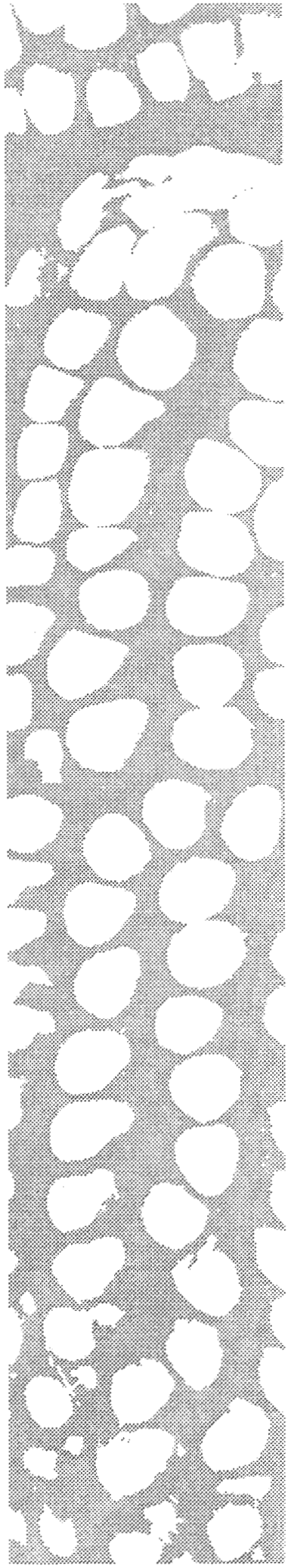
A Virtual Field Tour for the Board of Trustees

24 March 1999



CIMMYT

Sustainable Maize and Wheat Systems for the Poor

NRG

Natural Resources Group

Contents

The Natural Resources Group

A Virtual Field Tour for the Board of Trustees

It is a welcome custom that the Board of Trustees, during meetings held in Mexico, undertake a field tour. In recent years, field tours have been held in Poza Rica, Ciudad Obregon, and Toluca, hosted by either the Maize or Wheat Programs. This year, the Economics Program and the Natural Resources Group have the pleasure of hosting the field tour. These Programs, however, are not organized in such a way that large concentrations of effort may be reviewed in a single location. The answer has been to organize, in our headquarters buildings, a "virtual field tour." In our 90 minute segment of the virtual field tour the NRG will provide a condensed account of selected activities and accomplishments—within Mexico and around the world. Understandably, not everything done by the NRG will be presented.

Soils Research Facility

We will begin with a description of strategic research on biophysical processes in conservation tillage (collaboration with the Wheat Program, and with Michigan State University). This includes modeling conservation tillage and residue retention, and understanding the consequences of introducing conservation tillage for soil-borne diseases, and for soil chemistry.

We will then continue with a report on our role in the Risk Management Project for Southern Africa (collaboration with the Maize and Economics Programs, with the Soil Fertility Network, and with APSRU). Topics include modeling the performance of soil fertility management practices for drought-prone maize-based systems in Zimbabwe and Malawi, as well as how a modeling approach can be made to benefit smallholders.

Outreach Activities and Farmer Participatory Research

The NRG is very active in regional collaborative research: the Risk Management Project is only one example. We will therefore provide a panoramic view of some of our outreach activities in Asia, Africa, and Mexico (collaborations with the Maize, Wheat and Economics Programs, with the Rice-Wheat Consortium for the Indo-Gangetic Plains, and with NGOs in Mexico). Special attention will be given to our very substantial level of activity in farmer participatory research and to exciting processes of adoption presently unfolding in farmers' fields.

The GIS/ Modeling Laboratory (GISML)

The NRG field tour will conclude with demonstrations by our GISML staff on the country almanacs, on the Sustainable Farming Systems Database (SFSD), and on methods for spatial targeting of promising NRM practices (collaborations with Texas A&M University, with CIAT and IRRI, and with the CGIAR Consortium for Spatial Information). GIS tools introduced in the plenary session of ICW 1998 will be featured, and the slogan "cutting edge GIS tools for non-GIS users" will be explained.

The CIMMYT NRG: An Overview

The NRG works with CIMMYT Programs and research partners elsewhere to develop productivity-enhancing, resource-conserving practices, especially those associated with conservation tillage. As part of this, it helps others measure and anticipate the longer-term environmental and ecological consequences of technical change. Its sphere of expertise embraces "hard" and "soft" systems research and information management, including crop and system management, simulation modeling, decision support, GIS, and farmer participatory research. In the *germplasm x environment x management x people* (G x E x M x P) paradigm, the NRG makes strong contributions to dealing with "E" and "M" issues.

Established as a CIMMYT Program in September of 1996, the NRG comprises a Director and eight other international scientists, with nine research affiliates and consultants and suitable numbers of national technical and support staff. It has offices in Mexico (El Batán, Jalisco, Puebla); South Asia (Delhi, Dhaka, Kathmandu) and Southern Africa (Harare, Lilongwe). Among CIMMYT Programs, it has recently enjoyed the fastest percentage growth in special project funding.

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Sustainable Production through Conservation Tillage

"Conservation tillage and related soil and crop management practices should be the primary research focus of the NRG, with the goal of quantifying the effects of conservation tillage on water and nutrient use efficiency, soil quality, and productivity of maize- and wheat-based systems"

CIMMYT EPMR 1997

Conservation tillage offers maize and wheat farmers in developing countries an ecologically and economically sound way to increase productivity and reduce risks, over the long term. As a system that provides a cover to conserve soil moisture and replenish soil organic matter, it is a viable, biologically sound alternative to more traditional, high-risk farming systems that rely heavily on chemical fertilizers and herbicides.

Use of conservation tillage is not restricted to any particular environment or geographical region—it is a global performer. The NRG, in concert with the CIMMYT Wheat and Maize Programs and Michigan State University, is beginning to gather benchmark data on biophysical processes in rainfed and irrigated conservation tillage systems. First, these data will contribute to the development and promotion by agronomists of truly sustainable on-farm management strategies, providing accurate information to farmers and extension workers about the processes involved. In addition, they will constitute critical inputs for cropping systems simulation models such as DSSAT and APSIM, allowing development of a range of tillage, rotation and fertilizer strategies that provide favorable settings for the expression of yield potential by improved germplasm from CIMMYT and other sources. Major activities include tillage trials in Mexico and simulation modeling.

Tillage trials in Central Mexico

Initiated in 1991, the ME-2 sustainability trial at El Batán provides evidence of both the benefits and the processes behind the success of conservation tillage in maize and wheat farming systems. As discovered in similar work by CIMMYT in other parts of Mexico, the prerequisite for success is the combination of conservation tillage and crop residue retention after harvest. A consistent 25% yield advantage has been found for the 1996, 1997 and 1998 cycles for cereal rotations under conservation tillage. (Fig.1)

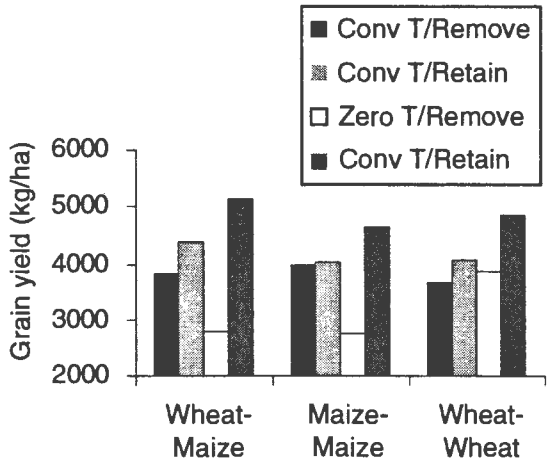

Figure 1. Yield gain through conservation tillage in tropical maize systems.

In addition to evidence of added soil organic matter, data collected at the ME-2 trial also suggests an increased presence of fluorescent psuedomonads (microbes that are useful in the biological control of soil borne pathogens) and decreased root rot incidence in zero-till/ residue retained systems. (Fig.2)

Conservation tillage reduces runoff of valuable water. A fivefold increase in water infiltration compared to that under more traditional tillage is evident in the J-8 tillage trial at El Batán. (Fig.3)

Similar evidence of the advantages of conservation tillage was described in the presentation by CIMMYT scientists Eric Scopel and Damien Jourdain concerning their work at La Tinaja, a low rainfall site in Jalisco. The 1996 data clearly shows that erosion was significantly reduced in the zero-tillage treatments with the residue retention ranging from 0-4,500 kg/ha. Maize yields ranged from 800-3,000 kg/ha in this trial.

Simulation modeling

Regarding yield advantages associated with conservation tillage, the magnitude of success is limited only by the soil and climate regime in which it is practiced. Crop and soil simulation models will play a key role in integrating the wealth of information being generated at CIMMYT on the processes that underlie conservation tillage. The NRG has developed a tillage routine for the DSSAT models that accurately simulates the impact of conservation tillage on soil nutrition, water and yields. For instance, the model generates plausible series of long-term maize yields under conservation tillage in the Mexican highlands, showing them to be more stable, despite variable rainfall, and less reliant on fertilizer sources of nitrogen than yields under conventional tillage (Fig. 4).

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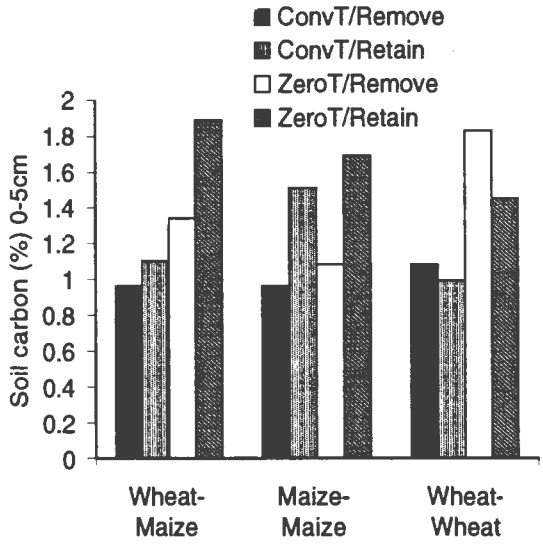

Figure 2. Soil carbon sequestration under conservation tillage.

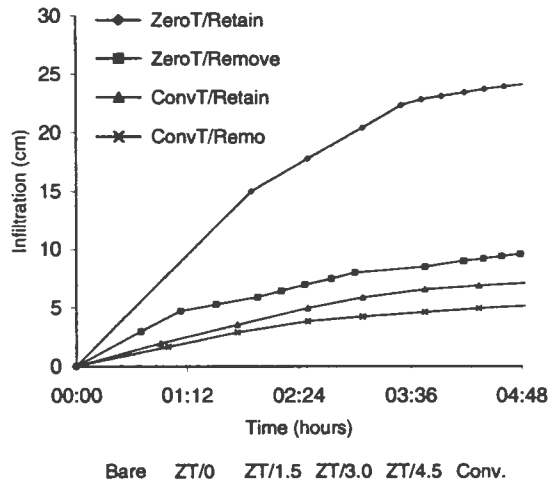

Figure 3. Increased water retention under conservation tillage.

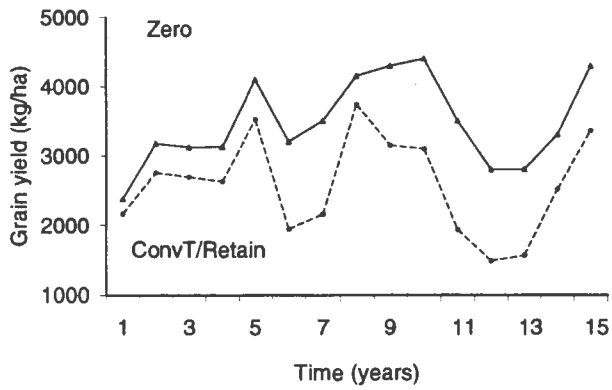

Figure 4. Simulated long-term maize yields under conservation tillage.

The Risk Management Project

Innovative Strategies for Food Security and Economic Stability for Resource-Poor Farmers in Southern Africa

Climatic risk, particularly from erratic rainfall, is a major constraint to the development and adoption of improved technologies for smallholders maize farmers in southern Africa. Some 70% of maize in the region comes from farms of less than 5 hectares, virtually all of it rainfed. Besides facing the constant threat of drought, farmers work some of the world's poorest soils in an economic environment where fertilizer use is both costly and risky. To meet the growing demand for maize and other staples, they need locally developed technologies that provide alternative sources of nutrients and improve soil quality.

The AusAID/ACIAR-funded **risk management project** (RMP) is unique in that it links three previously separate areas of research—analysis of climatic risk through crop modeling, the development and dissemination of improved technologies, and farmer participatory research—in a combination that holds great promise for addressing the above concerns. Fundamentally an offshoot of the highly successful Soil Fertility Network funded by the Rockefeller Foundation and coordinated by CIMMYT, the RMP comprises two subprojects: 1) farmer participatory research and 2) simulation modeling. The first addresses broad systems diagnostics, identifies stakeholders, elicits farmer taxonomies for soils and climate, identifies livelihood strategies of farm families, and fosters farmer experimentation on soil fertility management practices. The modeling effort involves the validation and application of the APSIM (Agricultural Production System Simulator), as well as promoting, through training courses and workshops, use of the model by national program researchers to study the biophysical performance of fertility management practices under specific soil and climate conditions. Of particular interest is the way in which participatory research and modeling are joined under this project, among other things allowing:

- Use of farmers' soil and climate taxonomies for model runs.
- Evaluation of farmers' own technologies by the model.
- Assessment of model outputs by farmers themselves.

Progress to date

Though little more than a year old, the RMP can claim significant achievements that include the following:

- Model results indicate that, in Malawi, retaining maize residues after harvest would increase surface soil carbon (an important indicator of improved soil fertility), but that farmers would have to apply fertilizers to offset the heavy, near-term draw-down on nitrogen involved in residue decomposition.
- In the low rainfall (<500 mm) regions in southern Zimbabwe, maize yields of 2 tons per hectare can be achieved with as little as 15 kg N fertilizer/ha (Fig. 1), and fertilizer applications in excess of 35 kg N are not economically viable.

Strategic value

Rather than devising a suite of new technologies, the RMP seeks to accelerate the adoption of relevant technologies — particularly the use of legumes in crop rotations and the timely application of animal manures to supplement inorganic fertilizers — already being developed by national programs, as well as to reduce the risks involved in smallholder systems, particularly through a better understanding and, eventually, enrichment of farmer decision making in southern Africa. Project impacts are closely linked to impacts from complementary research in areas such as germplasm improvement (for example, work to develop drought- and low-nitrogen tolerant maize varieties). The RMP thus exemplifies CIMMYT's systems-based approach to developing strategies for sustainable agriculture and can serve as a model for technology development and promotion by our research partners in developing countries.

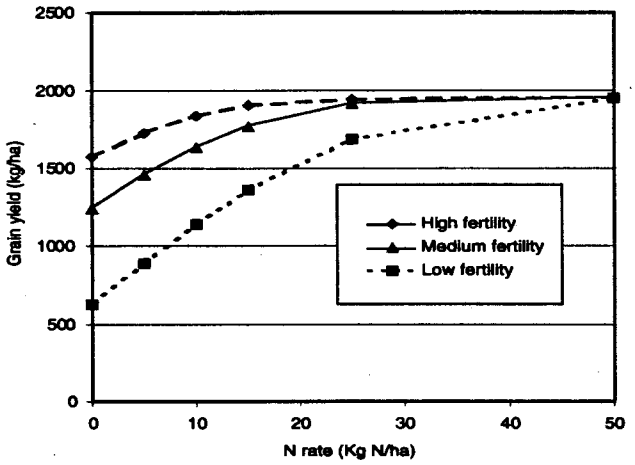

Figure 1. Simulated response using the APSIM model of a medium maturity maize variety to N application for three soil fertility regimes in southern Zimbabwe.

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Farmer Participatory Research: Achievements and Challenges

Participatory approaches emerged as a way to address the technology needs of highly diverse farming systems in marginal environments, where resources are limited and conventional approaches to research and development often failed. Participatory approaches range from researcher-driven studies that simply *involve* farmers, to projects in which farmers set the agenda, empowerment and education are key issues, and the participation of diverse stakeholders is sought.

Participatory initiatives of the NRG

There is a growing awareness in CIMMYT of the benefits of incorporating farmers' needs and viewpoints in technology development and dissemination, starting early in the process. Many NRG initiatives feature the input and participation of farmers and varied other stakeholders, as the examples here show:

- In Bangladesh, local women with previous experience in rural development and training were hired to organize and conduct whole family training sessions on wheat seed storage and wheat crop management. Use of this approach resulted in a 90% or better adoption rate of the improved technologies in target areas.
- Farmer-driven and managed tests of hand tractors and implements in the Indo-Gangetic Plains of South Asia, especially in Nepal, have obtained dramatic results and pointed the way for the sustainable intensification and diversification of rice-wheat cropping patterns. "Participation" in this effort includes notable cooperation among researchers, extension workers, private machine shop owners, credit institutions, non-government organizations, and others.
- A project in Zimbabwe joins participatory research and modeling to help farmers better manage the risks of maize production in drought-prone areas. Combining these "hard" and "soft" system research tools will allow use of farmers' soil and climate taxonomies for model runs, evaluation of farmers' own technologies by the model, and assessment of model outputs by farmers themselves. This initiative builds on the foundations of the Maize Program's Soil Fertility Network for Malawi and Zimbabwe.
- CIMMYT, the NGO "Alternativas," and local farmers and communities, with funding from the Hilton and Ford Foundations, are working together to sustainably improve maize-bean farming systems that support some 0.5 million poor inhabitants in dry, degraded areas of the Mixteca Region in southern Mexico. This will involve farmer assessment of new maize varieties as well as farmer experimentation with fodder crops, green manures, and mulching practices.
- Phase II of the conservation tillage research project in Mexico will test several participatory approaches to fine-tune and disseminate appropriate practices. Work will include farmer testing of zero-till implements developed for smallholders in Brazil, and expanded work on sources of mulch, including green manures. Finally, the project will seek expanded participation in Mexico, as well as functional links with conservation tillage research and dissemination efforts worldwide.

The Rockefeller Foundation Exploratory Initiative

This inter-institutional project aims at synthesizing global experiences on participatory approaches and farmer experimentation through networking across continents and a wide range of institutions (CGIAR, NARS, NGOs, electronic networks, etc.) and through documentation of selected case studies. A series of regional workshops will allow experts in the field of PA/FE to discuss their experiences and plan concrete mechanisms for inter-institutional collaboration. A report will be submitted to the Foundation in mid-to-late 1999 and will include concrete recommendations for long-term involvement by the agency in this area. The NRG is providing logistical support, assistance in accessing experience from outside Latin America and identifying collaborators and is also contributing various case studies based on the work of its outreach staff. Activities include:

Building and formalizing collaboration—FE Roundtable, Costa Rica, August 1998; miscellaneous public presentations and contacts; formal invitations to participate.

Elaboration of case studies on PA/FE experiences—Develop an analytical framework for comparing PA/FE approaches (February-March 1999); elaborate case studies (March-October 1999); submit report to RF (second half of1999).

Future workshops—Series of regional workshops, December 1999 to June 2000; international symposium on PA/FE (December 2000?).

Challenges for CIMMYT in participatory research:

- Given CIMMYT's expanded mandate and augmented range of partnerships, what should be the role of FPR in the Center . . . at headquarters and in outreach?
- How should farmer participatory research be institutionalized in the Center?
- How can we most effectively provide backstopping for outreach staff engaged in farmer participatory research?
- To what extent should CIMMYT seek a global leadership role in farmer participatory research?

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Integrating GIS and Crop Models

Improved Assessment and Targeting of Productivity Enhancing, Resource Conserving Technologies

Researchers attempting to develop sustainable technology interventions for cropping systems have traditionally faced two daunting challenges: first, how to scale up from what often appear to be very site-specific results and, second, how to obtain the long-term data needed for a true assessment of sustainability. Ongoing NRG research involves the use of modern information technology tools to address these concerns. Geographic information systems (GIS), for example, allow quantitative comparisons among regions and sites so that findings from one location can be extended to others where conditions are similar. Models, on the other hand, can simulate the performance and effects of a technology intervention over much longer time spans than are normally possible in conventional field trials.

The combined power of two information tools

An approach being explored by the NRG is to integrate GIS and modeling (Fig. 1). The resulting ability to evaluate technology options across space and time promises to add considerable value to the natural resource management research of CIMMYT and its partners. As part of efforts to develop and refine this methodology, the NRG is analyzing two maize cropping technology alternatives: 1) conservation tillage in Jalisco, western Mexico, and 2) use of green manures in Honduras.

The similarities and contrasts between these two cropping options make them ideal for testing a GIS-model interface methodology. Both enhance maize farming sustainability by increasing soil organic matter and conserving moisture. But

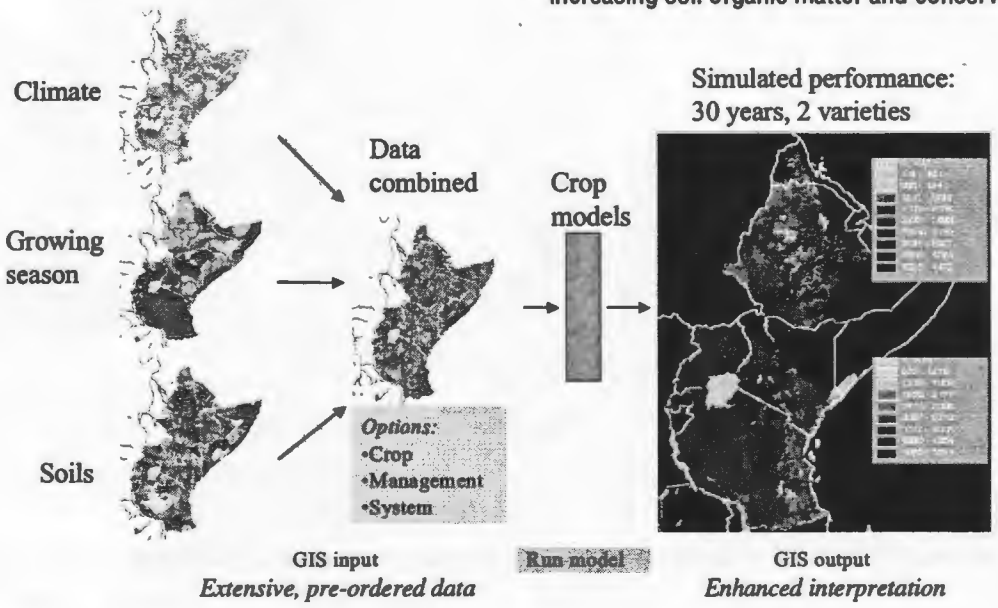

Figure 1. Integrating GIS and modeling.

green manures are favored in higher rainfall areas and reduce input requirements (i.e., they substitute for fertilizer), whereas conservation tillage often necessitates increased use of inputs (herbicides, mechanization) and its benefits are more pronounced in dry environments.

Methodological details

Integrating GIS and modeling software systems has proven relatively straightforward. An interface between ArcView GIS (gridded surfaces) and IBNAT crop models (sequence simulations) was developed by Collis and Corbett, Texas A&M Research Center, to run crop rotations over a number of years.

- Gridded climate surfaces (1 km² scale) are created and clustered in SAS to create an 'effective environment' layer, which is then processed to obtain climate profile (*.cli) files. Daily weather files are generated from these climate profiles.
- An optimal season layer, the growing season, is defined from monthly climate surfaces based on the precipitation to potential evaporation ratio (P/PE). This determines the planting date for the simula
- A range of three soil profiles is set up, based on soil taxonomy group.

A simulation layer is generated by overlaying the effective environment, start of the optimum season, and soil taxonomy groups. This simulation layer represents the zones of unique planting date, daily weather data, and soil information and forms the basis of any subsequent simulation scenario or experimental file configuration. The model is then run for all the unique combinations of the simulation layer. Model outputs are processed statistically, and variables may be mapped and undergo further manipulation or analysis in the GIS.

Status

The project has evaluated spatial interpolation techniques to create spatial climate surfaces from meteorological station data. We are still compiling soil information from soil profile databases.

For green manure cover crop simulations, a velvet bean (*Mucuna pruriens*) model was developed in collaboration with the University of Georgia. A conservation tillage module is being added to the crop modeling capacity in collaboration with The International Fertilizer Development Center (IFDC).

Preliminary simulations of maize yields in Jalisco, Mexico, match expectations of national program agronomists and give us confidence that our overall approach is sound (Fig. 2). We are awaiting development of a soil conservation module. For the Honduras case study, we are now running simulations and expect to complete them by late 1999. Validation of results from both case studies should be finished by mid-2000.

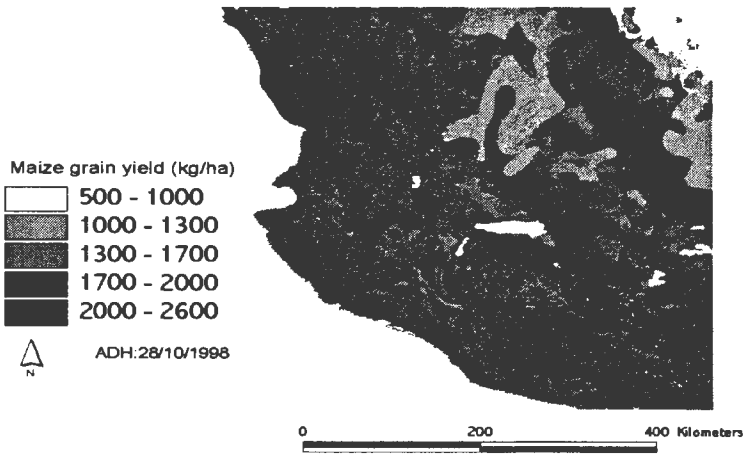

Figure 2. Simulated maize yields for Jalisco, Mexico.

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The Sustainable Farming Systems Database

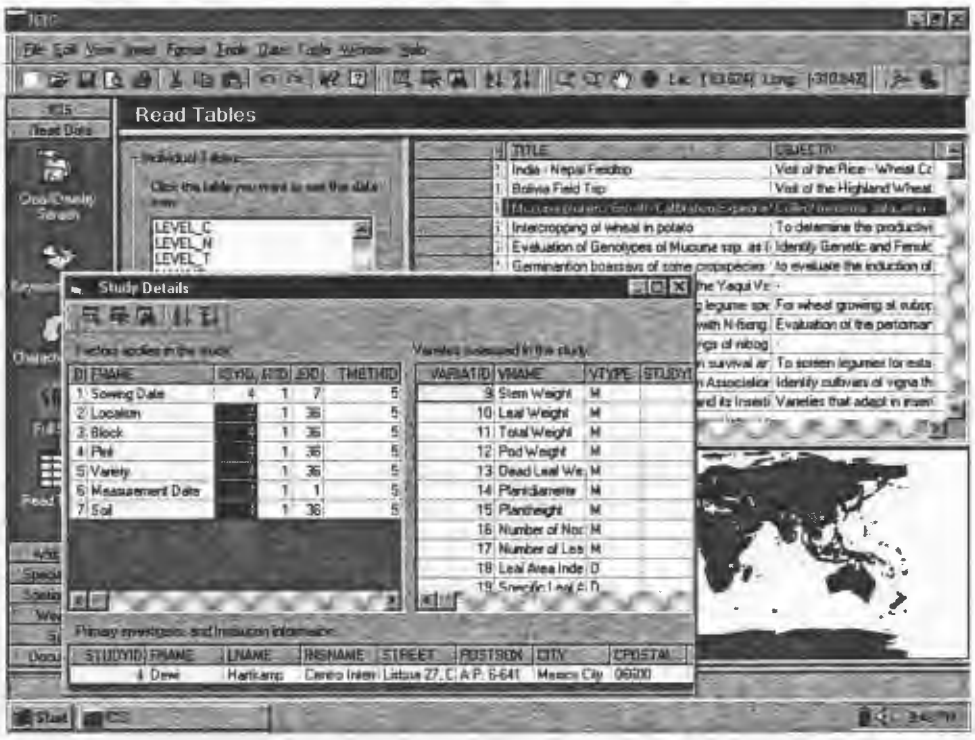
A Flexible Database for Research on Sustainable Farming Systems

Researchers and decision makers in agriculture and natural resource management increasingly require ready access to data on crop performance, farming practices, impacts of practices, and agricultural land use. Such data are a key ingredient for a "second Green Revolution" based on knowledge-intensive crop management. In addition, modern research tools such as geographic information systems (GIS) and crop simulation models also need voluminous and high quality data to be useful, especially when applied to studies of farming systems. How can such a range of rich, complex data from diverse sources be assembled and made easily accessible?

Relational database, diverse information formats

The NRG began work in 1997 to develop the Sustainable Farming Systems Database (SFSD)—a flexible relational database that can be run on a personal computer or network servers and which provides non-computer specialists the power of a relational database to manage and make available information of such varied formats as:

- Numeric data from field trials, including stored or calculated indices.
- Outputs of surveys recorded as text.
- Graphics and pictures.



The SFSD builds on CIMMYT's expertise in farming systems research in developing countries and its leadership in the development of the International Wheat Information System (IWIS) and the International Crop Information System (ICIS). The initial data stored will cover priority areas of NRG research, including several major maize and wheat production systems in developing countries. Among the sources:

- Long-terms trials that provide quality data on maize- and wheat-based cropping systems in tropical settings.
- Studies on South Asia's rice-wheat cropping systems, which account for 12 million hectares and feed and furnish livelihoods for well over 350 million inhabitants. The emphasis is on helping researchers respond to evidence of slowed or stagnating growth in system productivity.
- Information from joint CIMMYT-national program research on maize and wheat farming systems in sub-Saharan Africa, with a focus on the constraints (e.g., low soil fertility, drought, *Striga* spp.) that make these production environments some of the most risky in the world.
- Long-term research with national programs in Mexico, Central America, and the Caribbean to improve the sustainability of maize production, especially through conservation tillage and use of green manure cover crops.

Development and distribution timeline

A prototype SFSD will be distributed by late 1999 via compact disk. It will include user-friendly data input, query, and output software developed in consultation with natural resources researchers, agronomists, economists and others. Initial recipients will be research partners in the regions mentioned above, who are expected to enter additional experimental and survey data. Training will be provided through workshops, demonstrations, and personal consultation. Based on comments and data from first users, a final version will be developed for broader distribution, probably toward the end of 2000.

Future directions

Our aim is eventually to develop an SFSD that users can access or receive updates of via internet. Development of the SFSD is also seen as a means to promote information sharing, but the database software will include ways to restrict access to certain information, if so desired by the data provider. Funding for this effort presently comes from the NRG and ICIS projects. As interest in the SFSD grows, additional support will be sought for subsequent development, distribution, training, and maintenance activities.

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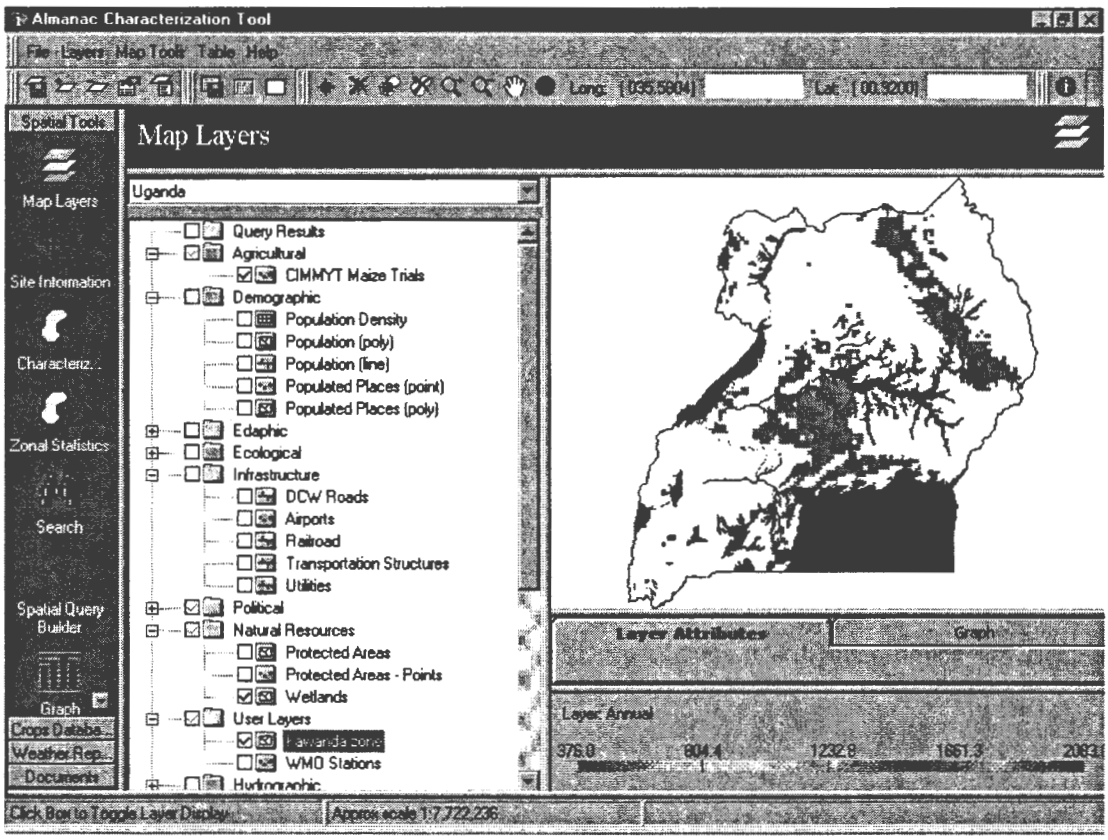
Africa Country Almanacs

GIS for National Programs Now!

With funding from USAID, the Integrated Information Management Laboratory (IIML) of Texas A&M University, together with CIMMYT's Natural Resources Group (NRG), has developed stand-alone, CD-ROM software that combines powerful and flexible GIS tools with preloaded data on climate, topography, soils, political divisions, land use, etc. The "Country Almanacs" put the enormous power of GIS in the hands of users ranging from agricultural and natural resource scientists to policy makers. The product's suite of easily accessible tools and country-level data, as well as textual information, enables researchers to explore such questions as:

- How representative of the country as a whole is a specific study site?
- What is known about the performance of new management practices or varieties in defined production environments?
- To which regions or sites will a newly developed management practice or crop variety be best suited?
- Which regions or sites fit a specified altitude and precipitation range and land-use category?

Users can manipulate and combine datasets and search results to create customized maps and tables. These can easily be exported to word processing, spreadsheet, graphics, or other packages. Text information in the Almanac includes Internet sites, major articles and journals relating to the country, general background information, popular field manuals and other selected CIMMYT publications, and a collection of ready-made maps.



Almanacs are currently available for researchers in Angola, Ethiopia, Kenya, Liberia, Sierra Leone, Tanzania, Uganda, and Zimbabwe. They are being distributed free-of-charge in sub-Saharan Africa, and have been promoted through several regional and in-country training courses, including the VI Regional Maize Conference for Eastern and Southern Africa, in Ethiopia, 21-24 September, 1998.

Piloting of a test version with researchers and national program partners led to several improvements, including development of on-line tutorials that walk new users through Almanac functions using real-life scenarios. Besides increasing the number of countries covered, Almanac developers are working to upgrade its search and analysis capabilities and to include key crop and farming systems databases developed at CIMMYT, such as the International Wheat Information System (IWIS) and the Sustainable Farming Systems Database (SFSD).

The Almanacs demonstrate a guiding principal of GIS at CIMMYT: the group is comparatively small, but the able to build strategic alliances with others who have access to resources and evolving technology, and thus offer the best of this technology to partners in developing countries.

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