural extension service (15 participants).
- April 2001 in Zaria (Nigeria) for staff of ABU / IAR, the Agricultural College and IITA (28 participants).
- August 2002 in Accra (Ghana) for scientists from Ghana, Nigeria, Burkina Faso, Sierra Leone, Ivory Coast, Nigeria, Kenya, Uganda and Zimbabwe. The workshop was entirely sponsored by the International Foundation for Science (IFS)

As a follow-up on the workshops in Togo and Benin a second workshop was organized in February 2001 in Lomé to provide an in-depth training to two persons each of ITRA and INRAB. These persons were meant to become the DST experts on QUEFTS, DSSAT and COTONS within their organizations, stimulating and supporting their colleagues regarding the use of models. Dr.Gérardeaux of CIRAD took care of the training on COTONS.

This workshop was also used to see how DSTs could be used in the current research programs of both research institutes. This has led to a number of case studies that are presented further below. Two other workshops were organized:

- A one-day workshop was held in Accra in September 2001 to discuss the role of agricultural models in enhancing agricultural research and development. A total of 33 staff from the Ministry of Agriculture, Agricultural Research Institutes and Agricultural Faculties of the Universities in Ghana participated in the seminar. Papers were presented by representatives of IFDC, University of Ghana and the Savannah Agricultural Research Institute in Northern Ghana
- A four days workshop in March 2002 on nutrient management support systems, jointly organized by IFDC-Africa and the Soil Management Collaborative Research Support Program (SM-CRSP), led by the North Carolina State University, the Texas A&M University and the University of Hawaii. In total 30

scientists from USA, Togo, Ghana, Nigeria, Benin, Burkina Faso, Mali, Senegal, The Gambia, Zimbabwe and South Africa participated in the workshop.

The workshops proved to be very effective in creating awareness and enthusiasm among researchers, as is shown by the evaluations of these workshops (see reports). However, the formation of core groups per research institute proved less effective for various reasons. Members of these core groups had to continue their daily work and were not entirely liberated for this work. Our experiences with graduate-students showed that a full time involvement in the modeling as well as in the empirical work is needed to acquire the required skills. These skills do not only pertain to the ability to manipulate the software but also to the whole range ('traject') from identifying the issue in the field, the required tools and the data needs, collecting the data, making the necessary observations, critically evaluating the data and preparing the data for the tool, applying the tool, and critically evaluating and interpreting the results.

The collaboration with IFS has led to a project proposal that aims to install Local Area networks (LANs) and Internet connections at scientific research institutions and universities in sub-Saharan Africa. The role of IFDC in this project is to provide training in the use of modeling, statistics and biometrics.

4.4 University courses on simulation modeling

In order to address the problem of a basic lack of knowledge on systems analysis and modeling, basic courses of 4 days on systems analysis and simulation modeling were organized for students and staff of universities. These courses were also used to create awareness at the universities about the possibilities of systems analysis and modeling and to stimulate the authorities to include these subjects into the regular curricula.

- Faculty of Agriculture at the National University of Benin (February, 2001 and January, 2002)
- Ecole Supérieure d'Agronomie, University of Lomé (March, 2001)
- University of Ibadan, Nigeria (January, 2002)
- ABU, Zaria, February, 2002
- Faculty of Agriculture, University of Ghana, April 2002

The basic courses at the universities were very well received, as shown by the evaluations (see reports). However, lack of skilled staff and lack of computers constitute an important bottleneck for the integration of this subject into the regular curriculum. Several serious attempts have been made and are still being made by university staff members to include systems analysis and modeling in the regular curriculum and obtain funds for it (Universities of Ghana, Bénin and Lomé).

This has led to a proposal from the National University of Bénin to start a collaboration with the Wageningen University with a view to set up a course in systems analysis and simulation modeling.

4.5 Case studies

As stated before, participants at the workshops were encouraged to identify current research themes of their institutes that could benefit from the use of one or more DSTs. COSTBOX would then be ready to support such efforts. In some cases it appeared difficult to come up with a concrete proposal. The University of Ghana and INRAB Benin developed proposals entirely on their own, but ITRA required some help in identifying suitable research themes. A proposal from ABU, Zaria arrived too late and could not be honored. Below the case studies are briefly presented and discussed.

QUEFTS

Soil fertility varies between agro-ecological regions but may also vary within these regions; even at village and farm level, important differences may be found. However, very often fertilizer recommendations don't take that variability into account and are often formulated at the national level. Applying doses of fertilizer that are not well adapted to local conditions may lead to nutrient losses and even to economic losses. QUEFTS is a decision support tool that helps determining N, P and K ratio's that are optimal for a particular combination of soil, crop and prices. However, it should be noted that QUEFTS does not take into account factors such as crop variety, climate, water supply and the effects of pests, diseases and weeds.

Three case studies have been carried out in which QUEFTS played a role:

1. Testing fertilizer recommendations for cotton in Northern and mid-Togo (ITRA)
2. A participatory approach for fertilizer recommendations in Southern Togo (ITRA)
3. Fertilizer recommendations for maize on very degraded soils in Benin (INRAB)

In addition Dr. B. Janssen of the Wageningen Agricultural University and the main author of QUEFTS, was requested to adapt the QUEFTS model to a variety of agro-ecological conditions and crops in West Africa, and to the integrated use of organic soil amendments and mineral fertilizers (see reports).
These case studies are briefly described below and conclusions drawn.

'A first version of QUEFTS for cotton'

Though the standard fertilizer recommendation for cotton includes topdressing of urea, many farmers prefer applying all fertilizer at once, as this saves labor. ITRA has therefore decided to change the composition of the fertilizer supplied to the farmers in such a way that it includes all nutrients required by the cotton crop ('engrais unique'). However, farmers now complain that the 'engrais unique' reduces yields. One of the possible causes is that an early application of the fertilizer increases leaching losses, as the total quantity of nitrogen was not changed. It was therefore decided to conduct an experiment in which the total quantity of N is increased at the expense of the quantities of P and K. The experiments were installed in Tsravékoé (Centre of Togo) and in Mango (Northern Togo).

The following treatments were compared:

1. 200 $kg.ha^{-1}$ NPKSBMg (20-15-13-4-0.75-3.5)
2. 150 $kg.ha^{-1}$ NPKSBMg (20-15-13-4-0.75-3.5) + 50 $kg.ha^{-1}$ urea.

The results of these experiments did not show significant differences, but they were used to develop a first version of QUEFTS for cotton (Tchagodomou and

Pocanam, 2002, see reports).

Soil and plant analyses and yields were used to develop a first version of QUEFTS for cotton. It appeared, however, that the development of a version of QUEFTS for cotton is facing a number of problems. To calibrate QUEFTS it is necessary to know the quantity of N, P and K that is absorbed by the crop. To that end the total biomass needs to be measured and the different parts be analyzed. However, cotton is losing a large part of its buds, flowers and bolls before harvesting, while not all bolls can be harvested as they may be infested by insects or diseases or are not properly matured due to drought. Another limitation was that the experiment was not set up to develop QUEFTS. In spite of these problems a first version has been developed, that may serve as a starting point for improved versions.

Figure 1 indicates the ability of QUEFTS to predict yields by comparing the observed data and the simulated data for two sites in northern Togo: Mango (18 farmers) and Tsravekou (10 farmers).

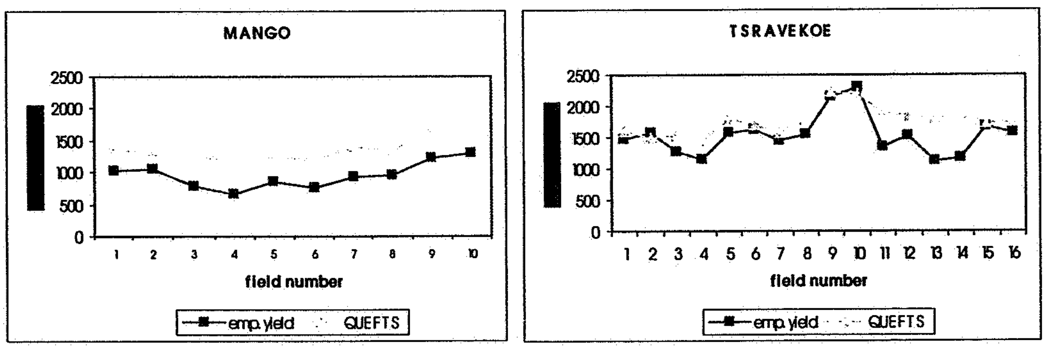

Figure 1: Comparison of simulated and empirical cotton yields per field in Tsravekoe and Mango

As may be expected, QUEFTS overestimates yields as it does not take the effects of drought, pests and diseases, time of sowing and weeds into account. While the observed data and the QUEFTS results show a similar tendency for Mango, the agreement between these data for Tsravekoe is less. This may partly be due to the fact that in Tsravékoé cotton is sown as a relay crop with maize, and in some cases maize was very late removed, preventing the cotton crop in its development.

Nevertheless the preliminary version of QUEFTS was used to explore optimum fertilizer doses for Mango and for Tsravekoe. In this exercise, it is assumed that the farmer is ready to purchase 4 bags of fertilizer, and that he can chose from a variety of fertilizer types: urea, K_2SO_4, NPK (12-20-18) and NPK (20-15-13). The results suggest that the best choice is 1 bag of urea + 1 bag of K_2SO_4 +2 bags of NPK (12-20-18) in Tsravekoe and 4 bags of NPK (12-20-18) in Mango. However, more research needs to be conducted to arrive at a reliable version of QUEFTS for cotton. Such experiments should then be set-up with the explicit purpose to calibrate QUEFTS: 'missing-nutrient-experiments' including several levels of N, P and K and a control. It is also important that care should be taken to collect all biomass that is produced to be able to properly estimate the N, P and K absorbed by the crop.

'A participatory approach for fertilizer recommendations in Southern Togo'

The standard fertilizer recommendation for maize in Togo is 150 kg of NPK (15-15-15) and 50 kg of urea. As soil fertility in Southern Togo shows considerable variations, especially with regard to potassium, a project was established to adjust fertilizer recommendations for maize to specific conditions, called Participative Learning and Action-Research for Integrated Soil Fertility Management. In this project a participative approach and the use of decision support tools were combined. The activities were carried out in three villages in Southern Togo (Sévé Kpota, Adjodogou and Kpétémé) in collaboration with ITRA (the Togolese Agricultural Research Institute) and CREMA, an NGO.

Figure 2. Discussions with farmers about fertilizer recommendations. The right picture shows the way bags of NPK and urea were represented.

First a participative soil classification was carried out. Farmers appeared to distinguish several soil types by their differences in color: black, red and white soils. Among the farmers that were using fertilizer, some were already adapting the fertilizer doses to soil type: they would apply only urea to the most fertile soils and a combination of NPK and urea to the soils that are less fertile.

Combining farmer knowledge with some analytical knowledge of these soils and using this as input into QUEFTS, a range of alternatives to the standard fertilizer recommendations were developed (Figure 2). Based on these preliminary results obtained with QUEFTS and discussions with farmers, fertilizer experiments were installed in each village, covering all soil types. Results were discussed with farmers and used as a basis to further adjust QUEFTS. QUEFTS was subsequently used for developing site-specific fertilizer recommendations, not only related to soil nutrient supplying capacity, but also to the capacity / willingness of the farmer to purchase fertilizer (Struif Bontkes et al., 2003, see reports).

Farmers of Sévé Kpota and a neighboring village will evaluate the recommendations in 2003. Tables 1 and 2 show the required quantities of fertilizer to obtain the highest net benefit in case the farmer is only ready to purchase one bag of 50 kg and if he is ready to purchase 4 bags. He may choose among four types of fertilizer: NPK (15-15-15), urea, K_2SO_4 and TSP. The prices of NPK and urea are 7500 FCFA per bag, for K_2SO_4 10000 FCFA/bag and TSP 15000 FCFA / bag. The

Table 1: Agronomic and financial performance of fertilizer recommendations for each of the three villages if the farmer is able to purchase one bag of fertilizer (50 kg) as predicted by QUEFTS.

Village	Fertilizer (bags ha^{-1})	Yield (kg ha^{-1})	Yield gain from fertilizer (kg ha^{-1})	Net benefits (CFA ha^{-1}) from fertilizer use	Value / Cost ratio (-)
Adjoudougou					
– 0.2 meq K kg^{-1}	1 K_2SO_4	1588	457	17401	2.74
– 0.3 meq K kg^{-1}	1 NPK	1662	170	2718	1.36
– 0.4 meq K kg^{-1}	1 urea	1824	191	3959	1.53
Kpétémé					
– Black soil	1 urea	1650	329	12279	2.63
– Red soil	1 urea	1675	250	7524	2.0
– White soil	1 urea	1750	297	10301	2.38
Sévé Kpota					
– Black soil	1 urea	5324	296	10262	2.37
– Red soil	1 TSP	3341	818	34097	3.27
– White soil	1 TSP	3125	731	29087	2.92

[a]Treatment net benefits: maize price * yield increase – costs of applied fertilizers.
[b]Value / Cost ratios: (maize price * yield increase) / costs of applied fertilizers.

Table 2: Agronomic and financial performance of fertilizer recommendations for each of the three villages if the farmer is able to purchase four bags of fertilizer (50 kg) as predicted by QUEFTS.

Village	Fertilizer	Yield (kg ha^{-1})	Yield gain from fertilizer (kg ha^{-1})	Net benefits from fertilizer use (CFA ha^{-1})	Value / cost ratio
Adjoudougou					
– 0.2 meq K kg^{-1}	2 urea + 2 K_2SO_4	2162	1031	26807	1.77
– 0.3 meq K kg^{-1}	2 urea + 1 NPK + 1 K_2SO_4	2245	753	12670	1.39
– 0.4 meq K kg^{-1}	2 urea + 2 NPK	2354	721	11100	1.44
Kpétémé					
– Red soil	2 urea + 2 NPK	2169	744	14638	1.49
– White soil	3 urea + 1 NPK	2293	840	20383	1.68
– Black soil	2 urea + 2 NPK	2202	881	22872	1.76
Sévé Kpota					
– Black soil	3 urea + 1 TSP	6222	1194	34162	1.91
– Red soil	2 urea + 2 TSP	4321	1798	62900	2.40
– White soil	2 urea + 2 TSP	4007	1616	52014	2.15

price of maize is set to 60 FCFA / kg. At present it is difficult for farmers to obtain K_2SO_4, and TSP is not at all available. The price of TSP was therefore arbitrarily set to 15000 FCFA per bag. These tables show that optimal doses of fertilizer may vary between and within regions.

It clearly shows that on the soils of Adjodogou and Kpétémé potassium is a limiting factor while on the soils of Sévé Kpota this is phosphorus. Both tables also show that the critical level for exchangeable K on the very degraded soils of Adjodogou is around 0.3 – 0.4 mmol. kg^{-1} soil as the recommended types of fertilizer change from K_2SO_4 to NPK and urea when exchangeable K increases from 0.2 to 0.4 mmol K. ha^{-1}. These results suggest that it would be useful to adapt fertilizer recommendations to the specific field conditions, to make other types of fertilizer available for farmers and to allow farmers to purchase the fertilizer they want.

'The use of QUEFTS in the improvement of the maize-groundnut system on degraded Terre de Barre at Adingnigon, centre of Benin'

Maize yields on the Plateau of Abomey in central Benin are low mainly due to soil degradation and Striga infestation. Since a number of years attempts are being made to improve this situation. Several solutions to this problem are being tested, such as :

- Promoting the use of fertilizer
- The use of chicken manure combined with 200 – 300 kg of fertilizer per ha.
- Introducing maize varieties that are resistant to *Striga hermontica*
- Agroforestry

However, farmers appear reluctant to most of these solutions. Within the framework of these activities INRAB has proposed to use QUEFTS to explore the possibilities for improving the existing fertilizer recommendations, while taking into account the readiness of the farmers to invest in soil fertility improvement. At present different fertilizer recommendations exist in the area, that were compared :

- 100 $kg.ha^{-1}$ NPKSB + 50 kg. ha^{-1} urea (CARDER-ZOU)
- 200 $kg.ha^{-1}$ NPK SB + 100 kg. ha^{-1} urea (SG 2000)
- 200 $kg.ha^{-1}$ NPKSB + 200 kg. ha^{-1} urea (CENAP)

Three different zones were distinguished according to their soil fertility and ten farmers per zone were selected to participate in the experiment. The results of the experiments were used to calibrate QUEFTS and to use QUEFTS to optimize fertilizer (Akakpo et al, 2002, see reports).

Figure 3 indicates the ability of QUEFTS to predict yields by comparing the observed data and the results using QUEFTS. The model always overestimates yield, which is caused by the fact that QUEFTS does not take other factors such as drought, Striga etc. into account. However the tendencies come out reasonably well.

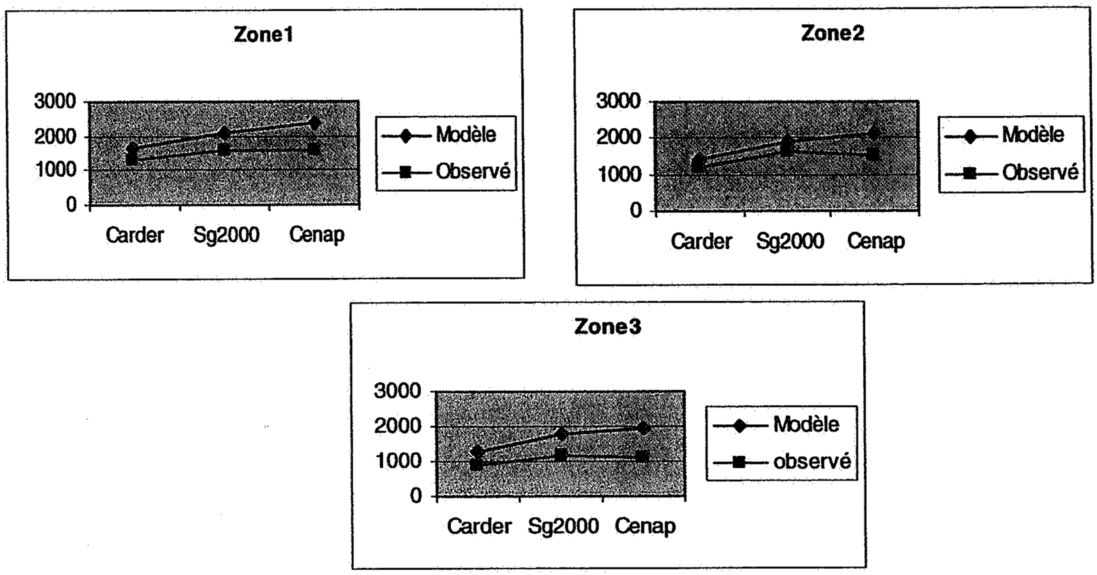

Figure 3: Comparisons of observed and simulated yields for three different zones

In Table 3, recommended doses according to CARDER, SG 2000 and CENAP are compared to the recommended doses using QUEFTS with and without the application of TSP to the groundnut crop.

Table 3: Comparison of fertilizer recommendations for the three zones based on QUEFTS with existing fertilizer recommendations

		CARDER (2 NPK + 1 Urea)	**SG 2000 (4 NPK + 2 Urea)**	**CENAP (4 NPK+4 Urea)**
ZONE1	**-TSP**	2 NPK + 1 Urea	4 NPK + 2Urea	6 NPK + 2 Urea
	+TSP	2 Urea +1 K_2SO_4	3 Urea +3 K_2SO_4	5 NPK + 3 Urea
ZONE2	**- TSP**	2 NPK + 1 Urea	4 NPK + 2Urea	6 NPK + 2 Urea
	+ TSP	2 Urea +1 K_2SO_4	4 NPK + 2Urea	5 NPK + 3 Urea
ZONE3	**- TSP**	2 NPK + 1 Urea	4 NPK + 2Urea	6 NPK + 2 Urea
	+TSP	2 Urea +1 K_2SO_4	4 NPK + 2Urea	6 NPK + 2 Urea

Conclusions that can be drawn from the Table 3 are that:

- In some cases QUEFTS suggests different doses for different regions due to differences in soil fertility
- If TSP is applied to groundnut, QUEFTS suggests to adapt the fertilizer doses to maize
- The doses that are suggested by QUEFTS are close to those recommended by CARDER (for 3 bags) and by SG 2000 (for 6 bags) if no TSP is provided to groundnut. However the doses calculated by QUEFTS if 8 bags are available do not concur with the recommendations made by CENAP.

Based on the experiences in Togo and Bénin some conclusions can be drawn with respect to the possibilities and limitations of the use of QUEFTS to formulate site-specific fertilizer recommendations. The results of these cases were discussed with representatives of agricultural research institutes, extension services, farmers' organizations and fertilizer distributors. All representatives agreed about the need for fertilizer recommendations that are adapted to specific field conditions. This would imply more types of fertilizer that need to be distributed according to the need of the various regions and production systems. This requires knowledge of region-specific fertilizer requirements and a distribution system that is able to deliver the right quantities per fertilizer type at the appropriate time. In addition, part of the fertilizer is donated to the country and it may be necessary to convince the donors to adjust the type of fertilizer donated.

QUEFTS is an interesting tool to help finding a proper balance between N, P and K. Its limited data requirement and user friendliness are also important advantages. It should be noted, however, that QUEFTS does not take into account factors such as water supply, weeds, soil depth etc. As these factors may often limit yields at farmers' fields in West-Africa, QUEFTS is more appropriate in comparing the effects of different fertilizer doses than a precise prediction of the yield. At present there are only well tested versions of QUEFTS for maize and irrigated rice. However, as the standard QUEFTS version was developed in Kenya and Surinam, the parameters need to be adjusted for other agro-ecological areas.

There is also the possibility to use QUEFTS in conjunction with another tool, e.g. DSSAT. DSSAT could then be used to determine the water-limited yield potential and this could be used to set an upper limit to the yields as calculated by QUEFTS.

An interesting initiative in this respect was recently taken by the International Water Management Institute (IWMI) to develop and adapt a set of models or 'tools', built from modules with a team of experts and in direct interaction with several research projects that are immediate users of these tools. IFDC is participating in this effort through its experience with QUEFTS.

In spite of the limited data requirement by QUEFTS, even these data are not always easy to obtain and the quality of these data is not always reliable. The COSTBOX program has given ample attention to the issue of quality and availability of data. The program collaborated closely with the soil labs of Togo and Benin. Analysis results were critically reviewed and collaboration between the countries was encouraged by exchanging samples and methods of analysis. Samples were also sent to other labs (IITA, ICRISAT, IFDC-USA and Wageningen) for comparison.

To improve availability and accessibility of data, geo-referenced data bases for soil and climate were developed in collaboration with the relevant institutes in Togo and Benin (see under GIS project).

DSSAT

Two case studies were carried out in which DSSAT played a role:

- Application of the DSSAT soybean model to assess soybean performance by the Department of Soil Science of the Faculty of Agriculture of the University of Ghana.
- Using DSSAT for an optimum combination of variety, sowing date and fertilizer for maize in Southern Togo with ITRA, Togo

'Application of DSSAT soybean model to assess soybean performance on a light textured Savannah Acrisol at the University of Ghana farm'

The background of this study was the decision of the government of Ghana to promote soybean production. To better target the efforts, it was deemed useful to explore the possibilities of soybean production across different farming zones in Ghana. The DSSAT 35 soybean model was supposed to be a suitable tool for that purpose. This case study was meant to allow university staff and students to become acquainted with this model and to test, and if necessary adjust it, for the Ghanaian conditions. The treatments included two planting dates and two planting densities. Limited testing of the DSSAT soybean was done (Adiku et al, 2002, see reports). Generally, the model captures well the trends in biomass, leaf area and seed yield as determined by planting date and planting density. Both total biomass and seed yields were lower for the late planting, which was also predicted by the model. It was concluded that, in spite of the limited testing, the DSSAT soybean model shows promise to be used to evaluate the performance of the crop in many parts of Ghana. This, however, will require more testing and geo-referenced data sets on soil and climate of the agro-ecological regions of Ghana.

'Using DSSAT for an optimum combination of variety, sowing date and fertilizer'

Maize is the most important crop of Southern Togo. However, due to a number of constraints, farmers are not able to make an optimal use of the available environmental resources. Irregularity of rainfall is one of these constraints and constitutes an important risk factor. To spread this risk, but also because of labor constraints, farmers use to sow their maize over a longer period.

To help farmers choosing the most appropriate variety for a particular sowing date, various combinations of maize varieties and sowing times were compared under farmer's conditions on two sites that differ in soil fertility and mean annual rainfall: Adjodogou (poor soils, low rainfall) and Seve Kpota (relatively better soils and higher rainfall). These data were used to develop parameter sets for Ceres-maize (DSSAT) for each variety. Subsequently DSSAT was used to conduct simulations over a number of years with various amounts and patterns of rainfall.

The results help to answer the question "when to sow which variety" and "how much fertilizer should then be applied", taking into account variability in rainfall and prices of fresh maize in order to optimize maize production in terms of yield and returns to inputs. It is believed that this approach meets the concerns of the farmer more adequately than the determination of the optimum sowing time, as the latter does not take into account the many constraints farmers are facing, such as labor, risk and prices (Dzotsi et al., 2003, see reports).

Three varieties were compared: AB 11 (medium duration), TZEComp4C2 (early maturing) and TZESRW x Gua314 (very early maturing). They were sown on three different dates in the first rainy season and on two different dates in the second rainy season on 5 farmer fields, in both Seve Kpota and Adjodogou.

In Figure 4 the empirical yields and the yields as predicted by DSSAT are compared, to test the performance of DSSAT. The fit is reasonable but there are always outliers often due to conditions that are not taken into account by the tool such as weeds, birds and the presence of trees.

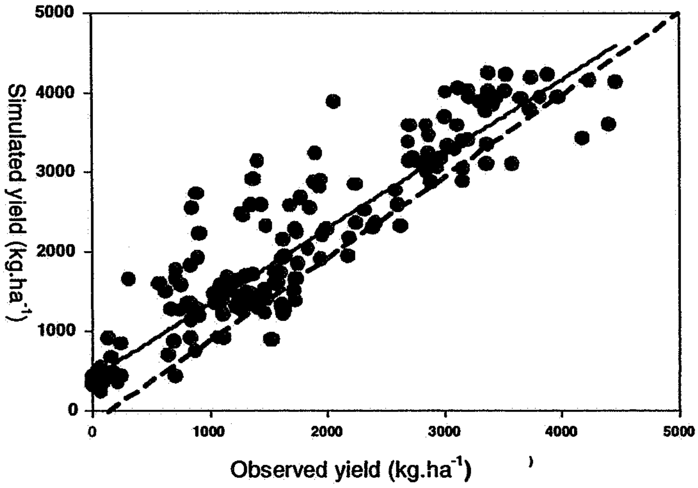

Figure 4. Comparison between measured and simulated yields in Seve Kpota and Adjodogou for 10 farmers, 3 sowing dates and 3 varieties.

DSSAT was then used to simulate the performance of these varieties over a number of years using historical rainfall data for both villages leading to the following recommendations:

<u>Seve Kpota</u>

1- The very early variety (TZEComp4C2) is the best variety to sow in the first rainy season (starting in April and finishing in June). This was confirmed by the fact that farmer's preferred purchasing this variety when seed was offered for sale to them.
2- In the second (shorter) season the very early maturing variety proved to be the best compromise between a reasonable yield and a relatively low risk.

<u>Adjodogou</u>

1- Also here the early variety came out as the best variety for the first rainy season. However, many farmers preferred the very early variety as this reduces the 'hungry season', showing that other factors than yield and reducing risk play an important role as well.
2- The very early variety is the best if farmers have to sow late in the first season and for the whole of the second season.

Fertilizer requirement may also depend on growth duration of the crop and water-limited yields. Simulations were therefore carried out to find optimum N-application rates as a function of variety and sowing time. The optimum N-application is here defined as the N-application that produces 80% of the maximum water-limited yield. This resulted in the following recommendations:

- Early variety if sown early: 80 kg N ha^{-1}, but 55 – 60 kg N ha^{-1} if sown late.
- Very early variety: 40 kg N ha^{-1}

This study shows the utility of decision support tools, as experiments of one season are not sufficient to provide an answer to questions pertaining to risks. The model can now be used in conjunction with GIS to provide recommendations regarding combinations of variety, sowing time and fertilizer requirement for a larger region.

Based on these results leaflets have been made to help the farmer choosing between varieties as a function of the preferred time of sowing. Figure 5 shows such a leaflet, showing the name of the varieties and sowing period and the range of yields that can be expected. The colors indicate the 'best' variety in terms of yield performance and risk; though this does not take into account other characteristics of the variety such as earliness, quality, and resistance to bird damage etc. This leaflet is based on the data for Sévé Kpota, but DSSAT may also be used in combination with GIS to extrapolate this knowledge to cover a larger region. An example of a first attempt is shown in the next chapter.

SOWING DATE	PREFERENCE			Yield ($kg\ ha^{-1}$) of the preferred variety
	INTERMEDIATE	EARLY	VERY EARLY	
April 12				4200 – 1600
April 26				4500 – 1600
May 10				3700 – 1300
May 24				2600 – 750
June 7				1600 – 500

Figure 5: A leaflet (translated from the local Ewe language into English) showing preferred sowing time per variety in the first rainy season (green: best variety; red: worst variety) and the expected range of yields of the preferred variety.

4.6 Geo-referenced information systems for Togo and Benin.

As has often been stated, availability and quality of data are an essential prerequisite for the use of decision support tools, especially with reference to soil data and meteorological data. Agricultural research institutes and meteorological stations usually have collected many data, but they are often not easily accessible, so that they are rarely used. It was therefore decided to develop geo-referenced data bases combining data on soils and climate in collaboration with the national agricultural research institutes and with the meteorological institutes in Togo and Benin.

These data bases were then be used in combination with the decision support tool IDSS (Information and Decision Support System) that combines DSSAT software with GIS to find the best combination of variety and sowing date in the various agro-ecological zones of Togo. The following data were collected:

- Existing data on soil profiles
- Administrative, topographical, hydrological, geomorphologic and soil maps (1 : 1000000)
- Existing meteorological data over a period of at least 20 years, including:
    - Temperatures (max, min, average per day, per decade per month);
    - Rainfall per day, decade and month;
    - Radiation or sunshine hours per day;
    - Evapo-transpiration.

Although the framework for the GIS has been completed for the two countries, and partners trained in the use of the GIS software (ARCVIEW), there remains still work to be done:

- The soil data bases need to be further adjusted, especially regarding the data for available P, as different methods of analysis have been used.
- Partners need further training in the application of the software
- It is intended to combine the soil map and the data on the soil profiles in the following way:
    - Data on the soil profiles per soil type are reviewed and organized in a number of categories. These categories should reflect variability within a soil type and relate to the way farmers classify their soils, e.g. black, red and white soils. These categories should be characterized.
    - To be able to link GIS to particular software (e.g. DSSA or QUEFTS) the format of the data base will need to be adjusted.
    - Information produced by combining GIS with a DST (e.g. DSSAT or QUEFTS) will then pertain to the different categories within a soil type with its climatic characteristics. This information can then be used to formulate recommendations that should be interpreted by extension staff / farmers who have to identify the relevant soil type.

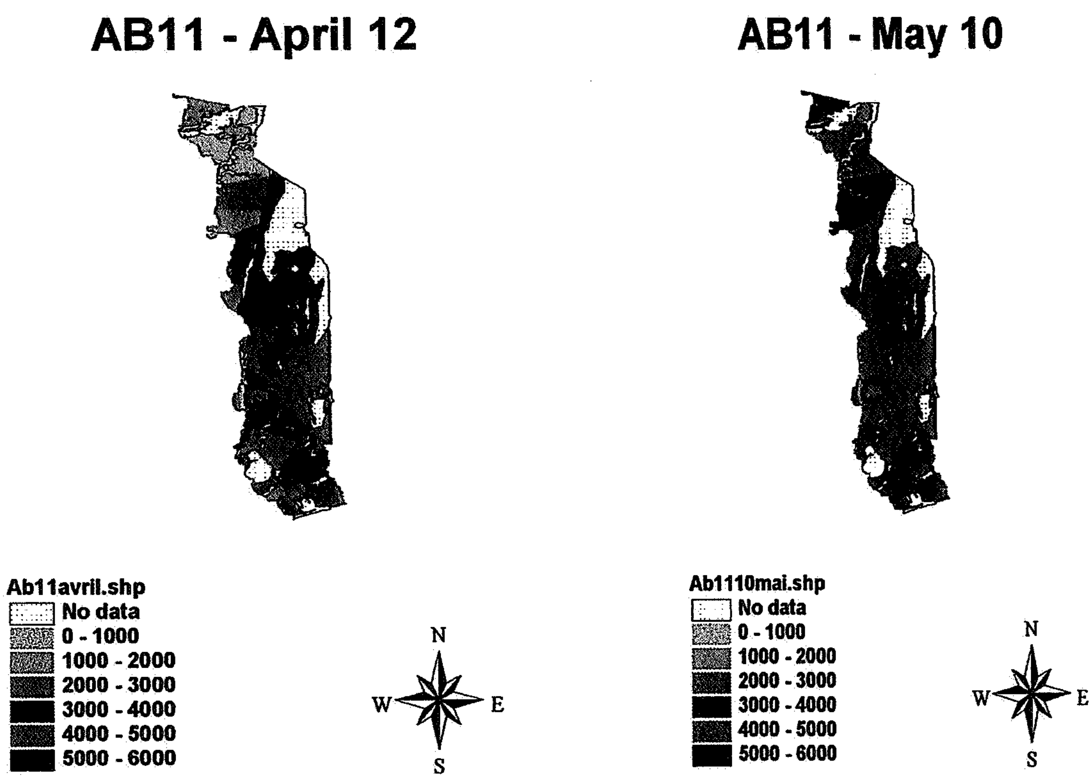

Figure 6: Effects of sowing dates (April 12 and May 10) on average yields (kg/ha) for a medium duration variety (AB 11in the various agro-ecological zones of Togo, using 46 kg N per ha.

4.7 Development of a guide for the use of decision support tools

Though in this project the main emphasis was put on two tools, there are many more of them. Each of these tools has strong and weak points. There is no best tool, but a tool that is best suited for a particular purpose. It was therefore deemed useful to develop a guide that provides an overview of number of tools, to help researchers selecting the tool (or combination of tools) that is appropriate to address the issue they are dealing with.

A Guide for the use of Decision Support Tools was developed in collaboration with a number of developers and users of a variety of tools. The purpose of that guide is to help potential users to obtain an overview of tools that exist, for what purpose they can be used, what is required to use them and where they can be obtained.

The guide includes different tools, such as tools based on expert knowledge (e.g. using decision trees developed at IFDC and at TSBF/CIAT), tools for monitoring nutrient flows and models such as QUEFTS, NuMaSS, the Rothamsted Carbon model, RIDEV, SARRA and DSSAT. The toolbox provides guidelines as to when to use which approach or combination of approaches, its data needs and how to interpret the results.

For each tool a case is described. Only tools are used that are relatively easily accessible. Indications are provided regarding the way this tool can be obtained. The following institutes / persons have contributed to the guide:

- IFDC-Africa Division: Dr. T. Struif Bontkes, Dr. M. Wopereis
- ITRA: Agricultural Research Institute Togo (Dr. A. Noaméshie, K. Egué)
- IITA, Ibadan, Nigeria (Dr. J. Diels)
- IACR, Rothamsted, UK (Dr. K. Coleman)
- ICRISAT, Zimbabwe (Dr. J. Dimes, Dr. S. Twomlow)
- APSRU- Australia (Dr. P. Carberry)
- WARDA (Dr. T. Defoer, Dr. S.M. Haefele, Dr. A. Sow)
- CIRAD (Dr. M. Dingkuhn)
- Wageningen University and Research Center (A. de Jager)
- IFDC USA (Dr. U. Singh)
- North Carolina State University (Prof. Dr. J. Smyth)
- University of Hawaii (Dr. R. Yost)
- Philippine Rice Research Institute (Dr. Casimero)

The 175 page-guide will be published in English and French by mid 2003 and is partly financed by the Technical Centre for Agricultural and Rural Co-operation (CTA).

5. TOWARDS A METHODOLOGY OF INTRODUCING DECISION SUPPORT TOOLS FOR SMALLHOLDER AGRICULTURE IN WEST AFRICA

Based on experiences gained in this project, ideas are formulated to further stimulate the introduction of decision support tools for smallholder agriculture in West Africa.

Improving productivity of smallholder agriculture in West Africa requires working towards site-specific recommendations in terms of crop and natural resources management. Such recommendations should take into account agro-ecological and socio-economic settings, including farmer preferences. In reality, blanket recommendations, that are presumed valid for large areas or even for an entire country, are still common in West and sub-Saharan Africa. This leads to situations where farmers lose confidence in extension messages and continue practicing traditional forms of low input – low output agriculture. To improve upon this situation, extension services should be able to deliver relevant information to the farmer, and governments and the private sector should be able to deliver the right inputs at the right time.

This implies that the extension service should have information allowing farmers and field agents to evaluate a number of alternatives taking into account the agro-ecological conditions and the needs and conditions of the farmer (preferred crop / variety, financial and labor constraints etc.). The agent should profit from the expertise that is present at village level and try to build bridges between local and outside expertise. Among others:

- S/He should be able to identify broad agro-ecological regions related to major soil types and climate

- S/He should be able to identify, using farmer knowledge, soil categories within a particular agro-ecological region, including the degree of nutrient depletion and/or other forms of soil degradation.
- S/He should be able to provide the farmer with alternatives on e.g. fertilizer recommendations adapted to soil type, crop and / or production system and sowing date, and depending on types of fertilizer available in the market and the amount of money the farmer is willing to invest in fertilizer inputs. Such alternatives could be summarized in leaflets as shown in one of the cases above.

Ideally, existing soil data bases at national research institutes should be used to make first best-bet estimations of optimal soil fertility management for agro-ecological regions, using a combination of soil and weather data bases, crop modeling and GIS. This requires:

- Calibration and validation of crop modeling tools for broad agro-ecological zones (Guinea savanna, Sudan savanna, Sahel, irrigated systems)
- Development and maintenance of soil and weather databases in such a way that they can be read by these tools
- Application and extrapolation to other areas by combining tools, data bases and GIS

Such an approach obviously requires reliable geo-referenced soil and weather data bases at regional and national level. A step in the right direction was made in this project for Benin and Togo. It will be very important to translate the various soil categories in a database to soil types known by farmers. Data bases need to be reviewed and updated regularly using feedback from extension pertaining to the results of their advisory work based on this information system. The latter requires a close interaction between research and extension and should be put in the hands of a department within the research institute that has close links with the extension department, like e.g. DARS in Togo.

Best-bet estimations on soil fertility management need then to be evaluated using a farmer participatory learning and action research approach. This requires more in-depth knowledge of the variability in terms of soil nutrient supplying capacity at the village level. This may be done using cheap soil kits. However, there may be doubt about the quality of such analyses and/or the reliability of regression equations converting the data into estimations of soil nutrient supply. As an alternative, crop color charts may be used to identify nutrient deficiency symptoms, and therefore, major nutrients limiting growth. Another possibility is the installation of nutrient-omission trials at representative sites within the village territory. In such trials the crop receives the full dose of fertilizer except for one element, e.g. the treatments NP, NK, PK; these treatments are then compared with the full dose NPK. Uptake of the missing nutrient is taken as a proxy for the supplying capacity of the soil for that particular nutrient.

As shown in this project, DSTs may be used for diagnosing problems and opportunities, identification of options for alternative management, analysis of farmer-led or researcher-led experiments and diffusion of promising technologies / approaches. However, to be able to do all this, DSTs need to be adjusted to the different agro-ecological zones of West-Africa. The application of these tools should, ideally, be the responsibility of the national research institutes, where they would establish core groups that promote the use of decision support systems in agricultural research and development. Such a core group would, again ideally, work full-time on this assignment. Important prerequisites for such approach is the availability of relevant and reliable biophysical and socio-economic data at the right scale, and, most importantly, trained staff.

To ensure high quality of soil data, it is necessary that soil labs increase their quality of work. Equipment is, however, often obsolete. A step forward would be membership of international networks that exchange samples to maintain quality standards.

A major bottleneck for the use of DSTs is the lack of trained and experienced staff. An occasional training course or a few PhD students do not suffice to create a critical mass of scientists that effectively apply DSTs. It would, therefore, be highly desirable to create a facility within West Africa, where systems analysis and modeling is taught to students and where agricultural researchers receive training and support on the use of DSTs. An important task could also be the adjustment of the tools to the agro-ecological conditions of West Africa. Such facility could become part of an international institute or a university. A number of initiatives to that effect have been undertaken by the project and have resulted in a proposal with IFS to improve access to internet and provide training in the use of models, and in a proposal of the University of Benin to collaborate with the Wageningen University to include systems analysis and modeling in the regular curriculum of the university.

6. ARTICLES, PAPERS AND REPORTS

Adiku, S.G.K, F.K. Kumaga and K.B. Laryea (2002): Effect of planting date and planting density on growth and development of soybean in the coastal savanna zone of Ghana. Faculty of Agriculture. University of Ghana, Legon, Ghana.

Agboh-Noaméshie, A. and K.M. Sedzro (2002) : Amélioration de la productivité du maïs et utilisation des modèles dans le transfert des technologies. Rapport Technique. Institut Togolais de Recherche Agronomique. Lomé, Togo.

Akakpo, C., M, Adomou, M. Alagbé, G. Kokodé and M. Igué (2002) : Utilisation des modèles pour l'amélioration du système maïs-arachide sur de terre de barre dégradée à Adingnigon au Bénin. INRAB, Bohicon, Bénin

Ankou, K.A., 2003. Approche participative et utilisation du modèle QUEFTS pour une gestion intégrée de la fertilité des sols : cas des terres de barre dégradées des villages de Kpétémé et d'Adjodogou dans la préfecture de Vo au sud-est du Togo. Mémoire d'Ingénieur Agronomie, Ecole Supérieure d'Agronomie, Université de Lomé Togo.

Dzotsi, A.K. (2002) : Application du modèle CERES-Maize de DSSAT `a l'analyse des stratégies de semis pour le maïs (*Zea mays L.*) dans les conditions de Sévé Kpota. Mémoire d'Ingénieur Agronome, Ecole Supérieure d'Agronomie, Université de Lomé, Togo.

Dzotsi, A.K., A. Agboh-Noaméshie, T. Struif Bontkes, U. Singh and P. Dejean (2003): Using DSSAT to derive optimum combinations of cultivar, sowing date and nitrogen fertilizer for maize in Southern Togo in: Struif Bontkes, T.E. and M.C. Wopereis (Eds) (2003) Decision Support Tools for Smallholder Agriculture in sub-Saharan Africa, a practical guide. IFDC, Lomé, Togo / CTA, Wageningen, The Netherlands (in press)

Ezui, G. (2001) : Evaluation et adaptation du modèle QUEFTS dans la prédiction du rendement de l'arachide dans les conditions agro-écologique du Togo: cas de Tsagba. Mémoire d'Ingénieur Agronome, Ecole Supérieure d'Agronomie, Université de Lomé, Togo.

IFDC / IAR-ABU(2001): Report on the International Workshop on the Use of Models in Agriculture, 9 – 12 April 2001, ABU-IAR, Zaria, Nigeria

IFDC / ESA (2001) : Rapport du cours sur l'approche système et la simulation, 26 – 29 mars, 2001. Ecole Supérieure d'Agronomie, Université de Lomé, Togo

IFDC / ITRA / ICAT (2000) : Rapport de l'atelier sur l'utilisation des modèles, 25 – 28 juillet 2000 à Lomé, Togo

IFDC / INRAB / FSA-UNB (2000) : Rapport de l'atelier sur l'utilisation des modèles, 21 – 24 novembre à Niaouli, Bénin

IFDC / UGFA (2001) : Report on agricultural modeling seminar: STEPRI, September 20, 2001, Accra, Ghana.

IFDC / ITRA / INRAB: Rapport de l'atelier sur l'utilisation des modèles et des SIG dans l'agriculture, le 13 décembre, 2002, Lomé, Togo

IFDC / IAR-ABU(2002): Report on the international course on systems approach and simulation modeling, 4 – 7 February, 2002, Institute of Agricultural Research and Faculty of Agriculture of the Ahmadu Bello University, Zaria, Nigeria

IFDC / UI-FA (2002): Report on the international course on systems approach and simulation modeling, January 29 - February 1, University of Ibadan, Nigeria.

IFDC / ITRA / INRAB (2001): Rapport sur la formation approfondie sur l'utilisation des modèles, 30 janvier – 9 février, 2001, IFDC Afrique, Lomé, Togo

IFDC / NCSU / Texas A&M / University of Hawaiï (2002): Report on the workshop on the use of nutrient management support systems, 12 – 15 March, 2002, Lomé, Togo

IFDC / UGFA / IFS (2002): Report of IFS/IFDC/Soil Science Department-sponsored International Workshop on Agricultural Systems Analysis and Modeling: August 13-16, 2002

Janssen, B.H. (2003): Adaptation of the QUEFTS model to agro-ecologcal conditions and crops in West-Africa. A report for IFDC-Africa. Department of Environmental Sciences, Wageningen University / IFDC-Africa.

Lamboni, D., 2003. Approche participative paysanne et utilisation du modèle QUEFTS pour la gestion intégrée de la fertilité des sols du village de Sévé-Kpota au sud du Togo. Mémoire d'ingénieur agronomie, Ecole supérieure d'agronomie, Université de Lomé Togo.

Röling, N. (1999): Models as tools: towards an analysis of reasons for the non-adoption of crop growth simulation models in West Africa as an input to the COSTBOX project. Wageningen University, The Netherlands

Singh, U., P.W. Wilkens, W.E. Baethgen and T.S. Bontkes, 2002. Decision support tools for improved resource management and agricultural sustainability. Chapter 6 in: Agricultural System Models in Field research and technology Transfer. CRC Press LLC, Boca Raton, Florida, USA

Struif Bontkes, T.E., U. Singh and V. Chude, 2001. Problems and opportunities in adopting system tools for decision-making related to soil fertility improvement in Africa. Paper presented at the INRM 2001 Workshop, Cali, Colombia.

Struif Bontkes, T.E. and H. Breman, 2001. The use of modelling in the search for sustainable crop-livestock systems in Southern Mali. Paper presented at the International Conference on Sustainable crop-livestock production for improved livelihoods and natural resource management in West Africa. Ibadan, November 19 – 22, 2001. ILRI / IITA / WARDA / ICRISAT / CIRDES / ITC.

Struif Bontkes, T.E., 2002. A quoi peut servir la modélisation? CORAF Action. no. 23.

Struif Bontkes, T.E. and M.C. Wopereis (Eds), 2003. Decision Support Tools for Smallholder Agriculture in sub-Saharan Africa, a practical guide. IFDC, Lomé, Togo / CTA, Wageningen, The Netherlands (in press)

Struif Bontkes, T.E., M.C.S. Wopereis, A. Tamelokpo, K.A. Ankou and D. Lamboni, 2003. The use of QUEFTS in search of balanced fertilizer recommendations for maize in Togo in: Struif Bontkes, T.E. and M.C. Wopereis (Eds) (2003) Decision Support Tools for Smallholder Agriculture in sub-Saharan Africa, a practical guide. IFDC, Lomé, Togo / CTA, Wageningen, The Netherlands (in press)

Tchagodomou, O.K. and Y. Pocanam (2002): Experimentation sur l'engrais unique. ITRA-CRASH / IFDC, Lomé, Togo