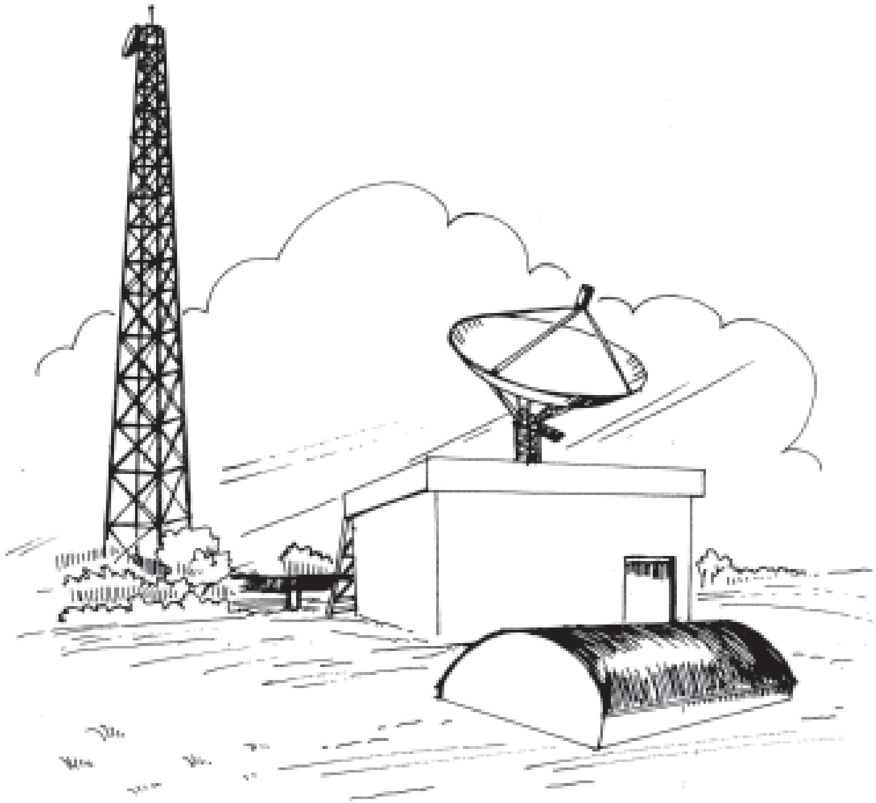
Modern Information Technology Tools for Efficient Management of Natural Resources



Users of IT Tools for Agriculture

- Policymakers
- Research managers
- Researchers
- Extension and development workers
- Farmers
- Consumers and the general public

Modern tools from information technology such as simulation models, decision support systems (DSS), geographic information system (GIS) and databases offer promise towards greater efficiency in fields such as natural resources management, yield forecasting, and developing contingency plans for monsoon variation.

Why Information Technology?

There is an increased interest in applying information technology (IT) to agricultural research and development. Diagnosing and solving problems at the local or farm level often requires consideration of factors ranging from impact of specific pests, to local management of water resources to availability of off-farm employment. Such a "systems approach" requires strong interdisciplinary collaboration, which in turn implies ready flow of data and information among stakeholders - a clear niche for databases and internet access. Furthermore, to view interactions of systems components, systems methodologies often rely on computer-based tools such as simulation models and GIS.

Information technologies offer numerous mechanisms for improved synthesis and interchange of information. There is potential for major "spillovers" in fields such as molecular biology and remote sensing. The "Web" is rapidly becoming a major storage place for information. Web-based technologies greatly improve accessibility thereby offering great opportunities for timely, targeted, and high quality information which can influence the various actions.

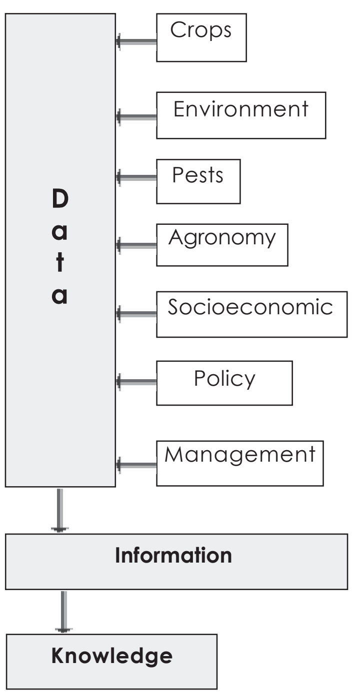
Types of Information

Information required in agricultural research and development efforts ranges from project descriptions to specific results of field or laboratory evaluations to qualitative indicators of farmer or consumer perspectives. Although "information" is used as a blanket term, the hierarchy of data, information, and knowledge better represents the spectrum used in agricultural research and development. Within "knowledge," a further distinction can be made between explicit and tacit knowledge. Explicit knowledge can be expressed in a symbolic form (e.g., a written description or a mathematical formula), while tacit knowledge is the more subjective "know-how" that grows from professional experience.

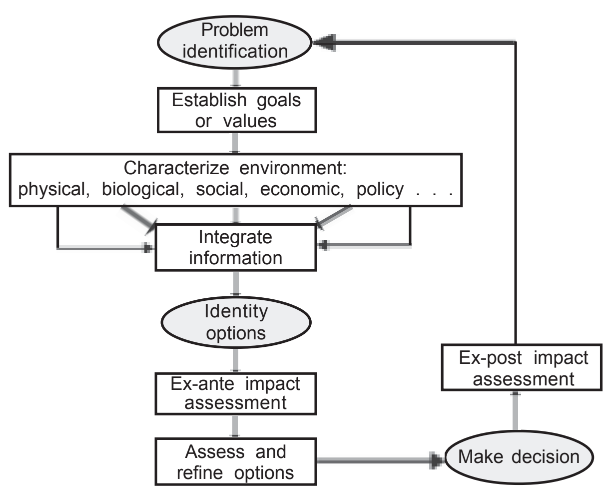
Information-based Tools for Agricultural Research and Development

While individual tools are useful, their value is multiplied when linked to required data and complementary tools to create a DSS. Information technology provides the tools that allow us to systematically generate, organize and make knowledge available to those who require it most – passing it from the hands (and minds) of researchers to the "real" users of the land and natural resources so that they are better empowered to manage their resources in a more informed and rational manner. These tools can be matched to user groups with the

Hierarchy of Data



Categories of Tools Useful in Decision-making for Agricultural Research and Development



Note: Rectangular boxes indicate tools and oval boxes indicate actions of decision-makers or other stakeholders. Source: English *et al.* 1999.

addition of categories of tools for technology diffusion (e.g., expert systems) and project management (e.g., project information databases).

Project Information and Knowledge Management Systems

For more effective collaboration within and among research and development networks, it is important to be able to keep track of 'who is doing what, where?', as well as the status and progress of on-going projects. Avoiding duplication saves substantial funds whereas targeted partnership and use of information are key factors to developing timely solutions to identified key problems. In addition, information systems can greatly contribute to build up and utilize institutional memories of information available with individuals and institutions in the different stakeholder groups. Management information concerns data on organizations, activities carried out in the past or on-going, collaborators, funding agencies, and expertise available. For monitoring data on allocations, expenditures as well as progress and outputs achieved are essential. Re-use of basic information is important to enhance efficiency of research and development efforts. Thus, three interlinked systems (see box) are being developed or are available in the Indo-Gangetic Plains (IGP).

Interlinked Systems in the Indo-Gangetic Plains

- The web-based **project information management system (PIMS)** was developed as a response to the need of the Indian National Agricultural Technology Project (NATP) management to monitor its program. The on-line version is being developed by the Indian Agricultural Statistical Research Institute (IASRI).

- The **regional-level information system** is a shared platform of the four national partners of the Rice-Wheat Consortium (RWC) in the IGP region. It is called Project and Research Information System Module (PRISM) and can be accessed at www.wis.cgiar.org/rwc. PRISM was developed on the lines of WISARD.

- **WISARD,** the web-based information system on agricultural research and development (www.wisard.org) contains detailed information and advanced search tools for projects and organizations. It creates stakeholder specific country directories and organizational profiles of projects. It allows free text, pre-defined, and advanced searches on-line on thematic, geographical, and institutional aspects. It is compatible with Interdev, the non-governmental organization (NGO) initiated system that provides interactive information on local knowledge and best practices.

The Country Almanac Series

Most agricultural and natural resource management decisions are strongly influenced by the spatial environment. GIS offers enormous potential for improving the efficiency of agriculture and natural resource management. However, the impact of GIS has been limited due to high costs of hardware and software, limited data availability, shortage of trained specialists, and lack of "spatial awareness" among potential end-users. The Country Almanac Series lowers barriers to effective use of GIS by packaging simple yet powerful analytic tools with a core set of data of spatial data relevant to agricultural and natural resource management issues (climate, soils, population, topography, land-use, etc.). To further enhance the utility of the Almanacs, tools for exploring daily weather data records and for viewing electronic documents are packaged with the Almanacs.

A Sample Almanac Map for Nepal

Almanacs are distributed on CD-ROM and accessed through a familiar Microsoft Windows user interface. Almanacs are in use in eight countries of sub-Saharan Africa and in Nepal. Proposals are under discussion for development of Almanacs for Bangladesh and India as well as a regional version that would cover the entire rice-wheat region of South Asia at lower resolution.

The Map Layers tool of the Almanacs provide standard map viewing and overlaying functions. Users may add or remove data layers as needed, and a meta-database documents data sources. The characterization tool permits creating zones using user-defined criteria for any data available in the Almanac. Although current Almanacs focus on national-level datasets, the system works equally well at sub-continent or district level.

The Sustainable Farming Systems Database

The Sustainable Farming Systems Database (SFSD) is an implementation of the International Crop Information System (ICIS Project 2000) developed by the Natural Resources Group of Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT). It can store results from natural resources research on crop performance, cropping practices, and environments from the experimental level to farm level to regional level.

Users can enter their own data from experimental results, surveys, expert opinions, on-farm monitoring results, census data, and scouting reports. Data may be selectively up-loaded to the central depository. Planned improvements to the SFSD will permit flexible queries about locations, single crops or rotations, maintenance and harvest practices, use of labor, machinery and chemicals, and traits of systems. Data can be extracted for use in other applications. These include spreadsheets, statistical packages, crop simulation models and GIS.

Models for Estimating Potential Yields and Yield Gaps

Potential yield is the integrated expression of the influence of radiation and temperature on crop growth and development of a particular crop or variety. Adequate water and nutrient supply and absence of all yield-reducing factors such as pests and diseases characterize this production level. Potential yield can be interpreted as the upper limit that is achievable by current varieties in a no-constraint environment. Simulation models can also be used to analyze yield gaps. Economic yields based on potential yield estimates, cost of cultivation, and simulated response to fertilizer can be used to determine the possible yield levels for different land evaluation units. Using the WTGROS model, variation in potential wheat yields was examined over India (Aggarwal *et al.*, 1995).

Rice Supply and Demand Analysis System

Another example of taking crop and economic modeling further in the development of DSS is illustrated by the Rice Supply and Demand Analysis (RSDA) system developed to model and analyze the balance between rice supply and demand at sub-national level (i.e., within the country), taking into account biophysical, socioeconomic, and policy factors.

GIS is used to explicitly provide the spatial dimension in modeling the three RSDA components, rice supply, rice demand, and rice balance, and to facilitate integration of biophysical and socioeconomic data and analysis. Such outputs from the model help in identifying areas of rice-deficit and in designing the rice distribution system in the country.

The RSDA system can be used also for exploring future scenarios of rice supply and demand. For example, one scenario could be increasing rice production by intensification of cropping through improvement and expansion of irrigation systems while another scenario could be lowering the reduction factor due to pests and diseases and post-harvest losses. From the demand aspect, different scenarios of income and price elasticities of consumption, and projections on population growth rate and urbanization will change estimates of future rice demand.

A Decision Support System for Land Use Analysis

A systems approach is needed to translate policy goals into objective functions integrated into a biophysical land evaluation model. A DSS has recently been developed to meet these needs (Aggarwal *et al.,* 2000). Quantitative policy goals for food security of the region are first established. Then policy views of the stakeholders in relation to production, income, social issues, and environmental degradation are quantified using published documents or personal discussions. A detailed land evaluation is conducted that considers spatial and temporal variation in soil and climatic resources of the region using relational databases, GIS, and remote sensing. This results in a number of homogenous agro-ecological units. Regionally-developed and tested transfer functions are used to determine soil moisture and nutrient characteristics of each agro-ecological unit.

Advantages of DSS

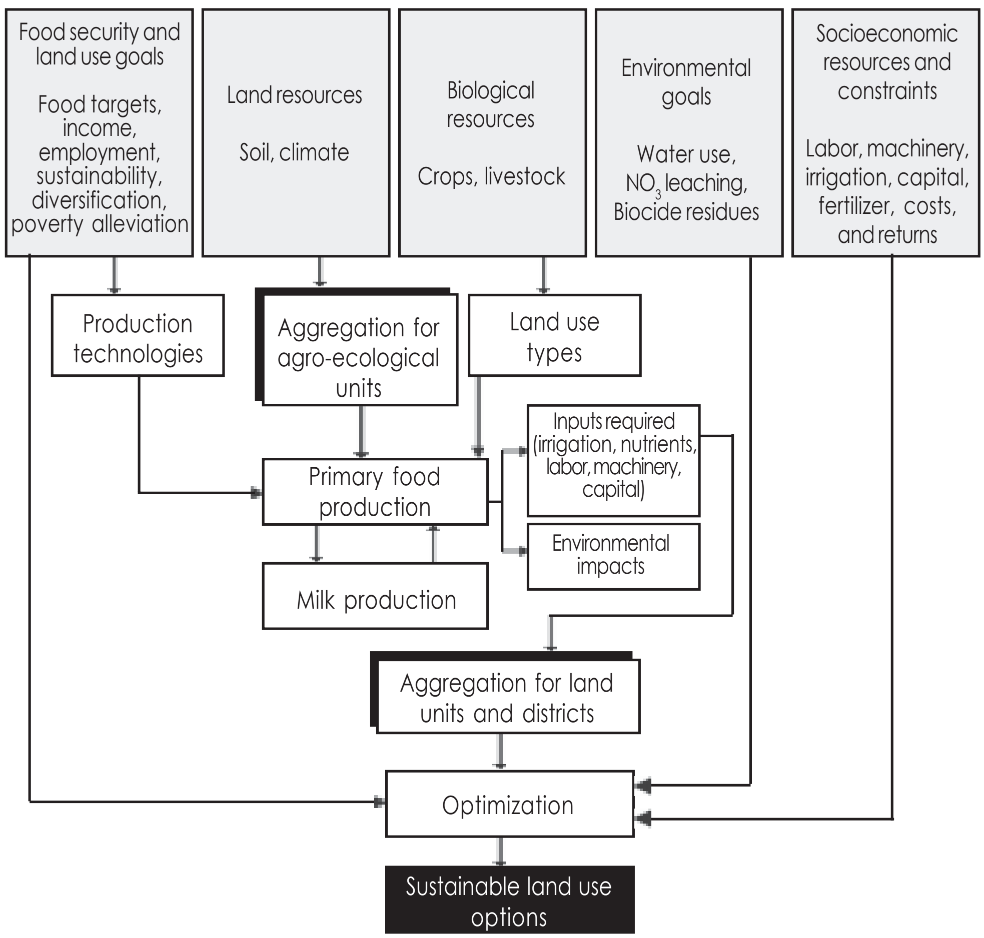
- Explores the opportunities for land use analysis and planning.
- Integrates the knowledge base of scientists from different disciplinary backgrounds.
- Addresses issues put forward by diverse stakeholders.
- Helps the user analyze whether the development goals are feasible and at what cost.

Considering the crops and livestock resources of the region, key land use types are defined. The possible production technologies and activities are defined based on the policy goals and socioeconomic resources of the region. Regionally calibrated and validated crop models are then used to estimate the food production potential of the different land use types with different production technologies for each agro-ecological unit. Potential yields are adjusted for the agro-ecological unit.

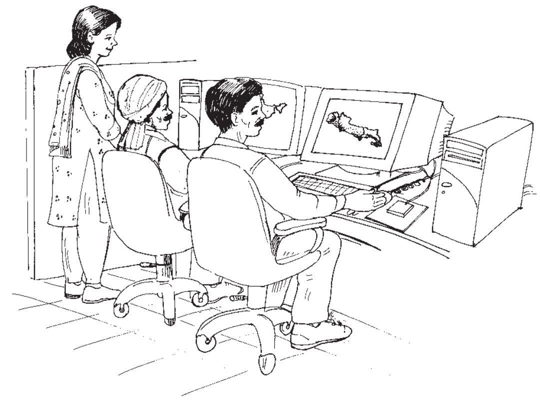
The model can assess environmental impacts and monitor the main ancillary agricultural output, crop residues. The latter provides energy to the livestock which, in turn, produce milk. Resulting dung produced is used for fuel or for organic manure, which in turn can further affect crop production.

By overlaying the district boundaries on the agro-ecological units map, the number and area of different land evaluation units in each district is determined. This is essential because socioeconomic data are generally available at this scale. Together with the assessment of socioeconomic resources of the region and specific goals for food security, environmental conservation and alternate land use, and options for sustainable land use are determined using interactive multiple goal linear programming.

Operational Steps Followed in the DSS for Land Use Analysis for Sustainable Food Security



Future Efforts



- Managers must ensure that end-users have the capacity and confidence to use IT tools.
- Tools and data should be updated.
- Good basic products are available in the region which need to be technically further developed and integrated in a continued interactive process with end-users.
- There is a dire need for further regular interaction on concepts, standards and implementation.
- Funding for finalization and integration of the various prototypes and products should be ensured.
- Meeting of key developers and users should be held once a year to develop standards, common procedures, share experiences, and plan future interaction.
- A web-platform for intermediate contact and exchange of ideas should be established.
- A user-group network for the various key domains should be created.

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